Edited by CARY KROSINSKY and TODD CORT

Sustainable Innovation and Impact

earthscan from Routledge

SUSTAINABLE INNOVATION AND IMPACT

Following the Brexit and Trump election cycles, consistent, long-term policy solutions to environmental and other societal challenges are becoming increasingly difficult to achieve. Stepping into this breach is a clear opportunity for innovation by public and privately held companies, as well as the increasingly significant role of investment and consumption.

Sustainable Innovation and Impact provides a roadmap of the many critical pathways of positive change emerging to achieve modern day societal success, including rapidly evolving corporate and investment innovation and impact strategy considerations. Exploring innovation around the future of energy, electricity and related technologies, as well as transportation and buildings efficiency, Krosinsky and Cort consider ideas framed around the circular economy, operational and supply chain strategies and the global economy.

Drawing together a diverse range of contributors and case studies, this book will be of great relevance to students, scholars and professionals with an interest in innovation, economics and sustainability more broadly.

Cary Krosinsky is a leading educator, author, advisor and social entrepreneur seeking to solve sustainability challenges through corporate and investment strategy. He teaches at Yale University, USA; Concordia University, Canada; the University of Maryland, USA; and Brown University, USA; and is the Co-founder of the Carbon Tracker Initiative and Real Impact Tracker.

Todd Cort is Lecturer in Sustainability at the Yale School of Management and Faculty Co-director of Yale's Center for Business and the Environment, USA.

"From his first book a decade ago, Cary Krosinsky has consistently proven his keen ability to foresee the evolution of sustainable investing. Now in this latest work with Todd Cort, he again proves he has his fingers on the pulse, making a convincing case for innovation and impact solutions as catalysts of the ongoing evolution of investing. Their work offers an informative and actionable overview on how to navigate this critical stage of a dynamic and rapidly evolving field."

Amr Addas, Lecturer, Sustainable Investing, Concordia University, and Vice President, External Relations for the Finance and Sustainability Initiative (FSI) in Montreal, Canada.

"This book informs, educates, and inspires, with proposed solutions highlighting the necessity for individuals everywhere to discover their own paths for creating impact in their own lives and for the world including through collaborations. To meet our biggest social and environmental challenges today and in the future, we must support and encourage just this type of innovation."

Jenny Chan, Senior Investment Officer, Doris Duke Charitable Foundation, USA

"*Sustainable Innovation and Impact* is a terrific read for anyone interested in breakthrough thinking and solutions for the 21st century. You'll be drawn in by the topics and quality writing—and emerge with a renewed sense of optimism about where we are and where we can go in an age of sustainability, sustainable finance and investing. Innovation and impact, together, allows us to deliver socio-environmental and economic growth, and justice, in our own backyard and across the nations of the earth. A 'must read' for all practitioners, funders and policymakers, investors, faculty, students and citizens."

Nancy Degnan, Senior Advisor, Education, Columbia Water Center, Columbia University, USA

"*Sustainable Innovation and Impact* by Krosinsky and Cort has arrived just when it was needed most. Sustainability has been on a twenty-plus year journey, and has reached the point where concepts once regarded as on the fringe of financial markets are becoming mainstream. But for sustainability to truly transform society we need to unlock new ideas. Krosinsky and Cort have brought together a collection of writers that challenge us to think differently. The ideas in this book are powerful and have the capacity to deliver meaningful benefits, but perhaps the most important thing this book does is to encourage us all to look for solutions in new ways."

Gordon Noble, Principal Adviser, John Grill Centre for Project Leadership, University of Sydney, Australia

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CONTRIBUTORS

Sarah Brandt is a 2017 graduate of Yale University with a degree in Environmental Studies and a certificate in Energy Studies. Sarah is now an Associate Consultant in the Chicago office of management consulting firm Bain & Company and has done freelance reporting for the Twin Cities cultural newsmagazine *City Pages* and the online Minnesota newspaper *MinnPost*.

Pascale Bronder is pursuing a B.S. in Environmental Studies as well as a certificate in Energy Studies at Yale University. Originally from Washington D.C, she's always had an interest in systems that can improve lives and ameliorate the planet. She interned at Abt Associates, where she became well versed in blockchain and grew to understand the deep potential the technology holds for social innovation. Outside of her studies, Pascale is also financial director of a student-run solar panel engineering club.

Steven Castano grew up in a Colombian household on the Jersey Shore. He graduated recently from Yale University where he majored in History and wrote his thesis on Cuban Shipbuilding and Forest Conservation in the 18th century.

Tiffany Chen is a senior at Taipei American School in Taipei, Taiwan. As a high school student, Tiffany loves to explore business and economics, and she enrolled in classes at Brown University during summer 2017 to further these interests.

Lillian Childress is an environmentally-minded author, researcher, and engineer. She currently works in R&D at an Israeli renewable energy startup. In her spare time she researches and writes about the environment, focusing on industrial waste and Chinese environmental policy. Lillian graduated in 2017 from Yale University with a degree in environmental engineering.

Christopher Codina-Lucia has a Bachelor of Engineering degree in Civil Engineering from McGill University and an M.B.A. from the John Molson School of Business (JMSB) at Concordia University. Spending most of his career in the construction industry both in urban and remote northern communities, Mr. Codina-Lucia currently works in project management on infrastructure projects in Montreal, Canada.

Melanie Condon works in External Affairs for the Sustainable Business and Communications function at Unilever. She handles issues and risk management for the corporate brand. She also works to ensure Unilever's Sustainable Living Plan is being embedded in the business as well as being communicated externally. Melanie has her M.B.A. from the University of Maryland, Robert H. Smith School of Business and her B.A. in Political Science and International Affairs from the University of New Hampshire. She currently resides in Washington D.C.

Todd Cort is Lecturer in Sustainability at the Yale School of Management, and Faculty Co-director of Yale's Center for Business and the Environment, teaching classes on a variety of subjects including Natural Capital, Wicked Problems and Sustainable Finance. He also works at the intersection of corporate responsibility and sustainable finance, with a main objective of reducing barriers to capital flowing into sustainable investments. In addition, he educates and collaborates with investors and fund managers to effectively integrate sustainability into investment strategies, ranging from fixed income to venture capital strategies, and he is Principal of NPV Associates with a long history of consulting with major corporations on strategy, assurance, risk and reporting.

Matt Dittrich, Yale M.B.A. '18, is a startup investor, operator and community organizer. Between years of business school, Matt joined the investing team at Trilogy Partnership, a venture capital and private equity firm based in greater Seattle, Washington. Previously Matt served as the Market Development Manager for nLIGHT, a laser company based in greater Portland, Oregon and Shanghai, China. Matt began his career on the Bain & Company team in London, UK, advising technology and private equity firms across four continents. Additionally, Matt is involved with his family wheat and wind farm and serves on a variety of boards and working groups, including the Whitman College Alumni Board, Opportunity for All, Yale University student government and a range of ESG-related initiatives – from access to higher education, to LGBTQ and women in business, to alternative energy and urban development.

Eric Esposito holds a B.A. in Environmental Studies and Economics and a Certificate in Energy Studies from Yale University, where he was a four-year varsity member of the Yale lightweight rowing team. He currently works in investment banking at Citigroup's Global Energy Group in Houston, Texas. He is interested in the role financial institutions can play in facilitating clean energy investment and opportunities for oil and gas companies to participate in an energy transition.

Richard Frazao has a Bachelor of Engineering in Mechanical Engineering from McGill University and M.B.A. from the John Molson School of Business (JMSB) at Concordia University. He is a dynamic entrepreneur with experience in a range of fields, whose interest in aquaponics stems from his passion for integrated/sustainable systems and personal hobby of building small systems.

Laila Gamaleldin is a high school senior with a keen interest in environmental governance and politics. Hailing from Cairo, Egypt, she is particularly captivated by the intersections of sustainability and development, and hopes to someday pursue a career that places her at the forefront of the rising environmental justice movement both in her native country and globally.

Cayley Geffen is a junior at Yale University double majoring in Economics and Environmental Studies. She is the Co-President of the Yale Student Environmental Coalition and a member of several groups on campus including the Dwight Hall Socially Responsible Investing.

Courtnay Guimaraes is a seasoned executive on IT for capital markets and works at the nexus of complex systems, open and exponential innovation, emerging change management and cognitive systems. She has previous experience with HP/HPE, Oracle, SAP, Telefonica, and banks including Itaú, Bradesco and Banco do Brasil. Courtnay has advised startups, products and new market creation within Idea Partners for SmartMove, Card4B, OR Blockchain Services, Mar Ventures and Blockchain Academy Brazil.

Masengo Kapanga is a proud first generation American of Congolese and Rwandan descent from Richmond, Virginia. A 2018 dual M.B.A./Master in Real Estate Development graduate of the University of Maryland in College Park, her studies were concentrated in finance and international development. Prior to the completion of her graduate studies, she spent five years in mortgage sales and operations at banks such as SunTrust and Citizens Bank and affordable housing development in the non-profit sector. She has also consulted for private companies in Kinshasa, D.R. Congo as well as Cape Town, South Africa in real estate Fintech and development.

Alex Kappes is a federal Human Capital Senior Consultant with Deloitte Consulting LLP. He graduated from Ohio University with a bachelor's degree in Economics in 2006. After graduation, Alex was commissioned as a United States Marine Corps Officer. He spent eight years in the Marine Corps which included deployments to Iwakuni, Japan and Bagram, Afghanistan in Support of Operation Enduring Freedom. After the Marine Corps, Alex joined a small veteran-owned software company, Chesapeake Technology International, as a Project Manager. Alex recently completed his M.B.A. at the University of Maryland's Smith School of Business.

Zach Knight is Co-founder and Managing Partner at Blue Forest Conservation. Before working as a high-yield bond trader, he began his career at Merrill Lynch working in structured finance, derivative structuring and correlation trading. Zach is a seasoned financial engineer who left the Wall Street trading floors to pursue his passion for environmental investing. Zach holds a B.A. in Economics from Cornell University and an M.B.A. with honors from UC-Berkeley's Haas School of Business.

Kristina Krasteva is a governance-focused professional with an information technology discipline, and has dedicated the last decade to risk management, audit and compliance. She holds a Bachelor of Commerce in management information systems from McGill University and a Master's in Business Administration from Concordia University in Montreal, Canada. Kristina currently resides in Copenhagen, Denmark.

Cary Krosinsky is an educator, author/editor, advisor and entrepreneur at the nexus of corporate, investment and sustainability strategy. He is considered a leading educator on sustainable finance, with ongoing engagements at Yale and Brown University, as well as the University of Maryland and at Concordia in Montreal. This is his fifth book; the four prior books are considered seminal texts on the subject of sustainable investing. Last year's *Sustainable Investing: Revolutions in Theory and Practice* was chosen by the People's Bank of China for translation to help better develop a culture of sustainable investing among the country's investor community. He is also Co-founder and Director of Real Impact Tracker and the Carbon Tracker Initiative, Principal at NPV Associates, Advisor at BlueSky Investment Management and Editor of the Journal of Environmental Investing, and recently consulted with many other leading organizations such as the Principles for Responsible Investment and the UNEP Inquiry into the Design of a Sustainable Financial System.

Marvin Krosinsky is a New York based architect in practice for almost 60 years, with projects cutting across disciplines including commercial, medical, sports and residential. Examples of his work include NY State's Canton Agricultural and Technical College, and his design for the Vietnam Veteran Memorial in Washington, D.C. which finished second to Maya Lin.

Peter Mahony is a senior at Yale University majoring in Economics and Geology with a focus on energy studies. He grew up near Seattle, Washington and after graduation plans to work in finance in Houston, Texas.

Alizeh Maqbool graduated from Yale in May 2017 with a B.Sc. in Physics. Her chapter in the book was inspired by her work for a seminar at Yale entitled

"Innovation and Sustainability," taught in the fall of 2016 by Cary Krosinsky and Howard Brown. She is currently working for the Government of Punjab in Lahore, Pakistan.

Andreia Marin Martins is Co-Founder of Usphera Immersive Technologies. She is a local development management specialist in Brazil and performs independent research on sustainability and technology.

Arthur Matuszewski is a management and organizational strategist with experience scaling high growth ventures at e-commerce company Wayfair, developing innovation and talent strategy at Fahrenheit 212 and evolving systematized management systems at the world's largest hedge fund, Bridgewater Associates. Arthur has also developed an innovative childcare company in NYC, educational programming at the Rhode Island Adult Correctional Institute, and has served as an ongoing advisor to various startups and venture investments with HOF Capital. He graduated from Brown University with a degree in Africana Studies and a focus on understanding how individuals and institutions come to shape their worldviews.

Jason Mazzella currently works as a Strategy Manager at Warby Parker in New York City. He spent two years at Bain & Company as an associate consultant and contributed to projects across industries including retail, private equity, and technology. During his academic career, Jason was awarded first prize for Massachusetts in the National Peace Essay Contest sponsored by the United States Institute of Peace for an essay on nonviolent protest, and the GALA Essay prize for his senior thesis "Queer Civil Society in Contemporary China: Understanding Variation in Success Across Gay and Lesbian Organizations." Jason graduated summa cum laude from Yale University with degrees in East Asian Studies and Economics in 2015.

Nora Moraga-Lewy holds a Bachelor of Arts in Environmental Studies and a Certificate in Energy Studies from Yale University. Her senior essay evaluated the potential of the Forest Trust's supply chain transformation strategy in addressing environmental governance challenges in Southeast Asia's palm oil industry. Nora has experience in diverse sectors and regions including private energy in Argentina, non-profit conservation in Italy, and academic institutional sustainability in Singapore and the United States. During her time as a research associate at the Environmental Law Institute (ELI), Nora coordinates the Environmental Peacebuilding program and contributes to reports on topics ranging from environmental rule of law (*UN Environment-ELI Flagship Report*, 2018) to flood hazard mitigation-related property acquisition in the United States. She is currently interested in the role of the private sector in addressing land tenure and indigenous rights issues in Latin America.

Mauricio Neves dos Santos is Co-Founder of Usphera Immersive Technologies, and was director and owner at Animake (a CG and VFX house founded in 2006), along with other animators, creators, illustrators, thinking heads and motion designers. From 2014, as partner of CGGO, Mauricio worked on the production of VR (Virtual Reality), from CG generated to real time engines (Unreal Engine) and continues to search for solutions through innovation strategy.

Chad Reed is a Co-founder and Partner at Blue Forest Conservation. A former U.S. intelligence officer, Chad spent the last five years developing innovative solutions to sustainable finance challenges, including stints with TerraForm Power and Sungevity in structured finance, risk management and investor relations roles. Chad holds a B.A. from the George Washington University, an M.A. with honors from the Johns Hopkins University School of Advanced International Studies, and an M.B.A. from UC Berkeley's Haas School of Business.

Gabe Rissman co-founded Real Impact Tracker to help the public understand and increase the impact of their investments. Previously he helped lead Yale's fossil fuel divestment campaign, as well as its undergraduate socially responsible investment fund, and its solar energy club. Gabe graduated from Yale with a B.Sc. in Physics in 2016.

Jeff Schwartz, CFA, currently is a Director of Financial Operations. He is responsible for the creation and monitoring of daily valuations for the firm and all fund accounting functions. Prior to this role he spent ten years with Oppenheimer Funds and three with Brown Brothers Harriman holding various roles within financial operations. Mr. Schwartz holds a bachelor's degree in finance from the University of Denver and a master's degree in business administration from the University of Maryland.

Pek Shibao is sustainability analyst with the Singapore Institute of International Affairs, a think tank focusing on political economy and sustainability issues in Southeast Asia. He also consults to Asia Research and Engagement, a firm specializing in ESG and responsible investment research. His areas of research include sustainable production in the Southeast Asian agricultural sector, deforestation and forest fires, haze, air pollution, and sustainable finance.

Susan Wang is a senior at Yale University, majoring in Economics with a certificate in Energy Studies. She lived in New Zealand and Japan before moving to the United States. She will be joining J. P. Morgan after graduation.

Ella Warshauer graduated from Brown University in 2017, earning an A.B. in Economics with a focus in environmental studies. She is interested in using holistic approaches to develop and implement methods for scaling sustainable financing solutions in the capital markets. She is particularly curious about infrastructure investing, transportation planning, water management, and urban planning. Ella started as an analyst at BlackRock in 2017.

Reilly Witheford is a junior undergraduate at Yale University studying Economics, in addition to being an Energy Studies Scholar. She is from Charlotte, North Carolina, but spent five years living in Germany, sparking her interest in sustainability both in Germany and around the world. She has pursued her interest in energy both in the classroom and out of the classroom through an internship with a renewable energy project developer, and she hopes to continue her involvement with sustainable industries after graduation.

Please note: Past and present affiliations listed in these biographies and of the book's endorsers are for informational purposes only. The chapter authors and endorsers have provided contributions in their own capacity.

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This book largely comes out of a single question which we like to pose to students in classes we have taught at Yale, Brown, Maryland and Concordia, and where most of these chapters originated, which is simply this:

Given the world's environmental, social and governance risks and opportunities, choose the issue within that resonates the most with you, and "Solve an unsolved problem."

We are grateful for the wide variety of thoughtful responses we have been receiving, the quality of which inspired this book, and could even see this sort of multi-disciplinary approach to solving problems forming an entirely new systemic solutions discipline of its own. Perhaps all it needs is a name, but for now, Sustainable Innovation and Impact will have to do.

There are as always too many people to thank, but in particular Yale's Michael Oristaglio is worth a special mention as head of the Yale undergraduate Energy Studies program. It's been fun and informative co-teaching some of the classes I've been honored to teach at Yale with him, and those classes helped lead to a number of introductions to students whose work is featured here. The capstone projects of that Energy Studies program are also well worth a look for those interested. It is an honor to serve on the Faculty Advisory Committee of such an excellent program. It's also an honor to teach with Todd Cort; my thanks are due to him for creating that opportunity and for collaborating on this work.

Whether coming from either Yale or Brown's world class undergraduates, from graduate levels at various institutions whose students are often in their 30s, or from the amazing high school students from around the world who were a joy to teach at Brown during the summer of 2017, the contributions to this book stand as testament to the quality of the next generation. They are ready to go now, as you will see as you dive into the chapters herein.

The next generation has, without question, the vision, drive, culture and strategy to make necessary change happen across global corporations and investment institutions, and within governments and policy realms as well.

We need to accelerate ongoing environmental and social transitions with haste, but more than anything, once you have had a chance to interact with young stars such as those whose work is featured here, you'll also come to know that of which we are fully convinced: To realize environmental and social transitions at the speed required, the transition we need to make most of all is to, as rapidly as possible, give the next generation the power and control to make these changes happen.

They, and likely only they, can do it – and now is the time.

1

INTRODUCTION

Cary Krosinsky and Todd Cort

These are unprecedented times.

Global economic growth and average lifestyles are at all-time highs, yet this has come with costs such as degraded environmental systems which otherwise support economies, societies and cultures. Other costs appear to include rising inequality, and the effects of automation are only expected to accelerate these.

Scientists predict that the next 20 to 30 years will be filled with severe challenges to our way of life. We need look no further than the turmoil in Syria or Venezuela to see examples of the direct consequences of degraded environmental and social systems, and these may well grow exponentially if we don't find a way to resolve present day challenges.

Environmental challenges we currently face, or will face in the near future, include:

- a lack of adequate arable land to grow the food we need as a global society
- freshwater shortages resulting from climate change shifts, infrastructure challenges and economic disparity
- deforestation in both the tropics and temperate regions
- ocean acidification and pollution destroying large swaths of marine ecosystems, such as coral reefs
- mounting toxic and other waste problems
- air quality challenges, particularly smog in urban areas
- increased frequency and severity of weather events such as hurricanes and droughts
- increasing challenges to terrestrial biodiversity
- greater numbers of climate and environment refugees.

The social dimension, while at times overlapping with expected outcomes as above, also sees continuing challenges emerge across a lack of adequate education, housing and financial services, as well as unequal access to energy.

Progress remains fragmented and uneven, although there is much to be encouraged by.

China has made great strides in eliminating energy poverty, but these challenges remain in India. Conditions are improving for a rising middle class in other developing nations, while in countries such as the United States and the United Kingdom, large swaths of society feel increasingly left behind, leading to unexpected election results which have environmental and social ramifications.

The interconnected nature of the global economy and such environmental and social challenges is becoming clearer, and fortunately, so are solutions to these challenges. However, what is needed to fix these problems is not simple. Many categories of solution in fact appear to be necessary. The common thread for these myriad solutions is innovation for impact.

Sustainability has become an issue of global competitiveness, requiring innovative thinking in areas such as:

- corporate strategy
- economics, currency and the future of money
- energy
- food and forests
- investment prioritization and strategy
- logistics and the future of transportation
- policy
- regional solutions
- technology.

The countries and regions which can best address these areas of innovation will almost certainly be those which will be the most economically vibrant in the coming decades.

However, as with social and environmental challenges, solutions will always have side effects and unintended consequences that must be managed. A full solution set must be multi-layered and complex by definition. A systems approach to innovation will be necessary, and therefore we see the need to run solutions within these diverse areas in parallel for best effect.

Unintended consequences have already been witnessed in regions such as Silicon Valley in the US. This region succeeds through a lens of innovation, leading to almost out of control financial success for the area as a whole, yet many have been economically left behind. An ideal systemic solution appears to require more consideration of the social dimension, creating opportunities for all categories of resident, thereby reducing inequality in order to achieve full economic health and vitality which all of its citizens might therefore benefit from – but how best to achieve this outcome?

Key questions and imperatives, as a result, continue to emerge, such as:

- how can innovation be a driver of better social and environmental outcomes?
- what do we mean by innovation in all of its manifestations?

- how can we create a symphony of solutions running in parallel for best effect, so that we can take full advantage of new technologies?
- how can we both maximize globalization while revitalizing local communities?
- what should corporations, investors and policymakers do to create positive dynamics among all such categories of innovative thinking?

This is exactly what this book intends to achieve – a review of solutions that, if run successfully in parallel, might keep us from driving over the environmental and societal cliff-edge that we will otherwise continue to race towards. Turning challenges into opportunities through innovation is the only way to drive future success. We all want a world that thrives.

What are these solutions and what do they start to look like?

That is precisely what we have worked on in some of our recent classes at Yale, Brown, Maryland and Concordia, and some of the best proposed solutions are featured here, among other views of what is soon to be required. As we wrote in our previous book on sustainable investing, the future of investing now requires sustainability to be fully "baked in," and for the environmental and societal outcomes we seek, there also needs to be a business case.

Millennials recognize this, and so do leading businesses such as Amazon, Alphabet and Apple. New business models have also emerged in the sharing economy, and global cities are rising up as booming and thriving metropolises where all sorts of solutions are emerging among the positive energy of their citizens. This dynamic now needs to be experienced and implemented in all countries and in all regions to take full effect. Solving these problems is our biggest challenge, and hence our biggest opportunity.

The chapters to follow propose solutions to integrated environmental and social challenges. We hope you enjoy this expedition and that it helps you find your own pathway forward. We all now need to play our part to help create the sustainable and economically vibrant future we all desire. It appears to be the only way.

2

WHAT IS INNOVATION?

Arthur Matuszewski

Innovation is the proverbial buzzword of our hyper-growth era. In 2017 alone, there were over 16 million articles and blogs featuring the word 'innovation' in the headline. At root, our fascination with innovation in theory and practice comes from the hope that things will get better, and that there will be ever-newer solutions to deliver value in our day-to-day lives.

There are numerous frameworks and methodological interpretations of innovation, assessing everything from its commercial impact, durability and technological sophistication to, more prosaically, the degree to which it offers something to someone that was not delivered before.

Rather than outlining ad nauseam these minutiae, the goal of this introduction is to share some guiding questions, examples and leading thoughts to assess and define innovation broadly and to determine the degree to which the provocations and ideas you'll be reading of might constitute that proverbial *new*.

Known need?

- Is there a clear and pressing problem, heretofore unaddressed?
- Is this a problem that has been clearly defined, distinct from broader thematic concerns?
- Are there clear stakeholders to this problem, or is responsibility for its impact unclear?

For example, trash is a clear problem of consumption, though there are many possible and attempted solutions to its resolution. The rapid environmental degradation of landfills and surrounding lands leads to clear and present danger to human and natural life therein, vs. the vaguer concern that this may contribute to global warming. Communities near landfills bear the responsibility of dealing with these localized negative externalities, and any solutions to waste management must consider their immediate concerns.

Unknown need?

- Are there problems that your solutions answer, but which are not yet understood to be the primary problems?
- Are there ways this notion will allow for further discovery, potentially solving multiple problems?
- Will this transform a system, or link disparate groups together, in a way that changes the dynamics of why different parties may care?

For example, before the advent of digital streaming, the solution entertainment companies sought to provide was how to get you physical media quicker, vs. the content of that physical media. Streaming content allowed for removing limitations, late fees, and the problem of physical convenience. By understanding better how people engage with content, the real-time data from streaming allows for more personalized recommendations, which in turn decreases the selection problem, and allows providers of content to produce yet better, more personalized, and more engaging content.

Known solution?

- Do you have a likely concept of the solution, or an understanding of which domain, discipline or technology may solve this problem?
- Does this solution exist elsewhere, where you may combine insights, or share best practices with others?
- Do you know who is responsible for addressing this problem, or who may be best positioned through unique resources, specialized context, or given capabilities to best solve it?

For example, it's broadly understood that a central limitation to mass adoption of electric vehicles today is the limitations of battery technology, requiring increases in the productive capacity of individual batteries via engineering. Other industries, such as portable device manufacturers, have struggled with how to compress battery technology and how to best limit power usage within their devices. Companies with the most battery production infrastructure, unique materials understanding, and technical acumen to iterate quickest through complex production challenges have a stronger chance of succeeding given the human and financial capital required.

Unknown solution?

- Does your solution require solving other, harder, technical problems along the way, or do you not know from what fields insights impacting your solution may come from?

- Does your solution lack any existing conceptual or real-world analogs, from which refinements/improvements can build off?
- Will your solution beget answers to other solutions, probably though not always before solving your target problem?

For example, producing highly personalized medicine based on individual genomes required a fundamental understanding of how human cellular biology was structured, which required both a working conceptual model and a means of testing and verifying these hypotheses at scale. While treating patients for illness relies on observational and diagnostic studies, proactively medicating and targeting long-term growth specifically follows a fundamental reworking of nutrition vs. x genome drug delivery. On the path to solving and transforming human genetics, there are multiple advances in large data-synthetic 'clinical' trials, drug formulation and genetic sequencing that predicate any meaningful progress if they do not maintain growth in tandem.

In the chase for discovering something new, it's right to start with clearly articulating both what's old and what's current while focusing specifically on the space between where you are and where you want to be.

The journey from past to present is the story that will determine the degree to which your next game changing move is doing that, vs. merely turning the dial slightly on what was done before.

That said, innovation is largely what you make, and it is largely relative. Innovation is not universal across contexts, and a lot of innovation emerges rightly from trafficking cultural and intellectual capital from one discipline to another to evolve new views on both problems and solutions.

Traversing from what's known to what's currently unknown is always a process of innovation. The benefit of innovation will ultimately be judged by stakeholders, and its success contingent on the value generated, however that value is to be defined.

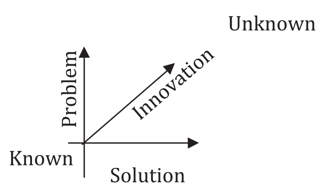

FIGURE 2.1

PART I
Corporate perspectives

When considering impact, whether from an environmental or social perspective, there is increasing focus being drawn to the phrase "impact investing." In practice, impact investing most often focuses on the provision of services for those less well off, such as education, financial services, healthcare and housing, and is estimated at just over US$110 billion.[1] Impact investing by this definition, rising just US$4 billion between 2016 and 2017, has been challeged to grow significantly.

Dwarfing impact investing, in fact something like 1,000 times larger in value, are existing corporations across all sectors, and mostly those which are publicly traded.[2] In fact, the value of publicly traded companies is now believed to be at a record high,[3] and beyond this, additional existing organizations operate from the realms of private investors or governments in the form of state owned enterprises. Markets have also seen a reduction of IPOs in recent times, and lots of dry powder housed within the worlds of private equity and venture capital.

All of this makes changing existing companies extremely important, though changing anything meaningfully that already exists is often very hard to justify on financial grounds alone. Think of all the buildings not yet retrofitted: surely if this were low-hanging fruit this would be occurring at a much faster pace. There is great inertia in the status quo, and this makes new mechanisms and innovations which can drive necessary environmental and social change even more important to develop and understand. We will dig into this throughout this book, looking at examples of specific technological implementations, but to start, here are a few changing constructs that can lead to both financial and societal benefit.

Alexander Kappes starts us off with a look at human capital. The most financially successful sustainable investment fund available to the US public over the past ten years has been Parnassus Endeavor, which simply looks at what are the best companies to work for, and we chose to work with this fund within the Brown

University endowment as a result of their long running success.[4] It turns out that successfully managing your people is one of the most important levers of change. Also important are multi-stakeholder dialogues for solving a range of challenges that companies face along with the communities where they operate. Nora Moraga-Lewy provides a successful case of such practices in a South American setting. Fixing for more complex, embedded challenges, which light touch standards have failed to solve, such as deforestation in Asia, requires in-depth analysis and consideration, and and we get a first-hand look at the state of affairs in Singapore from Pek Shibao. Singapore famously has been experiencing a great deal of deforestation-related haze.

We wrap up our first overview of corporate practices with Susan Wang's look at how one sector can consider developing and working towards a comprehensive sustainability framework as regards the healthcare sector.

Corporates need to do much more, but progress is underway.

Notes

1 https://thegiin.org/assets/GIIN_AnnualImpactInvestorSurvey_2017_Web_Final.pdf
2 http://unepinquiry.org/wp-content/uploads/2015/12/The_Value_of_Everything.pdf
3 https://www.thestreet.com/story/14229200/1/global-stocks-are-now-worth-more-than-the-global-economy-and-that-s-worrying.html
4 https://www.routledge.com/Sustainable-Investing-Revolutions-in-theory-and-practice/Krosinsky-Purdom/p/book/9781138678613

3

SEARCHING FOR SUSTAINABILITY IN HUMAN CAPITAL

Alex Kappes

The objective of this chapter is to analyze the effect human capital strategies have on long-term profitability, productivity, and overall sustainability. Additionally, we will attempt to identify key human capital traits which analysts could leverage to further differentiate socially sustainable firms for possible inclusion in an investment portfolio. Research and analysis on environmental, social, and governance (ESG) issues is an essential part of accurately assessing the risk and performance of organizations over the long term. Human capital, a social factor in ESG analysis, is fundamentally important to sustainability in that some level of human knowledge and skills is necessary for organizations to accomplish much of anything. By closely analyzing social factors like human capital and incorporating applicable data and metrics into investment decisions, investors can better identify companies that are ideal for strong future growth and profitability over the long term.

The evolution of human capital

There is little doubt that a large majority of companies understand the importance of sound human capital practices and their direct impact on sustainability. Businesses have realized that socially sustainable human capital approaches more fully employ the skills of their workforce which leads to greater innovation, product development, service delivery and increasing levels of productivity. By adapting recruiting, retention, and leadership strategies, hyper-focusing on a positive workplace experience, and adopting new cutting-edge technologies leveraged by employees, organizations are clearly seeing significant advantages of healthy human capital nervous systems. Businesses are also realizing that unhealthy human capital approaches can result in reduced productivity and profits, a poor reputation, and an overall unsustainable future.

According to Deloitte's annual 2017 *Global Human Capital Trends*, "business productivity has not kept pace with technological progress in recent years." In other words, the rate at which technology is being adopted and advanced within organizations is far outpacing progress in overall productivity. Additionally, according to Deloitte, companies with low productivity are losing out at a faster rate to competitors with higher productivity. Deloitte points towards inadequate human capital strategies as the primary culprit. "We believe the problem comes down to human capital strategies – how businesses organize, manage, develop, and align people at work." While many companies understand the importance of effective human capital policies and processes, businesses are still searching and at times struggling to implement human capital practices that better leverage technology in a way that facilitates long term sustainability.

Technology continues to advance at an extraordinary rate and it is having a significant impact on how organizations employ human capital strategies. Everything from machine learning, automation, mobile technology, and cloud services have presented businesses with complex and rapidly evolving organizational human capital challenges. Companies that can more quickly harness and leverage technological innovations as well as adapt and revise their own human capital approaches may enjoy a competitive edge over opponents. Additionally, outside investors that are successfully able to identify agile companies are better positioned to realize superior long-term returns on their investments.

The recruitment of talented people, evaluation and retention of employees, a dedicated focus on diversity and inclusion, and the application of analytics to the workforce are key components of an organization's human capital strategy and are of interest when considering the implications on a company's long-term sustainability. These aspects of human capital are becoming increasingly relevant and important for companies to analyze and adapt if organizations wish to maintain a competitive advantage within their respective industries. Additionally, investors in search of socially sustainable firms should closely consider the following human capital trends when vetting companies for possible inclusion in an investment portfolio focused on long-term growth.

Recruitment

Often referred to (and rightfully so) as the lifeline of an organization, companies are using a variety of new ways to find employees. A June 2017 *Wall Street Journal* article highlighted Unilever's radical new hiring experiment in which the company relies on algorithms rather than résumés to sort applicants and target potential hires. The company has hired 450 employees globally since implementing this new experiment and has stated that hiring has become faster and more accurate. Companies such as Goldman Sachs and Walmart are also implementing more robust digital recruiting strategies to expand their candidate selection pool. These types of experiment provide a "glimpse of a tech fueled future of recruiting in which humans write job descriptions and make final decisions, but software and algorithms do the rest." Businesses continue to make recruiting a top priority, and finding the right people has become more competitive than ever. According to

2017's *Global Human Capital Trends*, industry leaders are aggressively seeking and implementing new technological solutions into their recruiting strategies to include machine learning, robotics process automation, natural language processing, and predictive algorithms which are radically changing modern talent acquisition. Companies that successfully exploit technological innovations in talent acquisition will have a clear long-term advantage over their competitors.

Performance evaluation

In 2013 Jack Welsh, former CEO of General Electric (GE), said, "As a manager you owe candor to your people. They must not be guessing about what the organization thinks about them." In recent years, many industry-leading companies have begun to re-evaluate their long standing and traditional annual appraisal practices in favor of new agile performance management processes that provide more "candor" or transparency. Employers have realized that a greater percentage of the workforce would prefer performance feedback on a more reoccurring basis, allowing employees to quickly adapt and more efficiently align their efforts with organizational objectives. Modernized appraisal systems are having a positive impact on organizations seeking direct improvements in overall productivity due to a more adaptable and motivated workforce. Additionally, by better understanding individual contributions on a consistent basis, companies are better able to align rewards with performance, allowing organizations to better identify and retain quality individuals. According to a June 2016 *Wall Street Journal* article, GE, which over the years has represented the model for successful human capital management, is actively implementing an updated performance management system that allows employees the opportunity to improve faster and adjust more quickly. GE allows managers and direct reports to check-in with each other on a regular basis, holding brief annual summaries rather than a full review. Additionally, GE's 200,000-plus employees use a new mobile application called PD@GE which allows them to give one another feedback at any time. GE, along with many other companies including Accenture, Adobe, IBM and Cisco, has led the way in developing new evaluation methods that quantifiably enhance value within their respective businesses. By analyzing the current state of a company's performance evaluation and retention methods, an investor can better identify organizations primed for long-term growth.

Diversity

Research shows that diverse and inclusive groups outperform their peers. A January 2015 McKinsey & Co. article states "it is increasingly clear that companies with more diverse workforces perform better financially" (Hunt et al. 2017). The article goes on to state, "diversity is probably a competitive differentiator that shifts market share toward more diverse companies over time." The topic of diversity continues to be an important factor in how companies are perceived by both employees and customers. Companies are realizing that diversity and inclusion have a large financial impact on the bottom line, and thus businesses are spending an increasingly amount of resources to ensure they are getting diversity strategies right. In 2017's *Global Human Capital Trends* Deloitte states that a greater percentage of the global workforce, specifically millennials, sees diversity as a "mandatory part of corporate culture." By including the quality of an organization's diversity strategy into their selection criteria, investors can more accurately identify sustainable companies with the potential for above average future performance.

Workforce analytics

A *Wall Street Journal* article, "CIO Insights and Analysis," from Deloitte, accurately assesses that, "a company that understands its workforce needs better than its competitors may compete more effectively in the labor market and unlock more value from its workforce." Successful companies are leveraging workforce data and analytics to make more informed decisions that directly affect their business. Organizations are investing in analytical software tools that are providing new insights into a business's human capital strategy and operations to facilitate improvements in recruiting, retention, and rewarding improving overall workforce performance. Traditionally, many companies have focused their analytical reporting efforts on sales, marketing, and finance. However, it is becoming increasingly clear to business leaders that analytics need to be applied across the entire workforce management process and operations. IBM, considered globally a leading organization in people analytics, has demonstrated the benefits that can result from greater insights into a company's workforce. IBM's website states, "the ability to predict and prevent regrettable attrition has created a new benefit of $270 million alone." The application of analytics across a company is an important measure when successfully attempting to identify sustainable organizations.

Measuring human capital

The success or failure of a company is greatly impacted by and often attributed to the strength or weakness of an organization's human capital practices. Analysts in search of sustainable companies that demonstrate the potential for strong future growth must measure the overall condition of an organization's human capital environment. Until recently, there were not sufficient technologies and or processes in place for measuring direct contributions from investment in human capital. That has significantly changed over the last decade as systems and technological solutions have been developed for better assessing human capital, predicting organizational performance, and guiding organizations' investments in people. Organizations are adapting their strategies for measuring human capital performance, realizing that traditional metrics alone like employer turnover rate and total hours of professional training per year no longer suffice. Significant research is being conducted to discover methods that are more effective in measuring the direct impact human capital investments have on the bottom line of organizations.

Through surveys and research, Laurie Bassi and Daniel McMurrer, authors of a *Harvard Business Review* article titled "Maximizing Your Return on People," uniquely identified the following human capital best practices or core drivers: (1) leadership practices, (2) employee engagement, (3) knowledge accessibility, (4) workforce optimization, and (5) organizational learning capacity. The article states, "Improvements or declines in organizational performance can be tied directly to improvements or declines in human capital management practices." The authors generated a quantitative maturity score for a group of companies based on these core human capital drivers and discovered that a high maturity score was directly linked to revenue performance (Bassi and McMurrer 2007).

This research demonstrates two primary items. First, it quantitatively reaffirms that the quality of an organization's human capital approach (accounting for specific drivers) directly and significantly impacts company performance. Second, this research reaffirms the complexity and depth of human capital factors that can potentially influence the performance and long-term sustainability of an organization.

Human capital insight through data has an enormous impact on a company's decision-making process, leading to greater levels of productivity and profitability for those companies that choose to adopt and implement new technologies. Data and analytics increasingly influence people-related decisions inside organizations globally. Businesses are tapping into data points to better understand a variety of organizational issues, such as: Where are our best new hires coming from? Who are our top performers and are we keeping them? Who are our most critical employees and are we keeping them? How are we rewarding our best employees? How much does it cost to have a critical job unfilled? What are the key qualities that make up a high-performance team? Better data management strategies are forcing companies to ask questions that they had previously not considered. Companies that can implement these advanced software technologies within organizational structures benefit from higher levels of organizational awareness, adaptability, and profitability, and ultimately maintain a competitive advantage within their industry sector.

How do investors know if companies are implementing sound analytic strategies that positively impact their human capital processes? At times this can be a challenge, especially from the outside looking in. One way is to review a company's data strategy. Organizations are spending more and more resources on the development of robust data strategies. The data strategy defines how a company will use internal and external, structured and unstructured data from a variety of sources. Next, attempt to gain insight on what technologies (i.e. Salesforce, PeopleSoft, ServiceNow) companies are employing to process and visualize data to drive *real* insight which leads to better financial performance. Finally, if available, research internal analytic training programs and associated curricula being employed by companies to educate and train employees.

Wegmans is a good example of a company making sound decisions by implementing analytics to improve employee satisfaction while simultaneously cutting costs and increasing margins. Escalating health care costs paired with strong organizational growth forced Wegmans to reevaluate their cost structure specifically with respect to health care benefits. However, prior to changing benefit options, Wegmans used analytical analysis to accurately and quantifiably understand how much employees valued benefits and the associated satisfaction resulting from those benefits. Wegmans objective was to make changes to the health care program to reduce costs without reducing employee satisfaction. Through their analytical approach Wegmans discovered that health benefits were the deciding factor in whether employees joined and were retained by the company. Wegmans also realized that offering a basic health care coverage option to previously non-eligible employees greatly impacted overall incremental value for the company due to how much employees valued health care benefits. More specifically, Wegmans discerned that a $107 investment per non-eligible employee (total investment $1.5 million) felt like a $30 million benefit to the workforce. A happier workforce increases company profitability due to improved employee satisfaction and resulting increases in productivity. This example clearly demonstrates the social and financial benefits of workforce analytics for both the organization and their employees.

Conclusion

Human capital's impact on an organization's long term sustainability cannot be overstated. When searching for and evaluating companies for possible inclusion in portfolios oriented to socially responsible investing, it has become increasingly important for investors to consider a wider range of human capital factors beyond simple metrics. Everything from recruiting practices, performance evaluation, workforce analytics, and company diversity will have a significant impact on a company's competitive advantage and future profitability. Additionally, investors need to better understand data strategies, on-going analytic practices and enterprise-level technology solutions that are actively being implemented.

Ultimately, by better understanding levels of human capital commitment, investors can gain better insights and achieve better results by more accurately assessing the risk and performance of organizations over the long term.

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4

THE POTENTIAL OF MULTI-STAKEHOLDER ENGAGEMENT

Argentina's Ledesma as a case study

Nora Moraga-Lewy

Introduction

Sugarcane is a useful commodity that is not only harvested for sugar and livestock fodder; the cash crop can also be processed into rum, ethanol and various bioplastics (WWF 2012, 1). Sugarcane production – or more specifically, harvesting – is widespread. The plant grows well primarily in tropical climates, making North, Central and South America as well as Asia, Africa and Australia suitable for the crop. Together, the Americas produce about 35 percent of sugar worldwide (FAOSTAT 2017a). The Food and Agriculture Organization (FAO) estimates that sugarcane is the Americas' (and the world's) top commodity by production (FAOSTAT 2017b).

As is the case for many agricultural activities globally, there are negative environmental and social externalities and risks associated with sugarcane production. Meanwhile, the human population continues to grow and potential biofuel mandates will result in heightened demand for the crop and its products (Bailis et al. 2015, 1–2). A report by the World Wildlife Fund estimates a 49 percent increase in land area under sugarcane cultivation by 2050 due to this increased demand (WWF 2012, 53). It is ever more important to bring attention to the issues associated with sugarcane harvesting and inspire meaningful changes to farming and business practices that will help meet global needs while minimizing negative impacts on surrounding ecosystems and communities.

Some companies, including Argentina's Ledesma, have taken initiatives to implement mechanisms targeting specific problems associated with typical sugarcane production practices. This chapter will evaluate key lessons learned from Ledesma's case and gauge the potential of replicating this multi-stakeholder engagement model throughout the industry. The chapter will conclude with recommendations for specific local stakeholder or interest groups dedicated to solving the problems associated with sugarcane production, and with suggestions for future research and consideration.

The sugarcane industry: risks and challenges

Sugarcane production plays a significant role in the economies of many Latin American countries (see Table 4.1). Its value as a cash crop has been reinforced since Columbian trade, when it was first introduced to the continent. Commodities like sugarcane are difficult to govern given the fragmentation of production, disconnect between the crop and the marketed good, and typically a lack of associated brand recognition which could facilitate corporate accountability campaigns (Mayer and Gereffi 2010, 10–11). While sugarcane production practices can be improved by newer technologies or harvesting methods, cost is often a barrier or disincentive to widespread change – especially due to the aforementioned governance challenges (WWF 2012, 56).

Social risks and challenges

Ensuring compliance with national, regional and local rules and regulations can be difficult where there is lacking political will or capacity – either economic or technical (Borras et al. 2012, 857; Bhattarai and Hammig 2001, 996, 1005). Political will to enforce environmental and social standards in the agribusiness sector in Latin America may be influenced by the sector's significant role in both local and national economies (see Table 4.1). These economic factors are also linked to the social risks associated with the sugarcane industry. Agricultural laborers in many regions of Latin America and the rest of the world have relatively low bargaining

TABLE 4.1 Sugarcane production and net production value in American regions (2014)

Region	*Production (metric tonnes)*	*2014 net production value (constant 2004–2006 1,000 I$)*
Northern America	27,600,190	849,236.73
Central America	111,887,336	3,646,208.20
Caribbean	27,426,901	832,325.25
South America	840,800,369	27,244,664.52
Total	1,007,724,796	32,572,434.70

Source: FAOSTAT 2017a, 2017b.

Note: This table is meant to illustrate the scale and value of sugarcane production in the Americas. For more data, visit FAO.org/faostat. Argentina is South America's fourth largest producer of sugarcane. In 2014, Argentina produced 24,502,741 metric tonnes of sugar at a value of 804,596 (*constant 2004–2006 1000 I$*) (FAOSTAT 2017a, 2017b). Argentine sugar production is forecast at 1,723,651 metric tonnes (raw basis) for 2017–2018 (U.S. Foreign Agricultural Service 2017).

power, and political influence can be a challenge depending on the structure of and access to government institutions.

Even in contexts where adequate laws are codified and relevant regulations exist, for example, politically underrepresented rural communities or indigenous populations may still face challenges. A *de facto* system of weak rule of law can manifest in many ways, including the delegitimization or undermining of mechanisms for dispute resolution, exploitation and alienation of laborers, and a lack of consideration for customary rules and norms for resource tenure, among other issues (Borras et al. 2012, 848). While not unique to the sugarcane industry, forced or bonded labor, wage theft, and age regulation violations also pose concerns (U.S. Department of Labor 2012; WWF 2012, 54). In addition to reputational risks, there are many factors that cause a risk of conflict, which can escalate to violence, disrupting communities as well as the efficient production of sugarcane (Borras et al. 2012, 849; Mingorría 2017, 1).

Environmental risks and challenges

There are also urgent environmental risks and challenges associated with sugarcane production. This section highlights key risks and challenges associated with sugarcane harvesting in Latin America today.

Sugarcane harvesting is a highly water-intensive activity that requires land. While a global water shortage arguably does not exist, agricultural activities including sugarcane production can place high levels of local water stress due to use or aquatic resource degradation where the crops are harvested (Martinelli and Filoso 2008, 888; WWF 2012, 54–55). Land conversion and deforestation, which in turn result in biodiversity loss and carbon stock depletion, are some of the most publicized issues with agricultural activities in Latin America – and sugarcane production is no exception (Fischer et al. 2008, 29, 41–43; WWF 2012, 54). In addition to the loss of forest, methods used for clearing land for planting such as swidden, or slash-and burn, emit greenhouse gases (Fischer et al. 2008, 41, 57; Martinelli and Filoso 2008, 891; WWF 2012, 54). These techniques are used most commonly when equipment and time for cleaner harvesting methods are too expensive or not appropriate for scale (WWF 2012, 54).

Another negative effect of the techniques frequently used for clearing land for planting is the respiratory and cardiovascular health of laborers and surrounding communities due to the emission and aerial transport of particulate matter (Barbosa et al. 2012; Le Blond et al. 2017; WWF 2012, 54). The use of agrochemicals for pesticide and fertilizer can also be detrimental to human health – especially for workers who harvest the sugarcane (Barbosa et al. 2012; Ribeiro 2008, 1; WWF 2012, 54). Agrochemicals also seep into groundwater or become part of runoff, polluting watersheds and degrading water quality (WWF 2012, 54). The effect of various environmental conditions resulting from sugarcane production on human health invites consideration of human rights litigation and questions about compensation.

There is also a plethora of context-dependent externalities associated with the sugarcane industry. One example is the curious case of extremely high chronic kidney disease (CKD) prevalent in populations working for sugarcane plantations in Nicaragua (Laws et al. 2015). No proof of causation has been established todate, but epidemiologists have shown that there is some association between the abnormally high number of people suffering from CKD and their occupation as sugarcane farm and factory laborers (Laws et al. 2015).

The aforementioned social and environmental risks and challenges are not all manifested in every region where sugarcane production takes place at any given time, but the list demonstrates an urgent need to assess and improve the sugarcane industry's practices. Fortunately, there are also associated opportunities for companies to mitigate future challenges and to demonstratea commitment to social and environmental responsibility.

The Ledesma case

Ledesma is an Argentine agro-industrial company that produces sugar, fruit and paper goods (WBCSD 2007, 1). In 2013 the 100-year-old company represented 26 percent of industrial manufacturing and 13 percent of total annual goods produced in the province of Jujuy, and 18 percent of the sugar produced in Argentina (Vidal 2014). Ledesma is part of CEADS (the Argentine chapter of the World Business Council for Sustainable Development), FUJIDES (Jujuy Foundation for Sustainable Development), FUNDESNOA (Foundation for the Development of Northern Argentina) and the UN Global Compact, and it considers itself committed to social responsibility (WBCSD 2007, 1). Even with its philanthropic partner, Fundación Ingenio, in Ledesma's efforts to support regional development, the company's reputation has been affected by controversies and a difficulty meeting certain environmental and social responsibility standards.

Ledesma has plantations and refineries in various provinces in Argentina, but some of its most notable operations are in the province of Jujuy. Its Jujuy plantation, or *finca*, has sugarcane harvesting and refinement capacity (into alcohol and other products), cellulose and paper, fruit harvesting, and the capacity to produce over 51,000kW of biomass-energy (Bernal et al. 2008, 9). The landscape includes northwestern Argentina's *yungas,* or native growth forests, which are also considered a biodiversity hotspot (Bernal et al. 2008, 750). In reality, the Yungas region has ecosystems ranging from grasslands to high-elevation forest, and consists of a patchwork of traditional and formal tenure systems and protected areas (Bernal et al. 2008, 750–751).

Greenpeace was the first organization to bring attention to the unsustainable growth of Ledesma's sugarcane plantations, and the company had historically dealt with other controversies relating to its disregard for local economic development issues outside its own operations (Vidal 2014). Several environmental interest organizations, including Fundación Vida Silvestre, got involved in analyzing what steps Ledesma should take to avoid further damaging the high-conservation value forests surrounding its operations (Vidal 2014). Ultimately, negotiations with an organization called ProYungas proved the most fruitful. Founded in 1999 by a small group of professionally trained biologists, ProYungas would eventually serve as a facilitator and negotiator in Ledesma's transformation process (Fundación ProYungas 2015a; Vidal 2014).

Various notable social and environmental risk reduction initiatives emerged as a result of separate efforts to address the problems associated with Ledesma's presence in Jujuy. Examples include the creation of a *Paisaje Productivo Protegido* (Productive Protected Area, or PPP), improvements made in operational efficiency, and the company's Local Supplier Development Program (LSDP) (Fronti and D'Onofrio 2010, 31, 44, 48). These initiatives are described in Table4.2.

One of the most important characteristics of Ledesma's initiatives is the role of other stakeholders in addition to its own. With relation to the LSDP, Ledesma itself is responsible for identifying small and medium enterprises to replace outside suppliers, as well as providing management and financial assistance in order to strengthen regional job-creation and economic development (WBCSD 2007, 1; Fronti and D'Onofrio 2010, 31–32). With respect to the PPP, Ledesma must dedicate, fund and help manage a large portion of its land as a protected in what is called the "Yungas" of Jujuy in cooperation with ProYungas (Vidal 2014). As outlined in Table 4.2, the company has also pledged to streamline some of

TABLE 4.2 Three corporate environmental and social responsibility initiatives at Ledesma

Initiative	*What the initiative entails*
Local Supplier Development Program (LSDP)	• Identification of SMEs for financial assistance and management training in order to replace contracts with suppliers from outside Jujuy. • Participation from Ledesma in form of an operational team with members from head of supply, human resources, corporate social responsibility and external affairs. • FUJUDES serves as facilitator, providing consultants.
Paisaje Productivo Protegido (PPP)	• 2/3 hectares owned by Ledesma are to be maintained as a private reserve, labeled "Yungas"; maximum productive area is 61,000 of the 157,000 hectares. • Research support provided for conservation interest organizations.
Operational efficiency *(eco-eficiencia)*[1]	• 40% of biomass from cane sugar stalks is used to generate energy. • Half of the paper produced by LEDESMA is made from sugarcane fibers.

Sources: WBCSD 2007, 3; Comunidad RSE 2015; Fronti and D'Onofrio 2010, 23, 31, 44, 48)

[1] *Ecoeficiencia*, or "Eco-Efficiency," is characterized by the WBCSD as "environmental improvements that yield parallel economic benefits." It is achieved through the "delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the Earth's estimated carrying capacity" (WBCSD 2006, 27).

its operations and change cultivation and energy generation practices to align with its goals of reducing greenhouse gas emissions (Comunidad RSE 2015).

Ledesma benefits from its efforts. As a result of the LSDP, the company has more reliable product sourcing and reduced shipping and transport costs because of supplier proximity (WBCSD 2007, 3–5; Fronti and D'Onofrio 2010, 31–32). Less exposure to larger market interruptions is less risky (WBCSD 2007, 3–5). Using biomass from the sugarcane crop that would otherwise be burned or discarded (as well as from the unused parts of trees that Ledesma processes for its paper products) for energy generation is an important step towards reducing waste and expenses associated with its removal (Vidal 2014). It also contributes to greater stability in energy production and steps towards energy self-sufficiency, which reduces risks associated with the larger Argentine grid (Vidal 2014). Ledesma benefits from the natural "Yungas" reserve as a public relations icon as well as for the additional ecosystem services and long-term ecological stability (Vidal 2014).

The company's success would have been unlikely without help from conservation experts. ProYungas maintains an integral role in managing the PPP and is also responsible for holding the company accountable for several of its other environmental commitments (Vidal 2014). In the PPP initiative, ProYungas must set conservation goals and produce researched reports to show that the livelihood of its project ecosystem is worth conserving (Vidal 2014). Finally, the organization has also begun certifying many of Ledesma's products, so it must audit their operations (Vidal 2014). As a partner in so many aspects of Ledesma's commitment to environmental responsibility, ProYungas is ensured a voice at the table when the company proposes any expansion or a new operation (Brown and Ullivarri 2015). The organization also receives funding and means to work towards its conservation goals a well as the opportunity to generate community and national awareness with the addition of its brand on Ledesma products (Brown and Ullivarri 2015).

FUJUDES (Jujuy Foundation for Sustainable Development) is closely tied to and advocates for the communities that surround Ledesma's operations. FUJUDES and affected communities share the goal of economic development in the province of Jujuy (WBCSD 2007, 2–3). FUJUDES facilitated the creation of Ledesma's LSDP by providing support by contributing consultants to Ledesma's efforts and in return advanced its goals of promoting sustainable development in the province (WBCSD 2007, 2–3). The community in which FUJUDES and Ledesma operates now serves as more than hosts now that Ledesma is investing in it (Bernal et al. 2008, 39).

The community also now has a platform and framework for holding Ledesma accountable and the opportunity to participate in capacity-building activities (for sustainable living, education, health, economic development) when it chooses to – at least regarding certain environmental and social matters. The 11 companies that participated in the pilot LSDP program saw a combined sales increase of 80 percent in one year, creating a larger job market and in the long run a more stable local economy (WBCSD 2007, 1). The "Yungas" PPP is now a local landmark for the tourism industry as well as providing ecosystem services (Vidal 2014). With some support from Ledesma, ProYungas is also partnering with local artisans and smaller-scale agricultural firms to produce a new line of products certified as "*Producto Yungas*" that are now being sold nationally (Brown and Ullivarri 2015).

Overall, the economic activity generates resources necessary to maintain the quality of life and social stability of surrounding communities (Bernal et al. 2008, 18–19, 39; Comunidad RSE 2015). Ledesma has learned to consider environmental protection a part of its corporate mandate as an agribusiness, recognizing its reliance on the ecological for sustaining the conditions necessary for its crops to thrive many decades into the future (Comunidad RSE 2015).

Ledesma today

Ledesma continues to add innovative social and environmental programming to its philanthropic and operational agendas. For example, a partnership with the Enseñá por *Argentina* Foundation is promoting access to good education for all youth in Jujuy and sponsors additional career-oriented programming (Ledesma 2017b). The Foundation had already begun working with the province's Ministry of Education and had built a strong reputation for itself. With Ledesma's support, *Enseñapor Argentina* is able to expand the reach of its services (Ledesma 2017b).

Numerous notable initiatives have not freed the company of controversy. Labor condition and wage-related conflicts have been intermittent throughout the past decade, with the most recent emerging in September 2017 (Télam 2017). Strikes and protests lasting weeks blocked a national highway and ultimately attracted police suppression through interventions involving tear gas and rubber bullets (*El Tribuno* 2017). These social conflicts show that Ledesma's social initiatives aimed at extending the economic benefits of agricultural production to communities in its plantation's locality and region do not provide a means for addressing labor-related disputes – nor are they meant to. The social context in which the company operates requires consideration of issues of changes of practice that are beyond those which local organizations may be interested in addressing or capable of facilitating.

Key lessons and opportunities

The Ledesma case shows that adopting environmentally and socially responsible principles and practices to address challenges associated with business as usual can benefit both the company and other local stakeholder groups. While some benefits are long-term, others comprise immediate, less tangible services such as limiting the reputational risk and liability the company would otherwise face without having made commitments to protecting Jujuy's ecosystems and supporting the economic development of its surrounding community. The company has so far been able to improve the reliability of its fuel and product sources, which ultimately hedges a different kind of external market risk.

Ledesma and ProYungas successfully engaged a variety of local and regional stakeholders and their interests. This resulted in a variety of mutually beneficial partnerships, as well as the development of the "Yunga" brand, which in turn has

TABLE 4.3 Ledesma initiatives addressing issues associated with sugarcane production

Issue addressed or mitigated	*Initiative(s)*
Water intensity	Operational efficiency
GHG emissions and energy use	*Paisaje Productivo Protegido* Operational efficiency
Deforestation and biodiversity loss	*Paisaje Productivo Protegido*
Local economic stagnation	Local Supplier Development Program
Reputational risk to company	All mechanisms

resulted in awareness and interest from beyond Jujuy. Engaging Ledesma was also successful in part due to its secure ownership of land and its hierarchical structure (Ianni and Geneletti 2010, 754). Finally, one aspect of implementing this program that has not yet been discussed is the impact on the morale of the company's workers. At Alejandro Brown's (ProYungas) and Miguel Ullivarri's (Ledesma) July presentation, the pair discussed the less tangible benefit of these initiatives on the morale and engagement level of the company's employees. While Ledesma may not become waste-free and still faces challenges relating to labor-related conflicts, many observers consider its implementation of environmentally and socially conscious practices and initiatives a success for the company and its stakeholders.

Challenges to replication

It is important to understand not just the deliberate efforts but also the spontaneous elements driving Ledesma's relative success. Other agribusinesses throughout Latin America that are also confronting social and environmental challenges may be situated in vastly different contexts.

Sometimes, organizations or groups that become involved in private governance or corporate responsibility initiatives like those proposed and adopted by Ledesma face the challenge of maintaining credibility in the eye of a third party. It is not uncommon for advocacy organizations to draw fire for their involvement with highly criticized businesses, which might deter collaborative dialogue (Mayer and Gereffi 2010, 19). This has not been a prevalent issue in the Ledesma case, but it might be of concern in other contexts. Concerns over the legitimacy of involved parties can be addressed by introducing a third party group for verification or auditing, but this may be expensive, unnecessary, or logistically complicated (Mayer and Gereffi 2010, 6). Partners will have to evaluate this possibility on a case-by-case basis.

Economic feasibility plays a role in determining whether a firm or plantation will be able or willing to change its practices. It would be unreasonable to expect that small or even some medium firms would be able to invest US$6–12million for high pressure boilers or internal combustion engines to make use of biogas, for example, despite the three-year payback period for one of corresponding size (WWF 2012, 8). Whether or not there is specific demand for sustainably sourced sugarcane or forest products can also influence some companies' calculations of economic feasibility because of possible associated price premiums. This factor is variable depending on the scale of an industry and whether a company supplies domestic, regional, and/or international markets (Mayer and Gereffi 2010, 4, 12, 14). Because most sugarcane produced is traded domestically, transnational norms, rules, and market standards might not have a significant impact on fostering this demand (WWF 2012, 53).

Finally, it may be challenging for a firm to agree to make some commitment or change its company-wide practices, because of how fragmented sugarcane production can be depending on the region (WWF 2012, 12). Some firms that produce sugarcane also buy the crop from smallholders that it has less control over, and separating the two sources at the processing facility can be expensive and ultimately ineffective. If the Ledesma case is to serve as a model for replication, it may be that the solution to mitigating this and the other challenges is to start targeting companies like Ledesma where the supply chain is relatively integrated (where cultivation and processing are done in close proximity and by company affiliates) – and from there attempting to scale best practices outwards to smaller industry actors.

Recommendations for replication

There are several barriers to replicating a systematic, multi-stakeholder approach to addressing the environmental and social impacts of sugarcane production. Both internal company actors and interested outside stakeholder groups and organizations may facilitate adoption of such an approach by highlighting certain key points:

1. The case for operational and economic efficiency. If a company is externally driven to improve practices or mitigate externalities through a public campaign, and no market incentive such as a certification is necessarily applicable, they will likely need some additional internal incentive to act. We see in the Ledesma case that at this scale, if the upfront investments can be made, there is great potential for limiting waste and streamlining fuel sourcing to more reliable and less carbon-intensive biomass and gas – all of which is saving the company money in the long term. Even the local development program oriented towards local sourcing has helped the company reduce long-term transportation costs (WBCSD 2006, 16, 73; Vidal 2014).
2. Potential competitive advantages. This argument is related to the case for economic efficiency. A company may gain competitive advantage by addressing issues before they become reputational risks and before legislation and enforcement in a particular jurisdiction catches up with standards necessary for preventing further environmental degradation and social risks. In other words, while the economic benefit of improving practices might not seem as great as business-as-usual, the company could hedge risks significantly and end up ahead of competitors in either of the previously stated events (WBCSD 2006, 20–21, 24).

Initiatives should also consider the involvement of local, regional and even domestic government institutions in order to ensure long-lasting and broader change. This was not an important component of Ledesma's transformation, and it does not necessarily have to be a step taken at the beginning of the process.

However, for industry-wide or regional change, it is ultimately useful to have legislation favoring environmentally and socially responsible corporate governance. This recommendation may be most important for advocacy groups to consider and act on after finding a champion company like Ledesma to work on implementing operational and management changes.

Actors should not underestimate the value of strategic partnerships and coalitions with unlikely partners. It is unlikely that a single non-profit organization or NGO would be able to effectively provide the resources necessary to enact thorough changes, even for the benefit of external credibility. Reputable organizations like the World Wildlife Fund have received criticism for working with companies without third-party verification or auditing in other agribusinesses such as palm oil. But there is potential for creative strategic partnerships beyond the roles played by Ledesma, FUJUDES, ProYungas and the communities of Jujuy; we saw in the Ledesma case the development of "Productos Yungas" certification and the branding of "Yungas" as beneficial for local artisan goods and even the small tourism industry of the region. In other contexts, involving such groups more directly and even earlier in the process of transformation could be very productive.

Thinking systematically can seem tedious but may help ensure a successful initiative. As a company or relevant stakeholders work out how to approach an environmental or social problem, it can help to consider a variety of variables, both to avoid unintended consequences and to ensure that any transformation or improvement has the best chance of making a meaningful impact. Thinking about systems in terms of input, interactions, and output may consist of asking the following questions:

1. What are the dynamics of social movements? Will the movement have a catalyzing or detrimental impact on the goal of transformation? The input of ideas and information can result in the reinforcement or stagnation of a company's efforts depending on how communication and public relations are executed.
2. How can a firm optimize its efficiency by adopting concepts from industrial ecology? This question would target the idea of closing the production loop towards self-sufficiency of either a firm or region, which Ledesma seems to be working towards (though it is not necessarily framed as such).
3. Can harvest practices be changed to improve the efficiency of natural resource flow? For example, machines or equipment that eliminate the need to burn fields pre- and post-harvesting can be a valuable investment in terms of diminishing environmental impact as well as increasing the yield of sugarcane in a given season. The role and possibility of capital investment is important in strategizing. A useful resource for organizations considering this approach is the book *Thinking in Systems* by Donella H. Meadows (2008, for the Sustainability Institute; see also Ianni and Geneletti 2010, 750).

Future research and considerations

Examining Ledesma as an example of a company that has been relatively successful at addressing social and environmental issues through multi-stakeholder engagement reveals various challenges and opportunities. There are many knowledge gaps that could be the subject of further research supporting the development of a robust engagement strategy or model for replication.

A more thorough analysis of the economic incentives that may exist for companies to transform their practices or management goals to mitigate environmental and social externalities and risk, would be useful to organizations interested in replicating or taking lessons from Ledesma's case. For example, a better understanding of the certification schemes available for sugarcane production and whether a real market for the label exists can either indicate to a company that there is some market-driven incentive for improving practices *or* persuade an interest organization not to spend time attempting to deliver futile results by aiming for certification only. There are certification systems that exist for sugarcane and related commodities; Bonscuro, the Roundtable on Sustainable Biofuels (RSB), provides the most used but depending on the region there are often others available (WWF 2012, 56). Furthermore, other potential issues associated with striving for certification as the primary incentive for transformation, including insufficiently stringent standards and difficulty in tracing commodity separation from uncertified portions, should be carefully considered (WWF 2012, 56).

To accompany the recommendation that interested stakeholders and companies consider strategic partnerships, it would be useful to research major players and interest groups in a region as an organization develops a strategy for helping companies improve their practices. This should be accomplished at a local or regional level, and is thus the responsibility of the facilitating organization or the company itself to gauge as it begins the process of transformation.

Finally, it will be crucial to consider how to include smallholder farmers in dialogues regarding sustainable or responsible sugarcane production. While large firms control a large amount of production, it will be difficult to transform an entire industry without including the smallholder farmers, especially since many global supply chains directly or indirectly purchase from these more decentralized producers. This chapter has discussed topics relating to engaging various stakeholders around a company's social and environmental risks and opportunities; but the discussion has been limited by the specific case chosen for study. It should not be assumed that sustainable practices can trickle down from large firms to smallholders. Both large- and small-scale initiatives will be important to address the sugar cane industry's environmental and social risks.

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5

UP IN SMOKE

A study of palm oil-related deforestation in Indonesia

Pek Shibao

Summary

Indonesia's forests are a centre of rich biodiversity and play an important role in the regulation of environmental factors such as water, carbon and soil nutrient levels as well as overall climate change. They are home to 12 per cent of all known mammal species, including critically endangered orangutans, tigers and rhinos (Rainforest Action Network 2014), and serve as one of the world's largest carbon sinks (Page et al. 2011, 798). Yet, despite their importance, Indonesia's forests are currently experiencing the fastest rate of destruction in the world: between 2000 and 2012, over 6 million hectares were felled (Landen 2014). Rampant clearing for oil palm plantation development is one of the chief drivers of this deforestation (Nellemann et al. 2007, 28). Despite the establishment in 2001 of the Roundtable for Sustainable Palm Oil, a multi-stakeholder governing body establishing standards for and certifying the production of sustainable palm oil, illegal oil palm plantations continue to expand, threatening vulnerable areas such as national parks, peat swamp forests, and land owned by indigenous Dayak peoples.

This chapter explores the drivers behind palm oil-related deforestation in Indonesia and the environmental impact of such deforestation, and identifies some of the major companies and business practices responsible. It will then argue that the Roundtable for Sustainable Palm Oil is a flawed mechanism that is inadequate for preventing deforestation, and lay out guidelines for the changes that should be made if the current trend of irresponsible deforestation is to be reversed.

Reasons behind the expansion of the oil palm industry

Today, oil palm is one of Indonesia's most important cash crops. Indonesia is the world's largest producer of palm oil, producing an estimated 33.5 million tons in

2014, or 53.4 per cent of total output worldwide (Index Mundi 2014). About 80 per cent of the crop is exported, with export revenues estimated at 21.1 billion USD annually (Indonesia Investments 2014). Indonesia currently has 8 million hectares of oil palm plantations, up from 4 million hectares in 2000, and this is expected to increase to 13 million hectares by 2020 (Indonesia Investments 2014). This increase is fuelled by consumers in rapidly growing economies such as China and India, who have joined those in Europe and the US in using more palm oil for food and energy.

Why is there such great demand for palm as compared with other vegetable oils? First, palm oil is efficient to produce; it has the highest yield of all oil crops, and is the cheapest to produce and refine (Rainforest Rescue 2014). Second, palm oil is versatile, and its derivatives can be used in a wide variety of consumer goods, ranging from food products and cosmetics to detergents and candles. It is estimated that up to 50 per cent of goods used daily by the average consumer contain palm oil derivatives. Third, the Malaysian and Indonesian governments are stimulating interest in palm oil as a biofuel by increasing the percentage of palm oil blended into biofuels such as bio-diesel (Rusmana and Listivorini 2014; Environment News Service 2013). In addition, government policies in many Western countries continue to encourage use of palm oil-derived biofuel; from 2006 to 2012, usage grew by 365 per cent within the EU alone (Gerasimchuk and Koh 2013, 6).

However, much current demand for palm oil can be traced to a single root cause: poor oversight by governments of palm oil-producing countries, especially Indonesia. There, intensive industrial logging first began in earnest in the 1970s and 1980s, spurred by the construction of logging roads that provided access to remote rainforests (Welman 2013, 211). Government corruption and nepotism played a large role in the expansion of palm oil; in particular, former President Suharto distributed large tracts of forest to cement political relationships with army generals, and it is thought that his relatives and business associates still control much of the Indonesian palm oil industry (Aditjondro 2011). In addition, logging for timber combined with palm oil planting creates a highly lucrative business model. Selling timber harvested from clearing forests can generate revenue of approximately $1,000 per hectare, providing seed capital to convert cleared land into yet more profitable oil palm plantations (Andrianto et al. 2014, 18). This quickly created a problem of over-logging; for example, in the 1980s and 1990s, more timber was exported from Borneo than from Latin America and Africa combined, and in Kalimantan, the Indonesian portion of Borneo, 80 per cent of lowlands and virtually all mangrove forests were logged (Welman 2011, 205).

Lack of governmental oversight has also allowed oil palm-producing companies to rapidly continue expanding operations and plantation acreage, often via illegal means. Palm oil producers have been accused of expanding plantations through land-grabbing, including practices such as breaking profit-sharing agreements with local communities, overstaying concessions and failing to conduct proper environmental impact assessments (IRIN News 2010). Destruction of rainforests cripples indigenous communities that rely on them for subsistence, forcing villagers to work on plantations and in oil mills for low wages (Klawitter 2014). Protests by villagers are dealt with by hired mercenaries, who suppress unrest with the use of lethal force. As a result of such illegal operations, companies are able to reduce overhead and sell palm oil at extremely competitive prices, stimulating further demand and creating a cycle of unsustainable expansion.

So far, attempts by the Indonesian government at reining in offending palm oil companies have been ineffective. Though President Yudhoyono declared a moratorium in 2011 on the granting of new forest concessions, this law also included a sunset clause on existing concessions, which actually encouraged companies to increase the clearing rate of forests already under their ownership (Oakford 2014). In addition, the government lacks an accurate system for monitoring the rate of deforestation; a recent study in the journal *Nature Climate Change* found that government figures may have underestimated the actual rate of forest clearing by as much as 50 per cent, or up to 1 million hectares of primary forest, over the past 12 years (Margono et al. 2014). Finally, many palm oil producers operate under agreements with local authorities, over whom the central government has little control. As a result, producers are often able to flout conservation laws with impunity (Food Tank 2014).

Environmental impacts of oil palm-related deforestation

The environmental impacts of uncontrolled deforestation are varied and severe. One of the most immediately obvious effects is habitat loss. Indonesia's rainforests enjoy incredible biodiversity and are home to 10 per cent of known plant species, 12 per cent of known mammal species and 17 per cent of known bird species (Rainforest Action Network 2014). In addition, the Indonesian Ministry of the Environment estimates that more than half of its endemic species remain unrecorded. Many animal species that call the rainforest home, such as the Sumatran tiger, the orangutan, the Javan rhinoceros and the Sumatran elephant, have become critically endangered due to deforestation. These large mammals have been especially affected because of their dependency on large continuous tracts of rainforest and the increasing encroachment of loggers into protected areas: over the past 12 years, almost 40 per cent of forest loss occurred within areas of restricted clearing, and 16 per cent occurred within conservation areas that prohibit clearing (Margono et al. 2014).

Animals and plants are not the only ones who stand to have their homes destroyed by deforestation. Indigenous peoples, of whom the Dayaks constitute the largest group at 2–4 million, rely on the forest for housing and subsistence through foraging and agriculture (Minority Rights Group International 2014). Deforestation and illicit land-grabbing gravely threatens the traditions and livelihoods of these peoples.

A second major threat is the contribution of deforestation to climate change. The large-scale burning of forests for plantation use releases vast amounts of greenhouse gases such as carbon dioxide and methane. The most severe example occurred in 1997–98, when it is estimated that burning forests in Indonesia alone contributed 13–40 per cent of global fossil fuel emissions in that year (Page et al. 2002). Rainforests also play a significant role in ameliorating climate change by regulating the absorption and release of heat, moisture and carbon (Friends of the Earth 1992). As one of the world's largest carbon sinks, Indonesia's rainforests play a particularly important role, holding at least 57 billion tons of carbon that would otherwise be released into the atmosphere.

The burning of rainforests also creates pollution that impacts human health. Smoke from burning forests in Indonesia – containing sulphides, nitrous oxides and ash – may travel as far as Singapore, Malaysia, Thailand and Sri Lanka, reducing visibility and causing respiratory problems (Mongabay 2014a). In Indonesia alone, the 1997–98 fires created respiratory problems for 20 million people and caused 20,000–48,000 premature deaths (Heil 2007). There is also a risk that smog produced by fires may have long-term health effects, including disorders of the heart, lung, brain, eye and skin.

Finally, deforestation could have significant implications for watersheds and water supply. Rainforests serve as water catchment areas, and many of Indonesia's major rivers originate within rainforests, especially in Borneo (World Wide Fund for Nature 2014a). Hence, maintaining rainforests is essential for safeguarding water supply to downstream populations, as well as prevention of large-scale soil erosion and flooding.

There is also increasing evidence that despite the lucrative nature of the oil palm industry, oil palm-related deforestation may create large net economic losses when damage to health and the environment are taken into account.

For example, Varma (2003) found that net losses experienced by the Indonesian economy in 1997–98 as a result of forest fires amounted to 20.1 billion USD. Economic losses in heavily-affected rural villages may represent 50 per cent of local income (Harrison et al 2009).

One of the most worrying aspects of palm oil-related deforestation is the ongoing shift towards clearing more vulnerable types of forest, as lowland 'production' forests set aside for agriculture become depleted. One of these types of forest is the peat swamp forest, which accounted for 70 per cent of newly developed plantations in 2008 (Foster 2012). Peat swamp forests, found especially in Borneo, are unusual ecosystems consisting of diverse tropical trees that may grow down 20 metres deep (Bell 2014). The saturated soil in a peat swamp forest prevents organic material from decomposing, creating a dense carbon sink that stores an average of 2,000 tons of carbon per acre. As a result, peat forests release much more smoke and greenhouse gas than other types of forest when burned. In addition, drained or dried-out peat forests are highly flammable and prone to massive fires, especially during the dry season, which may continue to smoulder for months or years. As a result of peatland clearing, palm oil production may result in 20 times more greenhouse gas emissions than burning diesel (Bringezu et al. 2009).

Another area that is particularly at risk is the section of rainforest known as the 'Heart of Borneo'. This refers to the large swath of original primary rainforest within central Borneo that covers over 17 million hectares (World Wide Fund for

Nature 2014b). Though most of the Heart of Borneo is unsuitable for growing oil palm due to slope and soil conditions, this may not be enough to deter speculators as suitable lowland forests become increasingly scarce. Deforestation in the Heart of Borneo will lead to increased risk of erosion, flooding and fire, in addition to the problems described above.

Companies and business practices responsible for oil palm-related deforestation

In its 2013 report, *Commodity Crimes*, Friends of the Earth described palm oil as an industry that 'virtually depends on lack of transparency'. This opacity is most evident in the complicated supply chain that palm oil takes from producer to consumer, involving various groups of secondary actors who all contribute to the continuation of unsustainable palm oil growing practices.

In this section, I will draw on the case study of Bumitama Agri, a palm oil producing company established in 1996. Bumitama Agri is among the largest and fastest-growing producers of palm oil in Indonesia, with revenues of USD 392.2 million, a net profit margin of 24.2 per cent, a compounded annual growth rate of 35.8 per cent and almost 150,000 hectares of plantations planted as of 2013 (Chain Reaction Research 2014). Bumitama is listed on the Singapore Stock Exchange and currently has a market capitalisation of about 1.4 billion USD (Bloomberg 2014). Bumitama serves as a good example because its business practices provide a good microcosm of the flaws of the oil palm industry as a whole; despite being repeatedly criticised for a strategy based on aggressive illegal expansion, it has continued its operations with an open disregard for government orders and its own previous promises to cease unsustainable practices.

Bumitama and its fellow plantation owners and millers constitute the most major and perhaps most obvious group of offenders within the palm oil supply chain. As mentioned previously many such growers employ production methods of questionable legality. First, plantation owners have been guilty of developing land without receiving necessary permits. Indonesian law mandates that before developing a plot of land, growers must first obtain a Location Permit describing the plot's location, an Environmental Permit including environmental impact assessments and consultations with local communities and civil society organisations, and finally a Plantation Business Permit to begin operations. However, Bumitama's subsidiary company Ladang Sawit Mas obtained a Plantation Business Permit in May 2006, before it had obtained either of the two prerequisites, and without consulting with key stakeholders or complying with safeguards for environmental protection (Friends of the Earth 2013). Ladang Sawit Mas underreported the size of its land holdings on its Plantation Business Permit, allowing it to develop 1,300 hectares more land than it legally acquired.

Second, producers are guilty of ignoring complaints and breaking their promises to authorities. In April 2013, a formal complaint was filed against Ladang Sawit Mas by the NGO International Animal Rescue to the Roundtable on Sustainable

Palm Oil (RSPO), the chief international governing body for palm oil production. In response, Ladang Sawit Mas agreed to enter negotiations with RSPO for better monitoring and compliance, but satellite images proved that it continued to clear land illegally while negotiations were taking place (Friends of the Earth 2013).

Third, producers are guilty of using ownership changes and complicated subsidiary networks to escape punishment for illegal activities. In 2007, Indonesia passed a law holding government officials personally responsible for illegal land use within their jurisdictions. Following this, VS Industry, a grower that had been preparing to illegally develop peat swampland, decided to cancel these plans, citing 'regulatory issues with the local authority' (Friends of the Earth 2013).

However, instead of returning the land to the Ministry of Forestry in accordance with correct legal procedure, VS Industry sold the management rights to two companies, PT Karya Manunggal Sawitindo and Westbrook International. These companies are in turn owned by members of the Hariyanto family, the largest shareholders of Bumitama (Bumitama Agri 2012a, 134). Though Bumitama's investor reports clearly show that it is actively developing the illegal land in question, this complex chain of ownership means that it has so far been able to do so without censure.

Finally, use of slash-and-burn techniques to clear forest is widespread among producers. It is estimated that 34–60 per cent of the larger Indonesian fires in 1997–98 occurred within oil palm plantation concessions (Vayda 1999). Despite being banned by law in 1997, slash-and-burn continues to be the most widespread method of forest clearing in Indonesia, partly because alternative techniques may cost $50–150 more per hectare (Wakker 2005, 21). The speed at which forests can be cleared through burning also helps companies evade detection and punishment through legal and bureaucratic processes, which can sometimes take years to reach a decision (Greenpeace 2013).

The second group of culpable actors is local government. Inadequate oversight and legal protection for vulnerable communities have greatly enabled the illegal activities of oil palm producers. First, poor land use planning, mapping and coordination between departments prevent the government from overseeing forests effectively (Greenpeace 2013). Second, corruption and nepotism are rampant; in a notable example, the head of Ketapang district in 2011 also owned a controlling interest in a palm oil producing company guilty of illegal land grabbing (Friends of the Earth 2013). Furthermore, the need to pay off local government officials creates a perverse incentive to develop larger areas of forest to cover the cost of bribes (Wakker 2005, 27). Third, many local communities, such as indigenous Dayaks, do not have formal land rights, making it hard for them to contest the claims of encroaching corporations. Fourth, taxes payable are based on a producer's declared acreage, creating an incentive for companies to underreport. Finally, much of the legislation that has been passed to govern forests contains loopholes that provide avenues for exploitation. The shortcomings of President Yudhoyono's 2011 moratorium on deforestation have already been discussed. Another example of a major legislative loophole is the decree issued in 1998 that limits plantation areas to

20,000 hectares per province. However, publicly listed companies are not bound by this regulation, encouraging companies such as Bumitama to expand unsustainably with the goal of ultimately escaping legal repercussions through a successful IPO.

The third group of culpable actors is the suppliers that buy palm oil and distribute it to the global market. These companies, such as Wilmar and IOI International, are often large, publicly listed multinationals. Unfortunately, there is evidence that such companies have used their size and financial resources to support the illegal activities of palm oil producers, despite an ostensible commitment to the environment such as Wilmar's policy of 'zero deforestation'.

First and most directly, suppliers buy palm fruit from illegal producers; two large suppliers, Wilmar and Golden Agri-Resources, buy 90 per cent of Bumitama's output (Chain Reaction Research 2014). Second, suppliers may own equity in plantations and palm oil producing companies, creating a conflict of interest; for example, IOI bought 31.2 per cent of the shares at Bumitama's IPO (Investor.com 2013), and Bumitama between 0.9 and 4.3 per cent (Bumitama Agri 2012a, 256). Third, suppliers constitute part of the complex network of subsidiaries that act to deflect responsibility from producers. For example, Wilmar owns subsidiaries that have been accused of abetting deforestation in Borneo. When Friends of the Earth called attention to this, Wilmar moved to sell the controversial firms; however, some of the buyers are known to be holding companies with strong links to Wilmar (Klawitter 2014). Following violent protests by local communities in March 2014, Wilmar allegedly painted over transport trucks with Wilmar logos and continued refining palm oil from controversial plantations through a different company. Finally, suppliers may even enter into extensive, mutually supportive partnerships with illegal palm oil producers. For example, IOI buys crude palm oil from Bumitama at a discount and extends it interest-free loans. In return, Bumitama has set aside up to 27.9 million USD from its IPO proceeds to finance the capital expenditure of IOI subsidiaries (Bumitama Agri 2012a, 35).

Banks and other financiers of oil palm companies constitute the fourth link in the chain of culpability. First, major international banks have extended loans and provided other financial services to illegal producers, bankrolling deforestation and unsustainable production. Two major banks that have provided financial services to Bumitama are HSBC and Rabobank. HSBC's services included a 135 million USD loan to finance plantation expansion in 2010, underwriting Bumitama's IPO in April 2012, and acting as Joint Mandated Lead Arranger and bookrunner for a further 170 million USD loan in October 2012 (Environmental Investigation Agency 2013, 4). Rabobank has provided a total of 47 million euros in loans to Bumitama (Friends of the Earth Europe 2014a, 6). Though both HSBC and Rabobank have official policies that prohibit them from working with companies that engage in illegal deforestation (Proforest 2014; Rabobank 2014), both banks rely solely on RSPO membership to guarantee the sustainability of a client's business practices, an approach that is highly flawed and possibly inaccurate.

Besides failing to carry out due diligence in ensuring its clients do not violate its stated environmental policies, these banks have also been criticised for not using their power to persuade Bumitama to adopt more sustainable practices, nor providing stakeholders and NGOs with transparent information on how they intended to deal with the breaches once they had been brought to their attention (Environmental Investigation Agency 2013, 3).

The income from its IPO has allowed Bumitama to grow rapidly, with an estimated 114 million USD of the proceeds being earmarked for further plantation expansion (Bumitama Agri 2012b). As such, shareholders and investors in Bumitama must also shoulder the blame for the company's illegal deforestation. These investors include familiar names such as Credit Agricole, MassMutual, BlackRock and Fidelity Investments (Friends of the Earth 2013, 9). Individual shareholders also share some degree of responsibility. Prior to Bumitama's IPO in 2012, prospective investors were informed through Bumitama's prospectus that its expansion strategy included preferential operating rights to a plantation operating without mandatory licences. Despite this explicit admission of illegality, all shares offered were sold.

If the chain of culpability is extended a further step to include the financiers and investors of palm oil suppliers, the list of actors involved becomes even more extensive. Major foreign investors and financiers of Wilmar include the Vanguard Group, JP Morgan Chase, CalPERS, MassMutual, Barclays, Citigroup, ABN Amro and BNP Paribas (Friends of the Earth 2013, 17). Major foreign investors in IOI include Prudential, ING Group, Schroders, Pinnacle Fund Management and the First Swedish National Pension Fund. Several of these companies score highly in sustainable governance and ESG indexes, which raises questions about the methodology used to construct these indexes and the amount of investigation behind them.

The fifth group are the purchasers and consumers of palm oil. It is perhaps the most difficult for this group to escape culpability, as the complexity of supply chains and greenwashing of current certification standards make it difficult to separate illegal from sustainably grown palm oil (Mongabay 2014b). However, some companies have made a credible commitment to fully trace all the palm oil they use to individual plantations (see fifth section below), setting the standard of accountability for other large purchasers.

One final organisation that deserves particular attention is the Roundtable on Sustainable Palm Oil (RSPO), the largest international governing body for palm oil production. Though the RSPO and its GreenPalm Certification for sustainably grown palm oil are widely accepted as legitimate, in practice they have proven to be an ineffective and structurally inadequate mechanism for preventing unsustainable business practices. I will elaborate further on the RSPO in the following section.

The roundtable on sustainable palm oil and its inadequacies

The Roundtable on Sustainable Palm Oil (RSPO) is the chief international governing body for palm oil. Established in 2004, its stated mission is to 'develop and implement global standards of sustainable palm oil', including the GreenPalm certification, which is the most popular certification for sustainably grown palm oil (Roundtable on Sustainable Palm Oil 2012). The RSPO's members include many of the major suppliers of palm oil worldwide; Bumitama Agri became a member in 2007. However, the RSPO has routinely been criticised by various NGOs active in forest protection for systemic problems that render it unable to effectively carry out its mandate. The RSPO and its certification systems have been accused of being 'little more than greenwash' (Greenpeace 2008), and even the World Wide Fund for Nature, a primary founder and stakeholder in the RSPO, has stated in 2013 that RSPO certification can no longer be considered a guarantee of sustainable palm oil production (World Wide Fund for Nature 2013b).

The first common criticism of the RSPO is that its guidelines are not strong or specific enough to stop the spread of deforestation. The RSPO does not disallow its members from the clearing of all rainforest, but only primary and 'High Conservation Value' forests (Rainforest Rescue 2014). However, an internationally recognised definition of what constitutes a High Conservation Value forest does not exist, and it is hard to distinguish between primary and secondary forest in practice. This makes it easy for producers to encroach into protected and vulnerable forest areas without legal reprisal.

Second, the RSPO lacks adequate mechanisms to oversee its members' conduct, hold its members accountable to its guidelines and punish offending members. Though the process of being fully RSPO-certified requires an assessment of the environmental and conservation value of a producer's holdings, in reality this assessment is provided by the producers themselves, with little of the information being fact-checked by RSPO (Friends of the Earth 2013, 3). This is because the RSPO lacks a dedicated monitoring arm of its own. As a result, in multiple cases, RSPO has been unaware of flagrant violations of environmental policy by its members until complaints were lodged by concerned NGOs. Even after complaints are lodged, direct orders from the RSPO's Complaints Panel have proven ineffective in convincing companies to stop clearing forest or allow site access to NGOs for further investigation (Environmental Investigation Agency 2013). Complaints generally take months or years to resolve, by which time the bulk of the damage to the forest has been done. Furthermore, the RSPO requires its members to submit an annual report towards compliance with its principles, including a specific timeline for doing so; however, some members such as Triputra Agro Persada have consistently failed to submit this report, while other members such as Bumitama have consistently failed to meet its certification targets (Greenpeace 2008, 8). In neither case did these companies face any repercussions for their behaviour.

Third, the membership and power structure within the RSPO makes it susceptible to conflicts of interest. Of the executive board, which votes on resolutions and receives audited accounts, 75 per cent is made up of entities with interests in the palm oil industry, such as growers, processors, consumer goods manufacturers and investors. Only 25 per cent is made up of NGOs (Roundtable on Sustainable Palm Oil 2014a). Executive board members of the RSPO include HSBC and Rabobank, two banks that have financial interests in illegal palm oil growers (Roundtable on Sustainable Palm Oil 2014b). Furthermore, only large growers producing more than 500 tonnes of oil yearly have voting rights (Roundtable on Sustainable Palm Oil 2014c). As such, there appears to be little internal incentive for RSPO members to act in accordance with the organisation's stated objectives.

Fourth, the membership in the RSPO implies that all the subsidiaries of an RSPO-certified producer are also subject to the RSPO's guidelines, when in fact this is not the case. These subsidiaries are often responsible for directly executing some of the most extreme environmental violations perpetrated by the parent company. For example, it is highly likely that PT ASMR, a non RSPO-certified subsidiary of Bumitama, has been guilty of clearing high-conservation value forests and creating 'graveyards' of orangutan skeletons, for which the company is currently being investigated by the Central Kalimantan Natural Resources Conservation Agency (Parker 2013). Nevertheless, the Bumitama group continues to claim in its official materials that it applies RSPO standards in all its operations.

Fifth, the standards through which the vast majority of 'sustainable' palm oil is traded are misleading and flawed. There currently exist four schemes for trading RSPO-certified palm oil. The first is the 'book and claim' scheme, where RSPO-certified producers receive a GreenPalm certificate for each tonne of certified palm oil produced. These can then be sold to palm oil consumers and manufacturers, who can then claim to be 'supporting sustainable palm oil' (Greenpeace 2013, 3). These certificates trade for only about $3 each, much less than the price of palm oil, which is about $700 per metric ton. As a result, it is much easier and cheaper to buy non-certified palm oil, then purchase certificates of 'sustainability', than to actually source palm oil from sustainable sources. The second scheme, the 'mass balance' supply chain system, allows exact amounts of certified palm oil to be tracked as it passes through a particular supply chain. However, this scheme possesses its own flaws, as a trader may mix certified oil with any amount of uncertified oil yet be able to label their oil as 'certified'. Actual sales through the 'segregated' and 'identity protected' supply chains, which are completely traceable to individual mills or groups of mills, are extremely small in comparison to the 'book and claim' and 'mass balance' schemes.

Given the above shortcomings, it is clear that major structural changes need to be made to the RSPO if it is to adequately fulfil its stated mission. In fact, a Greenpeace report found that in 2009, despite holding only 14 per cent of forested oil palm concessions, RSPO members accounted for 21 per cent of deforestation (Greenpeace 2013, 1). This suggests that far from reducing deforestation, the ostensible legitimacy provided by the RSPO could actually be aiding its members maintain their unsustainable business practices.

What can be done? How each group in the supply chain can help arrest deforestation

The complex supply chain of global palm oil today is a double-edged sword. In earlier sections, we have seen how the large number of actors may stymie attempts to effectively oversee and legislate the palm oil industry. However, this also means that there are many ways for individual actors or groups to push for change. The ultimate goal of these actions must be to convince producers to cease their unsustainable actions. Since producers are motivated primarily by profit, it appears unlikely that they would independently adopt environmentally sustainable practices that would negatively affect their profit margins. On the other hand, they may be persuaded to do so if other actors in the supply chain threaten to withdraw financial and other means of support to these producers unless real change is seen.

The first group of actors with the power to instigate change is the government. Many deficiencies in oil palm legislation are due to endemic corruption problems within the local government, the solving of which is beyond the scope of this paper. Nevertheless, the central government can take steps to remove loopholes in legislation that have enabled exploitation and rendered laws ineffective at preventing deforestation. These include removing the sunset clause on the existing moratorium against deforestation and the exception on acreage restrictions for publicly listed producers. The moratorium may also be made more effective by incorporating specific performance indicators, such as explicitly banning the clearing of peatland, preventing overlapping forest use in spatial planning, and clearly defining the boundaries of High Conservation Value forests. In addition, commissioning independent reviews of suspicious companies through a third party, such as one of the many NGOs lobbying for forest protection, is a good way to sidestep the inefficiencies of local authorities. Finally, Indonesian courts have recently begun taking a stricter stance on offending companies. In January 2014, producer PT Kallista Alam was fined 9 million USD for illegally burning forests within a protected peat swamp ecosystem and ordered to pay 21 million USD for restoration costs (Tripa News 2014). Members of PT Kallista Alam's senior management were also fined and jailed (Satriastanti 2014). These convictions are an important precedent and send a clear message of non-tolerance to companies tempted to engage in illegal deforestation.

As direct purchasers of the fresh fruit bunches, as well as crude and refined palm oil produced by plantation owners, suppliers may be able to exert perhaps the greatest amount of direct pressure on illegal growers. For example, just two suppliers, Wilmar and Golden Agri-Resources, purchase 90 per cent of Bumitama's output (Chain Reaction Research 2014). In December 2013, Wilmar announced a plan to apply its 'No Deforestation, No Peatland, No Exploitation' policy to all suppliers, and in February 2014 Golden Agri-Resources announced similar plans to make its suppliers adhere to its 'Forest Conservation' Policy (Chain Reaction Research 2014). In response, Bumitama has stopped clearing in certain contested sites and stepped up its efforts to achieve full compliance with RSPO guidelines. However, besides the announcement of such plans, suppliers must also divest themselves completely from interests in producing companies as well as cooperate with NGOs in a more transparent manner, in order to dispel any suspicion that they may simply be using such plans as a form of 'greenwash'.

As the providers of seed capital in the form of loans and equity, financiers and investors are also capable of exerting great influence on the behaviour of illegal producers. Banks and shareholders may be able to leverage their creditor status to push for demonstrable change in producer operations. If lobbying fails, investors can demonstrate their refusal to continue supporting deforestation through divestment. In May 2014, Deutsche Bank led the way for other shareholders by selling its entire stake in Bumitama, following a petition of 87,900 signatures from concerned German citizens (Friends of the Earth Europe 2014b). An alternative and perhaps preferable approach is to conduct more stringent due diligence in order to avoid entering into partnerships with producers of questionable legality in the first place, rather than simply relying on the guarantees of flawed certifying bodies such as the RSPO.

As the ultimate source of demand for palm oil, customers and consumer companies are able to exert a ripple effect through the entire supply chain by making their sustainability policies more stringent. Several major consumer companies, including Kellogg, Mars, and Johnson & Johnson, have announced plans to improve their sourcing of sustainable palm oil (Chain Reaction Research 2014, 32), but the company that has developed perhaps the most extensive and credible commitment to this goal is Unilever. The company has laid out a comprehensive roadmap for sourcing all its palm oil from fully traceable and certified sources by 2020. It plans to do this via charting an incremental shift towards 'segregated' and 'identity protected' supply chains by geographical region of operations. So far, Unilever has already achieved its first target of covering all its palm oil purchases with GreenPalm certificates, and looks to be on track to achieve the rest of its declared milestones (Unilever 2014).

The RSPO, despite its shortcomings and history of inefficiency, remains the largest inter-sectoral governing organisation with a critical membership mass in the oil palm industry and an existing code of standards, albeit poorly enforced. The onus is on the RSPO to demand timely reporting and adherence to proposed timelines for adopting sustainable practices from its members, work with third party investigators to ensure the accuracy of reporting, and help its members achieve fully traceable supply chains. If producers repeatedly flout regulations, penalties such as fines or expulsion from the RSPO must be enforced to restore the organisation's credibility.

Conclusion

Palm oil-related deforestation is undoubtedly one of the most major environmental threats we face today. It is clear that unless vigorous measures are taken to arrest the alarming rate at which Indonesian forests are being cleared for palm oil, we will pay a heavy price in terms of damage to ecosystems, loss of natural resources, damage to health, and contribution to accelerating climate change. Illegal, profit-driven business practices have provided much of the impetus for such deforestation. However, business can also be harnessed as a powerful means to instigate change. By threatening the mechanisms by which producers obtain financial support, stakeholders and actors along each link of the global oil palm supply chain possess the most realistic possibility of convincing offending companies to alter their behaviour, and the greater the number of actors actively lobbying and applying pressure on producers, the greater the effect is likely to be. If all the sectors involved in the oil palm industry collaborate to take concrete action as soon as possible, it may yet be possible to fully reverse the damage that has been done to Indonesia's forests.

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SUSTAINABILITY FRAMEWORKS

Green chemistry and sustainable engineering in pharmaceuticals

Susan Wang

In an increasingly complex, transparent and interconnected world, actions and decisions of an individual, a company, or a government can profoundly impact society at unprecedented speed and scope. Earth's growing population and consumption patterns put increasing pressure on the planet's finite resources, moving issues of sustainability and long-term development into sharper focus. The UN Sustainable Development Goals (SDG 2015) address long-term development issues through 17 goals including areas such as climate change, innovation, and sustainable consumption and production, issues which are interconnected, and seem to require a multilateral effort to promote solutions through cooperation and innovation to better the interdependent world we live in.

Producing corporations need to dynamically respond to consumer preferences and improve efficiency and risk mitigation. Investors strategically allocate capital to different asset classes, from public and private equity to real estate, across different sectors to generate financial returns that also have increasingly visible social and environmental impact. In other words, consumers, producers, and investors are market participants endowed with the capacity for change and can drive positive impacts on society, economy, and the environment.

Issues such as water security, waste management, climate risk management, and sustainable industrialization have local to global implications on human health, environmental management, and economic development. When unaddressed, they can incur significant risks and costs to businesses, perhaps especially within supply chains. A sustainable long-term strategy includes more comprehensive evaluation of supply chains, including the lifecycle of products and services which can unlock new opportunities to enhance financial, social, and environmental return.

In recent years, companies have started to acknowledge and respond to increased shifts in consumer preferences and complexity of investor demand by integrating innovations and sustainable practices as forms of competitive advantage. Some companies have done so by enhancing product offerings, modernizing production and supply chain management, and embracing innovations, all to better manage reputational risks, production costs, and market leadership. For instance, in consumer retail, the market development of socially and environmentally conscious fashion and cosmetic brands highlights the value of sustainability amid growing demand. Kering, which owns major luxury brands such as Gucci, Yves Saint Laurent, and Stella McCartney, created the Environmental Profit & Loss framework which makes the invisible impact of businesses "visible, quantifiable, and comparable." The company examines the impact of its operations and supply chain, and proactively addresses externalities to better manage risk and identify opportunities. Some of its innovations include organic cotton for Alexander McQueen and Patagonian wool at Stella McCartney. Its work has gained external praise, and was ranked the most sustainable luxury company and industry leader by the 2017 Dow Jones Sustainability Index. Furthermore, commercial aviation companies such as United Airlines have invested in new fuel-efficient airplanes and aircraft retrofits such as split scimitar winglets which drastically increase fuel efficiency and reduce greenhouse gas emissions while improving the bottom line. Such demand for efficiency has created opportunities for parts manufacturers to develop more energy efficient products. In addition to companies, investors have committed capital and expressed interest in sustainable investing, suggesting increased investor momentum for environmental, social, and governance considerations that is increasing pressure on companies to act, creating a positive dynamic.

The competitive advantages of sustainability-driven businesses have gained attention and momentum with more clarity into the social and economic benefits of sustainability and correlation to financial performance. The narrative of social benefit and profit as mutually exclusive continues to be challenged as sustainability is proving to be a critical strategy for creating value and minimizing risk.

This chapter will focus specifically on innovations in the pharmaceutical industry and its strategic shifts to create long-term value. Its integration of more sustainability-driven frameworks across the value chain yields social, environmental, and firm-level benefits to all stakeholders, from shareholders to consumers. Many pharmaceutical companies have succeeded at establishing, implementing, and monitoring science-based sustainability goals, essentially designing sustainability goals into their business model and management to improve operational and resource efficiency while reducing risk exposure. Furthermore, institutionalization of sustainability in the pharmaceutical industry has the potential to offer a relevant blueprint for others to implement in their respective companies and industries.

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The US healthcare system relies on a capital and resource intensive pharmaceutical industry subject to a convoluted and dynamic regulatory environment. The government and private sector in concert fund research, development, production, and distribution of invaluable drugs, therapies, medical technologies, and services.

However, the cost of healthcare provision has become an increasingly alarming problem in the United States, overtaxing budgets and concerning many Americans. Healthcare costs per capita in the US are approximately $9,000, more than twice other OECD countries pay on average (OECD 2016). Yet this astronomical cost fails to translate to greater value. The US still records higher infant mortality rates and shorter life spans than OECD counterparts (OECD 2016). The rapidly rising cost of healthcare has outpaced economic inflation for years and highlights a fundamental problem that must be addressed for the long-term development of the country and its people. PwC's Health Research Institute projects 2017 growth of medical costs to remain the same at 6.5 percent and reported that price, not utilization, appears to be the clear driving force behind these costs (PwC 2017). The failure to address this sky-rocketing price tag inevitably reduces quality of life, financially burdens patients disproportionately to quality of care, and increases the threat of personal bankruptcy for those in need of healthcare in the United States (Emmanuel 2014). National Health Expenditure reached $3.2 trillion in 2015 while prescription drug spending in particular increased 9.0 percent to $324.6 billion in the same year (Center for Medicare and Medicaid Services n.d.). Issues of healthcare access, affordability, and quality coupled with environmental impact across the healthcare value chain have significant economic, social, and health consequences. The severe dislocation of cost and value across the system indicates the need for industry reform. Reshaping the topography of healthcare requires identifying areas of improvement and appropriate strategies to realign corporate incentives in a way that improves both social and financial returns.

The pharmaceutical segment in particular lacks the adequate legal accountability and business model to increase the value for each dollar spent and mass of resources used. For instance, higher complexity and purity requirements in the pharmaceutical industry are often used to justify the high waste per kilogram of product and high process mass intensity (PMI) compared to other chemical industries. Other sources of cost can be attributed to drug recalls and non-compliance fees, including following through with corrective and preventive actions, responding to warning letters from the FDA, and resolving consent decrees. Inefficiencies and high costs can be mitigated with a dynamic business framework outlined with sustainability considerations to create both short-term and long-term value. This can include building on volume-driven business models to reduce cost-per-value and tie suitability to profitability. For context, of the 30 largest pharmaceutical companies by revenue, 18 out of the 28 publicly traded companies made it into the Dow Jones Sustainability Index (DJSI). The average YTD and 1-year returns of the companies on the DJSI outperformed the average returns of non-DJSI companies on the list. Sustainability integration can provide a framework to improve profitability while minimizing environmental footprint and reputational, non-compliance risk. The nexus of business and sustainability creates competitive advantage, efficiency gains, and new synergies for businesses and society.

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Sustainability strategy can be thought of as an updated optimization function for pharmaceutical companies. The output of this new function includes delivering meaningful therapies and solutions through more efficient, greener means. In other words, doing more with less. In order to get rid of inefficiencies and redundancies in the chemical industrial processes and also maximize the utility of the resources used, companies must look introspectively at business operations as well as research and development to identify areas of growth. First, there is a need to assess the impact along the entire lifecycle of a drug in order to maximize efficiency, reduce waste, and minimize environmental footprint. This lifecycle encompasses research and clinical trials, mass production, and post-production. Lifecycle analysis insight into drug value chains and externalities can translate into cost reduction, resource efficiency and ecological benefits.

In addition to life cycle assessments, firms must ensure transparency and extensive analysis of operations, technologies, and supply chain across business segments. The ideal approach considers material extraction, manufacturing processes such as facility design, transport and logistics, and product use, as well as disposal and recycling. Many pharmaceutical companies have started to design sustainability into the organization, innovations, and ethos of their businesses, which make up three key components of a broader sustainability strategy applicable to other industries. This strategic positioning is reflected in the rise of (1) reporting of sustainability commitments, (2) green chemistry and engineering, and (3) sustainable industrial processes.

Corporate commitments

One noticeable trend is communication of corporate commitments to sustainability in different formats, including corporate sustainability reports, pledges to global initiatives, and support of the UN SDGs. Companies have started to set and self-report sustainability strategies and measurable goals while working collaboratively both within their sector and beyond to keep one another accountable. Global initiatives such as RE100 unite the private sector to commit to running 100 percent on renewable power by a set year in the near future. Committed companies include Apple, Johnson & Johnson, IKEA, JP Morgan, Facebook, Starbucks, Walmart, AstraZeneca, and Unilever, totaling 118 members, up from 82 in December 2016. Specifically, in pharmaceuticals, Novo Nordisk of Denmark is committed to sourcing 100 percent renewable power at all of its production sites by 2020 (RE100 2017). Similarly, biopharma company AstraZeneca has targeted sourcing 100 percent renewable electricity globally by 2025, with an interim target of 100 percent in the US and Europe by 2020 (RE100 2017).

Pledges organized by governments, such as the American Business Act on Climate Pledge, have also brought together companies and set standards to keep them accountable for change, ultimately creating opportunities for companies to make public commitments to the Paris Agreement and its goals for the environment and sustainable development. Lastly, company promises to shareholders and consumers increasingly include values and metrics related to sustainability, from environmental protection to community responsibility.

Company commitments across the industry require a corporate sustainability framework that embeds sustainability into the culture and operations of a business. Some argue that "culture eats strategy for lunch" (Leahy et al. 2013) and thus a bottom-up, coordinated effort with management support is necessary to broadly implement sustainable strategies. In 2005, Pfizer became the first pharmaceutical company to appoint a full-time green chemistry leader in the company. Pfizer established multidisciplinary green chemistry teams at each synthetic chemistry research site and connected leaders of research site teams along with those in manufacturing and Global Environmental Health and Safety (GEHS) to cross-pollinate and comprehensively coordinate sustainable strategies across the organization. Furthermore, Bristol-Myers Squibb (BMS) operates with cross-functional teams with a 2-year rotational program to maximize exposure to green chemistry. Amgen exchanges members from various green chemistry teams across small molecules, biologics, and medicinal chemistry who attend each other's meetings (Leahy et al. 2013).

Sustainability in research and development begins with updated *education* for current and future chemists as well as *training* for staff in new procedures and equipment, i.e. electronic lab notebooks (ELNs). Switching from paper lab notebooks to ELNs can help allow analysis of mass amounts of data and provide toxicity warnings, procedure suggestions, and other relevant information to improve product yield and minimize environmental and health hazards in the lab process. However, these equipment and structural changes come at a price. Thus additional investments allocated to green technology and tools are integral to developing in-house capacities for more efficient, greener procedures such as biocatalysis, continuous processing, and catalyst-solvent recycling.

Moreover, in order to monitor progress and enforce accountability across different companies and sectors, industries must develop *standardized metrics and targets* that are both easily trackable and comparable. One metric is the Process Mass Intensity (PMI), which measures the total mass of materials needed (input) to produce a given amount of product. E-factor measures the mass of waste per mass of product. BMS, for example, collects PMI and greenhouse gas metrics upon completion of each drug campaign. The data allow the green chemistry teams at BMS to analyze and identify areas of improvement across the drug campaign and life cycle in order to develop future strategies to improve the green performance of its business operations. In addition to developing and tracking sustainability metrics, companies also conduct analysis of greenness metrics correlated with manufacturing metrics such as product yield, or financial metrics such as Cost of Goods Sold and Revenue. Such correlation analysis provides opportunities for enhancing operational efficiency and profitability while minimizing the social and environmental footprint.

Capturing and quantifying the synergies between sustainability and profitability has become increasingly important considerations for the industry. Amgen's cost tracking software can examine in real-time the "total material use required to manufacture any desired final quantity of drug substance" and instantaneously calculate and correlate cost and E-factor (kg of waste produced/kg of drug substance manufactured) over sequential drug campaigns (Leahy et al. 2013). These sustainability-driven calculations and considerations suggest that greenness metrics have become an integral addition to general data collection and analysis for firm-wide performance review.

Besides industry-wide efforts, sustainability frameworks extend to *external collaboration* with academic institutions, institutes, NGOs, and governments to mobilize the pool of resources and capabilities to achieve sustainability synergies. The American Chemical Society's Green Chemistry Institute Pharmaceutical Roundtable (ACS GCIPR) (whose members include Amgen, AstraZeneca, Boehringer Ingelheim, BMS, Eli Lilly, Roche, GlaxoSmithKline, Johnson & Johnson, Merck, Novartis, Pfizer, and Sanofi) runs research grants, develops useful publicly available tools (such as the online reagents guide, solvents selection guide, and the PMI calculator), and publishes influential position papers to catalyze green chemistry and engineering in the global pharmaceutical industry (American Chemical Society).

Green chemistry and engineering

Bringing these commitments to reality requires further innovation in science and engineering. Notably, green chemistry and sustainable industrial processes improve energy and resource efficiencies and promote sustainable production behavior (Goal 12 of the SDGs). Green chemistry is an interdisciplinary field that encompasses chemistry, chemical engineering, toxicology, and ecology. It involves redesigning toxic molecules, synthetic routes, and industrial processes. Examples of innovations in green chemistry include creating catalysts that reduce reagents and waste as well as designing new molecules that avoid toxic structures.

Progress in the science and methods of green chemistry can be more widely implemented across drug development cycles and beyond commercial mass production. Green chemistry can be incorporated earlier in drug development cycles during drug discovery. Clinical trials, which are a resource- and energy-intensive activity, can implement greener methods for Phase II+ and invest in more efficient, greener routes to reduce PMI and E-factor and ultimately allow for cost savings. For post-commercialization, particularly generic drug manufacturing, efficiency gains and cost savings of greener methods can help alleviate downward pricing pressures from the off-patent price cliff.

In 1998, Paul T. Anastas, who is the director of the Yale Center for Green Chemistry and Green Engineering, together with John Warner published the "12 Principles of Green Chemistry" outlining strategies of greener chemical process and products (Anastas and Warner, 1998). Since its publication, corporate green initiates have cited and drawn from this influential literature on green chemistry as a fundamental guideline. Pfizer and Janssen, for instance, explicitly cite these 12 Principles on their corporate websites on green chemistry and sustainability. The principles are as follows:

1. *Prevention* of waste, rather than treat/clean up.
2. *Atom economy*: synthetic methods that maximize incorporation of all materials into final product.
3. *Less hazardous chemical synthesis*: synthetic methods less toxic to human health and environment.
4. *Designing safe chemicals*: minimizing toxicity with same integrity of chemical products.
5. *Safe solvents and auxiliaries*: eliminate the unnecessary and the innocuous (e.g. solvents, separation agents, etc.).
6. *Design for energy efficiency*.
7. *Use of renewable feedstocks*: renewable (not depleting) raw material/feedstock whenever technically and economically practicable.
8. *Reduce derivatives*: unnecessary derivatization (use of blocking groups, protection/deprotection, temporary modification of physical/chemical processes) should be minimized or avoided if possible, because such steps require additional reagents and can generate waste. Use enzymes instead.
9. *Catalysis*: catalytic reagents to reduce waste and maximize yield.
10. *Design for degradation*: chemical products post-use should break down into innocuous degradation products that don't persist in the environment.
11. *Real-time analysis of pollution prevention*: analytical methods needed for real-time, in-process monitoring and control prior to formation of hazardous substances.
12. *Inherently safe chemistry for accident prevention*: substances and their forms used in the chemical process should aim to reduce the potential for chemical accidents (releases, explosions, and fires).

These principles serve as strategic blueprints for innovation. For example, enzymes also known as "green catalysts" are renewable and biodegradable and therefore minimize byproducts and often only require water as solvent. Merck developed applications of enzymatic chemical reactions for its type 2 diabetes drug Januvia, ultimately winning the 2010 EPA's Presidential Green Chemistry Award (EPA 2010). These 12 principles also elucidate the scope of serious environmental, health, and ecological implications involved in the production of drug substances and their byproducts. The gravity of these repercussions also highlights deeper connections between business and society while raising issues of corporate responsibility.

Sustainable industrial process

Finally, industrial processes must complement corporate strategy and scientific innovations to not only *power* sustainable behavior across the life cycle of drugs but also *scale* sustainability.

One fundamental innovation in the pharmaceutical industry is continuous manufacturing. Switching from batch production to continuous processing increases reliability and minimizes environmental impact. In 2015, the FDA called on manufacturers to switch from batch manufacturing to continuous processing (Brennan 2015). Continuous processing requires less manufacturing space, enhances process reliability and increases flexibility to market demand, and reduces raw material use, energy consumption, and industrial waste (Brennan 2015). Furthermore, continuous manufacturing allows for constant monitoring of drug quality rather than requiring conducting batch-based testing which often produces large quantities of drug and product waste. Continuous processing can remove these wastes and significantly reduce environmental impact while cutting redundant costs for companies. In 2013, GlaxoSmithKline, a British pharmaceutical company, invested $50 million in a Singapore plant, becoming one of the first major drug makers to seriously commit to continuous manufacturing. By 2020, GSK plans to halve its operation waste through eliminating, reusing, recycling, and generating energy from waste. It plans to focus on its manufacturing process, utility infrastructure, and building design. GSK has already successfully reduced both hazardous and non-hazardous waste by reusing 126,000 tonnes of organic solvents since 2010 at six production sites. In 2014, GSK generated 159,000 tonnes of waste from its operations, which showed a 4 percent waste reduction from 2013 and 11 percent less than 2010. As of 2016, half of GSK's manufacturing sites and major R&D sites send no waste to landfill (Palmer 2015).

Facilities can also redesign production lines to recycle some reagents. Many facilities are also investing in greener energy generation. Pfizer recently installed FuelCell's combined heat and power (CHP) system at their Connecticut site. CHP generates electricity or mechanical power as well as useful thermal energy for heating and/or cooling purposes, ultimately increasing energy efficiency.

With the rise of biologics and biosimilars, which are more complex and costly to create than small molecule drugs, many pharmaceutical companies have pivoted their product pipelines to increase investments in biologics and biosimilars which often have higher barriers to entry and greater product margins. Along with increased production of biologics, single-use strategy has shown promise as a production technology to scale, increase flexibility, and reduce cost of biologics production without compromising the quality of medicine. Traditionally, facilities mass-produced single products at large manufacturing sites. This model is becoming obsolete as a way to respond to dynamic market demand (Jacquemart et al. 2016). Increasing trends towards single-use production strategies offer another example for momentum for more efficient production methods.

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Embracing a sustainable corporate strategy with innovations in green chemistry and sustainable industrial process engineering will help improve efficiency and productivity across the pharmaceutical value chain, ultimately allowing us to *do more with less*. The pharmaceutical industry has proved its capabilities for designing sustainability into the cultural DNA and organization of business as well as innovating in science, design, and process to benefit the society, environment, and firm's bottom lines.

This development of sustainable practices in pharma underlines the potential for other companies and industries to embrace sustainability and the associated social, financial, and environmental benefits. Sustainability will be the key to unlock the synergies between business and innovation to create long-term value.

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PART II

Investment perspectives

Long a focus of our earlier books, the investor's opportunity to drive change can often be under-appreciated, but it's now ever more clear what investor actions can be most effective. But the journey to finding robust answers to this challenge has been more complicated than meets the eye.

In September 2017, at a symposium hosted by the new Yale Initiative on Sustainable Finance and the Journal of Environmental Investing, we suggested that the ESG conversation to date has actually been backwards. Rather than building ESG databases and then figuring out what to do with them, in their current state of partiality (let alone impartiality), we should be focusing instead on what ESG data can tell us about how we are doing at implementing strategies, and at system-wide levels. In other words, we should seek outcomes, which can only be driven by the implementation of successful strategies at necessary scale.[1]

What then are fund managers or asset owners to do when making decisions and setting priorities for ESG across all asset classes?

We understand that many asset owners have other issues to address, for example ongoing shortfalls, or existing relationships. But innovation is accelerating, and it is becoming increasingly clear as to what is possible and what innovations are either more or less helpful. Investment trends and perspectives are diverse, but it is especially important for investors to understand how they can best prioritize their effort to maximize impact.

Laila Gamaleldin starts us off with an eloquent analysis of the divestment question being posed to asset owners, especially academic institutions. Melanie Condon then envisions a new function for corporations to manage for relationships with investors, sitting between the sustainability and C-suite, improving the more traditional approach to investor relations. Ella Warshauer then looks across asset class and argues for priority setting for maximizing impact. Jeff Schwartz reviews the state of carbon markets, where pricing mechanisms remain a key potential future tool.

We then go regional, with Lillian Childress providing a view of the latest trends in China and investing, followed by a look at developments in ESG across the high flying worlds of private equity and venture capital from Matt Dittrich, and you can easily imagine how these two perspectives will continue to merge into one.

Financial innovation also involves the development of creative new instruments, if not new asset classes.

Bringing the worlds of systems thinking, industrial ecology and design together with finance is a focus at Yale, in what we have come to call Systems Finance, and the chapter that follows from Alizeh Maqbool considers a potential case of systems finance in Pakistan. Zach Knight and Chad Reed then give us a look at their award winning work on Forest Resilience Bonds for Blue Forest Conservation, and we end this section with a look at the future of energy and finance from Eric Esposito.

Investment and finance will inevitably change. Here's an attempt to envision and encourage the kind of changes we increasingly need to see.

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1 www.thejei.com

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TO DIVEST OR NOT TO DIVEST

Laila Gamaleldin

The birth of a movement

Thick stacks of paper lined with signatures lay in Laurel Warren's hands. As the administrative assistant to the president of Swarthmore College, she had been handed a sign and a petition, both urging the college to divest from fossil fuels. Soon after, a 32-day sit-in outside the school's investment office would ensue in support of the same cause. Over the coming years similar scenes would play out in college campuses across the United States and internationally. From "Divest Harvard" to "Divest University of Winnipeg" student groups, the movement is gaining momentum. So far, 230 institutions have fully divested from fossil fuels, around 30 of which are educational institutions. Still, many universities facing mounting pressures from students have committed to partial divestment or a temporary pause on investment. With many strong advocates for and against divestment, the questions remain: Should universities divest from fossil fuels? How will it affect their endowments? Who is fit to divest? Will divestment bring about the desired change?

The evolution of the financial and social implications of fossil fuel investment

Fossil fuels were once a cornerstone of any successful portfolio. Between 2004 and 2008, the price of oil per barrel went from \$37.66 to \$91.48. Even when adjusting for inflation, that is still a 212 percent growth. With growing demand, the future of fossil fuels seemed bright. These days, however, investing in fossil fuels is not so promising. Large supplies in 2014 and 2015 caused high volatility in terms of barrel prices. Between July 2014 and March 2015, oil prices dropped from \$107 a barrel to \$42 a barrel. Natural gas prices are similarly tumultuous as demand varies throughout the year, with high demand in winter and low demand in summer. Lower commodity prices have also correlated with lower revenues for many fossil fuel companies. British Petroleum (BP), a British multinational oil and gas company, saw its total revenue plummet from $379 billion at the end of 2014 to $183 billion at the end of 2016. One of the company's main competitors, Royal Dutch Shell, an Anglo–Dutch multinational oil and gas company, has seen a similar drop in revenue. The company made revenues of $421 billion in 2014 compared to $233 billion in 2016. What once attracted so many investors to fossil fuels was their regular payment of dividends. A decrease in company revenue correlates to a higher chance of dividend cuts; if a company is making less money, it is less likely to continue distributing money to its investors. Noble Energy, an American petroleum and natural gas exploration company, was forced to cut dividends by 44.44 percent in January 2016. More dramatically, Husky Energy, a Canadian natural gas company, and Tidewater, an international petroleum services company, stopped paying dividends entirely that same month.

Coal, gas, and oil companies face additional safety risks. Spills can be detrimental to a company's image and profits. More importantly, however, they are terrible for the environment. Oil spills kill many birds and marine organisms, causing permanent damage to ecosystems. It is hard to remove oil from water entirely, so even with a company's best cleanup efforts there will still be remnants. For example, a 2007 study conducted by National Oceanic and Atmospheric Administration found that 26,000 gallons of oil were still trapped on Alaska's shorelines from the *Exxon Valdez* oil spill in 1989. Climate change, an issue threatening almost every aspect of life, is caused primarily by the burning of fossil fuels which emit greenhouse gases. Financially, the effect of spills and other incidents such as gas pipeline fires affect responsible companies to varying degrees. Exxon's stock dipped by a mere 3.9 percent in the two weeks following the *Exxon Valdez* spill. More recently, BP, on the other hand, experienced a 55 percent fall in stock price after its *Deepwater Horizon* oil rig exploded and sank in the Gulf of Mexico. Such incidents can also have a lasting social impact. Three years after BP's Gulf of Mexico spill, 43 percent of Americans still view the company unfavorably.

Socially, the general outlook on fossil fuels has become increasingly negative. As climate change continues to become a larger issue and as its effects begin to be experienced in everyday life, environmental advocacy has been on a steady rise. With the UN's prediction that global temperatures must stay within 2 degrees celsius of current temperatures in order to avoid serious issues, many governments and companies have been making efforts to reduce emissions and to shift to renewable energy sources. According to Greenpeace, the number of solar panel installations in China doubled in 2016 and the country managed to not increase their carbon emissions that same year. Even oil giants like BP have been investing significant sums in renewable and alternative energy technologies.

Diverse approaches to divestment

With all of these facts in mind, many universities still continue to invest their endowments in portfolios that include fossil fuel companies. Although complete and immediate divestment may seem like the most obvious answer, things are not always so clear-cut. The ways in which universities invest are extremely nuanced and often depend on many factors. The institution's size, board makeup, and the size of its endowment all play large roles in determining whether or not a university will divest. There are many risks and benefits associated with divesting entirely from fossil fuels, all of which must be carefully considered before coming to a final decision. Furthermore, questions remain about whether divestment is the most effective way of taking action against the largest perpetrators of climate change.

Taking note of the diminishing financial and social appeal of fossil fuels, college students across US campuses have started campaigns urging their institutions to divest from fossil fuels. One of the first of these efforts took place in 2011 at Swarthmore College, a small liberal arts school in Swarthmore, Pennsylvania. A campus group named Mountain Justice launched a campaign asking the college to divest from a list of energy companies it nicknamed "The Sordid 16." Their goals, according to their website, also include achieving a fossil-free endowment before the year 2020 by slowly and deliberately replacing each of the college's current 70 accounts with investment firms that do not place money in fossil fuel companies. The group has organized a series of sit-ins, demonstrations, and installations in support of its cause. Their petition has accumulated 975 student signatures, 950 alumni signatures, and 96 faculty signatures. Those numbers are quite significant considering that Swarthmore College's total enrollment is 1,581 students. But despite Mountain Justice's best efforts, the college administration maintains its staunch stance against divestment. Some Swarthmore officials are hesitant about using its endowment in support of specific causes for fear of politicizing funds meant for educational purposes. They also worry that this would detract from the endowment's primary purpose which is to produce the greatest possible return that can then be invested in students' education. Suzanne P. Welsh, vice president of the school's finance office, claimed that "To use the endowment in support of other missions is not appropriate. It's not what our donors have given money for." The financial drawbacks of divestment were also a large aspect of the college's refusal to divest. A study by the Board of Managers found that full divestment would cost it around $200 million over the course of 10 years. Considering that Swarthmore has an endowment of $1.9 billion, such a loss would make up over 10 percent of its total endowment. Independent studies have shown that divestment can cut the size of endowments by 2–12 percent. Losing such a substantial amount of the college's endowment would have a direct effect on students' educations and overall experience since a smaller endowment would translate to pay cuts, less financial aid, and generally less money available for campus services. And so, despite being the catalyst of the college divestment movement, Swarthmore College continues to invest in fossil fuels.

Hampshire College, a private liberal arts college in Amherst, Massachusetts, approached fossil fuel divestment with a much less skeptical eye than Swarthmore. Hampshire was one of the first colleges to divest entirely from fossil fuels. It invests its endowment of $40 million entirely in socially responsible investment (SRI) firms. The college believes its investments should reflect its mission of fostering social good. By investing in companies that are socially and environmentally sustainable, the college believes it is guaranteeing itself and its students the greatest possible long-term returns since companies that mistreat workers and the environment can only be successful for so long. A representative for the college stated in a press release, "Business practices that include safe and supportive work environments, products that build economic strength, and activities that benefit the disadvantaged, including charitable giving, enhance the financial security and long-term sustainability of companies in which the college invests." The college's website boasts a list of guidelines outlining which investment ventures are acceptable and which are not. Companies that the college will invest in are ones that provide beneficial goods, that support higher education, have fair labor policies, provide safe working conditions, and so on. Companies that invest in countries with serious human rights violations, that have environmentally harmful practices, or that manufacture or use unsafe products, are avoided. Only mutual funds with visions that align with Hampshire's are invested in. Despite critics initially claiming that divestment would harm the college's already small endowment, its investments were actually up 4.6 percent in 2015. To put things in perspective, Smith College, a nearby college with similar characteristics, experienced a −5.9 percent return that same year.

Most colleges take a stance somewhere between that of Swarthmore and Hampshire, choosing to divest only partially or temporarily. Harvard, the university with the largest endowment in the world, has stopped investing in coal, citing investments in the sector as "not currently financially prudent." Boston University, Stanford University, and Syracuse University have also taken similar stances on coal investments. At Yale University, $10 million were removed from the school's endowment as the university cut ties with thermal coal miners and oil sands producers, while also cutting links with two publicly traded fossil fuel companies. While the university has not divested entirely from fossil fuels, its investment office works closely with outside investors to assess the impact of new investments on the climate. Thus, despite not being entirely focused on fossil fuels, Yale's investment team pays close attention to broader global issues as well as hidden impacts. A true indicator of the university fund managers' dedication to sustainable investing is their refusal to invest with an energy company that did not take climate change into account. Yale's chief investment officer David Swensen told the *New York Times* that "the investment had been approved by the endowment's board. But when we sat down with the company and brought up these issues, they denied it was a problem, so we did not go forward with the investment." Ironically, the school's investment office pinpoints the administration's refusal to divest from fossil fuels 2014 as the triggering event leading to their increased focus on environmental and social issues. Despite not taking a definite stance on the issue, these universities still send a signal to large fossil fuel companies that their harmful practices will only be tolerated for so long. Even the tentative participation of such powerful, high-profile, universities in the fossil fuel divestment movement lends some legitimacy to the cause.

Drawing parallels

Many parallels can be drawn between the ongoing fossil fuel divestment movement and the movement that took place across college campuses in the 1980s urging colleges to divest from South African companies in an effort to end apartheid. The first of these protests took place at the University of California, Berkeley. A student named Ramon Sevilla, then in communication with Nelson Mandela, led these efforts. He also traveled across North America and Europe in order to gather support for the cause, leading to his arrest on several occasions. In 1986, students built a shantytown in front of the chancellor's office at UC Berkeley. Students at Smith College, an all-female liberal arts school in Northampton, MA, staged a sit-in as well as a blockade in protest of the college's choice to not divest from South Africa's apartheid regime. Meanwhile at Columbia University, students picketed and interrupted trustee meetings through demonstrations, eventually leading to the takeover of the Graduate School of Business. Once again, Hampshire College was the first educational institution to take significant action, choosing to divest entirely from South Africa in 1977. Hampshire was far from the only college to do this, however. In 1984, 53 educational institutions had divested entirely from South Africa. By 1988, that number had nearly tripled to 155 institutions. Much like with the current fossil fuel divestment efforts, many universities chose partial divestment as their preferred contribution to the cause. Harvard University is one example of an institution that took this approach. Although Harvard's fund managers did not divest entirely from South Africa, they adopted a policy of selective divestment. Ultimately, these efforts were not in vain. The combined efforts of a number of institutions, both educational and non-educational, resulted in \$350 million being pulled out of South Africa. Such a figure evidently took a toll on that country's economy and sent a clear message to those in charge. Eventually, under mounting pressure to mitigate racial issues, South Africa's apartheid regime resigned. Although by no means the main drivers, universities played a noticeable part in the success of the anti-apartheid movement, especially when it came to raising awareness.

How effective is divestment, really?

Even if more colleges were to divest, the question remains: what impact would divestment truly have? Some argue that fossil fuel companies will go unscathed since the majority of such companies are government-owned. Furthermore, the sum of all college endowments in the United States amounts to \$550 billion and only 2–5 percent of college endowments are invested in fossil fuels. Compared to the industry's \$4.5 trillion, the effects of divestment will barely be felt financially. Despite helping to create creating significant social change, the apartheid divestment movement, the inspiration behind the fossil fuel movement, was found to not have had a financial impact in a 1999 study by Harvard Business School. Proponents of divestment agree that, ultimately, college divestment will not make a large dent in the finances of big fossil fuel companies. They argue, however, that the real impact of these campaigns is to shift the public's perception of fossil fuels, ultimately leading to new policies that will effect real change. As Karthi Ganapathy, spokesman for divestment advocacy group 350.org puts it, "The goal of getting universities to divest isn't to financially burden fossil fuel companies; it's to tarnish their image." Advocates compare their efforts to those of tobacco divestment activists. Tobacco divestment efforts, while failing to hurt companies' finances (tobacco stock prices have been on an upward trend since the 1980s), triggered the creation of new tobacco taxes, stricter policies on tobacco sales, and the banning of smoking in many public places. So while college divestment will never directly bankrupt companies, it may nevertheless send the necessary signal to start the journey toward cleaner energy. Divestment is ultimately more of a statement or symbolic gesture than it is a direct method of achieving a goal.

Reservations about divestment

As mentioned previously, one common apprehension that university fund managers face when considering divestment is that they fear the politicization of their funds. Beyond that, they fear that agreeing to divest from a certain sector will lead to an outburst of demands to divest from a multitude of sectors. As one dean at Harvard put it, "Are we going to divest from sugar next?" Although fossil fuel divestment is now the most prominent divestment cause around college campuses, student groups across the nation are asking for divestment from a wide variety of stocks. Some groups are advocating for divestment from Israel and Sudan on the grounds of human rights abuses while other groups are asking for divestment from pornography and alcohol on the grounds of religious belief. The fear is that once one industry is blacklisted, many others will follow, limiting the number of viable stocks that a university could buy. University fund managers also assert that it is their fiduciary duty to garner the largest possible returns and that screening out specific sectors prevents them from fulfilling their duty. In short, they believe their job is to make the most possible money for the university, regardless of where that money is invested. Online advocacy group gofossilfree.com counters such claims, arguing that more harm than good is being done to institutions' endowments by investing in companies that are profitable in the short term but not in the long run. Furthermore, the group says that by placing their money in companies that have an adverse effect on the global community, universities are in fact harming the same people that they seek to educate. Most colleges include in their mission statements a few lines about creating positive social change . A segment of Brown University's statement, for example, reads "The mission of Brown University is to serve the community, the nation, and the world by discovering, communicating, and preserving knowledge." It is thus considered hypocritical by some that universities fund companies who contribute to such large global issues as climate change and pollution. In the words of Piers Telemacque, a journalist for the UK's *Guardian* newspaper, "You can't be preparing 7 million students for the future on one hand, while undermining every chance of a decent future."

Another issue posed by divestment is that once a socially conscious investor sells their stocks in a company whose practices they consider immoral, the stocks will simply be bought by another party that does not take the social impact of its investments into account. In this view, more harm than good is achieved through divestment. It is nearly impossible to change a company's practices without having a foothold within it. That ultimately makes full divestment ineffective and a hindrance to progress. Thus, in my opinion, shareholder engagement is the most effective way of making a difference. Shareholder engagement is when shareholders work with the boards of companies in which they invest in order to attain certain goals. Shareholder engagement has often been used to change policies and improve practices. Shareholder activists have done everything from raising minimum wages to forcing companies to release sustainability reports. This sort of progress is simply not achievable as an outsider. In order to fully address climate change, colleges in fact need to keep some holdings in fossil fuel companies.

Alternative solutions

What colleges must do, however, is be more conscious of who handles their endowments. Most educational institutions do not invest their own endowments directly but instead split them among a number of investment firms who hire full-time strategists to produce the greatest possible return. At Brown University, for example, 95 percent of the school's $3.2 billion endowment is given to outside investors. The large majority of these firms, however, are mainstream firms that do not take ethical considerations into account when making their investments. While efforts have been made to invest in sustainable companies, they, for the most part, have been symbolic gestures, with amounts of money large enough to make universities look like they are concerned with social issues but still not large enough to make a significant change. One way these institutions can protect their returns while being at the forefront of the mitigation of social and environmental issues is by shifting to socially responsible investing (SRI) firms. When considering possible investments, these firms take into account the financial as well as the social, environmental, and governance (ESG) aspects of the companies at which they are looking. This ensures that their investments are not only profitable, but also ethical and beneficial to society. By investing in SRI firms, colleges can ensure that their endowments are invested in a manner that is both profitable and in line with their stated mission. This may also be a good solution to the divestment issue. Many SRI firms continue to invest in fossil fuels not because they support the industry but because being a shareholder makes it possible to create a difference from the inside. SRI firms such as Calvert Investments, Parnassus Endeavor Fund, and Domini Social Investments place their money in companies that are profitable but have questionable practices, so that through proxy voting, letter writing, file resolutions, in-person meetings, and, when necessary, divestment, they can change these companies' practices for the better. In 2015, Domini worked with Southwestern Energy, an oil and gas company, in order to create an ongoing methane emission reporting project. These efforts are in many ways far more effective than divestment since their effects are tangible. In divestment, the stocks are simply passed onto another investor.

Ultimately, and as shareholder engagement continues to prove itself time and time again, it is becoming increasingly apparent that it, and not divestment, will be the main tool for changing the practices and reducing the harmfulness of oil, gas, and coal companies. As the educators of future generations and the centers of knowledge and growth, universities must lead the movement toward socially responsible investing. Only by engaging directly with the problem can a solution be achieved.

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8

SHAREHOLDER ACTIVISM 2.0

Melanie Condon

It is no secret that a popular tenet of Environmental, Social and Governance (ESG) investment funds is that people should becoming active, interested shareholders in the companies in which fund managers choose to invest. However, there is an untapped potential to take this interest from activism to advisement. Additional collaboration between investors and ESG focused companies (such as Unilever and Kering) could provide mutually beneficial profit and efficiency, along with other benefits and lower risks for all parties involved.[1]

Advisement vs. activism

The main difference between the activism that ESG funds currently participate in and collaborative advisement is shared responsibilities and the relationship between these two categories of entity (fund and firm). Shareholder activism can take many shapes, from slowly increasing your positon in a company as a means to influence business strategy to colluding with other shareholders to launch a hostile takeover, and it is not unique to ESG-focused investors. In fact, traditional investors have become more active as hedge fund returns have been lackluster and passive investment continues to outperform. Investors need to find new ways to produce alpha, and many believe taking a more active role as shareholders is the edge required. However, traditional shareholder activism has been of a more adversarial nature with little to no buy-in from companies themselves.

In late June and early July 2017, activist investor Daniel Loeb made the front page of the *Wall Street Journal* on several occasions for his aggressive purchasing of Nestlé stock to increase his position. Loeb noted publicly that he believes Nestlé was leaving profit on the table and could be better organized to provide more shareholder benefit. However, Loeb was also public about the tactic he wanted to employ with Nestlé, stating that he "intends to play a constructive role to encourage management to pursue change with a greater sense of urgency." Loeb, a traditional activist, has changed his tune, making many wonder if fund managers are becoming more attuned to the fact that working with companies rather than against them to improve performance is better for returns.

While Loeb is taking a friendly approach with his words, his actions put Nestlé on edge and forced them to speed up the company's strategic review by six months in order to demonstrate they are properly managed. In March 2014, McKinsey put together a report on shareholder activism which reported that a single action by activists puts executives on edge, and causes them to reflexively resist approaches by shareholders. That isn't to say that activists themselves are not to be blamed for any negative interaction, as many times McKinsey, based on data from activist success, found that approaches were often confrontational or "even with acerbic overtures." The report goes on to say that,

> Those executives who can set aside tone and style, though, will find that some activists do indeed have ideas that create value and improve shareholder performance. In fact, a collaborative, negotiated, or settled response to activist initiatives tends to lead to higher excess shareholder returns than a combative one.
>
> *(Cyric et al. 2014)*

In contrast, a collaborative settled outcome tends to lead to higher shareholder returns in the 3-year time horizon.

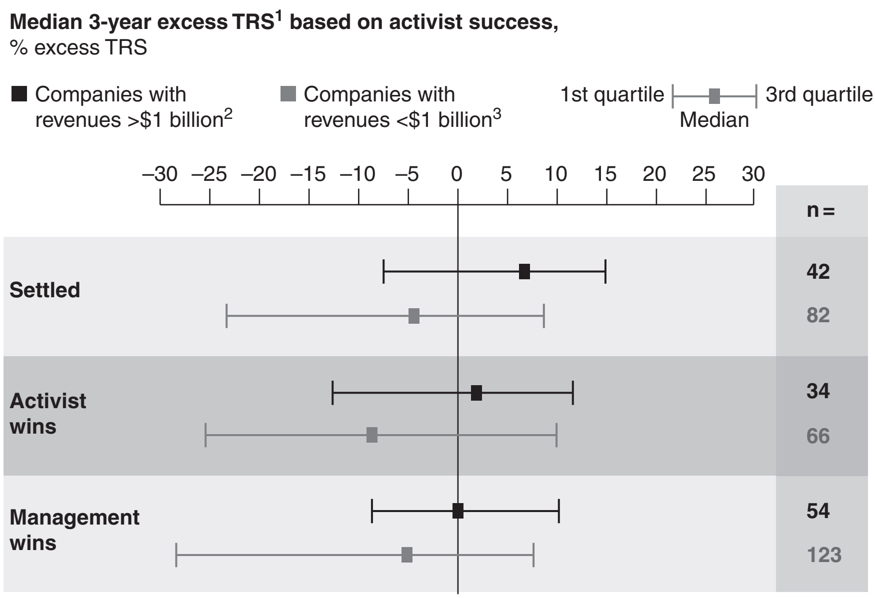

FIGURE 8.1
Source: Standard & Poor's Capital IQ, McKinsey analysis.

It is clear that activism does not create a calm or positive atmosphere between shareholders and the company. Yet, so many investors practice activism as a major strategy, and many of those funds that do so focus on ESG factors. Funds would be better off creating an atmosphere of trust and loyalty with their invested companies, rather than breed mistrust and fear.

The case for the ESG fund

First and foremost shareholder advisement is a means of alpha. In the simplest of terms, active investment funds try to provide better returns for their investors. In order to do this, they choose investment strategies they believe will provide higher alpha than other funds. All fund managers would likely agree that the more you know about companies you invest in, the better off you are (i.e. less risk, better potential understanding of long-term business model, better idea of market trends). I cannot think of a better way to gather more information on an investment than by creating a collaborative advisory relationship with companies and gaining insight and the potential to have input into their business models.

Approaching this from a more institutional viewpoint, there is tremendous opportunity for ESG funds to incorporate a collaborative/consultative approach in dealing with invested companies. This could take the form of hiring dedicated advisors whose sole job is to interact and advise invested companies based on research ESG fund managers already perform. Advisors could suggest acquisition targets, or R&D investment ideas, or help find renewable energy vendors, or suggest new social endeavors with which to collaborate.

In addition, a problem often said to plague ESG funds is the lack of available ESG data that companies report. Not only can there be a lack of reporting by companies (e.g. what are their source 1 greenhouse gas emissions? Or their gender parity numbers?) but also there is little continuity from one company to the next. A fund may be analyzing company A on a certain set of ESG factors that the company voluntarily reports, yet analyzing company B on a very different set of factors. It can be hard to make any long-term predictions on companies or properly evaluate a fund's investment strategy with so much ad hoc data. In formalizing an advisory role, investors can help eliminate some of these issues with continuity and poor data. An established relationship will allow the fund to better gauge data metrics from the company, and ask them to report on data that the fund believes is important for long-term growth.

Walden Asset Management, an Boston ESG firm, includes a "Shareholder engagement" section on their website. The title of the section alone suggests that their approach to shareholder activism is less adversarial and more of an advisory nature. Walden states in this section:

> As long-term investors, we encourage each company we engage to take actions that are consistent with the long-term interests of the company and its shareholders. Our experience demonstrates that effective shareholder engagement

can lead to improved corporate policies, more sustainable business practices, and greater transparency and accountability.

Some of the ways in which Walden puts these words into practice is in engaging with companies on board composition and structure, climate change, executive compensation, water risk, and a multitude of other factors that would not surprise you if you knew how Walden typically chooses their investments. On their website Walden lists some of the strategies they use to engage, including regularly initiating dialogue with corporate management where they discuss emerging issues and monitor the company progress towards ESG goals. Walden also utilizes shareholder proposal and proxy voting in situations where a company is not responsive to dialogue. This is an excellent example of moving towards Activism 2.0 but it does not go far enough. I believe if Walden were to establish an advisor role (discussed in more depth below) they would realize even better relationships with their investments and better returns.

Because ESG firms are characteristically long-term investors they are able to create long-lasting and useful relationships with companies. Simply put, a long-term investor has long-term gains to be made by strong long-term performance by the companies in which it invests.

Is it worth it for an ESG firm to invest time, effort and resources into cultivating an advisement relationship with its investors? First of all, investment firms are constantly looking for sources of alpha that can provide high returns for their investors yet keep risk at a minimum. If an ESG fund truly believes that those factors by which they evaluate investments create better profit then it is undeniably in their interest to see these factors utilized fully, and to continue providing expert analysis and information to these companies. For example, Firm A sends Company X through its decision model and determines that based on its impressive reporting of environmental factors, use of renewable energy in its operations and its goal to halve hunger in sub-Saharan Africa by 2030, this would be a sound investment. Six months after investing in Company X, Firm A hears that Company X is interested in pursuing the acquisition of a smaller company that is well known for labor violations in Africa and does not produce a sustainability report. Firm A must believe that acquiring this company will negatively impact the financial returns of Company X in the long run. Thus Firm A should open lines of dialogue with Company X to suggest a better acquisition target that has positive sustainability impacts on the world and reports on such impacts.

In speaking with an established ESG firm, I learned that one tactic it uses to engage with its investors is to send personalized letters to the CEOs of all of their holdings (less than 100), in which it explains its position in the company, why it took it, what its overall investment strategy is and why it would like to open lines of communication with the companies moving forward. The ESG firm noted that a few CEOs did actually respond, expressing interest in continuing a dialogue. I take this as a positive sign that CEOs do see the benefit in holding special advisory relationships with ESG firms. The more regular these types of relationships become, the more CEOs will likely respond, creating a new, positive dynamic.

The best way for funds to create such a relationship would be to create a role within the ESG fund that liaises with the company as a strategic advisor. The advisor would act as a consultant to the company based on its own diligent research, and would be fully integrated with both the research and investment of the fund. The advisor would ideally spend roughly half of their time sharing information and research from the ESG fund on market trends, ideas in sustainability, acquisition targets, etc., with its investments and the other half reporting back to the fund on information thay have gathered from the company.

This role needs to be institutionalized, and not be a secondary duty of a fund manager, in order to be successful. Companies need to know this is a dedicated relationship, and the fund needs to fully commit to the idea to boost confidence and ensure there are no constraints.

A role for third-party advisors?

The idea of institutionalizing advisement within a fund begs the question "Is there room for third party advisors in Activism 2.0? Could a consulting company make a business of being the middle person between ESG funds and ESG companies?"

There is a role for such services, but I do not believe it will be successful without shareholder advisement first originating within ESG funds. It would seem too gimmicky if coming from a third party, and it would not be sufficiently established for a company to feel it would be a good investment to pay for these services. After a few years, once advisement is more established, there could be a market for third party ESG investment advisory services.

These services would be particularly useful for companies not quite as established in their ESG work as others, but who are trying to move into this realm. Take Volvo for example, which has just announced that it will cease manufacturing cars with internal combustion engines by 2019 and focus only on hybrid and electric. This is an impressive feat in the automotive industry and one that would be applauded by the ESG world, yet Volvo may not know the ESG investor landscape as well as a company that has worked in sustainability for the past decade. Thus it could benefit from having advisors who understand the space and can be a bridge between firm and funds.

The case for ESG companies

Any advisor knows that there will not be a successful relationship if only one of the two parties is engaged. In fact, this is the primary issue with shareholder activism. The company is put in a defensive position by actions of the activist and relationships break down.

Why should a company be interested in getting advice from ESG funds that might hold less than 1 percent of its shares?

Many ESG companies pay a lot of money for market research and trend reporting to tell them what the temperature is in the "ESG world." This is in addition to competitive reporting and normal industry market tracking. Companies could surely benefit from free access to the ESG fund's research, and the fund should be happy to provide the research as it want its investments (i.e. the companies) to perform better. This is the clearest sense of a win-win relationship in the shareholder advisement theory.

Another positive for companies is in help with succession planning. Oftentimes, ESG companies, and especially those that were early adopters of the sustainability business model, were able to do so because of a visionary leader who ensured integration throughout the company. For example, Unilever became the sustainability powerhouse it is today because of the vision of current CEO Paul Polman when he took the reins in 2009. Much like Steve Jobs of Apple, Polman had a vision of how to differentiate Unilever and became an internal and external evangelist for his vision. Polman's vision was to reduce costs and risks of doing business, as well as understanding the duty companies have to give back to the society they are affecting. In order to do this he restructured the company, launched the expansive Unilever Sustainable Living Plan and integrated sustainability throughout every function of the company, holding everyone from executives through factory workers responsible for such integration. In the past few months Polman has said publicly that he plans to step down as CEO within the next few years. On hearing this, many wondered if Unilever would be able to continue its commitment to its Sustainable Living Plan without Paul Polman at the helm. In the same way, people wondered if Apple could continue to innovate without Steve Jobs.

Having an advisory relationship with ESG funds can help reduce the risk of a companies' sustainability vision leaving with their leaders. The fund, in having that long-term advisory relationship with the company, can hold the company accountable during periods of succession, to ensure the company continues its ESG investments. The fund can even help advise during this period, especially if the incoming CEO is from outside the company and does not fully understand how sustainability is integrated at the firm. Who better to understand this than the expert investment firm that has been advising the company? It is also able to provide an outside view of the company's sustainability initiatives that is a bit more removed from the company than an internal executive may be. This can be helpful to ensure any issues with the old CEO are not repeated with the new.

A further benefit to the company in collaborating with ESG funds would be as a means of protection to ward off other activist takeovers from non-ESG hedge fund managers and other short-term profit seekers. The ESG investors could be seen as "protection" from takeovers, as they are a sign to other investors that the company is engaged with Wall Street and is focused on long-term growth. It may dissuade other activists from getting involved, as their bid (especially if it is a hostile takeover) would not be warmly received by the ESG fund and potentially other shareholders who believe in the same business model.

In February 2017 when Kraft Heinz tried to buy Unilever and was swiftly rejected, it was clear from the stock prices following the bid that the market sided with Unilever. There was talk by investment media outlets that perhaps 3G (the private equity company with control of Kraft Heinz) would try to rally other shareholders to band together and pursue a hostile takeover, favoring shorter-term shareholder returns in lieu of long-term sustainability investing. In the end this did not occur, and many investors spoke out publicly that Unilever was a good business case of the "value and values model" and should not favor short-term cost-cutting measures. This is a good example of why an advisory role is needed between ESG funds and ESG firms. They are sailing in the same shipping lanes, taking in similar information, making similar inferences about the market and risks, yet they seem to rarely interact in a positive manner.

As was mentioned earlier, research on potential acquisition targets could be of particular benefit to ESG companies being advised by ESG funds. In certain industries, the landscape is dense with competitors. Take the fast-moving consumer product goods industry for example. There are a few large players who dominate, but more often there are multiple "disruptors" emerging, taking market share by being small and nimble enough to respond quickly to consumer trends. Often the response from the large players is simply to purchase the small disrupters and bring them into their operations. However, this can often disrupt the ESG business model that the large company is trying to institute. With ESG funds providing advisement, companies can get trusted research on acquisition targets that would be in line with the their own ESG business model and provide even better returns.

A related example involves the well-known investment firm Generation Investment Management, who became a major shareholder in Vermont-based green consumer goods company Seventh Generation. Seventh Generation had been resistant to acquisition moves in the past because they were concerned about diluting their sustainability messaging, and thus brand equity. It was reported that Generation Investment Management was a strong force behind convincing Seventh Generation to sell to Unilever in 2016. Generation Investment Management understood that Unilever was likely the only large company in the world who not only would be able to protect Seventh Generation's social mission, but actually shared that ethos as well. So far it has been a successful acquisition for both parties. Seventh Generation was able to organize a social mission board with a diverse membership that oversees all of its social activism work (much like Ben & Jerry's) and was able to take advantage of Unilever's size by lowering costs of certain inputs. Since joining Unilever, Seventh Generation has shown impressive growth and is quickly expanding into new markets and distribution channels. It is possible if not likely that this partnership would not have happened without the push from Generation Investment Management.

Conclusion

To conclude, creating a next generation of shareholder activism, known as shareholder advisement, is mutually beneficial to ESG investment funds and ESG companies. Funds benefit from lower-risk investing, the ability to help shape a company's long-term strategy, better insight into company management, and improved data. Firms benefit from expert research and knowledge of the market and ESG trends, advisement on acquisition and mergers, and an advocate for its business model to external audiences.

It should be noted that for the "shareholder advisement" idea to take hold, there would first need to be a company "champion" to institute such a relationship before other companies understood its benefits. I could see Unilever or Interface being such a champion, as they are both some of the strongest proponents of the ESG business model, and they believe strongly in promoting sustainability in other companies, including competitors.

Whoever this champion may be, it will be much better off than its competitors through opening itself up to collaboration with like-minded investors to provide not only better returns for shareholders but a better, more sustainable product or service for its consumers.

Note

1 Throughout this chapter I will be referring to ESG-focused funds or investors. This can be defined as investment which integrates sustainability research and ESG considerations as primary in investment strategies. "ESG companies" or "ESG firms" are public for-profit corporations that have stated goals to evaluate ESG factors as a measure of success in their businesses, or attempt to institute sustainability measures in business practices to benefit society and their business.

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9

FINANCING MECHANISMS FOR SUSTAINABLE INFRASTRUCTURE

Ella Warshauer

Urbanization is a global trend set to continue and change how we live, with very large economic, social, environmental and political implications. Cities are home to 50 percent of the world's current population, generate about 80 percent of global economic output, and account for 70 percent of greenhouse gas (von Gunten and Mainelli 2015). Furthermore, 65 percent of future productivity growth will come from the top 600 cities (Kim 2016). It is important therefore that we change the way we think about cities, particularly in terms of infrastructure.

Sustainable design is the key to infrastructure development in an urbanized world. While sustainable building practices have value that is quickly evident to environmentalists, businesses are more interested in productivity and monetary impact. The answer to both of these calls is sustainable design, which increases value to stakeholders across all aspects of the triple bottom line of environment, economy, and society.

As a society, we already possess the scientific and technological know-how to move towards global sustainability (Brown 2014). However, with high up-front costs and consistent maintenance and reinvestment required, infrastructure projects do not currently receive the attention they need. We face an infrastructure-financing crisis, characterized ironically by an undersupply of investable projects and an oversupply of private capital ready to be invested (Kim 2016). This presents a significant economic opportunity for the development of sustainable urban infrastructure.

The lacking state of infrastructure globally represents an economic risk requiring an estimated $90 trillion of investment over the next 15 years, more than is in place in our entire stock today (Corfee-Morlot et al. 2016). This represents about $6 trillion per year, an increase from the current rate of $3.4 trillion per year (Corfee-Morlot et al. 2016).

Forestalling infrastructure investment is costing the US its competitive edge economically and politically and is a threat to national security in the form of significant expenditures and stress on the financial system. For example, weather events such as storms, flooding, hurricanes, snow removal, and drought can all lead to unexpected expenditures for cities, damaging budgets and impacting business operations. The density of cities provides an opportunity for increasing efficiency through better planning processes.

We can close the financing gap by fusing city planning with creative financial techniques to address the intersection of climate change and economic development (see Chapter 20 for an illustration).

The development and financing of sustainable urban infrastructure projects will help make cities more efficient, increase quality of life for inhabitants, and strengthen the economy.

Defining sustainability and infrastructure

Infrastructure is the backbone of society and cities. We require urban infrastructure to foster innovation and creativity in safe, healthy, and accessible cities, and support cultural, social, and economic systems. Economic and environmental performance of cities can be linked through effective urban planning. The physical structures of cities can be designed to limit resource consumption, contributing to increased efficiency and higher utility.

We possess the scientific and technological capital to move towards global sustainability, yet the infrastructure crisis is characterized by an oversupply of capital and an undersupply of investable projects. This requires a transition in the way we think about urban infrastructure. In her book *Next Generation Infrastructure*, Hillary Brown suggests viewing the hardware of our industrial systems along ecological lines, and taking an integrated approach to planning, financing, constructing, and maintaining infrastructure. She proposes an approach that utilizes *systems thinking*, developing a greater sensitivity to the larger infrastructural context. With systems thinking, all stakeholders are involved in the development process. This creates shared value, and streamlines the process for developing solutions to issues that affect the triple bottom line. Not only do sustainable practices prove to be an effective risk management technique for businesses, but they also foster innovation, improve financial performance, build customer loyalty, and attract top employee talent. Overall, business can generate economic value by tackling social problems that intersect with their business's focus (Whelan and Fink 2016).

Infrastructure is broadly defined as "the basic physical systems of a business or nation, including but not limited to transportation, communication, sewage, water, electric systems, etc." For a system to be classified as sustainable, it must include additional attributes. While a universal definition does not exist, sustainable infrastructure should include systems that are synergistic, contribute few or no carbon emissions, serve local constituencies, are resilient, and protect biodiversity and ecosystem services.

There are many frameworks for developing holistic systems that fulfill these criteria. SEIS (Social, Ecological, Infrastructural Systems framework) is one method that integrates urban metabolism with life cycle assessments to articulate trans-boundary supply-chain emissions footprints of cities. The framework considers factors including environmental pollution, public health risks, supply chain risks, and global greenhouse gas (GHG) emissions. Infrastructure footprints are used to distinguish resources that have been used from available resources to support human activity in cities more efficiently, and should be leveraged throughout the sustainable design and development process.

Where will the capital come from?

A letter from the Norwegian Ministry of Finance to Norges Bank provides a helpful overview for how to think about investing in infrastructure (Nicolaisen and Slyngstad 2015):

> The value of global infrastructure assets has been tentatively estimated at around $20 trillion US dollars, of which 75 percent are in public ownership and 25 percent in private ownership. A private investor considering investment in infrastructure may choose from different types of financial instruments. There is a choice between debt and equity, between listed and unlisted, and between direct investment and investment through a fund.

Figure 9.1 illustrates the different pathways for various types of institutional investors and funds to gain exposure to infrastructure, including listed and unlisted projects, as well as through both debt and equity instruments.

An overview of asset classes and investment priorities

To understand what financial instruments best address the infrastructure financing gap, it is helpful to take a top-down approach to understanding what instruments comprise the investable universe.

Asset classes include: fixed income, property, public equity, infrastructure, and real assets. The following subsections present investment opportunities ordered largest to smallest by asset class, and identify fixed income, property, and public equity as areas with particular growth potential.

Figure 9.2 outlines the proportions allocated to each asset class. Many investors are unfamiliar with socially responsible investing, so investing in asset classes such as fixed income, property, and public equity can help mobilize capital at faster rates than for asset classes that mainstream investors are less familiar with.

Fixed income (22 percent of the value of everything)

The value of fixed income instruments represents the overall amount of cash lent out to other parties. This value has been calculated at USD $100 trillion, making fixed income the largest asset class. However, financing the sustainable energy

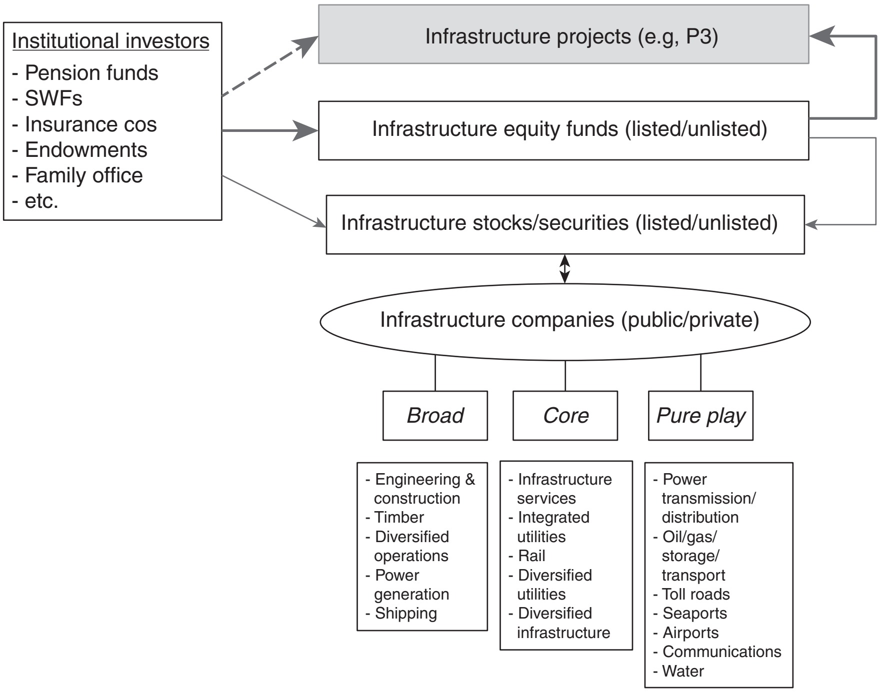

FIGURE 9.1

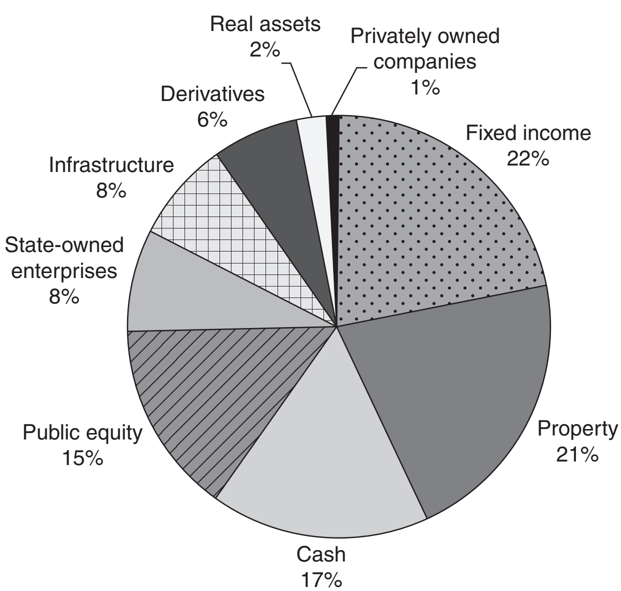

FIGURE 9.2

Source: Krosinsky 2016.

transition and the infrastructure-financing gap requires a deeper secondary debt market for sustainable infrastructure. Since the Global Financial Crisis (GFC), banks have been wary of long-term lending, which has left a void in the long-term infrastructure debt market. As a result, institutional investors have the opportunity to play a significant role in filling this financing gap.

There are many different instruments available within the fixed income asset class that provide investors with flexible financing options to fit a spectrum of risk-return profiles. Issuing bonds provides the issuer with the immediate capital needed to construct a project, while repayments can be spread over long periods of time. Climate-aligned bonds and municipal bonds are two examples that are gaining popularity in the sustainable infrastructure space.

Climate-aligned bonds represent the bond universe used to finance low-carbon and climate-resilient infrastructure (Boulle et al. 2016). As of 2015, there is $694 billion of climate-aligned bonds outstanding, which includes 3,590 bonds and 750 issuers. Sixty-eight percent of the bonds are allocated to transport, and 18.8 percent to energy. The proportion allocated to energy is expected to grow as the technology sector matures.

Figure 9.3 provides an overview of the entire climate-aligned bond universe. It indicates two main sectors to focus on: transport, energy, and multi-sector. Multi-sector is composed of energy, buildings and industry, and transport.

Currently, the Climate Bonds Initiative (CBI) is the only organization in the world working to mobilize the bond market for climate change solutions. CBI provides investors with climate-bond standards as well as a certification process for climate-bond issuance. The climate-aligned bond universe has been accused of "greenwashing," so the standards and certification process provided by CBI are important for increasing transparency, and reducing uncertainty in the market to help attract more mainstream investors.

The climate-aligned bond universe encompasses the green bond market. Green bonds are nearly identical in structure to other types of bonds, with a few key differences – they are labeled as green by their issuer, proceeds are earmarked for green investments, and the issuer must track and report on the use of proceeds to ensure green compliance (Natural Resource Defense Council 2015). Figure 9.4 indicates that within the green bond market, three sectors – energy, buildings and industry, and transportation – emerge as dominant. Investors are comfortable with fixed income investment vehicles – munis, revenue, general obligation, project, and securitized bonds. Applying sustainable practices to trusted, existing financing mechanisms exposes these principals to a broader network of issuers, governments, and financial professionals. As mainstream investors become more comfortable with sustainable investing practices, these three sectors and vehicles should see increasing allocations of capital.

Property (21 percent of the value of everything)

Property represents the value of peoples' homes, which totals to $95 trillion globally ($75 trillion represent peoples' homes, $20 trillion represent managed portfolios

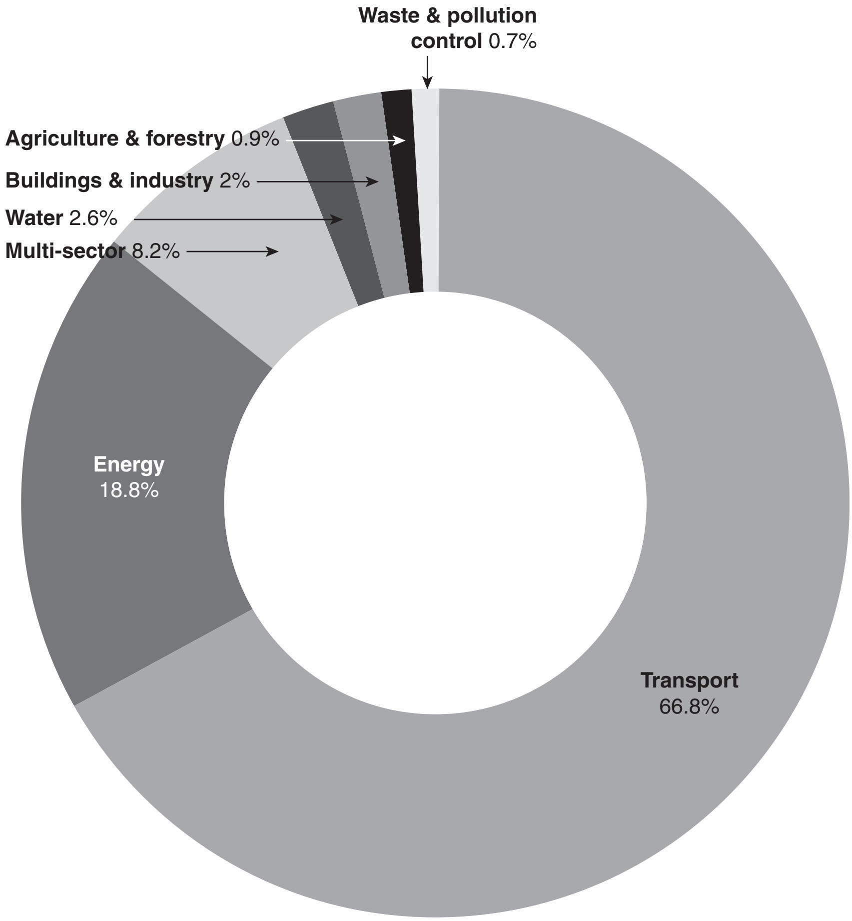

FIGURE 9.3
Source: Climate Bonds Initiative 2016.

of real estate) (Krosinsky and Forstater 2016). In the US alone, buildings account for 40 percent of energy consumption, signaling an enormous opportunity for increasing efficiency (US Green Building Council 2016). Property is the second largest asset class by the *Value of Everything*, and buildings and industry are the second largest sector in the green bonds market. The increasing rates of urbanization require special attention to sustainable infrastructure development and design in urban areas, as indicated by the amount of capital already dedicated to these asset classes. Many existing organizations are positioned to help retail and institutional investors leverage this opportunity, for example, via retrofitting homes, energy benchmarking and ordinance programs, as well as the property-assessed clean energy (PACE) financing model.

One framework for thinking about property in terms of sustainable development is called "green building." The United States Green Building Council (USGBC) is

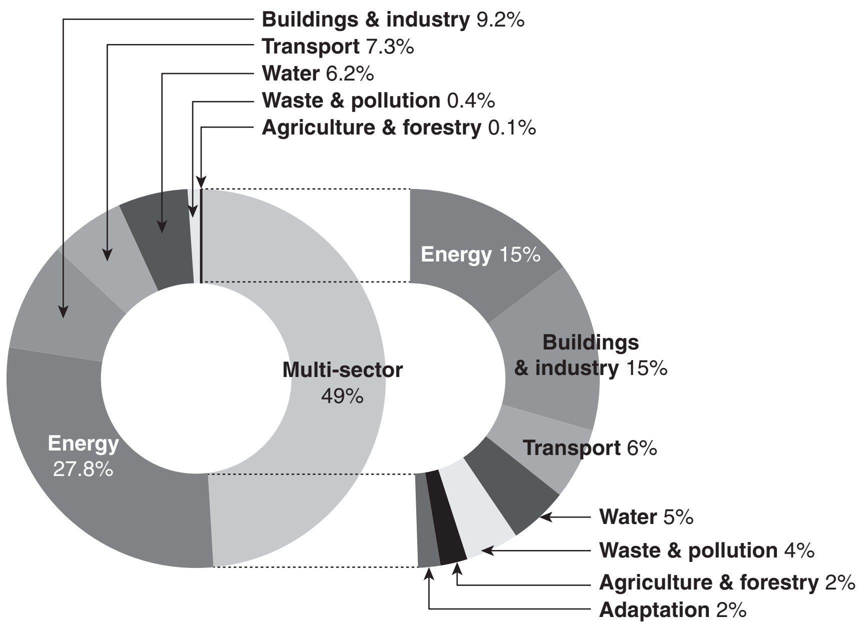

FIGURE 9.4
Source: Climate Bonds Initiative 2016.

a leading organization in this area, helping to establish the business case for green building. Green building is based on the idea of infrastructure development as a holistic concept, and helps us understand how the built environment can impact the natural environment, as well as the people who inhabit buildings and communities each day (US Green Building Council). Green building considers energy use, water use, indoor environmental quality, as well as other factors, into account. LEED (Leadership in Energy and Environmental Design) certifications are encompassed by green building as well.

Green building has many economic benefits that investors may overlook. Upfront investing in green building makes buildings more valuable. Increasing efficiency, lowering maintenance costs, and lowering energy use intensity all contribute to higher returns on investment. Green building projects increase by 4 percent in value on average, and can be expected to pay for themselves in just 7 years. The short-term, day-to-day costs of operating a green building can have the effect of reducing operating costs by 10 percent in just one year. The green building sector continues to grow at a pace faster than construction growth in the US, and LEED certified buildings have an impressive track record when savings are totaled and quantified. Between 2015 and 2018, LEED-certified buildings in the United States are estimated to have \$1.2 billion in energy savings, \$149.5 million in water savings, \$715.2 million in maintenance savings and \$54.2 million in waste savings (US Green Building Council 2016).

Green building projects can be financed using the Property Assessed Clean Energy (PACE) model. The PACE model is an innovative form of financing energy efficiency and renewable energy improvement projects on private property, where government funds the up-front costs of improvements. PACE assessment is a *debt of property*, meaning the debt is tied to the property itself, as opposed to the individual property owner (US Department of Energy 2016). This means that repayment obligation transfers with property ownership, incentivizing the current owner to make long-term energy efficiency improvements, since they do not have to worry about covering the up-front cost.

Investors can combine PACE with Energy Performance Contracting (EPC), guaranteeing that the efficiency savings produced by a project cover the project costs, for scalability. EPCs empower energy service companies to deliver energy and economic savings in the institutional and public buildings sector, and there are many available growth opportunities for this market, particularly via PACE programs. The market for energy service companies is projected to grow from $6.3 billion in 2015 to $11.5 billion in 2024, signifying that EPCs have the potential to play a larger role in financing sustainable infrastructure projects (Stutts 2015).

Property as the second largest asset class, combined with the increasing rate of urbanization globally, proves the additional need for sustainable design and innovative financing mechanisms in the urban infrastructure space. As more capital becomes available and as firms develop scalable sustainable investment solutions, we should see a closing of the financing gap, and progress towards more sustainable cities that benefit stakeholders across the triple bottom line.

Public equity (15 percent of the value of everything)

The third largest asset class is public equity, which is valued globally at $65–70 trillion.

Owning a significant amount of infrastructure assets has high potential for financing public infrastructure (von Gunten and Mainelli 2015). Equities in their purest form, as well as bundled in mutual funds, real estate investment trusts (REITs), and exchange traded funds (ETFs), etc., offer additional mechanisms for infrastructure investment. Hannon Armstrong's REIT (NYSE: HASI) specializes in "debt and equity financing to the energy efficiency and renewable energy markets," and states that investing best-practices should include analysis of the environmental benefit of the proposed investment. The company works with state and local governments, as well as private developers, and focuses on "assets that generate long-term, recurring and predictable cash flows." REITs have the potential to unlock capital to invest in small-scale infrastructure, and should not be overlooked by investors.

There are new opportunities for expanding sustainable infrastructure portfolios, and the process for investing in unlisted projects is becoming more widely adopted by mainstream investors. In a statement of December 2015, Norges Bank recommended committing resources to learning about investing in unlisted infrastructure.

The bank suggests some ways to streamline the process and take action (Nicolaisen and Slyngstad 2015):

> Invest together with companies the Bank already knows that are considering sourcing private capital to finance individual projects. Another possibility may be to invest together with other investors, financial institutions or development banks. Partnerships of this kind are often used for large infrastructure investments.

REITs can also be bundled to promote holistic, sustainable infrastructure projects that develop different aspects of specific communities. For example, REIT providers could offer a REIT that finances improving San Francisco's existing Muni bus system, soft-path storm water/urban greening along frequently used corridors, bike paths to ease stress on the bus system, or retrofits to homes to reduce stress on the electric grid. How can we package infrastructure investments to help investors fund projects with long-term time horizons, and incorporate systems-thinking by default? Can these products also address the question of social justice and "not in my backyard" (NIMBY) by bundling more attractive projects with less attractive ones, specifically those in low-income communities that don't have high rates of constituent advocacy, but are often the places that can benefit most from efficiencies?

Duration infrastructure (8 percent of the value of everything)

Infrastructure is widely considered its own asset class and traditionally includes highways, railways, ports, energy, water, airports and sometimes telecommunications infrastructure. However, this proves confusing, as investors can invest in infrastructure through other investment vehicles and asset classes. Literature suggests that what is traditionally referred to as the infrastructure asset class is defined by duration investments – projects that have 35–100-year timelines. Given evidence showing that long-term investing positively influences corporate performance by both strengthening financial performance and increasing innovation, the duration infrastructure asset class provides an opportunity investors should not overlook (Barton and Wiseman 2014). Infrastructure is a long-term investment involving many stakeholders, and is well positioned to draw more capital during a time where investors are interested in projects financed by joint public-private partnerships (PPPs). There is an opportunity here to shift away from away from short term and momentum-based strategies, and instead increase stakeholder value by investing in sustainably designed, long-term projects.

Real assets (2 percent of the value of everything)

Real assets consist of land, forests, gold and other tradable commodities, including fossil fuel projects that might sit outside of public companies or state-owned enterprises in private hands (Krosinsky 2016). The estimated total value of real assets is $10 trillion. The natural environment is directly tied to natural capital, and macroeconomic policies that appear to be loosely tied to land use actually pose a significant economic threat when prices, export incentives, and other economic mechanisms indirectly impact natural capital stock (Weingartner 2008). As the global population grows, real assets including land, forests, and water become increasingly valuable, and preserving healthy ecosystems directly improves air quality, water quality, and species diversity. Combining real assets and infrastructure can help finance projects that will continue to increase efficiency in the transition to a low carbon economy (Noble and Kay 2016). While financial mechanisms used to combine real assets and infrastructure are still developing, there is a strong business case for financing sustainable real asset projects. One way investors can become involved is through conservation finance.

Conservation finance is the bundling of real assets, such as tropical forests, with cash flows, such as sustainable timber, agriculture, and ecotourism, for risk mitigation, environmental and social impact, and market-rate returns (McKinsey Center for Business and Environment and Credit Suisse A.G 2016). In 2015, $52 billion flowed into conservation finance, but the field is experiencing slow growth. Some barriers to developing conservation finance as an asset class include lack of scalability, lack of a repeatable process, substantial search and transaction costs to identify conservation projects, little commercial support for early stage ideas, and high levels of perceived risk. Conservation finance aims to be primarily executed in debt and equity products, but is still in early stages of development – meaning it is still risky – focused on incubating new high-potential ideas, and requires much capital support. To overcome these barriers, the field should focus on developing replicable projects to address perceived risk, which would help attract mainstream investors who are familiar with rigorous investment approaches.

Innovative solutions for the future

Closing the financing gap using existing asset classes

The field of sustainable finance is rapidly evolving, and these sustainable strategies are here to stay. Based on the findings of this chapter, there are four asset classes and investment mechanisms that stand out in catalyzing the closure of the infrastructure financing gap: climate-aligned bonds, municipal bonds, green building/sustainable design, and REITs. Climate-aligned bonds and municipal bonds represent a strong opportunity because mainstream investors are already familiar with these mechanisms, and with the development of scalable certification processes and clear sustainability standards, these instruments are well positioned for growth. Second, with property representing the second largest asset class, improvements in sustainable design and green building present a cost-savings opportunity for investors, as well as healthier living and working conditions for inhabitants. Finally, REITs allow investors who are less familiar with technical aspects of sustainable infrastructure projects, or those who are interested in adding long-term infrastructure themes to a portfolio, to invest in complex sustainable urban infrastructure projects through the capital markets. Mainstream investors are comfortable with REITs, which will increase the rate at which capital is committed, making this asset class poised for growth as well.

Systems finance: a new asset class

Investors have long been interested in the idea of bundling. From the advent of securitization in the 1970s to the creation of the first ETF in the 1990s, packaging securities is a recurring theme that allows investors to mitigate risk, diversify their portfolios, and increase returns. This can be tied directly to the concept of systems thinking that Donella Meadows writes about in her book, *Thinking in Systems*.

One of the challenges of the sustainable investing process is helping investors to understand the business case for sustainable investing. Investments that are sustainable – meaning they do not harm people or the planet – create value for stakeholders, improve the triple bottom line, inherently mitigate risk and perform better in the long run.

There has been talk in the investment community about the development of a new asset class that uses systems thinking as a foundation for considering financing mechanisms for sustainable projects. In 2016, Marian Chertow, Cary Krosinsky, and Paul Lussier of Yale's Science Communications with Impact Network (SCWIN) released a statement citing the development of a platform for the creation of cross-sectoral participation in climate change adaptation investment along systems finance lines. They are developing a new category of investing in climate solutions via co-location and co-development of projects, which will accelerate net benefits that would otherwise not be experienced with net-negative carbon emissions (Lussier and Krosinsky 2016). This idea has developed alongside the ideas focused on in this chapter, and helps investors realize greater excess returns by bundling the benefits of systems thinking in one financial product, and diminishing risk. This variety of systems finance is defined by combining new energy innovation and industrial ecology, with an emphasis on closed-loop systems – systems that reuse each part of a process, turning waste into revenue. There is another variety of systems finance that takes a top-down approach and focuses on developing systems in communities, particularly in high density, urban areas. One example of this is the SF Public Utilities Commission and its development of the Sewer System Improvement Project, which leverages green bonds to bundle projects.

Given the current policy climate, now more than ever it is important to clearly communicate the business case for sustainable investing to mainstream investors. While some portion of the investment industry focuses on innovations in the systems finance space, big firms and their executives should commit more resources to incorporating sustainable investing into their firm's overall investment strategy. It will serve firms well to understand the different sustainable investment styles as they relate to each asset class, as well as which instruments to use for particular types of projects. As firms and individuals realize the benefits of sustainable, long-term strategy, more resources will be committed to developing financial instruments that are tailored to investors' needs.

Perhaps this will lead to the development of a product suite that can be applied to a range of sustainable infrastructure projects in the transport, energy, and building sectors. Or perhaps the increased resources will spur innovation in financial engineering, which will speed up the rate of development of systems financing.

This chapter focused on the financial mechanisms used to mobilize existing capital, and more work should be done to determine where private capital lies, and the best ways to leverage these funds.

Mainstream investors would be prudent to become familiar with more nuanced sustainable investing strategies, or risk being left out of an energy transition. There is an enormous opportunity in infrastructure – the strategies and mechanisms outlined above would be a good place to start the implementation process.

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10

CARBON MARKET SOLUTIONS

Jeff Schwartz

Introduction

From an economics perspective the problem that carbon emissions pose is one of negative externalities. The classic example is generally an industrial factory polluting the air. There is a clear cost to society by not having clean air; this could be increased rates of asthma, developmental issues in children, or simply aesthetics. Unfortunately, the market does not price that cost into the price of the good, and the cost of unclean air is borne by society, not the firm or consumers. This creates a negative externality on the supply and demand curve. Essentially the factory that is polluting has no incentive to not pollute since it is able to currently produce at a profit. By introducing a mechanism into this case, the specific cost of polluting moves from society bearing the cost to an explicit cost the factory must bear. This mechanism could potentially incentivize the firm to undertake capital projects that could reduce pollution if it makes economic sense. For example, if the firm had to pay $100 in fines for polluting but could undertake a project to avoid these fines for $75 the choice would be clear.

This classic example can be applied to carbon emissions as well, where various mechanisms for reducing the externality could be applied. Figure 10.1 shows this relationship clearly. Without a mechanism to reduce carbon emissions, the shaded area becomes the cost of these emissions borne by the public as a whole. By introducing a mechanism to address the negative externality, in this case a carbon tax as displayed by Figure 10.1, the shaded area becomes smaller as the cost is moved from society to the emitter. Economics gives us a clear understanding of how to tackle this problem. Now the challenge is how to effectively and efficiently put a system in place to switch the burden from society to the industries that cause the most carbon pollution.

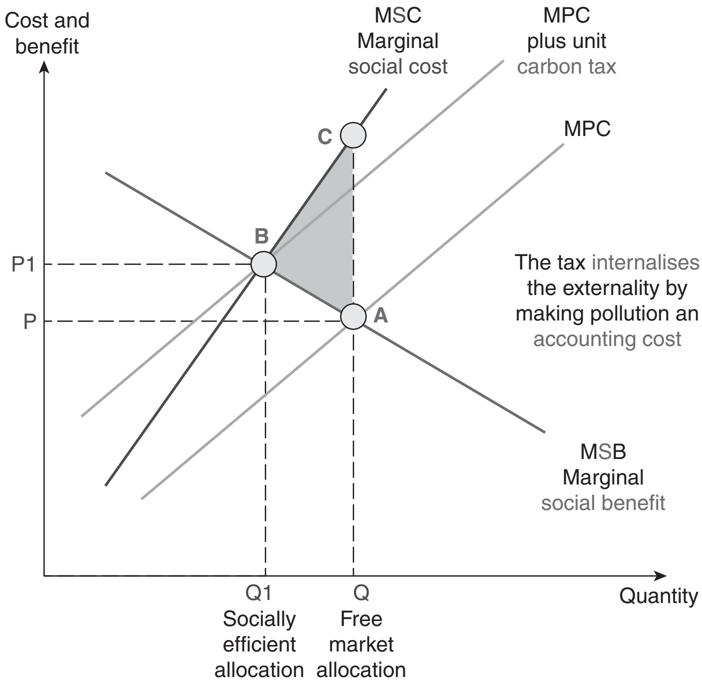

FIGURE 10.1 Introducing a mechanism to reduce carbon emissions
Source: Economics Online.

A key component of making any mechanism revolving around CO_2 emissions work is the cost applied to firms for their carbon emissions. This can, and has, taken many different forms. These included a carbon tax, formal cap and trade systems, and voluntary carbon exchanges. Overall these systems are a good first step but the lack of uniform enforcement creates a "free rider" problem witnessed in many other situations where taxes and regulations are viewed as limiting production. How can we move forward and address the needs in this market and potentially create a systematic shift that can limit carbon emissions? The following will investigate a few of the mechanisms mentioned above, and look at what has worked and what has failed. Finally, solutions to the existing problems will be proposed using a framework grounded in financial and economic theory.

Cap and trade

Cap and trade is widely accepted as potentially one of the most effective methods for reducing emissions into the environment. The scheme is simple enough in theory but it becomes difficult when you start to factor in practical issues such as reach and enforcement. The system is built to put a cap on emissions that a power plant, company, or individual creates. The trade portion then becomes the mechanism by which individuals or firms can monetize their efforts to reduce emissions. A firm that is below the cap can sell credits to a firm that has breached its cap. In the simplest economic terms, the trade is the function by which incentives are created at both ends of the spectrum. A heavy polluter will have to pay to continue operating status quo, while an efficient low emission firm can benefit greatly by the increased revenue from selling credits. The cap and trade program in of itself can be useful in reducing emissions as total allowances within the program can be reduced over time.

Cap and trade is simple enough to understand, but the problem comes in when trying to implement the system, as rule-making becomes complex and burdensome. One question to ponder is who and what do you specifically cap? Power generation could potentially be the first industry to look at in terms of how to cap emissions, as firms have a choice in how their power is generated. But how should the cap be applied to firms? It would make sense to apply the cap based on megawatt hour generated, but would this encourage diversified companies with multiple generation capabilities to switch from coal to wind or solar? Would the program incentivize firms enough to undertake costly changes?

These are a few reasons why cap and trade systems are notoriously hard to implement. Based on the questions above one needs to walk through a simple example of what a cap and trade scheme may look like. The first step in the process is to determine which industries and emitters will be targeted by regulation. For this example, let us assume that we only look to electric utilities to regulate. The second step is then to determine a cap. This may not be as easy as you think. In 2005 European Union members independently created caps and distributed them, but the initial cap in aggregate was too large so there was no meaningful reduction in emissions (*Los Angeles Times* 2007). A lot had to do with the global recession in 2008 where production and demand dropped off significantly. So what level do you set, and what kind of enforcement do you build into the system?

I have detailed out a stylized example to help get through some of the complexities of a cap and trade system. Let's assume that we only have four utilities in the industry of focus for cap and trade: All Coal, Hybrid A, Hybrid B, and All Renewable. These four firms' annual emissions and generation mix are detailed below. In Table 10.1 we show what the generation and emissions breakout looks like. For this example, let us assume that for every MW of generation, coal produces 2 lb of CO_2, natural gas produces 1 lb, and the others do not produce any

TABLE 10.1

Firm	*Generation*	*Coal*	*Gas*	*Hydro*	*Wind*	*Solar*	*Emissions*
All coal	1,000 MW	1,000	–	–	–	–	2,000
Hybrid A	1,000 MW	600	200	–	100	100	1,400
Hybrid B	1,000 MW	150	500	200	100	50	800
All renewable	1,000 MW	–	–	300	500	200	–

emissions. As can be seen, the total annual emissions in this industry amounts to 4,200 pounds of CO_2. So how do you begin to break out what the cap generally should be? Well, if the goal is, as it should be, to reduce emissions, then the total cap should be lower than the annual emissions – but how much lower? And can you get there effectively? Problems would arise as All Coal would lobby against any significant reductions. They would most likely fight for a per firm cap rather than a total cap. For now, let's assume that the first step sets standards for 4,000 pounds total annual emissions within the cap and trade system. This is a roughly a 5 percent reduction, but how do you allocate these credits? There are a couple of examples, but all have different outcomes.

One would view that allocating out 1,000 pounds of CO_2 annually to each firm would be the fairest solution. Hypothetically we would see the All Coal firm paying to buy credits and All Renewable selling credits. However, looking at the motivations of each firm is important. First, with a cap of 1,000 pounds per year Hybrid B and All Renewable meet their standards so no changes would take place. Hybrid A could change their allocations to 200 coal, and 600 gas with no changes to wind and solar to make the first cut. This would be an expensive proposition as they would have to spend funds on changing the allocations pretty significantly from coal to gas. This is where the price of non-compliance for breaching the limit, or the price of the carbon credit becomes significant. If the price is so exorbitant that it makes economic sense to undertake a large-scale project to change the generation distribution, then there is incentive for Hybrid A to change. Unfortunately, this high cost is also balanced by the cost of just shutting down operations. Hybrid A can meet the 1,000 cap by dropping coal generation from 600 to 400. But this assumes that the economics of Hybrid A is such that it can afford to drop the total generation to 800 MW annually. All of the sudden the market has less supply and either prices will move up or others would increase generation to meet the demand. If we assume that All Coal has the resources to meet the extra demand there would be no change in net emissions between the two firms. In this case less supply and higher prices essentially shifted the negative externalities to the consumer, and society is still bearing the cost of the pollution.

Continuing with the example, under the cap and trade system All Coal would have an option to buy credits, significantly reduce generation, or completely shut down operations. Let's assume that All Coal chooses to not drop generation, and it buys all the credits from All Renewable to meet its cap. Another option would be to drop generation and buy less credits; the choice is entirely dependent on the market and the cost of credits. For the market as a whole let's assume that Hybrid A simply drops coal generation to 400 and All Coal buys the credits from All Renewable with no change. Table 10.2 shows what the market looks like after our experiment. Emissions have been cut to 4,000 lbs of CO_2 annually, but generation has dropped to 3,800.

Now, let's assume that the market price, due to lower generation spikes, and exceeds the fines for breaching the cap. In this case All Coal may be the best suited

TABLE 10.2

Firm	*Generation*	*Coal*	*Gas*	*Hydro*	*Wind*	*Solar*	*Emissions*
All coal	1,000 MW	1,000	–	–	–	–	2,000
Hybrid A	800 MW	400	200	–	100	100	1,000
Hybrid B	1,000 MW	150	500	200	100	50	800
All renewable	1,000 MW	–	–	300	500	200	–

to supply the extra power. It now takes up the additional 200 in needed capacity to bring its generation totals up to 1,200. Now with that change, the total emissions of the market returns to 4,200. Essentially the entire purpose of the cap and trade system has broken down and emissions have remained stable with no reduction. What makes this equation work is the ability to generate energy from renewables at a cheaper cost than coal and natural gas. Based on a report published in April 2017 by the US Energy Information Administration, the "Levelized Cost of Electricity" (LCOE) has made the proposition for firms to move from coal to renewables more appealing, as any type of new coal production with carbon sequestration is almost twice as expensive as solar (PV) with current tax credits (US Energy Information Administration 2017).

Looking at the example above you can clearly see where a lot of problems come into play. First, who determines the size of the cap? How do the credits apply to the firms in the industry with the cap? Ultimately, how do you price out a system where all participants can agree to the price of a credit? In the example above, if there is free trade and the price of the credit is allowed to float it would ultimately end up near or close to the cost of the penalty for breaching the emission cap. Looking at just the trade in credits between All Renewable and All Coal we can see this in action. Let's assume that the penalty for breaching the cap is $100 per pound, but the regulators supply the credits to an auction market. All Coal would buy any credit priced under $100. If it is the only bidder in an auction market it could get the credits as cheaply as possible, say $50 a pound. If, however, the credits were supplied equally among the firms, what incentive would All Renewable have to sell the credits to All Coal? The only incentive is to actually sell the credits and monetize this regulation, so they would be inclined to sell to All Coal for under $100, but how much under this mark? If the market is big enough with a limited supply then the price should in theory reach $100.

So, with this, any regulation of cap and trade would be creating winners and losers. The regulation in essence becomes a subsidy for the renewable firms at the expense of the heavy emitters. In our example, Hybrid A, while producing renewables, is the only firm that has to change how it operates; it could potentially buy 200 credits from Hybrid B and pay the fines for emissions over the cap. Again, with this no real change has taken place. All Coal is essentially overly burdened with costs and it would know this going into the legislation. It would be the most incentivized to hire lobbyists and spend money to direct the policy in its favor or to block it completely. Given the complexity of any cap and trade regulation there would be plenty of room to avoid or create loopholes in the regulation. Additionally, if the renewable sector were to be subsidized significantly then it could lose the incentive to innovate and keep pushing the cost of renewables down. So, in effect a cap and trade program has stalled the market by punishing the emitters and rewarding those who do not, while removing incentives to innovate in the renewable sector.

One of the last major issues with a cap and trade system is the ability of the regulated industry to change location or regulated jurisdiction. If, for example, steel manufacturers were targeted for heavy caps on emissions in the US, but no such regulation existed in Mexico, the likely scenario would be that the steel manufactures would simply relocate rather than deal with onerous regulations. Time and time again we see this happening when industries relocate due to higher taxes, regulations, and overall feeling about the direction a county is heading with regard to regulation. So even with a highly complex, fair, and properly functioning cap and trade system it still may not be effective since the target companies and industries can relocate to a less regulated jurisdiction. This is where the problem becomes even more difficult as we now need to take into consideration the need for cross-border agreements to mitigate or eliminate this issue. This is just another added layer of complexity for regulators as there is an international component at work and that would likely mean extensive renegotiations of current trade deals.

There are some bright spots with cap and trade, as can be seen in California. It implemented one of the country's only cap and trade programs which requires a mix of industries to purchase permits to release CO_2 into the atmosphere. Recent reports have shown a near 5 percent reduction in carbon emissions in 2016 (Megerian 2017). There are, however, some concerns now that the supply of permits is becoming too large and may therefore curb future efforts to reduce emissions (Megerian 2017).

Carbon tax

With all of the problems that cap and trade presents, it is still seen as a viable solution. This is most likely because firms are agreeable to the method, as they have the ability to move around the system and in some cases avoid the regulation all together. Although this is a cynical view, it is still an important consideration when comparing methods of pricing carbon, especially when comparing the cap and trade system to a straight carbon tax. A carbon tax is a much simpler system, not only in its design but also in the implementation and enforcement. Simply, the carbon tax system can be implemented by placing a tax on how much CO_2 is emitted by certain industries and individuals.

The economics of this transaction is much simpler than any of the examples of cap and trade. With a simple Net Present Value analysis (NPV) we can predict whether a firm will make a choice to pursue renewables. For example, if the tax on a ton of CO_2 emitted costs \$100 and the firm expects to pay the tax for the next 10 years, with a discount rate of 5 percent the present value of that cost would be \$772. If it only cost \$500 today to increase energy efficiency or switch to renewable energy sources then firms would be inclined to move to renewables, as the NPV of the project would save roughly \$272. This is a very simple example, but it shows how easy a set and knowable system in place, like a carbon tax, can make business decisions easier.

As with the cap and trade system, the carbon tax is economically efficient in its reallocation of costs from society to the firm. This again begs the question, what exactly should the price of carbon be? We will get into that later, but it is clear that a straight carbon tax can be more effective than a complicated cap and trade strategy. Unfortunately, the tax is subject to the same problems that cap and trade has with regard to lobbying efforts to block legislation or reduce the effect of the regulation. Additionally, industries would still have the choice of moving to more favorable jurisdictions; however, since a carbon tax would be easier to implement it has the potential for easing some of the cross-border issues.

There are some challenges with a carbon tax system, as it may not properly incentivize firms to act in the best interest of society. From our example earlier, if the economics are right the All Coal firm would simply keep emitting current levels and pay the tax. With this, the amount of emission reductions for any point in time becomes uncertain. This is not the case with cap and trade, and is one of the main benefits of the program in that specific levels can be set and goals can be increased over time to further reductions at later dates. If we need to limit reductions to 100 tons of CO_2 emissions per year then that's the cap. There is no such certainty with a carbon tax system. But this ignores the basic truth of economic incentives. If the tax is high enough firms have a simple choice: change or be pushed out of the market. Carbon tax over the long run could be as much as five times as effective in reducing emissions over a cap and trade system (Congressional Budget Office 2008). Additionally, a carbon tax is much easier for a government to administer. There has been evidence that tax collection is easier and there is less tax evasion with a carbon tax over regular VAT or income taxes (Fay and Hallegatte 2015). Compare this to the regulation of a cap and trade market, measurement and enforcement of the caps, and overall problems with implementation in a cap and trade system and you can start to see the real benefit of the ease of administration for a carbon tax system.

While a carbon tax system may be the easiest to implement, there is still the hurdle of getting legislation passed to implement the system. In November 2016 voters in Washington State had a chance to implement the first such system in the United States. It failed, with only 42 percent of the statewide vote. A major reason for this failure, as some have said, was disagreement on how the funds should be used, as the bill was written to be revenue-neutral (Harvey 2017). This meant that revenue from the carbon tax would have offset other state revenue, mainly by lowering sales tax. Deciding the price of carbon for a tax is only half the battle, because once that is in place there has to be a plan for what to do with the proceeds of such a tax.

Price of carbon

CO_2 has proven to be difficult to price, and there is wide variation in how the measure is arrived at. How can you take into account the harm already done by previous emitters? How can you reasonably expect a developing economy to be willing to undertake reduction measures when the largest economies in the world are responsible for the current levels of CO_2 in the atmosphere? Are all measurement techniques accurate? What price makes both political and economic sense? These questions lead to extreme price volatility in the market, and high uncertainty. With high uncertainty it becomes difficult for corporate managers to effectively price out capital expenditures for emissions reductions, and extremely difficult for regulators or legislators to pin down a single price for a ton of CO_2.

Current estimates seem to be all over the board. For example, within the cap and trade market in California, the price of carbon offsets is $15.40 per ton as of November of 2017 (California Carbon Dashboard 2017). In 2015 in Mexico, the price of CO_2 was $1 per ton, where as in Sweden it was over $100 per ton (Fay and Hallegatte 2015). For individuals looking to offset their carbon impact, Carbonfund.org is selling offsets for $9.07 per ton (CarbonFund.org 2017). Such a wide disparity in data reduces the effectiveness of any system. Any meaningful global change has to involve a single price or single methodology for pricing carbon. This eliminates some of the issues discussed earlier with firms or entire industries relocating to countries with either lower taxes or less regulation. Also, a single price eliminates some of the future uncertainty in pricing and the volatility created by the normal business cycle.

So how do you go about finding the right price for carbon? You could take a simple approach and price it in absolute terms. It is widely understood that the goal of emission reductions is to reach a net zero global emission, where we have enough natural carbon sinks to absorb the carbon emitted. However, this will take some time to reach, and in order to keep the planet from breaching the 2°C warming limit this goal has to be reached by the end of the century (Fay and Hallegatte 2015). In 2014 the Intergovernmental Panel on Climate Change (IPCC) produced a carbon budget for the world. This budget essentially says that in order to stay under the 2°C mark, humans cannot burn more than 2,900 gigatons of carbon from the modern industrial age starting from around 1870. According to a calculator created by the *Guardian* we have already burned through roughly 2,137 gigatons of the budget and only have 763 gigatons left (Evershed 2017).With this information we can price carbon with some simplified math in a thought experiment. Table 10.3 shows the world's wealth per ton of carbon and, at each point of wealth lost, what the price of carbon should be. In this very simple and stylized example we assume that if the carbon budget is breached there will be some magnitude of wealth lost. This calculation is taking the estimated wealth of the world of $241 trillion (as of 2013) divided by the remaining carbon budget of 763 gigatons to get the dollar per ton of carbon price (Kharpal 2013). Assuming a 100 percent collapse in the wealth of the earth then a ton of carbon should be priced at

TABLE 10.3

Total wealth:	*241,000,000,000,000*	
Carbon budget:	763,000,000,000	
	Price per ton of CO_2	
	100% probability	*20% probability*
100% loss	\$316	\$63
50% loss	\$158	\$32
25% loss	\$79	\$16

\$316. This of course is an unrealistic assumption, but it proves a point. We know what is at stake, so why not use that to price out the very factors that are putting us at risk? Continuing with this example we can see that at 50 percent loss the price would be \$158 per ton and at 25 percent loss the cost would be \$79 per ton. We can get a more in-depth analysis with various statistical models, but we really have no population to observe, and this is to prove a point, not to get to a price everyone agrees with. But we can add in some probabilities to make the scenarios a little more believable. Given this we applied probabilities to the outcomes stated above. Table 10.3 also has the price of carbon based on the probability of the loss. Let's assume for ease of calculation that there is a 20 percent probability of these events occurring if the carbon budget is used up. At a 20 percent probability of a 50 percent loss of global wealth we reach a price of one ton of carbon at \$32. This seems more reasonable, and we can also take into account the price of carbon with the probability matrix we just created. The price in California of \$15.40 can be seen to be predicting a 20 percent probability of a 25 percent loss of global wealth. Again, this is a very simplified and stylized example, but you can see how complicated other models can become to price.

This example shows that we can spend unlimited amounts of time, energy, and resources to try and nail down a price for carbon. Additionally, figures are just that, figures. We have no real way to judge the economic impact of carbon emissions, or to truly understand the economic loss to society by judging the externality. If carbon traded on the open market like other commodities like oil we could have a better understanding of these costs. Even then market prices only take into account what information is public and known, and what can be reasonably assumed about the future. We are not at a point right now where anyone has a solid grasp on the damage, timing, or scale of global catastrophes created by climate change.

Solutions

Any solution to the problem of pricing carbon emissions can be as simple as we want. There is no need to overly complicate the issues to fit the needs of every individual player. There is a real need to focus on the externality problem and focus on those firms that are heavy emitters and those that are working towards solutions. If we can get the right mix of carbon taxes, incentive programs for energy efficiency, and international buy-in, the carbon tax solution could be a viable alternative to the cap and trade systems that most governments are looking to implement. Again, the issue of pricing comes into play, and what is considered to be “fair.” What I will lay out is a plan for the efficient allocation of resources, also known as cash, to the various parties involved. This multi-step process will look to incentivize, not punish the CO_2 emitters, and to reward innovation and effort to combat the buildup of carbon in the atmosphere.

The first step is to look at the price of carbon and what an effective tax scheme would look like. Let’s again undertake a thought experiment, and for this we will assume a price of $32 per ton of carbon based on our earlier calculations. According to estimates from the IEA, total annual CO_2 emissions in 2016 were around 32.1 gigatons (International Energy Agency 2017). With this, if every single ton of CO_2 were taxed governments would take in roughly $1.025 trillion worth of tax revenue. This assumes that every ton of carbon emitted per year can be accurately tracked and taxed. These are of course unrealistic assumptions.

To get a better understanding of how we can benefit from a carbon tax we can drill down specifically to the US and ask what types of revenue can be gained from a tax. In 2015 the US was the second largest CO_2 emitter next to China, with total emissions of 6.587 gigatons of CO_2, of which roughly 1.91 gigatons (based on 29 percent share of total) were emissions from electricity generation (Environmental Protection Agency 2017). Now let’s assume that the federal government implements a carbon tax solely for electrical generation at $32 a ton. That total revenue from the program would bring in just over $61 billion dollars. To put that in perspective, the total federal budget for 2017 was $3.65 trillion (Inside Gov 2017). While only a small percentage of the total budget, this figure is still larger than the total budgets for some agencies, so you can imagine what can be done with such an amount. Now again, this is based on our estimated cost of $32 per ton; if we use the lower threshold, like the figure from California of $15.40, the total revenue would only be around $29 billion. That’s a fairly wide disparity to overcome when looking to implement any policy. But as was seen with the failure of a carbon tax in Washington State, one of the important factors will be to determine how to spend this money.

Now for the good news. This tax is annual, and with that some of the effects can become exponential. For example, if some of these funds are used to plant a forest, then that forest will act as a carbon sink beyond the year it was planted, plus there would be only minor additional expenses beyond that initial outlay. And the next year more funds would be available for more projects.

As with any legislation around taxes there has to be some giveback through tax credits and incentives. But that is our goal after all, not to generate revenue but to reduce carbon emissions. By offering incentives to firms for sustainability projects they will be further enticed to make changes. If firms are faced with a heavy tax burden then it would make sense to lessen that burden through tax incentives to undertake new projects that would reduce their emissions. If tax incentives were in place to either offset the carbon tax or offset income taxes then it would make the choice very easy for the firms that need to change. Remember the NPV analysis we did earlier: if you incorporate in tax write-offs and incentives then that figure only grows and adds to the positive outcome of the project. In a sense you have created an internal carbon offset market where the fate of the firm is entirely in its own hands. If roughly 40 percent of the revenue generated from the carbon tax could be redistributed in the form of incentives, it would also encourage non-polluters to further invest in clean energy and sustainable practices to remain competitive with other firms in the industry. Think back to our stylized example: All Renewable would not be taxed, and would not benefit from any tax write-off, but it could potentially participate by taking some of the incentives. So this solution addresses everyone in the market, by not only taxing polluters but giving them a chance to change without irreparable harm.

Governments can go even further with this by increasing the funding for incentives through gas taxes, higher vehicle registration fees, and other consumer-based taxes. A lot of these ideas were incorporated into the Washington State carbon tax bill. These ideas not only create revenue for further sustainability projects, but they also help to incentivize downstream users. Take the example of a car manufacturer. It might be assumed that car makers are high on the list of polluters, but in reality the manufacturing process is not very carbon intensive. Most emissions come from the use of the cars after they have been sold. There could be a carbon tax levied upfront on new car purchases. This would incentivize consumers to factor in more fuel-efficient vehicles when making their choice or make hybrids more competitive. The EPA estimated that the average passenger car will emit 4.75 tons of CO_2 per year (Environmental Protection Agency 2016). If we assume an average life of 10 years for each car, then the tax would be anywhere from $700 to $1,400 depending on the price of carbon. When paying $20,000 or more on a new vehicle this would not be seen as a burdensome tax; furthermore, the tax can be based on overall fuel efficiency, which is mostly known to the consumer at the time of purchase.

An additional solution on top of these carbon taxes would be to create a robust voluntary carbon market. This has been one of the bright spots over the past decade, as this market has shown that a tradeoff system can work. Around 30 percent of the funds from carbon taxes should be earmarked for the projects typically undertaken by groups like carbonfund.org. These could include reforestation projects, and other work to ensure a growing capacity for carbon storage through natural systems. Some of this money could also be used for projects not directly linked to CO_2 but could help offset other greenhouse gasses. Such projects could include working on better ways to manage cattle ranches and the effect of methane from manure. In addition, most research and development grants are funded by government agencies; if 10 percent of these funds from taxes are earmarked for R&D we may find better ways to recapture carbon, or make renewables more efficient and less expensive.

The final key to the carbon tax initiative laid out above is to get buy-in from all the countries in the world. This would require them to accept the single price and have similar systems in place for taxing and incentivizing sustainability. This seemed to be an unlikely scenario until the Paris climate agreement was reached with 181 countries participating. The agreement in some sense requires larger nations to raise money for developing markets. The US, China, Russia, UK, and other developed nations should not hinder the growth of smaller nations in order to address a problem that the developed nations created. Money can be used for electrical infrastructure buildouts to ensure that renewables are being used. Again, the key here is to incentivize behaviors.

Conclusion

Overall, the market for carbon is complicated and there are multiple points where any meaningful change can be prevented by outside interests. However, the simpler the rule, the less chance there is for convoluted structures to be put in place that would make measurement and success criteria hard to judge. Clearly the carbon tax is the most effective and efficient way to reduce CO_2 emissions. But the question still remains as to what a good price for carbon should be, and how to tax it in a way that incentivizes firms to move from older technologies and fuels to newer, renewable options. As was seen in the voluntary carbon market, offsets can be as low as \$9 for a ton of CO_2. No one in the market has been acting as a financial intermediary for profit, and no firm is obligated to undertake these offsets. Yet this has been a successful program. A carbon tax can be a great extension on this type of work.

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11

INVESTING IN THE CONTEXT OF CHINA'S GREEN TRANSITION

Lillian Childress

Over the past two decades, the Chinese government has begun to champion policies targeted at growing the "green economy." A host of environmental policies, such as the Renewable Energy Law in 2005, the Energy Conservation Law in 2007, and the Circular Economy Promotion Law in 2008, all point to a growing focus on a national economy that sustains and protects the environment. A missing part of this strategy, however, has been the encouragement of impact investing, which still remains a relatively foreign term in China's economic discourse.

This chapter aims to examine the barriers to promoting impact investing in China, and offer insights into how impact investing can be incorporated into the already-present push to green and circularize China's economy. Impact investing is at a crossroads in modern day China: there is enough interest to generate a buzz around the new word, and a lack of high-visibility projects thus far makes the ground ripe for a well-run demonstration of the benefits of impact investing, but it is also at risk of being branded as simple "philanthropy," and being misunderstood before high-impact projects can take full shape. The challenge now is to demonstrate to relevant Chinese stakeholders that impact investment is a crucial component in the transition to a green economy.

A green policy history

By now, the skies of many Chinese cities have been clouded with the dull grey of air pollution, and the rivers fouled with streams of industrial pollutants. Rather unsurprisingly, there is a strong impetus to make these skies blue and these rivers clear again. Chinese government officials recognize that in order to build a strong foundation for future economic growth, the environment and human health must stay intact. Although it is widely known that enforcement of environmental law in China differs vastly depending on the region, with corrupt officials not hesitant to make an extra buck off of letting environmental harms slide by, it is clear that the state as a whole has consciously taken vast policy strides towards prioritizing environmental protection.

China's turn towards codifying environmental protection came almost directly after Deng Xiaoping ushered in the reform and opening up process: the Environmental Protection Law, one of China's most foundational environmental laws, was enacted in 1979 on a trial basis. It was not until 1989, however, that the law was amended and reenacted sans "trial" designation. As the effects of China's rapid industrial growth became painfully visible in the skies and rivers of the country throughout the next two decades, a wave of new environmental legislation followed. This includes the Cleaner Production Promotion Law of 2002, which was aimed at reducing resource intensity and pollution from industrial production, the Solid Waste Prevention Law of 2004, which attempted to manage and reduce solid waste, and the Renewable Energy Law of 2005, which introduced a national feed-in tariff system, cost-sharing mechanisms, and funding for renewable energy targets. Perhaps the most forward-thinking piece of environmental legislation that has come out of China is the Circular Economy Promotion Law of 2008, which demanded that regional governments incorporate resource reuse, energy saving, and waste reduction in their local development strategies. As part of the law, the National Bureau of Statistics even created a circular economy development index, which is a valuable tool for measuring the effectiveness of the law.

For all its innovation, however, one conspicuous absence from the Circular Economy Promotion Law, and the subsequent Circular Economy Development Strategies Action Plan released in 2013, was explicit mention of social enterprises and impact investing. The concept of balancing investment returns with social or environmental goals is unheard of by most in China. But this is not for lack of investment opportunities. A 2012 joint report by the China Impact Fund (CIF) and New Ventures China (NVC) estimated that the market size of small and medium-sized enterprises that could be suitable for impact investment is 25,000, which accounts for just environmental companies alone (China Impact Fund 2012). China's earliest impact investors have come mainly from philanthropy – but since 2010, the continuous establishment of private equity (PE) and venture capital (VC) funds focused on social enterprise has begun to shift impact investing from philanthropy towards commercial investment (UBS 2013). And now the question is how to translate this private sector movement into a public policy shift.

The major roadblocks

The status of impact investing in China is similar to that of impact investing in the United States 10 years ago. The term is widely unknown, and are there are few public or private institutions that promote it. Its reception is further complicated by the unique political, economic, and social structures that shape investments in China. Most Chinese investors, government officials, and other stakeholders are not yet familiar with the benefits of impact investing. A collection of successful case studies or high-visibility investments in social enterprises has yet to arise, leaving potential impact investors unable to see the benefits of impact investing in their own country. China is still far from the creation of an impact investment asset class, or even a robust set of indicators for Chinese impact investments. Furthermore, there is a general lack of knowledge among social entrepreneurs as to what constitutes a social enterprise, and the unique funding opportunities that may be available to it. The relatively unknown status of impact investing in China is a source of great potential for growth, but also source of risk that it will be misunderstood or written off. Tao Zhang, founder and managing director of Dao Ventures, a group of companies and affiliates that promotes and carries out advisory services, accelerators, capacity building, and impact investment, notes that

> Over-hype and lack of proven success cases at this stage could be very detrimental to the long-term development of impact investing on the ground because they could easily lead to a perception of "all talk and no action" on the part of those involved, especially given that the Chinese culture and by extension the mainstream business community tends to encourage less talk and more action.

For social entrepreneurs, the lack of capital from impact investors is deeply felt. A 2012 study of social entrepreneurs in Beijing, Shanghai, and other major Chinese cities conducted by the Foundation for Youth Social Entrepreneurship (FYSE) found that 86 percent of the social entrepreneurs who participated cited accessing mezzanine funding as one of their top problems in getting the venture off the ground (Lane et al. 2012). Indeed, for SMEs in China – and not just the social enterprises – capital from VCs and PE is not abundant. The VC and PE sectors are still not as developed as in the US or Europe, leaving many companies forced to fundraise through other avenues. The same FYSE study found that 77 percent of social entrepreneurs relied on their family and friends to raise seed funding for their enterprise. But while funding opportunities are scarce, the potential is large. The CIF/NVC report showed that there around 10 million industrial SMEs in China, but only around 1,000 invested cases, indicating an extremely limited presence of VC in the country. Moreover, Chinese VCs have even less experience dealing with impact-focused SMEs, putting these enterprises even more at a disadvantage. In addition, many government policies providing subsidies for renewable energy or creating environmental benefits only begin at a certain threshold, giving large enterprises an advantage (China Impact Fund 2012).

The lack of clear legal structure for impact investments – especially for investments in impact-focused SMEs – also is also a hindrance to their growth as an asset class. Social enterprises themselves also do not yet have a clear legal delineation. This absence of a defined set of laws detracts investors, who need assurance that their assets will be protected and that they will have legal recourse if the need arises (Kuo and Tang 2016). In addition, there are considerable barriers to entry for foreign impact investors. One problem that foreign investors have run into is capital conversion into the local currency upon entry and exit of the investment. Some Chinese SMEs have set up foreign subsidiaries to generate increased access to foreign capital, but this can be a costly process. In addition, many social enterprises are unaware of the common metrics that impact investors look for, so they have not collected data on impact or do not have it readily available (Lane 2012).

As it stands, many social enterprises lack the tools and support networks needed beyond funding that help them grow as an organization. Bin Li, founder of US-China Social Innovation Consulting, says that the biggest barrier to impact investing in China is developing large investment pipelines for applying the impact investing model. Li cites the multiple points of assistance and capacity building where social enterprises are lacking, such as human resources, strategic planning, operation process, and marketing, "while incubation, acceleration, and mentorship are insufficient in order to be investment ready," she says. Not only are these outside organizations important in capacity building, but they can also be important for helping social enterprises define themselves as such. In a country where the terms "social enterprise" and "impact investing" are still relatively unknown, many social entrepreneurs themselves do not know the support that may be available to them.

With a one-party government like China's, it can be difficult for outside lobbyists – especially foreign ones – to influence policy change. To create a friendlier legal environment for impact investing in China, it seems there needs to be more pressure from the inside. This means in-country VC firms and impact funds that champion impact investment as a vehicle for economic growth as well as for social or environmental benefit.

Integrating impact with policy

Due to environmental pressures and a newfound impetus to sustain long-term economic growth, China's environmental policy has become one of the most forward-thinking in the world. The 2008 Circular Economy Promotion Law is a prime example of the emphasis that China has already put on the transition to an economy that ingrains social and environmental protection and sustainability. What has been left behind is the recognition of what the private sector – particularly SMEs – can contribute to this green transition.

The renewable energy industry is one place where SMEs have been left behind by energy policy. In the past decade there has been a heavy push in China to invest in renewable energy. China now has the most installed solar capacity in the world, leading the rest of the world by a long way. In the first half of 2017 alone, China installed 24.4 GW of solar capacity (Clover 2017). By contrast, the total solar capacity ever installed in the United States up to 2017 was a little over 47 GW (Perea 2017). Many of these solar installations have been large-scale projects realized through top-down directives. There is considerable potential for SMEs to become involved in smaller-scale solar panel installations, for example in homes, restaurants, and shopping centers.

China's push towards installing solar power is just one example of where greater government support should be extended to SMEs, who are valuable players in the green transition, and can flourish under a regime that gives them ready access to VC and PE funds, as well as allowing them to enjoy the same subsidies and preferential treatment as larger enterprises do. In addition to preferential tariffs for renewable energy and increasingly stringent emissions targets, there is a need for the green policy toolkit to incorporate impact-focused measures such as the creation of "social impact bonds," more government-sponsored capital for environmental entrepreneurs, and preferred regulatory status for social enterprises.

On the private sector side, a robust set of indicators needs to be developed in order to help define impact investing in China, for there is no standardized industry-wide evaluation model for assessing social impact. This may include the creation of a formal accreditation body, like the B Corp in the United States, or the community interest company in the United Kingdom. It may also be funds themselves that pioneer these standards of evaluation. For example, the Lanshan Fund, an impact-oriented PE foundation, measures social impact through a quantitative quality of life index, that takes into account how an enterprise impacts material well-being, physical well-being, freedom and choice, social well-being, and security (Lanshan Group). In addition, third-party impact evaluations are important for standardization and consensus-building among actors. "From all the impact investing-themed conferences or forums that I have attended in China so far, I have yet to see a consensus regarding how impact investing should be defined and what criteria to use to evaluate the impact in the China context," Zhang says. "Apparently, without some sort of consensus, there is hardly an industry." This could be a role for an outside corporation, or in China's case, where many business activities are still controlled by the state, a governmental body.

One policy that integrates economic and environmental goals particularly well is the 2008 Circular Economy Promotion Law. The law was introduced as a means to set China's industrial growth and heavy resource use on a path towards long-term environmental sustainability (Mathews and Tan 2016). It focuses heavily on how existing enterprises must find new ways to save energy, share byproducts, and cut down on waste. However, SMEs rarely have high-volume waste streams. Furthermore, the law makes little mention of the role that innovative, environmentally focused SMEs play in aiding the transition to a circular economy. But even at a first-glance interpretation, the law makes itself favorable to investments in the type of enterprises that contribute to a circular economy. For example, Article 8 of the law states that

> The people's governments at or above the county level shall establish a responsibility system of targets for developing the circular economy and adopt measures such as planning, finance, investment, and government procurement to promote the development of the circular economy.
>
> *(National People's Congress 2008)*

Measures like this one, while perhaps not written with impact investment specifically in mind, are the groundwork for further integration of impact investment into China's circular economy vision, and therefore set the groundwork for more recognition and favorable policy treatment.

Similarly, more recognition of what impact investing is and the benefits it can bring will help accelerate the many policy shifts needed to promote a compatible environment for impact investments in China, both domestic and foreign. More high-profile impact investment funds and individual champions in the field will bring greater recognition to impact investing.

Bridging the gap

There is a great opportunity right now to show the benefits of impact investing and expand its influence in China. At such a crucial tipping point, it is imperative that impact investing be introduced in the right way, so that it is not written off as philanthropy or put in the same category as NGO activities. At the same time, China has already taken great strides toward promoting environmentally-conscious economic activities, at least on a policy level. An effective way to introduce impact investing is thus to promote it as the natural extension of green economic policy.

In order to convince the inner sanctum of government officials and other change-makers that impact investing is a worthwhile investment, so to speak, there needs to be a concerted effort from relevant stakeholders who have access to those in power. Indeed, there is also growing interest within the Chinese government to encourage entrepreneurship and innovation – those concerned with impact investing should ride on the crest of this wave and increase the pressure to adopt policies that promote growth of and investment in SMEs. Promotion of policies that encourage the growth of SMEs – particularly social enterprises – will directly encourage the growth of impact investing. Otherwise, impact investors may need to lead the charge to promote of this new asset class, and wait for the government to take notice.

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SUSTAINABLE PRIVATE EQUITY AND VENTURE CAPITAL

Matt Dittrich

The climate of ESG investing continues to evolve across all asset classes. Specifically, in private equity and venture capital, there are both *more* and *different* dollars being invested in ESG-aligned projects and businesses. Is this increase in dollars and differentiation being driven primarily due to emerging opportunities in ESG, or conversely, is it more attributable to the common perception that there is "too much capital chasing too few deals"? In other words, is the trend more fundamentally about ESG opportunity or, rather, lack of opportunity in traditional private equity and venture capital? The latter scenario suggests short-term, "softer" increases in ESG private investment; the former suggests long-term, "sustainable" increases. The distinction is of consequence. Capital ebbs and flows with the business cycle and hype around a given asset class. Yet, fundamentally attractive investments will get funded, regardless, over the long term.

This chapter has an agenda: to accelerate a long-term secular trend of increased ESG-aligned private equity and venture capital investment. With that preface, below, let's seek a clearer view of the ESG private equity and venture capital ecosystem, with recommendations for a way forward.

Playing field and state of play

Many a general partner (GP) has speculated, "Is there is too much capital chasing too few deals?" Technically, yes. Since 2012, the total amount of uninvested private equity and venture capital dollars ("dry powder") globally has set a record each year. In 2017, the figure climbed to $1.7 trillion. The risk appetite among limited partners (LPs) to achieve higher returns has perhaps never been more insatiable – given these times of sustained low interest rates, extreme public market efficiency and increased willingness to accept longer-term lock up periods. While dollar value of dry powder has skyrocketed, dollar value of exits has decreased each year since

2014. In 2017, this figure may be below \$300 billion, ~40 percent lower than the 2014 peak.[1] Moreover, new deals, or deployment of dry powder, has been flat from 2013 to 2016 at ~\$250 billion (MacArthur 2017). In 2017, deployment was down 12 percent vs. 2016, propelling average deal multiples to record highs (Pitchbook n.d. a).

Looking at venture capital as a subset within private equity, we see similar and perhaps even more dramatic trends. Venture capital dry powder is indeed at record highs, in excess of \$120 billion (Dang 2017), suggesting a great boost in popularity of the asset class among LPs. And venture capital exits have been few and far between, with a relatively low number of acquisitions as well as a decreasing number of venture-backed IPOs – in terms of number and dollar value – since 2014 (Gunderson Dettmer 2017). Shown another way, the number of private, venture-backed firms valued at more than \$1 billion ("unicorns") has broken records each year since the Global Financial Crisis and now stands at an incredible 214 firms, cumulatively valued at ~\$750 billion (CB Insights 2017).

As private equity and venture capital dollars have increased, relative to new investments and exits, we have also witnessed unprecedented permutations of GP theses (Pitchbook n.d. b). Today, there are more private equity and venture capital firms than ever: ~3,800, up more than 100 percent in the past 15 years, seemingly unabated by the Global Financial Crisis (Pitchbook n.d. c). As the community continues to boom, the endeavor to differentiate any one fund seems to be nearly as important as actually sourcing and making deals. For example, assertions about firm culture – "founder friendliness," "management experience," "team orientation," etc. – are prominent on virtually all funds' websites. Communication from firms about their theses is also salient – either in the direct form of mission statements or in the indirect form of white papers and press releases discussing industry trends and insights.

Broadly speaking, ESG can be thought of as one such thesis category, or niche, within the private equity and venture capital landscape. Over the last 15 years, as we have witnessed this boom in the number of funds and amount of capital raised, ESG-geared private equity and venture capital can be seen as having had a similarly incredible upsurge. In the early 2000s, there were only a handful of funds that could reasonably be classified as ESG-focused. Today, there are easily hundreds of funds – in all shapes and sizes (Rheingold n.d.). Many of these firms have found the ESG space as a way to differentiate as they fundraise as well as find and attract the best potential investments (ideally at good deal multiples). While the private ESG playing field is wide and fractured, players can perhaps be segmented into the following four categories: (1) private equity firms investing exclusively in ESG, (2) venture capital firms investing exclusively in ESG, (3) private equity firms investing in and outside ESG, and (4) venture capital firms investing in and outside ESG. In the following section I address prominent features and merits of these models of ESG investing, highlighting eight funds as case studies.

Players: private equity and venture capital in ESG

Private equity firms investing exclusively in ESG

In the world of ESG-exclusive private equity investing, lines arguably blur between classic private equity models and growth private equity strategies. However, private equity firms investing exclusively in ESG often focus on some combination of distressed companies that can benefit from ESG improvement and growing markets with inherent ESG opportunities. Investments are usually large minority, if not majority, stakes and ownership is shaped by relatively hands-on portfolio company management.

Blue Wolf Capital Partners serves as an excellent example. Blue Wolf, founded by Yale School of Management alumnus Adam Blumenthal, usually takes majority positions in middle-market private companies and then engages in turnarounds that deliver substantial ESG benefits (Blue Wolf Capital n.d.). For example, as examined in *Evolutions in Sustainable Investing*, Blue Wolf bought out a highly wasteful, labor-abusive sawmill and worked with management to dramatically boost operational efficiency, improve labor relations and promote stewardship among employees and across the community (Krosinsky 2012). Since its founding in 2005, Blue Wolf has undertaken similar turnarounds with much-heralded ESG (and financial) benefit, such as the very public transformation of Pictou Mill in Nova Scotia. As I previously articulated, "Blue Wolf's philosophy of 'rolling-up-sleeves' and turning around firms can deliver robust, tangible positive change – results, such as waste reduction and ethical labor relations, that regular people can benefit from and see every day" (Dittrich 2017).

The other prominent players in the ESG-exclusive private equity space might be classified as larger "growth-stage" investors who take significant, but minority stakes in established, growing companies. One strong example is LeapFrog Investments. Founded in 2007 by Andrew Kuper, LeapFrog has enjoyed high-profile endorsements from public figures, such as President Bill Clinton, and has raised over $1 billion (Smale n.d.). Their investment thesis is focused on established, fast-growing, "purpose-driven" companies that deliver ESG benefits across healthcare and financial services in emerging markets (Leapfrog Investments n.d. a). A powerful example is LeapFrog's investment in Goodlife Pharmacy. Goodlife has led the effort to provide delivery of pharmaceuticals and pharmacy services across East Africa; based in Kenya with 19 locations across the broader region, Goodlife now reaches ~1.2 million East Africans who previously struggled to access prescribed medicines in an efficient, safe, reliable way (Leapfrog Investments n.d. b). This is private equity growing an objectively-profound public good.

Venture capital firms investing exclusively in ESG

Venture capital firms investing exclusively in ESG often focus on higher-growth markets, differentiated companies with a fundamental ESG mission, significant minority investment stakes and partnership roles with portfolio companies (rather than absolute control over management). Venture capital – given its forward-looking, innovation-focused model – is perhaps a well-suited vehicle for ESG investing. In fact, many ESG-exclusive venture capital funds have been launched since the turn of the century. Much attention has been given to the cleantech space, which witnessed a fantastic fivefold increase in venture capital funding from 2004 to 2009, and then an equally shocking bubble burst, funding falling by ~60 percent from 2011 to 2014 (Gaddy et al. 2017). However, this sector-specific drama obfuscates the fact that many venture capital firms focused exclusively on ESG, but perhaps with more industry breadth, have thrived over the last 15 years.

DBL Partners is a superb example of one such firm. Originally founded as "Double Bottom Line" in 2003 by Yale School of Management alumna Nancy Pfund, DBL looks for startups that "can deliver top-tier venture capital returns and enable social, environmental and economic benefits." They are a classic "value-first" ESG-considerate investor that places a high premium on the ESG impact that startups can potentially effect (DBL Partners n.d.). With over $600 million raised, they've made pre-IPO investments in some of the most-promising startups in Silicon Valley, including Tesla, Solar City and SpaceX. Suffice it to say, DBL has enjoyed industry-leading returns for LPs – and industry-leading ESG value for society. Nancy Pfund often visits Yale University and, anecdotally, has publicly hinted at raising another nine-figure fund in the short term. Outsize performance begets outsize success – with compounding impact.

Based in an old waterside brownstone in Seattle's south downtown district, Elevar Equity manages a venture capital fund that seeks major impact in communities across the globe. In part through its secondary headquarters in Bangalore and Bogotá, the firm invests in a broad array of financial services startups that aim to significantly benefit "underserved" customers and communities across Southeast Asia and Latin America (Elevar Equity n.d. a). Since its founding in 2006, the team has raised ~$165 million and invested in 30 startups, in 13 of which Elevar was the first to invest money.[5] Elevar calls its ESG venture capital approach "human centered venture capital," constantly considering the impact of their investing on all stakeholders. And, according to their website, their portfolio companies have delivered more than 18 "essential services," created 40,000 jobs and served more than 20 million customers globally.[15] However great their impact, Elevar seeks to deliver great financial value. As partner Amie Patel told me, Elevar does not make, nor does it feel constrained by, "trade-offs between impact and return" (Elevar Equity n.d. b). It's probably telling that all of us in the Seattle startup community refer to Elevar's Pioneer Square headquarters as "Impact Hub."

Private equity firms investing in and outside ESG

To offer a reality check: the previous two categories (private equity and venture capital firms investing exclusively in ESG) comprise less than 5 percent of total private equity and venture capital investments (Black et al. 2016). The greatest opportunity for ESG – at least today – is in the remaining 95 percent of the market: the established, "traditional" private equity and venture capital firms who, increasingly, explore ESG investments. Traditional private equity and venture capital, especially larger, more established firms, are indeed beginning to look more at ESG investing. Some firms explicitly list ESG as an area of focus on their websites. Some firms have even raised and capitalized standalone funds, under their firm's umbrella, which have the exclusive mandate of ESG investing. Let's turn to examples from private equity.

KKR might be the starkest example. KKR was founded as Kohlberg Kravis Roberts & Co. in 1976 and is probably the first private equity firm – and perennially one of the top five largest private equity firms in history, now with assets of over $100 billion (KKR n.d. a). They were also a pioneer in ESG investing. In 2008, KKR launched their "Green Portfolio," originally built as a platform with capabilities for driving environmentally-focused operational improvements within their portfolio companies (Investopedia 2016). Today, KKR has expanded this platform from an environmental to a full-ESG scope, renamed the "KKR Green Solutions Platform" (KKR n.d. b). Similar to Blue Wolf's approach, a portion of KKR portfolio companies undertakes myriad ESG improvement initiatives, all with the resolute philosophy that such initiatives flow to profit margins: "Today, enhancing value includes building a stronger bottom line by improving the environmental, social, and governance (ESG) aspects of a business and thus focusing on the internal policies and external impacts of a company."

Bain Capital is unequivocally another old titan of private equity – founded in 1984 and now managing ~$65 billion in assets – and like KKR, Bain has also delved into the ESG private equity space with its $390 million "Double Impact Fund" (Bain Capital Double Impact n.d.). While KKR's approach is focused primarily on operational improvement of existing portfolio companies, Bain Capital's Double Impact Fund seeks out new businesses and projects looking to make positive impact in terms of ESG, analogous to LeapFrog (see above). Since being launched by former Massachusetts governor Deval Patrick in July 2017, the fund has made investments ranging from Impact Fitness, a chain of health clubs across regions experiencing high rates of obesity in the Midwest, to Living Earth, a recycler of organic waste based in Texas. The three core "impact themes" guiding the fund are "health and wellness," "sustainability" and "community building" (Bain Capital Double Impact n.d.) – perhaps a holy trinity of common good.

Venture capital firms investing in and outside ESG

"Dream Bigger" is the mantra that has become synonymous with the KPCB brand. KPCB, founded as Kleiner, Perkins, Caufield and Byers in 1972, is indeed "bigger," considered to be one of the world's five largest venture capital firms, and has invested an astounding $10 billion across 850 companies (Wikipedia n.d. a). And it does "dream," as far as ESG investing is concerned: according to their website, KPCB has an incredible 61 portfolio companies categorized under

"Sustainability," not to mention an additional 39 categorized under "Life Sciences" (KPCB n.d.). Further, according to *Pitchbook*, KPCB has consistently led its peers regarding the number of venture investments in cleantech over the past decade, and currently has about 40 portfolio companies categorized as cleantech (Tom n.d.). KPCB is perhaps the perfect example of a large, established, traditional venture capital fund exploiting its long track record of success to capitalize on emerging opportunities in ESG.

GE Ventures' corporate website claims: "We scale ideas and grow companies that advance industries and improve lives" (GE Ventures n.d.). Corporate venture capital firms are arguably well suited to wade into ESG investing, given their: structure (a sole LP, who doesn't complain much), long-term view of investing (relatively fewer liquidity concerns) and mandate to foster innovation and value for the parent company rather than purely achieve large exit returns per se. GE Ventures is a great example. Founded under the command of GE CEO Jeff Immelt in 2013, GE Ventures has invested $100–150 million in startups (Wikipedia n.d. b) – with varying levels of ESG benefits, from software analytics to energy efficiency to healthcare companies (GE Ventures n.d.). According to *Pitchbook*, GE Ventures has made investments in over 20 startups in cleantech, famously in wind power (Tom n.d.). It's difficult to estimate GE Venture's financial returns, but, assuming a conservative benchmark and the fact that it doesn't charge GE large fund management fees, GE Ventures is probably quite profitable, given publicly available information. However, the biggest benefit, and the reason corporate venture capital can be a powerful form of ESG investing, is that these investments are sharply aligned with the parent company's R&D and growth strategies, and can deliver incredible, unforeseen value – e.g. the wind power revolution which we have seen in the US Northwest that was in part made possible through GE Ventures' investments, GE R&D and ultimately GE manufacturing, installation and maintenance. As GE CEO Jeff Immelt told the Yale Climate Conference of September 19, 2017: "Drive innovation. It allows us to solve more than one kind of problem at the same time" (Immelt 2017).

Recommendations

Returning to the previous question: is this trend of increasing focus on ESG among private equity and venture capital firms fundamentally due to growing ESG opportunity per se, or lack of opportunity in non-ESG assets? I suggest both. The first phenomenon: ESG private equity and venture capital investing has become more financially attractive as technology, the way we live our lives, the way we understand the earth, our appetite for long-term value creation, etc. have changed since the private equity and venture capital business models were first conceived in the twentieth century. The second phenomenon: the unimaginable amount of liquidity that has flowed into the private equity and venture capital asset classes has buoyed the trend of increased ESG-focused investing. GPs are looking for a diversity of deals – and finding a scarcity. This second phenomenon can capitalize on the first: a larger number of firms can find deals by exploring ESG-aligned opportunities, funding and growing more ESG businesses and technologies and, as a result, multiplying future ESG investment opportunities. A virtuous cycle!

Tactically speaking, how should we think about driving this "virtuous cycle," accelerating the momentum behind ESG private equity and venture capital funding in the long term? My main recommendation: get more established, traditional private equity and venture capital firms to delve into ESG investing, in some form and to some degree. *Private equity and venture capital firms investing exclusively in ESG* play a very important leadership role in ESG investing. But the math is clear. As approximated above, just ~5 percent of ESG private equity and venture capital funding comes from this "exclusive" category of funds, while ~95 percent falls into our second category, *private equity and venture capital firms investing in and outside ESG*. Today, the greatest proximal opportunity to increase the share of ESG investment within private equity and venture capital asset classes is to increase the number of established firms – and dollars committed – that consider ESG. As total private equity and venture capital dry powder approaches $1.7 trillion,[1] the proverbial "pie" today is too massive to not fight for a larger slice.

What should we do to encourage more of these established, traditional private equity and venture capital GPs to consider ESG? Again, I envision a virtuous cycle: (1) GPs increasingly take advantage of the current state and opportunity to move into ESG in order to help differentiate their firms, as well as to discover emerging opportunities (e.g. geographies, technologies, needs), (2) GPs are further incentivized by current stakeholders in their firm (e.g. LPs and portfolio company managers), (3) GPs are incentivized by outsiders to the firm (e.g. prospective portfolio company managers, government and media). A comprehensive, fleshed-out discussion of such a model would take tomes. Below, I offer just a few cursory observations and ideas.

1. *GPs increasingly take advantage of the current climate and opportunities to move into ESG in order to help differentiate their firms, as well as to discover emerging opportunities*: As previously discussed, there is an unprecedented number of private equity and venture capital firms. Differentiation has never been more necessary, and ESG practices can be a powerful means to this end. Further, the ESG investment lens can help uncover new high-reward opportunities. As demonstrated by Blue Wolf, ESG-related operational improvements can unlock outsize financial gains. Additionally, as seen with KPCB, investing in "sustainability" can foster innovative companies that make new markets – and astronomical returns. Plus, GPs can market their ESG efforts to LPs and prospective portfolio companies by releasing CSR reports, ESG-related insights, and by weighing in on relevant public policy debates.
2. *GPs are further incentivized by current stakeholders of their firm*: Current stakeholders of private equity and venture capital firms, namely LPs and current portfolio company managers, can do more to incentivize GPs to move into ESG. LPs should find ESG private investing to be an attractive new space

within an already financially-attractive asset class. For example, endowments, such as that of Whitman College (in which I am involved), often actively look for GPs who: play in "new" spaces, consider societal benefits and externalities and take very long-term perspectives. LPs should educate themselves on the full benefits inherent to ESG investments and demand such opportunities from GPs. Additionally, portfolio company managers should also find ESG-minded GPs attractive and seek them out. For example, GP capabilities and dedicated resources, such as KKR's Green Solutions Platform, can help portfolio company managers improve their bottom lines, better serve their customers and improve their reputations. These managers ought to engage their prospective and current GP owners – perhaps in the next board meeting – and, like LPs, call for more ESG consideration.

3. *GPs incentivized by outsiders to the firm*: Many actors who don't have a direct relationship with a given GP – e.g. entrepreneurs and governments – can and should incentivize investors to move into ESG. For example, new startup founders with ESG-related missions ought to seek out ESG-minded investors when fundraising. If founders indeed care about their mission, they should "vote with their feet" and offer their investment opportunity to GPs who consider ESG, thus channeling deal flow to – and enhancing competitiveness of – these investors. In the context of today's massive dry powder accumulation, fundraisers have unprecedented power over funders. Additionally, governments – local and national – who have ESG-aligned agendas ought to do more to incentivize ESG focus among GPs. Favorable net interest tax breaks, carried interest protections and subsidies for ESG-minded portfolio companies are just a few salient tools that governments can employ to recruit GPs into the ESG space, as well as to increase ESG investment among current ESG-conscious GPs.

The virtuous cycle can now oscillate: point (1) creates awareness and opportunity for points (2) and (3), and points (2) and (3) further encourage point (1). Barriers and risks remain around increasing private equity and venture capital focus on ESG, including uncertainty in the business cycle, developing technologies, emerging markets, and unfavorable or volatile regulatory environments, as well as other hurdles addressed or implied above. Yet, as momentum behind this virtuous cycle compounds, we can ascend mountains, while accelerating – sustainably.

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13

ISLAMIC SYSTEMS FINANCE

Alizeh Maqbool

At Yale, the recently discovered notion of *systems finance* aims to tie together what traditionally have been distinct, individual contributions to promote sustainable development through investing, with an aim of better integrating such efforts so that they can work in congruence with one another to further improve sustainability and society. This chapter expands upon the realm of systems finance to include the Islamic investing model.

Since the concept of systems finance is fairly new and somewhat unexplored, I will help elucidate some of its desirable features by mentioning what I consider a prime application of it.

Using this example as a starting point for further discussion on the matter, I will draw a parallel between the goals sought by the founders of systems finance and those achievable in the Islamic financial model. Finally, I will argue that Islamic finance is, in fact, just one subset of the overarching systems finance set.

Definitions

As mentioned in Chapter 9, Cary Krosinsky, Marian Chertow and Paul Lussier conceived what has been described by the Science Communications with Impact Network at Yale as "a new way of matching long term societal benefits, near term financial gains and sustainability under carbon negative investment" (Lussier and Krosinsky 2017).

In this sense, the systems finance approach is expected to have a positive impact on three clearly delineated entities: people, through social benefits, profit, through a financial upside, and the planet, through sustainability and carbon negativity (Lussier and Krosinsky 2017).

By combining technical discoveries with industrial symbiosis, systems finance is envisaged to "create new categories of investment in climate solutions through the colocation and co-development of technologies and their applications" (Lussier and Krosinsky 2017). While severely bent towards climate solutions, the latter aspect of achieving this goal through "colocation and co-development" clearly suggests different segments working in tandem to introduce efficiency and sustainability (Lussier and Krosinsky 2017).

A model for systems finance at work: ecoenergy

Founded by Shazia Khan, an environmental lawyer and expert in off-grid clean energy solutions, and Jeremy Higgs, who has extensive experience in the nonprofit sector in Pakistan, EcoEnergy delivers "clean energy to rural Pakistan" (EcoEnergy 2016). The company provides solar technology, outsourced from other places, to people who would otherwise have limited access to electricity; by acting as a last-mile distributor, the company operates to establish the last link between manufacturers across the world and consumers in rural Pakistan (EcoEnergy 2016). Since the consumers that EcoEnergy targets are in low-income, rural households, the company provides an affordable pay-as-you-go payment model so that users only pay for what they use in monthly installments. (EcoEnergy 2016)

Indeed, EcoEnergy's business model is particularly attractive for an investor who has a penchant for sustainability, whether it is environmental, social or financial, or even a combination of all three. To increase social mobility, the company is working to make electricity accessible to the underprivileged class in Pakistan; in doing so, it claims to be providing livelihood by promoting entrepreneurial activities (EcoEnergy 2016). To protect the environment, the company focuses on solar technology, instead of using the huge reserves of fossil fuel readily found in the country; in addition EcoEnergy is also attempting to raise awareness of environmental issues as it seeks to educate rural populations on the benefits of replacing fuels such as firewood, dung and kerosene with solar solutions (EcoEnergy 2016). To make it financially attractive for investors, the company aims to ensure security through its geographic scope, which would limit its work to areas unaffected by the political instability that can be seen in other parts of the country. Moreover, the futuristic vision of the company means the on-ground team remains up-to-date with data on consumer behavior, and explores more refined ways of tackling the problems facing them (EcoEnergy 2016). Over a casual conversation, Khan boasts that this economic stability is reflected in a 95 percent repayment rate from customers for the products that it distributes. While the company only operates in Pakistan at present, Khan mentions that she plans to expand her work to similar settings in developing economies, where her team will be familiar with the needs and challenges there.

EcoEnergy's example is given to serve as a practical illustration of the idea that Krosinsky, Chertow and Lussier have presented. We have seen that even though EcoEnergy, both in its name and its mission, serves primarily to contribute to the cause of environmental sustainability, it has a positive impact in other sectors as well. For this reason, it seems plausible to conclude that ensuring sustainability in any one sector does not limit sustainable development in other areas; rather, it is possible to develop sustainably across different fronts – in fact, it is only this holistic sustainable thinking that makes a project sustainable overall.

Systems finance: extending beyond carbon negativity

The current definition of systems finance focuses largely on carbon negativity, but the concept also aims "to bring multiple stakeholders together to craft solutions" (Lussier and Krosinsky 2017); bringing these stakeholders together might benefit by extending the scope of the systems finance network. By assessing EcoEnergy, a firm aimed primarily at environmental sustainability, we have already realized that sustainable development in different areas of society is intrinsically tied together. Establishing links within existing paradigms to improve overall sustainability will then not only provide more "opportunities for corporates and investors" (Lussier and Krosinsky 2017) but also help establish the "nexus of green infrastructure, efficiency, innovation, design, systems thinking and finance" that the concept aims to achieve. (Lussier and Krosinsky 2017)

As far as expanding the scope of sustainable investments (beyond carbon negativity) is concerned, many might think that the preexisting sustainable finance model already provides comprehensive guidelines to improve sustainable practices. To this effect, it may be worthwhile to define the concept of sustainable finance. According to Swiss Sustainable Finance (2014), sustainable finance includes "any form of financial service integrating environmental, social and governance (ESG) criteria into the business or investment decisions." In expanding systems finance beyond carbon negativity to include other models of sustainability, it may seem as though it has a significant overlap with the goals of sustainable finance. Indeed, the two are closely related in that they aim to achieve the same end.

Nevertheless, merely by assessing the nature of sustainable finance and systems finance, an important distinction can be made between the two. The systems finance approach, in emphasizing "colocation and codependence" (Lussier and Krosinsky 2017), aims to find or develop interacting technologies and systems in order to enhance sustainability. In this sense it inculcates a holistic approach in assessing how the links between different sectors of society can be exploited to improve the society's compliance with sustainability – these assessments are not to be defined by any strict criteria. Sustainable finance, on the other hand, merely provides a rigid breakdown of the different factors that need to be considered to enhance a business' or investor's adherence to sustainable practices; it provides a screening metric to determine the degree of sustainability that businesses and investors incorporate. By linking potentially sustainable systems with other sustainable systems within the systems finance model, we can hope to achieve greater sustainability overall. In a sense, one may even argue that systems finance increases the compliance of businesses with the ESG criteria that sustainable finance outlines; the sustainable finance model is then just a subsidiary of systems finance, as it helps ascertain the degree of sustainability incorporated into different financial systems.

Before we can identify businesses that fulfill the ESG criteria outlined within sustainable finance, we need to find or develop models that presently, or in the future, have the potential to contribute to overall sustainable practices.

Islamic finance as a subsidiary of systems finance

When tasked with identifying possible systems, there are several directions that we can turn to; a convenient move would be to include a model that is already well established. If we are able to find such a pre-existing system, our task will be limited only to indicating how this system falls within the ambit of sustainable development that systems finance promotes. Conceivably, this would be considerably easier than developing sustainable systems or models from scratch. To this effect, a sphere that many might not have previously considered, but one that has the potential to supplement efforts in the drive towards sustainability, is the Islamic financial model.

Support for Islamic finance as a sustainable model is presented in a report published by the Islamic Development Bank, which cites Islamic finance as a "system which helps to stimulate economic activity and entrepreneurship towards addressing poverty and inequality, ensures financial and social stability, and promotes comprehensive human development" (The Role of Islamic Finance in Achieving Sustainable Development Goals 2015); by doing so, this report claims that the potential goals that Islamic finance can accomplish are "all relevant to SDGs [Sustainable Development Goals]" (The Role of Islamic Finance in Achieving Sustainable Development Goals 2015). It might seem that the authors, probably loyal supporters of Islamic finance merely because they are Muslims, are pre-emptively branding it as sustainable finance. However, if Islamic finance does in fact have the potential to accomplish all the goals its supporters contend, we will be unable to deny its relevance to the Sustainable Development Goals – and, by extension, to the mission of systems finance as well.

Before we begin to analyze the correlation between sustainability and Islamic finance, it may be reassuring to point out that this idea has garnered support in more objective circles, i.e. groups that do not attach importance to religious compliance when analyzing the effectiveness of a business model. The World Bank, for example, points out that Islamic finance is directly linked to the Bank's mission in "reducing poverty, expanding access to finance, developing the financial sector, and building financial sector stability" (World Bank 2015). Such an assessment of the Islamic finance model by a secular body, I hope, is enough to convince you to spend your time reading what follows: a comprehensive breakdown of Islamic finance in order to present it as a consummate investment model assuring sustainable development.

In order to understand how the principles of Islamic finance are grounded in sustainability, it is imperative to understand the relation of its theoretical principles with the practical rules that are delineated in Islamic law.

Negative screening: compliant with systems finance, or not?

One distinguishing feature between the existing conventional model of finance and that presented under the Islamic *Shari'ah* law is that the former is based largely on the concept of accrued interest, whereas the latter strictly forbids it. In addition to the prohibition of *riba'a* (interest), *Shari'ah* also bars *gharar* (uncertainty), *maysir* (gambling and speculation), and hoarding, as well as trade in certain commodities (including the pork, alcohol and others that are forbidden to Muslims in general) (Kammer et al. 2015).

In prohibiting engagement with many items, Islamic finance promotes a negative screening approach that is not necessarily harmful to long-term benefit; after all, even if some investors choose not to invest in certain industries or financial instruments, that does not preclude others in the world from doing so – such businesses and financial institutions could certainly find support from investors elsewhere. Indeed, on an individual level, the choices we make, however positive they may be in their impact on the rest of the world, cannot guarantee the ripple effect that we would prefer. As a starting point, however, before individuals can hope for change on the macro scale, they must think introspectively by starting at the micro scale.

Despite the restrictions that *Shari'ah* imposes, different groups of individuals can use *Shari'ah*-compliant investing in different ways to ensure an overall sustainable portfolio. Muslims looking to invest their funds in the manner prescribed by Islam can be assured that in practicing their religion, they are also impacting society positively, at least in their individual rights. Muslims who might initially feel reluctant to abide by Islamic rules of investing simply because of the limitations it poses can be assured that these limitations are motivated not just by the spirituality of faith, but also by the materiality of sustainable development in this world. Non-Muslims, on the other hand, may feel less inclined to use the negative-screening model that Islamic finance presents; for such people, and also for others choosing to adopt the concept, there exists the possibility to use negative screening as a starting point, to further complement it with shareholder activism and positive screening (Ahmed et al. 2015). After all, if we do in fact employ the systems thinking approach that systems finance promotes, we should consider merging different institutions to find solutions to current and future problems. Positive screening involves seeking companies that have set particularly high standards for factors that fall within the ambit of sustainability – such as environmental friendliness, product safety, workers' rights, etc. After an initial round of screening as suggested by Islamic finance, those who are not morally opposed to investing in categories forbidden in Islam can choose to add companies that have set high sustainability standards in areas that positive screening mechanisms (for example ESG-compliance) look for. Similarly, stakeholders can also be actively engaged with businesses they invest in to help these businesses incorporate sustainability over the long term – stakeholders who are not morally opposed to the industries that *Shari'ah* forbids can choose to invest in companies that bring decent financial return, alongside a promising future in terms of their potential and willingness to employ sustainable practices; other stakeholders, tied down by the code laid out by *Shari'ah*, can choose to engage with businesses that have the potential to realize better financial gains in their compliance with sustainability and Islam. In this sense, *Shari'ah*-compliant investing provides a sustainable filter both for those who adhere to Islam – by laying down the Islamic code, upon which they can expand through shareholder activism – and those who do not – by providing an initial screening mechanism, which can be expanded on through positive screening and shareholder activism.

Moreover, the values-first approach of Islamic finance, in its outright declaration of the standards of acceptable, arguably sustainable, investing, can help form a generic code for those who are not necessarily well-versed in sustainable investing; similarly, it may be helpful for those who would prefer institutional screening by a third-party organization (Krosinsky and Purdom 2016). Much like the ESG criteria that many socially conscious investors use at present, the laws of *Shari'ah* can help define a metric of its own. As discussed earlier, both Muslims and non-Muslims alike can use such a metric. And while it may initially seem that the existence of the ESG metric could lead to the duplication of efforts to this end, the importance of having a *Shari'ah*-defined screening metric cannot be denied given that more than 23 percent of the world's population is Muslim (Hackett and Lipka 2017), and at least some of this number attach importance to investing in accordance with Islamic laws. Knowing that the Muslim population is expected to grow by 73 percent by 2050 (Hackett and Lipka 2017), and that this metric may in fact be of benefit to non-Muslims as well, only strengthens the case for defining a *Shari'ah*-compliant investment metric. Moreover, going in line with the systems finance approach of "creating new categories of investment" (Lussier and Krosinsky 2017), a *Shar'iah*-compliant screening tool will only serve as an additional conduit towards achieving the sustainability that the concept of systems finance hopes to capture.

The sustainability of the elements of the Islamic financial model

Islamic finance is not all negative in that it is not limited to merely restricting what one is allowed to do. Instead, it is an entire system of many elements that interconnect and have an overarching purpose. As we argue that Islamic finance is inherently just a branch of the overarching concept of systems finance, we must demonstrate that sustainability is the overarching purpose of the Islamic finance model. In order to understand how this function is achieved, we must delve deeper into the different elements and interconnections that define this system. The Islamic Development Bank claims that Islamic finance has the potential to contribute to three areas which contribute to sustainability: "financial stability, financial inclusion and shared prosperity" (The Role of Islamic Finance in Achieving Sustainable Development Goals 2015). In what follows, let us examine these three areas by looking at the specific instruments that instill these properties in the Islamic financial framework.

A few paragraphs in this chapter can certainly not do justice to the Islamic finance model. Instead, only to understand its incorporation of sustainability, we can outline some of the fundamental principles of this model.

Financial stability

Financial stability within Islamic investing stems from the idea that Islam does not consider money and monetary tools as commodities; instead, it reduces their stature to that of a "medium of exchange" (World Bank 2015). The World Bank has concluded that profits in Islamic finance must be linked with "an asset, or participation and risk-taking in a joint enterprise" (World Bank 2015). Through such linkages, I argue, stable economic development can be ensured.

Linking financial return to an asset, instead of other intangibles, is a concept that is practically applied in the consideration of *sukuk* (or Islamic bonds) versus conventional bonds. *Sukuk*, defined as "asset-based securities" (Jamaldeen n.d.) comprise partial ownership of tangible assets; because their value is based on that of the underlying asset, they are not influenced by arbitrary variables, such as debt and price variation. Bonds, on the other hand, are "debt instruments" (Jamaldeen n.d.) and they involve the settlement of debt between the lender and the borrower; since bonds comprise the trading of debt, which can cause interest rates to fluctuate and an exaggerated inflation of prices, they can create bubbles in the economy that can potentially lead to economic crises of the likes of recessions and depressions (Mohammed 2014). Not surprisingly, when the value-at-risk (VaR) for a portfolio including both *sukuk* and bonds was compared with one without *sukuk*, it was found that the VaR for the former was much smaller (Alam et al. 2013); this suggests possible diversification advantages that can be obtained by including *sukuk* in one's portfolio. Given this information, *sukuk* emerge as the clear winners in terms of inculcating stability within a financial system.

This brings us to the second part of the World Bank's description of the Islamic finance model – to participate and take risks as a collective, rather than as an individual (World Bank 2015). In such cases, when the risk is borne by more than one individual, its impact is disseminated and, thus, diminished. In particular, joint setups such as *mudaraba, murabaha* or *mushraka* help introduce this kind of stability into the financial system.

Mudaraba, which is a trustee-financing contract, involves two parties, one of which provides capital, whereas the other provides expertise (World Bank 2015). Whereas both sides share profit according to a predetermined ratio, the financier alone sustains the losses (World Bank 2015). Given that *Shari'ah* forbids issuing conventional bonds, i.e. the trade of debt, this places the creditor in peril in the event of a loss. In order to avoid such an event, the financier should perform the necessary due diligence to determine where funds should be spent (The Role of Islamic Finance in Achieving Sustainable Development Goals 2015). Accordingly, the individual providing expertise will also be motivated by financial success since he or she will get a share in profits, thus ensuring stability or profitability for both contractors.

Murabaha, described as cost-plus-sale, involves two transactions; the first entails the purchase of an asset from the client, and the second involves the client repurchasing the asset at a price higher than the initial one at which the asset was sold (World Bank 2015). In this case, *riba'a*, or interest is avoided, while at the same time allowing the client to purchase goods on credit. Since an extra financial institution acts as an intermediary in the sale of goods and, in fact, also acts as the owner until the second transaction has been completed (Investopedia 2017), the terms of this contract place a huge burden on the financial institution. The financial institution will act in a way so as to ensure that funds are lent out only to those clients who can promise they will be able to repay for the asset; clients are also under check since they run the risk of being blacklisted if they default on payment. Moreover, in ensuring that a tangible asset is being purchased, the debt that is owed never exceeds the physical asset under question – in this sense, the overall debt in the market never exceeds the value of the underlying tangible assets that exist (The Role of Islamic Finance in Achieving Sustainable Development Goals 2015). This prevents debt from spiraling out of control, thus avoiding economic disasters.

In a *mushraka*, or an equity participation contract, multiple entities contribute capital, share profits according to a predetermined ratio, and sustain losses based on the relative proportion of initial capital invested (World Bank 2015). In being liable for the steps taken by other partners, each party is motivated to cooperate with others to make the most feasible decisions for their undertaking. In such a shared ownership, the actions of individual partners will not affect the overall undertaking as much as the collective decisions that they make, thereby promoting economic efficiency, accountability and greater willingness to cooperate (The Role of Islamic Finance in Achieving Sustainable Development Goals 2015). Moreover, since profits are not necessarily shared based on one's prior financial standing, individuals can decide to divide profits based on other variables, including the likes of effort and expertise. As a result, different individuals will bring different forms of value to the table, allowing each of them to capitalize on their skill or finances to run a successful venture.

Through some of the fundamental institutions of Islamic finance, therefore, we see that the framework seeks overall to create a system of checks and balances. This creates a system that is stable; by reducing overall risk, the model fulfills Meadows' definition of resilience, as it is "able to survive and persist within a variable environment" (Wright and Meadows 2012).

Shared prosperity

In analyzing the instruments that we have looked at so far, we have really only focused on the features that contribute to financial stability. One common denominator that is hard to ignore in all of these concepts, however, is that of joint ownership. Through a shared ownership of assets, multiple individuals in society are able to derive benefit.

Sukuk, bonds based on underlying assets, ensure that investors deploy their funds in a way that translates into economic activity. On the other hand, investors in bonds earn money from the interest they earn over time; if we try and understand the underlying money-making mechanism in this case, gains are made by the purchaser of bonds not due to any work done by the investor, or any increased production in the economy – rather, to put it simply, more money is being earned from the existing money in the market (Cafariello 2014). Thinking about this scenario for a fleeting moment should lead you to the question: how can one possibly make more money, based on the limited amount that exists, without putting in any effort? Surely, someone in this set-up is losing money, so the lender is essentially hoping to increase his or her wealth at the expense of others. Now, compare this model to the money-making model of *sukuk*: the investor makes more money when the value of the underlying assets increases – in other words, one has to work, by "producing something, cultivating something, or trading something" (Cafariello 2014) which directly impacts the industrial production of the region. An increased net value in regional production obviously benefits not only the *sukuk* investor, who is now likely to get a higher return from the increased profits, but also others in the region.

Extending this idea of shared prosperity to the *mushraka*, we note that multiple partners are able to enter undertakings. Since investors are free to choose how much money they wish to invest, and are assured that in the event of loss, they only lose an amount that is proportional to what they initially invested, people of different financial means can combine their abilities to ensure prosperity. In particular, the idea that profits gained by each investor are not tied to their initial investment empowers different partners in their own right – while one may be able to provide more capital, another may have more useful skills, and both might be able to make the same amount of profit. Through pooling their resources, and working cooperatively, such an investment model promotes goodwill (The Role of Islamic Finance in Achieving Sustainable Development Goals 2015) – in partnering, investors will want to collaborate to optimize for gains, and in this way will ensure each other sustainable earnings.

Similarly, even though Islam prohibits interest, it does allow for borrowing and lending that is grounded in assets, as is seen in the *murabaha* contract. While the financial institution can purchase an asset on behalf of the client, the client can agree to pay a higher price for purchasing the same asset on a later date; these payments can be made on a pre-defined basis. So while interest is bypassed for future payments, a fixed additional fee may be charged, thereby allowing debt-like purchases.

Through promoting shared ownership and joint enterprise, Islamic finance has the potential to optimize for return on assets, whilst also establishing a sense of goodwill in community. These two potential characteristics within the Islamic financial model alone can assure overall sustainability within a society.

Financial inclusion

Underlying economic progress in Islamic finance is the concept of wealth sharing, so as to mitigate the unfortunate eventuality in which large amounts of wealth end up being in the hands of a small segment of the population. In the US, an economy dictated by the conventional mode of finance, for instance, 20–42 percent of wealth is owned by 1 percent of the population (Lam 2016), while 13.5 percent of the population lives below the poverty line (Proctor et al. 2016). This situation is far from ideal, and certainly far from the overarching aim of ending poverty through the United Nations Sustainable Development Goals.

Under *Shari'ah*, clear definitions are laid out regarding the different ranks of wealth, and the amount that each must give to the poor on an annual basis. This mandatory sharing of wealth is known as *Zakat*, and forms the third pillar of Islam – its position as such goes to show the importance that Islam attaches to the idea of sharing one's wealth with those in need. Not only does this ensure that those in need are able to, at the very least, meet their basic needs, but the flow of wealth from the pockets of the rich to the hands of the poor reminds individuals to consider monetary well-being a privilege, not something that should be taken for granted. Along similar lines, *Shari'ah* encourages the wealthy to install *awqaf* (endowments), which can be dedicated to social empowerment (Ahmed et al. 2015). Together, *Zakat* and *awqaf* can help ensure that in addition to meeting the bare needs of the poor, social institutions can be developed for the community as whole (Ahmed et al. 2015). In this sense, perhaps *Shari'ah* diminishes the importance that is attached with monetary gain; rather, it is concerned more with the social aspect of equitable distribution of wealth.

In addition to mobilizing wealth from the upper socioeconomic rungs to benefit those at the bottom, institutions such as *mudaraba* play a role in developing talent and promoting growth (The Role of Islamic Finance in Achieving Sustainable Development Goals 2015). By providing capital to skilled individuals, Islamic finance encourages the development of innovative ideas. Since the individual in question need not be concerned with sustaining financial loss, he or she can use the finances provided through this contract to set up small and medium-sized enterprises, known more commonly today as start-ups. In a sense, *mudaraba* also seems to place a greater emphasis on human ability, or skill, rather than mere monetary gain; by providing the necessary means to intelligent individuals, who may have the capability to revolutionize world economies, this concept allows for social mobility.

Through proliferating wealth based on financial need and expertise, Islamic finance discourages the amassing of wealth, provides livelihood to the poor and creates opportunities for social upward mobility. By promoting entrepreneurial ideas, this framework also impacts the economy, in what might eventually turn out to be a financial upside for both individuals and nations. In promoting financial inclusion too, Islamic finance proves to be a sustainable financial model.

Conclusion

When we look towards promoting the concept of systems finance worldwide, we will have to cater to people with different opinions and different sets of beliefs, some Muslim, and others not. Regardless, it is necessary that we expand the domain of this concept to include existing and newer systems, which, when integrated, form the "nexus" that systems finance hopes to achieve (Lussier and Krosinsky 2017). Through the discussions in this chapter, we have seen how many elements of the Islamic financial model contribute to financial stability, prosperity and inclusion; and such traits, combined with an investment-screening mechanism, make this model a suitable addition to the network of systems that promote sustainable investing.

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14

FOREST RESILIENCE BONDS

A case for investing in forest health

Zach Knight and Chad Reed

Underappreciated but essential environmental assets, forests provide clean water and air, stabilize soil, sequester carbon, support habitats for countless species, foster recreation, and much more. Yet today, too many forests – especially across much of the western United States – are unnaturally overgrown. The combination of excessive overgrowth and a changing climate has increased wildfire size and severity, while progressively threatening the ability of forests to provide ecosystem services essential to thriving communities and natural habitats.

According to the U.S. Forest Service (USFS), 40 percent of land under its management (approximately 65–82 million acres) is at a "high risk" of severe wildfire (U.S. Forest Service 2012), which too often results in devastating fire seasons and threatens habitat, homes, and downstream water quality and quantity. Unfortunately, recent trends indicate that severe wildfire may be the new normal (Union of Concerned Scientists 2013). As a result of both overgrowth and climate change, wildfire seasons have lengthened by 30–45 days over the last 30 years while individual wildfires themselves are now larger and more severe.

In 2015, wildfire burned over 10 million acres of land across the United States for the first time in recorded history. Sadly, this was no anomaly: 9 of the 10 worst fire seasons have all occurred since 2000 (National Interagency Fire Center 2018). Wildfires have been particularly vicious in the western U.S., choking Seattle with smoke, ravaging the renowned Columbia River Gorge, and threatening Los Angeles with the largest fire in the city's history. In future, threats to communities are likely to intensify as nearly 40 percent of recent development in the western U.S. has occurred in wildfire-prone areas (Glickman and Sherman 2014).

Ecological restoration, which includes forest restoration, is defined by USFS as "restoring the functions and processes characteristic of healthier, more resilient ecosystems, even if they are not exactly the same systems as before" (U.S. Forest

Service 2015a). Indeed, forests restored to a more natural density face lower risk of severe wildfire, which protects lives, homes, and habitats, while also avoiding the release of devastating carbon emissions.

Other potential benefits of forest restoration include the protection of water quality and the provision of additional water quantity for both consumptive and hydroelectric uses (Simonit et al. 2015). By reducing forest density to a more natural level, there is less vegetation competing for the same amount of precipitation, allowing forests to be more resilient to drought and beetle kill while also potentially freeing up water volumes for downstream users such as water utilities, hydropower plants, and farmers (Anderson et al. 1976). Further, high severity wildfires burn organic matter in the soil, releasing stored carbon, damaging water quality, and affecting soil stability (Certini 2005). By reducing the occurrence of high severity fires then, forest restoration can also reduce the occurrence of these destructive side effects, thereby protecting water quality and avoiding sedimentation events for downstream users.

Also notable are the economic impacts from restoration, namely direct restoration jobs and indirect support jobs, which can be estimated from restoration projects themselves. Restoration workers are hired locally, supporting rural economies and communities. With long-term restoration planning, this opportunity can be a source of stable employment that contributes to community resilience.

The "fire borrowing" challenge

Despite the multifaceted social and environmental benefits conferred by restoration, the Forest Service alone has traditionally funded all restoration costs on land it manages as well as supporting private landowners across hundreds of millions of additional acres of forest land. But increasingly, USFS, which readily acknowledges the unhealthy and overgrown conditions of its forests, lacks the financial resources to implement treatments at scale.

The current budget crisis is due in large part to a vicious cycle known as "fire borrowing," in which USFS "borrows" funds from non-fire related appropriations to fund fire suppression. The Forest Service now directs more than half of its budget just to put out fires. Left unchecked, fire suppression is expected to rise to two-thirds of its total budget by 2021, leaving available nearly $700 million less each year for proactive restoration and other initiatives to promote forest health. The Forest Service is literally paying for today's fires out of the funds designed to prevent tomorrow's.

Given the $65 billion-plus[1] need for forest restoration across the U.S. (including $6–9 billion in California alone), an ambitious new approach to financing forest restoration is needed. One such approach, the Forest Resilience Bond, provides a platform for the public sector, private investors (such as pension funds and endowments), and stakeholders who benefit from the positive ecosystem services of forest restoration to come together to close the funding gap.

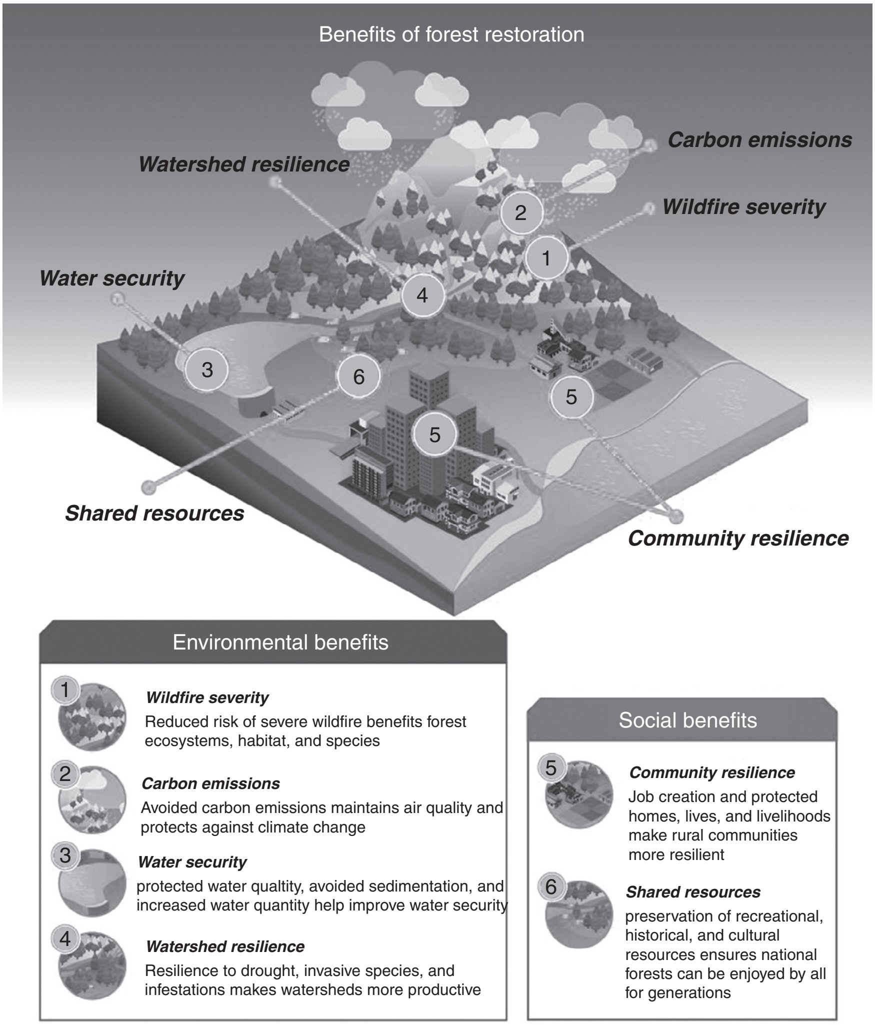

FIGURE 14.1

The Forest Resilience Bond: a collective action platform to unlock the value of ecosystem services

Forest restoration generates positive environmental impact and economic value not just for the Forest Service but also for a wide array of beneficiaries: water and electric utilities save funds due to protected water quality, avoided sedimentation, and (in certain cases) increased water quantity; state governments save on their share of fire suppression and clean-up costs while making progress toward stated goals like building rural community resilience and protecting air quality; local communities benefit from job creation and environmental preservation; and the larger global community enjoys the benefits of fewer carbon emissions and a healthier climate.

While in many cases the economic value of ecosystem services generated by forest restoration far exceeds its costs and would make a compelling economic case for investment, relevant public and private sector stakeholders often have varying interests, diverging priorities, and little history of working together. Each stakeholder also differs in its urgency to address specific issues, as well as its ability to contribute resources to restoration projects. Further, ownership concentration of USFS land complicates efforts to ensure all those enjoying the benefits of forest restoration (not just a single land manager) share in its significant costs.

To align costs and benefits of all beneficiaries, Blue Forest Conservation and its partners are developing the Forest Resilience Bond (FRB). The FRB is a public-private partnership that enables private capital to finance the substantial upfront costs of forest restoration. Beneficiaries of restoration such as USFS, water and electric utilities, and state governments make cost-share and/or pay-for-success payments over the life of the investment (up to 10 years) to provide investors competitive returns based on the project's success.

A systems-level approach to building environmental impact markets

In addition to the goal of scaling restoration across the western U.S., a primary purpose of the FRB is to encourage the application of innovative finance to other environmental challenges by harnessing a systems-level approach. This approach engages all impacted stakeholders in the development process and, in turn, facilitates the deployment of private capital to support crucial environmental interventions.

The FRB is able to achieve this by integrating three main components: (1) measuring of ecosystem service benefits conferred by restoration activities; (2) innovative contracting to convert benefits into payments from beneficiaries; and (3) financial structuring to turn beneficiary payments into cash flows for investors. By incorporating all three essential components into a collective action platform, the FRB is able to bridge the gap from the value that restoration provides to the undeployed capital seeking conservation investment opportunities. This alignment

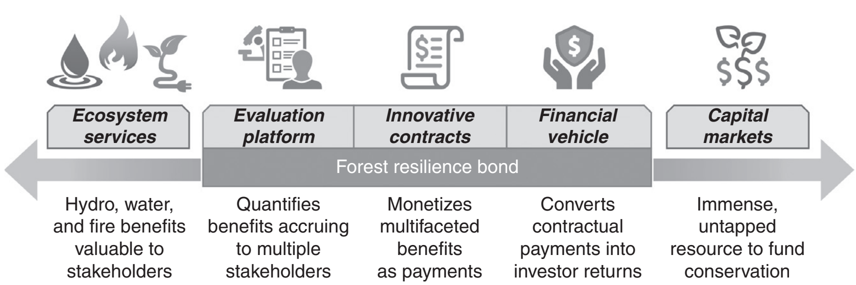

FIGURE 14.2 Bridging the gap between forest restoration and private capital

creates the opportunity to scale forest restoration with a sustainable source of financing.

Measuring ecosystem service benefits

The first step to enabling private investment in restoration is to quantify the expected ecosystem services associated with a given intervention. Measurement plays the crucial role of precisely quantifying what investors are financing and what beneficiaries are receiving. However, the value of ecosystem services is highly dependent on beneficiaries and their specific cost structures and obligations. While some ecosystem services are derived from avoiding substantial costs that would result from a high-severity fire, others are potentially revenue-enhancing. Translating the measurement of benefits to economic value can help stakeholders understand the economic opportunity of the FRB.

The FRB utilizes academic and industry research to scale forest restoration in a manner that is grounded in science. Applicable technologies employed include satellite data and ground-based sensors to measure changes in forest water use, sediment models and measurement stations to study water quality, and remote sensing to estimate avoided emissions. Without the collaboration of many highly motivated research groups and institutions, the quantification and valuation of many ecosystem services would not be possible.

Most importantly, measurement of ecosystem benefits serves as the basis for contracts that empower stakeholders to pay only for benefits received while shifting risk to investors, a key element to ensuring participation by risk-averse public stakeholders, such as utilities.

Innovative contracting

A common question about the FRB is, "How do investors earn back their money?" A more traditional investment approach is to purchase real assets (such as forest land), make improvements, potentially earn income from management activities (such as the sustainable harvesting of timber), and then resell it at a profit. One goal of the FRB is to keep public land in the public domain, so instead of relying on the purchase and later resale of assets, the FRB instead enables better land stewardship by financing restoration treatments and monetizing the resulting ecosystem services.

Given that there is no transfer of land ownership as part of the FRB, the cash flow generation mechanism is not immediately obvious. Instead of a more traditional asset-backed approach, the FRB creates cash flows exclusively from the economic value that forest restoration confers. Therefore, contracting with beneficiaries is the critical step in converting such benefits into cash flows for investors.

The FRB relies on a variety of contract types with multiple beneficiaries to monetize the restoration benefits. The development team expects that cash flows will be contracted from beneficiaries as follows:

- USFS reimburses a predetermined percentage of restoration costs, initially as work is completed and eventually amortized over five to 10 years.
- Utilities pay a predetermined fixed percentage of restoration costs (to compensate for protected water quality) amortized over 10 years.
- Utilities may also make pay-for-success payments based on measured increases in water volumes or other performance metrics over 10 years; and/or
- States pay a predetermined percentage of restoration costs, initially as work is completed and eventually amortized over 10 years.

In collaboration with utilities, the FRB development team has established a hybrid payment contracting arrangement that combines fixed payments for broadly accepted benefits (e.g., protected water quality) with variable but capped payments for watershed-dependent benefits (e.g., augmented water quantity). Some benefits, such as the reduced risk of severe wildfire and corresponding protection of water quality, are more easily monetized through fixed payments. In this case, utilities pay a certain amount every year as compensation for the risk reduction as a result of the restoration treatments. Other benefits, such as increases in water volumes, can be independently measured and then monetized through pay-for-success contracts in which the utility only pays for verified outcomes. Given the more variable and less certain nature of water quantity benefits, pay-for-success contracts allow utilities to only pay for measured benefits while shifting performance risk to investors.

What differentiates the FRB from other approaches to forest restoration is not only the use of investor capital to finance the initial costs of treatments but also the innovative cost-sharing among beneficiaries. By bringing together multiple payors to share the financial burden of forest restoration through both cost-sharing and performance-based payments, the FRB creates compelling economics for beneficiaries while providing diversified cash flows from creditworthy counterparties and resulting stable returns for investors.

Financial structuring

While the FRB represents a new approach to funding restoration, the investment structure itself is quite similar to infrastructure financing. An analogous example is the financing of a utility-scale solar generation asset, in which funds are raised based on contracted cash flows from the monetization of electricity that will be generated. Similar to a solar asset, forest restoration also creates value – but in the form of ecosystem services – which are monetized as contracted cash flows to enable beneficiaries to repay investors. In fact, the FRB may be considered a natural infrastructure financing with fire, water, carbon, and social benefits serving as the basis for payments from beneficiaries to investors.

Due to the perceived financial risk and smaller size of initial pilot projects, Blue Forest Conservation plans to utilize a blended capital structure which will include raising funds from concessionary sources that can tolerate higher risk, such as program-related investments (PRIs) from foundations. In this case, Blue Forest Conservation would employ a two-tranche financial structure for the FRB: one tranche for the market-rate capital and another for the concessionary capital, potentially including a credit enhancement grant or guarantee. For subsequent fully market-rate transactions, the currently contemplated financial structure assumes multiple tranches and mirrors a securitization or infrastructure project finance deal (or some combination of the two), and includes covenants and a cash flow waterfall to protect senior debt providers.

From an investor's vantage point, the bankruptcy-remote special purpose vehicle (SPV) could be an issuer of fixed income securities, a loan obligor, or some combination thereof depending on the nature of the contracted cash flows. For the initial pilot projects, the FRB will focus on loans over securities to ensure transaction costs are low and projects can be funded quickly. While deal economics and corresponding mechanisms for providing returns to investors may change, the FRB structure itself is designed for flexible deployment of capital based on investor demand and contracted cash flows from beneficiaries.

A step-by-step guide to implementing a Forest Resilience Bond project

A typical FRB project proceeds as follows:

1. *Beneficiaries identify a project in need of funding* – The FRB development team works with USFS, utilities, forest collaboratives, and other beneficiaries to choose a restoration project.
2. *Metrics of success are determined* – The development team collaborates with researchers and beneficiaries to determine what constitutes a successful outcome (e.g., successfully restored acres, reduced sedimentation, augmented water quantity) and how it will be measured.
3. *Beneficiaries sign contracts* – USFS, utilities, state agencies, and other beneficiaries sign contracts with the FRB special purpose vehicle to repay investors over time based on agreed-upon metrics of success.
4. *Investors provide upfront capital* – The development team raises funds from investors (pension funds, foundations, family offices, etc.) to cover upfront restoration costs.
5. *Implementation partners carry out restoration* – USFS monitors implementation partners as they conduct restoration activities according to USFS guidelines.
6. *Independent evaluators measure success* – Successfully restored acres, increased water volumes, or other metrics of success are measured and confirmed, at which time payment to investors by beneficiaries is triggered.
7. *Beneficiaries make payments* – Beneficiaries make contracted payments to the FRB.
8. *Investors are repaid* – The FRB structures payments from beneficiaries as cash flows to investors.

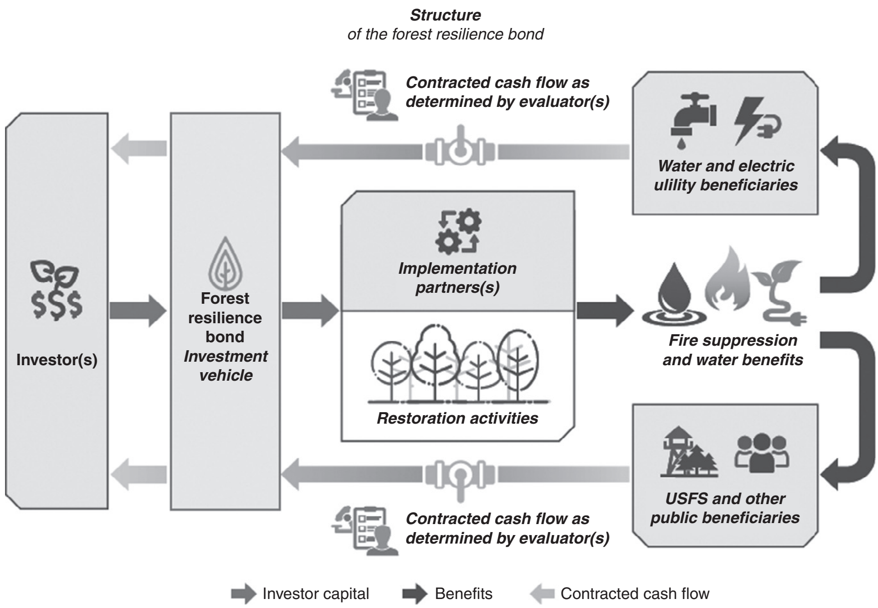

FIGURE 14.3

Note that these steps are broadly applicable to other efforts to apply innovative finance to other environmental challenges.

Opportunity for impact

Small, one-off restoration projects do not address the millions of acres at risk, nor do they warrant the time and costs of due diligence for institutional investors. Given the multi-billion dollar need for forest restoration across the U.S., the FRB presents an unparalleled opportunity for investors seeking stable returns and environmental impact *and* for the Forest Service, state governments, and large utilities to sustainably fund restoration at scale.

The potential impacts of successfully scaling forest restoration are numerous and widespread. Reducing the risk of severe wildfire can protect thousands of communities and millions of homes – in California, one in three homes (4.5 million) is at risk of wildfire (U.S. Forest Service 2015b).

Preventing high-severity fires also protects firefighters, 14 of whom lose their lives on average every year fighting wildfires across the U.S. (Bales et al. 2011). Forests restored to a healthy density will also be in a better position to store carbon. California's 18 national forests, for example, sequester over one billion metric tons of carbon (Stephens et al. 2013), equivalent to 38 years of emissions from Los Angeles (Higuera et al. 2015).

In addition to reducing fire severity, restoration can improve water quantity and quality for the tens of millions of Americans who rely on forested watersheds for their water supply (North et al. 2015). Finally, restoration directly creates 15 full-time jobs for every 1,000 acres treated (U.S. Forest Service 2015b), providing employment opportunities in rural, often lower income communities.

Guiding insights for the development process

Drawing on the lessons learned in the development of the Forest Resilience Bond, the FRB development team emphasizes the following five key insights to broadly guide the feasibility and development of environmental financings similar to the FRB.

Cultivate internal champions

Beneficiaries – especially those that are public-sector in nature, highly regulated, and/or traditionally risk-averse – often have an inherent and understandable bias against challenging the status quo. For an outsider, convincing such beneficiaries that it is in their best interest to think about a challenge differently, collaborate with others in a novel manner, and pay for existing or expected benefits can be a daunting task. Instead, new approaches are often better received if they are presented by established and trusted sources, such as internal champions within an organization who can more easily push for change. Finding and cultivating relationships with such internal champions – or *intrapreneurs* – is often essential to affecting lasting institutional behavior change.

Match capital to development phase

Project development is often a long and arduous process that should be supported by specific types of capital at each stage in the development process. Patient capital (usually in the form of foundation and public sector grants) is crucial in the early stages of exploration and stakeholder engagement. Once projects are ready for market, concessionary capital may be needed to achieve proof of concept through pilot projects. Only once risk is appropriately mitigated and returns are robust should financing be raised from institutional and other market-rate capital sources.

Psychology matters as much as economics

Even if it makes economic sense for a beneficiary to pay for an intervention, if another party appears to be free-riding, the beneficiary is less likely to pay for a service that others are receiving for free. A sense of fairness is paramount. The internal politics of beneficiary institutions may also further complicate an otherwise straightforward economic decision.

Contracting is an iterative process

Contracting requires flexibility, collaboration, and iteration. Seasoned legal professionals can help create a customized menu of contracting options for each beneficiary. However, each beneficiary should be treated as a customer whose needs must be fully understood and addressed. It is crucial to flexibly and collaboratively iterate toward solutions that satisfy the needs of both beneficiaries and investors.

Don't overlook governance

In any multi-stakeholder engagement, strong governance processes and procedures are essential to ensure that incentives are properly aligned, environmental goals are not compromised, conflicts of interest are avoided, and transparency is prioritized.

Note

1 At a cost of $1,000 per acre restored, the 65–82 million acres of high risk of severe wildfire suggests a $65–82 billion restoration need.

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15

FINANCING THE FUTURE

Free market solutions for an energy transition

Eric Esposito

If the world is serious about limiting the effects of climate change, the energy sector must diverge significantly from business as usual and undergo a transformation. A US led transition has the potential to be an example for the rest of the world, and is necessary to limit global warming to 2°C. Primary energy consumption in 2016 for the US was 97.4 quadrillion Btu, of which 81 percent came from fossil fuels (US Energy Information Administration 2015). In order to limit the average global temperature increase to 2°C with a 50 percent probability, the Intergovernmental Panel on Climate Change (IPCC) estimates that humans must limit total CO_2 emissions to 3,000 gigatonnes (Gt). Having already emitted 1,970 Gt through 2014, the remaining carbon budget is 1,013 Gt (International Energy Agency 2015).

Historically, economic growth and energy related emissions were closely tied, creating conflict between economic development and limiting the effects of climate change. A decoupling of economic growth and energy related emissions is important and achievable. In fact, limiting emissions could be a major driver in the global economy in the upcoming decades.

Limiting global warming to 2°C does not and should not harm the social welfare of people in developing countries by restricting energy consumption in the name of science. If part of the argument to prevent climate change is moral, then the solution to the 2-degree scenario (2DS) must allow developing countries to grow economically, even if it means increasing energy demand. Almost 20 percent of the world's population does not have access to power, and 40 percent does not have access to clean cooking facilities. These numbers are expected to fall with global GDP growth, which is estimated to increase three times from $80 trillion in 2015 to $260 trillion in 2060. Non-OECD countries will contribute two-thirds of that GDP growth. However, their emerging markets tend be highly energy intensive (Citigroup 2015). Demand for energy is estimated to grow by 35 percent by 2035, with 96 percent of that growth from non-OECD countries (BP 2015). An energy transition that moves away from fossil fuels to renewables and incorporates energy efficiency will address the climate change challenge and limit GHG emissions without preventing economic development in underdeveloped countries. In 2014, for the first time in 40 years, the world economy grew by 3 percent without increasing energy related CO_2 emissions. This was a promising sign that economic growth and CO_2 emissions can move in opposite directions, because in order to limit the effects of climate change to an average global temperature increase of 2°C, energy related CO_2 emissions must be reduced by 50 percent by 2050 globally (Capalino 2015). A successful energy transition must meet these emission reduction goals while promoting sustainable economic growth.

The case for an energy transition is strong, but its implementation faces many barriers. With the exception of a small minority of climate deniers, people believe that anthropogenic climate change is occurring. The challenge lies not in convincing consumers and investors that a transition to clean energy would have benefits, but in crafting a cost–benefit analysis that advocates for investment in clean energy. Clean energy investment needed for a 2DS is an average annual investment of $2.7 trillion for the next 35 years (Capalino 2015). While these numbers seem staggering, investing in a clean energy transition would have no net costs. The Carbon Tracker Initiative estimates that these $2.7 trillion per annum investments, including fuel savings, yield a net present value of (NPV) of $5 trillion. This NPV uses a reasonable discount rate of 10 percent, which accounts for the fact that individuals prefer $1 today versus $1 tomorrow. Citigroup, a leading financial institution, released a report that presented two possible energy paths: "action" and "inaction." Their "action," in essence, is an outline of an energy transition that intends to "mold our energy future driven by a blend of emissions, economics, avoided costs and the implications of climate change." They estimate that under Citi's "action" scenario, total spending on energy including both capital expenditure and fuel will be $190.2 trillion over the next 25 years. Under the "inaction" plan, macroeconomics are allowed to freely drive energy markets without consideration for the climate effects of burning fossil fuels and still results in $192 trillion in energy spending, $1.8 trillion more than in the "action" plan (Citigroup 2015). It has become clear that the US energy transition depends on significant increases in investment. In addition, investing in a 2DS has been shown to be less costly than business as usual. With all this in mind, one may wonder why a US energy transition is not already in full swing. However, even with $76 trillion in institutional assets, renewable energy totaled only $318 billion out of the $1.6 trillion in total primary energy investment in 2014, far off the $2.7 trillion target (Mills 2015). While investments in renewable energy have increased year over year (YoY), investments fell by 18 percent in 2016 to $287 billion, down from $349 billion in 2015 (Bloomberg New Energy Finance 2017). If the US energy transition is to be successful, the leading financial institutions in the US must work to find suitable clean energy assets to match strong investor demand. Both companies and institutional and individual investors need to increase investment in clean energy and efficiency.

Short-termism

Achieving the 2DS is possible with an accelerated energy transition but will require significant investment from businesses not only in the energy sector but also across industries. Company investment in clean energy in 2014 totaled $54 billion including $15 billion in research and development (R&D) (Bloomberg New Energy Finance 2017). With the benefits of leading the transition to a renewable energy future so great, why is investment lagging?

One of the biggest barriers to corporate investments in clean energy is excessive short-termism that limits long-term investment. The current US brand of capitalism now feels frantic and is increasingly focused on quarterly profits to please shareholders. A share of an S&P 500 company stock is held for an average of only 200 days. Publicly traded firms are rewarded handsomely for handing out cash dividends, making capital expenditures (capex) and R&D investments less desirable (*Economist* 2015). For the companies in the S&P 500, from 2004 to 2013, 51 percent of profits were spent on stock buybacks and 35 percent handed out as dividends (Galston 2015). Firms have spent $7 trillion of net income on share buybacks since 2004 and $700 billion in 2014 (Hanauer 2015). "Quarterly capitalism" is standing firmly in the way of a climate change response by limiting R&D and energy efficiency capex. There is insufficient reinvestment which is stifling research and development, creative solutions, and longer term growth.

In a December 2015 article, the *Economist* attempts to undermine "corporate myopia" on the grounds that firms invested heavily in the $500 billion shale revolution (*Economist* 2015). However, investments and capex in shale oil and gas extraction now yield returns in the very short run. Jeff Currie, Head of Commodities Research at Goldman Sachs, explains that "the time after which you commit capital and when you actually get production going is much shorter for shale projects." Conventional petroleum extraction projects had a timeline of about 5 years, but that has now dropped rapidly to approximately 28 days (Goldman Sachs 2015a). It is investment in long-term projects, not month-long projects, that will keep the US economy strong by creating jobs through innovation.

Disturbing results from a survey in the *Journal of Accounting and Economics* show that 55 percent of CEOs and CFOs would pass on long-term development projects that met their return on investment standards in order to ensure that quarterly earnings estimates were met (Galston 2015). While it sounds absurd that CEOs would be able to keep their jobs for knowingly passing on profitable investments that would help build the long-term success of the firm, CEOs who try to buck the trend put their job at risk. David Crane resigned from his role of CEO at NRG in December 2015 after criticism of the stock's performance. Crane was responsible for taking NRG, since its emergence from bankruptcy in 2003, to a leading position in energy markets (Pyper 2015). In a 2014 letter, Crane outlined his vision for NRG to become the Apple or Google of the energy industry. His goal was to revolutionize the energy industry by building NRG into an energy company that would connect, enable, and empower consumers (Crane 2014). He restructured

NRG into three groups, NRG Business, NRG Renew, and NRG Home, with the latter two focusing on renewable energy (Cardwell 2015a). NRG was investing in the US energy transition and would have been well positioned to be a long-term industry leader, but low oil and gas prices caused short-term pitfalls and shareholders forced a reversal to its old business model. The shareholders that pressured NRG to reprioritize its coal and natural gas business have missed a serious opportunity for long-term profitability and to accelerate the transition to clean energy.

The obsession with short-term considerations will, in the words of Laurence Fink, chairman of BlackRock (the world's largest investor, managing almost $6 trillion), "jeopardize a company's ability to generate sustainable long-term returns" (Galston 2015). If the effects of CO_2 emissions are ignored today, then climate change will jeopardize the economic growth and development through an estimated loss of $72 trillion (−2.5 percent) in global GDP for a 4.5°C increase. Including health impacts and other environmental externalities, climate change could impose an 11 percent loss in GDP per annum for centuries (Citigroup 2015). Not only is it good moral and environmental sense, but it is also good business to invest in the energy transition.

An economic system with short-term decision-making and long-term consequences is ill equipped to accelerate a renewable energy transition. Fundamental to climate change is the time delay where emissions are harmless today but extremely damaging in the future. To limit warming to 2°C, costs must be incurred today for benefits in the future. Climate change is a problem with shocking similarities to the 2008 financial crisis. Short-term thinking is extremely damaging and unlike the damage caused by the 2008 financial crisis, which only lasted for a few years, the detrimental consequences of climate change will last for hundreds of years. Government policies meant to limit the effects of climate change have been largely unsuccessful. Therefore, business and market solutions will be central to a clean energy revolution. The government through the Securities and Exchange Commission, has the power to mitigate "quarterly capitalism" by imposing rules restricting stock buybacks. Changes in the tax code could promote reinvestment by making it tax-advantaged (Verhage 2015). Lower taxes on capital gains are supposed to encourage long-term investment, but this lower tax rate is available after holding assets for only one year. There is nothing long-term about a one-year investment, and the US tax code should reevaluate the qualifications for capital gains. To push consumers to refocus on the long-term, the capital gains requirement should be extended to three years, and to incentivize even longer holdings, the capital gains tax rate should decrease with time. Fink suggests a zero rate on 10-year holdings, and rates higher than income taxes on capital gains held for less than 6 months (Fink 2015). An updated tax code is a reasonable response to promoting long-term growth and will be important for incentivizing clean energy investment.

Regulation is a viable solution to corporate short-termism, but the politics of changing regulatory regimes face their own problem with short-termism. Political offices are held on election cycles of 2–6 years, which pressures politicians to prioritize policies with visible short-term effects over policies in which the benefits might not be seen until after they have left office. In addition, investors are uncertain about the future of important renewable energy subsidies that may disappear as seats in Congress change. In 2016, there was uncertainty around a 30 percent federal tax credit on solar investment that was set to expire at the end of 2016 (*Wall Street Journal* 2015). According to Bloomberg New Energy Finance, the effects of those subsidies expiring would have caused solar installations to drop by 70 percent in 2017 (*Wall Street Journal* 2015). While the solar subsidies were extended in December 2016, along with a lifting of the ban on oil exports, renewable energy subsidies still face uncertainty. The extension was only extended for three years at the current levels and falls significantly thereafter (Lacy 2015). The bottom line is that Federal solar and wind subsidies have been the training wheels that renewable energy needs. They helped provide an additional $24 billion to developers of renewable energy from 2008 to 2014, which helped costs fall 10 percent annually (Chediak and Martin 2015). Shifting political sentiments put long-term investment in renewables at risk. While the renewable electricity production tax credit is still in effect, the Trump administration has been actively pushing a pro-fossil fuel agenda, making it harder for renewables to compete for investment. A reversal of supportive policies would be a major setback in the energy transition, because lower petroleum prices are putting even more pressure on cost competitiveness of renewables.

In December 2016, COP 21 in Paris presented the US with an opportunity to commit its government to long-term renewable energy policies. While the US initially declared its support for the agreement, following the transition to the Trump administration, the US withdrew from the agreement (Trump 2017). This reversal in policy highlights the detriment that political systems can have, disrupting policy, creating uncertainty, and acting as barriers to new renewables energy investment. The political short-termism that exists must be addressed with firm, long-lasting commitments to an energy transition such as a signed commitment to the Paris Climate Accord that is quickly ratified in Congress.

Many companies are still hesitant to invest heavily in renewable energy, efficiency, and other sustainability measures. While these policies could help accelerate the energy transitions by increasing corporate reinvestment, the level of investment will be insufficient until companies can fully quantify sustainability investments. A metrics system for sustainability factors can help to demonstrate tangible value.

An energy transition will not be accomplished by activists or governments alone. An energy transition must be driven by the free market. Non-profits can help encourage policy and help design metrics to help create an environment welcoming of renewable energy investment, but businesses and investors still need to allocate capital. The world's largest investments come from the world's largest banks, and so financial institutions will play an imperative role in leading the energy transition.

Financial institutions have enormous power in shaping the world's energy future through their allocation of capital. The calls for a response to global warming from anthropogenic CO_2 have a strong grassroots background, and many involved in the environmental movement are critical of Wall Street and free market capitalism.

While nonprofits and community activism have played a valuable role in bringing the climate conversation to the world stage, the world's leading financial institutions are the best positioned to drive the energy transition required in a 2DS. Banks are well equipped to tackle the challenge of financing the clean energy transition because of the enormous resources at their disposal. In addition, they are experienced in risk assessment and management.

Wall Street's major financial institutions have the balance sheets and the influence to accelerate investment for an energy transition. They also know the opportunities for positive public relations and big profits. In 2008, investment banks Citigroup, J. P. Morgan, and Morgan Stanley created "The Carbon Principles," which outlined a commitment to using an "Enhanced Environmental Diligence Process" to consider climate change risks when assessing fossil fuel projects (Citi et al. 2008). Many banks are taking advantage of the hype surrounding the buildup to COP21 to announce major allocation of capital to clean energy. In February 2015, Citi CEO Michael Corbat announced Citigroup's commitment to invest $100 billion in sustainable growth in energy, clean tech, and green infrastructure projects. Goldman Sachs announced a similar initiative that November by expanding its target for clean energy financing and investments to $150 billion by 2025 (Goldman Sachs 2015a). These commitments are an important step toward financing the clean energy transition, as the problem of climate change has been difficult to tackle politically, making market-based solutions necessary.

Investors, capital markets, and market correction

Finding $2.7 trillion in investment annually sounds like a daunting task, but the institutional investors through capital markets will account for a significant part of that investment. Institutional investors hold $76 trillion in assets (Capalino 2015). The transition to renewable energy and limiting warming to 2°C can be accomplished if investors reallocate more of their assets to clean energy. In addition, capital markets have the capacity to easily absorb $2.7 trillion per year. Equity has a market cap of $70 trillion and fixed income has a market value of $166 trillion (Citigroup 2015). Relative to the size of existing capital markets, investment in the energy transition is small.

Institutional investors will be important for filling the gap in renewable investment necessary for a rapid energy transition. With $76 trillion in institutional assets, there is a large market for renewable energy investment. However, even with massive capital markets, there is an insufficient supply of clean energy investment vehicles that meet the desired return and risk profiles for investors. The supply and demand imbalance means some investors are willing to pay premiums on desirable assets that become available. New assets are being created to meet this demand. One creative equity vehicle is share ownership in yield companies or yieldcos. Yieldcos are companies created to purchase the drop-down assets from a parent renewable company. Many solar companies have adopted this model to raise inexpensive capital in part as a response to the master limited partnership, which is a tax advantaged structure popular in the midstream oil and gas vertical. Yieldcos are exposed to the same double taxation as corporations, but creative accounting is used to create a tax advantage. Through intentional operating losses and tax credits, yieldcos are able to create a "tax shield" (Ernst and Young 2015). Dividends paid out of profits and earnings are taxed as such, but cash dividends that exceed the profits and earnings are considered returns to capital and reduce the tax base (Wheeler 2014). Yieldcos provide investors with a low risk profile and predictable dividends while also raising capital for its parent company. The yieldco model is new and there has been recent volatility due to investor speculation (Cardwell 2015b). In addition, mismanagement and failing governance at some of the most prominent yieldcos, such as the bankruptcy of SunEdison in April 2016, has left investors skeptical (Hals and Groom 2016). However, the yieldco structure has sound fundamentals and should be able to deliver attractive investment opportunities for income-focused equity investors.

In addition to equity, fixed income also offers potential for renewable energy investment. In recent years, green bonds have entered the market and their issuance is growing. Green bonds act like a typical fixed income instrument but are used exclusively to finance "green projects" such as renewable power generation or energy efficiency. In order to meet the requirements for a "green" label, the projects being financed must meet certain specifications and involve auditing and reporting. In 2014, $37 billion in green bonds were issued, up from $15 billion in 2013. The value of green bonds is on track to add an additional $40 billion in 2015, having added $29 billion in the first three quarters of the year (Mills 2015). This growth is promising but falls short of expectations that predicted an issuance of $50 billion to $100 billion. Like yieldcos, the market for green bonds is still evolving, but once a standardized accreditation process and set of industry guidelines are set, green bonds will be able to grow to become a major part of fixed income assets.

Within fixed income, covered bonds also have the potential to bring billions of dollars to renewable energy projects. While covered bonds are not new (they have been around for about 250 years), they offer advantages to regular green bonds. Covered bonds are backed by assets and also by a guarantee from the issuer or the government, which greatly reduces risk. In addition to a higher credit rating, a government-backed green bond alleviates investor risk of government regulation instability. With governments covering bonds, it makes the government a stakeholder in the success of renewable energy projects and makes it unlikely that they will change subsidies or regulatory policy (Citigroup 2015). It is through these new renewable energy investment vehicles that the energy transition will move forward.

Market-based solutions will be the biggest driver in the clean energy transition. The only truly sustainable way to achieve a lasting solution to climate change is through the markets. The energy transition is something that should be self-driven by markets as long as they operate correctly. However, the free markets in their current form have not allowed for an energy transition to take place because the cost of energy is underpriced. Today's energy markets are based on an incorrect price of energy that ignores externalities. A correction of the markets is needed, and pricing carbon is that correction. Correcting for a serious market failure is no easy task and nearly impossible on a global scale. Cap-and-trade programs and a carbon tax regime are ways to adjust the price of energy so that it more accurately reflects its cost. Actions to encourage investment in renewable energy are important to limit the effects of market failure.

Oil and gas and renewable opportunity

Low oil prices are hurting renewables now in the short run, but they are also hurting themselves. Big majors and small independents have slashed billions in capex. Investing these funds in renewable energy projects would help diversify and reduce risk.

Oil and gas companies have some of the largest market capitalizations in the world. The oil and gas sector has a combined market cap of $4.8 trillion, up over 20 percent since the low in January 2016 (Financial Times 2015). While low prices may help fossil fuels retain market share, the oil glut is putting extreme stress on oil companies' cash flows. Even with prices recovering and stabilizing, in the future oil and gas companies will need to operate within their means. One popular and compelling argument for a renewable energy revolution was high energy prices. When oil is trading over $100 per barrel, the ROI for renewable energy and efficiency projects is extremely high. However, with the price collapse in 2015 which bottomed out in February 2016 with prices falling to below $30 per barrel (the first time since 2003 and lower than during the 2008 financial crisis), the low prices have cut deeply into the earnings of oil companies (Raval 2015; US Energy Information Agency 2017). Four of the supermajors – Royal Dutch Shell, Exxon Mobil, Chevron, and BP – had earnings fall 70 percent in 2015 (Kent 2015). Despite plummeting revenues, oil companies are still desirable investments because of their consistent dividend payouts. Over the last year, the supermajors have increased their dividends by 10 percent, handing out $28 billion to shareholders (Kent 2015). As the long-term profitability of many projects becomes uncertain, many oil companies are prioritizing dividends over value creation. Martijn Olthof, a senior portfolio manager at APG Asset Management NV, criticized this behavior, saying "the dividend yield isn't something that drives value" and suggesting that "management of these companies should try to spend time trying to create value for the business rather than trying to attract shareholders with promises of stable and growing dividends" (Kent 2015). A commitment to a 2DS could leave 60–80 percent of fossil fuel reserves of publicly traded companies designated as unburnable (The Carbon Tracker Initiative 2013). In addition, ignoring the unburnable carbon problem, there is $1.1 trillion in possible capex over the next 10 years that require $80 per barrel to break even (The Carbon Tracker Initiative 2014). Billions of dollars in capex were cut when oil was trading under $50 per barrel and the "lower for longer" scenario became widely accepted (Rudnitsky 2015). Michele Della Vigna, Head of European Energy Research at Goldman Sachs, estimates "between

$700 billion and $1.3 trillion of projects will not be needed any longer" (Goldman Sachs 2015b). Oil companies looking to exist in the coming decades must act now to create a new business model where they diversify their assets and revenue base.

The energy transition will have winners and losers, and oil companies that are leaders and accelerate the energy transition will very likely be winners. Low oil prices represent an opportunity for oil companies to reallocate investment and canceled capex to renewable development and deployment. Smart long-term thinking will position some oil companies to transform into diversified energy companies with a major renewable component that will protect them from price shocks.

Oil companies have previously made attempts at sustainability to promote a transition to clean energy, but more is needed. In 2000, BP began a rebranding campaign to turn the old "British Petroleum" to "Beyond Petroleum" (Esty and Winston 2006). Since then, BP met its goal of $8 billion in renewable investment but then reverted to its old business course by failing to set future investment targets and withdrawing from all of its solar operations in 2011. Only one supermajor oil company, Total, seems to be taking advantage of the opportunity to build long-term value with renewable energy investment (Morton 2015). Total has made the most serious commitment to renewables with its 65 percent ownership of SunPower. In September, Total continued to expand its renewable portfolio by purchasing a 23 percent stake in Eren, a renewable power producer with wind, solar, and hydraulic assets (Keohane 2017). Total's strategic vision is one that should be replicated across the oil and gas sector to accelerate the transition to a clean energy future. While it is still too early to see how these strategic decisions will affect Total's business in the future, it has been able to perform alongside Exxon and Chevron (profits rose 50 percent for Exxon and Chevron and 40 percent for Total YoY) who have stayed more focused on oil and gas exploration and production (Olson and Kent 2017). Total's renewables, power, and gas segment may be small, generating $97 million in operating income compared to $1.4 billion from their upstream oil and gas segment in the third quarter of 2017, but it is has the potential to position itself as an industry leader in the future amid an energy transition. In addition, the renewables, power, and gas segment has a return on capital employed (ROCE) of just under 7 percent (Kent 2017). While once a largely ignored metric by oil and gas investors, the oil price collapse has shifted investor focus from growth to returns.

Total could be one of the corporate leaders in its transition from an oil company to a diversified energy company with an integrated business model to "capture all of the synergies in our business base and areas of expertise" (Total 2015). These synergies include strategic risk reduction and a complementary relationship between shale gas and renewable energy. The decision by DONG (Danish Oil and Gas) to change its name to Ørsted following the divestiture of its remaining oil and gas assets in the spring of 2017 is an indication that Total is on the right path and that other majors should seriously consider ways to prepare for the future (Reuters 2017).

While renewables and fossil fuels might sound like unlikely bedfellows, a Citi research report, *Shale and Renewables: A Symbiotic Relationship*, discusses how shale gas and renewable energy can interact as complements not competitors. Many environmentalists argue that natural gas and renewables compete directly for investment within the energy sector. However, natural gas, which has a diverse use in industry and transportation, serves a different role than that of renewables, which is primarily distributed electrical generation, allowing both to have a significant share of the energy mix. Natural gas-fired power plants can increase the penetration of renewable energy into electricity markets by meeting peak demand, thus addressing the problem of intermittency with solar and wind energy. The nature of renewables is that energy output is intermittent, which causes problems where demand curves have both base and peak loads. Investment in natural gas electrical generation should encourage more renewables because it alleviates the problem of peak demand. It is quick and easy to turn gas-fired power plants on and off, making natural gas a desirable source to "counteract the supply imbalances created by renewables" (Channell et al. 2012).

The oil and gas sector is itself undergoing a transition as US shale oil and gas production capacity has created a major market disturbance. Even if oil companies choose to ignore the signs for a clean energy transition, they will struggle in the "new oil order" where OPEC and the US fight for market share in a market with limited growth prospects. The best way for US producers to compete with OPEC is to invest heavily in alternative energy sources. Energy companies across the board are experiencing falling revenues. The companies that recognize the unique opportunity to invest in renewables will be well positioned to outcompete OPEC and domestic oil producers that fail to innovate. In the early stage of the transition, markets are beginning to recognize the value of renewables in the energy mix, with the example of Total having smaller losses and bigger gains than its competitors (Whittail 2015).

Even with all the right incentives, transforming the energy sector will take time. It is important to create a realistic and intentional energy mix that is flexible. Technological advances, today and in the near future, may take decades before they make up a substantial share of the energy mix. For example, it was not until 60 years after being commercially produced that oil came to make up 10 percent of the energy mix (International Energy Agency 2015). While renewables are being deployed at an increasing rate, fossil fuels will still be an important source of the world's primary energy. A successful energy transition will result in an energy mix that is diverse and clean. Not only will the new energy mix limit warming to 2°C, but it will limit producers and consumers from damaging price shocks and demand imbalances. Investing in the renewable energy transition is an investment in a better future, and as investors and companies begin to see value over an extended period of 10–20 years, the reasons for a clean energy transition will become increasingly obvious. By working through free market mechanisms, the US can accelerate an energy transition that promotes long-term sustainable economic growth.

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PART III
Regional innovations

Innovation is a sometimes chaotic endeavor, and new ideas which at first can seem exciting sometimes end up leading to worse impact outcomes.

For example corn-based ethanol showed promise in the Midwest US as a low-carbon fuel source, only to disappoint with more carbon emissions being measured across the product life cycle (not to mention higher food prices which resulted).

Innovation is complicated, multi-layered, multi-faceted and frequently surprising almost by definition, and can vary due to regional requirements and local culture. But if we dig down and look hard at how to solve complex problems, especially on a regional basis, we can end up with better solutions, ones that may have seemed counter-intuitive at first.

In this regard, here are few such creative regional attempts to solve problems. First, Steven Castano looks at the Northeast US and its use of natural gas, suggesting a unique solution to a multi-layered challenge. We then introduce a Brazilian perspective from Andreia Marin Martins and her colleagues, with a look at a country which has hit difficult times, but with a vision of innovation which might just help it rise up again.

We then look at two perspectives on waste, from Jason Mazzella and Reilly Witheford, followed by an example of an infrastructure solution to a city's many likely future challenges from architect Marvin Krosinsky; and we end Part IV with Masengo Kapanga's analysis of the beneficial future potential for impact investing in Africa.

Complex challenges require complex solutions – and systems thinking – or so it would seem.

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NEW ENGLAND'S WINTER CHILLS

Steven Castano

With the closure of Brayton Point, "the largest coal-fired power plan in [the]New England [region]" in June 2017, the region lost approximately 1,500MW of coal fired generation as it continues to move away from coal- and oil-based electricity generation (Serreze 2017). According to ISO New England, which is responsible for overseeing New England's energy market and power grid, this 1,500MW loss in generating capacity is expected to be replaced by "new gas-fired generation, [yet the] additional infrastructure to deliver or store natural gas is [not being developed]" (Shelor 2016). In short, this decision to increase the region's dependency on natural gas-fired generation, without constructing the necessary infrastructure to handle the increase in supply, may lead to a surge in natural gas and electricity prices during the cold winters in New England. Such prices in New England during the winter months are much higher than in the rest of the United States, due to "transport constraints [to the region] … as most of New England's gas is piped via New York from points south and west through a limited number of pipelines [that cannot meet the region's consumption levels during the winter]" (Lanfear 2016).[1] Because of a logistical bottleneck, the New England area has to pay more money to transport its natural gas from the Marcellus shale region in order to satisfy its energy consumption needs during frigid winter months. Although the construction of additional natural gas infrastructure could help assuage this quandary, it is important to recognize that this is a seasonal issue.

For most of the year, existing natural gas infrastructure is sufficient to meet the region's energy needs and the "low price of natural gas is setting the wholesale price of electric energy [which is driving the region's dependency on natural gas as] power plants using more expensive fuels are getting squeezed financially" (Walton 2016). Constructing additional natural gas pipelines could lower the region's natural gas prices during the winter, but at the risk that these new pipelines are not fully utilized during the rest of the year. Without an adequate year-long demand for these pipelines, it is unlikely that these natural gas pipelines will be built, as was the case with Kinder Morgan's recently canceled Northeast Energy Direct pipeline which "couldn't get enough utilities and local distribution companies to sign up for firm commitments [to utilize the pipeline]" (Kraft 2016). Instead of constructing new natural gas pipelines, it may prove more feasible to improve the region's existing infrastructure as a solution to New England's winter energy shortage. Yet, the viability of this option is growing less likely as New England's municipalities begin to "block mandates that would pass along construction costs [of any pipeline] as part of a consumer's monthly [electric] bill" (Kraft 2016). Banning this approach forces utilities to pay for a larger percentage of pipeline construction, making them reticent to carry forward with projects given the large amount of debt they would accrue in the process. As a result, many experts have recommended that New England begin diversifying its energy mix with hydropower and wind, given controversies surrounding the construction of natural gas pipelines. Furthermore, by improving the region's energy grid and incorporating further usage of distributed generation it may be possible for New England to successfully tackle seasonal energy shortages and reduce its reliance on natural gas.

In recent years, the construction of natural gas pipelines in the New England region has drawn the ire of protestors and residents alike. Kinder Morgan's scrapped Northeast Energy Direct Pipeline was opposed by environmentalists because of its $3.3-billion price tag and the planned construction of new stretches of pipeline that could become redundant given the existence of another "competing pipeline project" at the time. As mentioned, Kinder Morgan canceled its Northeast Energy Direct Pipeline because it could not garner the support of enough natural gas shippers to reserve firm capacity. Yet, Spectra Energy's planned 123-mile expansion of its existing Algonquin pipeline, which was once viewed as a viable alternative to Kinder Morgan's Northeast Energy Direct project, has also faced increased opposition in recent months (2016). Growing criticism leveled against Spectra's Access Northeast project concerns the pipeline's $3-billion price tag and the common practice of letting utilities pass along the cost of the project to consumers in order to pay for the project. Utility companies reserve capacity to ship natural gas on a pipeline by paying a hefty reservation fee along with a transportation fee for natural gas which is transported. In order to cover expenses associated with these fees, which are utilized by master limited partnerships (MLPs) to pay for the construction of a pipeline, utilities raise prices on their customers' bills, thereby "[having] the state's electrical ratepayers … assume the financial risks associated with building natural gas pipelines" (Kelly 2016).[2] However, courts in Connecticut, New Hampshire, and Massachusetts have passed rulings prohibiting the "funding of Access Northeast pipeline construction by [the state's] electric ratepayers," forcing many electric distribution companies (EDCs) to withdraw pipeline capacity they had reserved on the project (Shelor 2016).

Traditionally, criticism leveled at natural gas pipelines focuses on "concerns over climate change – with peer-reviewed scientific research concluding that because of methane leaks, natural gas [has its drawbacks as an energy source]." Yet, by focusing on the economics of constructing natural gas pipelines, these recent rulings in New England could carry significant repercussions (Kelly 2016). Spectra is finding it difficult to secure firm shippers on its Access Northeast project "after some New England states have effectively nixed contracts with electric distribution companies [by preventing them from passing on costs to ratepayers]" (Fisher 2016). Although Spectra is considering replacing those EDCs with local distribution companies, given the large demand "of unmet local distribution company load [during the winter]," recent setbacks have forced the company to push back the project's projected completion date from 2018 to 2019. Without additional natural gas infrastructure to support the region's large reliance on natural gas, "winter demand spikes [could] leave New England in a 'precarious' position" as the price of natural gas skyrockets during the winter months because of the expensive transportation costs (Walton 2016).

While imported liquid natural gas (LNG) could conceivably make up for the region's inadequate natural gas infrastructure, there are a few pitfalls with this approach given the "region's limited LNG storage space, [transportation difficulties with overseas shippers], and LNG's expensive and often variable pricing" (Kraft 2016). Furthermore, LNG often has to be ordered in advance, which makes it difficult to accurately assess how much natural gas the region needs during the volatile and frigid winter months. While the construction of additional natural gas infrastructure may prove more prudent than relying on LNG imports, recent rulings have called into the question the feasibility of the former approach. Yet, regulators in New England should be praised for their decision to recognize that

> while natural gas might be cheap at the moment, the industry has a long history of sudden price spikes and dramatic collapses … [meaning] any natural gas infrastructure built today will be expected to remain in service throughout these severe ups and downs, leaving consumers in the lurch.
>
> *(Kelly 2016)*

However, by preventing utilities from passing along the cost of natural gas pipelines to their consumers, regulators in New England run the risk of repressing the construction of additional natural gas infrastructure. Furthermore, as of 2015, natural gas makes up 49 percent of the region's power, with 60 percent of all new generation proposed to utilize gas-fired generation, indicating the region's increasing reliance on natural gas as its primary fuel source. (Shelor 2016; Kraft 2016). Without additional improvements in the region's existing natural gas infrastructure, New England may find itself experiencing significant natural gas price surges during the winter months "because so much of the region's generating capacity runs on natural gas, [meaning] the price of this single fuel source sets the price for wholesale electricity about 70% of the time." In order to reduce the region's reliance on natural gas, many New England states have as a result begun to invest in hydropower and wind power as ways to diversify the region's energy mix.

As New England continues to move away from coal and nuclear power as sources of energy, it will become vital for the region to replace those sources with natural gas or renewable energy. Currently unfavorable financial factors are making coal and nuclear power less viable as energy sources, as demonstrated by Entergy Corp's decision to shut down the Pilgrim nuclear power station in Massachusetts by 2019 due to "reduced revenues and increased operational costs" (Walton 2015). The decision to decommission Pilgrim adds an additional strain to satisfying the region's energy demand in an environmentally conscious manner, as the plant "provides about 5% of the region's power and makes up 84% of Massachusetts' non-carbon emitting energy" (Walton 2015). While the energy generated by Pilgrim could be replaced by more renewable energy alternatives, "once Entergy's Pilgrim facility is shut down, Massachusetts will be out of the nuclear business … [and unable to reap the benefits provided by nuclear power plants, which are:] carbon-free energy, onsite fuel storage, and large-scale generation that is ready on demand" (Walton 2015). Yet, it is more conceivable that instead of investing in renewable sources of energy to satisfy this demand shortage, the region may instead utilize natural gas given the "glut of cheap shale gas [from the prolific Marcellus]" (Walton 2015). Moreover, while the region has made significant strides to incorporate hydropower into its energy mix, this decision is being met with dissent from certain influential groups.

Hydropower from Canada, specifically Quebec, could provide the New England area with a cleaner form of energy that would decrease its reliance on natural gas, yet many lawmakers in the region have expressed concern with this approach. In particular, a bill recently backed by "Massachusetts Republican Governor Charlie Baker … that would make room for the importation of a huge chunk of hydro power from Canada [has received criticism from lobbyists because of the bill's price tag and environmental concerns]" (Marotte 2016). In particular, the bill's detractors have expressed dissatisfaction with the decision to "carve out a deal for Hydro-Québec and its U.S. partner Eversource Energy [for about] one-third of the state's electricity consumption [by locking into a 20-year contract with the company which would be subsidized by Massachusetts utility customers]" (Marotte 2016). Establishing a long-term contract with Hydro-Québec would certainly increase the reliability of peak-day delivery services to New England during the cold winter months, but it raises the question if this deal "would reduce competitive pricing in the energy market [by relying on a long-term fixed contract with one energy provider for a third of the state's energy supply]" (Marotte 2016). Furthermore, in order for Hydro-Québec to deliver its hydropower to the region, New England would need to construct "a $1.6-billion transmission line to carry [large scale] hydro power from Quebec to markets in New England … [which] has triggered an outcry from residents and environmentalists over the negative impact it would have on the area's scenic beauty, tourism activity, and property value" (Marotte 2016). Even though hydropower is viewed as a cleaner source of energy compared to natural gas, much of the same criticism leveled against the construction of natural gas infrastructure has been used to argue against the construction of hydropower infrastructure. Moreover, the decision to rely on a foreign energy supplier to satisfy the region's energy consumption has sparked backlash from the New England Power Generators Association, which claims that "the deal could end up costing the state's ratepayers up to $777-million (U.S.) more a year while exporting jobs and tax revenues" even though domestic sources of energy could be utilized instead at a less expensive rate (Marotte 2016). Although Governor Baker succeeded in August 2016 in passing the aforementioned bill, it is clear that the controversies generated over the use of hydropower will become more prevalent in the coming years as Massachusetts becomes obligated by law to "solicit long-term contracts [for] 1,600 megawatt of offshore wind power and another 1,200 megawatts of hydropower or other renewable resources, such as land-based wind or solar" (Schoenberg 2016).

One of the benefits of Governor Baker's bill is the extensive support provided to New England's fledging wind power industry. Although utilizing wind power in New England has been discussed extensively over the years, numerous proposals "ran into roadblocks, including high costs, murky rules about the use of the seafloor, and stiff opposition from people who did not want their ocean views marred by machinery" (Gillis 2016). Despite the opposition from environmentalists, the construction of wind power infrastructure has become more economically favorable due to "economies of scale [which are driving] falling prices [as] … every time wind power doubles, there's a 19% drop in price [according to the Bloomberg New Energy Finance research organization]" (Randall 2016). In short, promoting the construction of more wind farms will reduce the cost of wind power in the long run and make the energy source more competitive compared to natural gas. Furthermore, the U.S. Department of the Interior has already begun "auctioning off the largest area of federal waters in the nation, [off the coast of Massachusetts for the development of offshore wind power]" which will enable New England to generate more wind power in the coming years (Phillips 2015).

It is estimated that the recently auctioned area "known as the Massachusetts Wind Energy Area [off the coast of Martha's Vineyard], could support up to five gigawatts of wind energy… enough to power nearly 1.5 million homes" (Phillips 2015). Although this energy production will prove invaluable as the region continues to move away from coal and nuclear power, much of the U.S. wind power industry in New England remains in a nascent state compared to other parts of the country. The New England wind power industry experienced a setback in recent years with the stagnation of the planned "Cape Wind [project which consisted of 130 offshore wind turbines that was marred by] ferocious opposition from oceanfront homeowners [who felt the turbines would be too close to shore]" (Gillis 2016). However, the favorable economics of wind power, coupled with increasing legislative support in many New England states for the construction of more offshore wind farms, makes the industry confident that "thousands of [wind powered] turbines may eventually ring the United States coastlines … [due to the growing interest in wind power]" (Gillis 2016). In particular, the topography of the New England coastline makes it a favorable region for the construction of offshore wind power as "the strong breezes in the ocean can produce steadier power … [despite] it being easier and cheaper to build turbines on land" (Gillis 2016). In addition, the higher costs associated with creating offshore wind farms "are likely to fall sharply as domestic industry scales up to meet the demand," thereby providing an incentive for New England states to invest in wind power due to the cost reductions from increasing economies of scale (Gillis 2016). Investing in renewable sources of energy such as hydro and wind power will enable New England to reduce its carbon footprint and lower its energy expenditures over time. But this investment alone may not be enough to alleviate the region's winter energy shortages.

Most of this discussion has focused on reducing the region's reliance on natural gas, yet part of the solution to the region's seasonal energy shortages may lie in revitalizing New England's energy grid. The New England area has made great strides in the past decade to reduce its energy consumption "as Rhode Island, Maine, Massachusetts, and Connecticut … have all created statewide policies towards greater overall energy efficiency," yet these achievements have not reduced the overall energy expenditures in the region (Einhorn et al. 2016, 4). By making improvements to the region's energy grid and infrastructure it may be possible to capture additional benefits that are not currently being realized. States such as New Hampshire and Vermont, whose energy infrastructure is not up to date, demonstrate "[the two lowest] annual energy savings range [in the region] at 68 GWh [and 113 GWh respectfully]" compared to Massachusetts at 749 GWh, which possesses a more modern energy grid (Einhorn et al. 2016, 5). New England's energy shortage is exacerbated by the area's inefficient grid system, which makes it "difficult to meet peak demand due to infrastructure [deficiencies]" (Einhorn et al. 2016, 9). Along with upgrading the region's aging infrastructure, it may be possible to improve the efficiency of New England's energy grid by "adopting better practices from [the Midwest Energy Grid such as] … [utilizing] security constrained unit commitment and centralized economic dispatch … to ensure that resources are priced and dealt with demand" (Einhorn et al. 2016, 10).

By ensuring that grid operators are properly allocating resources based on real time data and market needs, it will reduce the region's energy expenditures during peak demand days during the winter. Furthermore, incorporating real time pricing to "better reflect the costs of energy production within the [region] … may encourage consumers to adjust utilization behavior as to lessen peak demands" (Einhorn et al. 2016, 13). If New England ratepayers have an incentive to use less energy because of the high costs that they will incur during the winter months, it may reduce the region's energy needs during those critical periods. It may be possible to achieve this outcome through the implementation of a "smart grid concept [that] allows energy companies to utilize current data when they are making operation decisions … [so] they can raise the price [of electricity during peak periods to encourage] customers to utilize less electricity during this period [and thereby reduce the risk of infrastructure failure from overuse]" (Einhorn et al. 2016, 11). Efforts to incorporate this technology into the region's energy grid are currently ongoing. As of 2015, National Grid, one of the largest utility companies operating in the New England area, proposed installing "[advanced] metering in every home within five years … that would collect costumers' interval usage data, so that it would be usable in the ISO-NE energy and ancillary service markets" (Walton 2015). If National Grid follows through on its proposal it could encourage many of its competitors in the region to follow suit. Providing more real-time data to the region's energy grid would enable operators to fashion an "advanced distribution management system … [that could] create a self-healing grid that automatically re-routes power in the event of an outage" (Walton 2015). This would enable New England's energy grid to better weather the critical peak demand days during the winter and minimize any damage caused by potential outages. In short, any discussions to resolve the region's seasonal energy shortage should integrate improvements in the region's energy grid in order to mitigate the region's energy expenditures and improve its consumption efficiency.

Innovations in the region's energy grid may prove essential to maximizing New England's energy efficiency. Over the course of the last decade, distributed generation resources have been rapidly implemented within the region and are on course within 10 years to "[convert New England's energy grid] into a hybrid grid where up to 20% of the power system's resources are made up of power resources connected directly to retail customers or to local utilities [rather than] the transmission system" (Brooks 2016). In essence, distributed generation resources are defined as "small-scale electric generators that are connected to the distribution system … [and] reduce a consumer's demand for energy … [while] producing small amounts of electricity that can be [returned to the power grid]" (Jackson et al. 2013, 3). The implications of this technology are staggering, as these resources can be utilized to reduce the region's energy expenditures on a per household basis. Furthermore, by encouraging the installation of these resources across the region, it may be possible to "[reduce the] peak load levels [that are served] by the [region's] electric grid" which would lower the price of electricity during critical periods and reduce the risk of infrastructure failure from overuse as well (Jackson et al. 2013, 3). The biggest obstacle that New England currently faces regarding distributed generation is its lack of integration into the New England ISO's energy forecasts.

Until recently, New England ISO did not "incorporate distributed generation resources into its system forecasting," making it difficult to account for the benefits provided by these resources (Jackson et al. 2013, 2). Without a concerted effort to keep track of the distributed generation resources installed within the region, and the impact of those devices, it is difficult to "align ISO's assumptions about future load levels with the reality of reduced load growth across the region" if these resources are not accounted for (Jackson et al. 2013, 4). As a result, insufficient data has made it difficult to model the impact of these resources on New England's wholesale electric market, given that "ISO has paid very little attention to these resources" (Jackson et al. 2013, 4). The electricity generated by these resources could in theory be returned to the power grid and sold to other consumers, but in its current state "most [of the electricity produced by] distributed generation resources is smaller than 5 MW [making it unlikely that the electricity produced by a single household would be returned to the wholesale market]" (Jackson et al. 2013, 4). However, as these resources become more ubiquitous and widespread, it may be worthwhile for New England ISO to investigate whether the electricity produced by these individual household DG resources could be bundled together and returned to the wholesale electric market. Yet, if New England ISO does not begin to acknowledge the benefits provided by distributed generation into their energy forecasts, the region runs the risk of "overinvesting in [New England]'s transmission and generation capacity" by failing to capture the impact of the 2855 MW of distributed generation resources that will be installed in the region by the end of 2021" (Jackson et al. 2013, 20).

Many of these suggestions to diversify New England's energy mix and revitalize its energy grid come in the aftermath of the 2013–2014 polar vortex. The devastation caused by this frigid weather and critical demand period highlighted many of the deficiencies surrounding the region's energy infrastructure during the winter. In particular, New England's reliance on natural gas made it particularly vulnerable to power shortages; during one of the coldest days in January, "six natural gas generators on the New England system reported to ISO-NE that they were unable able to affirm they would be able to procure [enough] fuel [on January 7, 2014] … leading the New England system to experience 15 forced generation outages" (ISO New England 2014, 2). The six natural gas generators in the region were unable to procure enough fuel because of "pipeline infrastructure constraints [coupled with] … a compressor failure on the Texas Eastern [natural gas pipeline] system [which connects to Spectra's Algonquin Pipeline and other pipelines that service the New England region]" (ISO New England 2014, 3). The compressor failure on the Texas Eastern system meant that not enough natural gas was travelling through certain sections of the pipeline because the compressor station was not generating sufficient pressure to force the natural gas through the pipeline. This incident demonstrated to New England officials the vulnerability of the region's limited natural gas infrastructure, as the failure on the Texas Eastern system meant that while "most of the area's pipelines were operating at or near capacity [to compensate for the damage in other places] … a significant amount of the ISO-NE gas fleet was off line due to economics or burning alternate fuel [because of the natural gas shortage]" (ISO New England, 2014, 3). While improvements in the region's natural gas infrastructure may curtail the damage wrought by infrastructure failure, the incident revealed to many the necessity of diversifying the region's energy mix. Reducing the region's reliance on natural gas lessens the risk of "[natural gas] generating units [becoming] unavailable [if] there is an [inadequate] pipeline capacity [because of any significant infrastructure damage]" (North American Electric Reliability Corporation 2014, 2).

Many of the initiatives to reduce New England's reliance on natural gas and improve the efficiencies of its energy grid will take a few years to implement, which leaves the region vulnerable to winter energy shortages and power outages in the meantime. As a result, it will become imperative for the region to utilize the lessons it learned in the aftermath of the 2013–2014 polar vortex to mitigate the damage wrought by any energy shortages during peak demand days. Already, the New England region faces the challenge of another cold season given the arrival of the "bomb cyclone", a historic and intense winter storm in early January 2018, which caused severe power outages and increased use of oil for electricity generation in the New England region due to energy shortages (Chesto and Conti 2018; Samenow 2018). With the advent of another frigid winter, the region's energy infrastructure and generating capacity will be severely tested. However, if New England continues to reduce its reliance on natural gas and promote initiatives to revamp its aging energy grid, eventually it will be able to successfully combat the chilly winters and reduce its energy expenditures.

Notes

1 According to the U.S. Bureau of Labor Statistics, the average price of natural gas per therm in the Boston area was $1.50 during the winter while the rest of the country paid around a $1.00 for the same amount.

2 Essentially MLPs are contracted by utilities and natural gas producers to created natural gas infrastructure to transport natural gas.

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17

INNOVATION AND IMPACT FROM A BRAZILIAN PERSPECTIVE

Andreia Marin Martins, Courtnay Guimaraes and Mauricio Neves dos Santos

Brazil has a large economy facing immense challenges and, despite current circumstances, is slowly recovering from an economic recession[1] to face a more thriving future.

To become sustainable and at a scale befitting the size of the country, various conditions seem to be required. This short chapter will focus on the opportunities and challenges in three different fields: government, private sector and civil society.[2] Special attention is paid to the technological ecosystem and its sustainable innovation impact on the entire economy, dealing with Blockchain, AgTechs, FinTechs, Social Entrepreneurs, Startups and Coworking spaces that are changing the way individuals and companies are doing business, leaving business-as-usual behind.

To understand where Brazil and its citizens are today, and how they are facing the current situation, let's start by analyzing the main challenges.

The government: corruption, debts, bureaucracy and regulation

A couple of years ago, when the Lava-Jato (Car Wash) Operation[3] started, many things changed in the political and private sector, even in civil society, turning everything upside down in a way never seen before in Brazil's history. At first no-one could imagine what would be discovered within many of Brazil's largest enterprises and so many political authorities. People watched as almost all of the economic and political pieces fell apart.

Brazil is large and contains enormous quantities of natural resources, including the Amazon Forest and huge agricultural area, able to feed many millions,[4] as well as meteorological challenges created by climate change and international trade patterns. Nevertheless, the country could move its production system towards more sustainable development, using its immense rural potential. There are some serious issues to be overcome in labor and social realms, mostly as a result of corruption scandals,[5] fighting modern slavery, and fairly distributing the economic benefits of the sector to rural populations. However, there is also intense pressure to make the agricultural sector more sustainable and productive in order to address the UN's Sustainable Development Goals and promote innovation.[6]

Another big challenge is debt. Brazil's total external debt was US$544.1 billion[7] in 2016, and internal debt was around US$1.2 trillion[8] in 2015. These high levels reflect the inability of authorities to manage the system, causing damage to Brazil's development capacity. The total amount paid in 2017 in taxes by Brazilian people was US $563.8 billion.[9] Debt levels create problems in infrastructure, healthcare, education, and many other essential sectors, reducing the capacity of the country to look for sustainable development and to provide for the elemental needs of its citizens.

To overcome this situation Brazil needs to promote a new future by clearing up systemic corruption, creating mechanisms to build accountability for public expenses, improving the political system and modernizing the regulatory and bureaucracy frameworks in order to jump into the 21st century economy.

In this regard there are several initiatives that are helping to do that in an efficient way. An example of civic participation is the Institute for Technology and Society of Rio de Janeiro (ITS Rio)[10] and its mobile app Mudamos[11] where people can sign electronically to support laws proposed by popular initiative, revolutionizing previous physical mechanisms of participation in the public sphere. A key role of ITS Rio is in the field of research, and the report "Algorithm Transparency and Governance: A Case Study of the Credit Bureau Sector"[12] is proof of how technology can manage personal data and protect people in the digital era.

Another example of how active citizenship can change reality is the "Serenata de Amor (Serenade of Love) Operation – Artificial Intelligence for Social Control of Public Administration."[13] This crowdfunded project is an AI bot called Rosie that tweets all the inconsistencies found in public expense accounts, highlighting the public profile of every politician in social media . It has found more than 8,000 suspicious reimbursements so far, reflecting more than US$1 million of public funds.

The current situation is still very bad. Central government is immersed in serious corruption scandals, reputations are poor and confidence is low,[14] and the unemployment rate is too high.[15] However, across many sectors there is increasing participation in the market, especially by those investing in sustainable strategies and becoming digital, reinforcing the benefits of the new economy, based on the concept of Peter Diamandis' "6Ds of Exponentials: Digitized, Deceptive, Disruptive, Demonetized, Dematerialized and Democratized," "Technology is disrupting traditional industrial processes," says Diamandis, "and they're never going back."[16]

Innovation in Brazil

The private sector was hit by corruption scandals as much as the governmental sector, because the largest Brazilian enterprises have close links with the government.

Several top executives were arrested as part of the Lava-Jato investigation and the private sector was severely shaken.

Today the country is facing a "decline in investments to the lowest level since 2000, mainly due to the retraction of the private sector."[17] Along the lines of the global crisis, the internal market was severely damaged by uncertainties, public and private mismanagement and lack of investment capacity. Another critical issue in this scenario is the high rate of family indebtedness, which has reached 58.2 percent,[18] the highest for 7 years.

The figures are not good, but there is hope at the end of this analysis because despite everything there is still space to overcome the challenges and start to promote sustainable development. This is beginning to happen in several different areas.

In the agricultural sector, for instance, improvements in yield which "reduce waste during food producing, improving techniques, equipment and packages during the sowing, harvesting, distribution and storage process, shortening the distance between producer and consumer"[19] have guaranteed better outcomes. In accordance with the Food and Agricultural Business Principles (FAB Principles)[20] extra effort was made to reach the goals, making the sector more sustainable and accountable, voluntarily releasing the annual report about the steps taken towards each of the six principles: (1) aim for food security, health and nutrition; (2) be environmentally responsible; (3) ensure economic viability and share value; (4) respect human rights, create decent work and help communities to thrive; (5) encourage good governance and accountability; and (6) promote access and transfer of knowledge, skills and technology.

The startup ecosystem is doing a good job in this regard with examples such as "Maneje Bem"[21] which aims to be Brazil's biggest online family farmers' community. Their objective is to "disseminate sustainable agriculture through digital platforms and contribute to the connection of the productive chain of organic."[22] The startup will use IBM Watson for research and analysis.

Another good case from agriculture is SpecSolo, which describes itself as:

> a technological package for soil analysis that uses vibrational spectroscopy and artificial intelligence techniques, using precise and efficient algorithms, developed with the aid of a robust database, with more than 120,000 samples of soils representative of Brazil. It has the advantage of analyzing soil samples in a non-destructive, fast and economical manner: dozens of fertility parameters (soil organic carbon, pH, calcium, magnesium, phosphorus, potassium, among others), and soil physics can be analyzed simultaneously in just a few seconds.[23]

In the retail sector, transformation is even greater, as per the example of Pier X, an experience-focused platform that combines technology, fun and culture in a 'phigital' environment – where you seek to be present through the physical and eliminate intermediaries through digital.[24] CEO Gustavo Schifino says consumer behavior has changed from simply wanting to possess things to being more conscious and aware about impact, seeking better experiences with very low environmental impact.

Such transformations represent on the one hand a huge challenge, as everything is changing at an exponential rate that requires adaptive capacity and flexibility, while also offering many opportunities to create efficient, more reliable and accountable processes, products and enterprises geared towards a more sustainable and innovative environment.

Social entrepreneurs: changing civil society

Numbers of social entrepreneurs have grown exponentially to become a force of change in the traditional market, solving social problems and bringing profits in a very fair way, transforming social purpose into business endeavor.[25] Brazil currently has about 20 funds which between 2014 and 2015 raised more than US$100 million in investments aimed at companies with social impact. That number represents almost half of total investments in the same area over the last 10 years.[26]

There are lots of examples of how young and talented people are accomplishing this. The Asta Network, for example, has become a driving force for good through innovation, education and design by transforming waste into assets and empowering artisans to become entrepreneurs.[27] The FazGame is a startup which aims to improve and innovate education using games and storytelling. It is changing the way teachers, schools and students are learning through its very amusing and professional online platform.[28]

Empathic efforts to understand each other, care and help every single person to overcome limitations and thrive in life are helping new companies succeed through this new social movement.

Sustainable innovation in Brazil: the blockchain perspective

Blockchain is the ultimate lever for bringing so-called Third World innovation up to speed alongside more advanced countries, and in some cases even leapfrogging ahead. We already have examples from similar countries and the technology (with the other exponentially disruptive levers) is now mature.

First, in the main use of this new architecture, creating a new virtual currency can be the only way of surviving. At the time of writing, Venezuela and Zimbabwe are the main cases where only through global cryptographic digital assets can the population store value and even maintain possession of their wealth.[29]

After that, a bureaucracy killer is the next simple and practical application, with some cases being so drastic they can provide refugees with a single proof of their existence, even in their miserable (and sometimes deadly) path to survival in developed countries.[30] In Brazil, we´ve got to be clearer about our democratic state, and we've built an open system to make it clear we're supporting laws[31] with our votes. And we can build an alternative system of general records (asset possessions, house titles, land titles, and so on) using new digital signatures and document recording systems.[32]

And lastly, our entrepreneurial ecosystem can also obtain funding for social enterprises and other startups using global trading of crypto-assets, through crypto-exchanges.[33]

Finally, in the world of cooperative distributed applications, we can launch new post-platform businesses that could even outpace global titans in services, such as importing the new coworking services models that is only possible in blockchains.[34]

Setting the stage

To achieve this idealistic, almost utopian scenario, we must prioritize education, incentives and cooperation among companies, governments and ecosystems to levels never seen before.

On the educational side, streamlined curricula must be designed and taught in every way possible, not only in traditional institutions, but on the web, through cooperatives, and beyond.[35]

On the companies/corporate side, we must enforce the concept of open innovation by nurturing incubators, accelerators and ecosystems as we're doing in the south of Brazil.[36]

As far as the government is concerned, besides keeping a flexible attitude on the regulatory side, e.g. 'sandboxing' or protecting new enterprises while they mature,[37] tax incentives would be more than welcome, especially in our hugely overtaxed country.[38]

Our role as industry leaders

As industry leaders, we must take immediate action and build companies, empower individuals to build companies, nurture innovative leadership and create wide and fierce competition. We're seeing the most dramatic changes that could have enormous benefits for a developing country such as Brazil.[39]

Closing considerations

Decentralization is not a technology; it is a new and powerful economic model.[40]

For the first time, sustainable models can exist in sync with fierce competition and capitalism, without the concentration of forces usually seen today.

Of course, there is much more we could say about Brazil and its potential to thrive through sustainable innovation and impact, but we can only go so far in this short chapter.

It's a brave new world. *Alea iacta est.*

Notes

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18

AN EXPLORATION OF LANDFILL TAX AS A WASTE MANAGEMENT STRATEGY

Jason Mazzella

While most people are familiar with the concept of imperialism, fewer have encountered the supposedly parallel – and fictitious, for the time being – idea of "experialism." Introduced in David Foster Wallace's 1996 epic *Infinite Jest*, the term describes an absurdist hypothetical of what might happen in a world characterized by rampant consumption and waste production. Faced with a literal overflow of waste, the fictional United States government physically cuts off parts of northern New England to create the "Great Concavity": an isolated, giant landfill into which the rest of the country can deliver its trash, toxic or otherwise. The United States then forces Canada to take stewardship of this region, "experializing" that which it inevitably produces but cannot (or will not) treat safely or recover. Wallace wrings the conceit for all its cautionary worth, further describing the scientific production of a chemical used to neutralize the toxics in the Concavity which functions *too* well, and leads to the necessity of regularly dumping contaminated waste as to prevent uninhibited overgrowth of a now completely poison-free forest. This dystopian depiction of a society so dependent and consumed by waste is hilarious in the context of the story – people construct enormous catapults to fling their waste into the Concavity and children tell tales of the monstrous creatures that roam the landscape of trash. The roots of the story, however, are anything but humorous when viewed in conjunction with the waste management environmental crisis that the United States faces after decades of rapid economic growth and consumerism. In particular, the status and usage of American landfills demands more of our attention, and domestic watchdogs should look at foreign case studies to evaluate the potential of placing a tax on landfill use as a waste management system.

Many consumers are completely unaware of how much waste is produced on a daily basis – as a civilian in a household it is easy to forget what happens to your trash after it is picked up by the city or a disposal company. Corporations are often more conscious of their waste production because the treatment or discarding of waste, especially inorganic waste, is costly and may figure prominently in their bottom line. Excluding industrial, hazardous, or construction waste, the United States in 2014 produced upwards of 4.4 pounds of municipal solid waste per person per day (EPA 2016). Municipal solid waste includes packaging and food waste, as well as larger or heavier material such as furniture, computers, or tires. This figure is actually at its lowest since the mid-1980s, having peaked at nearly 5 pounds in 2000 and slowly decreasing since then. This improvement is not to be taken for granted – in the United Kingdom, waste per person per year increased 14 percent between 1996 and 2006 to more than half a ton per year. However, British waste per person per year is still lower than American production on an absolute level (United Nations 2008, 115).

The metric of greater interest here, however, is how much of that waste is recovered in some way, either through reuse, recycling, or (at the very least) disposed of in a method that allows for energy production like some incineration techniques. In 2014, only about one quarter of the 4.4 pounds per day per person was recycled. More than half, 54 percent, is sent to a landfill (EPA 2016). Again, this is a vast improvement from the 89 percent that was sent to landfill in 1980, but this dumping still constitutes a large portion of our waste's final destination. More than 100 million pounds of municipal solid waste alone is sent to landfills in the United States every year. Furthermore, composting recovery rates differ by category of waste. The Environmental Protection Agency reports highest recovery rates for paper and metal deposits, while plastics and food sit towards the bottom of the list (EPA 2016).

Landfills also present many problems across the environmental, economic, social, and political spectrum. The EPA asserts that "modern landfills are well-engineered facilities that are located, designed, operated, and monitored" as to comply with regulations and minimize harm, but there are many tangible and intangible externalities and controversies that are unavoidable with such widespread use (EPA 2014). There are over 3,000 municipal solid waste landfills operating in the United States. Each has an average lifespan of less than 20 years, which means that local governments are continually faced with decisions regarding the construction, expansion, and closure of facilities. The landfill footprint is generally trending toward fewer but larger sites: facilities have been closing at a higher rate than they are opening, but the average size is increasing swiftly (EPA 2012). This trend exacerbates some of the issues landfills present and mediates others.

One of the greatest controversies surrounding landfills is the siting process. First, landfills need to be constructed in areas that will have minimal impact on the environment around them – that is, away from water tables, faults, wetlands, or floodplains. Adherence to these tenets can be difficult to assess and disputes can arise easily, especially given the prevalence of "not in my backyard" attitudes. These complaints are not unfounded, as there are indications that proximity to a landfill can be linked to generally lower living satisfaction as well as more tangible health problems arising from the waste, the fumes it produces, and the scavengers it may attract (Bartelings et al. 2005). The confluence of these environmental and political factors can make it very difficult and costly to even find a place for the landfill, let alone manage the issues it will create once operational.

An active landfill then presents two major environmental drawbacks: the loss of potentially recoverable resources and the emission of landfill gases. First, sending waste to a landfill is often cheaper than separating and recycling the recoverables within. The Dutch Institute for Environmental Studies has documented a hierarchy of waste handling (Bartelings et al. 2005). In this hierarchy, landfilling sits at the bottom, and market interventions would be necessary to elevate the marginal short-term cost to a level that would both reflect the true overall cost of landfilling and induce recycling or even incineration regardless of the type of waste. As a landfill user interviewed by PBS explains:

> What's wrong with the system now is that landfilling is so cheap, it becomes the easiest thing to do. We basically make our decisions based on immediate costs and defer the long term impacts to another day or another generation.
>
> *(PBS 2012)*

It is difficult to say how much of the waste currently landfilled is a candidate for recycling or repurposing – new technologies are being developed constantly to recover resources more effectively, so any current figures likely underestimate the potential, especially if proper incentives are introduced to make landfilling more costly. Second, the natural bacterial decomposition of organic waste in municipal solid waste landfills produces a mix of gases that contains both methane and carbon dioxide. Methane is a greenhouse gas thought to be nearly twenty times as detrimental as carbon dioxide, and the constant production of methane by landfills is cause for serious environmental and social concern (EPA 2011).

The distinction between public and private landfills is also controversial in its own right. Increased capital and operating costs have prompted the consideration of privately owned or operated landfills in many municipalities, trading higher gate fees for the opportunity to avoid construction costs (Hauser 1994). A private landfill also deflects controversial siting decisions away from the government and may be an effective shield against vitriolic public opinion. Some have claimed that private landfills also offer higher productivity, though well-managed public facilities have been shown to match their rates (Hauser 1994). The breakdown of private and public facilities varies by region due to different governments' fluencies in operating and financing landfill schemes; Florida is mostly public, for example, but Ohio has a strong competitive environment that encourages private facilities (Segal and Moore 2000).

Whether public or private, landfills are a widely used waste disposal option with a slew of harmful effects and long-term social, environmental, and economic costs. Despite some improvements in proportion recycled and waste per capita, the rapid growth of solid waste – in some locations, growth rates are faster than the economy overall – have sparked conversations over how best to mediate and discourage landfill use (Bartelings et al. 2005). As in other efforts to discourage polluting behavior, such as carbon emissions, policymakers have largely turned to debating the merits of two economic instruments: taxes and cap-and-trade schemes.

The logic behind a tax is simple. Charging a premium for landfill usage, in addition to the standard gate fee, effectively increases the marginal cost of using a landfill and reduces its attractiveness relative to other options like incineration or recycling. In the vast majority of countries where such a tax has been introduced, it is directly applied to the landfill operators themselves and expected to be passed on to the clients (consumers or corporations) by way of proportionally increased fees. It is also common practice to operate at least two different tax rates for different types of waste depending on how easily the waste could be disposed of by a preferred method. For example, the United Kingdom classifies a low rate for "inactive" waste, such as concrete and other inorganic compounds, and a high rate for "active" waste like wood and plastics (HMRC 2014). The higher fee for active waste places a greater incentive to divert materials that can readily be recovered resources if recycled through a process that, without the tax, would be more expensive. The tax is most often charged through unit-based pricing, which has the advantage of most effectively influencing the consumer's behavior and following the "polluter pays" principle. It may, however, involve high administration costs and could potentially promote illegal disposal of waste (Bartelings and Linderhof 2006). As with other taxes of this type, it also leaves uncertain the final volume of waste that will be landfilled – this is sensitive to the clients' willingness to pay and the elasticity of demand for landfills.

The other standard instrument, cap and trade, leads to uncertainty on the other side: the level of landfill waste is known, but the cost of achieving such a mandate is uncertain. Cap and trade is an allowance system, in which the government sets a limit on how much waste can go to all landfills in aggregate (a cap) and either auctions off or distributes permits that can be sold and purchased in a marketplace (trade). This encourages efficient allocation in that permits will end up with those most willing to pay for the right to pollute. In many situations, the first round of permits is gifted to companies to encourage early compliance. This stands in contrast with the immediate cost imposed by a tax, and may cause differences in the timeline of success for each method. As discussed below, the United Kingdom presents an optimal case study for analyzing the interplay between cap-and-trade schemes and a straightforward tax, as both strategies have been employed since 2005.

Both mechanisms would have tangible effects on the different players involved in the waste landfilling chain. First, the government setting the tax or allowance receives revenues. The size of the revenues depends on the size of the tax or pricing of the allowances, and they can be utilized in a variety of ways as discussed below. The landfill operators themselves should not be affected profoundly, as the added tax they are compelled to pay the government is passed on to their clients by way of charging higher fees. As such, the clients themselves are most affected – as we should expect from a well-constructed tax if we assume that clients are indeed the "polluters." They face higher costs of landfilling and, depending on the degree to which the costs rise, may shift their waste disposal choices towards incineration or recycling to maintain the cheapest portfolio. This cheapest option will inevitably be higher than it was without the tax, representing the welfare loss attendant with any tax. It is possible that small and medium enterprises will face disproportionate short-term losses if they do not have the resources to change their operations quickly and avoid the tax, as has been demonstrated in the United Kingdom (BusinessGreen 2013). On the other side of the equation, those operating recycling or incineration facilities might be expected to benefit from a tax because it incentivizes diverting waste towards their businesses. However, there are some potential negative externalities to these players as well: it is possible that the tax would indirectly reduce the quality of materials sent to the recycling sector or that it would increase processing costs beyond capacity (Ploumis 2013). Given concerns of capacity, a landfill tax might encourage investment opportunities in the construction or operation of new recycling facilities to meet increased demand. There could also be opportunities for investment in companies specifically dedicated to front-end waste reduction or zero landfill initiatives, as the rising cost of landfill dumping may give them a renewed competitive advantage.

The aggregate of these tax effects constitutes an overall monetary welfare loss – as does any tax – because supply and demand are forcefully mismatched. In exchange for this monetary loss, instituting a landfill tax must drive potential non-monetary benefits. The most obvious of these is the social benefit of reducing landfill waste levels and thus mediating the environmental and social concerns that were discussed above. Evidence from the Netherlands suggests that the reducing landfill waste does not lower methane emissions on a 1 to 1 basis, but that a 10 percent reduction in waste volume might result in a drop of nearly 7 percent in greenhouse gas emissions (Bartelings and Linderhof 2006). It has been estimated that the diversion of just paper and cardboard from landfills in 2012 reduced carbon dioxide emissions by more than 150 million metric tons, the equivalent of removing 33 million cars from the road for a full year (EPA 2012). Landfill closures, or even the slowing of new facility construction, may lower the likelihood of aquifer or soil contamination while safeguarding property values and health outcomes around the potential site. In penalizing disposal of active waste more than inactive waste, a well-structured tax can also disproportionately reduce the amount of recoverable waste that ends up in a landfill.

Given that this foregone landfill waste still requires disposal, a landfill tax complementarily encourages disposal methods higher up on the environmental hierarchy of treatment options. Though incineration too can produce undesirable particulate emissions, technological advancements have increased the safety of and reduced the material pollution from waste incinerators more so than for landfills (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety 2005). Recycling treatment options produce tangible resources out of waste that can be sold or reused in future production, pushing toward the idealized closed loop of a zero waste production cycle. Recycling can also be a powerful energy saver: every ton of mixed paper recycled can save the energy equivalent of more than 160 gallons of gasoline – volumes that could rise substantially under a well-structured landfill tax (EPA 2012).

Furthermore, the overall heightened cost of waste disposal induced by a tax can strongly incentivize the crucial front-end waste reduction, through design or diverting byproducts to other uses, which must complement landfill improvements for a comprehensive solution. Indeed, both of these ends – promoting recycling and incentivizing front-end waste reduction – can be furthered by the tax through indirect pathways as well as those direct mechanisms. There is precedent for utilizing revenues that have been generated by the tax to fund recycling subsidies or grants for efficiency innovations (Bartelings and Linderhof 2006). This "carrot and stick" mix of policies can be a more powerful agent for change than either incentives or punishments on their own, while ensuring that the government is not viewed as profiting at the expense of its constituents and their businesses.

Revenues from a tax can also provide funding for other environmental initiatives to benefit the community (Fischer et al. 2012). For example, New Zealand returns half of its landfill tax revenues to local authorities to cover costs of improving monitoring and treatment techniques, and has established a "waste minimization" fund to explore other options for progress (Ministry for the Environment 2008). Programs to explore more efficient energy generation from captured landfill gas also present an attractive (if hopefully temporary) area for investment of tax revenues.

Finally, there is growing interest in the practice of utilizing the physical plants of mature landfills as a site for solar energy generation. Closed landfills are largely ineligible for use in traditional ways, but constitute large plots of land in open spaces that can effectively be prepared for and covered by solar panels. A covered landfill in Hartford, Connecticut was recently the first in the state to institute such a plan. Over 4,000 solar panels on the site can now generate as much as a megawatt of electricity each day, which can power up to 1,300 households when combined with energy creation from gas wells that capture and sell gas emissions (Dowling and Zhang 2014). Although it is true that a landfill tax would reduce the supply of these emissions for energy generation, this is not a powerful argument against a tax because it mistakes the mediation of a negative externality for an intrinsically positive effect – energy production from "dirty" sources should not be a factor in a sustainability solution unless excising those sources carries prohibitive long-term costs. That being said, the EPA's Landfill Methane Outreach Program, under which new landfills are outfitted so as to maximize recovery and use of landfill gas as an energy resource, should not be construed as encouraging landfill dumping. As long as the problem exists, mediation tactics are valuable and are worthy of attention for improvement (EPA 2011).

A discussion of the potential benefits and drawbacks of a landfill tax should naturally review historical examples of such programs and their efficacy across a variety of metrics as to verify the more theoretical effects posited above. There is a fairly extensive set of examples from which to draw insights – over 20 countries in the European Union alone have implemented some variation of a landfill tax (Fischer et al. 2012). We now focus on the United Kingdom, where landfill taxes and cap-and-trade schemes are more than a decade old and are well documented.

The United Kingdom first instated a tax on landfilling in 1996 with the express goal of "internalizing [the] externalities" that accompany regular landfill use (Bartelings et al. 2005). Given the UK's national obligation on local authorities to collect household waste for free, the "polluters" who bore the tax in this sense were not only corporations that utilized landfills, but also local governments, who now scrambled to find methods of reducing household waste and encouraging better separation of recyclables. However, the tax included a prohibition on charging individual households based on volume so that local governments could not shunt responsibility for improvement onto citizens without much power to make structural changes (United Nations 2008, 114). The overall strategy cites an emphasis on minimizing volume but supplements this primary goal with incentives for new investments and delivery structure reforms, as well as public grants for efficiency innovation. For example, a program called the Tradable Compliance Credit System which accompanied the landfill tax allowed private companies to collect and process used packaging and submit their contributions for public rebates, drawing the private sector into the fight against landfill growth (United Nations 2008, 114).

Upon its inception, the United Kingdom's landfill tax charged £2 per ton of inactive waste and £7 per ton of active waste (Bartelings et al. 2005). Though it is evident that the absolute rate for active waste is higher, the relative increase in cost of disposal was actually higher for inactive waste (Bartelings et al. 2005). These rates were held steady for the first 3 years of the program, after which the standard active rate was increased incrementally each year. The price increase was prompted by reports that questioned the efficacy of the program in its first stages, possibly due to rates that were too low to systematically alter landfilling behavior. Some studies reported increased recycling and large reductions in demolition and construction wastes (Bartelings et al. 2005). Others attribute these effects to confounding factors such as packaging regulation changes, citing the lack of success with regard to municipal solid waste figures, which continued to outpace economic growth overall (Martin and Scott 2003). Given these reports' reasoning that the slow speed of improvements was based on the persistent relative cheapness of UK landfills, the active waste tax figures were continuously increased. By 2014, the active rate had risen to £72 per ton and inactive rates had inched up to £2.50 (Maccioni 2013).

To bolster the initially sluggish effects of the landfill tax, the British government in 2005 introduced the Landfill Allowance Trading Scheme (LATS), a cap-and-trade system that set an upper limit on biodegradable waste. This system offered more assurance that volume goals would be met, but allowed local governments to meet current needs by borrowing permits against the future or selling unused permits in the marketplace. Officials estimated that £10 million worth of permit exchanges took place in the first round of LATS operations (United Nations 2008, 114). The program also announced that the ceiling for biodegradable landfill volume would decrease rapidly in subsequent years, incentivizing forward planning for waste reduction and diversion.

The combination of LATS and higher tax rates appears to have contributed to "the fastest improvement in recycling rates of any EU country between 2001 and

2010" (BusinessGreen 2013). The share of waste recycled in the United Kingdom increased from 6 percent to 26 percent over the same period, and the lowest proportion was sent to landfills since the first estimates were recorded in 1983 (United Nations 2008, 114). This success is, however, tempered by a variety of ongoing challenges. Though the government has set further goals to reduce the absolute volume of active waste landfilled from 7.5 million tons in 2013 to 5.2 by 2020, improvements seem to have slowed in the late 2000s despite continued hikes in the tax rate (Reichel 2013). The price of LATS permits has still not reached zero, indicating persistent demand for the option to landfill potentially recoverable active waste. Furthermore, there have been indications that the rising tax has disproportionately affected small and medium enterprises that can devote fewer resources to restructuring their waste management strategies: one report estimates an overall economic loss of £500 million (BusinessGreen 2013). The British government has continued to support the concept that, in the long term, a stronger case for recycling will cause systematic adjustment and social benefits that have no hurdle cost. In terms of behavioral change, the British experience with landfill taxes is an ongoing success story, but more attention should be paid to the costs incurred by such a high tax rate and whether adding policy instruments might promote further diversion or alleviate the burden on local governments and small businesses.

Another example of an additional policy option – a complete ban on landfilling of combustible waste – has been implemented in the Netherlands. The basics of the landfill tax are largely similar in the Netherlands and the United Kingdom, though some interesting divergences merit further discussion. First, the Netherlands initially charged the same tax for active and inactive waste at €13.25 per ton, which in itself caused some early decreases in landfill volume. After a few years, the government began raising the active waste rates and saw continued improvements in both recycling and incineration compared to landfill volumes. Recycling rates rose 30 percent and incineration of combustible waste by 75 percent from 1996 to 2003 (Bartelings and Linderhof 2006).

While the United Kingdom had difficulty managing municipal solid waste because it refused to place the burden of improvement on its citizens, the Netherlands took a more comprehensive approach that placed some responsibility on citizens to monitor their waste production. For businesses, the Netherlands imposed mandates that producers reclaim certain waste from products they sell to drive front-end waste reduction and better use of materials. Finally, they paired a tax on landfilling with a subsidy for incineration. This mix of initiatives worked so well that the Netherlands began importing British waste for incineration, and in 2012 the tax and subsidy mix was abolished because the government was paying out more than it was earning in revenues (Scharff 2013).

Given these successful early experiences across the European Union, the absence of a widespread landfill tax in the United States is surprising. This lack of attention could be due to a number of factors and obstacles to change. First, there may be misgivings about the economic welfare loss associated with a tax for businesses and local governments and how it compares to the long-term economic and social benefits. This uncertainty is justified – as should be clear from the case studies above, most of the literature is focused on quantifying the effect of a tax on waste volumes and spends less time analyzing the economic implications. Closer examinations of European experiences from a strictly economic point of view are likely necessary to impel American action, especially given the American aversion to new taxes that may be passed on to individuals or small businesses.

Furthermore, the United States frankly faces higher-impact options for new nationwide environmental policies. Although waste management is an important issue that needs to be addressed – and the sooner the better, given the myriad environmental benefits that spring from incentivizing improved front-end resource management – it is not the most glamorous cause on the list. Issues of air pollution have captured the public consciousness to a greater extent, and clean energy incentives are more inspiring than trash reduction. Political realities necessitate judicious selection of big ticket, national environmental issues for action. As such, adoption of a landfill tax in the United States will likely be better served by local or state government initiatives until it can gain widespread attention. Alternatively, corporations might consider independently committing to reducing landfill use, which may both offer the company a competitive advantage in resource management and attract eco-minded customers.

If and when the United States moves to consider implementing a landfill tax, there are a variety of lessons to be drawn from the European experiences despite some shortfalls in the recording of their true economic costs. First, the tax must be high enough to make landfilling more expensive than the next cheapest option. If the marginal cost of landfilling an extra ton of waste is raised but not raised beyond incineration or recycling cost, the tax will bring an economic welfare loss without providing a social benefit – this is not a tax to be phased in as in the United Kingdom. The British experience also indicates that a tax can be set too high and illustrates the potential danger of diminishing marginal returns to the landfill tax. Optimal pricing may require experimentation and study of landfill demand elasticity, but the tax should not be continuously or blindly raised if landfill use persists.

Second, the tax should be specifically transferred to the source of waste most harmful or most in need of reduction; for example, only when the Netherlands transferred responsibility to households did municipal solid waste decrease. The tax should be structured to ensure that the polluter pays, though there are arguments for treating either producers or consumers as the polluter that must be carefully considered. Third, and possibly most important, the landfill tax should not stand on its own, but be embedded in a mix of policy instruments that also promote alternatives. The goal is not just to reduce landfill use, but to divert what was previously landfilled to recycling or incineration and to cut waste out before it is produced. Subsidies for recycling, producer reclaim mandates, incentives for delivery innovation, and stricter bans on biodegradable landfilling add a "pull" to the landfill tax's "push" up the hierarchy of waste treatment options. A coordinated effort to accomplish positive steps rather than solely reduce harmful actions will have more of an impact.

Careful attention to and emulation of the successful European experiences with landfill taxes and cap-and-trade schemes should position the United States to explore the benefits of implementing such regulations on domestic waste management; both the United Kingdom and the Netherlands' success in reducing their landfill use through different mixes of policy and economic instruments provide a strong case for action. Reducing the amount of biodegradable and inactive waste sent to landfill can both limit environmental degradation of land and water around the site, reduce harmful methane emissions, and increase the amount of recoverable waste diverted to reuse and recycling. European countries with history of a landfill tax seem not to have experienced any significant business or economic disruption that would outweigh the social and environmental benefit of such systemic changes, though more research should be done to explore how policy might best mitigate the negative effects of a tax on smaller corporations and consumers themselves. Local pilots of the program may be able to provide further evidence or draw attention to the issue. Though not the highest impact reform in terms of slowing climate change or solving the energy crisis, waste management improvement through a landfill tax scheme should be an easy and effective step forward towards a cleaner and less cluttered future.

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19

GERMANY'S SIMPLE SOLUTION TO COMPLEX WASTE CHALLENGES

Reilly Witheford

Throughout the past century Germany has without a doubt become an international leader in sustainability. The country has implemented efficient public transportation systems and renewable energy sources, and it turns an impressive 62 percent of its waste into new products or fuel (Container Recycling Institute 2016). In the 1970s, when the world experienced a rise in the number of one-way beverage containers (containers that could only be used once, and not refilled) in place of refillable bottles, Germany was quick to find a solution. To combat the unfortunate consequences of littering and global warming that would come from the increased use of one-way containers, a deposit law was implemented to help preserve the existing refillable bottle systems. The country's current beverage container system, which involves both the use of refillable bottles and compulsory deposits on one-way containers, has successfully increased recycling and reduced waste while also creating more jobs.

Germany's bottle collection laws: a simple solution to a complex waste problem

Germany's current methods of bottle collection are by no means an old system. Their implementation was sparked by the rapid increase in the number of one-way beverage containers in the 1970s leading to concern over their disposal. The first waste law in 1977 was designed to preserve the existing refilling systems, for fear that the industry would switch completely to one-way containers if the right infrastructure for the preservation of refillables were not put in place (Grass Roots Recycling Network and Institute for Local Self-Reliance n.d.). The law allowed the government to pass ordinances to regulate the beverage container market. In 1991, it passed the Ordinance on the Avoidance of Packaging Waste to make manufacturers responsible for taking back the packaging of their products. The ordinance set a target for beverage companies, obliging them to package 72 percent by volume of their products in refillable containers (Container Recycling Institute 2016). With this Packaging Ordinance, Germany gained a reputation "as a pioneer in mandating producer responsibility for packaging waste" (Grass Roots Recycling Network and Institute for Local Self-Reliance n.d.).

In 1993 the percentage of refillable containers peaked, and in 1997 it fell below 72 percent for the first time. This was primarily due to the increasing prevalence of beer cans and one-way mineral water bottles (Grass Roots Recycling Network and Institute for Local Self-Reliance n.d.). However, Germany still remained an international leader in refillable containers despite this. And as a response to the decline in refillables, in 2003 the government instituted a standard compulsory deposit of 0.25 euro on all one-way beverage containers, regardless of material or volume. The law was designed to reduce littering from such containers and to protect the environmentally-beneficial refillable system (Container Recycling Institute 2016). This deposit applies to "environmentally non-beneficial beverage containers made of metals, glass and plastic" (Resch 2009, 33). However, it excludes juices, milk, and wine, and drinks in "ecologically advantageous packaging" such as cartons (Federal Ministry for the Environment 2014, 3). Beverage fillers and retailers pay for the entirety of this system, and the industry keeps any unredeemed deposits.

Before this deposit law was passed, refillable containers had already been subject to a deposit of lesser value (0.08 euro for beer bottles and 0.15 euro for water, soft drink, and juice containers), leading consumers to believe that drinks in reusable bottles were more expensive than drinks in one-way packaging (Resch 2009). But after the one-way deposit law was passed, beverages in one-way containers became more expensive than refillables due to their higher deposit, unless the deposit was redeemed after the container was used.

Organizing bottle collection through the Deutsche Pfandsystem GmbH

To define the deposit-refund system for one-way beverage containers, in 2005 the beverage and beverage container production industries established the Deutsche Pfandsystem GmbH (DPG, or "German Deposit System"). DPG established a uniform label, which is integrated into the barcode of all one-way beverage containers as an easy identifier of its mandatory deposit (Anker Andersen A/S n.d.). The DPG also "provides the legal and organizational framework for the settlement of the deposits between companies participating in the system" by setting up clearing houses that balance out deposit surpluses and deficits between distributors (Anker Andersen A/S n.d.). This is necessary, because some drink retailers, such as gas stations, sell more drinks than they take back empty drink packaging, and vice versa (Federal Ministry for the Environment 2014).

Collectors of used beverage containers (both refillable and one-way) include shops, supermarkets, or independent collection centers, and they collect containers either automatically or manually. Manual collection involves a customer returning their used beverage containers to a cashier who pays them the refund owed for the deposits on the containers. Automatic collection involves reverse vending machines, which take in used beverage containers and scan them for labels (including the DPG one-way label) that indicate the value of the deposit on each of them. The customer then receives a receipt with the refund owed on their deposits, which can be redeemed upon shopping (Anker Andersen A/S n.d.).

Environmental and social benefits of refillable bottles and deposit laws

When empty refillable bottles are returned by the customer to a retailer, they are then sent to the beverage manufacturer for washing and refilling, thus giving them a much lower carbon footprint than one-way bottles (Container Recycling Institute 2016). One-way packaging generates more waste, consumes more energy during the manufacturing and disposal processes, and contributes more to the greenhouse effect (Federal Ministry for the Environment 2014). While one-way containers are only filled once before they are (ideally) recycled, refillable glass bottles can be circulated an average of 40 times, and refillable PET bottles can be circulated around 20 times, before they have to be recycled (Resch 2009). Refillable bottles also have a much lower impact on global warming – the status quo one-way PET bottle generates 139 kg CO_2/liter of waste, whereas a refillable glass bottle of the same size only generates 84 kg CO_2/liter, and a refillable PET bottle of the same size only generates 68.7 kg CO_2/liter (Resch 2009).

As long as both refillable and one-way beverage containers are returned to the retailer for a refund on the deposit, both beverages have the same net cost. However, in effect, refillable beverages end up cheaper for consumers, because of their reduced waste management costs and initial beverage prices. Refilling systems have boosted the German job market, as they require more labor effort than one-way systems – 53,000 jobs would be lost by switching completely to one-way beverage containers (Grass Roots Recycling Network and Institute for Local Self-Reliance n.d.). The mandatory deposit law has allegedly "put an end to the throwaway mentality," and in a 2000 poll, 69 percent of Germans said they preferred to buy beverages in refillable containers (Federal Ministry for the Environment 2014). Before 2002, an estimated 1–2 billion one-way containers were littered, but the deposit law has in effect created "zero" littering of one-way containers by resulting in a 95–98 percent rate of return (Resch 2009). While the best way to promote refillables would be to ban all one-way beverage containers, European law prohibits this, because it would interfere with the internal market. Thus, Germany has done the best it can to be environmentally friendly, given the barriers set by EU law, through its mandatory deposit on one-way containers (Federal Ministry for the Environment 2014).

It is important to note that while Germany is a leader in refillable bottles and one-way deposit systems, its is not alone. Similar container deposit programs exist elsewhere in Europe, and even in some states of the USA. However, the US does not use any refillable bottles, as this would not comply with its Food and Drug Administration (FDA) regulations. In Europe, Sweden has had a can deposit since

1984 and a one-way bottle deposit since 1994, and Denmark implemented a one-way deposit in 2003 (Federal Ministry for the Environment 2014).

Conclusion: assessing barriers to waste-eliminating beverage container systems

While Germany has successfully implemented a beverage container system that effectively eliminates waste, it is not to say that this solution can't be implemented in other regions where mandatory deposits or refillable bottles have not yet been put in place. However, there are definitely barriers to this, such as the FDA regulations in the United States, or the sheer cost of setting up bottle refilling machinery. Clearly, establishing the right infrastructure is one of the key ingredients to finding simple solutions to major climate issues. If there are too many barriers to setting up a similar bottle system to Germany's, a country can still learn from the organizational framework used to set up this effective system, and implement this knowledge in other efforts to combat climate change.

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20

INFRASTRUCTURE AND THE FUTURE OF NEW YORK CITY

Marvin Krosinsky

Coastal regions of the world have a great deal to consider in the face of increased storm intensity and potentially dangerous sea level rise from climate change. Superstorm Sandy demonstrated how New York City in particular was exposed. In light of that experience there are several courses of action which should be considered.

Sandy damaged or destroyed 305,000 housing units in New York and 346,000 in New Jersey. At least 106 people died.[1] One estimate saw over $70 billion of damage caused by this single storm.[2] Protecting buildings located on seashores and exposed bays which risk damage from wind, waves and future high water surges must be addressed for ongoing economic health and to minimize disruption.

Building codes in lower Manhattan used to require floors to be built at an elevation of 12 feet above mean high water level as measured at Sandy Hook, New Jersey. Superstorm Sandy's storm surge was measured at 14 feet in lower Manhattan and 12 feet in Island Park and Long Beach on Long Island, yet the building codes for Island Park and Long Beach for any home's first floors were only 10 feet above mean high tide.

Most of the damage from Sandy occurred around New York's upper and lower bays, around Long Island's Great South Bay, and along New Jersey's bays including Navesink, Manasquan and Barnegat. This happened as the storm surged into New York's lower bay from Long Island Sound, through the narrow passage into the East River, and via Rockaway and Atlantic Beach inlets, as well as various New Jersey shore inlets. Other properties located along various New York, New Jersey and Connecticut beach fronts were also severely damaged.

The cost of protecting various water inlets, bays and miles of beach fronts in such regions is quite high. However, most such inlets are narrow with the exception of Lower New York Bay between Sandy Hook and Breezy Point, which is about 5 miles wide. Similar situations, in which tidal surges move through relatively narrow inlets, exist around the world, i.e. San Francisco, Holland, Venice, the river Thames in London, etc. This points to the opportunity to focus on these

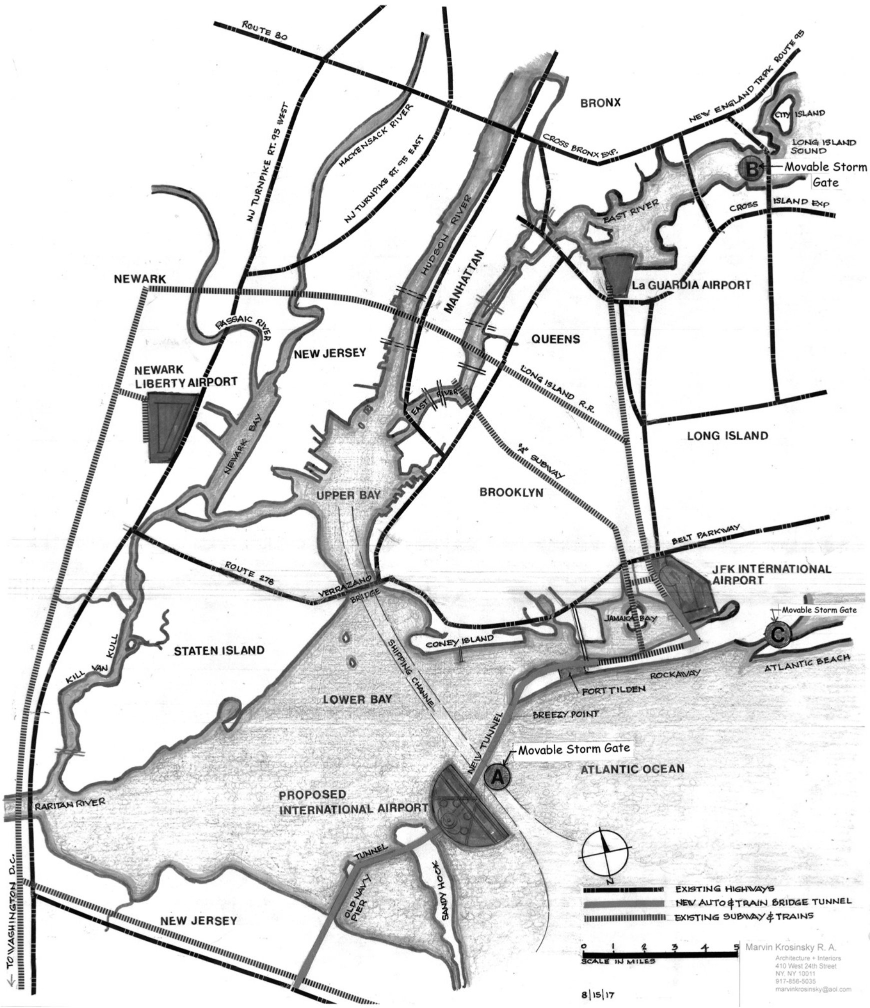

FIGURE 20.1

narrow inlets and look for ways to counter severe weather and rising sea level threats from climate change; and specifically, to consider the potential for developing new infrastructure to that end.

It may be possible to combine both barrier construction at inlets and income generation from new infrastructure to offset the costs of such barriers. For example, since demand for transportation facilities in the NY Metro area has outgrown current capacity and the state of New York's airports is famously poor, there is an opportunity to build a major new international airport near the narrow inlet located off the coast of Sandy Hook.

While not all new infrastructure can pay for itself, this proposed offshore airport facility, along with other developments listed below, would be able to generate enough income to repay private bonds which could fund construction of a coastal barrier to protect much of the flood-prone coastal areas from future storms such as Sandy. Such bonds could be offered as Green City Bonds or other similar forms of municipal finance, and could also be enhanced through public-private partnerships.

Example projects

1. The funding of a new international airport, strategically sited, helping to narrow the gap between Sandy Hook and Breezy Point (see Figure 20.1).
2. The inclusion of a waterfront barrier consisting of engineered sand dunes, inlet gates, sheet piling water barriers under the boardwalk (see the City of Long Beach's new boardwalk), as well as new raised highways and rail lines, marine growth, shellfish beds and fishing reefs which will stop, slow and absorb the flow of flood waters.
3. A rail system and roadwork which connects JFK airport to Newark Liberty airport and the existing connection to LaGuardia airport (which could instead be shut down and sold to help fund the new airport).
4. A bypass highway to reduce ongoing heavy traffic on the Verrazano Bridge and the Belt Parkway.
5. The airport should be powered by energy producing systems such as solar, wind, tidal generators and geothermal, with excess energy production sold to local utilities, helping reduce energy consumption in the region and its airports.
6. 100 percent recycling of trash and sewage (i.e., zero waste).
7. Development of fishing and oyster reefs which would help control tidal action, purify coastal ocean water, provide recreational fishing grounds and protect existing wetlands.
8. Development of a college and science laboratory to stimulate similar developments around the world.

An economic study should be undertaken by the federal and tri-state government agencies to investigate this regional opportunity and to determine the best way to fund and proceed with such a project.

This study should include establishing a schedule for planning, construction and financing the project as quickly as possible, because another Sandy may happen sooner than we think.

Other regions, given expected sea level rise in the decades to come, could learn from this example, creating new sources of revenue for all categories of organization involved.

Notes

1 https://www.huffingtonpost.com/2013/10/29/hurricane-sandy-impact-infographic_n_4171243.html
2 https://www.thebalance.com/hurricane-sandy-damage-facts-3305501

21

AFRICAN IMPACT INVESTING

Masengo Kapanga

Background

Africa is ripe with investment possibilities and opportunities. It's a common theme oft repeated when the subject of investment in emerging markets is brought up, and with good reason. Sub-Saharan Africa's population has reached 1.033 billion, with an overall population growth rate of 2.7 percent, and an urban population growth rate 4.1 percent, which by comparison, is 200 million more than the populations of the European Union and the United States combined, growing 2.5 times faster than India and 5.4 times faster than China (World Bank n.d.). However, GDP is far behind, with Sub-Saharan Africa as a whole at \$1.5 trillion, the European Union at \$16.4 trillion, the United States at \$18.6 trillion, China at \$11.2 trillion, and India at \$2.264 trillion respectively.

The largest exports out of the continent are all raw materials: petroleum, crude oil, cocoa beans, lumber, rubber, and minerals such as copper, cobalt, diamonds, gold, iron ore, aluminum and zinc. The continent's natural resources are abundant, and with a small population density (43.7 people/km^2) given the massive portion of unpopulated land there are significant sustainable opportunities to be developed.

Social entrepreneurship in Africa

One of the most popular methods to spark development and infrastructure investment in Sub-Saharan Africa has been through social entrepreneurship and non-governmental organizations (NGOs). Microlending, private corporate donations, and government aid from Europe, the U.S.A., and China have largely financed the projects and initiatives of NGOs and social enterprises. The precedent is that social entrepreneurship emerges when needs are not fulfilled by the government or private sector, and when fulfilling these needs can lead to strong positive externalities (Rivera-Santo et al. 2015).

There are three contextual dimensions that are particularly pertinent to Africa that can influence social enterprises: acute poverty, colonial history, and ethnic group identity. Acute poverty is a global affliction and not exclusive to Africa however, neither are the benefits from its eradication. As such, social missions are more likely to engage in specific targeting of poor communities in their business model. In the case of sub-Saharan Africa where there are high levels of visible poverty, the "probability of compassion being transformed into social entrepreneurial ventures" increases and strengthens the perception of importance of the social mission by members of the venture (Rivera-Santo et al. 2015).

The majority of African countries have had independence for the last 50 years, yet in spite of this the imprint of colonization is still heavy within economic, institutional, and cultural spheres. It influences the view of, and trust in, economic institutions and how social entrepreneurship is perceived. The continent's former British colonies tend to be more prosperous and have more developed formal institutions than African countries once colonized by the French, the Belgians, the Germans or the Portuguese (Rivera-Santo et al. 2015). A country with a strong belief in formal economic institutions can influence a social enterprise to perceive its activities as for-profit but not change the activities themselves.

Ethnic identity has a strong influence over the Sub-Saharan African business environment, more than anywhere else in the world. In particular, there is the *ubuntu* approach, which holds that tribal or ethnic interdependence and reciprocity is valued above individualism. This approach developed out of South Africa as early as the mid-nineteenth century, and later became popularized as a philosophy throughout the continent in the period of 1960s decolonization. Inherently, social missions will adopt a more social approach, instead of for-profit, that will incorporate the tribal culture and ethnic identity by using group or community decision making (Rivera-Santo et al. 2015).

An example of social entrepreneurship as an entrée to sustainable investing on a multinational level in Africa is Solektra International and the Akon Lighting Africa project. Solektra provides solar energy grids as well as water filtration methods to expand access to electricity and potable water that is not bottled. Solektra's mission:

> Based on an ambitious economic model, Solektra Int's mission in Africa is comprised of two major goals: 1. To devise clean and affordable energy solutions. Since social and economic growth is impossible without energy, Solektra Int proposes to capitalize on Africa's resources to ensure a large access to solar-powered electricity. 2. To provide access to clean drinking water. Solektra Int has established partnerships to spread the use of biological water purification systems.
>
> *(Solektra Global Energy Solutions n.d.)*

Solektra has two financing models. The first is through partnerships with governments and the second is through micro-credit funds and NGOs. Solektra, through tenders, proposes partnership agreements with governments, which agree to pay for the installation of their public infrastructures in 3–5 years. Additional aid is donated by local banks and credit lines from international partners for exportations. This is how national infrastructure can be installed. Solektra's management of operations is by micro-credit funds or NGOs. The funds and/or NGOs guarantee payment for the facilities, projects will be paid for. Allowing for payment in small installments, this sort of financing also offers the advantage of a close working relationship between the organization and the client throughout the entire process (Solektra Global Energy Solutions n.d.).

Akon Lighting Africa is an initiative founded by the Senegalese-American singer Akon to promote electrification and development. Public-private partnerships have been established with Solektra, Give1 Project, Akon Corporation, Huawei, Sumec, and Nari, as well as promising relationships with a number of African heads of state. Thus far there is an average investment of $75,000 per village that produces an average of 100,000 street-lamps, 1,000 solar micro-generators and 200,000 household electric systems. Akon Lighting Africa also provides two types of employment: direct and indirect. Direct employment, a network of young people, is hired and trained to install and maintain the solar equipment, and given technical expertise. Indirect employment in small businesses, cafés, agriculture, evening classes, night transport is all kept buoyant with electricity. The goal is for the initiative to become a benchmark for future social electrification missions, and ALA has started to carefully monitor its activities to quantify the number of direct and indirect jobs that have been created (Akon Lighting Africa n.d.).

Solektra partnered with USAID to provide local populations with "Lifestraw" filters, which convert contaminated water into clean, safe drinking water using reverse osmosis. They are produced a Swiss manufacturer, Vestergaard, and are microbiological water filters that remove virtually all bacteria (99.9 percent), reducing infection risk to local populations. A community model can be installed in schools for up to 200 people. A portable, auto-filtering family model (4 or 5 people), which can safely store up to 25 liters of water can be installed. There is also a portable kit, "Lifestraw Go," which consists of an individual water bottle with interior filter for personal use (Solektra Global Energy Solutions n.d.).

To date, Solektra and Akon Lighting Africa are currently operating in 14 countries: Mali, Niger, Senegal, Guinea (Conakry), Burkina Faso, Sierra Leone, Benin, Equatorial Guinea, Gabon, Republic of Congo, Namibia, Madagascar, Kenya and Nigeria. There have also been plans to expand operations to an additional 11 countries by 2016, but there is currently no update on the success or failure of the expansion.

The problems

Unfortunately, there is still not a lot of research on corporate responsibility, sustainable development, and social entrepreneurship on a broad, multi-national African scale.

Most published research focuses on a single nation and a single indicator, which limits our collective ability to understand current or most recent progress or limitations of sustainable investment. However, as it pertains to social entrepreneurship and NGOs there has been plenty of research soundly declaring such organizations to be ineffective or miniature stop-gap measures for Hoover Dam-sized problems.

There are many issues and problems that prevent the proliferation of sustainable investment via social entrepreneurship, NGOs, and to a larger extent Sub-Saharan African governments. The most pressing of these are: Sino-Africa relations; scalability; diversion of resources from other initiatives; emphasis on financial sustainability; narrow vision; and socio-political environment.

Sino-Africa relations have evolved to the extent where the African states now have the opportunity to take a more assertive role in trade negotiations to ensure that their labor, environmental, and human rights are respected (Besada and O'Bright 2017). China's investment and engagement in Africa is no different than any other major economic power's involvement with the exception of one key point: non-interference in the internal affairs of other countries. The past 50 years have seen American and European interference with elections of heads of state – which has even gone as far as the assassination of an elected head of state – to cement their trade positions. China's non-interference has been of particular interest to African heads of state, particularly to authoritarian leaders. China is now Africa's single largest trading partner, accounting for 15 percent of all African trade, while Africa accounts for only 5 percent of Chinese trade (Besada and O'Bright 2017). China's investment in African infrastructure as part of trade deals has been of great help, but it has yielded only short-term returns. China has pledged to invest an additional $5 billion in development funding in addition to $20 billion in the form of a credit line, and signed memos cancelling all debt owed by Liberia and Mozambique ($30 billion). However, when it comes to the African Mining Vision (AMV), a continental agreement signed in 2009 to encourage the development of transparent, equitable and sustainable growth supporting extractive industries, this has not been echoed in China's Africa policy discourses and cooperation frameworks (Besada and O'Bright 2017). At the moment both China and Africa need each other; but if Africa does not restructure, and pressure China to translate its rhetoric into action, it runs the risk of losing much natural resource wealth for very little in return.

Social entrepreneurship is an attempt to use a microeconomic solution for a macroeconomic problem: the structural transformation of an economy (Nega and Schneider 2014a). Microfinance and other programs that create microenterprises have extremely limited economic potential. There is no evidence that micro-enterprises generate sufficient economies of scale to provide a foundation for real economic development (Nega and Schneider 2014a). This in turn causes the social entrepreneur to seek capital from NGOs, the private sector, and the state that have failed to address the problem that the enterprise is attempting to solve.

Social entrepreneurship diverts funding from larger-scale enterprises that could generate jobs likely to create a more lasting and significant impact on the community. The need for financial sustainability also inherently limits the nature and scope of the enterprise because the financial goals will take precedence over the social mission. Social entrepreneurs are focused on a specific problem or market niche; success with the social mission will not drive effective sustainable economic development.

Lastly, are the socio-political issues. At one end of the spectrum, reliance on NGOs and social entrepreneurs can weaken the state. Instead of strengthening the state and making it accountable it creates the illusion that these services or products can be delivered by non-state actors in the long run. Solektra and Akon Lighting Africa are prime examples, because the lack of access to electricity and potable water is the responsibility of the state. However, these two initiatives are taking up the task of supplying large portions of the African continent with electricity and clean water, creating new jobs, and stimulating local economies. These solutions are temporary at best, and create problems where there previously were none. For example, funding for maintenance after installation, or replacement in the event of damage or theft since there is no stable insurance market to cover such costs. Pollution is also a serious concern, not unlike the problems facing the Keurig k-cup and its inability to be recycled. Are the water filters biodegradable? Are schools and families now required to keep purchasing new filters? This also does not address the lack of centralized plumbing and water filtration infrastructure.

At the other end of the spectrum we might find the authoritarian state, bent on staying in power, using microfinance and social entrepreneurship to control the poor for political purposes (Nega and Schneider 2014b). For example, the Ethiopian government used microfinance, Western donors pouring in resources for microfinance programs that went directly to the ruling party-owned and regional government-supported monetary financial institutions. According to Nega and Schneider, approximately 89.4 percent and 88.9 percent of clients and total loan portfolio were owned by the Ethiopian government. In addition, the government's repressive organs that collect these loans are notorious for rewarding supporters and punishing opponents with these microfinance instruments (Nega and Schneider 2014b). In short, the state must have a defined role and be held accountable, otherwise funds meant for building economic development are wasted.

The most glaring of these problems, at both ends of the spectrum, is the issue of profitability and return on investment. Sustainable investing on a corporate level is essentially non-existent on the African continent. The continent's financial markets are essentially comprised of companies focused in raw material resources such as oil, precious metals and gems, rubber, and agriculture. The only other industry that offers the possibility of consistent returns is telecommunications. Currently however, the telecoms industry in Africa has very little diversity or competition to drive growth and the possibility of higher returns. The main weakness of social entrepreneurship is that these social missions are capital intensive and usually have no expectation of profit or return. This must be addressed for future endeavors in order to to make sustainable investing attractive to corporate entities and ensure the proliferation of sustainability as a benchmark within future financial instruments.

A framework

Most recently a theory-derived framework for sustainable entrepreneurship was developed. It is a collaborative, multi-system model that takes a macro perspective on the relationships and impact of sustainable entrepreneurship. It posits five partnerships for the social enterprise, and the role of each partner, in order to succeed in the social mission. The five partners are: government, private sector, community, NGOs, and development agencies. This is not a novel premise of partnership for a social enterprise; however, the framework does define the role or approach for each partner to maximize the chance of success.

The government, in its economic role, should provide conducive fiscal policy (such as subsidies and tax holidays), training and technical support, vendor support/supply contracts, etc. In its political role, the government should generate support for sustainable enterprises at local and legislative levels. Given the rise of sustainability reporting and information, sustainable entrepreneurs will be able to find eager partners among angel investors, venture capitalists, commercial banks, and firms in the supply chain. In addition, retailers will be looking to improve their brand image and mitigate the risk of sourcing from precarious suppliers (Juma et al. 2017). The community will provide the talent pool needed to grow the sustainable enterprise. As such, the community will be both the creator of opportunities for the sustainable entrepreneur but also the consumer of the enterprise's benefits. Sustainable entrepreneurs may help the NGOs in improving the quality of their interventions in a community. NGOs have relationships within the community that would support new innovations, which would be invaluable to a social enterprise (Juma et al. 2017). Development agencies offer capacity building and seed capital for sustainable entrepreneurs whose goals include sustainable development, economic growth, and poverty alleviation. These agencies are also looking for enterprises that are producing innovations to address local social, economic, and environmental issues as well as global ones. Intrinsically, sustainable entrepreneurs can become essential partners in development agencies' global plans (Juma et al. 2017).

Conclusion

Social entrepreneurship has the potential to be a catalyst for change and evolution towards sustainable investment in Africa. However, it is imperative that it be viewed on a macroeconomic level for it to have a significant and successful long-run impact. Too often, the solution has been to simply pour resources into a very specific financial instrument or issue which has never been successful. It is important to keep in mind that Africa is not a monolith; it is vital to understand that the continent is comprised of 54 nations of differing cultures, ethnicities, financial maturity, and political environments. The commonality between all 54 nations is that social entrepreneurship and/or NGOs alone have not created a lasting impact. Lasting change and development has always been created by a tense balancing act between communities, the state, and outside parties, as well as social entrepreneurs and NGOs. I believe that this approach can still be successful.

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PART IV

Technological innovation and the future

We've come a long way reviewing innovation strategies for improved impact, cutting across corporate strategies and investment decision making, as well as regional and complex decision making to solve intricate challenges. We finish now with a look at the future and a variety of forward-looking solutions.

The most impactful sectors from an environmental perspective remain the combination of electricity generation and transportation. These are the two biggest contributors to the US GHG footprint,[1] and this is certainly true for many other countries as well. So what innovative solutions are emerging to tackle these largest environmental challenges?

We start with a look at smart microgrids by Sarah Brandt, followed by a review of blockchain as a potential driver of positive change by Pascale Bronder. Tiffany Chen then considers artificial intelligence as a solution set to tackling sustainability challenges, followed by Cayley Geffen's chapter on the state of high speed rail in the US, and then a look at the potential for shared solar by Gabe Rissman showing how carbon reducing strategies can continue to drive low carbon progress in the US, regardless of ongoing political twists and turns.

From there, Kristina Krasteva reviews the state of renewable energy technologies. Reilly Witheford then returns to look at the future of the electric car, and is followed by Christopher Codina-Lucia and Richard Frazao, who consider aquaponics as an impact solution in Canada's north, where food prices are abnormally high and the quality of nutrition very low.

After this, with an example of an innovatory implementation, Pascale Bronder shows how through design and intentionality we could use better materials to create necessary infrastructure and generate energy in the process, just one of myriad innovations being developed to help close loops and improve on construction outcomes. We end with Peter Mahony's review of geoengineering, something we may well need to consider if global carbon emissions do not begin to fall dramatically.

Much work is underway on improvements in design through research and development, as well the ongoing evolution of the sharing and shared economies, applying technologies for better net impact.

We hope these examples inspire you to think about developing and exploring your own possible solutions, or how you might consider scaling some of these new ideas.

Innovation is coming from everywhere now, both globally and regionally and across all sectors, and can sometimes lead to unanticipated if not surprising outcomes. Financial markets sometimes worry that everything is now "priced in," but innovation pretty much ensures that won't be the case.

ESG data, even as it improves, will never tell you who will win the race to create the driverless, zero carbon automobile, let alone the electric truck of the future that the market will eventually take to the most. Neither does the ESG data do a very good job predicting the future of the electric utility, which appears to be in the process of ongoing major transformation. Include buildings, which are the next largest component, and right there you have the major part of the global GHG footprint.

Innovation may well be the most important pathway to improving our futures both societal and financial. Certainly, digging in and giving innovation strategy serious thought would appear to be at minimum an extremely important consideration for us all.

Note

1 https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions

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SMART MICROGRIDS

Sarah Brandt

As described in Chapter 20, Hurricane Sandy left coastlines and communities in New York and New Jersey severely damaged in its wake. The gravest effects in New York City were concentrated in the lower third of Manhattan, as neighborhoods like Greenwich Village went days without power. There, amidst the rare scene of a New York neighborhood blanketed in black, one building stood out, emanating the soft glow of electric lighting throughout the four days of darkness.

The Brevoort is a 1950s-era co-op tower that installed its own combined heat and power (CHP) generation system in 2010, enabling the building to produce its own power. Thus, while Hurricane Sandy caused ConEdison's grid to fail, the Brevoort was able to isolate its CHP system from the rest of the grid and work independently, maintaining operation of the building's boilers, water pumps and even elevators as its neighbors struggled to secure candles and flashlights in their frigid apartments. Essentially, the Brevoort had created its own grid to power itself: a "microgrid."

Problems with the current grid

As Hurricane Sandy demonstrated, the US power grid is highly vulnerable. Its infrastructure is aging and in need of upkeep, and its layout is unnecessarily complex and would benefit from a serious redesign. As a result, the grid is susceptible to costly blackouts that can spread throughout large areas in a matter of minutes. Blackouts can be triggered by extreme weather events like Sandy (a risk exacerbated further by the growing threat of climate change), or by spikes in demand or hostile cyber-attacks.

The threat of power losses might be the most patent issue facing the grid presently, but environmental and economic concerns plague the system as well. The grid is currently set up in a way that favors centralized fossil fuel generation, thereby putting small-scale renewable energy production at a disadvantage. Meanwhile, the dated technology of the transmission lines, circuit breakers and transformers on the grid means that transporting electricity is costly and inefficient. In certain areas like New York City, electricity actually costs more to transmit than to generate.

Clearly, the grid is in need of significant revitalization. The standard response to an outage or other issue on the grid is a quick, isolated repair. These patchwork fixes can provide short-term improvements, but they do not address the systemic problems central to the grid's failures. What the grid needs is a comprehensive overhaul that will improve its function for the century to come. While the aftermath of Sandy revealed many aspects of the grid that need to change, it also highlighted one possible strategy for improvement.

The Brevoort co-op was resilient to the outages of Sandy because of its structure as a microgrid. It could connect seamlessly to the rest of the grid, but isolate itself instantly in the case of any threat to the broader system. Had all of lower New York been composed of similar microgrids working both in sync and in isolation, the fallout of Sandy would have likely been no more serious than that of a routine rainstorm. The future of the national grid could take such a form. In place of the current, complex system of massive and inflexible regional grids, the grid could one day be a system of independent yet interconnected microgrids with the adaptability and resilience to withstand the pressures posed by changing technologies and a changing climate.

A brief history of the grid

Though microgrids might seem like an innovative departure from the current grid system, the concept of local electricity generation is not particularly new. In fact, America's earliest electric power systems in the 1880s were small, central stations serving only a few blocks of consumers. The first of these early "grids" was actually established within walking distance of where the Brevoort sits today. In 1882, Thomas Edison helped create a highly localized grid that supplied electricity to 59 New Yorkers on Wall Street – a system that would be considered a microgrid by today's standards.

This localized practice of energy distribution was phased out with the innovation of the transformer in 1891, which enabled high-voltage transmission of alternating current over long distances. With this new capability, electricity from the hydroelectric power station at Niagara Falls could travel miles, rather than blocks, to serve consumers as far distant as Buffalo, New York. As technology improved and power could be transmitted at increasingly higher voltages, utility companies spread their reach beyond neighborhoods and cities to serve entire states and regions. These companies expanded rapidly, with utility capacity growing on average 12 percent per year between 1900 and the 1930s. As a result, the grid began to take shape, forming the sprawling and complicated structure it has today.

By the 1960s, the US grid had become massive, wide-reaching and remarkably interconnected. The grid developed to this size primarily because of the economies of scale associated with traditional electricity production. Large coal-, gas- and oil-powered generation plants are much more cost-effective when they have capacities between 1 GW (1,000 MW) and 3 GW (3,000 MW), each capable of powering around a million homes. Thus, it is economically effective for those technologies to utilize a large, central power station that produces a lot of energy and distributes it out far and wide. But while a large centralized power system may be optimal for fossil fuel-based generation, the opposite is true for renewable energy generation. In the case of renewables, it is actually the decentralized structure of the micro-grid – where small-scale generation happens close to the consumers served – that allows for maximum efficiency. Microgrids were the building blocks for the nation's entire electrical system decades ago, so a return to the microgrid is not only an idea attractive in theory, but also a notion grounded in history.

Microgrids as a solution

Formally known as "distributed energy resources," microgrids are decentralized alternatives to the traditional grid structure. They deploy energy generation close to the consumers they serve, rather than at a few large facilities many miles away. Where the current grid relies on power plants with production capacities between 1,000 and 3,000 MW, a microgrid uses technologies with generation capacities of around 10 MW or less. Microgrids use fuel cells, microturbines, and renewable sources like wind turbines and solar panels localized at the level of individual factories, homes, businesses, campuses and municipalities. These small-scale sources of electricity feed into the grid, creating a small grid that operates parallel to the broader grid – integrated yet able isolate itself in the case of an outage or security threat. Beyond this general structure, another distinguishing feature of microgrids is the fact that they are often "smart." Microgrids can easily deploy "smart grid" energy technologies that improve efficiency and reduce costs, while simultaneously ensuring that the grid keeps up as new technologies evolve and are introduced into the energy sector. The general set of characteristics of a smart microgrid is as follows:

- *Integrated yet independent:* Microgrids should not be thought of as alternatives to the grid, but instead as supplements to the grid that facilitate a gradual departure from its traditional structure. A microgrid does not need to be completely detached from the current grid. Instead, it can operate in conjunction with the broader grid, allowing individual microgrids to buy power from the national grid in times of need and to sell power back in times of excess. At the same time, the microgrid can isolate or "island" itself at any time, effectively severing its connection with the grid to either contain an outage to itself, or to shield itself from an outage in the broader grid.
- *Renewable energy integration:* With growing evidence of the link between fossil fuels and climate change, there is increasing interest in switching to a low-carbon economy powered by renewables. The hurdle that remains, however, is figuring out how electricity from renewables can reach customers when they need it. As the U.S. power grid was designed before current renewable

technology had even been dreamed up, its infrastructure favors energy generation from coal, oil and gas, which, in contrast to renewables, are highly controllable and only require crude technologies and a basic grid format. Renewables, on the other hand, need sophisticated controls and many feed-in points capable of accommodating a bidirectional flow of energy. A smart microgrid can integrate energy storage, data-driven demand response, and an infrastructure conducive to various feed-in points to enable renewables to proliferate.

- *Energy storage:* Renewable energy sources like solar and wind power are inherently intermittent, meaning the sun doesn't always shine, and the wind doesn't always blow. When clouds are out and the day is still, renewables need a backup source of energy. Traditionally, fossil fuel plants would step in with "peaker" generators designed to turn on only in times of insufficient energy supply. But a low-carbon alternative to meeting that demand involves feeding in electricity from batteries that store renewable energy from a particularly sunny or windy day when production of renewable energy exceeds demand. Stored energy can react to demand spikes much more quickly than a peaker turbine from a fossil fuel plant can start up, which allows grids powered by renewables to respond to peaks in demand in a more environmentally friendly and economically viable manner. Storage can be large-scale, like the 100 MW 'Powerpack' system Tesla recently developed in Australia, or small, like through the 10 kWh at-home 'Powerwall' batteries, also developed by Tesla.
- *Electric vehicles:* Another way to store excess energy, aside from the systems discussed above, is in the battery of an electric vehicle. When they aren't out driving, consumers can keep their car plugged into the grid to enable a bidirectional flow of energy that allows the vehicle to either take electricity in from the grid to charge it, or send its battery's electricity out to the grid during times of peak demand.
- *Smart grid technology enabling demand management:* Just as renewables produce energy in an intermittent manner, the way society consumes energy is intermittent as well. Demand hits a lull around 5 a.m., when most households have powered down, but hits a peak around 5 p.m., as people return home from work and power up their laundry machines and turn on their lights. Smart technologies can help ease the strain of this imbalance in demand. While a "smart grid" can mean a variety of things, most smart grids are characterized by data processing and communications that make information management a central aspect of the grid. Our grid currently uses advanced metering infrastructure from the 1990s, which integrates demand response according to time of day. In contrast, the smart grid can deliver information and react in real time, vastly improving efficiency. With real-time data, utilities can incentivize customers to adjust the time of their electricity use through time-based rates. Better yet, with smart appliances and other technologies plugged into the grid, this process could occur automatically. Returning to the electric vehicle model, for example, the grid could use "smart charging," a process where a plugged-in vehicle can automatically stop charging when the load is high, and

restart later when demand decreases. Or, similarly, a consumer could program their dishwasher to run when electricity rates are lower. The possibilities of a smart grid depend on the exact suite of technologies deployed, but their abilities only increase as smart technologies develop and improve.

The benefits of microgrids

In terms of reliability, security, environmental impact and economic performance, the microgrid outperforms the traditional grid structure. Its advantage in each realm is explored in more depth as follows:

- *Keeping the power on:* Extreme weather events like Hurricane Sandy can cause catastrophic blackouts that spread rapidly throughout large swaths of the grid. Outages can be inconvenient, as functions like heating, lighting, charging your phone and sometimes even flushing the toilet fail. But more pressingly, outages can be dangerous if hospitals or retirement homes lose power, leaving the weak and elderly vulnerable. Finally, outages are costly. As businesses lose power and are forced to close down, the economy incurs significant losses in productivity. The Electric Power Research Institute (EPRI) estimated that every year power outages cost US businesses more than $120 billion in lost productivity. Smart microgrid technology can prevent these losses by making the grid "self-healing," meaning it can instantly respond to threats in order to avoid or mitigate outages. Whereas a localized outage on the traditional grid can spread widely and ripple into a massive outage, a smart grid with data integration is able to locate the problem, isolate it to minimize the number of customers affected and more quickly heal it in real time.
- *Protecting against national security threats:* As we move to an increasingly digital society, the threat of cyberattacks is more prevalent and pressing every day. By depending on highly centralized power stations, Americans are more prone to the threat of cyberattack, as these stations are easy targets for cutting power to thousands of Americans instantly. A decentralized structure with many more generators to target, hedges against that risk by diversifying utilities. Further, by integrating new, smart technology, the grid can more easily identify compromises to the system and respond to them instantly.
- *Improving economic and environmental efficiency:* With microgrids, electricity is generated near the customer, thus reducing the losses from transmission and distribution. Further, a smart grid can deploy technology to do load adjustment in real time, automatically reducing the energy usage of various customers during times of peak demand. Through load adjustment, microgrids avoid the need for peaker turbines, which are the most inefficient and expensive generators that operate on the traditional grid. Additionally, microgrids significantly contribute to the deployment of renewables and electric vehicles, aiding the nation's transition to a clean energy economy. And as the price to produce energy through solar photovoltaic and natural gas CHP continues to drop,

feeding such small-scale energy production back into the grid becomes increasingly viable.

- *Benefitting the consumer:* Microgrids equipped with smart technology bring consumers far more control and freedom over their power use. Consumers have already begun the process of installing smart home devices to manage their electricity use, deploying appliances like the Nest thermostat, but the potential to expand these technologies is significant. By integrating a number of smart appliances into an "internet of things" that can program air conditioners to automatically turn down when electricity prices are high, for example, or program the dishwasher to run when prices are low, consumers can save money and improve efficiency. Further, consumers can actually make money by generating their own electricity. A microgrid system eases a consumer's ability to install solar panels on their roof or home energy storage in their basement that can both power their own home and feed energy back into the grid. Additionally, smart grids facilitate the proliferation of electric cars by incorporating a plugged-in vehicle as a form of energy storage that can make money for the owner. When supply is low and demand is high, the microgrid can essentially buy back the energy from a car's battery at a higher rate than was paid when the vehicle was charged at a time of low demand.

Scaling smart microgrids

Currently, microgrids exist at the scale of businesses, universities, and buildings like the Brevoort in Greenwich Village. As these small-scale success stories add up, communities and municipalities have started to take notice. From Spokane, Washington to Boulder, Colorado, cities have begun experimenting with how to pursue microgrids at scale, with some early successes and inevitable barriers.

Washington utility invests in grid of the future

From its headquarters in Spokane, Washington, Avista Utility operates an electric grid powering thousands of homes in Eastern Washington and Northern Idaho. Theoretically, then, Avista should feel threatened by microgrids, as the concept of the microgrid could challenge the traditional grid structure that is central to Avista's core business. Yet rather than be a protester of the microgrid, Avista is a proponent. This past May, Avista won $3.5 million in state grants to fund a microgrid project that it says aligns with its culture of innovation. And while resilience and security are the obvious advantages of microgrids over traditional grids, Avista's interest in the project is economically motivated, as well. Preferring the term "shared energy economy" to "microgrid," Avista's vice president of energy delivery, Heather Rosentrater, hopes the utility can demonstrate how a grid based on a system of small-scale renewable generation can be more economically efficient than the current model. Just like Uber provides ride sharing and AirBnB provides home sharing, Avista sees microgrids as being able to provide energy sharing in a way that costs less for both consumers and producers.

An eager Boulder hits roadblocks

As early as 2011, Boulder, Colorado expressed an interest in microgrids. A survey around that time found that by owning its own utility, the city could buy energy from more renewable sources at average prices either equal to or lower than those offered by the broader utility, Xcel Energy. That year, residents voted in support of their city purchasing the infrastructure of its portion of the grid from Xcel, with the hopes of forming a community-owned utility that would operate as a microgrid. Unfortunately, more than five years later, progress remains stalled. Due to years of discussion and unsuccessful negotiations between Boulder and Xcel, the two companies have yet to reach an agreement that would allow the city to completely seize ownership of its grid.

Steps for scaling

As Boulder's microgrid plans stall while Spokane's forge ahead, it is clear that public enthusiasm for microgrids is not sufficient to breed change. Citizen support is important, and a necessary precursor to any plans to scale a microgrid. But the key to success, where Boulder fell short, is a willingness to cooperate with utility companies. Where Boulder saw an opportunity for independence, Spokane saw a microgrid more as a chance for integration. Thus, in order for microgrids to scale up to the level of municipalities, and eventually beyond, cooperation with utilities is essential.

While utility support for microgrids is imperative, government support is important as well. Completely overhauling the grid comes at a very steep price. To accelerate such a broad investment in renewables, information technology, storage, and other aspects of the smart microgrid, there need to be more financial incentives, as was the case in Spokane.

On a more technical level, microgrids need the right setup of infrastructure and technology to operate at maximum efficiency. A smart microgrid functions best with a suite of innovative energy technologies working in concert. Many of the technologies, however, are either still in nascent phases or remain too expensive. Further investment in research and development will be crucial for such technologies to reach the scale (and therefore price) necessary for implementation. And even after the technologies have developed sufficiently, they need to be integrated together seamlessly in order to optimally operate. For instance, renewable energy cannot be scaled without sufficient storage. Further, electric vehicles should not be scaled without demand response management to regulate their ideal charging time. If electric vehicles are all charged at the same time, say, after work, the stress on the grid will be enormous. But with demand management, the smart grid can automatically schedule charging around times the grid is, or is not, under stress. Thus, planning the optimal arrangement of infrastructure will be an initially complicated process. To determine the ideal structure, a few successful pilot studies are needed at the level of cities.

After a few municipalities like Spokane complete successful pilots and demonstrate how beneficial microgrids can be to all parties involved, more eager municipalities could eventually follow suit. And with help from government and private sector investment to accelerate the process, the proliferation of microgrids could soon be inevitable.

Conclusion

As Hurricane Sandy revealed, the grid as we know it is in a vulnerable state. Its problems, however, do not by any means start and end with Sandy. More extreme weather events will continue to test the grid, and cyberattacks might increasingly strain the system. Less acute issues exist as well, as the grid's environmental and economic failures persist and worsen by the day. In the face of climate change and a growing demand for electricity, we cannot continue to rely on the old, centralized structure of a grid dependent on fossil fuels. Instead, we must revitalize the grid by switching to a smart microgrid structure. Doing so is not only smart; it's essential.

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23

EFFECTIVE DISRUPTION

How blockchain technology can transform the energy sector

Pascale Bronder

Blockchain technology sounds like an ethereal unicorn to anyone outside of the financial technology (FinTech) world. Despite people's best efforts to explain blockchain, it remains a mystery to many. Though understanding blockchain may seem daunting now, by the end of this short chapter not only will you have a working definition of what it is and how it works, you will also get an in-depth look into blockchain applications for social good and in the energy sector.

What is blockchain technology?

Blockchain, also known as distributed ledger technology, is a digital record book. It tracks transactions. Operating across different computers – personal, corporate, or government – transactions are time-stamped into a block,[1] and a series of those blocks creates a chain. Every time a new block is added or verified, it is updated in real time on the networks of everyone participating on the blockchain. To form and verify a block, every member involved in a transaction must actively agree that the transaction occurred. This consensus of members makes a blockchain immutable. Every new block is built on top of the cryptographic computer coding of all the preceding blocks. Therefore, the only way to change or alter a transaction is by creating a new transaction that all the constituents agree to.

End-to-end transaction monitoring makes blockchain immediately auditable. Whatever is stored in the block – whether it be money, health records, school fees, land ownership titles, locational geo-stamps, etc. – can be tracked, and everyone on the blockchain can see exactly whose hands the transaction passes through. With blockchain, you know what is being traded, when it happened, and whom it's going to.

These qualities generate the value of trust. Blockchain is a distributed network, so there is no central power to oversee and collect data from activity. The network is made up of the people who own it, allowing direct transactions, and eliminating middlemen and third parties. The decentralized structure of blockchain means that you don't have to trust the other entity (be it a person, a bank, an organization, etc.) because everybody involved must verify the information. With this level of accountability, there is less risk during transactions.

With a working idea of what blockchain is, where can it be applied?

Not everything needs a blockchain solution. In order for this technology to be most effective, one must find applications that require the transparency, certainty, immutability, and security it offers. The most common discussion revolving around blockchain involves cryptocurrencies and opportunities for more efficient data and information transfers, as well as streamlined administrative processes. While these are important in order to run faster, cheaper, and more easily auditable systems, the real transformative power of this new technology resides in the innovative solutions it could generate for global problems. Blockchain for social development has enormous potential to improve the quality of life and economic well-being of people worldwide and dramatically change the field of international development.

Finance and digital identities

This is the largest field being targeted by blockchain developers today, and with good reason. About 1.1 billion people in the world lack a verified identity (World Bank 2017), without which securing loans from financial institutions is nearly impossible. Using biometrics or human verification of others in one's personal network, searchable and reliable identities can be created on a blockchain. The implications go far beyond basic financial services. Imagine that refugees' digital identities could show that they were professors, doctors, reliable laborers, or trusted vendors, enabling migrants to continue their professions and not start their lives from scratch. Farmers could access loans or microloans to update equipment, bringing larger yields. The $580 billion of remittances sent to developing countries a year (Pew Research Center 2015) could be channeled directly from one person to another through mobile banking, thereby eliminating steep fees, and placing more money in the hands of those who need it most.

Supply chain

Blockchain is the most reliable way of tracking transactions. If you're trying to figure out the provenance of a good, such as a bag of coffee or a prescription medication, supply chain end-to-end tracking is invaluable. The life cycles of products become accessible and transparent. Products can be tagged with QR codes that allow monitoring of GPS locations during every step of production. This gives consumers an enormous amount of power in terms of choosing whom to buy from and determining whether certifications are legitimate and if industry best practices are actually being applied.

Climate and energy

Climate financing, governance and security, energy access, and distributed renewable energy are four standout use cases in the climate and energy space as it relates to blockchain. There are also great prospects for pollution monitoring. If a smart meter is placed next to a factory or in a city, the monitor would have its own identity and connection to a blockchain, and the feedback of pollution data would give a transparent and incorruptible view of the air quality. In climate financing, funds meant specifically for renewable energy development or conservation, mitigation, or restoration efforts can be tracked to ensure beneficial outcomes from climate projects. Information provided through any of these cases of blockchain use will enable countries, companies, communities, and citizens to make more educated and effective decisions.

How can blockchain transform the energy sector?

Peer-to-peer energy trading is a specific use case that allows us to deep-dive into the real value added of blockchain technology. Tying in finance, community resilience building, and renewable energy expansion, I believe this is the most interesting and disruptive blockchain application. Peer-to-peer energy trading is happening from Brooklyn to Bangladesh. Functioning within a geographically tight-knit group or community like an urban neighborhood or slum, renewable energy asset owners (people with a solar panel, for example) can trade their excess generated electricity with their neighbors. Brooklyn Microgrid, a blockchain project of LO3 Energy, is connecting people to buy and sell electricity directly with their neighbors, bypassing utility companies. Me Solshare, a blockchain startup operating in Bangladesh, is connecting houses that have solar panels with each other in order to improve peoples' livelihood and market participation. Access to electricity has major implications for alleviating poverty, including prolonging the hours that people can be productive, whether for work or education. In Bangladesh, if people have a demonstrable identity, they are able to get a loan from their bank to purchase a solar panel. They can use energy generated from this clean and consistent electricity source in places where it was not previously accessible. After consuming what they need, the user can sell their extra energy to their neighbors, creating a community microgrid. Microgrids also improve community resilience against black- and brownouts, where the central electricity grid might not be reliable. There are 65 million people in Bangladesh who currently don't have access to the centralized grid (Cardwell 2017).

Blockchain fits into this solution through the use of smart contracts. Smart contracts are digital facilitators and enforcers for transactions that can occur automatically once the constituents of the network have set all terms. Me Solshare provides a "SOLbox" – a bi-directional DC electric meter – which is an individual's access to community trading (Me Solshare n.d.). While many blockchain applications can run on the simplest mobile devices with SMS only, these SOLboxes interact with each other using their built-in wireless internet connection. The SOLbox costs $30, which can be paid in installments (Badiei 2016). As a reference, kerosene costs about $2 a month (Foysal et al. 2012), and can be replaced by electricity for lighting and charging electronics. If a user wants to sell electricity, they place their SOLbox in "sell mode." When a user needs electricity, they can add money through a mobile banking network into their digital wallet, then set their SOLbox to "buy mode." The smart contract, which can connect the amount of electricity generated from each individual's solar panel via the smart meter to every digital wallet of members in the community and even to the banks who issue the loans, completes all the proper accounting at the end of the day. Bangladesh's largest mobile banking network is bKash, and each SOLbox system can work with prevalent local mobile currencies. Another example of these local cryptocurrencies is M-Pesa, which is widely used in Kenya and Tanzania, and expanding to Afghanistan and South Africa. This system of trust is reliant on blockchain's infrastructure. The finances are tracked and conducted through the smart contract, including repayments of loans over time, resulting in less social and economic risk for users.

Models like these ones hold high growth potential, as more than 4 million homes in Bangladesh are already retrofitted with solar panels (Foysal et al. 2012) and solar panels are becoming increasingly cheaper to purchase and install. Peer-to-peer energy trading demonstrates the value of decentralized networks, and is the best way to realize the true life-changing benefits this technology can bring to the underserviced individuals and communities of the world.

Note

1 For example, when it comes to Bitcoin, blocks within the chain are files of data representing permanently recorded transactions not previously registered. As a result, the chain becomes a ledger or ongoing audit trail of all such interchanges. Once a block is completed in this fashion, it then makes way for the next block in the chain, and will never be removed.

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ARTIFICIAL INTELLIGENCE AS A SOLUTION TO SUSTAINABILITY CHALLENGES

Tiffany Chen

Digital technology trends and innovations are emerging as a key component of an evolving world. It relates to an exponentially increasing number of objects and concepts, causing a further progression towards a society where technology is fully integral. Artificial intelligence is starting to gain a strong poistion in various industries, and it can influence issues such as climate and environmental change. Artificial intelligence can enable a more comprehensive view on systemic issues, and can interpret and analyze data at a much faster pace than prevous methods, benefitting individual companies and entire industries. With its ever-growing presence, artificial intelligence can be positioned as one aspect of the solution to sustainability, and can contribute to the improvements aimed at environmental, social, and governmental change.

Artificial intelligence is the collection of technologies that enables machines to sense, comprehend, and learn. Machine learning, one specific branch of artificial intelligence, can potentially lead to the ability to conduct detailed analysis through adapting algorithms, and can help machines improve their performance. Data is also an important contributing factor to artificial intelligence. As Big Data expands pervasively, the influx of mass data enables a more comprehensive perspective, and can benefit the effectiveness of machine learning by providing machines with larger quantities of data to assess.

Influences on environmental challenges

Environmental challenges are the primary sustainability branch that can be clearly influenced by the development of artificial intelligence. Artificial intelligence provides mass data interpretation, which directly relates to various types of research in environmental fields. Large amounts of information from monitoring the Earth can be input to machines, and artificial intelligence can interpret the data to produce new conclusions.

EarthCube and Digital Crust

One major ongoing project is the EarthCube, which uses machine learning to construct a 3-D living and adaptable model of Earth. Conducted by the National Science Foundation (NSF), the model was created through the combination of data from all disciplines – from the geochemistry of the oceans to the composition of the atmosphere – to predict how various systems of the Earth will respond to different environmental conditions. This project involves developing a cyber-infrastructure to improve the access and sharing of geoscientific data, and its goal is to "enable geoscientists to tackle the challenges of understanding and predicting a complex and evolving solid Earth, hydrosphere, atmosphere, and space environment systems." Through artificial intelligence, geoscientists can gain a holistic perspective on the environmental conditions of the Earth, and how different factors will cause environmental and societal impact. Thus, issues regarding an ecological balance and sustainability can be better addressed with concrete data and analysis. The information provided from EarthCube can be implemented and used in a multitude of ways. For instance, since the Earth is carefully mapped out, ecological factors can be monitored for potential catastrophes, and can perhaps be used to provide warnings. Environmental and climate trends are also shown, and this information can be utilized by companies and governments to create better environmental goals or implement a more sustainable and responsible corporate strategy. Additionally, the US Geological Survey is working in tandem with the NSF to produce Digital Crust, a project that will project more accurate information on the subsurface processes of the Earth. Digital Crust can be map out scenarios of different environmental factors influencing each other with machine learning, showing predictions of the possibilities of climate change. The project turns datasets into a large database as a resource for geoscientists, and stresses open access of its materials for conducting syntheses on patterns and other environmental research. Scientists can use this data to strengthen their arguments regarding different environmental challenges. Studies supported by concrete facts can have a bigger influence on shaping society's mindset on the importance of sustainability. The growing amount of analysis driven by artificial intelligence provides new information, which impacts potential policies and can trickle down to affect corporates as well.

eBird

Another way artificial intelligence and monitoring impacts environmental sustainability is in specific ecosystems and industries. Cornell University's Institute for Computational Sustainability conducts an extensive amount of research on how sustainability can be affected through computer systems, as their vision is "computer scientists can – and should – play a key role in increasing efficiency and effectiveness of the way we manage and allocate our resources, while enriching and transforming Computer Science." They stress the combination of computational thinking and sustainability, and they want to balance environmental, economic, and societal needs from a computational standpoint. One project called eBird utilized machine learning in the field of species conservation. eBird is an app that allows ordinary people to submit data about birds they observe in their locality, which produces a large database that can be used for research and analysis. Artificial intelligence is then used to predict migration patterns and changes of habitat for certain species, which contributes to a better understanding of the ecosystem and the impacts of environmental change. These predictions are shared with policy-makers, who can truly make a concrete impact on protecting bird habitats with legislation. For example, the Nature Conservancy used the predictions derived from eBird to create a system of retaining water in Californian fields for birds to stop over in during migration season, which increases the rate of success in completing the migration. The combination of environmental challenges and technology, specifically Big Data and artificial intelligence, can create a large impact on sustainability through policies and public involvement. The conclusions drawn using artificial intelligence are evidently effective in influencing specific policies and sectors.

Influences on social problems

Artificial intelligence can also play a significant role in researching social issues, leading to improvements in sustainability. Since the United Nations' 2030 Sustainable Development Goals include multiple goals specifically addressing social challenges, the urgent need solve social problems can be addressed through artificial intelligence.

Reducing poverty

Goal #1 in the UN's 2030 Agenda is no poverty, and the Stanford Sustainability and Artificial Intelligence Lab has taken a step towards providing a solution. Eliminating poverty requires massive amounts of accurate data on current poverty conditions, but this data is often difficult to acquire due to a lack of innovative data collection methods in poverty-stricken countries. The team at Stanford uses machine learning to monitor high-resolution satellite imagery to determine the socioeconomic status of different areas. They utilize a combination of high-resolution satellite imagery of daytime with a satellite image of the Earth at night to deduce which specific parts of the world are in poverty. This unconventional method consists of multiple steps. First, the night imagery provides a basic guideline of areas of poverty across the world, because places that are less developed usually lack light at night. Next, machine learning algorithms pick out indicators of socioeconomic status, such as roads, urban areas, waterways, and farmlands, in daytime high-resolution imagery. The combination of these factors results in an accurate detection of poverty areas, creating data with a better representation of world poverty levels. Currently, the Stanford team has created poverty maps of Nigeria, Uganda, Tanzania, and Malawi. The use of artificial intelligence to predict poverty is effective at creating data that was previously unattainable. This project shows that artificial intelligence can be a solution to obtaining data that is relevant to sustainable development, and is crucial in driving global recognition for the sustainability movement. This development has paved the way for future artificial intelligence and societal projects, and has pushed society one step closer to the UN's 2030 Sustainable Development Goals.

Zero hunger

Artificial intelligence can also help achieve the UN's 2030 Agenda goal of zero hunger. Stanford's Sustainability and Artificial Intelligence Lab believes addressing crop yield is essential in understanding food security and other environmental problems, and has a project for understanding crop yield through machine learning. Their approach can predict crop yield months before harvest, which answers important questions regarding food security in specific regions. Their methodology for this project includes scanning a plain map to produce remote sensing data, which is then converted into a histogram. This histogram is input to a convolutional neural network with machine learning algorithms to produce a crop yield map of certain farmland areas. A monthly prediction is created, which allows constantly changing elements such as harsh weather or droughts to be factored into consideration. Currently, the team has implemented their solution in predicting the soybean yield for the United States. This can help create better informed planting policies and decisions, such as determining an appropriate food level and upgrading risk management of crop-related products. As the agenda for sustainable development is gaining momentum, artificial intelligence can yield concrete data for accurate usage. In the case of crop yield, ensuring a precise forecast can resolve myriad food challenges, trickling down to food production, sales, and waste.

Influences on corporate strategy

In addition to environmental and social challenges, artificial intelligence has the potential to completely change the corporate system. Accenture views artificial intelligence as a new factor of production, and believes it can promote increasing business profitability across multiple industries. An Accenture study assessing the effect of artificial intelligence in 16 industries showed that "AI has the potential to boost rates of profitability by an average of 38 percentage points and could lead to an economic boost of US$14 trillion in additional gross value added by 2035." Accenture posits that artificial intelligence can boost business profits through three main bottom line areas: intelligent automation, labor and capital augmentation, and innovation diffusion.

Intelligent automation

Intelligent automation can benefit companies by being more efficient than traditional automation, as time and resources can be saved. For instance, supply chain management is an integral part of most companies, and the implementation of artificial intelligence to make supply chain management more efficient is gaining ground in the market. Companies such as Tesla and Johnson & Johnson have turned to Elementum, an AI start-up, to streamline their supply chains. Elementum offers services such as monitoring incidents and tracking transportation and manufacturing records to improve supply chain management. Since it analyzes more than 10 million incidents per day, it can effectively provide solutions and warnings to minimize errors. Sales activities can also change with the emergence of artificial intelligence. Lattice Engines is streamlining the sales process through artificial intelligence through learning companies' buying patterns. Dell's European marketing department cut its sales leads by 50 percent using Lattice Engines' platform, which generates higher efficiency and revenue. Automation plays a key role in most companies' processes, and an intelligent procedure can increase organization and profits of individual companies and markets.

Labor and capital augmentation

Labor and capital augmentation is the second bottom-line area that Accenture has identified, because they believe workers can delegate low value tasks to artificial intelligence and perform more productive main tasks. Applications of artificial intelligence in this area can include business research and maximizing asset utilization rates. Conatix's semi-automated business intelligence system uses machine learning to enable companies to "discover, source, structure, and share previously unstructured data and information from outside their organizations." This algorithm saves valuable time in traditionally tedious business research, and is highly adaptable to different feedback from companies and industries. Another artificial intelligence startup called NEM is using algorithms to predict and prevent failures on wind farms. NEM analyzes instances of wind turbine failure as data sets, then monitors turbines in real time to detect symptoms and problems. In heavy industries such as energy and manufacturing, asset downtime is often associated with revenue loss, and artificial intelligence can minimalize potential asset failures by predicting them earlier. This massively changes the profitability of various industries, as a source of error can be eliminated to reduce revenue loss. This method affects many industries that are crucial for the transition to sustainability, such as the energy industry, and can alter the direction of energy production towards a greener society.

Innovation diffusion

Innovation diffusion is the last aspect that Accenture identified as an area where artificial intelligence can be implemented to boost business revenue. Artificial intelligence can drive innovation by increasing the speed of developing new products, which can reduce redundant costs and create new revenue streams. Berg Health has used artificial intelligence to monitor cancer progress with trillions of data points, which has seen it able to "halve the development cost of a single drug from

US$2.6 billion to US$1.3 billion." Artificial intelligence also helped create new products by assessing designs in an analytic manner. Autodesk's computer-aided design system, Dreamcatcher, uses AI algorithms and cloud computing to create virtual prototypes. These prototypes are then tested by removing different materials and experimenting until an optimal product is created, and the algorithm comprehends how each individual material contributes to the performance of the product. The healthcare industry has already applied Dreamcatcher to designing facial implants, and the automobile industry used Dreamcatcher to develop a new roadster. The application of artificial intelligence in innovation has completely changed productivity, and this approach to maximizing efficiency and generating revenue simultaneously pushes technology forwards, which facilitates a greener and more sustainable viewpoint on different industries. Creating innovatory products can cut down on waste and unnecessary resources while increasing output, which is a sustainable mindset that companies should look to implement. Innovation can also lead to new business models, and new business models lead to more innovation, creating a positive cycle of development in society.

Responsible artificial intelligence

While artificial intelligence certainly brings many benefits to the pursuit of environmental, societal, and corporate development, it is vital to recognize the importance of responsible artificial intelligence. As morals and ethics can relate to sustainability, ensuring that artificial intelligence is practiced safely is a current topic garnering much debate. Artificial intelligence is often compared to the Industrial Revolution in the sense that it will drive a market revolution, and it is imperative that responsibility is considered during innovation. The Asilomar AI Principles, developed at the 2017 Asilomar Conference with the Future of Life Institute, contains 23 principles designed to ensure that artificial intelligence is practiced safely and responsibly. These principles are broken down into three large categories: research issues, ethics and values, and longer-term issues. There haves already been calls for and moves towards responsible artificial intelligence, and the fear of artificial intelligence becoming uncontrollable should not halt its development. Careful maneuvering of artificial intelligence is imperative, but it can definitely offer one solution to sustainability if practiced responsibly.

Conclusion

Artificial intelligence is crucial in developing new information systems, and this affects environmental, societal, and corporate challenges. It is revolutionizing monitoring, business processes, and many other areas through large data analysis, and has the potential to make a big impact on the sustainability of the Earth. Sectors that have applied artificial intelligence are seeing new benefits and revenues, and this implementation will increase as artificial intelligence develops into a more widely applied technology. Using artificial intelligence responsibly is important and should be viewed as a mindset instead of a guideline, as responsible artificial intelligence largely influences sustainability. As technology develops and matures, it is evident that artificial intelligence will be a factor that shapes industries and economies, leading to a more sustainable Earth.

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THE POTENTIAL FOR HIGH-SPEED RAIL IN THE US

Cayley Geffen

Background and politics

The creation of a high-speed rail network in the United States would create thousands of jobs, modernize America's infrastructure, increase travel safety, and reduce CO_2 emissions. However, the United States government has not prioritized the construction of a high-speed rail system and American rail infrastructure has fallen far behind the global railway standard. Currently, two high-speed rails are under construction in the United States – one in Florida and one in California. Though President Obama proposed a high-speed rail plan in 2009 and emphasized the importance of a high-speed rail in the Northeast, little progress has been made to implement the proposed system. Hopefully, a comprehensive high-speed rail network will be constructed and implemented in the United States at some point in the near future.

The conversation about building a high-speed rail network in the United States is not a new one. In fact, creation of a high-speed rail system was first suggested in the High Speed Ground Transportation Act of 1965, which aimed to initiate planning and construction of a high-speed rail between Washington and Boston in the Northeastern US. Since then, several additional and alternative plans have been suggested; however, there currently exists no operational high-speed rail anywhere in the US. The failure of our government to move forward on a high-speed rail project is largely due to lack of adequate funding and oversight, which will be discussed later in this chapter.

Under the current Trump administration, the future of high-speed rail remains unknown. However, there is some evidence to suggest that President Trump supports the construction of a high-speed rail system as part of his effort to rebuild America's infrastructure. On the president's website, one of his listed positions on infrastructure is: "Implement a bold, visionary plan for a cost-effective system of roads, bridges, tunnels, airports, railroads, ports and waterways, and pipelines in the proud tradition of President Dwight D. Eisenhower, who championed the interstate highway system" (Donald J. Trump Campaign 2016). Like the interstate highway system, a high-speed rail network could dramatically change the way Americans travel. The interstate highway system is one of President Eisenhower's greatest legacies, and similarly President Trump could be credited for the creation of a high-speed rail infrastructure if he were to make this project a priority and implement a thorough network of rails around the country. In the process of carrying out such a project, the president would also be able to take credit for the jobs it would create all across America, especially in rural, post-industrial era areas.

During his campaign for the presidency, Trump occasionally commented on the need for a high-speed rail. In one speech, he discussed the Chinese high-speed rail system, saying: "They have trains that go 300 miles per hour, we have trains that go chug … chug … chug" (Edwards 2016). This admiration for the high-speed rail network in China indicated Trump's dissatisfaction with the current state of America's rail system. Trump also declared that: "China and these other countries, they have super-speed trains. We have nothing, this country has nothing. We are like the Third World, but we will get it going and we will do it properly" (Doyle 2016). This statement suggests that Trump's plan to make America's infrastructure "great again" includes updating and modernizing America's rail system to include a high-speed rail network. Even though his administration continues to deny the human causes of climate change, the president and the Republican Party's plan might in fact have a positive effect on our environment as a result of the administration's focus on the economic and social benefits that would accompany a high-speed rail project. These economic and social benefits have been clearly demonstrated in countries with such networks, particularly China and Japan.

High-speed rail systems, implemented in almost twenty countries around the world, have been very successful. The first high-speed rail, the Shinkansen in Japan, was built from 1959 to 1964 to connect Tokyo to Osaka. The Shinkansen to this day is one of the most effective high-speed rail systems in the world, transporting 155 million riders per year and 424,000 riders per day (Central Japan Railway Company 2016). In 1981, the TGV in France became the world's second functioning high-speed rail, connecting Paris to Lyon. Despite taking almost 20 years to build, the TGV has been a great success and has consistently generated high profits. Since the construction of the TGV, many more high-speed rail networks have been constructed throughout Europe and Asia. China now lays claim to the world's most extensive network, with over 5,000 miles of rail. The international success of high-speed rail, especially over vast distances in countries such as China, provides a model which suggests that the implementation of such a system in the United States would not only be a profitable infrastructure investment but also would provide many social and environmental benefits.

Why does the US need high-speed rail? Meeting the transportation needs of a growing urban population

Urban populations in the US are growing at a rate that is significantly higher than rural ones. One of the biggest challenges that cities will face is supplying options to meet the transportation demands of growing populations. Because of storage limitations and expenses, it is no longer realistic for every family in a city to own and use cars as their primary mode of transportation. While CitiBike, Uber, and Lyft are impressive innovations designed to assist the non-car owning city dweller, there are few feasible alternatives to cars for city-dwellers who need to travel over 50 miles from their residence. Currently available rail travel options are often complicated, confusing, and time-consuming; and air travel, while also time-consuming, is not an affordable option for day-of-travel transportation. A high-speed rail system could meet this transportation demand in a cost-effective and time-saving manner.

Current high-speed rail projects underway in the United States

The four most publicized high-speed rail projects currently under development in the United States are located in California, Florida, Texas, and the Northeast. These are not the only projects being planned, but they are the four projects most likely to be completed. Their planning, design and construction is an important first step in bringing high-speed rail transportation to the United States.

California High-Speed Rail

The California High-Speed Rail Authority is building the first publicly funded high-speed rail project in the United States. It is being funded by the federal and state governments and by a tax measure approved by California voters. When complete, the rail will run from San Francisco to Los Angeles in under three hours, with the trains reaching speeds of over 200 mph. The system will include 24 stops between the two destinations, including Fresno, Bakersfield, and San Jose. Currently, this project is on schedule to be completed by 2029 (California High Speed Rail Authority 2016). California's high-speed rail has been met with mixed reactions from different stakeholders. While most California residents are excited about the benefits promised by the project, policymakers have criticized the high spending of California High-Speed Rail Authority and lack of project oversight.

All Aboard Florida high-speed rail

All Aboard Florida (AAF) is a privately owned railway company in the process of constructing a high-speed line that will connect Miami, West Palm Beach, Fort Lauderdale, Port Canaveral, and Orlando. This project is privately funded through a combination of debt and equity. The opening segment, called Brightline, is predicted to connect travellers from West Palm Beach to Miami in approximately half the time it would take travellers to drive the same distance. AAF aims to promote tourism in Florida as well as increase the interconnectivity of Florida's urban centers. (All Aboard Florida 2015)

AAF announced that the opening line of the first segment of the rail, Brightline, was 70 percent complete as of December 2, 2016. The Brightline Rail was on track to open in late 2017, despite delays caused by financing problems and Hurricane Irma. This means that Brightline will likely be the first operational high-speed rail in the country.

Texas Central Railway

Texas Central Partners LLC is a privately owned company that is planning to construct a high-speed rail called the Texas Central Railway. This high-speed rail project is funded by several Texan investors and investment groups. With the participation of guidance from Japan Railways, the privately owned Japanese high-speed rail company and owner of the Shinkansen, Texas Central aims to create a high-speed rail that connects Dallas and Houston in only 90 minutes, compared to the current driving commute time of four hours (without traffic). The Texas Central project will provide construction jobs to thousands of communities in rural Texas, particularly in Grimes, Madison, and Freestone counties. Texas Central aims to begin construction of this rail in 2018 and begin operation by 2022. Currently, the environmental impact statements for the proposed routes are in review (Texas Central 2016).

Northeastern high-speed rail

Though a Northeastern high-speed rail is not yet in construction, Amtrak is in the process of creating a construction plan for a high-speed rail from Boston to Washington, D.C. The target date for completion is 2040. Amtrak predicts that the project will create 44,000 jobs per year during construction and up to 120,000 permanent jobs. Currently, Amtrak is in the process of completing an environmental impact assessment on the construction of a new tunnel under the Hudson River that will need to be constructed to accommodate a high-speed train from New York to New Jersey.

The path of the proposed Amtrak high-speed rail will differ significantly from the path of the existing Acela line because the rail segment from Boston to New York City will run through Hartford, Waterbury and Danbury, Connecticut instead of the current Acela path through New Haven, CT and Providence, RI. Amtrak's proposed path is intended also to create economic growth in the above-mentioned post-industrial areas of Connecticut. In the area to the south of New York City, the rail will have stops in Newark and Trenton, NJ, Philadelphia, PA, Wilmington, DE and Baltimore, MD, and has the potential to increase economic productivity in these areas. Travel time on the Amtrak line is predicted to be far faster than car travel or Acela travel, and may even be able to compete with air travel times between cities located on the line. The Boston to Washington high-speed rail travel time will be slightly over four hours, and the time from Washington to New York and from New York to Boston will be two hours.

Because of the high population density in this area, this project has the potential to be the most travelled high-speed rail in the United States, justifying the difficulty and time needed for its construction (Amtrak 2010).

Environmental benefits of high-speed rail

Reduced CO_2 emissions

Completion of any high-speed rail has the potential to significantly reduce CO_2 emissions in the areas served. In every country that has implemented a high-speed rail line, the project has proven to greatly increase energy efficiency per passenger per kilometer when contrasted with alternative travel options such as motor vehicle and air travel. Diverting air and car travellers to the high-speed rail would significantly reduce CO_2 emissions in the transportation energy sector, which is the second largest contributor to total CO_2 emissions in the US. Additionally, high-speed rail can run on energy from the grid, which may be created by renewable energy sources, unlike airplanes or cars, which require fossil fuels that release CO_2. In the current Japanese high-speed rail system, CO_2 emissions per seat are 1/12th the amount of the emissions of a Boeing B777–200 per seat (Tanaka et al. 2010).

Improved air quality

Studies have found that commuters in urban areas waste an average of $1,700 per year on extra gas burned due to traveling in bumper-to-bumper traffic (White 2014). This is not only an economic problem for commuters, who are wasting their hard earned money, but also constitutes a health hazard for adults and children whose health is impacted by living, working and playing in areas with significant smog and air pollution caused by idling traffic. High-speed rail has the potential to divert some of these motor vehicle commuters to an alternative form of transportation, which would decrease traffic and road congestion, thereby reducing the amount of air pollution and CO_2 emissions caused by idling and slow-moving cars.

Less waste from "car junking"

Almost a million cars get "junked" every year in the United States. While some parts of junked cars can be refurbished and sold back to the automobile industry, many parts, particularly the frames, end up as waste in junkyards. This neither a sustainable nor an environmentally friendly practice. High-speed rail could reduce the amount of junked cars for two reasons. First, people would be able to utilize the rail instead of their car for long trips. This would reduce the miles put on their car, which would increase the longevity of the vehicle. Second, if the high-speed rail was accessible and affordable for city dwellers, some may choose not to buy a car. If fewer cars are owned because city dwellers no longer see the need, there will clearly be fewer cars junked each year.

Economic benefits of high-speed rail

Job creation: construction, manufacturing, small businesses, and tourism

Job creation will be the greatest economic benefit of high-speed rail creation in the US. Proponents of the California High-Speed Rail project claim it will create between 20,000 and 70,000 jobs annually during the next 20 years of construction. Job creation is of particular importance in California's Central Valley, an area that has experienced extremely high unemployment rates due to the recent 5-year drought and a steady influx of people seeking work in the area. Similarly, construction of the Texas high-speed rail will provide jobs in rural Texas counties that record high unemployment rates.

Manufacturing industries in various states will also benefit from the implementation of high-speed rail projects. Siemens Corporation in Sacramento, California, is building the trains for California High-Speed Rail and has the capacity to expand to build more trains for other high-speed rail projects. Additionally, the steel manufacturing industry, an industry that President Trump aggressively courted to win the election of 2016, will benefit from the need for large amounts of steel necessary to construct high-speed rail lines. Another economic group expected to benefit from high-speed rail construction is small businesses. The California High-Speed Rail Authority has made it a priority to create business opportunities for small businesses, including construction and manufacturing companies, to help build the rail.

Lastly, increased tourism is expected to contribute to significant job growth in the tourism industry in many regions where high-speed rails are implemented. For example, the Florida high-speed rail will connect Orlando, Port Canaveral, West Palm Beach and Miami. Each of these cities is a major tourist destination. The rail has the potential to facilitate increased tourism by allowing travellers who may have come to visit only one of these areas to visit more or all of them. The appeal of Florida as a vacation destination will increase as travellers have the opportunity to easily vacation in several different locations all during one trip. More visitors will lead to more jobs in Florida's tourism industry and promote economic benefits for the state of Florida as well as its residents. Implementation of high-speed rail in other states should have a similar effect.

Promote economic growth

Job creation is not the only economic advantage of high-speed rail construction. In other countries with high-speed rail, communities near the stations have experienced significant growth in productivity. In Japan, statistics have shown that in cities where high-speed rail has been introduced, particularly mid-sized cities, economic productivity has increased significantly due to increased tourism and access to urban markets. In the mid-sized city of Kakegawa, in the year following the construction of a high-speed rail station, employment rose 8 percent, production rose 38 percent, and overall sales rose by 39 percent (Smith 2009, 232) Similarly, a high-speed rail system in the United States has the potential to raise productivity, particularly in mid-sized cities. This could provide a significant boost to middle-class America, a demographic in severe need of such help.

Social benefits of high-speed rail

Safety

High-speed rail travel is a safer form of travel than motor vehicle travel. In over 50 years of operation, the Japanese high-speed rail has not caused a single fatality. Internationally, the number of fatal high-speed rail accidents is close to zero. In contrast, fatalities to drivers, passengers and pedestrians caused by motor vehicle accidents are the fourth leading cause of death for Americans. By removing the need to drive between cities, high-speed rail has the potential to drastically decrease road deaths. First, tired travellers or those visiting families in far away cities may choose to use high-speed rail instead of driving. This option could remove tired drivers from the highway, which will, in turn, reduce road accidents. Second, an option to travel less expensively and faster by rail instead of by automobile could remove inexperienced and impaired drivers from the road, again reducing motor vehicle fatalities.

The creation of the Texas Central HSR would provide an alternative travel route for people travelling between Houston and Dallas who otherwise would have to travel by motor vehicle or bus along I-45, the second most dangerous highway in America. Every year, I-45 sees over 1,000 fatalities and tens of thousands of car accidents (Begley 2016). Implementation of the Texas Central HSR would allow people who need to travel on short notice to have a safer alternative to driving four hours on I-45, especially if they are tired or unwell. Air travel on short notice or on the day of travel is prohibitively expensive for most families and, realistically, is an option only for the very wealthy.

Increased access to higher education

High-speed rail not only benefits city-dwellers, but also has substantial benefits for rural areas. Both the California and Texas high-speed rails in construction plan to have several stops in the rural areas through which they run. The California HSR will traverse the Central Valley, a historically rural area, and the Texas HSR will run through Grimes County and Madison County, which are also rural, low-income areas. Individuals living here do not have easy access to vocational training schools or other institutions of higher education. If the high-speed rails proposed in Texas and California were to offer student discounts, as the Metro-North and many high-speed rails in other countries do, this would increase the accessibility of urban training schools, community colleges and state universities for people who live in rural areas. This would allow individuals to pursue higher education while based at home, which would significantly increase the affordability of higher education.

Challenges and potential solutions to high-speed rail infrastructure in the United States

Creation of a clear funding process

As seen in the above descriptions of current projects, there are various methods that can be used to fund high-speed rail projects. However, one of the most common challenges to the success of high-speed rail growth in the United States is lack of funding. The government needs to consider different schemes to create a clear plan for funding high-speed rail projects. In Japan, all high-speed rails are owned by Japan Railways Company (JRC); however, JRC is partially owned and largely funded by the Japanese government. A similar funding scheme could be implemented in the US in order to privatize high-speed rail construction and operation while simultaneously providing government oversight and funding. Alternatively, the federal government could embark on a large public works infrastructure project, which would include funding high-speed rail development in cooperation with state and local governments. Regardless of the solution, a clear funding method must be created to facilitate high-speed rail planning and construction in the United States.

Creation of a high-speed rail bureau

One of the main criticisms of high-speed rail development is lack of adequate government oversight. In other countries with high-speed rail networks, there are government bureaus or organizations that provide oversight on operations and development to all high-speed rails. In the United States, the Federal Railroad Administration (FRA), a branch of the Department of Transportation, is responsible for myriad issues, including high-speed rail research. But because of the necessity of maintaining and overseeing all of the current passenger and freight railroads, the FRA is unable to devote a significant portion of its resources to high-speed rail research, development and oversight. An entirely new federal bureau or organization is needed in order to conduct adequate research and planning and to provide oversight for the future implementation of a comprehensive high-speed rail network in the United States. This branch could be directly under the Department of Transportation or under the FRA; however, it needs to consist of an independent team of rail professionals committed to ensuring the safety and affordability of high-speed rail projects. This group must create clear federal guidelines for high-speed rails and provide oversight to high-speed rail projects to ensure they meet these guidelines.

The future of high-speed rail

Potential for innovation

One of the most exciting aspects of high-speed rail projects is the potential for innovation. Once high-speed rail systems are constructed and in place, they can be retrofitted to accommodate even more efficient and faster infrastructure, such as Maglev trains. Maglev trains, short for magnetic levitation trains, are high-speed locomotives available in Japan and China that are magnetically levitated above rolling stocks. Contrasting magnetic poles decrease track friction, which enables high-speed trains to reach previously unrealized high speeds of up to 400 kilometers per hour. When Maglev trains are placed in a low pressure tube, they can reach even greater speeds of 500 km/h or more (Lee et al. 2006, 1921) This innovation – a Maglev train in a high-pressure tube – is being created by Tesla and has been dubbed the Hyperloop by the company's CEO Elon Musk. Once tracks with low curvature are created for an initial high-speed rail infrastructure, they can be retrofitted at a future date to become Maglev trains, and possibly Hyperloops in the even farther future. In this way, high-speed rail projects can create the potential for many generations of high-speed rail innovations to continue to increase speeds, safety and energy efficiency.

A high-speed rail for every megaregion

The idea of megaregions has emerged in recent years as a way to best represent urban regions of the United States. Megaregions are groups of highly populated areas with similar politics, industries and communities. Ideally, the US high-speed rail network will include one connection in each megaregion. Some examples of suggested megaregions include the Great Lakes area, the Texas Triangle, the California Corridor, Cascadia (Washington and Oregon), the Gulf Coast, and the Northeast.

The most logical megaregion for the next emerging high-speed rail development in North America is the megaregion of Cascadia. A high-speed rail connecting Eugene and Portland, OR, Seattle, WA and Vancouver, BC would connect four cities which are each home to large numbers of technology companies, passionate artistic communities, and active environmental organizations. Development of a high-speed rail network in this megaregion would exponentially increase the potential for cooperation and innovation among these cities. Ideally, the high-speed rail serving this megaregion would eventually connect to San Francisco. Cascadia is an ideal location for the next high-speed rail development because it is a technologically savvy area consisting of individuals with a great passion for innovations that will benefit the environment. In addition, the demographic makeup and political leanings of most voters in this area would likely approve a tax measure to help fund the rail.

Conclusion

Ideally, high-speed rail should aim to connect all the cities of North America's megaregions and ultimately connect all megaregions to one another, connecting business areas and promoting cooperation and innovation across America. Additionally, an extensive high-speed rail network would create thousands of jobs in the vast rural areas between highly populated cities, as well as facilitate access to education and job opportunities for rural residents. High-speed rail lines have the potential to be the future of American transportation, grow the American economy, create jobs, and promote sustainable development. We hope that the current administration's plan to upgrade America's aging infrastructure will include as a high priority the planning and construction of high-speed rail networks that will ultimately serve to provide significant environmental, social and economic benefits to all Americans.

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26

SHARED SOLAR

Gabe Rissman

Solar power offers environmental, climatic, and economic benefits over fossil fuels. Many people and businesses are taking advantage of the distributed nature of solar power by installing solar panels onsite. However, many Americans are currently unable to host a solar installation. Fortunately, the city of Ellensburg, Washington invented shared solar, which brings the benefits of cheap, environmentally friendly, distributed power to people currently unable to house solar panels.

What is shared solar?

Shared solar, also called community solar, describes a solar installation that is jointly owned or leased by customers who are able to use the electricity produced by the system to offset their electricity bills. Customers either pool together money to purchase the system, or subscribe to the electricity produced by the system owned by a third party solar developer or the utility, and receive credit on their electricity bill for their share of electricity produced. Projects using the subscription model often employ virtual net metering, which lets customers receive credit at the retail electricity rate for the electricity produced by the shared solar installation.

Why is shared solar helpful?

Shared solar is the only option for many Americans to enjoy the benefits of distributed solar power by allowing for off-site installation. Only people who own a home have the decision-making authority to install a solar system onsite, so renters have been left out. In order for a homeowner to go solar, one needs adequate roof space, quality, orientation, tilt, and sun exposure.[1] Next, a homeowner would have to have the upfront capital to purchase a solar system, or have the creditworthiness to get a loan for the system or sign a power purchase agreement to purchase electricity from an onsite third party-owned system. Additionally, businesses that operate in buildings with undesirable roof characteristics are unable to affordably install solar. According to a 2015 National Renewable Energy Lab report (NREL), around 49 percent of households in the United States are unable to go solar.[2]

Shared solar is environmentally and economically beneficial, and can help to reduce energy inequality in the United States. While many households have reduced their energy costs with solar installations, lower income households have generally been unable to reap the economic benefits of distributed solar power because they are often renters and have lower credit scores. However, lower electricity prices are important to lower income households because they spend a higher percentage of their budgets on energy costs.[3] The White House has a goal to develop 1 GW of solar for lower income households by 2020, and expects community solar to play a large part.[4]

In addition to expanding cheap energy access, shared solar also allows for a lower price of electricity because installations are able to take advantage of economies of scale, since bigger installations serving multiple customers are cheaper on a per unit basis than single home or business installations. This is partly because shared solar can reduce customer acquisition costs through community marketing and because the solar installer no longer has to do a site assessment for each individual roof. Shared solar also increases siting flexibility – when solar is no longer restricted to the rooftop of the end-user, it can be placed strategically to optimize annual solar irradiation and grid integration, while providing grid benefits.[5] Finally, shared solar removes a barrier to access for many people because ownership or subscription shares can remain with the customer if the customer moves to the same utility service area, or can be sold to any other customer in the utility service area.

First shared solar in Ellensburg

The city of Ellensburg, Washington solved these energy access problems and opened up the doors for the huge potential impact described above. In 2006, 73 residents of Ellensburg, whose homes unsuitable for solar and who wanted to participate in a first-of-its-kind model to increase energy access and reduce solar costs, bought ownership shares in a 36 kW solar system – the first ever shared solar project.[6] The project was administered by the municipal electric utility, and was only possible with the strong support of the utility director, the local chamber of commerce, and the city council.[7,8]

Even with funding from a local environmental foundation and from the utility's credit program, the owners had uneconomic payback periods.[9] The economics were so unfavorable because panel prices were still high in 2006, the project received no federal or state tax incentives, and the customers were credited at the wholesale rate of solar power. Though they wouldn't be saving money, the owners still bought into the system for the greater good.

To fulfill its desire to have shared solar, Ellensburg had to innovate on multiple levels. To figure out crediting, the city maintained a spreadsheet that tracked owners' investment amounts and kWh produced to assign electricity credits.[10] The marketing materials distributed to get people to sign up emphasized the importance of expanding access to solar, and the ability that a first-time project like this could have to get the ball rolling.[11] It seems like Ellensburg did this because it saw the potential it could have on solar if the city acted as a model. One participant noted that people came from all over to look at the solar installation. Other groups then followed Ellensburg's lead. In 2007, a Sacramento municipal utility set up a shared solar project, and others in Oregon and Utah came soon after.[12] In 2009, the momentum started by the Ellensburg project led to shared solar legislation in Washington, allowing owners of shared solar to receive a $0.30 per kWh incentive, in addition to the credit from the utility.[13] That same year, Ellensburg added a second phase to the project, and is now planning phase 4.[14] However, the legislation has some way to go, as it limits shared solar project locations to local government properties unless they are owned by a utility, and caps shared solar to 75 kW, eliminating the siting and pricing benefits of shared solar.

Shared solar potential

Fortunately, a number of states followed Ellensburg's lead with stronger legislation and expectations that much more support for and investment in shared solar will come. Colorado, for example, was the first state to mandate community solar, incorporating 6 MW of community solar per year into its 30 percent renewable portfolio standard.[15] Colorado's law also requires utilities to make a good faith effort to incorporate lower income households into shared solar programs.[16] New York, too, incorporates participation from lower income households into its shared solar legislation,[17] and California piloted a virtual net metering tariff for its Multifamily Affordable Solar Housing program.[18]

Shared solar is growing quickly thanks to Ellensburg's leadership. Five states passed shared solar legislation in 2015, bringing the total to 14 plus the District of Columbia. Twenty-six states have shared solar projects, up from just 1 in 2006.[19] People are starting to collaborate on shared solar, with 100 organizations joining the DOE National Community Solar Partnership program, and the founding of the Coalition for Community Solar Access, the first shared solar industry association.[20]

By the end of 2017, there will be over 800 MW of cumulative installed shared solar capacity, with over 400 MW coming in 2017. There are almost 3 GW of shared solar currently under development across 29 states as of 2017, which means that shared solar will make up 20–25 percent of the non-residential solar market. Through 2016, California had the most installed shared solar capacity, and California, Massachusetts, Colorado, and Minnesota made up over half of the shared solar market. Through 2021, California, Maryland, Colorado, Minnesota, Massachusetts, and New York are expected to be the major areas of growth in shared solar capacity, with New York expected to be the state with the most new shared solar capacity.[21]

Most shared solar is expected to be led by third party developers. However, due to policy delays in 2016, utility led models (of which there are about 150 in existence or development) constituted the majority of shared solar capacity additions.[22] As of early 2017, Xcel Energy significantly outpaced other utilities in utility-sponsored shared solar projects. The company had 96 MW installed or expected, compared to 25.2 MW from NRG, with the second most capacity of any utility.[23]

In the future, shared solar can benefit from support from multiple stakeholders. States can incentivize or mandate shared solar. Local governments can choose to host projects on public land or fast-track community solar projects for development. Utilities and solar developers can build shared solar projects in optimal locations for solar irradiation and grid integration.[24]

Shared solar challenges

The main obstacles to the growth of shared solar are legislative hurdles. While projects have occurred and can occur without state-level legislation if administered by the local utility, the opportunity set is greatly reduced. Even in states with legislation, there are limits to the capacity of each solar installation (often individual projects cannot exceed around 1 MW), the amount of electricity each customer can subscribe to, and the types of property that can house a shared solar installation (Washington mandates that shared solar be on community-owned property).[25]

Additionally, the inability to monetize federal tax credits remains a challenge to community-owned models of shared solar (though utility projects and projects developed by a business with a large tax burden or with a tax equity investor can take advantage of the tax credits). The tax credits can be vital to the affordability of the project, as the federal Investment Tax Credit is worth 30 percent of the project cost, and depreciation benefits can save another 30 percent.[26] These community-owned models also face SEC registration and reporting hurdles. One case in Maryland set a precedent, where community members joined together to form an LLC to develop the shared solar project. It was able to avoid SEC requirements by limiting non-accredited investors to 35 people, advertising by word of mouth, and making small disclosures. The owners were then able to individually take tax benefits.[27] The National Renewable Energy Lab also advises that shared solar should be able to avoid SEC requirements if the participants participate for personal consumption purposes, as opposed to profit-seeking purposes.[28]

Possibility the largest legislative challenge to be overcome in order to expand shared solar deployment is solidifying net metering policy. Virtual net metering allows shared solar projects to be economical because customers are credited at the higher, retail rate of electricity production, as opposed to the lower, wholesale rate. Thus, utility companies that oppose net metering present the biggest challenge to the widespread adoption of shared solar. Utilities are generally opposed to net metering because it reduces the number of customers paying for their full services. Additionally, utilities argue that solar customers still make use of the grid, and should pay for grid availability provided by the utility, otherwise customers who do not have distributed generation will have to pay to make up for the underpayment of customers who do have distributed generation, though some shared solar programs sometimes allow utilities to receive a fee for grid services. While net metering caps are stalling planned shared solar in Massachusetts, this problem is not insurmountable, as New York waived its cap to allow for shared solar projects to continue as planned.[29]

It is also possible that the net metering challenge will be overcome when the full value of solar is fully assessed. Minnesota and Austin, Texas currently compensate solar customers for the value of solar, instead of the retail rate through net metering. Austin's value of solar credit is actually higher than residential rates for regular customers, showing that solar actually provides more benefits than costs, which would contradict the utilities' claims against shared solar.[30,31] Additionally, a valuation of solar assessments in Maine put benefits at $0.33 per kWh, and the Acadia Center environmental advocacy group valued the grid benefits of solar at $0.20–0.26 per kWh in Connecticut, both above retail electricity prices.[32]

Conclusion

Thanks to the innovative work of Ellensburg, Washington, shared solar has already helped people in 26 states, who otherwise would not have had the opportunity, to access distributed solar power. Because of shared solar's siting flexibility and larger scale, it could be a primary driver of growth in the distributed solar market, providing large environmental and economic benefits. While obstacles remain, shared solar represents a major innovation in expanding access to, and reducing the price of solar.

Notes

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RENEWABLE ENERGY TECHNOLOGIES

Kristina Krasteva

A shifting paradigm

Today's energy context is marked by a shifting paradigm, away from exclusive reliance on fossil fuels and towards a transition to cleaner sources. This inevitability is not only exacerbated by the finite availability of economically-viable fossil fuels, but also by the rising investment-to-production-yield required because of increasing depletion of easily accessible resources (Heinberg and Fridley 2016). Our current energy system is – simply put – not sustainable.

The shift away from fossil fuel industries has started gaining momentum. For example, in its *2017 US Energy and Employment Report*, the US Department of Energy noted that 45 percent of power generation jobs in the country are now in renewable and low carbon emission sources. In France, all newly built rooftops must now be covered in plants (that help reduce energy consumption by insulating buildings) or in solar panels (CS Globe 2015). London's inauguration of the world's largest floating solar farm in 2016 (Harvey 2016) was quickly superseded by news of Japan building an even larger one due to open in 2018 (Vaughan 2016). Meanwhile, in June 2017, China switched on a floating solar farm with a capacity more than six times greater then London's and three times greater than Japan's (Brandon 2017), signalling a clear path forward. Germany has been making strides by not only committing to a clean energy transition, but by implementing a steady plan. In 2016, it managed to consume 100 percent renewable energy during the course of a day (Shankleman 2016). Meanwhile, Portugal succeeded in running only on renewables for 107 consecutive hours (Neslen 2016). The Frankfurt School's FS-UNEP Collaborating Centre for Climate and Sustainable Energy Finance together with Bloomberg New Energy Finance reported in their *2016 Global Trends in Renewable Energy Investment* that global investment in renewable power capacity reached a new high in 2015 and represented more than double ($265.8

billion) the investment in fossil fuels ($130 billion). While new investment in renewables fell slightly to $241.6 billion in 2016, the year marked a record in renewable power capacity installations, marking a continued trend (Frankfurt School 2017). Moreover, prices of renewable energy dropped significantly in 2016 – to the point that renewables are now in the position of undercutting fossil fuel prices and are capable of competing on that front (Frankfurt School 2017). The public and private sectors can no longer afford to remain complacent in this decisively shifting landscape. The investment and expanding capacity figures indicate a trend towards better technologies that can render a renewables-based system more economically viable than a fossil fuels-based system. Nations and firms that are best positioned to embrace and champion the transition to clean energy will be the biggest winners, benefitting from their ability to exploit the increasingly lower costs of ever-improving technologies.

Renewable energy sources and technologies

This section will highlight the five predominant sources of renewable energy, while introducing some existing and emerging technologies under the umbrella of each source. It is to be noted that nuclear energy, while considered a "clean" energy, is not in fact "renewable." Renewable energies are characterized by their ability to replenish themselves indefinitely. Although nuclear power production generates a low level of carbon emissions, it will be considered nonrenewable for the purpose of this chapter because of its dependence on uranium – a finite deposit – in its electricity generation process. Moreover, power plants create nuclear waste that is considered a radioactive pollutant. This arguably offsets some of the benefits of using nuclear energy as a lower-polluting emissions alternative. In keeping with those energy sources that are considered truly "renewable", this chapter will focus on solar, wind, hydro (including ocean), bioenergy, and geothermal sources.

Solar energy

The sun beams enough energy in less than one hour to satisfy the energy demand of the entire planet for a year (*National Geographic* n.d.). Solar energy technologies harness the sun's light and heat and use either direct or indirect methods of electricity generation. The predominant direct technologies are solar thermal heating and solar photovoltaics (PV), while the main indirect technology is concentrating solar power (CSP).

Solar photovoltaics

Solar photovoltaics, also known as solar cells, consist in the use of solar panels that employ various materials with semiconductor capabilities to capture sunlight and convert it to electricity. There are three main generations of the technology, classified according to commercial maturity stage and type of underlying materials used

(IRENA 2012a). The first generation is fully commercialized and employs silicon as the primary semiconductor. Silicon is one of the most abundant materials on Earth and is the most widespread material used in solar cells. It is a capable semiconductor, but its efficiency at absorbing sunlight is moderate. The second generation uses thin-film solar cells that employ up to 99 percent less material than the first-generation PVs. These solar cells are more flexible and much thinner, which can offset some of the cost of materials. That said, the efficiency of the amorphous silicon or copper used as semiconductors is lower than that of first generation PVs. However, because of the significant reduction in materials, the overall efficiency is improved. The third-generation PV technologies have not yet been commercialized for the most part. They vary in materials used, but one of the emerging ones uses organic solar cells that are highly flexible and lightweight. The usage of graphene for organic solar cells is discussed in a later section.

Solar PV prices have been declining steadily and significantly since the technology's inception. Indeed, the price of a solar panel per watt fell from $101.05 in 1975 to $0.61 in 2015 (Richard 2015). This sharp price depreciation has led to an exponential growth in the available solar PV capacity, with 2016 marking the largest increase (75 GW added).

Solar thermal heating

This type of technology consists in using the sun to provide direct heating to buildings. It is primarily used for water heating. Solar collectors capture the sun's heat and use it directly as a source of warmth. The growth in GW-thermal capacity has been increasing year on year at a moderate but steady pace. The total world capacity as of 2016 is 456 GW-thermal. The use of this technology varies depending on the region. For example, in North America and Australia, solar heating is primarily employed for swimming pools, whereas it is used for domestic hot water systems in the rest of the world. The market is currently dominated by China, which has 71 percent of the global share. But positive trends can be seen elsewhere: in 2016 alone, Denmark doubled its solar heating capacity, prompted by favorable regulatory bodies and its Energy Ministry (REN21 2017).

Concentrating solar power

Concentrating Solar Power (CSP) makes use of heliostats (mirrors) to focus and reflect the sun's energy onto a collector, where the concentrated heat can be stored or used to drive an electric generator. One of the major advantages of CSP technology is that storage costs are significantly lower for heat-derived energy than for electrical energy. Electricity gets stored in batteries that are a large contributor to the prohibitive costs associated with optimizing all the potential energy absorbed by photovoltaics. In contrast, heat energy storage in molten salts can be upwards of 100 times more cost-effective, thus increasing energy conversion efficacy to 90 percent with the lower storage costs (REN21 2016). However, CSP technology has not yet reached a point of being highly affordable and remains a heavy capital expenditure. It is best suited to large-scale utility and industry electricity generation. Another concern regarding CSP is that it is most efficient at capturing heat when installed in vast, arid surfaces that typically lack water. Yet, CSPs need water to operate properly. This presents a challenge to both bring water to the plant and to have adequate transmission and distribution (T&D) lines to bring power to the more populous areas where demand is higher.

Nevertheless, CSP plants have emerged in various places around the world. For example, the US has integrated some CSP plants with fossil fuel plants in order to lower overall energy costs. Chile uses and is building additional CSP plants to power some of its local mines, namely Minera El Tesoro, Minera Dayton, Codelco and Collahuasi. Morocco aims at becoming an energy exporter to Europe via the installation of 2 GW of solar energy capacity by 2020, as a start. It recently opened the first phase of its Noor CSP plant. By the time the following two phases go live in 2018, the Noor CSP plant will be the biggest of its kind in the world (Roselund 2016). Moreover, 2015 marked a year of record global CSP capacity increase, in particular from the two countries that already dominate the market: Spain and the United States (REN21 2016). In contrast, 2016 was a slow-growth year, but saw South Africa double its capacity and lead the CSP market in new additions (REN21 2017). The country is using CSP technology to aid its manufacturing industry, banking on the idea that cost reductions will be achieved through economies of scale. Studies support this: the International Energy Agency forecasts a continuous fall in the costs of CSP technology over the next few decades, which will drive a sharp increase in production (IEA 2010).

Emerging solar technologies

The sun's potential is almost limitless. It provides "free" fuel that simply needs to be captured and converted for electrical usage. Combined with continuously falling costs, one may wonder why we are not relying more heavily on solar power. There are four main concerns or limitations faced by solar technologies. The first issue is space. Where should solar panels and large farms be placed? Many worry about possible land degradation and loss of agricultural potential. A second issue is efficiency. While there is virtually limitless solar energy, there is a limit to how much of it can be captured and retained. This limit depends on the materials used, such as silicon, copper, and others. It also depends on the availability of a storage system, without which most of the captured energy would be wasted. The current record for PV technology efficiency was broken in May 2016 by a team in Australia – and now stands at 34.5 percent efficiency (Cosmos 2016). However, the actual figure is lower in installed PVs. A third concern is the disposal of the equipment at the end of its life. Panels can be bulky and their decommissioning should be carefully planned for. Finally, a more permanent drawback of solar energy is its intermittent availability. Because the sun doesn't shine at all hours of the day (in most locations), there has to be reliance on either another energy source or on sufficient storage capacity. The former reduces the speed of adoption of renewable energies, while the latter is very costly at the moment. Three emerging technologies that deal with some of these issues are highlighted in this section.

Transparent solar cells

Transparent Solar Cells (TSC) are a promising new technology that could become a part of any glass, window or plastic surface. The thinner, transparent solar cells let visible light through while capturing UV and infrared light and sending it to a converter to generate electricity. The immediate application of this technology is in mobile devices, as TSC can be embedded in the screens and allow for devices to charge when exposed to sunlight. More interestingly, however, TSC can be implemented in skyscrapers and other building windows. This would alleviate the space issue outlined above, as exploiting the vertical areas of tall buildings can greatly increase the available solar cell surface. The technology currently operates with a 10 percent energy conversion efficiency, which is quite a bit lower than standard PVs. However, improvements have already shown a reachable potential of 22 percent efficiency (Bloomberg 2015), making this a commercially viable innovation. In fact, Spanish company Onyx Solar has already carved a market for itself, working on large-scale global projects like Apple Store's walkable transparent solar glass (Lambert 2016), the Dubai Frame building and the Miami Heat stadium. The company even manufactures transparent photovoltaic furniture that stores energy (Onyx Solar n.d.). Innovations in transparent cells have been making headlines recently; some scientists have even created see-through wood that can be placed in front of solar cells to increase the absorbed light and reach an efficiency potential of 30 percent (GMA 2016)!

Floating solar farms

Floating solar farms consist of solar photovoltaic power plants that are located on water rather than on land. This is one effective way to deal with the issue of space, particularly in areas that do not have much available terrestrial surface. China is one country that has adopted floating solar farms, thereby economizing on its agricultural land. The country recently opened the largest solar farm in the world. In addition to providing land space savings, water-based farms are also more efficient (BCSEA n.d.) than their ground-based counterparts. The reason for this is that water provides a cooling effect to the photovoltaics, which are typically less efficient at higher temperatures (MWH 2016). The platforms on which the system rests are made of 100 percent recyclable materials, which aids in the disposability issue outlined earlier. Floating panels have minimal impact on the ecosystem because they are usually installed in closed water inlets. They are also resistant to extreme weather conditions. This configuration has already been deployed in areas that have unoccupied water surfaces, such as in London, which harbours Europe's largest floating solar farm.

The power of graphene

Graphene is, in simple terms, a single layer of carbon atoms that is very flexible, highly conductive and 200 times stronger than steel. It is a much better conductor than silicon, the currently prevalent material used in solar photovoltaics. Graphene's applications extend to many industries, particularly in the field of nanotechnology. It also has the potential to revolutionize the renewable energy sector by optimizing the space, efficiency and intermittency issues outlined above. Because of its flexible characteristic, graphene can be used to coat solar cells of the generation of paper-thin photovoltaics that can replace the bulky PVs that are the current industry standard. Moreover, these graphene-layered solar cells can eventually be printed, eliminating much of the production cost. The technology is already heralded as revolutionary in the electronics industry, where companies like Samsung have been investing heavily in developing future-generation products. Some examples of expected applications are foldable electronics (such as TV sets), flexible, transparent mobile device screens, solar-capable clothing fibers that can charge devices in the consumer's pocket, electronic newspapers, and, eventually, intelligent windows with virtual curtains (De La Fuente n.d.). Aside from reducing the space requirements of PVs, graphene-based solar cells are believed to yield up to 60 percent efficiency (Bilal 2015) – a staggering improvement on our current technology. The material's natural light absorption capability is not very strong, so scientists have found inspiration in the surface of moth eyes (*Sciencenews Journal* 2016) and have mimicked it to create a light-absorbent material to use for solar cells (Chang 2016). This has increased efficiency significantly, even making the technology capable of absorbing indoor light for energy generation (Knapton 2016). Graphene is also ecologically friendly, as it is essentially a single layer of graphite – thus, aiding the disposability issue. One very promising application of graphene is that it can be used to create all-weather solar panels. Specifically, graphene is capable of generating energy when it rains by binding to positively charged ions from rainwater, which creates an electric current. The existing efficiency of these solar cells is around 6.53 percent – a respectable start (Nield 2016). One of the crucial properties of graphene is its ability to act as a supercapacitor. This has implications for energy storage because batteries and supercapacitors are very expensive, while graphene-based supercapacitors are believed to be significantly more efficient at storing energy, more lightweight, and bear a relatively lower cost of production than standard storage units (De La Fuente n.d.). Graphene will inevitably be an important part of the energy transition.

Wind energy

Wind is the second most prominently available renewable source of energy. The most popular wind technologies are turbines that extract the kinetic energy from moving air and convert it to electricity. In addition to requiring no fuel costs, wind turbines are considered space-efficient relative to first-generation solar photovoltaics. Similar to solar technologies, wind turbine costs have been falling and there has been significant capacity growth despite large initial capital investments. Wind is an intermittent source of energy and, as such, relies on alternate forms of energy as backup or on enhanced storage capabilities to avoid wasting collected energy. Another issue is the need to have a vast array of transmission lines bringing power to populous areas from the often less populated windy areas where energy farms operate. Moreover, people complain about the noise that wind turbines make. Finally, it is believed that the technology endangers winged animals' habitats – in particular those of birds and bats. Wind turbines can be found on shore and off shore (in water). Placing wind farms in water has a few advantages. For one, it deals with the noise problem as the turbines can be far from villages or towns. Also, energy capturing efficiency is greater because winds are often stronger off shore.

Wind power capacity has been increasing significantly over the last decade. The last three years in particular have marked higher-than-average contributions, bringing the global total to 487 GW by the end of 2016.

Almost half of the additions made in 2016 were in China, representing an important increase in the country's overall wind capacity. Wind energy is now commercially active in over 90 countries, denoting an exciting time for widespread opportunity in the sector.

Emerging wind technologies

Two emerging technologies are highlighted below, although at this time neither can truly rival existing wind energy systems.

Bladeless wind turbines

Bladeless wind turbines have emerged as a solution to the noise and wildlife threat complaints. Proponents and companies that are trying to carve a place in the bladeless market claim that substantial savings can be made in manufacturing and operating costs. Vortex, the leading company trying to push this technology, claims that manufacturing, operational and maintenance costs are significantly lower than those of standard wind turbines (Vortex n.d.). This is a source of contention among industry analysts, and a healthy skepticism should be maintained until the technology reaches a more mature stage. It is also purported that efficiency would be higher because of the relatively lower number of materials used in the bladeless technology models. While they are yet to be commercially adopted, bladeless turbines appear to be a promising improvement on traditional models.

Airborne wind energy

Based on the premise that winds are faster and more powerful at higher altitudes, kite-inspired airborne wind technology promises a better efficiency than traditional wind turbines. In fact, one company, KiteGen, claims it has successfully harnessed up to 3.3 times the power of standard wind turbines with its airborne technology

(KiteGen 2016). While this is an interesting development, it is still in the research phase and has yet to achieve the optimal cost balance to be commercially adopted.

Ocean energy

Ocean technologies exploit energy from oceanic movements like tidal currents and waves to generate electricity. Some of the more common ones are Tidal Energy Converters (TECs) that capture the tidal flow energy caused by the gravitational interaction of the sun and the moon and convert it to electricity. TECs are very similar to wind turbines, except that the turbines are submerged. Another type of ocean technology is Wave Energy Devices, which captures and converts the kinetic energy of wave movements into usable electricity. Ocean waves and tidal movements hold tremendous amounts of energy, but they are lagging behind solar and wind sources. Despite the "free fuel" provided by waves and currents, and the area efficiency and the stability of the energy source compared to their more intermittent solar and wind counterparts, tidal and wave technologies are still in early development stages, with high costs. One of the reasons for this is the difficulty in maneuvering in harsh oceanic environments. Moreover, it is uncertain how marine energy technologies and the T&D network associated with them will affect marine ecosystems. The most promising aspect of ocean energy is its constant availability, which would eliminate the need for expensive and space-consuming storage. There are currently about 30 tidal and 45 wave energy companies, and the technology is developing, but very slowly (Schweitzer 2015).

One technology that was developed to deal with the issues of marine ecosystem disturbance is the CETO Wave Energy System. This technology is fully submerged to minimize visual impact. It was designed as a giant buoy that has no blades, but simply moves with the currents and waves and collects energy in a non-invasive manner. Moreover, it not only co-exists with marine life, but also attracts it and allows for the formation of ecosystems around it. In addition to its electricity-generating properties, the CETO Wave Energy System also collects and desalinates water, providing zero-emission fresh water (Carnegie Wave Energy n.d.). The system has already been installed in Perth, Australia and three additional projects are underway.

Hydropower energy

Hydropower technologies generate electricity by capturing and converting energy from flowing water. The main technologies are conventional hydroelectric dams that produce electricity when water is passed through the dam, making the integrated turbines spin. One of the main benefits of these systems is that power can be produced at a constant rate since the movement of water can be controlled. For that reason, hydroelectric dams are often cited as being complementary to solar and wind farms in an all-renewables energy system. There are no CO_2 emissions associated with dam electricity production since the fuel used is water. Moreover, the water control allows for better curtailment of floods. Although hydroelectric dams are widely used and have many benefits, they also create large-scale wildlife habitat destruction and human displacements. They present a high capital investment and require government commitment and support. Currently, the largest producer of hydroelectricity is China, which has captured 28 percent of global capacity. It is distantly followed by Brazil (9 percent), the US (9 percent), Canada (9 percent), Russia (4 percent) and India (4 percent). In 2016, the largest contributor to hydropower capacity increases was China, adding 8.9 GW, followed by Brazil with 5.3 GW and marginal increases from Ecuador, Ethiopia and Vietnam, among others. Energy capacity from hydropower sources at the end of 2016 was estimated at 1,096 GW, making this a prime renewable player (REN21 2017).

Bioenergy

Bioenergy consists in the application of various organic plant materials and conversion techniques to produce heat, electricity and fuels. In its most primitive form, using organic materials to derive heat through combustion is a form of bioenergy. One example of this is burning wood for heat. Biomass gets converted as organic matter derived from plants or other organisms is transformed to biofuel in solid, liquid or gas form. Biogas and biofuels play an important part as renewable energy sources in the transportation sector. There are various biomass conversion methods that yield heat or electricity. Photobioreactors use sunlight and CO_2 to cultivate micro-organisms that generate biomass through photosynthesis. They are already used on some European buildings to generate heat. Anaerobic digestion converts biomass in a usable fuel to power internal combustion engines, turbines, fuel cells, and others (IRENA 2012a).

Bioenergy capacity has been on a steady rise, reaching 110 GW in 2016, with the United States and the European Union leading the way in electricity production from biomass.

Algae-based biofuel

Biofuels can be produced from varying sources of plants and crops. One of the most promising feedstocks are microalgae (Slade 2013). In contrast to other useful crops such as palm oil, soybeans or sunflower, microalgae's production potential is vastly superior, yielding 2,000–5,000 gallons of fuel per acre per year (versus 600 gallons for the second most-productive, palm oil) (Trent 2012). Algae-based biofuel is a leading candidate to replace gasoline, diesel and jet fuel. It can also use industrial waste, such as CO_2 and wastewater, to derive the nutrients needed for conversion. By consuming CO_2 it is able to offset some of the CO_2 emitted during the energy conversion process, hence it is being heralded as an almost carbon-neutral technology. On the other hand, algae-based biofuel production requires a lot of land and water and still represents a high capital investment. In addition, the microalgae growth can be tricky as the organisms need an even light source and steady temperatures.

One application of microalgae for biofuel production is the floating algae pods system proposed by the NASA-backed OMEGA system (Offshore Membrane Enclosures for Growing Algae). Microalgae colonies live in plastic containers in the water, consume treated wastewater from cities or factories and, using the sun's rays and CO_2, emit oxygen and produce biofuels in a carbon-neutral system. The water provides constant temperature control, which makes it a more stable environment (Trent 2012).

The algae pods can provide large amounts of biofuel, but are still at a developmental stage and the costs of operating them independently are prohibitive. The vision of a future that could encompass this technology includes an integration of various energy sources into one clean power system. The energy transition scenario goes like this: fossil fuel-powered factories and utility buildings release wastewater, which gets captured by a technology similar to OMEGA and used to nourish algae pods. The system is supplemented with floating solar panels (ideally, graphene-coated), offshore bladeless wind farms and wave energy converters. Output from intermittent resources can be captured in supercapacitors, while non-intermittent marine energy sources provide the balance of required energy. By consolidating many of the technologies, there is potential for lowering the costs of such a system (Trent 2012).

Geothermal energy

Geothermal energy technologies use steam and hot water generated by the heat from the Earth's crust to produce electricity. Unlike solar and wind energy, geothermal is not intermittent, which makes it an excellent source for meeting the base energy demand (Maehlum 2013). Its ecological footprint is smaller than that of hydroelectric dams, and costs have been falling in recent years. However, in extreme situations, geothermal plants have been linked to earthquakes. They are also capital intensive and produce CO_2 emissions – but only about one eighth as compared to emissions from typical coal plants. The energy source is available anywhere on the planet, but it is really only economically viable where it is easily accessible, which makes its relevance location-specific. Finally, the thermal efficiency of electric plants ranges from 10 to 23 percent, which is surpassed by other energy sources like solar PVs.

Some of these deterrents could be the reasons why additions to geothermal capacity have been slow and marginal. In 2016, Indonesia and Turkey added the most capacity, with 205 MW and 197 MW, respectively, while the US maintained its market leader position, with 3.6 GW (REN21 2017).

Driver for renewable energy technologies

Despite low fossil fuel prices, 2016 saw a record increase in renewable power capacity. Whereas final global energy consumption from renewables represented 23.7 percent of all consumption in 2015, renewable electricity capacity jumped to

24.5 percent in 2016. Renewable power capacity additions represented roughly 62 percent of all new power in 2016. This year-over-year growth in the power sector is mainly driven by the falling costs in solar PVs and onshore wind electricity (due to favorable regulations) (REN21 2017). Currently, hydropower capacity represents 16.6 percent of all electricity production, followed by wind power (4 percent), bio-power (2 percent), solar PV (1.5 percent) and geothermal, concentrating solar power and ocean-derived electricity (0.4 percent in total) (REN21 2017). While the power sector has been moving swiftly in the direction of renewables, the heat and cooling sector has remained steady in 2016, represented by about 25 percent renewable sources. The renewables in this sector stem primarily from biomass and solar energy, and are used in buildings and industry. In the transportation sector, renewable energy is mostly represented by biofuels, which account for 4 percent of global fuel consumption.

The reason for this disparate representation of renewables in the three sectors can be attributed to varying government policies. In the power sector, renewable energy policies have been adopted in almost all countries – in most cases, there are multiple types of policies per country. This has led to a rapid increase in investment. The transport sector has added policies with renewable energy obligations – currently in about 68 countries. However, low oil prices act as a deterrent for rapid, mainstream shift towards renewables. The heat and cooling sector comprises only 21 countries with policies including renewables obligations, and this number has not been growing in the last few years (REN21 2017). In order to accelerate the use of renewables in all sectors and facilitate the transition to clean energy, governments need to be involved and to formally adopt policies to entice the private sector. Investment injections are a necessary fuel to unlock the technological potential of some of the most promising advancements in renewable energy.

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THE FUTURE OF THE ELECTRIC CAR

Reilly Witheford

You've seen a rise in the number electric vehicles on the roads in recent years, and you've seen charging stations popping up in parking lots, but have you bought into the electric vehicle trend? Electric vehicles (EVs), vehicles that run on energy stored in rechargeable batteries, are becoming increasingly popular in our modern-day society due to their environmental and economic benefits. And Tesla Motors' successful marketing of luxury electric vehicles has helped lure even more people onto the electric vehicle train. EVs have a much lower carbon footprint than do traditional gasoline-powered cars, so if we want to address both the issues of climate change and of dependence on fossil fuels, switching from gasoline-powered to electric vehicles is a great place to start. However, there are barriers to electric vehicle popularity, including high upfront costs, low battery range, lack of charging infrastructure, and social norms. In order to overcome these barriers, solutions must be put into place, which include reducing the cost of batteries, increasing the availability of charging infrastructure, changing norms, promoting government incentives for electric vehicle owners, and finding alternative ways to implement electric vehicles in developing countries.

Electric vehicles have huge environmental benefits – they put out zero emissions, so the only pollution that results from their use is in the electricity generation stage. Fortunately, electricity is getting cleaner through increased dependency on solar and wind power in the place of coal, natural gas, and oil. As long as our electricity keeps getting cleaner, "electric vehicles and renewable power create a mutually beneficial circle of demand" (Randall 2016). While they are more expensive upfront, electric vehicles are more economical than gasoline-powered cars in the long run, as the cost per mile for electricity is eight times cheaper than gasoline (Kilday 2016). In addition, electric vehicle popularity would render the economy less sensitive to fluctuations in global oil prices due to energy independence (Energy.gov 2014).

The history of the electric vehicle

Electric vehicles are by no means a new or relatively new phenomenon. When cars were first invented, there was a debate as to whether the gasoline-powered or electric car would prevail. The first electric car was invented in 1890, and by 1900 electric cars made up a third of all vehicles on the road. Initially, they were preferred to gasoline-powered cars due to their low noise-levels and emissions. However, with the creation of Ford's affordable Model T (a gasoline-powered car), electric vehicle popularity slowly began to decline. Gasoline became cheaper, filling stations began popping up around the United States, especially in rural areas where few Americans had access to electricity at the time, and most importantly, the gasoline-powered cars could drive for much longer distances than their electric counterparts.

It wasn't until 1976 that interest in electric vehicles was revamped with the Electric and Hybrid Vehicle Research, Development, and Demonstration Act. In response to soaring oil and gas prices, especially after the 1973 Arab oil embargo, the American government sought an alternative source of energy for cars. However, at the time electric vehicles could only reach a speed of 45 miles per hour, and their range was a measly 40 miles, so it was hard to realistically implement electric vehicles into society (Energy.gov 2014).

The modern electric vehicle

Fast forward to 1990, when interest in electric vehicles was renewed by the Clean Air Act, closely followed by the release of the Toyota Prius, the world's first mass-produced hybrid electric vehicle, in 2000. The Prius instantly became popular due to rising gasoline prices and growing concern about carbon pollution. Then, in 2003, the Silicon Valley electric vehicle startup, Tesla Motors, was born. Tesla's first luxury electric car, the Model S, has a range of up to 280 miles, which has made electric vehicle popularity more realistic than ever. Because of Tesla's success, other car companies followed suit and began developing their own electric cars. In 2010, the Chevrolet Volt (a plug-in hybrid) and the Nissan Leaf (a plug-in EV) were released. But consumers still faced the issue of where to charge their electric cars, so the Obama administration passed the Recovery Act in 2009 to invest $115 million through the Energy Department in a nationwide charging infrastructure, which contributed to the now 18,000 chargers across the country (Energy.gov 2014). Eventually, by 2016, almost every car maker was marketing a "mainstream electric car" (Crowe 2016).

Electric vehicle sales trends

There is no doubt that interest in electric vehicles is growing. Sales are now growing exponentially, along with the number of options available for electric vehicles. In 2016, EV sales grew by 60 percent worldwide (Randall 2016). And by mid-December 2017, more than 893,000 electric vehicles had been sold worldwide, compared to the 777,000 sold in 2016 (InsideEVs 2017). If we continue to see such sharp upward trends in electric vehicle sales, they could eventually spark a new oil crisis. But the initial projected 10 percent of all vehicles in the United States being electric by 2020 has now dwindled to only 1 percent (Winton 2016), and the sales of gasoline-powered vehicles are still growing alongside those of electric vehicles. It is hard to say if the current increase in electric vehicle sales actually correlates with a significant increase in popularity, but it's certainly a good start. New battery technology has improved the electric vehicle's range and helped cut battery costs by 50 percent in the last five years, making electric vehicles more affordable. And in 2012, the "EV Everywhere Grand Challenge," an Energy Department initiative, was launched under the Obama administration in hopes of making electric vehicles as affordable as gasoline-powered cars by 2022 (Energy.gov 2014).

Electric vehicles as a luxury: the struggle to bring down the cost of the lithium-ion battery

It is true, electric vehicles are very expensive in comparison to their gasoline-powered counterparts – and that is primarily due to the high cost of their batteries. Electric vehicles are powered by lithium-ion batteries, which require low maintenance and have high energy density – their energy density is typically twice that of the standard nickel-cadmium battery. But lithium-ion batteries also cost around 40 percent more than their nickel-cadmium counterparts (Cadex Electronics 2017). The battery alone in Tesla's Model S costs $50,000 (Reese 2016). Of course, this battery is high-end and can last very long distances, but battery developers are struggling to make a battery that can go the same distance at a much lower price. The "holy grail" of batteries would be a functioning metallic lithium battery, rather than just lithium ion, because that would provide higher energy density at a lower cost. However, metallic lithium is less stable and more dangerous than lithium-ion. And even the lithium-ion battery still requires a protection circuit to maintain its voltage and current within safe limits, and to keep it from being over-charged or discharged too far. There is also an issue of battery aging over the long term through self-discharging, but the self-discharge rate of lithium-ion batteries is less than half that of nickel-cadmium ones (Cadex Electronics 2017).

Inadequate resources for the development of a "super-battery"

In 2010, the US, China, Japan, the UK, and South Korea, among other countries, decided that batteries "were the next big thing in the global economy" (Crowe 2016). Every country wanted to create a super-battery. China and the US were especially driven by their enormous dependence on foreign sources of energy, namely oil and natural gas. They wanted to become "more secure from an energy perspective," or to become energy independent (Crowe 2016). After Tesla's success, there was a "frenzy period" in the Silicon Valley, where venture capitalists would throw millions of dollars at anyone who claimed they could do something with batteries (Crowe 2016). But there's one huge barrier to the development of this so-called "super battery": physics. You can only pack so much more energy in a small space at a very low price. And electric vehicle batteries require a ton of electricity to power the car, so whence will we derive all this electricity if electric vehicles start to take over the transportation industry? According to projected sales for 2040, electric vehicles will draw the equivalent of 10 percent of humanity's electricity produced last year.

Another downside to batteries is that they draw from finite resources, which raises the question as to whether they are actually a better alternative to fossil fuels. However, according to the projected demand up until 2030, battery technology will require less than 1 percent of known reserves of lithium, nickel, manganese, and copper, and within that period battery developers will have a chance to shift to other source materials if necessary (Randall 2016). Researchers are even looking into new ways to produce lithium without having to extract it. And even if batteries do draw from finite resources (as do gasoline-powered cars), their environmental benefits greatly outweigh the costs. It is interesting to note the geopolitical aspect of the lithium industry: OPEC countries can't boast the same supply of lithium as they can oil. Roughly 80 percent of the world's lithium supply comes from Chile, Australia, and Argentina combined, and the rest comes from China, the USA, Zimbabwe, Portugal, and Brazil in smaller amounts. In addition, only four major companies currently account for the vast majority of our global supply of lithium, and these include Albemarle, SQM, FMC, and Sichuan Tianqi (Assis 2015).

Battery investment opportunities

There are many opportunities to invest in batteries nowadays, and people are taking advantage of them. According to *Oil and Energy Investor*, "2016 [was] the year of the battery," as companies and universities were coming out with battery technology breakthroughs that could transform the energy industry (*Oil and Energy Investor* 2016). And the benefits of improved battery technology won't only be enjoyed by the electric vehicle industry – solar panels can also use improved batteries to store and provide energy when the sun isn't shining. *Oil & Energy Investor* suggests investing in Tesla Motors, Solar City (a solar-power installer chaired by Tesla CEO Elon Musk), Panasonic (which is collaborating with Tesla on their "Gigafactory"), and Sony, who have announced that they will market lithium-sulfur batteries in 2020, promising 40 percent better energy capacity (*Oil and Energy Investor* 2016). Goldman Sachs has also made a case for investing in batteries, because "energy storage will change the way the power grid operates … and large-scale battery storage is gaining momentum" (Assis 2015).

The most prominent reasons to invest in batteries include the fact that their costs have already come down, their technology is improving, private and venture-capital funding has grown, and policy support is emerging (Assis 2015). Goldman Sachs estimates that the energy-storage business has the potential to be a $150 billion market within a few years. Like *Oil and Energy Investor*, Goldman Sachs recommends investing in Tesla Motors, Solar City, and Panasonic, and also notes FMC and Albemarle Corp (lithium producers), in addition to Samsung. Recently, Samsung has been "trying to diversify away from small batteries for mobile products into large-size batteries for cars and energy storage" (Assis 2015). Given the increase in demand for lithium with new battery technology and electric vehicle popularity, investing in lithium or batteries will likely lead to future profitability.

Tesla Motors as a leader in the electric vehicle industry

Considering the aforementioned investment strategies, there is no doubt that Tesla Motors, a Silicon Valley startup, has quickly captured the demand for electric vehicles and become a leader in the electric vehicle and battery industry. Its unofficial mission has been "to show that EVs could be cool," and it definitely has succeeded in doing so (Davies 2016). But Musk's ultimate mission is "to save the world from climate change" (Dyer and Gregersen 2016). In the beginning, the company only offered two cars, the Model S, a luxury Sedan that can go up to 280 miles on a single charge and starts at the very high base price of $70,000 (but the average sale price is $100,000), and the Model X SUV (Davies 2016). But in March 2016, Tesla announced its new, affordable electric sedan designed for the masses, the Model 3, which retails for $35,000 and whose battery range is up to 215 miles. The Model 3 retains many of the luxury features found in the Model S and X, including "Autopilot" and a full-roof sunroof (Davies 2016). Within just a month of its announcement Tesla had already reeled in 400,000 preorders. For context, most of the best selling cars in America, such as the Honda Accord, generally hit around 300,000 in sales each year. This release reflected Musk's philosophy on the path of success, which is to "start at the high end of the market with cars like the Model S and then move downmarket, producing more affordable cars" (Dyer and Gregersen 2016). Musk is convinced that the Model 3 will "push EVs into the mainstream and the technology to an inflection point" (Davies 2016). In mid-2017, Tesla began to deliver the Model 3 to its employees and company insiders, and by December 2017 the company had begun regular customer deliveries to those who had made the first reservations. However, the Model 3 has a preorder list of about 450,000, and Tesla was only able to produce 260 of the vehicles in the third quarter of 2017 – partially due to initial problems with its battery, which is produced by Panasonic (Archer 2017). Therefore, at this point early on it is hard to tell whether Musk's fervent claims about the success of Model 3 will be realized or not.

Tesla's advanced battery technology

Tesla's technology gives its cars a range that is two to three times greater than that of its competitors. Musk announced last year that "the energy density of its batteries is increasing on the order of nearly 5 percent per year," and that he is confident that Tesla could make a car with a 400-mile range today (Muoio 2016). Tesla recently began the construction of a massive battery plant in conjunction with Panasonic, the $5 billion Gigafactory in Nevada, which is designed to reduce the cost per unit of Tesla's batteries by eliminating the middleman (Muoio 2016). The factory began the mass production of battery cells at the start of 2017, and it is set to be the largest building by area – in August 2017 only around 30 percent of the building was finished. According to Musk, Tesla is "currently producing more battery capacity in its unfinished factory than any one single plant elsewhere in the world" (Lambert 2017). And he has promised that by 2020 the factory will produce more lithium-ion batteries annually than the total amount produced in 2013, which will drive down marginal costs (Assis 2015). Without the Gigafactory, "there wouldn't be enough batteries to launch the Model 3" (Dyer and Gregersen 2016). In short, Tesla's future depends on battery technology.

Is Tesla to the car industry as Apple is to the electronics industry?

This why Tesla is "the Apple" of the car industry: its CEO, Elon Musk, is a celebrity, much like Steve Jobs, and its products go viral immediately once they are on the market. People who want a smartphone generally want an iPhone; people who want an electric car (or just a luxury car in general) want a Tesla (Reese 2016). Consumers are willing to pay more than their previous cars to get their hands on a Tesla. Tesla has disrupted the car industry by making people rethink the way that cars and car-buying should work. Instead of selling cars through franchised dealers, consumers purchase cars directly from Tesla. And autonomous driving is now a given in all Tesla models through its "Autopilot" system, which, while it's not completely autonomous yet, is pushing Tesla ahead in the race to the driverless car (Dyer and Gregersen 2016). Tesla's international network of 3,000 superchargers, "where owners can plug in for free and charge the battery to 80 percent in as little as 30 minutes" (it used to take hours), is another large contributor to its success (Davies 2016). And Tesla's Model 3 is just one of the first of many affordable (sub-$40,000) electric vehicles to come. When Tesla announced its Model 3, carmakers scrambled to develop their own rival affordable electric vehicles for release between 2016 and 2019 (Reese 2016). The only company to beat Tesla in that race was Chevrolet with its $30,000 Bolt, which became available in 2017 (Davies 2016). Tesla's Model S now "outsells its competitors in the large luxury class," proving that good sales techniques can thrust electric vehicles to the forefront of the automobile market (Randall 2016).

However, Tesla still has yet to see a profit, as Musk often "oversells what the company can do in the short run" (Dyer and Gregersen 2016). But given the initial popularity of the Model 3, Musk believes that it's the product that can drive the company to profitability. In addition, much of the company's losses "are a result of significant investments in sales and R&D to launch Models S, X and 3, and to build the battery Gigafactory" (Dyer and Gregersen 2016). In order for Tesla to realistically make a profit, it's going to need to borrow some of the money-saving techniques used by other carmakers, like sharing parts between models and finding the best value parts. And in the end, "sustaining Tesla's lofty stock price depends on Model 3 volume" (Dyer and Gregersen 2016).

Profits aside, Tesla still has no true direct competitor as of yet. Other car makers just don't compete in terms of battery technology and vehicle aesthetic. Like Apple, Tesla's products wow people in a way that your average car maker's products just don't. But even Apple itself is working on an electric car that is said to be released in 2019 (Reese 2016), and they very well might become the true competitor to Tesla. Dyson is also trying to expand into new sectors by investing a billion pounds in battery research over the next 5 years, and it has received a subsidy of £16 million from the UK government's 2016 budget to undertake research on longer lasting batteries (Kahn 2016).

Tesla's close competition

In the meantime, some of Tesla's close (but not direct) competition will remain Chevrolet's Volt and Bolt, the Nissan Leaf, the Chinese BYD e6, and the BMW i3, which just received a battery boost that raises its range from 100 to 195 miles, making it a closer competitor to the Model 3 (Charlton 2016). Tesla's competition can use the popularity of the Model 3 to their own benefit by leveraging the momentum created by its release and revealing the "comparable performance and appeal" of their own electric vehicles to consumers (Dyer and Gregersen 2016). But currently GM's Chevrolet Bolt only targets 30,000 sales per year, whereas Tesla is targeting as much as 500,000 per year for its Model 3, which is why GM just can't be a true rival (Dyer and Gregersen 2016).

Of course, one has to wonder whether Tesla's forecast is reasonable, given that production of the Model 3 is lagging behind projections and the thousand-dollar deposit is refundable, meaning that not everyone who preordered the Model 3 will actually purchase the car (Archer 2017). And "skeptics say that Tesla overpromises, rarely hitting ambitious timelines" (Dyer and Gregersen 2016). In the past 6 years Tesla has fallen short on more than 20 projections. In all likelihood, its goal of 500,000 vehicle sales in 2018 is very aggressive and probably impossible. But Musk's tendency to overpromise is what has driven the company to innovate, forcing employees to find quick solutions to production issues (Dyer and Gregersen 2016).

Barriers to the complete transition from gasoline-powered vehicles to EVs

Even with Tesla's unprecedented growth in popularity, there are still a number of barriers that stand against a complete transition from our traditional gasoline-powered vehicles to electric vehicles. First, electric vehicles have a high upfront cost, which is daunting for many consumers, even if EVs are more economical than gasoline-powered cars in the long run. However, battery prices are dropping rapidly (they fell by 35 percent in 2016), and if the forecasts of electric vehicles costing the same or less than their gasoline-powered counterparts in the next 6 years are realized, cost will no longer be as significant an issue for consumers (Randall 2016).

However, in order to drop prices to make electric vehicles more affordable, manufacturers are meeting great losses. As stated earlier, Tesla has yet to make a profit, and GM is losing as much as $49,000 on every Chevy Volt (Charlton 2016). With the current lack of interest in electric vehicles outside of Tesla's brand, it's hard to justify these losses. In addition, the range of current electric vehicles just can't compete with that of gasoline-powered vehicles, even with Tesla's high-end batteries. But "drivers generally no longer need to fear running out of juice on the road, stranded without a power outlet," because of the increase in frequency of charging stations across the United States (Dyer and Gregersen 2016). Despite this increase, there still aren't sufficient charging stations set up for convenient long-distance travel.

Finally, the European mandatory 2020 CO_2 emission target of 95 g/km is currently European car makers' greatest concern, since there is large fine for non-compliance (ICCT 2017). Europe's automobile industry is focused on making its current gasoline-powered cars cleaner rather than developing new electric models to achieve the target. However, it can be argued that this target might become an incentive for the continent's car makers to market new electric vehicles, as that would vastly reduce their carbon footprint.

Social norms pushing consumers away from EVs

The greatest barriers to electric vehicles gaining vast popularity are societal norms. Our culture is more used to gasoline-powered cars – gas stations are everywhere. Charging cars isn't the norm, and many people aren't willing to try something new and begin charging their cars. Electric cars are often perceived as something only for people who are "green," liberal, or environmentally friendly. But even though electric vehicles are increasingly being seen "as incredibly powerful vehicles, with amazing acceleration, and fun to drive," something that anyone can enjoy, as Wharton professor John MacDuffie claims (Randall 2016), and despite lowered costs, they are "still widely perceived as luxury vehicles" (Kilday 2016). And American consumers especially want big cars, which is an issue when there are currently few electric SUV and truck options. Ford does have plans to market electric pickup trucks by the end of the decade, but it's a question of whether people will buy them in large quantities (Crowe 2016).

Solutions to mainstreaming electric vehicles

Given these barriers, solutions have to be developed to increase electric vehicle popularity and help them become a more widely accepted form of transportation. Something has to happen to prevent electric vehicle sales from actually dwindling to 1 percent of all car sales in 2020, compared to the initial hopeful projections of electric vehicles accounting for 10 percent of all cars in that year (Winton 2016).

Increasing the prevalence of charging stations

First of all, the number of charging stations needs to increase to make charging more convenient for electric vehicle owners. Other car companies need to establish charging infrastructures like Tesla's "Supercharger" network, because it makes driving an electric vehicle so much more convenient. Given the frequency of gas stations across the country, charging stations need to become a mandatory feature of all gas stations for long-distance travel. In order to further reduce the carbon footprint of electric vehicles and increase battery efficiency, solar power should be integrated into their energy source – something that Musk has suggested will be a feature of future Tesla models (Dyer and Gregersen 2016).

Rethinking what it means to be a car company

We need to rethink the way that car companies work, modeling new business models after Tesla, which is striving to become both an energy and car company with its Gigafactory and potential solar engagements. In order for electric vehicle popularity to really soar, a direct competitor to Tesla needs to emerge. Ride-sharing services like Uber and Lyft can be used strategically to boost electric vehicle popularity by requiring a certain number of drivers to drive electric, or by giving incentives to drivers who drive electric. This would be especially influential in our modern world where young people are using ride-sharing services more often than ever before, because changing social norms has to begin with the youth.

Changing social norms

Changing social norms will break down the greatest barrier to electric vehicle popularity. Consumers must be willing to pay more to drive electric today than they would for a gasoline-powered car, and manufacturers must accept very low profit margins. There is a lack of widespread knowledge of the severity of pollution and the limitations of fossil fuels that needs to be remedied by educating everyone on these current issues. If more people actually understood the consequences of driving gasoline-powered cars, maybe more people would be willing to switch to electric vehicles. It will take time, but eventually "young people will not be comfortable being in a car that's just pure combustion" (Crowe 2016). For now, it may be worthwhile to focus on promoting hybrid vehicles, even though they still require some fuel, because they provide drivers with a longer range than do electric vehicles, so consumers may be more willing to make the transition from a gasoline-powered car to a hybrid vehicle than directly to a plug-in electric car. In general, changing social norms will help revive competition with Tesla by increasing interest in electric vehicles, which will promote even further innovation.

Reducing the cost of EVs

Apart from changing social norms, one of the most important goals for electric vehicles is to reduce their cost, because that is also one of the largest barriers hindering electric vehicle popularity. This has to start with battery costs coming down, even more than they have already, as they account for most of the car's cost.

Government incentives must be put in place to lower the upfront cost of electric vehicles and make them more attractive to consumers. Luckily, these already exist in many developed countries. In the US, the government gives tax breaks from $2,500 to $7,500, depending on the size of the car's battery, to electric vehicle owners. However, this was only a short, five-year initiative, as a GOP tax bill killed the electric vehicle credit in November 2017, which means it won't apply to customers purchasing the Model 3 in 2018 (DeBord 2017). But some insurance companies still offer discounts on insurance for electric vehicle owners (Isidore 2016). In Germany, the government gives out rebates of as much as €4,000 to EV owners, and they have set a goal of 1 million EVs in Germany by 2020. Germany is setting its sights high with this goal, as today only 30,000 of the 3 million cars in Germany are electric. (Nichols and Jennen 2016). In May 2017, Germany's chancellor Angela Merkel declared that "as it looks at the moment, we will not achieve this goal" (Behrmann and Delfs 2017). China gives extremely high subsidies of around $14,240 per EV, which is important given that it is the largest market in the world for electric vehicles. Many Chinese cities offer free license plates and free parking places for EV owners. In addition, the government has funded a 65 percent increase in charging stations since the end of 2015 (De Feijter 2016). And in the UK, the government gives grants covering up to 35 percent of the cost of the car (Gov.UK n.d.)

Even though incentives are already in place in many countries, governments need to continue to subsidize both consumers and research institutions in order to improve battery technology, reduce the high cost of electric vehicles, and speed up innovation. Given the increased dependence on electricity that comes with electric vehicle popularity, investing in utilities and infrastructure could lead to large revenues from energy consumption. In addition, infrastructure investment could promote the installation of charging stations, the improvement of the electricity grid to support increasing electricity needs, and consumer education on EVs (McDonald 2016).

The challenge of implementing electric vehicles in developing countries

While the infrastructure for electric vehicles in the form of charging stations and government incentives is already in place in many developed countries, car makers face the challenge of selling electric vehicles in developing countries. Electric vehicles could make a huge difference to the environment if they were to bcome widely used in developing countries, where imports of oil have steadily risen over the last decade and led to unregulated increases in air pollution (Kilday 2016). However, as long as crude oil prices continue to fall and electric vehicles remain expensive, new drivers in developing countries will continue to choose gasoline and diesel (Kilday 2016).

Therefore, it is imperative that car makers lower the cost of electric vehicles, especially in developing countries where consumers have less money to spend. Governments in developing countries must give tax breaks for EVs and encourage foreign investments. Private players could be the ones to set up charging infrastructure if the government doesn't have adequate funds to do so itself. In addition to high costs and a lack of infrastructure, there is also little awareness of electric vehicles in developing countries, and a lack of options. Possible projects to solve this include marketing electric trikes as an alternative to scooters for consumers who are unable to purchase electric cars, and utilizing electric taxis, buses, tourism vehicles, and trucks for shipping (Duda 2012). In the end, implementing EVs in developing countries would bring long-term economic benefits, as electricity is cheaper than gas in such countries.

Conclusion: the uncertain future of the automobile industry

Ultimately, we can only hope that electric vehicles will continue to gain momentum and eventually become more popular than gasoline-powered vehicles. While a complete takeover would be the most ideal scenario for our environment, a more realistic goal would be for 30 percent of all vehicles to be electric by 2030. And while driverless cars seem to be on everyone's mind nowadays, we need to address pressing energy and pollution concerns before we move on to the "fun stuff." If companies follow the example of Tesla's "Autopilot" system, eventually the first driverless car will be electric, and will potentially become the ideal car of the future. And as long as Tesla remains the "Apple" of the car industry, we can expect to see upward trends in electric vehicle popularity in the coming years, given its CEO's passion for change and excellent marketing skills. It will be important to watch what happens to the Model 3 in the near future, as it may well become the spark that ignites an unprecedented boom in electric vehicle popularity, which is what our world really needs.

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AQUAPONICS IN CANADA'S NORTH

Food supply for remote communities

Christopher Codina-Lucia and Richard Frazao

Introduction

Food insecurity is a growing problem worldwide. As populations increase and arable land becomes less available we begin to see food shortages in many parts of the world. Compounding the problem is the lack of fresh water resources required for traditional farming. Even wealthy countries such as Canada face challenges when it comes to food insecurity. In 2011, approximately 1.6 million Canadian households (or 3.9 million individuals) experienced some degree of food insecurity (Expert Panel on the State of Knowledge of Food Security in Northern Canada 2014). A large percentage of these people live in remote northern communities across Canada. The main driver of food insecurity in Canada's north is the high price of foods in these regions. The highly priced foods create a negative spiraling effect on communities as they lead to increased food insecurity, poor food choices, poor nutrition and ultimately to the serious negative health issues that are currently plaguing Canada's northern communities.

We believe that a solution to the food crisis that Canada's northern communities are currently experiencing would be to set up an aquaponics installation in each of the affected communities in order to sustainably provide each community with a variety of vegetables and fruits at lower prices than at present. Aquaponics presents an interesting opportunity as it uses 90 percent less water than traditional farming, produces approximately 6–10 times the amount of food per square foot and can be used in a variety of settings from urban centers to rural environments. Aquaponics is a closed ecosystem of aquatic animals, bacteria and plants living symbiotically. The fish produce excrement that is broken down into nitrates by nitrifying bacteria and the plants absorb the nutrients, leaving behind clean water for the fish, and the cycle continues.

Social issues and challenges

Canada's northern communities are perfect candidates for large-scale aquaponics systems. For the most part, these communities are made up of large Aboriginal populations, which have experienced in the past and continue to experience several social issues, some of which include high poverty levels, access to health care and education, adequate housing and water supply, and justice problems (Centre for Social Justice n.d.; Sawchuk 2015). The social situation for northern Aboriginal communities is slowly improving at different rates for each community. However, there is one issue that seems to be lagging behind, and that issue is food insecurity. The food insecurity problem is magnified in the Canadian far north, where between 2007 and 2008, 70.2 percent of Inuit households in Nunavut experienced moderate (compromise in quality and/or quantity of food consumed) to severe (reduced food intake and disruptive eating patterns) food insecurity. In contrast, when looking at averages for all Canadian households, it is seen that the moderate level of food insecurity falls to 5.1 percent and the severe level falls to 2.7 percent (Expert Panel on the State of Knowledge of Food Security in Northern Canada 2014).

Given that a large part of the population in Canada's north are affected by food insecurity to some extent, something must be done to ensure the affected people get the proper nutrition they deserve. Before we explain how aquaponics can aid in lowering food insecurity levels, it is important to examine how the food insecurity problems have developed and what effects they are having on communities.

Food prices

One of the main drivers of food insecurity in Canada's northern communities is the high price of food. One study suggested that in the period between 2007 and 2010, in some of the most isolated northern communities, providing a nutritious diet for a family of four cost between \$360 and \$450 a week, in comparison to between \$200 and \$250 in the south (Statistics Canada n.d.). Another study found that the 2010 weekly cost of a food basket for a family of four living in Ottawa (a supply center) was estimated at \$226, in comparison to the other extreme, where the cost for a similar food basket in Pangnirtung, Nunavut (importing community) was estimated at \$460 (Expert Panel on the State of Knowledge of Food Security in Northern Canada 2014).

The high price of food in Canada's northern communities is driven by several costs that can be put into two main categories, namely transportation costs and other logistical costs that are associated with running a grocery store in northern Canada.

Transportation costs

Food transportation costs in Canada's north are very high, largely due to the vast geographic distances between communities, the sparse populations and the harsh cold weather conditions. About one third of Canada's land is accessible by all-weather roads and rail lines. Such methods of transportation contribute to reducing the price of food transportation and that is why for the most part the cost of a food basket for people living in the more populated, southern parts of Canada is much less than for people living further north. (Expert Panel on the State of Knowledge of Food Security in Northern Canada 2014).

Less populated areas must use other methods of food transportation such as marine transport, air transport and transport by ice roads. Marine transport is the least expensive method of transportation for coastal remote communities. However, marine transport is greatly dependent on weather, climate and ice flows and is usually restricted to a few deliveries per year because of such limitations. Air transport involves transportation of items using either a helicopter or an airplane. Transportation by helicopter is very expensive and is limited in terms of cargo space. Transportation by airplane is limited by the need for runway infrastructure which is expensive to build and maintain. Finally, transportation by ice roads or winter roads using trucks or cat-trains (several sleds attached to a caterpillar tractor) is a way of keeping the cargo on the ground and minimizing the need for air transport. Ice roads are generally constructed across or near bodies of water directly on the ice, while winter roads are constructed across forests (clearcutting the forest along the route where needed). Transportation by ice/winter roads is becoming increasingly unreliable as climate change slowly raises temperatures and reduces the operating season of such roads. As previously mentioned, the cost of food in northern communities can be roughly double that in Canada's southern cities such as Montreal and Ottawa. Although transportation is significant in terms of getting the food to the communities, it only makes up between 10 and 20 percent of the difference in prices between northern communities and southern Canadian cities. The other 80 to 90 percent of the cost difference is made up of other logistical costs that relate to operating a grocery store in a northern community (Expert Panel on the State of Knowledge of Food Security in Northern Canada 2014).

Logistical costs specific to northern grocery store operations

The other logistical costs that are specific to grocery store operations in northern Canada are the construction and maintenance of the building, labor, inventory/warehousing, food spoilage and theft, market size, retailer profit margins and inadequate infrastructure for food processing and production. Generally, due to the lack of qualified workers and the distance for delivery of materials, construction costs in northern remote communities are higher than in southern Canadian cities. Adding to maintenance and construction costs is the cost of energy in some northern regions. In 2011, the average price of electricity in Nunavut was around 75 ¢/kWh (varying between 52.39 ¢/kWh (Iqaluit) to 102.71 ¢/kWh (Kugaaruk)) (CBC News 2011) compared to the average residential price of electricity across major Canadian cities, which was around 11.84 ¢/kWh (Hydro-Quebec 2012). Labor is also more expensive in northern communities due to higher wages and isolation allowances that are given to workers in such regions. Food spoilage costs (especially in terms of fresh produce) are greater in northern regions due to the long distances that foods must travel and the harsh weather conditions. In terms of market size, grocery stores operating in northern regions have fewer customers than do larger grocery stores operating in major cities, and as a result their per person costs (total costs/number of customers) is much higher. Finally, food costs in northern communities are heavily influenced by the profit margins of grocery stores operating in such regions. Most northern communities usually have one, perhaps at the most two or three grocery stores operating in the community. These stores often have a monopoly in terms of food sales and contribute to food costs by raising food prices to increase their profits (Judd 2016; Expert Panel on the State of Knowledge of Food Security in Northern Canada 2014).

The two major grocery businesses that operate across northern Canada are the North West Company (NWC) and Arctic Co-Operatives Limited (ACL). The NWC operates under the Northern Store (122 stores) and North Mart (seven stores) chains located across the Yukon, Northwest Territories, Nunavut and the northern portions of eight inland Canadian provinces (North West Company 2016). ACL is made up of 32 community-based enterprises that are located across the Northwest Territories, Nunavut and the Yukon (Arctic Co-operatives Limited 2016). Overall, the high price of foods in northern Canadian regions is a large driver of food insecurity in such regions (Expert Panel on the State of Knowledge of Food Security in Northern Canada 2014).

Health issues and the lack of food education

Other issues that relate to food insecurity in northern Canadian communities are the downstream health issues and the lack of food education. Consumption of fruits and vegetables in northern communities is generally lower than in southern cities largely due to the high prices (as previously discussed), limited quantities available, poor quality and the lack of food education. On the contrary, processed foods are gaining popularity in northern communities across Canada, mainly because in most cases they are the most available and most affordable types of foods in such regions (Queen's Native Student Association 2015). A diet rich in processed foods and that lacks a regular intake of fruits and vegetables can lead to serious health problems such as obesity, cardiovascular disease and diabetes. Studies have suggested that up to 75 percent of Aboriginals living on reserves are overweight or obese (Public Health Agency of Canada 2011). In addition, northern Aboriginal populations, when compared to other Canadians, have higher rates of risk factor for cardiovascular disease (Canadian Institute for Health Information 2013). It is noteworthy that the risk of cardiovascular disease increases with an intake of trans fatty acids and obesity, and decreases with the consumption of vegetables and fruits (Earle 2011). Diabetes was rare among the Aboriginal population prior to 1940; however, it has now reached pandemic levels in some communities across northern Canada (Young 2000). One study suggested that up to one in five people in northern Canada are living with diabetes (Public Health Agency of Canada 2011). Another health issue related to food insecurity is depression, and that must be observed closely because Canada's northern Aboriginal communities are currently struggling with high suicide rates (Queen's Native Student Association 2015).

Although it is important that fruits and vegetables are readily available at reasonable prices, such a scenario would not guarantee that people living in northern communities would consume these fruits and vegetables and have nutritionally adequate diets that could reduce the aforementioned negative health effects. Many inhabitants of such regions did not grow up with regular vegetable/fruit consumption and therefore do not realize all the benefits of eating such produce. Nutrition security comes when people living in such regions are educated on how to select, prepare and consume foods based on nutritional value and health benefits (Committee on World Food Security 2012). There are a few existing programs that look to educate northern communities about proper nutrition, including the Nunavut Food Guide Recipe Program and the Nunavik Food Guide (Expert Panel on the State of Knowledge of Food Security in Northern Canada 2014). However, there has been no drastic change in the rate of occurrence of the aforementioned negative health effects. Therefore, more needs to be done to educate northern communities on the health benefits of eating more vegetables and fruits.

Current solutions

Two of the current attempts to reduce food costs and food insecurity in northern Canada are government programs and traditional native ways.

Government programs

A few government programs exist to lower food costs in northern communities. One of the largest of these is Nutrition North Canada, which was launched in 2011 by Aboriginal Affairs and Northern Development Canada. Its purpose is to lower the high price of perishable foods such as fruits and vegetables (Woo 2014). The program lowers food costs by giving subsidies directly to retailers in several northern communities, and the retailers are then supposed to pass on the cost savings to consumers through price reductions. Critics argue that even with the subsidies, the high prices remain (Shingler 2014), and some believe that retailers might be keeping part of the subsidies in order to increase their own profits instead of passing the full cost reduction to the consumer. In addition, several northern communities are completely excluded from the program, and it is noteworthy that the entire Quebec side of James Bay includes some of these communities. On the other hand, the Government of Canada claims that the program has been a huge success. Between April 2011 and March 2015 the cost of a food basket for a family of four dropped by an average 5 percent (or $94 per month), saving a family of four over $1,100 annually. This is compared to an average increase in food prices of 9.9 percent over the same period (Nutrition North Canada 2016).

Traditional native ways

Another solution to the high cost of food which is more in line with traditional native practice, is to live off the land through hunting, fishing and gathering. Hunting, fishing and gathering activities, and the consumption of traditional foods thereby, can benefit the mental and physical health of northern Aboriginals through an increased connection to the land, enhanced cultural experiences and the nutritional benefits of traditional non-processed foods (Expert Panel on the State of Knowledge of Food Security in Northern Canada 2014). Gathering is generally limited to the summer months and consists of collecting only a few items such as blueberries, raspberries and mushrooms. Hunting and fishing continue to be popular in northern communities, but there are many limitations. Many cannot afford such activities due to the high price of equipment deemed necessary – a boat, a snowmobile, etc. – and this feeds the gradual shift from traditional foods to store-bought processed foods. To add to this, many lakes and rivers located near or downstream of a hydroelectric site contain fish contaminated with high concentrations of mercury. The mercury is leached from the flooded soils at hydroelectric dam sites and builds up in fish which, depending on the location of the dam (e.g. James Bay, Quebec), might then be consumed by people living in downstream communities. Mercury can lead to serious health problems for those who consume the contaminated fish in large quantities (Health Canada 2008).

Northern market for aquaponics

The population of northern Canada that could benefit from an aquaponics system is estimated at more than 500,000. This includes over 37,000 in the Yukon, over 44,000 in the Northwest Territories, and more than 36,000 in Nunavut (Statistics Canada 2015); the balance is made up of communities across Labrador, northern Quebec, northern Ontario, northern Manitoba, northern Saskatchewan, northern Alberta and northern British Columbia. It is noteworthy that there are approximately 1.4 million Aboriginal people living in Canada (Statistics Canada 2015).

Canada's average annual consumption of vegetables is approximately 90 lbs per person (Statistics Canada n.d.). In comparison, the annual consumption of vegetables in northern communities is estimated at less than 40 lbs per person. The difference in values is largely due to higher prices, limited quantities available, poor quality of fresh produce and lack of food education in northern Canada. The average price for vegetables nationally is $3/lb, while in northern communities it is upwards of $13–$14/lb.

Using the above-mentioned values, the current northern Canadian vegetable market is estimated to be worth $260,000,000 (500,000 people × 40lbs/person × $13/lb). The end goal of using aquaponics systems in northern communities is to lower vegetable prices to $6.50/lb (approximately half of the original price) and to increase vegetable consumption in these northern communities.

Overview of aquaponics

Aquaponics mimics the natural nitrogen cycle in nature. In lakes and rivers, aquatic animals break down the food they consume to produce both solid and liquid waste. Liquid waste is rich in ammonia while solid waste contents will vary depending on diet. In nature solid waste is further broken down by detrivores (e.g. shrimps, worms) releasing ammonia and nutrients into the water. The ammonia is broken down by nitrosomonas bacteria into nitrites (NO_2) and the nitrites are further broken down into nitrates (NO_3) by nitrobacter bacteria. Nitrates are an essential nutrient for plant growth. All the nutrients now available in the water are then taken up by plant roots and combined with basic sugars produced during photosynthesis, enabling the plant to grow. Aquatic life consumes plants and thereby continues the cycle. Aquaponics replicates this process in a closed system.

Aquaponics designs

Many designs for aquaponics systems exist, each with advantages and disadvantages. The various different designs are too numerous to mention, but there are some common elements.

Grow beds

Grow beds are either media based or floating. Media beds tend to be filled with grow media (such as clay beads or gravel) in order to accommodate plants with more complex root structures. Fruiting plants such as tomatoes, peppers, cucumbers, etc. generally grow best in these types of media. The media also serve as a bio filter trapping effluent and partially uneaten food. By adding worms into the media bed more nutrients can be extracted. The media beds are also designed to drain periodically in order to let the roots "dry out." The major downside is that these beds do clog over time and need to be "restarted," and so most commercial applications that use them do so without worms and pre-filter the solids.

Leafy plants such as lettuce or bok choy are often grown on floating rafts as they have simpler root structures. Floating rafts allow for better access to the roots, easier harvesting and less labour. They are generally the preferred method in commercial systems. Floating beds especially need good filtration as there is no medium to trap debris and waste which could damage the roots in the wetter conditions.

The major challenge in most aquaponics systems is solid waste handling, maintaining sufficient oxygenation and balancing the ratio of plants to aquatic life.

Aquatic life

Aquaponics systems can use different types of aquatic life but in general tend to use fish. Fish tend to have a high feed conversion ratio relative to other animals, making them an ideal animal for aquaculture. Some species of fish make better candidates for the close quarters living conditions of an aquaponics system. The most common species tend to be Tilapia as they are omnivorous and tend to tolerate crowding. Tilapia also tend to better tolerate a wider temperature range which is important for the growth of the plants.

Plants

A wide range of plants can be grown in aquaponics systems depending on system design. Flowering plants tend to have higher nutrient loads than leafy greens and growing them tends to reduce the output of other plants. This is an important consideration in commercial systems as most growers select the most valuable plants. Many urban growers tend to produce large volumes of herbs such as mint or basil and see large revenues in the winter months. In a remote community a variety is more important, and as all food prices are high, the variety may actually be beneficial.

Light and heat

Aquaponic systems generally rely upon either natural lighting, artificial lighting or a combination thereof. The main determinant is local climatic conditions. In Canada's north natural light is not constant and temperatures are too low for year round growing. Aquaponics systems should therefore rely primarily on artificial lighting and only use solar if insulated glass is not prohibitively expensive. The main challenge here is that in some of Canada's northern communities solar energy is sporadic, with several months filled with days of 24 hours of light or darkness. Using efficient LED grow-lighting and ensuring buildings are well insulated is therefore paramount to ensure that energy costs are minimized.

Benefits of aquaponics

Water usage and pesticides

Globally, water usage is becoming an increasingly important issue as approximately 70 percent of all accessible fresh water is used for agriculture (World Wildlife Fund 2016). More troubling still is the ever increasing usage of pesticides. Pesticides tend to slowly leach into the water table. It takes time to notice them, however, as they percolate slowly through the soil, taking up to 20–50 years to appear. The effects are far reaching: even in undeveloped areas, as much as 65 percent of water and 57 percent of fish tissue contain pesticides (USGS 2016).

Water usage in aquaponics systems tends to be approximately 90–98 percent less than in traditional farming and contains no pesticides (as they would harm the fish). By reducing the amount of pesticides these systems improve water usage in farming as well as food quality.

Since the systems are closed by design, water is continually reused. There are three major sources of water loss in these systems. Primarily, water is lost by evaporation; this will vary depending on how much water is exposed to the air and this is mostly from the fish tank(s). Second, water is taken up by the plants and fish and retained in their leaves and flesh respectively. When fish and plants are harvested, water is effectively being removed from the system. Lastly, a small amount of water is lost when removing solid waste. Dumping large volumes of water is generally not done as it can be detrimental to the system because new water is unlikely to come populated with beneficial nitrifying bacteria.

Land usage, growing season and local production

Since aquaponics does not rely on soil there are also fewer negative impacts on agricultural land usage. In traditional farming there is often erosion, drought and displacement of natural fauna.

Aquaponics can be installed almost anywhere in the world. In cold climates, for example, where there is permafrost, aquaponics can be housed in insulated buildings. By using grow lights the growing season becomes 365 days a year. With a year-round growing season and readily available nutrients there are multiple harvests or continual harvests throughout the year. The land usage is optimized and output per square foot is often 6–10 times that of traditional farming.

Since the systems can be placed directly within urban or remote communities, food transportation times and costs are drastically reduced. This local production allows major transportation savings and serves as a source of pride for local communities (e.g. "locavores"). Most importantly, producing one's food locally helps ensure maximum freshness and nutritional value.

Organic

Aquaponics is often compared to hydroponics as they are both soilless growing techniques. In hydroponics, however, a nutrient solution must be mixed together from laboratory chemicals and pesticides are often used. Over time the solution becomes contaminated or toxic and must be dumped. The whole process cannot easily be certified organic due to these factors. But since the aquaponics process mimics nature, the requirements are often stricter than regulations on organics; if the fish are fed an organic diet then the fish and plants are certifiable as organic.

This represents an interesting opportunity for aquaponics to compete with organics in many potential applications. In remote communities where organics are not usually available, an organic certification would represent another differentiator and improve confidence in the quality of the output.

Case study: northern Aboriginal community, Quebec, Canada

Community description and problem outline

There are several ideal candidates for a large-scale aquaponics system in Canada's north. Waskaganish, Eastmain and Chiasasibi are small coastal Cree villages located on the east coast of James Bay. It is noteworthy that several of these communities' rivers and water sources were greatly reduced in the early 1980s due to hydro-electric activity in the area. The communities are accessible year round by an all-weather road and by air transport. The villages are approximately 1,200–1,400 kilometers away, or about a 15-hour drive, from Montreal. Their nearest urban center is Val d'Or which is about 700–900 km distant, or a 10–12 hour drive. The outdoor growing period is limited to 2 or 3 months, due the harsh winter climate that can see absolute minimums of below 0°C even in summer (Weather 2 n.d.). The communities have populations of 800–5,000 permanent members, not including contract workers such as teachers, construction workers, and so on. They are governed by a local government or council, each made up of a chief, deputy chief and several council members, who are responsible for most decisions in the community. The communities have a few restaurants that generally offer foods typical of more southern Canadian cities. There are usually a few grocery stores, some locally owned which tend not to sell fruits and vegetables, and often one owned by the Northwest Company, which has a quasi-monopoly in terms of selling fruits and vegetables in these localities. This 'Northern' store will carry a very limited supply of overpriced fruits and vegetables (e.g. $3.79/cucumber, $11/pack of baby spinach, $9.99/head of lettuce, $3.29 for two corns, $10.92 for three peppers, etc.).

Given that fruit and vegetable prices are very high and that the communities have a limited quantity of fresh produce available, they are very good candidates for aquaponics farms. Furthermore, an aquaponics system is in line with the mission and vision of some communities. For example, one community is focused on self-sufficiency and providing a better quality of life for future generations: its mission statement talks of a concern to provide the highest quality service to its members so they may flourish economically. An aquaponics system will allow communities to be self-sufficient in terms of producing locally grown vegetables and fruits for decades to come. Clearly, if vegetable prices decrease as predicted, it will benefit members of the community economically. Finally, an aquaponics system will enhance the quality of life of current community members and of future generations as an increased supply of fresh produce will likely lead to an increase in consumption of fruits and vegetables, which will bring forth a long-term reduction in the aforementioned health issues plaguing northern communities.

Overview of a sample system

A community of about 800 people was chosen as the candidate for the sample (hypothetical) system which is described below. Given that members of these northern communities currently consume few vegetables, the assumed demand is roughly half the Canadian average of 90 lb per capita. Using 45 lb per capita, a system capable of supplying approximately 35,000 lb of produce per year would be required. As demand grows the system can be structured so as to "stack" grow beds for more produce and allow a higher fish stocking density. The filtration, however, will be designed to be large enough for full demand (70,000 lb of produce) as the incremental cost is minimal when compared to replacement.

The proposed system will be closed loop and minimize as many inputs as possible. As the building and system will need to be built from the ground up it can be customized as such.

Building

In this community it would be best to use a well-insulated (ideally earth sheltered) building instead of a greenhouse. Given that at this latitude there is little sunlight for much of the year, artificial lighting is required. Windows and skylights can be added for supplemental light as long as they are well insulted and within budget. A 14-foot minimum clearance will be required in order to ensure that grow beds can be stacked as demand increases. A small administration area as well as a space to sell directly to the public will be required in the front of the facility.

Tanks and fish stocks

The fish tanks should be made of fiberglass with a window in order to check on fish health. Further study will be needed in order to evaluate whether tilapia is a suitable crop given the local tastes in the community. A better fish stock for local tastes would be trout; however, given trout's preference for colder waters, this would limit the type of produce to lettuce.

Grow beds and plants

Grow beds should be mounted onto racks and in phase 1 be one level high. As demand increases in the community, additional levels can be added. Based on observed habits there seems to be a strong preference for lettuce in these northern communities as they can be used in healthy foods (e.g. salads) and as sides or garnishes (e.g. to hamburgers), so it would be the primary crop. As a variety of produce will be necessary; some media-based grow beds should be integrated for fruiting plants (e.g. tomatoes, cucumbers).

Filtration and compost

A large filtration system ready for full capacity production is to be installed. The filtration should be based on what is used in aquaculture and sized to operate without the plants should the need arise, the reason being that should an unforeseen event occur (e.g. a tomato blight) it would be beneficial to decouple the plants from the fish temporarily to avoid losing both crops. The solids extracted from the solid filter portion should be recuperated, however (unlike aquaculture), and mixed with the offcuts from harvested plants. Together this high quality organic matter can be composted using soldier fly larvae. The larvae serve as food for the fish, and the adult flies (which are harmless to humans) serve as pollinators. The compost itself can serve as a source of heat (temperatures in excess of 50°C/122°F are possible) and at a later stage in the project the methane can be recuperated and burned to generate heat in the winter months.

Strategy and project cost

Project costs can vary greatly depending on the chosen strategy. The most suitable strategy for the project is to partner with the community and reduce food prices. Lowering food prices will help ensure acceptance of the project and help boost demand, which in turn should help improve nutrition. Although dropping prices reduces the possible revenue it also helps reduce risks. Partnering with the community also helps reduce costs as the community does not pay taxes on projects it operates. Overall, the project should operate at a profit, all while halving the cost of fresh produce.

Food education is perhaps one of the most important elements of this strategy, as local tastes will need to change. A food education program is essential to encourage good nutrition and to increase the consumption of healthy unprocessed foods. This should start with the children in the community. The idea here is that at some stage in the approval process a "prototype" system may be required. The prototype system should actually be housed in the local school and cared for by the children. This would not be a first, as many US schools are integrating aquaponics in their food education programs. Using the commercial aquaponics system as an additional teaching tool with regular field trips and student projects will help to integrate the project into the community.

Realization

There are several funding options available and the most likely scenario is a combination of them. Specifically, government or grant funding coupled with band financing would be the best combination. Some band funding is a must in order to show other investors that there is confidence and appetite for the project.

Government funded

Currently the Nutrition North Canada program is not financing the northern communities studied, as they are accessible by an all-weather road. It could, however, be an interesting pilot project for Nutrition North to help finance, as these communities are good test markets and already have the basic infrastructure to support such a project. Nutrition North should definitely be considered as a source of funding for future projects as they are currently spending about $300–350 per person in food subsidies.

The Industrial Research Assistance Program (IRAP) is another interesting funding source as it funds research projects. Given that a fully closed system (the integrated methane recuperation, rainwater and composting portion) has yet to be realized, such a project carries scientific uncertainty, which might make it a good candidate for an IRAP research grant.

The Aboriginal Diabetes Initiative is a program whose main mission is to reduce the diabetes rate among First Nations. This is in line with the aquaponics project, and the initiative has recently received $275 million to invest over the next 5 years.

For profit

Companies that build aquaculture equipment such as Pentair or AST might make good partners, as the project allows them to test new designs and ideas as well as attract good publicity. Other potential corporate partners or investors could be food producers with a sustainability mindset such as Chobani.

Band funded

Wealthier bands, such as those with additional capital due to hydroelectric activity, may be able to fund the projects independently. While it is important that they fund a portion to show engagement, it may be better if they share the investment with other parties to reduce the risk as well as obtain available government funding.

Conclusion

Due to the high food cost in Canada's more remote regions it is feasible to establish for-profit aquaponic farms and make significant returns. More importantly, however, such a project may be more likely to succeed if it were to incorporate a social goal. Therefore by aiming to improve access to less expensive and healthier foods, the project may be able to more easily secure government funding, and change local tastes for healthier foods. Such projects, if properly designed and managed, should be priority candidates for government funding as they can have significant positive impacts on the health and economies of northern communities.

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INNOVATION IN MATERIALS AND ENERGY

Pascale Bronder

The companies and products that stick out in the world of innovation are those that solve specific problems effectively and with resources never before considered. With the pressure to outlive the reserves of fossil fuels and accommodate growing populations of cities, innovations in energy production emerge in an ever-expanding world of technology. The beauty of disruptive products and systems is that their beneficial use seems obvious and overdue. Pavegen, a London-based start up, presents an energy-generating floor tile that demonstrates the potential for such innovation to shape future cities and energy advancements.

As seen with the development of solar panels, a new technology like Pavegen's will require lots of research and investment. The first solar cells were produced in the 1950s as part of the Space Race and advanced with government funds and engineers (Inman Solar 2015). As the prices of photovoltaic cells have plummeted to levels 100 times lower than 40 years ago (Shahan 2014), the technology has advanced to roof tiles produced by Elon Musk's company (Tesla 2017). Thus solar panels are becoming a building material, and Pavegen's floor tiles are on the same trajectory.

Development of the technology

The emerging technology generates power by harnessing the energy of human footsteps. Founded in 2009 by Lawrence Kemball-Cook, Pavegen designs, manufactures, and installs this flooring, data, and energy-providing tile. The company's growth is incredible to watch, as their commitments to partnerships and installations bring them collaborators like Google, Adidas, the World Wildlife Fund, and governments (Pavegen (a) n.d.). The technology of the floor tile has also evolved greatly during the company's lifespan and shows room for further development.

Originally, the tiles were square, thick, fit together by a built structure, and only generated electricity when people stepped on their center. The Pavegen 2.0 boasted an 82-mm thin depth (a 45 percent reduction on the previous model) as well as a central luminaire. Recently, Pavegen released the sleeker, triangular tile, the V3, which outperforms the others (Pavegen (b) n.d.). The improved technology can harness 5–7 watts of power per step on the tile. The increase is thanks to the sensors placed at each corner of the triangles, which fit together in a matrix. Compression is what's behind the technology. As the tiles are pressed down to a depth of 5 mm and rise again, they generate a steady 12–48 volt electrical flow (Pavegen (b) n.d.) through electromagnetic induction (Manthorpe 2016). The hardware is therefore dynamic – i.e. it uses movement instead of constant pressure, perfect for generation by pedestrians. All versions of tile have a capacity for wireless data output, which adds to their function. To date, the company has manufactured three versions of fully functional product out of thousands of prototypes. As for aesthetics and style, the sleek geometric designs made of steel, recycled aluminum, and other materials certainly attract investors and clients. The minimalist look and seemingly simple technology excites people to envision its use every place they step.

Applications and implications

An energy-generating floor tile addresses multiple social and environmental challenges. The first is energy production in high-traffic, developed cities where fossil fuels are mainstream yet the opportunities to harness human energy are plentiful. Starting out with the goal of developing a large commercial product might have been difficult, but once word spread, Pavegen began completing installations, increasing its marketing, and receiving an influx of investor money (including crowdsourcing). There are now more than 100 permanent installations, including V3 tiles at London's Heathrow Airport, Harrods department store, and at West Ham Station for the city's 2012 Olympics; in northern France at St. Omer train station, in many other sports venues and schools, and in DuPont Square in Washington D.C. funded by the Federal Government (Pavegen (c) n.d.). The focus on public spaces, and the marketing that highlights the product as a renewable, clean energy source, plants the seeds in people's minds that an energy transition away from the current status is feasible.

The second social problem the clean energy-generating floor tile addresses is the lack of electrification and safety in developing countries. Pavegen's partnership with Shell Oil, which aimed to enliven communities through building state-of-the-art soccer fields for children, produced successful installations in Rio de Janeiro, Brazil and Lagos, Nigeria (Williams 2016). As spectators and teams move around, bright lights illuminate the field, creating a safe place to play for kids day and night. Numerous studies show the benefits of exercise, particularly team sports, in improving individual wellbeing and fostering a sense of community. From pictures of the installations, it is clear that the spaces previously used for soccer were in need of improvement. By adding the technology that extends productive hours into the night through electrification, such improved facilities offer the opportunity for more soccer clubs and teams to form. But this technology has many more applications. Brazil's and Nigeria's low electrification rates mean that students often can't study into the night, housework or paid work takes up most of the daylight hours, and so social advancements come slowly. Energy-generating floor tiles can help mitigate such situations, and exemplify the versatility of off-grid energy generation; and with an expansion to other facets of societies, there is potential for even larger impact.

The third result of this technology is the social connection the company creates through the product. Pavegen sells permanent installations, but also services pop-up events. By creating temporary, interactive set ups, "Pavegen Live" boosts brand exposure, garners worldwide interest, and also provides a great public relations exercise for the hosting company, agency, or organization. Participants get first-hand (foot?) experiences by charging their phones or illuminating surrounding lights by walking, jumping, and dancing. Some noteworthy temporary installations include an array of panels at the finish line of the 2013 Paris Marathon (Khadilkar 2013), where the runners were greeted by screens and lights powered by their own strides; and the phone-charging station at a music festival in England where, as fans danced, their phones received probably much needed energy boosts. Along with partnerships with Adidas and Coca Cola, Pavegen pushed the social outreach of their technology during 2016's Earth Hour hosted by the World Wildlife Fund, when a 48-tile dance floor and all the excited residents of Singapore attending the event sent live data directly to Twitter. Most recently, Pavegen partnered with Google to create an art instillation at the 2017 Berlin Festival of Lights (Pavegen (d) n.d.). People who attend events and interact with Pavegen's technology feel empowered to be able to make their own contribution to the creation of electricity, a staple of today's life. By engaging individuals with a technology that has great implications for sourcing energy in populated areas like cities, innovation can emerge from inspired insights about the societies and systems everyone lives in. A city powered by people will need the residents behind it, and Pavegen is pursuing that global outreach one installation at a time.

Potential improvements

Two clear steps to spreading this technology include advancing the energy output per step and bringing the price down to be cost-competitive with regular floor material. Because Pavegen seems to value the efficiency of their product evidenced by their release of three models in only six years, their commitment to improving the technology seems to continue. The engineering of more responsive tiles appears to be within reach, though Pavegen is still currently considered a start-up, meaning funding is important for the company to grow.

Along with increased investment, an increase in competition would also rapidly advance energy-generating flooring while driving the price down. The closest competitor to Pavegen is the Holland-based company Energy Floors. Founded just a year before Pavegen in 2008, Energy Floors focuses solely on sustainable dance floors (Energy Floors (a) n.d.). Their creation was spurred by opening the first sustainable dance club, and use of their energy-generating tiles instead of conventional fossil fuel sources helped meet the city of Rotterdam's 2025 goal of reducing its CO_2 emissions by 50 percent (Energy Floors (b) n.d.). Like Pavegen, they hold a mix of permanent and pop-up installations in their portfolio, and even partner with some of the same companies. Just like in the Space Race, competition will fuel better innovations, and society will benefit from such progress.

Energy storage is another important improvement. Even if Pavegen focuses on powering non-essential light fixtures like eye-catching displays in airports, for example, the function of these floor tiles is crucial given that lighting uses about 20 percent of global electricity generation (Black 2006). Public areas that require lighting are the best location for such tiles, but even these sites have moments of low-foot traffic. Batteries and energy storage are therefore important to get the most out of every step and keep lights on longer. Pavegen's Washington D.C. installation contains an energy storage component, but that multiple hundred thousand dollar project only holds the capacity to keep the lights it powers on for four hours after dark (Pavegen (e) n.d.). Improving batteries is a challenge for every renewable energy source, and the future technological advancements would benefit Pavegen's products.

Finally, pricing and costs are large obstacles to widely distributing energy-generating floor tiles. Vincent Miceli, president of Pavegen USA, made it clear in an interview that seen purely as flooring, the price is comparable to the most expensive marble in the world, which could be around $700 per square foot. Costs come from the technology and manufacturing. Currently, according to Miceli, manufacturing occurs in multiple factories under the careful watch of the CEO in order to ensure top quality and easy alterations to design. Moving to a more streamlined production style, however, could keep all parts of their product under one roof and minimize various expenses paid to multiple manufacturers. With efficient manufacturing, Pavegen can scale up and make their tiles more financially competitive. Taking the massive potential of this technology to every location that desires it will be slow. However, each of Pavegen's clients is promoting further innovation with their commissions, and with time, its tiles are expected to reach the company's goal of being a cost-competitive material.

The future of energy-generating floor tiles

The best applications for energy-generating flooring technology include dance floors, sports fields, and airports such as those already equipped with it, but also as a substitute for concrete on sidewalks and new building construction. Beyond the current capabilities, the impact of this compression technology could be applicable under treadmills, in the soles of shoes, in shopping malls, and as shock absorbers in cars and bikes, utilizing the compression mechanism that is the method of energy generation.

Another enormous untapped area of opportunity for energy-generating floor tiles is Asia. Some of the heaviest foot-traffic areas occur in the densely populated countries of East and Southeast Asia. One example is the Shibuya neighborhood in Japan, a packed commercial area where around 2,500 people walk to the other side of one of the many crosswalks every time the light changes (DiNuzzo 2017). The potential in pure human movement is astounding. Another example is Nanjing Road, a pedestrian street in Shanghai, China. Lined with shops and restaurants, there are many establishments here that could save money from the harnessing of steps outside their doors. Despite their inability to hook the tiles up to a grid, individual shops could power advertisements, window displays, lights, or interactive activities with the electricity generated and captured. Human-powered energy sources could become the next complementary system to the well researched and implemented earth- and environment-powered renewable sources like solar, wind, and geothermal.

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GEOENGINEERING

Peter Mahony

Anthropogenic climate change is the defining problem of our generation and a complex one, and if not mitigated will have irreversible effects on the sustainability of our planet.

On an individual level humans have a longstanding and remarkable ability to think through complex problems and to devise and implement innovative solutions. For millennia this system of recognizing a problem, devising a solution, and finally implementing the solution has been remarkably successful; however, when it comes to addressing climate change this basic human instinct has broken down.

While it may be an oversimplification to claim that there is a lack of greenhouse gas regulation because global warming and its effects are not immediately appreciable, there has historically been a lack of motivation to rein in GHG production to safe levels because not enough people acknowledge that it is very much a pressing issue.

Solving the issue of climate change is difficult because individuals cannot appreciate the consequence of their own personal, seemingly minor carbon pollution. The challenge is that it is nearly impossible to fully rationalize how an individual's miniscule carbon contribution can aggregate across a population to affect something as pervasive as the global climate, and yet individuals are also expected to switch from the incumbent polluting technologies to green technology for reasons they cannot fully comprehend. For example, many citizens are skeptical that driving to work is warming the climate, especially when they cannot sense the temperature increasing.

As a result they will not replace their gas-driven car with an electric alternative because there doesn't seem to be a pressing reason to do so. This lack of clear motivation to address climate change on an individual level has culminated in weak political incentives to enact pragmatic carbon regulations on a national or international level.

There are effectively three strategies to managing climate change. The first approach is to decarbonize the economy through market-based regulations. The second and third methods fall under geoengineering and involve sequestering carbon directly from the environment to offset emissions, and reducing the solar energy that is converted to heat through albedo alterations.

While creating regulations to effectively reflect the damage carbon dioxide inflicts on the environment is the most conventional method, it hasn't garnered the ubiquitous support it needs to be successful. In 1973 while teaching at MIT, David Gordon Wilson first proposed a carbon tax that would de-incentivize the use of polluting machinery (Berdik 2014). But the concept has only now gained traction over four decades later and in that time carbon emissions have continued business-as-usual with only limited subsidies for efficiency improvements. From 1990 to 2015 the US alone produced an additional 6.6 gigatons of CO_2 representing about 0.35 percent of the global carbon budget (EPA 2017). There appears to be a dangerous lag between when regulation is needed and when political motivation catches up.

The time lag between carbon emissions and carbon regulation presents an opportunity for geoengineering because if strong regulations are not enacted soon the remaining 1,000 gigatons of CO_2 budget will be used up. To prevent drastic ecological consequences a coalition of nations or a single actor operating unilaterally may endeavor to change the global climate through geoengineering. Here we will define the leading geoengineering methods for mitigating anthropogenic warming, by discussing carbon dioxide removal (CDR) and solar radiation mitigation (SRM).

Carbon dioxide removal (CDR)

CDR techniques remove carbon dioxide from the atmosphere and convert it into different chemical compounds that do not have global warming potential. The atmosphere's greenhouse effect is then diminished while the carbon is bound in the modified compounds.

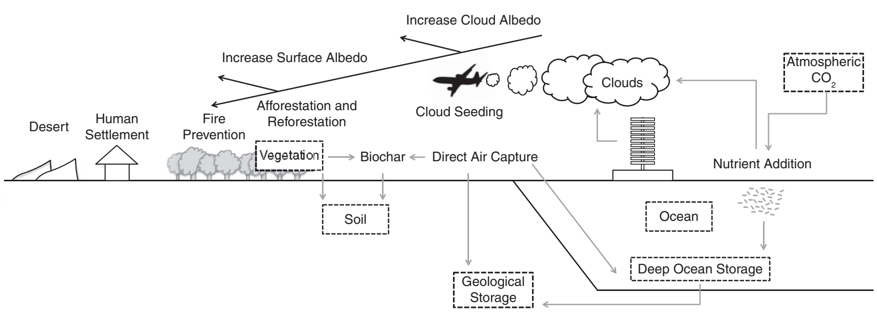

FIGURE 31.1 Basic carbon dioxide removal and solar radiation methods
Adapted from Lenton and Vaughn 2009.

The carbon cycle consists of four main chemical reactions: combustion, photosynthesis, weathering, and metamorphism. Combustion is the burning of reduced carbon to form carbon oxide compounds, releasing energy in the process. This is the fundamental chemical formula behind burning organic material, coal, oil, and natural gas, and the largest atmospheric flux of GHG pollutants. As we have already explored, reducing combustion by market-based regulations is the first approach to limiting climate change. The second carbon formula is metamorphism. Metamorphism is the geologic process where carbon compounds in rock material are vaporized and released in volcanic eruptions. There are no proposed methods for limiting this flux, as geologic processes are out of our scope and control. The last two formulas, photosynthesis and weathering, are particularly important for geoengineering because they are carbon sinks, removing atmospheric carbon from the atmosphere and returning it to a solid form. Photosynthesis is the biological method for harnessing solar energy, where organisms take in carbon dioxide and water to create complex glucose sugars and oxygen. The sugars can then be converted into the durable fleshy tissue of the organism, thus sequestering the carbon until the organism is burned or decomposed. This is the fundamental chemistry behind afforestation/reforestation and nutrient addition in the open ocean. The last formula – weathering – has the longest carbon residence time and is effectively a permanent sink. When exposed to the elements, calcium silicate minerals on the continents are broken down into their constituent ions and washed into the oceans where they recombine with atmospheric carbon dioxide to form calcium carbonate in shells. These carbonate shells eventually form limestone and are sequestered for millions of years. The chemistry behind weathering governs where the carbon in direct air capture technologies can be stored.

Afforestation and reforestation

The first method of carbon sequestration – forest replanting – has become commonplace, not because it is necessarily the most effective at sequestering carbon or mitigating climate change, but because it presents other benefits and is politically expedient. Proponents of reforesting, particularly conservationists, may brand themselves as helping to reverse climate change, but there is little evidence to support this claim on any meaningful scale. Admittedly, the growth of vegetation is, a fundamental way to sequester carbon but in the case of reforestation and conservation projects, once the forest has reached maturity the rate of carbon sequestration into biomass rapidly decreases (Jandl et al. 2007). However, if the trees are harvested and used as building material, the carbon trapped in the wood is removed from the environment for the lifespan of the structure. A potential risk attached to reforestation is that expanding terrestrial forest ecosystems could reduce available arable land, and with a growing global population reducing the available land for farming is problematic. That isn't to say that reforesting isn't important for protecting at-risk species or preventing erosion, but it shouldn't be regarded as a solution for reducing overall atmospheric carbon.

Nutrient addition

A second biological method is to fertilize plankton blooms in the remote ocean. Plankton perform photosynthesis like trees and potentially could be a larger carbon sink than terrestrial vegetation. It has been postulated that if the iron content in the oceans were artificially increased, plankton populations would explode, pulling carbon from the atmosphere (Lenton and Watson 2000). While this hypothesis sounds promising, it is nearly impossible to predict the entire portfolio of consequences that changing the chemistry of the world's oceans would cause. The ecological repercussions could be boundless and, if the marine environment were to collapse, the seafood industry would follow, changing the dietary practices of much of the global population. Simply put, the ecological uncertainties of manipulating the entire marine ecosystem preclude any serious consideration of nutrient addition.

Direct air capture (DAC)

In direct air capture methods, carbon dioxide is filtered from the atmosphere and later sequestered. The clean coal effort has yielded several promising methods for scrubbing carbon from smoke stacks as well as directly from the atmosphere (Kumar et al. 2015). However, the question remains: what do you do with the carbon once it has been captured?

The first proposed method is to pump the carbon into the deep ocean. The gaseous carbon dioxide, when exposed to the liquid water, would react to form carbonic acid compounds. This same reaction occurs between atmospheric carbon and the ocean surface, thus decreasing surface pH and causing ecological complications (i.e. coral bleaching). However, when the carbon is instead pumped into the deep ocean it is less likely to have severe ecological implications. If the carbon were pumped to depths exceeding 1,000 meters, it would not have appreciable ecological complications because the bathypelagic zone has very little ecological diversity and the oceans are heavily stratified, limiting vertical mixing. Additionally, if the carbon dioxide were injected to 1,000 m, the residence time would be on the order of 300–500 years (Liro et al. 1992). However, our understanding of the deep ocean biology and ocean dynamics is extremely limited. It is possible that the abyssal ecosystem plays an important role that we are not aware of, or that the influx of deep ocean carbon could change ocean cycling.

The second proposed method is to inject carbon into geologic structures. Carbon dioxide is currently used in enhanced oil recovery or EOR, for extracting additional fossil fuels from aging fields. The shale oil boom has popularized the use of EOR techniques and in the US 17 million tons of anthropogenic CO_2 has been sequestered by this method (IEA 2016). Other viable geologic disposal methods include injecting CO_2 into unminable coal seams, deep saline aquifers, and depleted oil and gas fields that are enclosed by impermeable shale layers to prevent carbon dioxide from escaping to the surface. If once injected the carbon forms carbonate minerals, disposing carbon into geologic structures could retain carbon dioxide for millions of years (Zhengrong and Lin 2014).

Biochar and climate-smart agriculture

The ultimate sequestration method is to use carbon as a fertilizer for agriculture. Biochar is a method of increasing the carbon concentration in arable soils by burning waste biomass and then incorporating the charred material into the soil. Given that plants harness carbon and convert it to glucose by photosynthesis, more available carbon should facilitate increased productivity. Biochar has been used as a fertilizer for at least 2,000 years, and if widely utilized it could sequester an estimated 1.2 gigatons of carbon per year with a residence time 10–100 times longer than uncharred biomass (Paustian et al. 2016). This method is preferable to nutrient addition and direct capture because it is cheap, its effects are well understood, and it can be reproduced at a large scale.

Solar radiation management (SRM)

Beyond CDR there are also geoengineering methods to curtail global warming via albedo alterations, in which the reflectance of the earth is increased so that more solar energy is returned to space. When sunlight enters the atmosphere, most of it passes through the upper atmosphere to reach clouds and the planet's surface. Upon impact with opaque material, a portion of the energy in the light is absorbed and converted to infrared heat. Albedo is a measure of the amount of incoming light that is reflected instead of absorbed, such that mirrors reflect all light, white and light colors reflect most light and dark colors reflect the least. By increasing the planet's albedo, less sunlight is converted to heat and retained. If planetary albedo is properly controlled, it could offset the greenhouse effect and stabilize the temperature.

Similar to carbon sequestration, there are both biological and non-biological methods to increase planetary albedo. The biological methods may be more economic because they are augmented by biological systems, but the uncertain ecological implications could limit their application. The primary biological method is to enhance phytoplankton-based cloud seeding while the non-biological methods are more diverse.

Cloud seeding

Cloud seeding relies on introducing minute particles into the atmosphere that water is able to coalesce on to form clouds. These particles are known as cloud-condensing nuclei, and the resulting clouds help to reflect some incoming solar radiation.

The circulation of sulfur mitigates cloud formation over the oceans where sulfate aerosols act as a cloud-condensing nuclei. Sulfate enters the troposphere as an aerosol from sea-spray or indirectly via the oxidation of the biological waste product dimethyl sulfide or DMS (Smil 1985). Sea-spray constitutes a large, consistent flux but it has been suggested that further increasing sea-spray flux could increase cloud formation (Salter et al. 2006). It is also possible to promote marine cloud formation by increasing DMS production or augmenting the oxidation of DMS to sulfate. Nutrient fertilization has been proposed to increase DMS production but as we've seen, this is not a feasible option because it is not possible to predict all future environmental feedbacks. The second method is to augment the oxidation of DMS to sulfate by removing trace compounds from the atmosphere. When the atmosphere contains trace bromine oxide radicals, a significantly higher portion of the atmospheric DMS is converted to the non-cloud-forming dimethyl sulfoxide series instead of the cloud-forming sulfate (Glasow and Crutzen 2003). Accordingly, if the atmosphere is scrubbed of bromine oxide compounds, the amount of DMS that follows the DMSO pathway will decrease, and cloud formation should increase. Nonetheless, this is a purely theoretical method and there is a dearth of methods to scrub bromine at atmospheric scales.

Over terrestrial environments there has been a long history of cloud seeding to increase precipitation over arid regions. The methods for terrestrial cloud seeding involve emitting cloud condensing nuclei and cooling the atmosphere to promote ice crystals to form. Since the 1970s at least, 15 states have used cloud seeding programs where airplanes release silver iodide or potassium iodide as cloud condensing nuclei and liquid propane or dry ice as cooling agents, ultimately kickstarting cloud formation (Dennis 1980).

Surface albedo alteration

Surface albedo strategies include forest fire prevention, white-painting structures and roads, and releasing metal particles on deserts. Surface albedo alterations are potentially the most expensive and least effective geoengineering methods; however, they may offer other benefits that could justify their consideration.

Fire prevention has been treated as a human health, or an ecological issue, but it also helps to limit climate change by increasing global albedo. The green foliage absorbs more light than ash would, and if the forest were to burn, the previously photosynthesized carbon would be released. Since fire prevention is already economic for its ecological and immediate health benefits, it will probably continue indefinitely with or without pressure to manage climate change. That isn't to say that fire prevention isn't without its controversies or potential improvements, but it would be redundant to argue for its application when it is already enforced.

The second method of increasing surface albedo is to increase the albedo of man-made structures. This would have almost no immediate effect on the planetary albedo, but could reduce energy usage. Buildings and homes cover far too little of the planet's surface to change albedo appreciably, but during the summer months lighter colored roofs retain less heat and could lower air conditioning expenditures (Royal Society 2009). If only new structures were built with lighter colored roofs, the increased roof albedo would cut energy costs without appreciably changing global albedo.

One of the more radical methods of increasing surface albedo is to release metal particles on deserts (Gaskill 2004). This should only be considered as a last resort because sandy deserts are already relatively reflective and the additional stress of metal contamination could force endemic species into extinction.

Conclusion

The list of geoengineering methods described here is not exhaustive, but is intended to show some of the potential consequences of the most popular methods.

The historical lack of regulation regarding carbon dioxide emissions has shortened our time to decarbonize the economy before the severe consequences of climate change are realized. Consequently, geoengineering must be considered as a feasible approach to augmenting the decarbonization efforts, but it mustn't diminish our motivation to decarbonize the economy.

The principle of geoengineering is for humans to change particular inputs in the environment to facilitate planetary modification. Any such modification is a radical approach to reining in climate change because we often have incomplete information and do not fully understand the implications of changing the environment. Nonetheless, some methods are safer than others. The first geoengineering method to be utilized should be direct air carbon capture, in which the carbon dioxide is used as a fertilizer or disposed of in geologic structures. If climate change is not mitigated by this technique, more drastic methods may have to be be considered.

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