FONTAINE RESEARCH PARK CASE STUDY:
DEVELOPING CARBON-NEUTRAL MODELS FOR THE UVA AND THE COMMONWEALTH

BUYING A GREEN CONSCIENCE:
THE DEVELOPMENT AND STABILIZATION OF CARBON OFFSETS

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Systems Engineering

By
Bailey Thran

November 2, 2020

Team Members:
Thomas Anderson
Andres Clarens
Daniel Collins
Chloe Fauvel
Harrison Hurst
Nina Mellin
Arthur Small

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

Signed Bailey Thran Date: 11/24/2020

Approved: Date:
Catherine D. Baritaud, Department of Engineering and Society

Approved: Date: 2/9/21
Andres Clarens, Department of Engineering Systems and Environment

Approved: Arthur Small Date: 02/08/2021
Arthur Small, Center of Economic Policy Studies

Climate change presents a systemic risk to all citizens on Earth. It threatens the basic elements of life: access to food and water, health, land use, and physical and natural resources. According to Nasa's Climate Change division (n.d.), "the Intergovernmental Panel on Climate Change (IPCC), which includes more than 1,300 scientists from the United States and other countries, forecasts a temperature rise of 2.5 to 10 degrees Fahrenheit over the next century" (para. 2). This once seemingly premature scientific field of study now breaches into the lives of all individuals, as citizens of all countries start to see its consequences. Diverging weather patterns eliminate natural habitats as glaciers shrink and hurricanes strengthen, the Earth further deviates from its natural ambient levels that threaten future living conditions (Brennan, 2020; Lin, Emanuel, Oppenheimer, & Vanmarcke, 2012). As scientists predicted in previous years, intense heat waves, extended droughts, and accelerated rising sea levels reveal the Earth's riot against increasing greenhouse gas levels (Houérou, 1996; Meehl & Tebaldi, 2004; Sierro et al., 2009). Citizens of the Earth experience firsthand the interplay of science and technology with society.

Environmental punishments impede on human well-being, and society must now project forward to minimize carbon emissions. In response, UVa assembled a network of students, professors, and third-party players across multiple fields to develop a plan to achieve carbon-neutrality by 2030, and eventually fossil independence by 2050. Further, this technical project will expand the scope to the State of Virginia to consult the Department of Mines, Minerals and Energy (DMME) on crafting a separate plan with the similar end goal. Alongside the technical aspect of the project, the Science, Technology and Society (STS) Research Project will narrow the focus to a major agent in sustainable finance by looking at the inconsistency of carbon offsets and the network that stabilized the innovation. As the market for offsets grows, a critical lens must be applied to this accepted process to analyze its environmental effectiveness. With more institutions pledging carbon neutrality, now more than ever both the government and its citizens must hold corporations and communities financially and environmentally accountable for their public promises. The loosely coupled topics will help paint a clarifying picture on different environmental strategies that aim to achieve the same goal. However, the different methods behind both processes may highlight the key motivations of attaining such goals.

Eight members compose the technical group. System engineers Thomas Anderson, Daniel Collins, Chloe Fauvel, and Bailey Thran, team with environmental-track civil engineers Harrison Hurst and Nina Mellin to provide an array of knowledge across multiple concentrations: economics, computer science, and environmental sustainability. Systems Engineer Arthur Small and Environmental Engineer Andres Clarens advise the project with their extensive knowledge in environmental economics and anthropogenic carbon flows. Small received his Ph.D. in Agricultural and Resource Economics from the University of California at Berkeley and currently holds a senior research position in the Department of Economic Policies Studies at the University of Virginia. As an economist and decision scientist, Small offers specialized knowledge in issues regarding energy, climate, and environment (Small, n.d.). As a professor in the Department of Civil and Environmental Engineering, Andres Clarens concentrates in carbon capture and sequestration and researches strategies surrounding negative emissions (Clarens, n.d.). In addition to applying the advisors' environmental expertise, the team uses graduate student Roger Zhu to provide the analytical tool TEMOA in the team's evaluation of energy sources. To supplement the group's efforts, many department leaders within the University of Virginia provide project statuses and insight on required areas of research. Once the team presents their strategy proposal to the facilities management in January 2021, the technical project will shift focus and work more closely with DMME to provide a second proposal in May. A final report will be presented sometime in the later half of the second semester, as the final date is to be determined.

FONTAINE RESEARCH PARK CASE STUDY: DEVELOPING CARBON-NEUTRAL MODELS FOR THE UVA AND THE COMMONWEALTH

According to the US Energy Information Administration's (EIA) Annual Energy Outlook (2020), economic growth is the primary contributor of energy demand and related CO_2 emissions (p. 19). Further, the Outlook noted that "energy-related CO_2 emissions in all [2020 Annual Energy Outlook] cases decrease early in the projection period before increasing in the later years through 2050 as economic growth and increasing energy demand outweigh improvements in efficiency" (p. 146), as summarized in Figure 1. As conduits for economic growth, corporations and institutions largely influence environmental outcomes, thus such groups should be held partially responsible for their environmental contributions.

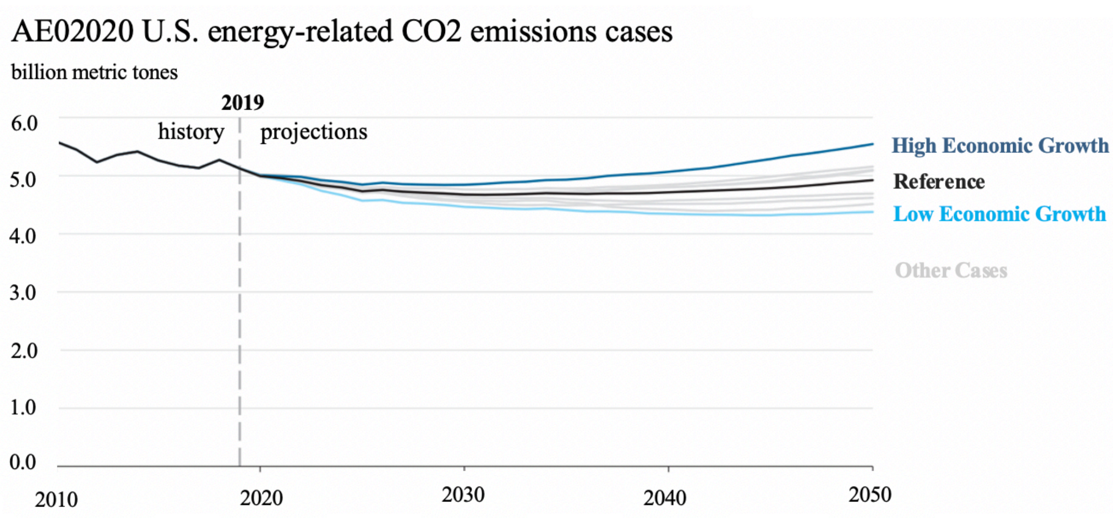

Figure 1. U.S. Energy-Related CO_2 Emission Cases. The graph shows that economic growth is a main driver for CO_2 emissions and that emissions are projected to increase. Adapted by Thran (2020) from U.S. Energy Information Administration (2020).

Over the past several months, a large number of businesses pledged commitments to decarbonize their operations. Companies such as Microsoft, Delta, and Shell, as well as states like California and Virginia, promise to cut their carbon emissions to zero over the coming decades. However, in many cases, these institutions do not yet have detailed plans outlining the path toward achieving these goals. The technical group will team with UVa and the Commonwealth to design two plans, one for decarbonizing the University and one for decarbonizing the Commonwealth. Throughout the process, the team will work with stakeholders within both institutions and use modeling tools to identify activities that will cumulatively enable goals.

In order to achieve this goal, the University deployed a network of department leaders and experts to implement the strategy, and in January of 2021, all relevant stakeholders will meet to formalize the plan. The technical team will assist in breaking down relevant information and scoping the project to a specific area of study. Carbon-neutrality umbrellas multiple dimensions of emission reductions: renewable resources, loading balancing initiatives, transportation reduction, and so on. To provide useful information, the technical project narrowed its frame by looking at the new development of the Fontaine Research Park and exploring its sustainable opportunities. In the past few years, the University assembled a group to expand the Fontaine site by renovating previous landscape and adding new research buildings. The technical team decided to utilize the site's early design phase to target the greatest impact at the University.

FORMING OBJECTIVES

Three main objectives have centralized the team's focus. First: develop a case study. As a large institution, understanding the interplay of different agents and actors within the network remains difficult and can quickly become disordered. The project aims to use Fontaine as a case study in order to expand the University's understanding of distributed energy on campus, especially in the context of developing new buildings and retrofitting existing ones as both are main aspects of the current design. Second: create a model. As of 2020, the Virginia Clean Economy Act now mandates Dominion Energy by law to implement 100% renewable energies by 2045 (Yarmosky, 2020). The University of Virginia, as one of the largest energy consumers in the state, plays a crucial role in reaching state emission goals. In addition to achieving the University's own goals, the team questions how the institution could influence other organizations to pursue similar distributed energy projects by serving as a model. Third: incorporate the community. Reducing emissions requires action from all members of the community; engaging and persuading students, faculty, and Charlottesville residents to join the initiative will play a crucial role in the project's success. The team aims to explore community dimensions of adoption and transmission to reduce emissions in order to ensure a long-lasting solution.

To develop the three main objectives, the team had to research the school's and state's energy statuses to provide context for the project's capacity. Research conducted from the University shows that electricity proves to be the primary driver in greenhouse emissions, as presented in Figure 2. Electricity use has shown a steady decline, however drastic methods must be implemented to achieve the 2030 goal. Conversations with key stakeholders such as Cheryl Gomez, the Director of Facilities Management at the University, Jesse Warren, the Sustainability Program Manager for Buildings and Operations, and Sathish Anabathula, the Associate Director of Power and Light, shared background for different dimensions of electricity use on campus.

Discussing areas which lacked thoughtful information and research helped guide the team to focus on distributed generation at the Fontaine Research Park site.

Figure 2. Carbon Reduction Progress. The chart shows electricity to be the main contributor of greenhouse gas emissions and demonstrates a decline in electricity-correlated emissions. (Adapted by Thran (2020) from University of Virginia (n.d.)).

METHODS AND OUTCOMES

Different analytical tools will structure the evaluation of the plans. Energy systems modeling, life cycle assessment, and carbon footprint calculations will help make informative decisions on a cost-benefit approach. Energy modeling programs such as TEMOA and R Studio, coupled with Excel, will formalize raw data across multiple variables to bring insight for future plans. The team aims to determine the extent of which to implement different renewable energies, load balancing technologies, and other resources to optimize emissions reductions in both the micro-grid and the Commonwealth. Carbon-neutral plans typically involve large systems with many working components. Building a model for other institutions and states may accelerate both the national and global emission reductions by helping provide solutions for intertwined systems. The study may allow for greater resource allocation on research and development initiatives that will shift marginal abatement cost curves and eventually produce greater reduction outcomes. The team will have the Rivanna supercomputer at its disposal to help process large data files that run on our programs. Finally, in 2021, the research and work will be presented in a technical paper. With the research, the team anticipates to publish a document for UVa's Carbon-neutral plan with specific designs and technologies that will be put in place on grounds. The form of the document is yet to be determined. Additionally, the published paper hopes to encourage other institutions to develop models by using the technical report as a framework.

BUYING A GREEN CONSCIENCE: THE DEVELOPMENT AND STABILIZATION OF CARBON OFFSETS

In simple terms, companies, states, and individuals use carbon offsets as an accounting mechanism to balance their own pollution with third party reduction credits, however typically larger entities use these credits to meet environmental standards. Compliance schemes, such as the United Nations Framework Convention on Climate Change, Kytoto Protocol, and the European Union Emission Trading Scheme allows carbon offsets to be bought and sold to achieve certain targets (World Bank, 2015). However, there remains a wide variety of programs that certify offsets with different methods and procedures.

The process of issuing carbon offsets poses many challenges, two of which include the quantification of carbon benefits, i.e. the reduction of emissions, and the verification that offsets achieve such reductions. In 2005, the World Bank analyzed eleven main programs used to issue carbon credits and compared the different aspects of each one. As shown in Figure 3, An offset must complete six different phases, however their research showed some programs skipped certain steps. Sohngen (2010) study explores the development of a forestry offset and outlines the difficulties in monitoring and verifying low-cost forestry offsets. He explains that a “forestry carbon sequestration or emission reduction program can only work if a valid system of measuring, monitoring and verifying (MMV) carbon credits on the landscape can be developed and implemented cost-effectively” (p. 6). Poor policy designs could essentially make many low-cost offsets misleading, and potentially harmful. Jardine (2009), Sohngen (2010), and Wara (2007) have addressed inconsistencies with offset calculations and note that poorly designed offsets schemes could undercut the efficiency of emission limits.

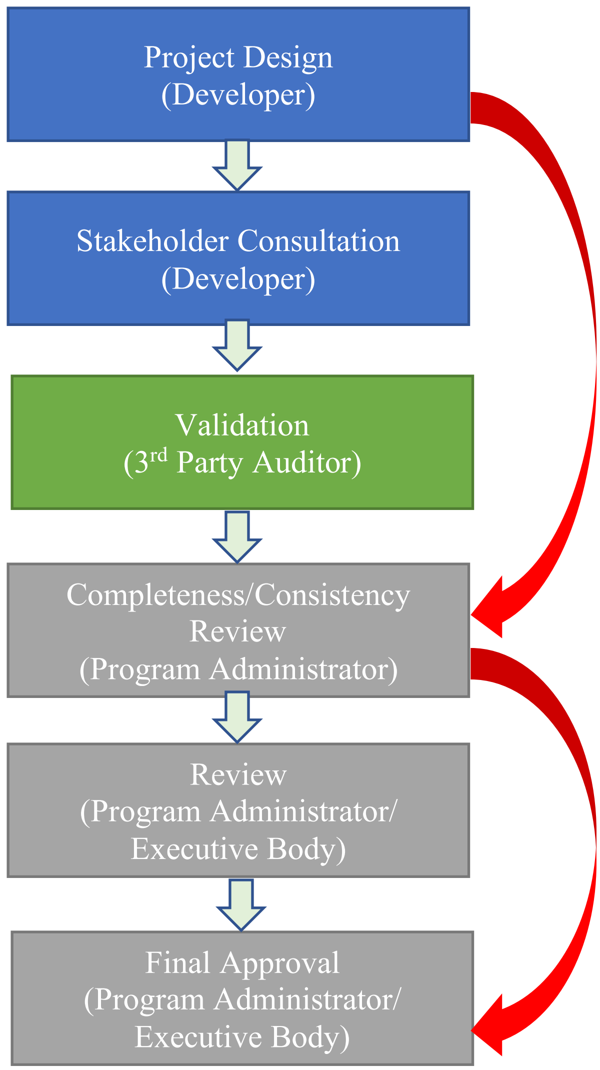

Figure 3. The Process to Issue Carbon Offsets. The global process shows inconsistencies in phase completions across multiple programs. (Thran, 2020)

Professor Kevin Anderson also points out the issues of sending misleading price signals to the market, which in turn decreases emission reduction incentives:

> The promise of offsetting triggers a rebound away from meaningful mitigation and towards the development of further high-carbon infrastructures. The UK government's purchase of offsets through the CDM and its simultaneous drive towards both additional airport capacity and the exploitation of UK shale-gas reserves are just two such examples (Anderson, 2012, p. 1).

In short, offsets may remove the mandated responsibility of corporations to reduce emissions. The environmental goal of offsets simply involves reducing emissions, however buying carbon offsets allows legally mandated parties to claim reductions that were going to be produced either way. In theory, an offset scheme should allow firms to maximize flexibility to achieve environmental objectives (Field & Field, p. 257), rather than putting restrictive requirements that would increase compliance costs. However, this flexibility often fails to provide desired results. Issues with double-counting credits and the ability to increase emissions through cheap reduction alternatives eventually lead to harmful consequences. Thus, the production and distribution of bad, cheap offsets result in higher emissions than without the accounting mechanism.

As of May 2020, German bank Berenberg projected that the value of the global market for carbon offsets could total $200 billion by the year 2050 (Watson, 2020). If research suggest offset schemes result in ineffective outcomes, then why do countries continue to legitimize this innovation? In order to understand this question, one must break down the innovation into three parts: the motives for its development, the materialization of the artifact, and the diffusion of the innovation. As environmental laws mandate new business compliances and more institutions pledge carbon neutrality, understanding how the environmental inefficiencies of this innovation emerged proves crucial for instilling a better solution. To craft efficient legislations, the government and offset-issuing programs must achieve a better understanding of past failures. The STS Research Paper will explore these three ideas in order to understand how the innovation stabilized within the global market. Studying the interplay of social practices during the development of quantifying a carbon “price tag” for environmental assets will shed light on the offset façade that society crafted.

The paper will investigate these questions using Latour's and Callon's Actor-Network Theory (ANT) (Callon, 1987; Latour, 1987) to structure the research and analyze the multiple dimensions of the artifact's development. Bijker and Pinch's (1984) idea of interpretative flexibility will play a key role in understanding the motives that influence the establishment of carbon offsets and how the innovation has molded to fit these multiple goals. The corporate motives of maximizing profits often distorts the ethical dimensions that aim to uphold their environmental stewardship. In turn, both corporations and individuals look toward the technical aspect of offsets to balance the organization and cultural components. Figure 4 contours the three dimensions in Pacey's triangle (Pacey, 1985), within the context of the development phase of an offset: materialization. All three aspects simultaneously shape the innovation, as each one plays a

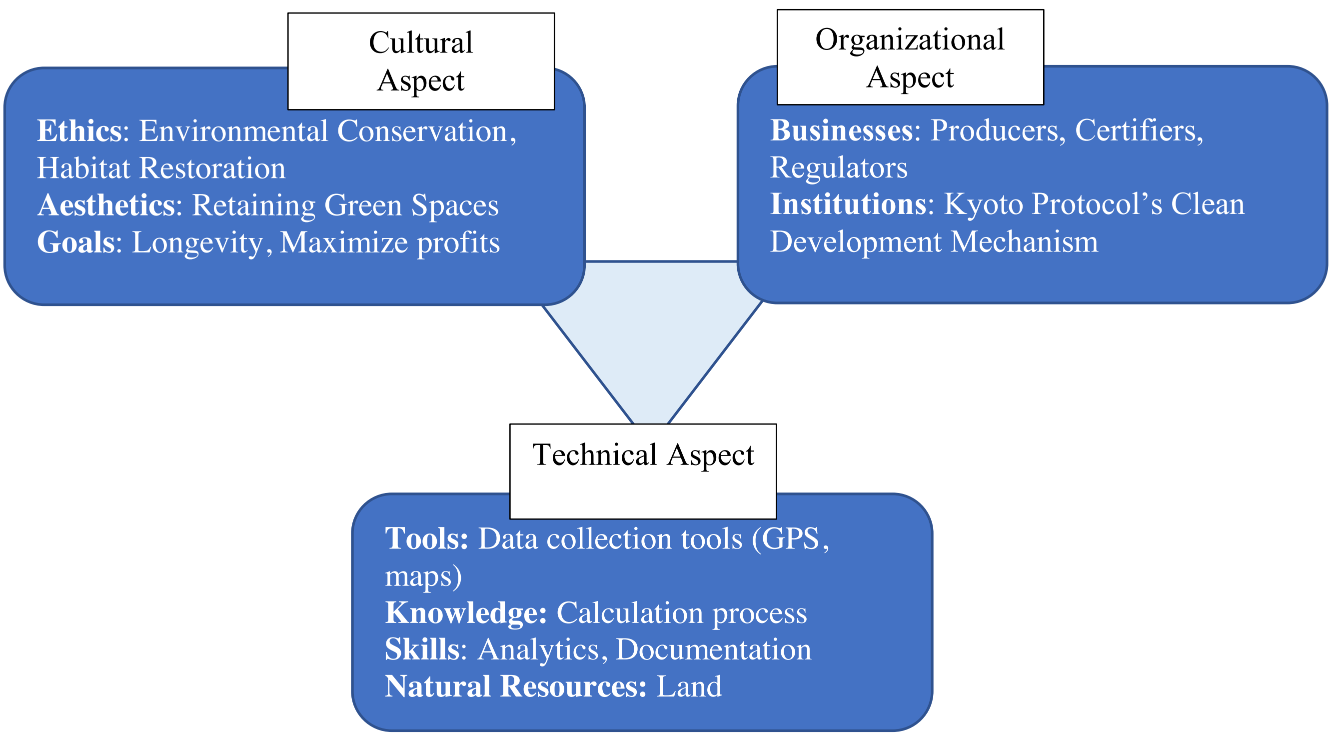

Figure 4. Applied Pacey's Triangle. This figure demonstrates a few key examples under each aspect within the forestry data collection phase, however the figure in no means is an extensive list of all instances. (Adapted by Thran (2020) from Pacey (1983)).

role in the development of the offset. Ethical values for reducing emissions influence the institutions implementing and creating offsets, while the technical aspect involves the natural resources that create the innovation. Exploring these three aspects throughout the paper will help establish the process of how the innovation emerged.

Carbon offsets remain one of the most controversial emissions reduction mechanisms within environmental policies. The loosely coupled STS Research Paper analyzes an alternative path for achieving the goals of the technical project, thus in turn gives insight on the benefits of the two approaches: one through engineering technologies and processes, the other through financial book-keeping. Both remain common practices, and often institutions couple the two methods within one model. Google for example couples its carbon offsets with other initiatives such as creating efficient data centers and investing in renewable energies ("Google Sustainability", n.d.). As Figure 5 outlines, there are multiple groups surrounding the innovation, each with their own set of problems. Carbon-reduction includes strategies such as distributed generation, research and development, load-shifting, demand response, and incentive strategies to reduce transportation and electricity use. Additionally, utilizing some strategies can provide resources to exploit others. By using the research and arguments outlined in the STS Research Paper, more informative decisions may be made in developing new mechanisms for achieving emission reductions while still providing effective environmental results.

Often, the commodification of carbon storage allows companies and individuals to seemingly satisfy their environmental ethics while still pursing operations as before. In turn, offsets can be seen as both buying a clean conscious and fulfilling authorized requirements. Though carbon offsets offer misleading information, some research has shown the beneficial

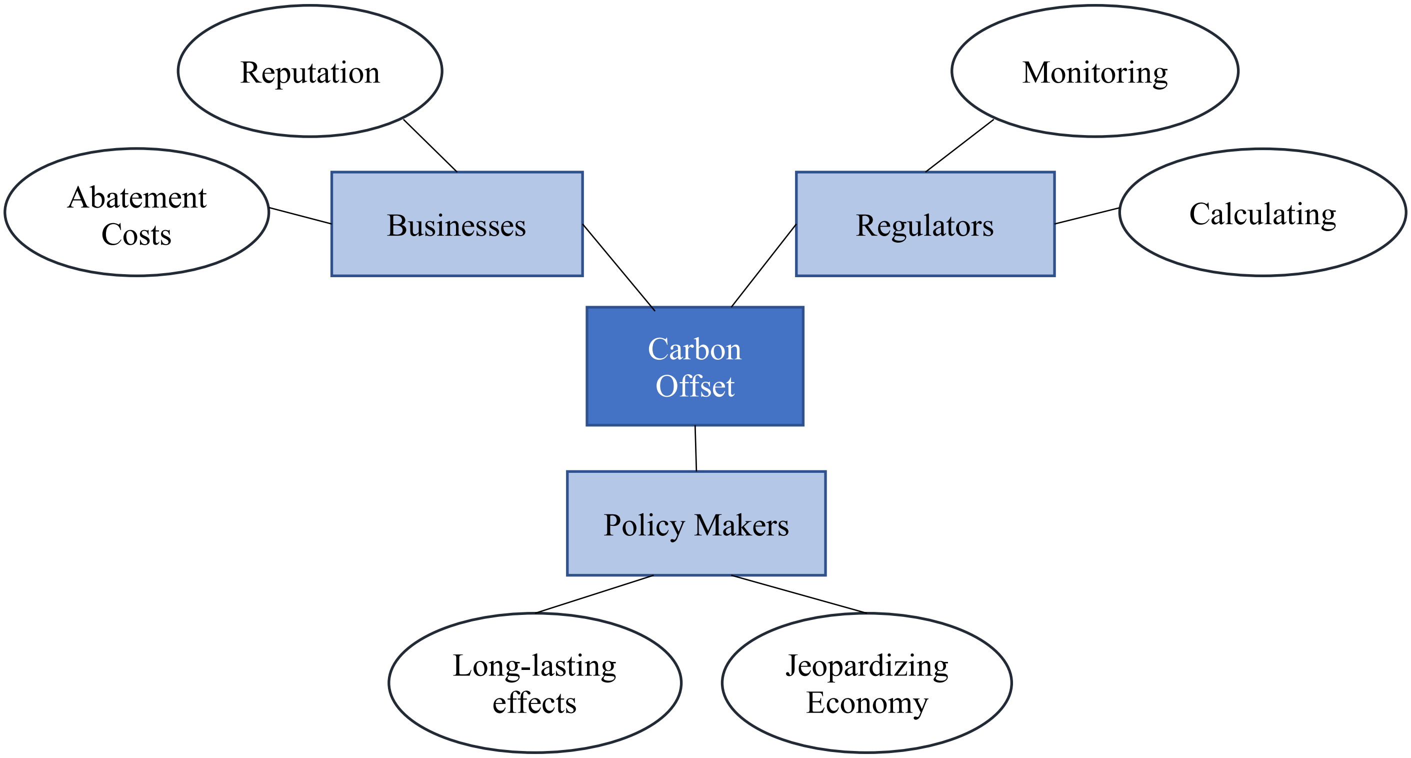

Figure 5. Artifact, Social Group, Problem. This figure shows some example problems associated with different social groups. (Adapted by Thran (2020) from Bijker (1984)).

components that increase engagement with developing countries. Professor David Victor summarizes that "engaging developing countries may require massive transfers of resources, and the only politically feasible way to mobilize and channel those resources is through mechanisms such as offsets that keep the full cost hidden and away from public budgets" (2020, p. 1). Offsets can help achieve the adaptation and socio-economic transition outcomes by stimulating undeveloped economies. However, the prospectus outlines the need for future research that can utilize both flexibility it provides corporations and stimulation of other economies, while still achieving environmental goals. Society must challenge the stabilization of offsets and either reconstruct the innovation or develop a new one in whole. Victor (2010) suggests:

> The United States should use its market power more wisely by setting rules for price offsets according to quality, creating a system of buyer liability, and adopting other rules that will create stronger private incentives to identify and reward (with higher prices and better delivery terms) high quality projects (p. 2).

Yet, this may be easier said than done.

WORKS CITED

Anderson, K (2012). The inconvenient truth of carbon offsets. *Nature, 484*, 7. doi:10.1038/484007a

Bijker, W., & Pinch, T. (1984). The social construction of facts and artefacts: Or how the sociology of science and the sociology of technology might benefit each other. *Social Studies of Science, 14*, 399-441. doi: 10.1177/030631284014003004

Brennan, P. (2020, August). *Stunning forecast: A century of ice loss for nearly 100,000 glaciers*. Retrieved from Nasa's website: https://climate.nasa.gov/news/3008/stunning-forecast-a-century-of-ice-loss-for-nearly-100000-glaciers/century-of-ice-loss-for-nearly-100000-glaciers/

Callon, M. (1987). Society in the making: The study of technology as a tool for sociological analysis. In T. Huges, & T. Pinch (Eds.), *The social construction of technological systems: New directions in the sociology and history of technology*, 83-103. London: MIT Press.

Clarens, A. (n.d.). Andres Fernando Clarens. In *Engineering*. Retrieved from https://engineering.virginia.edu/faculty/andres-fernando-clarens

Field, B., & Field, M. (2016). *Environmental economics: An introduction* (7TH ed.). New York, NY: McGraw-Hill Companies.

Houérou, H. N. (1996). Climate change, drought and desertification. *Journal of Arid Environments, 34*, 133-185. Doi: 10.1006/jare.1996.0099

Latour, B. (1987). *Science in action: How to follow scientists and engineers through society*. Milton Keynes: Open University Press.

Lin, N., Emanuel, K., Oppenheimer, M., & Vanmarcke, E. (2012). Physically based assessment of hurricane surge threat under climate change. *Nature Climate Change, 2*, 462–467. doi:10.1038/nclimate1389

Meehl, G. A., & Tebaldi, C. (2004). More intense, more frequent, and longer lasting heat waves in the 21st century. *Science, 305*, 994-997. Doi: 10.1126/science.1098704

NASA Global Climate Change. (n.d.). The effects of climate change. In *Facts*. Retrieved from https://climate.nasa.gov/effects/

Pacey, A. (1985). *The culture of technology*. Cambridge, MA: The MIT Press.

Rogers, M. E., Singhal, A., & Quinlan, M. M. (1962). *Diffusion of Innovations*. New York, NY: Free Press of Glencoe.

Sharma, A. (2020) “We Do Not Want Fake Energy”: The Social Shaping of a Solar Micro-Grid in Rural India”. *Science, Technology and Society, 25*, 308-324. doi: 10.1177/0971721820903006

Small, A. (n.d.). Arthur Small. In *Center for Economic Policy Studies*. Retrieved from https://ceps.coopercenter.org/node/494006

Sohngen, B. (2010). Carbon Offsets in Forest and Land Use. Holmes, K (Ed.). *Modeling the Economics of Greenhouse Gases*. Retrieved from https://www.nap.edu/read/13023/chapter/18

Thran, B. (2020). Applied pacey’s triangle. [Figure 4]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Thran, B. (2020). Artifact, social group, problem. [Figure 5]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Thran, B. (2020). Carbon reduction progress. [Figure 2]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Thran, B. (2020). The process to issue carbon offsets. [Figure 3]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

Thran, B. (2020). U.S. energy-related CO_2 emission Ccses. [Figure 1]. *Prospectus* (Unpublished undergraduate thesis). School of Engineering and Applied Science, University of Virginia. Charlottesville, VA.

University of Virginia (n.d.). Climate Change & Action. In *UVA Sustainability*. Retrieved from https://sustainability.virginia.edu/steward/climate-action-energy

U.S. Energy Information Administration. (2020, January). *Annual energy outlook 2020 with projections to 2050*. Retrieved from https://www.eia.gov/outlooks/aeo/pdf/AEO2020%20Full%20Report.pdf

U.S. Energy Information Administration. (2020, January 29). AEO2020 U.S. energy-related CO2 emissions cases. Retrieved from https://www.eia.gov/outlooks/aeo/pdf/AEO2020%20Full%20Report.pdf

Victor, D. (2010). The Politics and Economics of International Carbon Offsets. Holmes, K (Ed.). *Modeling the Economics of Greenhouse Gases*. Retrieved from https://www.nap.edu/read/13023/chapter/21

Watson, F. (2020, May). Global Carbon Offsets Market Could Be Worth $200 billion by 2050: Berenberg. Retrieved from S&P Global website: https://www.spglobal.com/platts/en/market-insights /latest-news/natural-gas/051320-global-carbon-offsets-market-could-be-worth-200-bil-by-2050-berenberg

Wara, M. (2007). Is the Global Carbon Market Working? *Nature, 445,* 595-596. doi: 10.1038/445595a

World Bank. (2015, January). *Overview of Carbon Offset Programs: Similarities and Differences*. Retrieved from http://documents1.worldbank.org/curated/en/891711468309365201/ pdf/939450WP0201500ers0385391B00PUBLIC0.pdf

Yarmosky, A. (2020, April). *Governor Northam signs clean energy legislation*. Retrieved from Commonwealth of Virginia website https://www.governor.virginia.gov/newsroom/all-releases/2020/april/headline-856056- en.html