Evaluating the Role of Government in Establishing Sustainable Energy Infrastructure in Massachusetts

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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

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Methane's Deadly Impact

Methane (CH_4) is the second most abundant anthropogenic greenhouse gas (GHG) after carbon dioxide (CO_2), and has 25 times the warming potential over a 100-year period (EIA, 2020c). In the United States, the leading cause of anthropogenic CH_4 emissions is natural gas production (EIA, 2020b). Once released into the troposphere, CH_4 undergoes a complex series of oxidation reactions that results in the production of ozone (O_3). While the O_3 layer in the stratosphere is beneficial, the production of O_3 lower in the atmosphere is dangerous. The inhalation of O_3 causes the muscles in the respiratory system to constrict, leading to inflammation and damage in the airways, weakening of the lungs' infection-fighting abilities, and aggravation of existing lung diseases (EPA, 2021). Aside from respiratory harm, tropospheric O_3 leads to cardiovascular damage, contributes to central nervous system impairment, and causes over one million premature deaths annually, half of which can be attributed to CH_4 (Bott, n.d. and *Ozone,* 2020).

In the 2000s, many scientific discoveries regarding the impact of natural gas and CH_4 took place in Boston, Massachusetts. As leaks from the natural gas infrastructure were found, the state government funded large restoration projects. However, with the discovery of the increasingly detrimental effects of CH_4 in the troposphere, government agencies supported a move away from natural gas as an energy source. The disjunction between past and present government policy implies that scientific advancement influences state legislature. Furthermore, this begs the question "To what extent are government entities effective in co-producing solutions to mediate the detrimental environmental impacts of decaying energy infrastructure in Massachusetts as climate science rapidly advances?" This relationship between science and government is evaluated under the framework of co-production in the continuation of this paper.

Using both discourse and policy analysis, as well as a historical case study, the interrelation of sustainable science and the Massachusetts government will be delineated to understand the future of energy infrastructure in the state.

Research Methodology

To accurately analyze the role of government in the evolution of energy infrastructure in Massachusetts, several key aspects must be considered: historical governmental response to scientific findings that disagree with administrative policies, current government policy regarding energy resources, and current discourse between government officials and scientists in regards to recent scientific findings. The keywords used to fulfill this research include the following: methane, natural gas, co-production, sustainability, Massachusetts. Succinctly, this paper uses a historical case study, as well as discourse and policy analysis, to identify how effectively the Massachusetts government fulfills its role as a co-producer of energy infrastructure and policy. The historical case study focuses on the governmental response to several studies conducted between 2011 and 2014 by Boston University, Duke University, and Harvard University. In addition to analyzing the research, this paper assesses the statements and policies from government entities in response to the studies. The information learned from the historical case study is used to further characterize the current role of government in mediating the negative impacts of old energy infrastructure. Discourse and policy analysis is used in relation to current events, specifically those occurring in the last five years. Within this window, several papers on the cause of natural gas leaks and their impacts are used to contextualize the governmental response. Additionally, statements from politicians on the current conflict regarding the GSEP help characterize how individuals from different government entities view their role in addressing environmental concerns. These statements are compared to those from

scientists and advocates to delineate the divide between the two co-producers. This paper briefly analyzes recent policy suggestions that stemmed directly from scientific advancements in the last five years. The culmination of individual perspectives and collective action is synthesized with the added context of the historical case study to determine if the government is currently fulfilling its role in addressing adverse environmental impacts from natural gas infrastructure.

The Consequences of Using Natural Gas as an Energy Source

In 2020, natural gas accounted for 34 percent of the United States' energy consumption, second only to petroleum (EIA, 2020c). CH_4 makes up over 90 percent of natural gas (EIA, 2020a). Because natural gas is essentially CH_4, it maintains the same environmental and public health risks. These risks are multiplied as natural gas is transported throughout the country, increasing potential exposure and infrastructure failure. Additionally, the cast iron pipelines transporting the gas have been used past their life expectancy. As a result, the vast majority of the cast iron pipelines have corroded over time and the pipe walls are weakened and damaged. The failure of the iron has caused natural gas to leak into the soil, and consequently add CH_4 to the atmosphere (Gallagher et al., 2015).

Many municipal GHG inventories have attempted to account for CH_4 leakage from the natural gas system using meter data supplied by gas companies. These estimates, however, are wildly inaccurate. In the early 2010s, a series of damning studies in the Boston area showed that there was far more CH_4 leakage linked to natural gas lines than previously disclosed. In 2012, a study conducted by Boston University and Duke University found 3,356 methane leaks exceeding up to 15 times the background level in Boston (Phillips et al., 2012). To contextualize the magnitude of natural gas lost through these leaks, Harvard University published a similar study in 2015. The findings of this study indicated that natural gas loss was two to three times

greater than that recorded in the Massachusetts GHG inventory (1.1%) (McKain et al., 2015). The publication and subsequent widespread knowledge of these findings prompted the government in Massachusetts to take action.

The result of this action was the Gas System Enhancement Program (GSEP). The GSEP is a multiyear, multi-billion-dollar project to replace the majority of Massachusetts' 21,000 miles of gas pipelines (Shankman, 2021). The gas companies involved in the GSEP focus on replacement rather than repair of gas lines, stressing the importance of long-term economic savings. The implementation of this program was initially hailed as a victory, and the program currently has a $20 billion price tag (Shankman, 2021).

Since 2015, numerous developments have occurred in climate science. Most importantly to this investigation, is the growing support for the total discontinuation of natural gas use. Because natural gas is a fossil fuel and non-renewable resource, continued widespread use makes a general shift toward renewable energy more difficult. Additionally, the extraction and storage of natural gas requires significant infrastructure and releases both CH_4 and other by-products into the troposphere. The by-products, which include CO_2 and hydrocarbons, contribute to air pollution and climate change. These revelations were not ignored by the Massachusetts government. Currently, a legislature is in place that supports the discontinuation of natural gas use by 2050 (Shankman, 2021). This legislature and the GSEP conflict both economically and environmentally. These contradicting policies implicate an unstable future for Massachusetts' energy infrastructure, and a resolution is needed quickly as 2050 approaches.

The Importance of Co-production Theory in Sustainability Science

The theory of co-production presents a form of knowledge production based on simultaneous dynamic interactions between technology and society. At its very core, the

framework of co-production illustrates how scientific beliefs and their associated technologies evolve parallel to the institutions that put these beliefs and objects to use (Jasanoff, 2010). In addition to describing the ways in which people organize themselves, co-production encapsulates society's values and the assumed responsibility of inventors. The work of Sheila Jasanoff, a professor of STS at Harvard University, remains at the forefront of co-production theory. Jasanoff's analysis of decades of STS research resulted in the conclusion that nature and society reinforce each other, allowing cycles of stability and change (Jasanoff, 2010). Furthermore, Jasanoff's work emphasizes the failure of technological determinism in describing societal developments. Technology does not drive history. Instead, legal and political institutions simultaneously lead and are led by society's investments in science (Jasanoff, 2010). Wiebe Bijker, a Dutch professor, expanded on this topic in the 1990s, noting that technological developments are reflective of the economic and political resources, cultural preferences, and creative faculties of their makers (Bijker, 1997).

Co-production theory has been largely developed in three distinct fields: STS, sustainability science, and public administration. As a result, the overarching definition has been muddled, but there are enough commonalities for the theory to be effectively implemented between fields. In the late 1990s, authors Gary Kofinas and Fikret Berkes separately used co-production as a basis to research adaptive co-management of socio-ecological systems (Miller & Wyborn, 2020). Specifically, they investigated ways that governments could share power with local Indigenous communities to sustainably manage resources. Within the field, scholars disagree with the fundamental principles of both Kofinas' and Berkes' research. Kofinas and Berkes envision co-production as a normative aspiration, leading to the implication that co-production of science is not a given (Miller & Wyborn, 2020). According to scholars, this

definition causes scientists to miss the inevitable politics of structuring knowledge and societies. Furthermore, it lacks the acknowledgement of the existent co-production of knowledge that is inherent in modern societies, and obscures the power differences among scientists, stakeholders, and communities. Such power differences greatly impact policy implementation in the United States today. In fact, the power imbalance between politicians and scientists in Massachusetts directly contributed to the creation of two potential energy futures. The power structure within the Massachusetts government will be revisited later in this paper.

Elinor Ostrom, an American economist, helped establish a widely accepted definition of co-production. According to Ostrom, co-production is a de-facto reality, and is present within every aspect of society (Gummesson, 1987). Though she largely worked on her theories in relation to public and business administration, Ostrom contributed research to the field of sustainability science as well. Specifically, she argued that environmental policies are co-produced with local users and communities who, in shared normative institutions, help manage pooled resources (Gummesson, 1987). Both the concept of pooled resources, and environmental policies, are heavily prevalent in the investigation on the role of government in mediating effects of old energy infrastructure. The continuation of this paper will rely heavily on both Jasanoff and Ostrom's ideas of co-production, in an effort to encompass the perspectives of the fields of STS and sustainability science.

The Variability of Government in Co-production

Co-production in relation to Massachusetts' environmental policy includes three co-producers - the scientific community, the government, and the residents. The establishment of policy regarding environmental protection requires work from each of these co-producers. These unique roles allow for the development of a cycle of production of new knowledge and action.

The scientific community collectively produces peer-reviewed knowledge of the world that can lead to implementations of associated technology. In the instance of environmental research, this involves passing policies, protecting resources, or restricting damaging projects. The role of government in environmental co-production in Massachusetts has not been stable in recent years. Theoretically, the role of the government is to use knowledge gained from scientific research to design policies that ensure that the local and regional environment is protected in the future. However, the government is not a singular entity. It is a collection of individuals with their own desires and loyalties. Consequently, these individuals may not operate with an equitable mindset in regards to protecting their citizens. When an elected official's interests conflict with that of the greater community, they work directly against co-production. This opposition halts all progress and allows current problems to escalate further. Therefore, while the government should perform actions as outlined in the theory of co-production, it can also act as a hindrance if the goals of the government are disjointed from those of the collective community. Individual residents play an important and understated role in the co-production process. Residents can utilize the knowledge produced by the scientific community to advocate against potentially harmful practices that may otherwise go unrecognized due to personal conflicts of interests within the government.

Historic Co-production of Environmental Policy in Massachusetts

There are many state level policies regarding environmental regulations in Massachusetts. The presence of these policies is evidence of distinct collaboration between science and government. More specifically, each policy acts as a product in Elinor Ostrom's theory on co-production (Gummesson, 1987). To understand the current co-production in Massachusetts, it is necessary to determine the origin of previously created products, or policies. In relation to the natural gas lines and CH_4 leakage, the GSEP is particularly important.

Prior to 2014, there were no statewide regulations on repairing or replacing the decaying natural gas lines (Gallagher et al., 2015). However, there were noticeable problems occurring from excessive CH_4 leakage. After trees lining the streets started dying, the scientific community, particularly those in academia, began investigating the cause behind the destruction (Duncombe, 2021). A study conducted by Boston University and Duke University between August and October 2011 found that there were thousands of leaks in Boston alone. Over 785 miles of roadway, the researchers found 3,356 leaks with CH_4 concentrations of at least 2.50 ppm (Phillips et al., 2012). This concentration level is 37% above the background CH_4 levels published by the National Oceanic and Atmospheric Administration (Phillips et al., 2015). In addition to establishing that the leaks were significant, in both amount and severity, the study also attributed them specifically to the natural gas lines, as opposed to landfills, with specific isotopes. The presence of ^{13}C (carbon molecules within CH_4 that include an extra neutron) indicates that the CH_4 originates from a fossil fuel source. In response to these findings, and those of a similar study by Harvard University in 2012, the Massachusetts Legislature developed a plan to reduce CH_4 leaks and repair natural gas pipelines (McKain et al., 2015). This work came at a critical time, as the 2014 Massachusetts gubernatorial elections would inevitably result in a change of governor. Governor Deval Patrick was approaching the end of his two terms, and the shift in power would disrupt the implementation of any plans in development. Patrick has a history of supporting healthcare and education reform, and scientific research. With the upcoming elections, there was a push to resolve existing legislation, and the Massachusetts Legislature passed An Act Relative to Natural Gas Leaks (the “Gas Leaks Act”) (Department of Public Utilities, n.d.). The Gas Leaks Act allows local distribution companies to submit annual plans to repair or replace aged natural gas infrastructure to the Department of Public Utilities

(DPU), in the interest of public safety and to reduce lost and unaccounted for gas. Specifically, these plans cover the replacement of aged (non-cathodically protected steel, cast-iron, and wrought-iron) infrastructure, in accordance with the data produced by the aforementioned studies (Department of Public Utilities, n.d.).

This end result, a government-funded plan that aims to work with gas companies to replace their infrastructure, is a product of the creation and development of knowledge and subsequent actions carried out by those consuming this knowledge. This balance illustrates the importance of both parties in this act of co-production. Without scientists, the knowledge would not be available to learn from and act on. Without the government, a state-wide, fully-funded program could not be implemented, and the problem would persist. As such, there appears to be a cycle of the creation of knowledge and action in the realm of environmental protection in Massachusetts. Scientists locate and understand the problems. Additionally, they outline the overarching goal that needs to be met in order to remedy these problems. The cycle continues as the government institutes a plan for accomplishing this overarching goal. This cycle seemed to work in 2014, when the GSEP was implemented and gas leaks were being fixed. In the modern day, however, the cycle has been disrupted. Science and technology have developed, and have outlined greater problems with natural gas. The government, however, is at a standstill.

Conflicting Goals of Modern Day Energy Policies

The GSEP is still in effect today. The most recent data published by the DPU shows that in April 2021, the GSEP for six gas distribution companies was approved for 2021 (Department of Public Utilities, n.d.). This number has remained constant for several years, and consists of all the major natural gas distributors in the state. However, as more information is discovered about

climate change, several progressive sectors of the government have begun to develop plans for the reduction of the state's carbon footprint.

Perhaps most significant, is the state's goal to achieve net-zero greenhouse gas emissions by 2050 (Ismay et al., 2020). In December 2020, the Massachusetts Executive Office of Energy and Environmental Affairs published a report identifying cost-effective and equitable strategies to achieve this goal (Ismay et al., 2020). These strategies include moving away from the use of fossil fuels and natural gas in the energy sector. Instead, it is proposed that, beginning in 2030, Massachusetts builds 1 GW of solar power and offshore hydropower until 2050 (Ismay et al., 2020). Aside from potential environmental effects from the construction and destruction of the energy infrastructure, this plan requires a huge monetary investment. Currently, Massachusetts has already spent over 20 billion dollars replacing natural gas pipelines through the GSEP (Shankman, 2021). Despite these large-scale economic implications, the government continues to carry out both plans.

Looking closer to the present, in December 2020, Governor Charles Baker established a statewide GHG emissions limit of 45% below the 1990 GHG emissions level for the year 2030 (Baker et al., 2020). This limit brings up a few problems. First, the study by Harvard University published in 2015 found that the state was not calculating their GHG emissions correctly (McKain et al., 2015). State inventories use estimations and complicated calculations to record emissions, rather than taking measurements. As a result, estimations are always lower than measured emissions (McKain et al., 2015). Secondly, if the natural gas lines were leaking at the rate described in the Boston studies, the GSEP should have caused a large reduction in emissions. Current measurements, however, have indicated that replacement of the pipelines has not caused a significant change in CH_4 emissions (Abel, 2021).

Therefore, the GSEP is an ongoing monetary investment, a large use of resources, and it is not producing the intended results. In addition to not producing the desired results, the GSEP directly contradicts the goals outlined for 2030 and 2050. In 2014, a clear cycle of co-production was established. Now, however, the co-producers appear to be disjointed and nonfunctional. The scientific community is updating its views and producing new results constantly. In total, it acts much in the same way as it did eight years ago. The government, however, has experienced change. Likewise, the government is the piece of the cycle not moving forward. As mentioned earlier, science acts as the producer of knowledge and the government acts as the producer of action. The knowledge is available, and has been briefly outlined in this paper. A definitive path of action, however, is currently nonexistent.

Production of Knowledge by the Scientific Community

To fully understand the necessary action by the government, the reasons behind the failure of the GSEP must be distinguished. The GSEP targeted a specific, though large, problem in the natural gas supply chain. It focused solely on repairing the infrastructure for midstream transportation of natural gas. The preceding studies also focused only on the connection between companies and consumers, without examining the potential leaks coming from either end of the supply chain.

In 2021, a comprehensive study was conducted on the environmental risks in the exploitation and utilization of natural gas (Fu et al., 2021). At all points in the process, upstream collection, midstream transportation, and downstream combustion, there are significant risks poised to the environment and human health. Upstream extraction consists mainly of seismic exploration, drilling, on-site transportation, and natural gas purification (Fu et al., 2021). While conventional natural gas exists in highly porous and permeable reservoirs, unconventional

natural gas is mostly found in low-permeability rocks. As a result, it is difficult to produce and has led to the practices of horizontal drilling and formation stimulation (Fu et al., 2021). Currently, hydraulic fracturing is the most common type of formation stimulation technology used to collect unconventional natural gas. In hydraulic fracturing operations, the fracturing fluid is pumped under high pressure, and sand is mixed with the fracturing fluid to support the fractures created (Fu et al., 2021). Afterward, the resulting wells should be sealed to prevent natural gas, fracturing fluids, chemicals, and contaminated water from leaking into the groundwater supply (Duvvuri et al., 2021). This process is highly disruptive, and frequently causes air, water, light, and noise pollution; interrupts wildlife activities, land use, and water use; and even induces earthquakes (Fu et al., 2021). Despite the large risks associated with upstream extraction of natural gas, there is not much the Massachusetts state government can do to regulate these practices. As a result, the focus of the Massachusetts Legislature must remain on midstream and downstream practices.

The midstream transportation environmental risks are well studied. The real hazard stems from old pipelines corroding over time and leaking natural gas into the surrounding soil. The CH_4 then migrates into the water table, and into the atmosphere (Shankman, 2021). Furthermore, it has the potential to poison nearby vegetation. This phenomenon was the root to the Massachusetts fight against natural gas (Duncombe, 2021). Arboreal deaths were mounting among the trees lining the streets in the state. These trees could no longer access oxygen through their roots because of the high concentrations of CH_4 (Duncombe, 2021). This visual display of damage motivated the initial studies in Boston, prompting further government action. In addition to the damage to vegetation, the high amounts of CH_4 in natural gas contribute to the greenhouse effect. Aside from the subsequent warming and disruption of weather patterns, the resulting

increase in tropospheric ozone contributes to millions of related illnesses and deaths annually (Duvvuri et al., 2021). The GSEP aims to combat these hazards, but recent measurements have shown that the plan has had little effect. A long-term study, released in October 2021, in the Proceedings of the National Academy of Sciences, found six times more CH_4 leaking into the air around the Boston area than the most recent estimate issued three years ago by the Department of Environmental Protection (Abel, 2021). The scientists at Harvard University and Boston University found that despite laws requiring suppliers to spend billions of ratepayer dollars reducing leaks in their network of aging gas pipes, the CH_4 appears to be flowing into the atmosphere incessantly. Maryann Racine Sargent, the lead author and a research scientist at Harvard's School of Engineering and Applied Sciences, explains, "This study shows that we have a systemic problem and that the state is missing a big source of emissions," (Abel, 2021). This is exceptionally evident when reviewing the data collected during April 2020. The study collected emission data from five sites between 2012 and 2020. Two sites were compared after the pandemic struck to examine downstream CH_4 leaks - a tall residential building in Copley Square and a smaller building at Boston University. It was found that emissions were 42 percent lower at the Boston University building than the average of previous Aprils in the survey (Abel, 2021). Conversely, the emissions measured at the building in Copley Square were about the same as they were in the previous Aprils. The absence of individuals at Boston University indicates that the reduction in downstream use led to a reduction in CH_4 emissions (Abel, 2021).

Downstream combustion emissions have had relatively little attention compared to midstream processes. Recently, however, leaks and incomplete combustion have become large causes for concern among scientists. Over one-third of U.S. households, more than 40 million homes, cook with gas (Jordan, 2022). Stanford University published a study in January 2022

exploring emissions of gas stoves during combustion, ignition, extinguishment, and while the appliance was off. This research discovered two key pieces of information. First, more than three-quarters of CH_4 emissions occurred while stoves were off, suggesting that improper gas fittings and connections to the in-home gas lines are responsible for most emissions (Jordan, 2022). In other words, reducing use would not make a significant difference in CH_4 emissions if the gas stove is still in the home. Second, the researchers estimated that natural gas stoves emit up to 1.3 percent of the gas they use as unburned CH_4 (Jordan, 2022). This led researchers to estimate total CH_4 emissions to be substantially more than that currently reported by the EPA for residential sources. These findings indicate a problem on a much larger scale. The EPA, a federal agency, may be incorrectly estimating the CH_4 emissions nationally. If policies are designed with these published numbers, actual change may be nonexistent.

The GSEP and carbon mitigation programs indicate that Massachusetts, specifically the government and scientific community as co-producers, have a shared objective of reducing CH_4 emissions. However, after eight years, their plan is not working, and the strategy must be revisited. Erin Murphy, a senior attorney at the Environmental Defense Fund, summarizes that "Massachusetts has well-intentioned programs that are designed to reduce methane emissions, but [the Copley Square] study shows that they may not be working," (Abel, 2021). Furthermore, she offers suggestions for utility regulators instead of pipe replacement. The EDF advocates for the use of CH_4 detection technologies, pipe repair, and pipe retirement (Abel, 2021).

Stagnation Caused by Conflicting Viewpoints

According to the cycle outlined in 2014, this newfound knowledge produced by the scientific community should lead to government action. This, however, has not been the case in recent years. The American political system is complex, tense, and sometimes incredibly

ineffective. This is highlighted in the ongoing dilemma in Massachusetts. The vast majority of politicians at all levels in Massachusetts push for natural gas reform. Their reasoning is not unanimous. Some focus on the environment, while others focus on economic consequences. However, one particular individual does not agree with this reform. Governor Charles Baker, who has been in office since 2015, continuously advocates for natural gas companies (Vardi, 2017). The disjunction between the general Massachusetts Legislature and the governor has created stagnation in the co-production cycle with the scientific community. Viewing this political system as a microcosm, one could observe that the theoretical co-production that should take place within a governmental system fails here because of the lack of common ground and subsequent absence of cooperation and co-development of solutions (Miller et al., 2020).

Several outspoken representatives have begun efforts to move away from natural gas as a main energy source. Bill H.3298, "An Act relative to the future of heat in the Commonwealth", was proposed by Representative Lori A. Ehrlich and Senator Cynthia Stone Creem in March 2021. The bill would provide the opportunity for natural gas customers to connect to non-emitting renewable thermal infrastructure and establish a gas transition trust fund (Creem and Ehrlich, 2021). This plan allows for a gradual transition away from natural gas, while still working toward the net-zero greenhouse gas emission goals for 2050. It does not address the GSEP, however. Therefore, more communication and collaboration would be needed to evaluate the costs and benefits of the GSEP even if the bill is passed. The House vote on the bill has been delayed twice and has a new deadline of May 2022. In this instance, bureaucratic red tape has hindered the timely processing of sustainable environmental plans. Aside from legislation, politicians have spoken out individually against the natural gas industry. Senator Elizabeth Warren has criticized the industry for increasing its prices in late 2021 (Woodward, 2021). This

sentiment has earned her a lot of pushback from industry professionals. Despite these qualms, Senator Warren did not petition bill H.3298 (Creem and Ehrlich, 2021). The contrast between her speech and action are further indicators of the immense turmoil within the political system. These contrasting sides, along with red tape and restrictions, destroy the efforts of co-production.

Apart from the ineffective collaboration between senators and representatives, the personal interests of Governor Baker have hurt the co-production process. In the mid 2010s, Spectra Energy proposed new natural gas pipeline projects that would run across the state (Vardi, 2017). After the discoveries regarding CH_4 leakage and the establishment of the GSEP, there was fierce opposition across Massachusetts to the pipeline projects. Residents, campaigners, and politicians were outspoken about their objection to the plans (Vardi, 2017). Despite the backlash, however, Baker consistently backed Spectra's plans.

In late 2016, Baker's political campaign committee used the services of the law firm Mintz Levin (Vardi, 2017). The firm's lobbying arm ML Strategies represents Spectra in Massachusetts. Several expenditure disclosures by the campaign committee include payments to Mintz Levin for "legal consulting" (Vardi, 2017). ML Strategies has been lobbying for Spectra Energy since 2015, as they began to push for their new pipeline projects. After receiving approval for the projects from the Federal Energy Regulatory Commission (FERC), Spectra needed a final permit decision by Massachusetts regulators under the authority of the Baker administration (Vardi, 2017). Baker has close connections with senior figures at ML Strategies. Bill Weld, one of the firm's lobbyists, was Baker's previous boss and political mentor (Vardi, 2017). Stephen Tocco, the chair of ML Strategies, was Baker's former colleague in Weld's administration. Mark Robinson, an attorney at Mintz Levin, served on Baker's transition committee when he took the governor's office in 2015 (Vardi, 2017). These connections helped

Baker significantly with his political career. In May 2015, ML Strategies held a fundraiser for Baker, raising almost 30,000 dollars (Vardi, 2017).

A month after taking office, on the back of the initiation of the GSEP, Baker told lobbyist groups that he would like to see the expansion of the existing pipeline system's capacity (Vardi, 2017). Four months afterward, Spectra hired ML Strategies to lobby on its behalf in Massachusetts. ML Strategies was hired to "monitor legislation on energy and environmental legislative proposals and the potential impact on Spectra Energy's existing operations," according to lobbying disclosures (Vardi, 2017). Residents, environmental organizations, and other campaigners fought hard to sway the view of the governor. The result was thousands of postcards sent to Baker, many radio interviews for increased publicity, and dozens of requests to the FERC for reconsideration of the approval (Vardi, 2017). Baker never changed his stance, but the projects failed in 2017 as major constituents pulled out.

This instance of turbulence in the governing of Massachusetts adds complexity to the cycle of co-production. While scientific organizations fought against the pipeline projects, the true impact was multiplied by the thousands of residents voicing their opinion. Here, it is obvious that science and government are not isolated entities. While they may frequently move and act without consideration of individuals, the quantity of voices plays a large role in the end product. Without the immense backlash, there is no guarantee that the gas suppliers would have pulled out of the project. As such, individuals play an important role in the co-production cycle, especially when there is conflict between the co-producers of science and government.

New View of Co-production - Defining the Government's Role

The cycle of co-production in relation to environmental policy in Massachusetts includes at least three co-producers - the scientific community, the government, and the residents. Each

co-producer holds a distinct role in the production of knowledge and action regarding environmental protection and sustainability. The evolving energy situation in Massachusetts exemplifies how scientific ideas and associated technological artifacts evolve alongside the representations, discourses, and institutions that put these ideas to use (Jasanoff, 2006). The role of the scientific community is straightforward. Collectively, it produces peer-reviewed knowledge of the world that can lead to practical implementations of technology. In the instance of environmental research, this knowledge is used to create and pass policies protecting resources or restricting activities. The residents also play a prominent, yet complicated role in the co-production process. As seen in the attempted establishment of statewide pipelines by Spectra, residents can utilize the knowledge produced by the scientific community to advocate for themselves and speak against potentially harmful practices that may otherwise go unrecognized due to personal conflicts of interests. Finally, the role of government in environmental co-production in Massachusetts has wavered over the years. One could say that the role of the government is to use knowledge gained from scientific research to craft policies that ensure that the local and regional environment is protected for as long as possible. However, the government is not a singular entity. It is a collection of individuals with their own desires, interests, and loyalties. Because humans are not infallible, these individuals may not operate with an equitable mindset in regards to protecting their citizens. When a prominent elected official has their own interests that do not align with the greater community, they work directly against co-production. This opposition halts the process of progress and allows current problems to escalate further. Therefore, while the government should perform actions as outlined in the theory of co-production, it can also act as a hindrance if the inner workings of said government are in poor condition. In the case of energy infrastructure policy in Massachusetts, the government is not

fulfilling its role in co-producing solutions, because of a lack of cohesion within the governmental structure.

Limitations and Suggestions

The greatest limitation to this research is the vast amount of information, policies, and studies that have been performed regarding the natural gas leakage in Massachusetts. The topic itself grows only more complex as it is examined further. Furthermore, one cannot assume that the government is currently fulfilling its intended purpose in the cycle of co-production. Initially, it was presumed that the government was operating in accordance with the theory, based on the historical case study. However, upon further research, this assumption was erroneous. The dysfunction within the government further complicates the workings with other co-producers, adding more layers to break down and analyze. Additionally, this topic was researched with two main co-producers in mind. As more work was done, it became clear that residents played an important part in determining the path of energy infrastructure in Massachusetts.

These limitations lead directly into the future research on this subject. First, it is advisable to allow more time for research, or to assemble a team of researchers to delve deeper into each facet of this topic. Second, first hand interviews with both scientific nonprofit organizations and politicians in Massachusetts would be invaluable to this research. Some politicians, in particular Governor Baker, consistently refuse to comment to well known energy nonprofits. As a result, there may be better potential for an interview request coming from an outside source that holds no precedence in Massachusetts to be accepted. Outside of this particular ongoing situation, co-production could be used to understand the breakdown in government response to other environmental problems. Notably, the abysmal responses in the 1976 dioxin crisis in Seveso, Italy and the recent water crisis in Flint, Michigan, stand out as potential future projects. With all

future research projects, however, it is important to understand the role of not only science and government, but also individuals.

Theory and Reality Are Not Synonymous

Local government entities ideally serve as the action mechanism in mediating the detrimental environmental effects of old energy infrastructure in Massachusetts. Realistically, because governments are not a singular being, and instead rely on a multitude of individuals to cohesively function, this is often not the case. Identifying why there is a distinct difference between theoretical and empirical functioning may offer understanding on how to improve future governmental productivity. The implementation of such measures, of course, would be incredibly difficult. The theory of co-production can also be usefully applied to other situations regarding the government and environmental policies, particularly in the United States where the cultural and societal background is well known. Overall, there is a distinct cycle of co-production involving science, government, and individuals. The functioning of this cycle depends on each piece working internally, as well as externally. Furthermore, changes in the system, as seen in Massachusetts, can cause the degradation of the co-production cycle.

Works Cited

Abel, D. (2021, October 26). Massachusetts vastly underestimates emissions from natural gas, study finds . BostonGlobe.com. Retrieved March 1, 2022, from https://www.bostonglobe.com/2021/10/25/science/state-vastly-underestimates-emissions-natural-gas-study-finds/

Baker, C., Polito, K., & Theoharides, K. (2020, December 30). Determination of Statewide Emissions Limit for 2030. Boston, Massachusetts; Executive Office of Energy and Environmental Affairs.

Bijker, W. E. (1997). *Of bicycles, bakelites, and bulbs: Toward a theory of sociotechnical change*. MIT Press.

Bott, R. D. (n.d.). *Methane*. Climate & Clean Air Coalition. Retrieved February 12, 2022, from https://www.ccacoalition.org/es/slcps/methane

Creem, C. S., & Ehrlich, L. A. (2021, March 29). Bill H.3298 192nd (current). Massachusetts Legislature. Retrieved March 1, 2022, from https://malegislature.gov/Bills/192/H3298

Department of Public Utilities. (n.d.). GSEPs pursuant to 2014 Gas Leaks Act. Mass.gov. Retrieved March 1, 2022, from https://www.mass.gov/lists/gseps-pursuant-to-2014-gas-leaks-act

Duncombe, J. (2021, November 5). The surprising root of the Massachusetts fight against natural gas. Eos. Retrieved March 1, 2022, from https://eos.org/features/the-surprising-root-of-the-massachusetts-fight-against-natural-gas

Duvvuri, R., Sattler, S., McNamara, J., & Jacobs, M. (2021, July 15). Unveiling the public health burden of natural gas. Union of Concerned Scientists. Retrieved March 1, 2022, from https://blog.ucsusa.org/science-blogger/public-health-burden-natural-gas/

EIA. (2021a). Natural gas explained. Natural gas explained - U.S. Energy Information Administration (EIA). Retrieved February 1, 2022, from https://www.eia.gov/energyexplained/natural-gas

EIA. (2021b). Natural gas and the environment. eia.gov. Retrieved February 1, 2022, from https://www.eia.gov/energyexplained/natural-gas/natural-gas-and-the-environment.php

EIA. (2021c). U.S. energy facts explained. U.S. Energy Information Administration (EIA). Retrieved February 1, 2022, from https://www.eia.gov/energyexplained/us-energy-facts/

Environmental Protection Agency. (2021, May 5). *Health effects of ozone pollution*. EPA. Retrieved February 12, 2022, from https://www.epa.gov/ground-level-ozone-pollution/health-effects-ozone-pollution

Fu, J., Liu, Y., & Sun, F. H. (2021, January 1). Identifying and regulating the environmental risks in the development and utilization of natural gas as a low-carbon energy source. Frontiers. Retrieved March 1, 2022, from https://www.frontiersin.org/articles/10.3389/fenrg.2021.638105/full#h6

Gallagher, M. E., Down, A., Ackley, R. C., Zhao, K., Phillips, N., & Jackson, R. B. (2015). Natural gas pipeline replacement programs reduce methane leaks and improve consumer safety.

Gummesson, E., The new marketing—developing long-term interactive relationships Long Range Plann., 20 (4) (1987), pp. 10-20

Ismay, D., Miller, B., Chu, H.-H., Miziolek, C., Walsh, M., Edington, A., Perry, D., Hanson, L., & Laurent, C. (2020, December). Massachusetts 2050 Decarbonization Roadmap. Massachusetts; Executive Office of Energy and Environmental Affairs.

Jasanoff, S. (2006). States of knowledge: The co-production of Science and Social Order. Routledge.

Jordan, R. (2022, January 27). Stanford scientists find the climate and health impacts of natural gas stoves are greater than previously thought. Retrieved March 1, 2022, from https://news.stanford.edu/press/view/42487

McKain, K., Down, A., Raciti, S. M., Budney, J., Hutyra, L. R., Floerchinger, C., Herndon, S. C., Nehrkorn, T., Zahniser, M. S., Jackson, R. B., Phillips, N., & Wofsy, S. C. (2015). Methane emissions from natural gas infrastructure and use in the urban region of Boston, Massachusetts. Proceedings of the National Academy of Sciences, 112(7), 1941–1946. https://doi.org/10.1073/pnas.1416261112

Miller, C. A., & Wyborn, C. (2020). Co-production in Global Sustainability: Histories and theories. Environmental Science &; Policy, 113, 88–95. https://doi.org/10.1016/j.envsci.2018.01.016

Ozone. American Lung Association. (2020, April 20). Retrieved February 12, 2022, from https://www.lung.org/clean-air/outdoors/what-makes-air-unhealthy/ozone

Phillips, N. G., Ackley, R., Crosson, E. R., Down, A., Hutyra, L. R., Brondfield, M., Karr, J. D., Zhao, K., & Jackson, R. B. (2012). Mapping urban pipeline leaks: Methane leaks across Boston. Environmental Pollution, 173, 1–4. https://doi.org/10.1016/j.envpol.2012.11.003

Shankman, S. (2021, October 4). As Massachusetts envisions a fossil fuel-free future, gas companies are quietly investing billions in pipelines - the Boston Globe. BostonGlobe.com. Retrieved February 1, 2022, from https://www.bostonglobe.com/2021/10/03/science/massachusetts-envisions-fossil-fuel-free-future-gas-companies-are-quietly-investing-billions-pipelines/

Vardi, I. (2017, February 28). *Revealed: Massachusetts governor Charlie Baker's close ties to lobbyists for Spectra Energy, whose pipeline projects he backs*. DeSmog. Retrieved March 1, 2022, from https://www.desmog.com/2017/02/28/massachusetts-governor-charlie-baker-close-ties-lobbyists-spectra-energy-pipeline-projects-he-backs/

Woodward, C. (2021, December 6). Woodward: Energy pros put Liz Warren on Blast for Industry attacks. Boston Herald. Retrieved March 1, 2022, from https://www.bostonherald.com/2021/12/07/woodward-energy-pros-put-liz-warren-on-blast-for-industry-attacks/