An Actor Network Theory Analysis of the Failed California Hydrogen Highway Blueprint Plan

A Research Paper submitted to the Department of Engineering and Society

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia • Charlottesville, Virginia

In Partial Fulfillment of the Requirements for the Degree

Bachelor of Science, School of Engineering

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Spring 2023

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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Introduction

In 2004, California Gov. Arnold Schwarzenegger announced a bill that would begin a massive infrastructural redesign project known as the Hydrogen Highway Blueprint Plan (HHBP). This project aimed to build hundreds of hydrogen gas stations along California's highways, providing incentive for consumers to purchase hydrogen fuel cell vehicles as a means to lower California's carbon emissions and jump-start the U.S.'s conversion to a hydrogen economy. However, this huge project failed spectacularly with very few stations being built and huge amounts of money wasted on its conception. The currently accepted understanding of this failure is that the plan was far too ambitious and would require more funding to complete than switching to the use of electric vehicles (EVs), but this interpretation is mainly based on reports of a biased media and misinterpreted scientific studies. While it is true that switching to the use of hydrogen fuel cell vehicles would be extremely expensive, the cost of altering our economy and infrastructure is a necessary expenditure to decrease our carbon emissions and will be necessary for any redesign, including that for EVs. The goal of this paper is to provide readers with a deeper understanding of partisan-based media bias and its control over the public's actions and thoughts about subjects that are more difficult to understand for laymen, such as climate change and hydrogen power. Here, I lay out arguments that point to media's partisan bias and misunderstanding of scientific research as the major contributors to the HHBP failure. I will show how these flaws brought about voter and consumer disdain for an otherwise viable climate change diminution plan. To structure my analysis, I employ the Actor-Network Theory (ANT) framework which allows a network, such as the HHBP, to be deconstructed into a series of relationships between the parties required for the system to operate (actors) and the network builder, who is the central actor of the system through which all relationships are formed. In

studying each of the relationships in the HHBP network, I show the points of failure between actors that led to its collapse, drawing directly from Schwarzenegger's announcement speech itself, which outlines his plans as well as the actors needed to complete them. I will then exhibit media articles that clearly opposed a hydrogen economy along with thorough research articles describing the validity of the HHBP and a hydrogen economy as a cure to the climate crisis.

Background

In this section, I briefly discuss the scientific knowledge needed to understand the points I will be making in the following analysis. There are two main methods of producing hydrogen: electrolysis of water and steam methane reforming (SMR). Currently, the former is far from a viable source of hydrogen, but the latter process is already widely used in industry to provide hydrogen for ammonia production. SMR requires a methane-rich natural gas feedstock and steam input, which reacts endothermically (absorbing heat) to produce a mixture of hydrogen, carbon dioxide, and carbon monoxide. These processes are rather energy intensive as they require pressurization and heating; however, a common workaround of the high energy costs is autothermal methane reforming (ATR). In an ATR system, methane is reacted exothermically (releasing heat) with oxygen in the same reactor as the SMR takes place, thus heating the process to much higher temperatures than traditional SMR, improving overall hydrogen production rate and rendering heat input unnecessary. Carbon products are then captured via chemical scrubbers, which is relatively easy due to its high output concentration and volume in comparison with vehicle emissions. It can then be sold or sequestered, minimizing its release into the atmosphere to near-zero.

Literature Review

Currently, most literature studies involving California's Hydrogen Highway Blueprint Plan focus strictly on the economic viability of Schwarzenegger's plan. While this is important, these studies' failure to address the sociopolitical factors that exacerbated the problem leave a gap in the current understanding of the problem. One study, conducted by Dr. Joseph Romm, begins by making the bold claim that hybrid gasoline-electric vehicles "will likely become the dominant vehicle platform by the year 2020," a claim that immediately introduces his bias, and one we can retrospectively see was false (Romm, 2006). Romm then dives into his reasoning for the California hydrogen economy failure, citing two major sources: economic disadvantages of alternative fuel, and negligible greenhouse gas (GHG) reductions. While completely accurate in the former, his latter argument misunderstands the purpose of converting to hydrogen from gasoline, assuming that producing GHGs in a centralized location (from hydrogen production) poses the same threat as millions of gasoline-powered cars burning fuel. He then cites this as the reasoning behind limited government funding that would never allow for alternative fuels to break into the current gasoline market. Unfortunately, the same erroneous argument is used today to downplay the effectiveness of electric vehicles; however, capturing and storing GHGs in a centralized, factory setting is vastly simpler and cheaper than trying to capture tailpipe emissions, making it a viable way to reduce GHGs and one worthy of governmental market intervention.

Another work by William Korchinski cites politician's misunderstanding of hydrogen production as a source for the failure (Korchinski, 2007). In this paper, Korchinski quotes Schwarzenegger's claim that hydrogen is a fuel that can be produced in California without relying on other countries' oil. He then gives a brief overview of hydrogen production, showing that, even though hydrogen can be produced in California, we will need to import a great deal of

natural gas from other countries to make it. His rather lengthy analysis of hydrogen as an alternative fuel source in general moves past just the California HHBP, but his points still directly apply. The major point is that at the time of Schwarzenegger's plan and initial investment, politicians believed that we were already technologically capable of converting to a hydrogen economy with no sociopolitical or economic repercussions and that it would increase our energy independence. However, once more was learned about the viability of hydrogen at the time, funding had already been allocated to the California HHBP even though much more R&D was needed before it could ever be feasible. While Korchinski's analysis begins to look at the sociopolitical issues that brought forth the HHBP failure that the previous study neglects, it disregards many of the major actors in this problem; therefore, I will use Actor Network Theory (ANT) to further develop Korchinski's analysis from a sociopolitical viewpoint rather than the economic perspective from which he approached the problem.

Conceptual Framework

The ANT approach to California's HHBP failure provides me the ability to view each actor within the HHBP network and draw on its relationships with others to pinpoint the causes of the system's failure. This framework, developed by Michel Callon, follows the relationships between the actors in a network and actors relationships with the network builder by studying the actions of the network builder itself and the effects that these actions have on the stability of the network (Callon, 1987). These actors are heterogeneous; they can be people, groups, objects, or ideas. In ANT, each actor's degree of effect on the network is determined by its relationships with the other actors as laid out by the network builder and is independent of the actor's objective social power. In this study, I use Callon's concept of translation, which will allow for a more in-depth study of the actual network building process and how it creates a power dynamic

that can make the network flourish or collapse. Utilizing the concept of translation allows for each actor's responsibilities in the network to be isolated and critiqued, determining at which point the network builder failed to properly form or maintain the network (Callon, 1986).

There are four main stages of translation: problematization, interessement, enrolment, and mobilization. Each of these stages is important to the successful development of a functioning network with each being directly or indirectly controlled by the network builder (Callon, 1986). Problematization refers to the actions of the network builder in assigning roles to other primary actors. This is accomplished by breaking problem into multiple parts to determine the actors needed to fully solve the problem. Furthermore, the primary actor defines itself as the focal point of the entire network by creating "obligatory passage points," which allow the network builder to focus each actor in on the main problem the network is solving. The next stage is interessement in which the network builder coerces the necessary actors into its network by altering their interests so that they match those of the network builder. This must be done thoroughly as to keep the actor from disturbing the stability of the network via collaboration with other networks holding unaligned interests. Once recruited, enrolment occurs, and actors are assigned their roles and relationships within the network. The final stage of translation is mobilization. Mobilization happens as the network builder makes itself the primary representative of the entire network and each of the enrolled actors begin their designated work. At this point, the network builder should have complete and undivided control over each actor in the network, obtained by gaining the favor of independent entities, or allies, that convince the actors of the validity of the problem that is to be solved by the network (O'Connell et al., 2014).

I use this framework to study the California HHBP in multiple parts. First, I will examine each human and non-human actor associated with the network and then utilize the concept of

translation to determine at which point the network builder failed to properly connect a crucial actor to the network. This will allow me to isolate the failure from the rest of the network for further analysis. I will then determine how this actor misconnection caused enough instability in the network to unravel it and lead to its complete failure by analyzing the relationship between the misconnected actor and the others in the network.

Analysis

Network Formation

Before presenting my arguments, I first reconstruct the network by identifying the relevant actors and their roles. I then utilize the concept of translation to better understand the relationships between these actors and develop an awareness of the power dynamic within the network. In identifying the heterogeneous actors of the network, I consulted relevant articles identifying the key components of similar problems (Elliot, 2011). The pertinent human actors are: (i) *consumers* who currently use traditional gasoline-powered vehicles, (ii) *voters* who each hold their own educated or uneducated views of hydrogen as a fuel source and elect representatives with this in mind, and (iii) *elected representatives*, which in this case refer specifically to Arnold Schwarzenegger (iii-a), George W. Bush Jr.'s administration (iii-b), and Barack Obama's administration (iii-c). I have also identified the non-human actors involved in this network by utilizing a scientific understanding of the processes in question and their needs (Isenstadt & Lutsey, 2017, Greene, Ogden, & Lin, 2020). These actors include: (iv) *hydrogen-powered vehicles* that were available at the time of the HHBP's conception and (v) *R&D funding* allocated to clean energy development for the purpose of reducing GHG emissions and mitigating climate change.

I further substantiate my claim by analyzing connections between the different actors as they were built by the primary actor. Each of these relationships can be accurately understood by following an actor through the translation stages of network building. The most appropriate way to begin this analysis is with Schwarzenegger's own announcement of the HHBP commencement plan (Schwarzenegger, 2004). In this statement, Schwarzenegger first provides his inspiration for the HHBP before describing the other actors, their roles in his plan, and why they should help. This is my basis for the assumption of Schwarzenegger as the primary actor around which the HHBP network is built. Since his speech was the beginning of the plan's public release, it is also a reasonable point at which to begin analyzing the translation of the network.

To visualize the relationships in the network, I provide a figure depicting the ideal relationships the network builder (pink) intended to form that would have resulted in a functioning network (Figure 1). Beginning with problematization, Schwarzenegger defines the actors and their respective roles clearly in his announcement. He notes that hydrogen-powered cars will be put on the roads and given hydrogen gas stations at regular intervals along the highways, defining the hydrogen-powered vehicle's role as a replacement for gasoline-powered vehicles and the consumer's roles as purchasing and driving these vehicles. He acknowledges that building these stations and further refining the cars will require funding and research, which will be secured through negotiations with the federal government, thus requiring voters to push representatives for a

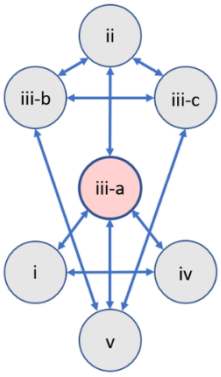

Fig. 1. Bidirectional relationships between actors in the theoretically perfected HHBP network

hydrogen economy and representatives to follow through with their promises (Schwarzenegger, 2004).

The next step in translation, interessement, is carried out in the latter half of Schwarzenegger's speech and through actions taken directly after signing the proposed HHBP bill. First, Schwarzenegger convinces voters and consumers of the cause by promising "clean air" and "a healthy environment for generations to come," drawing on the people's perceived disdain for the smog surrounding their cities and obscuring the beautiful mountains and trees of California (Schwarzenegger, 2004). With voters and consumers persuaded and state funding received through Schwarzenegger's black-boxed relationship with the state, federal funding still must be acquired. This was done by convincing federal representatives, such as those in the Bush administration, of the viability of the HHBP via an ally already within the federal government: U.S Secretary of Energy Spencer Abraham, who was already a proponent of a hydrogen economy and vouched for the HHBP's GHG reduction potential from within (O'Dell, 2004). Other allies were also utilized, such as congressmen Fazio, Ose, and Thompson who initiated grants to UC Davis for fuel cell research (Fell, 2004).

In the enrolment and mobilization stages of translation, which are difficult to pinpoint but easy to analyze with respect to the way in which it should have worked, each actor accepts its role and relationships with other actors. Voters vote for proponents of a hydrogen economy, representatives follow through with their promises to supply funding to hydrogen technology, hydrogen-powered vehicles continue to be refined by the highly funded research, and Schwarzenegger keeps the network intact by supporting the use of fuel cell vehicles from within the California state government, thus completing each of the connections depicted in Figure 1. As my analysis of the HHBP network states, each actor and its relationships are pertinent to the

stability of the network; therefore, in the next two sections I will direct readers to the points of failure within the network that caused its collapse.

Partisan Bias Generated by a Biased Media

As discussed previously, power dynamics within the network are not derived from the objective power of the individual actor but from the power it holds over its relationships with other actors. Although in an objectively powerful position, Schwarzenegger had little power to convince the public that a hydrogen economy was doable. The public was instead swayed by media coverage of the Bush administration's plan to grow a hydrogen economy. While some media sources (typically those biased towards the Republican cause) spoke in favor of a hydrogen economy, there were also those that preferred the EV over the hydrogen powered alternative (biased towards the Democrat's cause). Here, I argue that rather than being due to a true incompetency in the hydrogen economy, the HHBP failed due to sour opinions of President Bush and his relationship with a party well known for their partiality to oil, which were exacerbated by biased media coverage.

During 2004 and many years prior, researchers were calling for more funding of hydrogen-power research, which was finally answered by the Bush Administration in the form of an $18 billion grant (National Archives and Records Administration, n.d.). The Bush administration was a strong proponent of hydrogen power; whether this was due to Republican's affection for oil or a true belief that a hydrogen economy could bring about a greener future is questionable, but irrelevant to this study. However, the media's perception of the federal government's reasoning coupled with its lack of understanding of scientific research were the main causes of the failure to fully enroll and retain voters and consumers in the HHBP network. A clear indication of this is seen in an article by Matthew Wald, one of many articles naming the

Bush administration's hydrogen plan as a farce and "unrealistically aggressive" (Wald, 2004). Wald further notes that about hydrogen power: "hydrogen production uses fuels like coal or natural gas, and those create pollution." Broad accusations such as these make hydrogen power seem like a nonsolution, and while partially true, I will further discuss in the next section how this is a misinterpreted fact that has little bearing on hydrogen's overall usefulness in the fight against climate change. Furthermore, his use of buzzwords, such as coal, natural gas, and pollution only advance readers' distrust of hydrogen. Since the public mainly understands natural gas, coal, and pollution as anti-environmental, this is the argument that almost all news sources that are against hydrogen power for cars use. For example, another article by Harrison Sheppard (2004) states, "Hydrogen plants would most likely run on natural gas, which results in high emissions of carbon dioxide," again utilizing the buzzwords that laymen of the situation can easily understand as bad.

Voters and consumers alike took these scathing media reviews to heart, pulling away from their hopes in a hydrogen economy and looking instead towards an EV future. This resulted in a breakage of the network relationship between representatives, such as Bush and Schwarzenegger, and their voters. Voters and consumers instead turned outside of the HHBP to a new network whose goals directly clashed with that of the HHBP's. Nationwide voters elected President Obama in 2008, who immediately cut funding for fuel cell vehicle research, instead opting to fund EV's. While both hydrogen fuel cell vehicles and EV's are viable options, the structure of the U.S. government continues to fail researchers as the frequent sways of power keep research from being completed before funding is revoked and

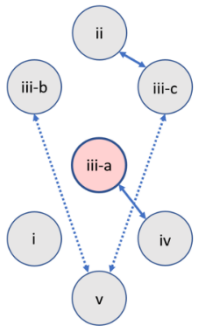

Fig. 2. Failed network, broken arrows depict inadequate connection and lack of arrows represents complete disconnection

moved to something else entirely (Elliot, 2011). Obama's budget cuts lowered money allotted to this research to about $68 million, halting the R&D that was needed to turn the hydrogen economy and HHBP into a successful carbon reduction breakthrough (Biello, 2009). Loss of voter and consumer approval propagated through the network as shown in figure 2, disconnecting the necessary funding from fuel cell vehicles and disconnecting the network from the primary actor.

An Argument for Hydrogen

In the previous sections, I presented my analysis of the HHBP network and the effect of media coverage on public opinion, which ultimately led to the dissolution of the network. My previous argument, however, requires that hydrogen fuel cell cars actually be a valid solution to climate change since I argue that it was media bias rather than accurate reporting that led to voter and consumer withdrawal. Here I show that, had they been given the proper funding, fuel cell vehicles could have presented a highly useful alternative to gasoline cars due to their low environmental impact and the centralization of the GHG emissions associated with hydrogen production and usage. To equalize in my readers' minds the usage of fuel cell vehicles and EVs, I will base this claim on the same claim that is made by EV promoters – generating hydrogen (or electricity in the EV's case) in centralized locations allows for far easier carbon capture than at the tailpipe of each vehicle.

As my primary source of information, I utilize an ATR study conducted by Oni et al. in 2022; however, this technology has been available and in use since the 1950s relatively unchanged (Oni et al., 2022, Speight, 2014). As was touched on in the background section, ATR units utilize their own heat of reaction to drive the SMR reaction that produces hydrogen. Not only does this lower the energy-cost of production, but substantially reduces the GHGs produced

in powering the plant with the only other non-negligible sources of GHG generation associated with the production facility coming from steelwork and concrete production (Oni et al., 2022). A typical ATR plant can produce over 600 tonnes of hydrogen per day, generating large amounts of carbon dioxide in the process; however, since carbon dioxide is produced as a concentrated stream from a very large reactor, it becomes economically viable to capture and sell it as a coproduct for enhanced oil recovery (EOR) or calcify it to be stored underground, removed from the atmosphere. Thus, even prior to the massive amounts of research that would have been able to jumpstart hydrogen production far past what it has crawled to today, hydrogen production and the HHBP in general had the ability to be a successful and economically viable option for GHG reduction and climate change mitigation.

An Incomplete Argument Against Hydrogen and its Rebuttal

As I have shown, hydrogen production for use in hydrogen fuel cell vehicles is a feasible achievement already, also noting that with proper funding, it could become an even more attractive climate change mitigation resource; however, there are still multiple arguments against its use. Many of these arguments stem from its distribution hurdles and the costs associated with complete redesign of the current gasoline infrastructure. Rather than looking into easily disputed media articles or opinion pieces, I have instead chosen to review a journal article that provides quantitative analyses of the costs associated with infrastructural redesign to support highways filled with hydrogen powered vehicles conducted by Greene, Ogden, & Lin (Greene, Ogden, & Lin, 2020). This article shows that infrastructural redesign would be extraordinarily costly due to hydrogen's incompatibility with current gasoline pipes and storage. Furthermore, due to the small number of fuel cell vehicles currently in use, another major hurdle will be determining where exactly to locate these fuel stations and pipelines. I found this paper to be extremely well

written and quantitative in its analysis of the pitfalls of "hydrogen highways." This paper not only raised questions about the viability of implementation, but also attempted to answer these questions (it should be noted by the reader that it is this that I refer to when mentioning media's misunderstanding of scientific research, since two opposingly biased media sources could take this article and, with the help of confirmation bias, draw two completely different conclusions from its results). However, through studying other quantitative research pieces, such as Isenstadt's and Lutsey's thorough review of the implementation of hydrogen infrastructure, it is clear that with favorable public opinion and proper funding (similar to that received by EVs now) costs of infrastructural integration and hydrogen production alike fall drastically with market and production growth just as they have for EVs (Isenstadt & Lutsey, 2017). This underscores the importance of public opinion and funding on the economic feasibility of any new technology, further highlighting the true cause of network disintegration in the HHBP network.

Conclusion

In this study, I have presented evidence drawn from a variety of sources connected to the HHBP and its attempted implementation supplemented with scientific studies regarding its large-scale viability that attempts to convince my readers of the causes behind its failure. Utilizing the ANT framework, I have broken the HHBP network into its relevant actors and drawn conclusions from their relationships, pinpointing the broken connection between voters and consumers caused by media misinformation. I have also shown through cited scientific research the validity of my claim that the media was indeed reporting misleading data to convince the public of the HHBP's ineffectiveness. Through this analysis, I hope to have shown my readers the dangers of inadequate sourcing and partisan bias on new and useful technologies. Furthermore, I hope that this analysis of the HHBP leaves my readers with an urge to look

outside of their “echo-box” news sources for information regarding policies that have a major effect on our lives and planet. Engineers can slow climate change, but this will require a disregard for partisan bias and a steady stream of R&D funding that cannot continue to be pulled with each newly elected leader.

Word Count: 3920

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