Accelerating the Transition to Electric Vehicles by Developing Compound Solutions That Consider Multiple Perspectives and Create Synergistic Relationships

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By

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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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Introduction

Today, it is commonly known that humanity is facing a crisis with the emission of greenhouse gases (GHG) from different sectors that exacerbate climate change. According to the International Energy Agency (IEA), "the transportation sector accounts for a 23% share of global energy-related GHG emissions." (IEA, 2017, n.p.) The following graph displays CO2 emissions from fuel combustion by sector from 1960 until 2014, in which the increasing trend of GHG emissions and the 23% share of the transportation sector can be observed.

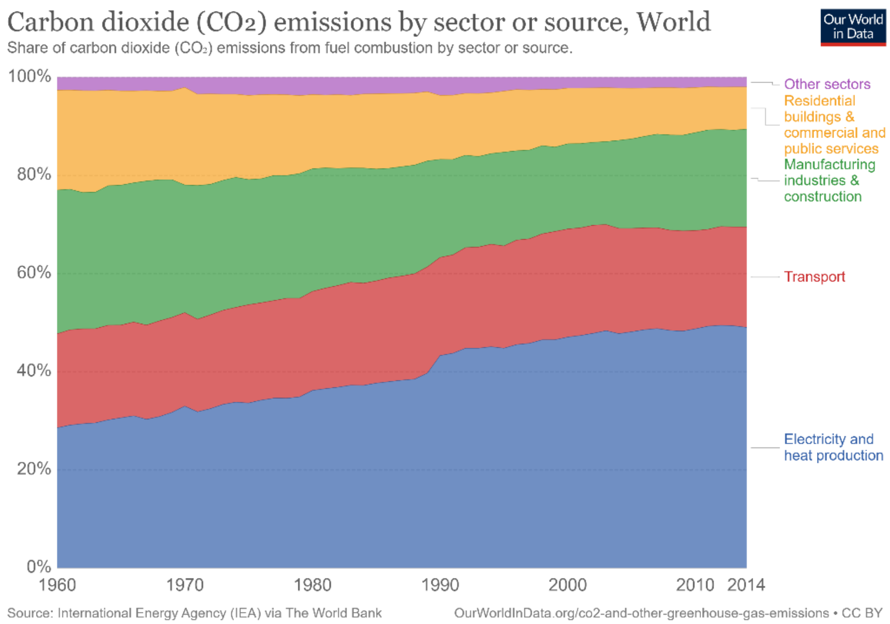

Figure 1: Green House Emission by sector since 1960 to 2014 (Ritchie & Roser, 2020, n.p.)

Developing and implementing electric vehicles (EVs) can be part of the solution to reduce GHG emissions. However, even though EVs present substantial benefits to the environment, there exist serious barriers with their adoption that countries need to address in order to accelerate the adoption of EVs. Energy and environment researchers state the problem as follows:

> There is a variety of barriers for the uptake of EVs, and these barriers exist at both micro- and macro-levels. While the micro-level barriers (such as high upfront costs, poor technical performance, and insufficient charging infrastructure) have influenced the producer and consumer preferences for EVs, the design and implementation of effective policies for removing these barriers has been significantly hindered by the macro-level barriers (such as fragmented authority, local protectionism, and perverse incentives in policy-making and implementation). (Li, Yang, & Sandu, 2018, p. 1521)

My STS research will use multi-level perspective (MLP) to analyze what it takes to promote a major societal transition such as adopting EVs. Also, my STS research will use the STS technological-cultures framework to understand what makes successful a technical artifact in a specific region. In this paper, I argue that different policies that are being implemented or studied in other countries to accelerate the adoption of EVs can be reproduced successfully in the United States, as long as we have a strong understanding of the technical culture and the socio-technical structure of the U.S.

Part I: Policies to Accelerate the Implementation of EVs Are Most Likely to Succeed in the US if They Have a Comprehensive View of the Socio-Technical Barriers

EVs were introduced to society more than a hundred years ago, according to the U.S. Department of Energy (2019, n.p.) However, after internal-combustion engines (ICE) were invented and gas prices decreased, the need for EVs virtually disappear until recent decades. EVs provide benefits such as no carbon emissions, noise reduction, and low maintenance. Nonetheless, there are some serious barriers with the adoption of EVs. According to energy policy experts, Li, Yang, and Sandu, these barriers can be divided in two categories (micro-level and macro-level) and they affect both the producer and consumer in different ways. Both of these barriers will be explained in detail in the following paragraphs from the consumer and producer standpoint.

Micro-Level Barriers

First, let us consider the producer micro-level barriers. These are the barriers that EV's manufacturers or potential producers face. Energy policy experts Li, Yang, and Sandu explain that the producer micro-level barriers consist mainly of technological uncertainty. The following epigraph presents an example of the technological uncertainty manufacturers afront in China:

> Major auto makers in China seem to have considered [EV development] investments as too risky, especially in the backdrop of substantial technological uncertainty and low consumer acceptance of EVs. They have therefore tended to prioritize investments in the conventional vehicle markets, with a view to maintain their dominated market position, and adopted a 'wait and see' strategy in the EV markets.[14],[15] For example, in 2015, the five largest auto makers in China accounted for more than 70% of conventional vehicle sales, but accounted for just 15% of EV sales,[16] suggesting their reluctance to invest heavily in the EV markets. (Li, Yang, & Sandu, 2018, p. 1514)

It seems as though major car manufacturers (producers) are unwilling to invest in new technologies such as EVs because their current practices are profitable, and they are locked into their current manufacturing process. In other words, it is hard to break existing structures.

On the other hand, we have the consumer micro-level barriers. These are the barriers that the potential buyers of EVs face. Consumer micro-level barriers consist of technological factors, financial factors, and infrastructure factors (Li, Yang, & Sandu, 2018, p. 1514-1515). Technological factors include facts such as it takes longer to charge an EV than to fill a conventional car gas tank. Therefore, drivers opt for a vehicle they can refill in a couple minutes rather than waiting for one hour or more to recharge. Financial factors are the high upfront costs and high maintenance costs EVs have at the moment. Infrastructure factors, explain Li, Yang, and Sandu (2018), is limited access to charging facilities. Both of these last two factors are due to the lack of EVs in the market since a higher number of EVs would yield a lower price and a wider recharging network. In addition, the energy policy experts point out that demographic, social, and psychological influences shape the way in which consumers perceive the micro-level barriers, resulting in a wide variety of consumer preferences, which some of them degrade the view of EVs hindering their adoption.

Macro-Level Barriers

Macro-level barriers are barriers at the political or societal level. Again, taking as an example China, researchers Li, Yang, and Sandu describe how China possesses several institutional and political factors that impede the implementation of policies that address the micro-level barriers (Li, Yang, & Sandu, 2018, p. 1515 -1516). Those political and institutional factors are denominated Macro-level barriers and consists of fragmented authority, local protectionism, and perverse incentives. The energy policy experts narrate how China has several ministries that have the capacity to implement policies that address the micro-barriers described above. However, these ministries have different and sometimes opposing views on specific topics, which results in significant delays or abandonment of the policy programs. For example, China has urban planners (especially, in large cities, such as Beijing, and Shanghai), and they are concerned with the land-intensive nature of charging infrastructure and its potential impacts on other land usages. On the other hand, China's public utilities see the development of charging infrastructure as a profit-making opportunity. These opposing views of these two entities result in significant delays in the development of charging infrastructure. This example clearly illustrates how not having a single entity to lead policy implementation can lead to constant disagreement and inaction as a result. It also supports my claim that understanding the political system of a country operates, especially with respect to enacting laws related to new technologies, is essential for the successful and rapid adoption of EVs. This begs the question of what can a society do to accelerate a transition to EVs.

How to Accelerate the Transition to EVs?

Currently, Nordic countries are leading the transition to electric mobility, so in this section, I present some of the transition research produced in these countries. Policy and transition experts Kotilainen, Aalto, Valta, et al. (2019) explain that the Nordic countries are "open societies bent on innovation, making them well adaptable to a transition toward electric mobility." (p. 574) These countries have a common decarbonization target that is reflected in all their sectors, particularly the transportation sector. The Nordic experts mentioned above explain that, for a transportation transition, societies need to pay attention to both the technologies and socio-technical systems, and they present some recommendations from their research.

The most relevant of those recommendations are: (1) develop a mix of path creation policies and destabilizing policies (i.e. disrupting policies), (2) use a systematic cross-regime policy approach, (3) avoid confusion from technology neutral approach, and (4) employ a mix of strategies to break behavioral patterns. (Kotilainen, K., Aalto, P., Valta, J. et al., 2019, p. 593-595) The first recommendation, path creation policies, are policies that create or incentivize the use of the new technology (e.g. free toll for EVs). On the other hand, destabilizing policies are the ones that affect the current regime. (e.g. restriction on polluting companies). The Nordic experts explain that governments tend to prioritize path creation policies, but they argue that destabilizing policies have a stronger effect in influencing actors on changing to a new system.

Systematic cross-regime policy refers to how sectors affect one another. For example, the transportation sector is interconnected to the energy sector. Therefore, "governments should evaluate the policy mixes more systematically to understand the compounded effects of multiple regimes in the transition toward EVs." (Kotilainen, K., Aalto, P., Valta, J. et al., 2019, p. 593). Moreover, the experts explain how governments should avoid a technological neutral approach, that is when governments want to wait for the market to make a selection (e.g. Biofuels vs EVs). They argue this approach is "unlikely to deliver fast enough the required decarbonization outcomes." (Kotilainen, K., Aalto, P., Valta, J. et al., 2019, p. 594) Lastly, the experts recommend that governments should use a mix of strategies to break behavioral patterns. The authors suggest that "resources to be also assigned toward enabling infrastructure and informational and educational projects paving the way for less environmentally harmful consumption" (Kotilainen, K., Aalto, P., Valta, J. et al., 2019, p. 595) is essential for a transition to EVs. All these recommendations will be discussed further in Part III.

Part II: The Multi-Level Perspective and Cross-Cultural Comparison Frameworks Provide an Understanding of the Complex Dynamics of Transitioning to Electric Vehicles

In his journal article "The Multi-Level Perspective on Sustainability Transitions: Responses to Seven Criticisms. *Environmental Innovation & Societal Transitions"* Frank Geels presents and defends the multi-level approach (MLP) as a useful framework despite seven big constructive criticism, concluding that MLP can be used to design and implement solutions to sustainability transitions. In this section, I describe the MLP framework and explain how it can be applied to accelerate the adoption of electric vehicles in the United States. Also, I will use Bijker, "Differences in Risk Conception and Differences in Technological Culture" as a cross-cultural framework of comparison to contemplate the use of foreign transportation policy in America.

Describing the Multi-Level Perspective (MLP)

MLP is a framework that recognizes the multi-dimensional nature of and structural change needed for socio-technical transitions. Geels argues that MLP goes beyond studies of single technologies; MLP, he argues, also emphasizes the importance of structural change, that is, "how emerging innovations struggle against existing systems" (Geels, 2011, p. 25). While there exist other relevant approaches to socio-technical transitions, Geels explains that MPL focuses on "concrete energy, transport, agri-good systems, etc." while including more details in its "various groups, strategies, resources, beliefs and interactions" (Geels, 2011, p. 26). Moreover, Geels explains how MLP sees transitions as "non-linear processes that result from the interplay of developments at three analytical levels: niches (the locus for radical innovations), socio-technical regimes (the locus of established practices and associated rules that stabilize existing systems), and an exogenous socio-technical landscape." The following figure below depicts the three levels and their relationships. Each individual analytical level is explained in the following paragraphs in their hierarchical order (socio-technical landscape, socio-technical regimes, and niches) and how they relate to each other.

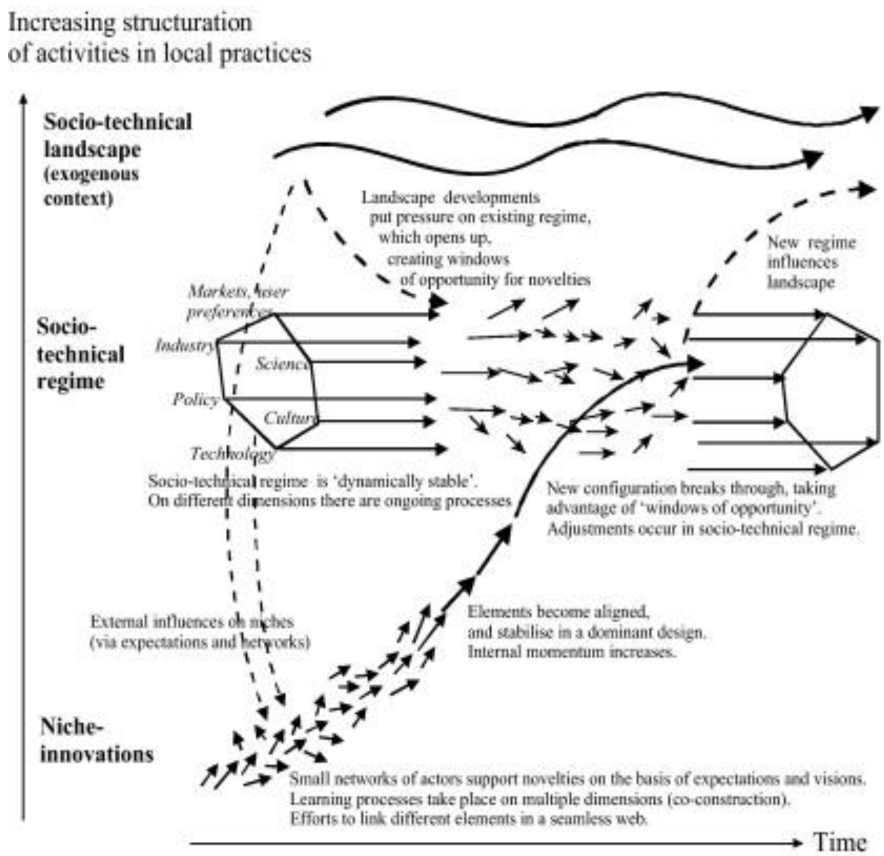

Fig 2. Multi-level perspective on transitions (Geels, 2011, p. 28)

The top level from Fig. 2, the socio-technical landscape, is the backdrop that sustains society, and it consists of "demographical trends, political ideologies, societal values, and macro-economic patterns" (Geels, 2011, p. 28). The socio-technical landscape is not easily affected by the bottom two levels; instead, it is affected over longer periods of time. The socio-technical landscape can be thought as the beliefs a society holds, which they do not change overnight. The middle level, the socio-technical regime, involves markets and consumer preferences, industries, policies, science, and technology. Geels states that "The socio-technical regime forms the 'deep structure' that accounts for the stability of an existing socio-technical system" (Geels, 2011, p. 27). It can be thought of as the actors that run a society. Lastly, the bottom level, niches, consists of protected spaces such as “R&D laboratories, subsidized demonstration projects, or small market niches where users have special demands and are willing to support emerging innovations” (Geels, 2011, p. 27). Here is where entrepreneurs and scientist innovate to address problems of the current regime.

The takeaway from MLP is that every socio-technical transition is unique, and they result from interactions among the three different levels. Geels explains that the most common interactions are: “(a) niche-innovations build up internal momentum, (b) changes at the landscape level create pressure on the regime, and (c) destabilization of the regime creates windows of opportunity for niche-innovations” (Geels, 2011, p. 29). These interactions will be discussed further in Part III.

Describing Differences in Technological Culture

In his journal article, Wiebe Bijker (2007) describes the difference between American and Dutch coastal engineering, and he argues that the difference in both countries does not lie in expertise or competence, but instead it lies in technological culture. Both the American and the Dutch culture have been shaped by natural disasters, Hurricane Katrina and De Ramp, respectively. However, the countries responded in two different ways. The author states “The American practice focuses on predicting disasters and mediating the effects once they have happened, in brief: on ‘flood hazard mitigation.’ Dutch practice is primarily aimed at keeping the water out” (Bijker, 2007, p.147). Bijker suggests that these differences in coastal engineering style are related to “the differences between American and Dutch societies, or rather technological cultures” (Bijker, 2007, p.149).

The three key elements of technological culture are: geography, political culture, and technical literacy. By geography, Bijker refers to how different the U.S. and the Netherlands are, particularly how the Netherlands has more sea coast and more river borders per square mile. Consequently, this fact makes the Netherlands pay more attention to keeping the water out since they have more water around. By political culture, Bijker denotes how both countries have a different conception of the role of the state. The Dutch accept that the national state has a central role in all sectors of society as opposed to the Americans, which Bijker characterizes as "neo-liberal, without belief in the common good as something that the government should define and protect; there is an inclination to privatize and individualize public functions, rather than to defend their value" (Bijker, 2007, p.149). By technical literacy, Bijker means that the Dutch citizens seem to know more about coastal engineering than the Americans. This discrepancy is due to "the active role that citizens, both as action groups and as unorganized individuals, play in public debates, hearings, or on the discussion pages of national newspapers" (Bijker, 2007, p.149). Then Bijker concludes that "high taxes and imposing infrastructures, may be more acceptable when citizens better understand the risks and the technical means of coastal engineering defense" (Bijker, 2007, p.149). This is an important conclusion to consider because, if a government is to promote a technology such as EVs, then its citizens must have a solid understanding of the issue, just like the U.S. public allows spending a lot on defense because the public has a better understanding of the risk of not having a strong military.

Applying MLP to Accelerate the Adoption of EVs

First, is important to understand how sustainability transitions, such as EVs' adoption, are different from other transitions, which Geels refers them as 'emergent.' By emergent, Geels refers to entrepreneurs exploring commercial opportunities driven by demand (Geels, 2011, p. 25). Transitions are described as "shifts from one regime to another regime" (Geels, 2011, p. 29). Geels describes three essential characteristics of sustainable transitions: they are goal-oriented;

they do not offer obvious user benefits; and they have an empirical domain. First, by goal oriented, Geels means that sustainability transitions seek a collective good (e.g. fight climate change); however, private actors (car manufacturers) do not have compelling incentives because usually these collective goals do not provide them with a substantial benefit, at least in the short term. Second, by not obvious user benefits, Geels refers to the higher price and perhaps lower performance of the new technologies associated with the transition, which do not benefit the user. For EVs, these not obvious benefits relate to the higher cost of EVs compared to conventional vehicles, and the longer time it takes to charge than to refuel. Third, by empirical domain, Geels explain that large companies such as car manufacturers have existing specialized manufacturing and vast experience with their current products, which make them reluctant to invest in new risky technologies. This empirical domain relates to the example presented before where the Chinese producers were reluctant to invest in EVs.

Now, considering the complexity of sustainable transitions, it can be inferred that, to produce a change in a regime, e.g. transition from combustion-engine vehicles (ICE) to EVs, "processes in multiple dimensions and at different levels which link up with, and reinforce, each other" are needed (Geels, 2011, p. 29). In simpler terms, to promote a transition to EVs, there is no simple solution that can be implemented at any of the three levels (socio-technical landscape, socio-technical regimes, and niches). Instead, approaches that considered the multi-dimensionality of the issue and the complex dynamics among the levels are necessary. One approach Geels implicitly offers in his analysis is structural changes to lock-in mechanisms (institutional commitments, sunk investments in machines, power relationships, political lobbying, among others). Geels states "These lock-in mechanisms create path dependence and make it difficult to dislodge existing systems. So, the core analytical puzzle is to understand how environmental innovations emerge and how these can replace, transform or reconfigure existing systems" (Geels, 2011, p. 25). The key again is in understanding the dynamic interaction between the three different levels and how they transform the status quo.

Part III: To Accelerate the Transition to Electric Vehicles, the US Needs to Address the Micro and Macro Level Barriers by Understanding Sustainable Transitions and the Technological Culture

Although a transition in the transportation sector to a greener technology is necessary to avoid drastic effects to the environment, simply developing EVs will not produce a fast-enough transition. Transitioning to a new technology encompasses many driving factors. MLP presents an interesting framework for transitions and illustrates the mechanics of how transitions take place. Moreover, using existing mechanisms from other countries to accelerate the implementation of electric vehicles can help the United States act more swiftly. I argue that having both a solid understanding of socio-technical transitions and the cultural differences between countries is necessary to successfully accelerate the implementation of EVs.

First, I present in Figure 3 how the MLP applies to the transition to EVs. The goal is, as Geels stated it, to "shift from one regime to another regime" (Geels, 2011, p.25) That is, shift from internal combustion engines (ICEs) to EVs. The three interactions Geels describes for a transition to happen are depicted on Figure 3 as squares arising from the arrows connecting the three different levels (niche-innovations build up momentum, changes at the landscape level create pressure on the regime, and destabilization of the regime creates windows of opportunity for niche innovations). In the following paragraphs, I explain how the research presented throughout this paper relates to these three interactions.

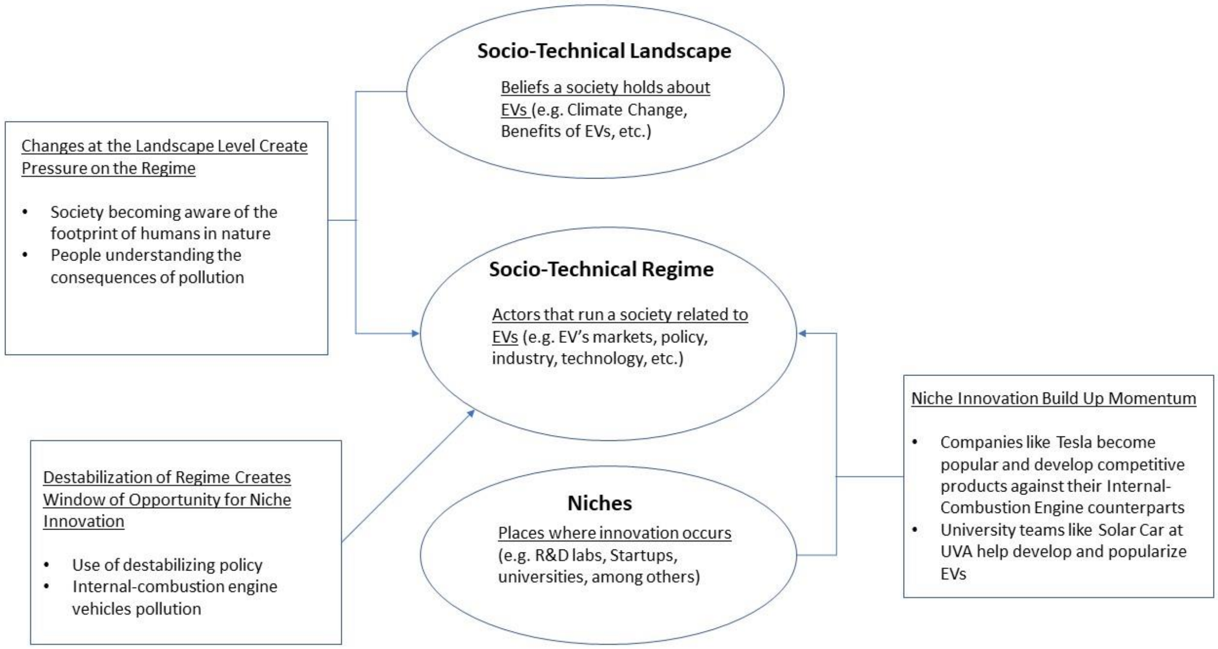

Figure 3: Multi-Level Perspective Applied to the Adoption of EVs (Created by author.)

Addressing Micro Level Barriers to Build-Up Momentum

EVs have obvious difficulties to compete against ICE, which has had existing products, services, and infrastructure for a much longer period. Therefore, policies promoting investment in EVs are needed to obtain a decent competitor against ICE. Most of the research should focus on addressing EVs' high upfront costs, poor technical performance, and insufficient charging infrastructure. Writing this paper made it clear to me that, if EVs are not competitive against current ICE vehicles, a country may use strategies that have been effective in other countries, but the EVs will not become popular enough (at least in timely manner) because of their upfront cost, technical performance, and infrastructure deficits. That is why laboratory research and university technical teams such as Solar Car are important to foster EVs' advancement. Therefore, governments should invest heavily on helping such actors. Likewise, helping startup companies that develop EVs by means of tax cuts or funding can significantly improve how these niches perform against ICE, facilitating the momentum needed by EVs.

Foster Technical Literacy to Create Pressure on the Current Regime

As depicted on Figure 3, changes at the landscape level create pressure on the current regime. The main path to change a society's belief is through education. That is what Bijker refers as having better technical literacy. Consumers in the US have behavioral patterns when it comes down to selection of products such as EVs. Such selection is based on multiple factors such as demographics, psychology, and social circles. The government then by means of educational campaigns can target cultural perceptions of EVs in such a manner that it presents the collective benefit in the long run of adopting EVs. That is what Kotilainen, Aalto, and Valta describe as "paving the way to less environmental harmful consumption" (p. 594). To me, it became clear that once the public becomes more aware of the multidimensionality of electric vehicles and their benefit to their communities, then the public will be more accepting of inconveniences that come with the transition to EVs. This is the example mentioned earlier that the U.S. is willing to invest a big percentage of its GDP in the military because the public is aware of the risks of foreign threats. Similarly, if the U.S. public is better informed about the risk of not adopting EVs, then they will be more accepting of stronger measures such as restriction of polluting vehicles or fiscal policy that benefits EVs.

Destabilizing the Internal Combustion Engine Regime

A take-away from the recommendations of the Nordic experts was to avoid technological neutral approaches, that is, when the government waits for the market to make a decision instead of supporting one. Particularly, this recommendation seems quite relevant for the U.S., where the capitalist culture favors this type of behavior. The U.S. cannot afford to wait for the market to decide between electric vehicles and other forms of non-contaminant fuels (bio-fuels, or Hydrogen) because such a decision may take decades. Therefore, I argue the U.S. should take a stand with EVs and support them, and then start destabilizing the current ICE regime. Such action will not be easy. Institutional commitments, sunk investments, and power relationships with ICE are entrenched in our society. However, for the transition to happen, I believe the government should try to dislodge these existing systems through a system of policies while helping the affected institutions (automotive industries, gas industries, among others) transition to other environmentally friendly options.

Conclusion

Throughout this paper, I maintain that the U.S. can accelerate the adoption of EVs by having a stronger understanding of the multi-dimensionality of socio-technical transitions and the important role of domestic technological culture. With such an understanding, agencies in charge can promote compound solutions that consider multiple perspectives and therefore use synergetic strategies that take into account how actors affect each other. The U.S. can implement policy that successfully addresses both the micro-level and macro-level barriers of EVs as long as the agencies in charge understand socio-technical transitions and the local technological culture.

There are several implications for the U.S. agencies in charge of developing policy that address the micro-level and macro-level barriers. First, agencies can have a better understanding of the synergy that is required from all the actors pertaining to the adoption of EVs. Second, agencies can comprehend the importance of further fostering the development of EVs so that destabilization of the current regime by niches that Geels explains can occur. Third, agencies can take more into account the importance of the public's technical literacy to advance their policies.

Agencies can then develop more educational projects that pave the way for the adoption of EVs by increasing public acceptance of the burdens they may cause. These frameworks are theoretical, and they do not perfectly describe how society will behave in face of such big challenges; however, I conclude that both MLP and technical-culture frameworks are a good place to start accelerating the transition toward EVs.

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