Selective Government Subsidization of Electric Vehicles Can Maximize Environmental Returns and Drive Consumer Acceptance of Electric Boats

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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

In his book, *Polluting for Pleasure* (1993), Andre Mele estimated that approximately 150 million to 420 million gallons of unburned fuel are emitted into aquatic environments each year by recreational boats (p. 29). There is a vast array of recreational watercraft propulsion systems, and each has benefits and consequences. Watercraft most notably can be propelled by gas motors, electric motors or humans. Boats that are powered by petrol, oil, or diesel harm the environment the most by a significant margin. In fact, gas-powered boats add chemicals and metals to water, which can influence the type and amounts of aquatic wildlife (Vermont Water Quality Division, 1999). Human-powered boats are not viable alternatives to gas boats due to their minimal speed, power and size. Electric boats are the most viable environmentally friendly alternative to gas boats. However, boat manufacturers do not have the necessary technological capabilities or government support to produce electric boats with comparable price, range or power. Yet, hybrid electric boats offer a compromise. These boats can be powered by gas and electricity and combine the favorable aspects of gas and electric boats: low emissions and more comparable range, power, and price. With the current state of public sentiment towards habitat destruction, most consumers still choose to purchase gas boats over electric boats. As a result, manufacturers lack the necessary government support and consumer demand to mass produce electric boats. Lacking demand, production, and technology forces recreational boaters to continue to disrupt aquatic ecosystems with gas-powered watercraft.

Politicians and shipping organizations have previously acknowledged and expressed willingness to address aquatic habitat destruction. An examination of “Hurricane Katrina: One Year Later,” a statement released by the American Society of Civil Engineers Hurricane Katrina External Panel (2006), reveals the need for technology, culture and organizations to work synergistically for an effective solution to be developed. Although the electric car and electric boat industries share many similarities, the rapid increase in prevalence of electric cars greatly surpasses the growth in electric boating. Thus, there must be some critical technological, cultural, or organizational factor that has prevented a similar surge in consumer acceptance of electric boats. In this paper I argue that subsidization is the most effective form of government intervention due to its ability to limit the financial limitations of electric vehicles. I explain that prioritization of government subsidization for hybrid electric cars can maximize environmental returns, technological innovation, and even consumer acceptance of electric boats.

Part I: Economic Constraints Are the Primary Inhibitor of Consumer Acceptance of Electric Boats

The negative effects of recreational boating on aquatic habitats are clear. As aquatic habitat destruction has accelerated, some politicians have begun to campaign for limitations on the use of gas-powered boats. To adequately protect aquatic ecosystems, greater limitations on gas-powered watercraft must be enforced unless widespread acceptance of electric boats can be achieved. A study by the National Marine Manufacturers Association explains that “in America’s nearly 1,800 federal lakes, which host more than 900 million visits each year and generate over $44 billion in economic impact, almost 40 percent are said to suffer from some source of pollution or habitat degradation" (Fontaine & Dunn, 2007, p. 57). Figure 1 below depicts the precarious state of America's largest bodies of freshwater. Consumer acceptance

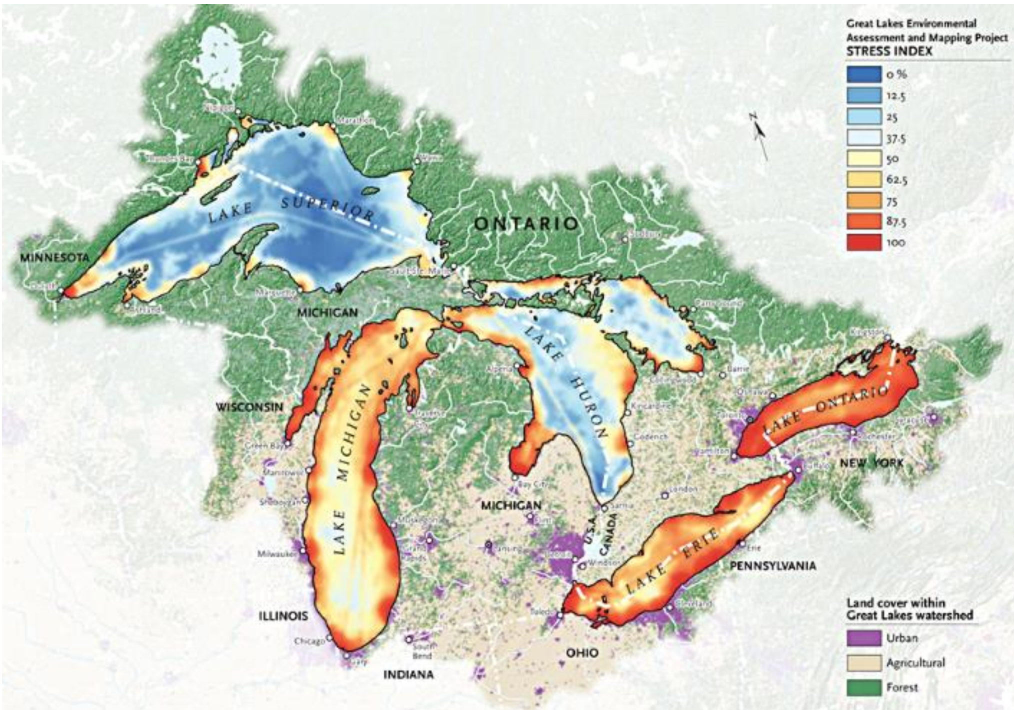

Figure 1: Tremendous ecological strain is placed on the Great Lakes - home to more than a fifth of Earth's freshwater (Walker, 2013).

of electric boats is the favored solution for mitigating aquatic habitat destruction while preserving the recreational boating industry and alignment with cultural values.

As explored earlier, electric boats currently lack the power, range and price to compete in an open market with gas-powered watercraft. Monica Anderson (2017) reveals that approximately three-quarters of U.S. adults are concerned about helping the environment but only about one-fifth of U.S. adults try to protect the environment consistently. With a low proportion of citizens actively aiming to protect the environment, a transition from gas boats to electric boats is unlikely. Thus, American adults do not value the environmental protection provided by electric boats enough to sacrifice power, range and price. Boat manufacturers that recognize this lack of demand for electric boats know that production of electric boats would likely be unsuccessful. Consequently, electric boats have achieved slow proliferation mainly through purchases by affluent environmentally friendly consumers.

Nevertheless, hybrid electric boats offer consumers the best aspects of gas boats and electric boats. Hybrid electric boats can be gas or electric powered to retain power, range and environmental friendliness. These boats are cheaper then fully electric boats but still more expensive than gas boats. Hybrid electric boats produce less total environmental returns than fully electric boats but have greater environmental returns per dollar and can be marketed to consumers with greater ease. As a result, hybrid electric vehicles offer a unique alternative. However, the government currently subsidizes fully electric boats to a greater extent than hybrid electric boats. Figure 2 below shows the distribution of fully and hybrid electric vehicle sales and compares their sales to total vehicle sales globally. Clearly fully electric vehicles comprise a

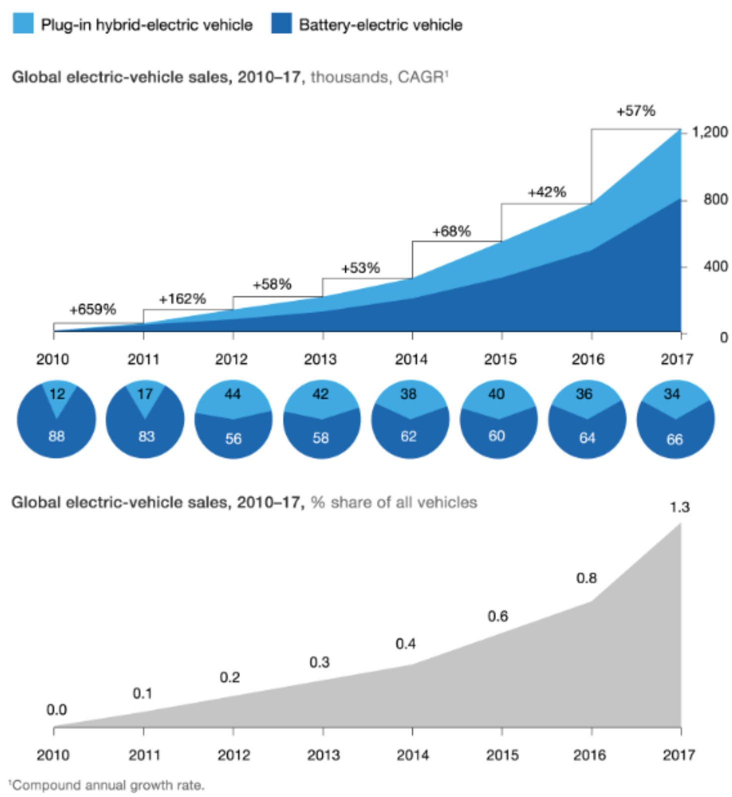

Figure 2: Global electric vehicles have grown quickly from 2010 to 2017 yet still comprise a small fraction of total vehicle sales (Hertzke, Muller, Schenk, & Wu, 2018).

greater proportion of electric vehicle sales than hybrid electric vehicles. Although there has been significant growth in all electric vehicle sales, electric vehicle sales still only accounted for less than 1.5% of all vehicle sales in 2017. Government subsidization has likely driven growth of electric vehicle sales and the relative prominence of fully electric vehicles over hybrid electric vehicles. Nevertheless, it is unknown if fully electric boats should receive greater subsidization to maximize electric boat proliferation and minimize aquatic habitat destruction. Thus, it is important to understand how the government can most effectively intervene and how subsidization should be allocated. An improved understanding of these actions would enable more efficient reductions to aquatic habitat destruction and increases in electric boat proliferation.

The key inhibitors of electric boat proliferation must be understood to enact effective changes to cultural, technological, or institutional to reduce barriers to proliferation. In his book titled *Technological Change: Its Impact on Man and Society* (1970), Emmanuel Mesthene presents a model for thinking about the contingent and predictable avenues through which technological innovation can lead to conflict and social or political innovation. This model has been employed to explore potential rejections of electric boats and the possibility for eventual widespread acceptance of the technology. Figure 3 below depicts the four main factors in the electric boat sociotechnical network that affect electric boat proliferation. These factors should be targeted for driving increased electric boat proliferation. Thus, avenues through which electric

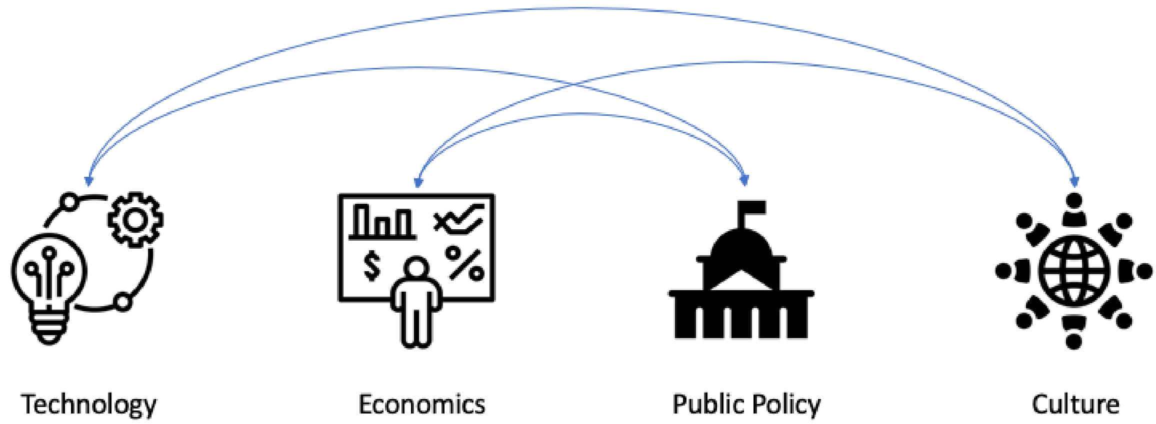

Figure 3: Technology, economics, public policy, and culture are the four essential actors in the electric boat sociotechnical network

boats could find widespread acceptance would involve at least one of the following shifts: increasing consumer sentiment towards environmentally friendly technology, government subsidization of electric boats, bans on gas boats, effective marketing for electric boats, and increased manufacturing focus on electric boats. The framework introduced by Mesthene is also complemented by the economic approach to technological determinism set forth by Robert Heilbroner. Heilbroner (1994) describes this approach as "applying an analytic understanding to such large-scale social changes as the composition of the labor force and the hierarchical organization of work, not to mention the dynamic characteristics of economic activity as a whole" (p. 73). Economic feasibility drives much of supply, demand, and public policy, so this framework better informs the likelihood of different avenues of electric boat acceptance. The electric car industry has achieved much greater proliferation than the electric boat industry yet the two exhibit many similarities. Case studies on the electric car industry have been used to provide insight into how similar progress can be made in the electric boat industry. These insights help to reveal the importance of economic constraints and government intervention in the journey towards widespread acceptance of electric boats.

Part II: Electric Car Industry Case Studies Reveal the Importance of Government Intervention in the Electric Boat Industry

Three case studies have been analyzed under two complementary frameworks set forth by Mesthene and Heilbroner. In his book titled *Technological Change: Its Impact on Man and Society* (1970), Mesthene presents a model for thinking about the contingent and predictable avenues through which technological innovation can lead to conflict and social or political innovation. This model has been employed to explore the avenues through which different initiatives may either fail or succeed in proliferating electric boats. Even with significant research and development expenditures in electric vehicle technology, technological advances have been too slow to spur significant proliferation. Cultural values towards environmentally friendly technology are not easily controlled. Government intervention has the greatest flexibility and power to influence electric boat proliferation and was chosen to be the subject of analysis.

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Three revealing case studies on the electric car industry are used to uncover the importance of economic constraints and government intervention for the widespread acceptance of electric boats: "New Opportunities for Electric Car Adoption: The Case of Range Myths, New

Forms of Subsidies, and Social Norms," "No Time for Pessimism about Electric Cars," and "Getting the Most Out of Electric Vehicle Subsidies." In the first text, from the journal of Energy Efficiency, the authors conducted a choice experiment among new car buyers to uncover the main perceptions affecting an individual's decision to buy an electric car. Results from this experiment revealed that the portrayal of the range of electric cars to consumers significantly affects an individual's perceived importance of range when buying a new car. In fact, the portrayal of the range of electric cars frequently acts as a barrier to electric car purchases. Furthermore, the study showed that social support is likely a significant factor involved in the decision to purchase an electric car. However, financial constraints were found to be the largest inhibitor to electric car purchases by a significant margin (Bobeth & Matthies, 2018, p. 1773-1778).

The second text, from the journal of Issues in Science & Technology, focuses further on the physical barriers to adoption of electric cars and how they may be combatted. According to the article, the main barriers to adoption of electric cars include the acquisition cost, driving range, recharge time, and battery and electric grid systems. Technology remains a significant barrier to adoption but government intervention could significantly reduce barriers to adoption caused by acquisition cost and inadequate battery and electric grid infrastructure. The text further illustrates why and how the rates of adoption of fully electric vehicles has differed from hybrid electric vehicles. As seen in Figure 4, fully electric vehicles achieved much greater adoption rates in the months after it was brought to the market than the rates achieved by hybrid electric

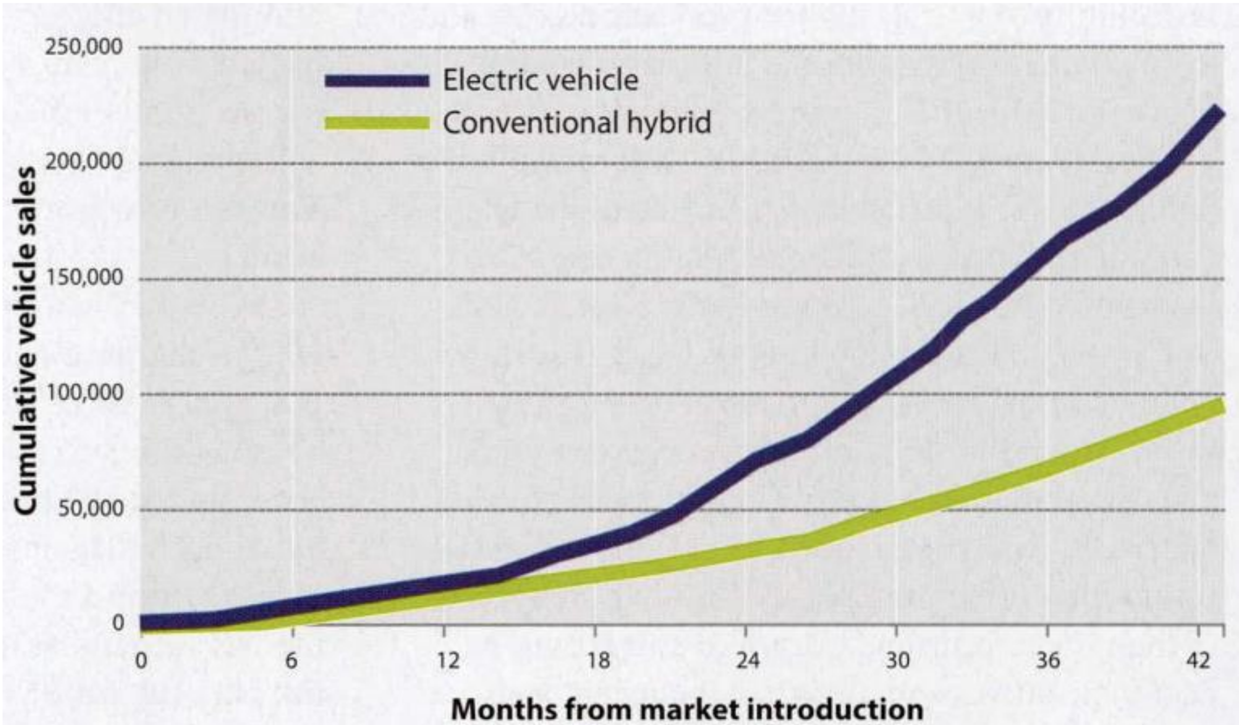

Figure 4: Cumulative sales of fully electric vehicles grew much faster after market introduction than conventional hybrid vehicles (Graham, Cisney, Carley, & Rupp, 2014, p. 37).

vehicles. The authors explain that it seems logical for consumer to adopt hybrid electric vehicles at higher rates due to their greater flexibility provided by its range and power. However, the authors reveal that hybrid electric vehicles were introduced to the market at an earlier date than fully electric vehicles. Thus, the relative success of hybrid electric vehicles was likely influential in improving the rate of sales of fully electric vehicles when they were introduced to the market – hybrid electric vehicles revealed the potential for success with fully electric vehicles. Differences in adoption rates are also affected by government subsidies. In fact, “the purchase of the conventional hybrid and EV were not equally subsidized by the government. EV purchasers were enticed by a $7,500 federal tax credit; the tax deduction – and later credit – for conventional hybrid ownership was much smaller, at less than $3,200” (Graham, Cisney, Carley, & Rupp, 2014, p. 36-39).

The last article, from the journal of Issues in Science & Technology, analyzes the effects of a variety of government subsidies and policies on the adoption of electric vehicles. In this article, academic literature and government studies were used to quantify the lifetime externality costs from the use of gas and electric vehicles. The authors explain that traditional subsidization of electric cars does not maximize its benefits. Government subsidies are currently greater for fully electric vehicles than hybrid electric vehicles. However, hybrid electric cars are more robust and offer better environmental externalities per dollar spent than fully electric cars. The authors argue that hybrid electric cars should receive greater subsidization. Hybrid electric vehicles do not face barriers to adoption due to their power and range and are more cost efficient. Thus, hybrid electric cars have greater marketability so greater subsidization may better drive demand which would increase learning, innovation, and growth in the electric car market. The article explains that the most efficient government policies would target externalities directly, such as taxes on gasoline, but such government legislation is unlikely to pass and implement effectively (Michalek, Chester, & Samaras, 2012, p. 25-27).

These articles have been analyzed using the previously stated frameworks due to the importance of the economic constraints in electric boats. Knowledge of how methods of government intervention can drive electric car acceptance have been applied to the electric boat industry. Significant differences between the markets for cars and boats exist and have been analyzed to alter the projected success of each form of government intervention. This analysis has great potential to guide the electric boat industry to success similar to the electric car industry.

Part III: Hybrid Electric Car Subsidization Provides a Uniquely Promising Method for Driving Consumer Acceptance of Electric Boats

The electric car and electric boat industries are very similar yet they differ for one significant reason. The boating industry is composed of a much greater proportion of recreational consumers. Whereas many consumers use cars daily, many consumers use their personal boats recreationally on an infrequent basis. Consequently, consumers of electric cars can generally expect much greater total fuel and environmental savings than consumers of electric boats. As a result, consumers may be much more inclined to invest their money in green technologies that result in much greater environmental benefits per dollar spent. Consumers that value environmentally friendly technology would rationally invest in the green technology with the greatest environmental returns. Nevertheless, the electric car and electric boat industries have many commonalities. Both industries have barriers to adoption that include the acquisition cost, driving range, recharge time, and battery and electric grid systems.

Due to its greater purpose as a recreational vehicle, consumers are much more sensitive to changes in the price of electric boats. Cars are much more of a necessity to most individuals than boats. Thus, the price elasticity of demand is much higher for boats than for cars. Consumers also value the green technology in electric boats much less than electric cars due to its lower total environmental returns. Thus, price and performance comparability to gas vehicles is more important for electric boats than electric cars. As explained previously, economic constraints are one of the largest barriers to adoption of electric cars. However, economic constraints pose an even greater barrier to widespread adoption of electric boats. As a result, electric boats must be subsidized at a higher rate than electric cars to spur equal growth in proliferation.

Furthermore, electric cars and electric boats face the same major barriers to adoption: acquisition cost, driving range, recharge time, and battery and electric grid systems. Both electric cars and electric boats face technological barriers to adoption due to limitations on driving range and recharge time. Additionally, electric cars and electric boats are priced at a premium over their comparable non-electric counterparts. Lastly, electric cars and electric boats experience a lack of established charging infrastructure. Electric vehicles can easily be charged at home but face difficulties finding publicly available charging stations. This barrier to adoption is even greater for electric boats. Charging station infrastructure is much more inadequate at the shores of most bodies of water than on roads. Charging stations on bodies of water are necessary for all electric boats that are stored on bodies of water. As a result, even greater investment is required for adequate charging infrastructure for electric boats. Nevertheless, some electric boats could be charged at road charging stations. Most initiatives that reduce barriers to adoption for electric cars would also reduce barriers to adoption for electric boats to a similar extent.

Analysis of the electric car industry has revealed that electric cars and electric boats face many of the same barriers to adoption. Yet, barriers to adoption are stronger for electric boats. As explained previously, the main factors affecting the proliferation of electric boats are technology, environmentally friendly sentiments, and financial constraints. Technological advances have proved to be inadequate in reducing financial constraints and public sentiments are difficult and slow to control. Thus, financial constraints are the easiest to directly address to spur electric boat acceptance. As explained by Michalek, Chester, and Samaras (2012), traditional subsidization of electric cars does not maximize its benefits. The authors argue that technology-specific subsidies are generally not the most effective subsidies. Subsidization of the research and development of electric boats may increase the rate of technological innovation but does not translate into decreases in electric boat prices – the most important factor affecting the electric boat purchases. Government policies should instead aim to reduce nontechnical barriers to adoption such as price and battery and electric grid infrastructure. Currently, government subsidies are greater for fully electric vehicles than hybrid electric vehicles. Yet, hybrid electric vehicles are more robust and offer better environmental externalities per dollar spent than fully electric vehicles. Hybrid electric vehicles face less significant barriers to adoption due to their power, range and cost efficiency. With greater marketability and utility, greater subsidization of hybrid electric vehicles would better drive demand in the electric vehicle market. Greater demand would incentivize increased hybrid electric vehicle production and proliferation which would increase learning, innovation, and growth in the full electric vehicle market. This change to subsidization prioritization would be effective for all types of electric vehicles. However, subsidization of all types of hybrid electric vehicles may not be the most efficient use of government funds.

After analyzing the three case studies it became clear that economic constraints prove to be one of the most important factors affecting the rate of adoption of electric vehicles. Thus, widespread adoption of electric vehicles should be driven by subsidization of hybrid electric vehicles over fully electric vehicles due to greater marketability and environmental returns per dollar spent. This subsidization change would drive hybrid electric vehicle demand which would increase technological innovation and learning. These developments would bring improvements and price reductions to fully electric vehicles leading to increased proliferation of electric vehicles. As previously explained, however, economic constraints are much greater for electric boats than electric cars. As a result, greater subsidization of hybrid electric boats would be needed to achieve the same results that would be found with hybrid electric cars. Hybrid electric car subsidization maximizes environmental returns and innovation per dollar spent – directly affecting electric boat innovation. Thus, consumer acceptance of electric boats is actually best driven by subsidization of hybrid electric cars. Figure 5 depicts the pathway from hybrid electric car subsidization to growth in consumer acceptance of electric boats. The government should

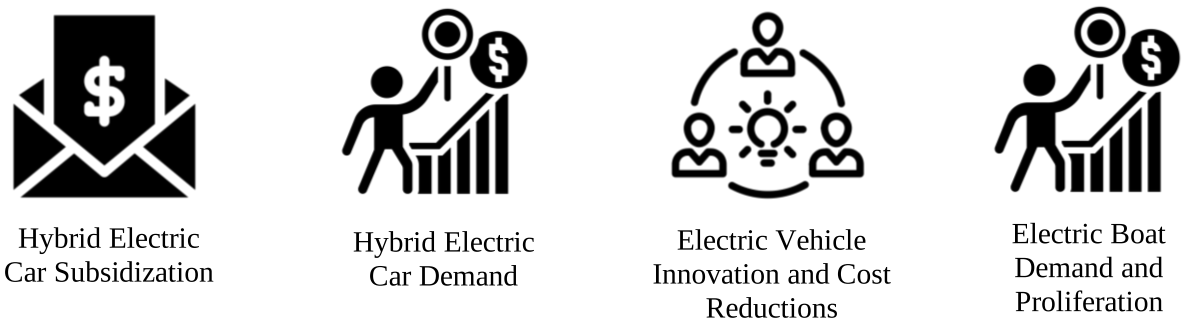

Figure 5: Increased subsidization of hybrid electric cars can ultimately lead to increased electric boat proliferation

also help establish adequate infrastructure on bodies of water and roads to ease the charging of electric boats as a secondary support for electric boat adoption. The analysis above has significant implications for the growth of the electric boat industry. It is clear that government intervention is integral for the growth of the electric car and electric boat industries. However, hybrid electric car subsidization is better able to drive electric boat acceptance than hybrid electric boat subsidization. These conclusions should be investigated and considered further by the government in regards to future electric vehicles subsidization.

Conclusion

In this paper I argued that economic feasibility of electric vehicles is the main factor affecting the widespread adoption of all electric vehicles. I explained that government intervention is best positioned to affect the financial constraints of electric vehicle adoption and has the greatest ability to accelerate the rate of electric boat proliferation. After analyzing the three case studies it became clear that hybrid electric vehicles have greater marketability and environmental returns per dollar spent. As a result, subsidization of electric vehicle should focus on hybrid electric vehicles to best drive electric vehicle demand. Increased electric vehicle demand would lead to increased electric vehicle production that would also increase technological innovation and learning. However, it became clear that economic constraints pose a greater barrier to adoption in the electric boat industry than in the electric car industry. In fact, subsidization of hybrid electric cars is more efficient than subsidization of hybrid electric boats. This realization led to the surprising conclusion that environmental returns and consumer acceptance of electric boats is best driven by hybrid electric car subsidization. This conclusion has significant implications for future government policy changes towards electric vehicles. It is clear that government intervention is integral for the growth of the electric car and electric boat industries. However, the government should focus its subsidization on hybrid electric car to best drive electric boat acceptance and environmental returns. These conclusions should be investigated and considered further by the government in regards to future electric vehicles subsidization.

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