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Power Up: Advancing the Automotive Industry through Energy Storage

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Washington Internship for Students in Engineering, WISE

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EXECUTIVE SUMMARY

This report proposes policy recommendations to promote innovative storage technologies with application to Electric Vehicles (EVs) and Plug-In-Hybrid-Vehicles (PHEVs). Federal, local, and state governments should take the following measures to integrate and normalize the EV/PHEV market:

1. Reform the $7,500 tax incentive in place for current EV/PHEV owners and modify it to a point-of-sale rebate for consumers.
2. Implement a 5-year-federal-tax-free period for startups that are developing the EV battery market to facilitate innovation of inexpensive, long-range batteries.
3. Encourage and protect consumer usage of EVs through raised standards and incentives.

While the renewable energy storage market has grown from $111 million in 2013 to $441 million in 2015, it is expected to exceed $2.9 billion by 2021. This growth in innovation is not proportional to fuel use in the transportation sector. In 2014, fossil fuels made up 92% of the total energy consumed by the U.S. transportation sector, in comparison to 60% of total U.S. energy consumption across all sectors. Thus, these policies will spur growth to achieve EV market integration and surpass President Obama's goal of 1 million EVs on the road by 2015[1].

A point-of-sale rebate of up to $10,000 should replace the $7,500 tax incentive. This incentive was proposed in 2009 as part of the American Recovery and Reinvestment Act during the Great Recession in order to stimulate EV growth. However, the policy is outdated and serves as a tax refund for small batteries (under 20 kWh). This new policy will benefit middle class consumers

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[1] The U.S. reached about 400,000 EVs on the road by the end of 2015.

who do not have the money upfront, as well as encourage manufacturers to drive down EV costs and begin fading out the point-of-sale refund.

A 5-year-tax-break for startups would allow innovation on the university level and bridge the gap between academia and industry. A similar pilot program was launched in New York, *START UP NY*, and it proposed a 10-year-tax-free period for startups working at or near partnering universities. This program costs the state of New York $323 million. Thus, if implemented on a federal level, this could reach $1 billion. Reducing federal oil subsidies, which amounted to $37.5 billion in 2014, can easily offset this cost.

Encouraging and assuring consumers is necessary to make EVs prevalent and competitive with internal combustion vehicles. Regulatory standards, financial incentives, and non-financial incentives governing tail pipe emissions, parking privileges, car pool lane access, and toll reductions are few of many policies that could encourage consumer acceptance. Much of the drawback of integrating EVs to the market is the lack of consumer awareness, and consumer uncertainty about safety, range, and cost. In order to combat such concerns, these policy alternatives could be introduced, in addition to state and local incentives.

The bottom line is that electric vehicles are here to stay. These groundbreaking, clean technologies, along with fuel cells and other zero-emission technologies could potentially be the future of the automotive industry. Policy reform of tax incentives, startup incentives, and consumer protection and encouragement will foster innovation, cost reduction, energy security and independence in the United States, and long-rang targeting that pose a viable alternative to traditional internal combustion engine.

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PREFACE

ABOUT THE PROGRAM

The Washington Internship for Students in Engineering (WISE) was founded in 1980 through the collaborative efforts of several professional engineering societies to encourage and prepare future leaders in the engineering realm to contribute to increasingly important issues at the intersection of science, technology, and public policy.

Each summer, the WISE societies select outstanding engineering students from a nation-wide pool of applicants. The students spend nine (9) weeks living in Washington, D.C. during which they learn how government officials make decisions on complex technological issues, and how engineers can contribute to the legislative process and regulatory public policy decision-making.

ABOUT THE AUTHOR

Mena-George Basaly graduated from the City College of New York in June 2016 with a Bachelor's degree in Chemical Engineering and concentrations in economics and mathematics. At CCNY, he was heavily involved in the AIChE Student Chapter. He has previously held internships at SkyBridge Capital and MBS Value Partners to gain exposure to the world of finance and Wall Street, and then ventured into the tech world to intern at Global Futures Group, a smart cities startup that helped deepen his interest in clean energy. After the WISE Program, he will launch his career at Cognizant Technology Solutions as a Technology Consulting Analyst.

ACKNOWLEDGEMENTS

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LIST OF TABLES AND FIGURES

LIST OF ACRONYMS

AC	Alternating current
APPA	American Public Power Association
BTU	British thermal unit
DC	Direct current
DOE	Department of Energy
EERE	Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EPA	Environmental Protection Agency
EV	Electric vehicle
GHG	Green house gas
IRENA	International Renewable Energy Agency
kWh	Kilowatt-hour
Li-ion	Lithium Ion
Na-S	Sodium Sulfur
Ni-Cd	Nickel Cadmium
PHEV	Plug-in-hybrid-electric-vehicle
PV	Photovoltaic
RPS	Renewable Portfolio Standards
SBIR	Small Business Innovation Research
STTR	Small Business Technology Transfer

INTRODUCTION

The renewable energy storage market has grown from $111 million in 2013 to $441 million in 2015 and is expected to exceed $2.9 billion by 2021 **[1].** Renewable energy storage has propelled incredible advances in battery technology, which has allowed the industry to grow at such a rapid pace. The International Renewable Energy Agency (IRENA) expects the global share of renewables to double by 2030 **[2].** This expansion means a rapid increase in electric vehicles (EVs) and plug-in-hybrid vehicles (PHEVs).

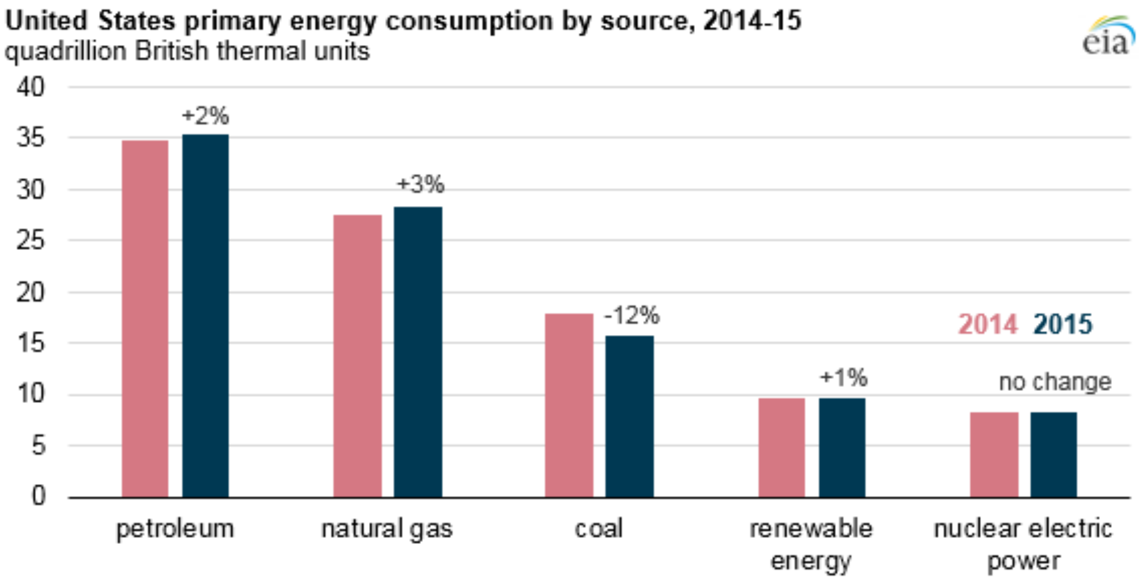

Figure 1: US energy consumption by source from 2014 to 2015

According to the United States Energy Information Administration (EIA), the United States consumes approximately 10 quadrillion British thermal units (BTUs) of renewable energy, which is significantly less than petroleum and natural gas, as portrayed in **Figure 1.** Coal provided 16% of the total energy use in the US, down from 18% in 2014.

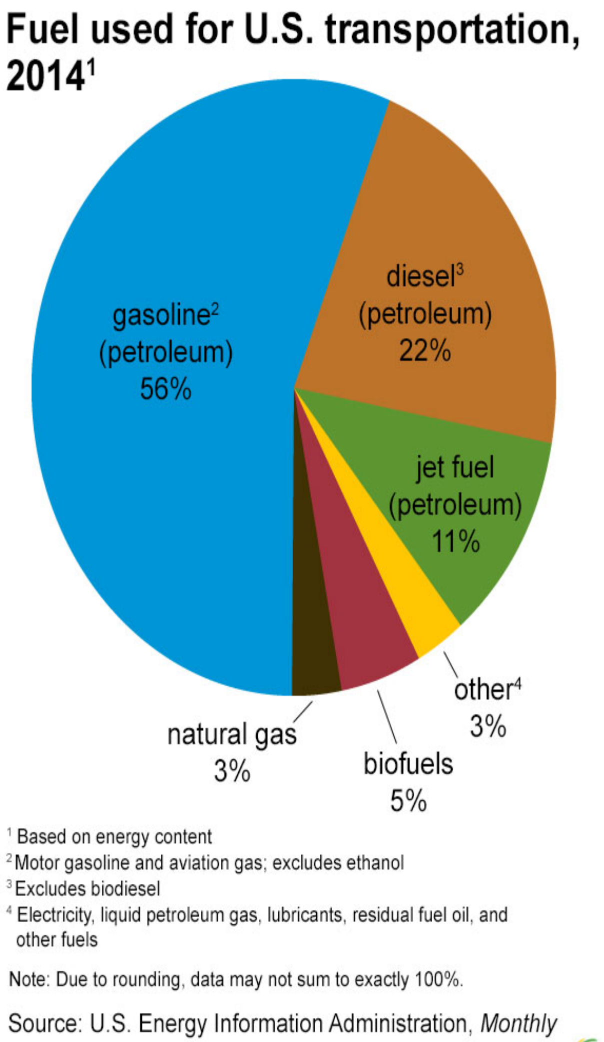

Figure 2: Energy consumption by fuel type in the transportation sector in 2014

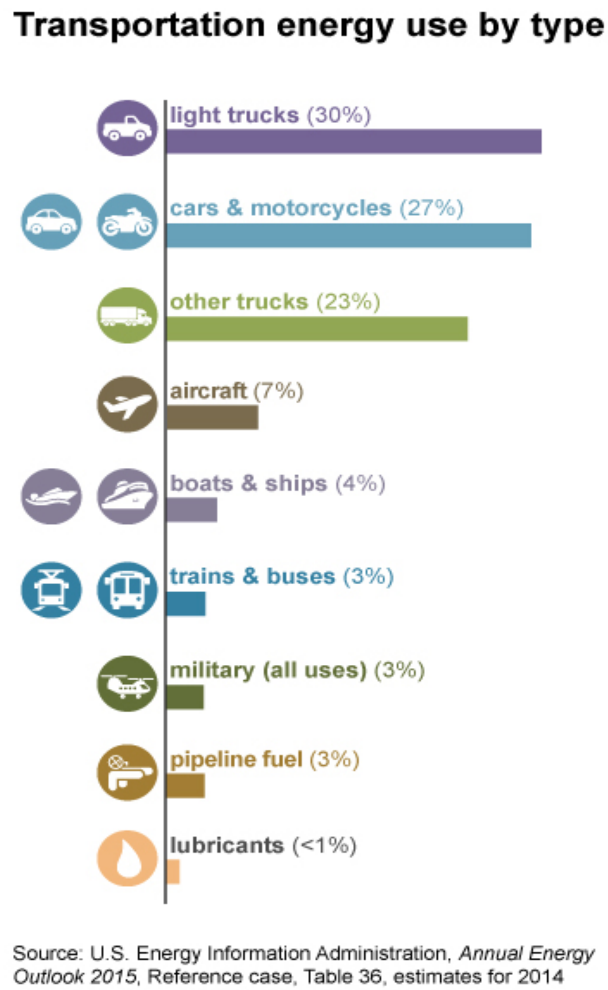

Figure 3: Energy consumption by mode of transportation in 2014

Natural gas increased to 29% in 2015, an increase larger than that for any other fuel. In the transportation sector, electrical batteries are almost miniscule.

Figure 2 indicates that less than 3% of the transportation sector was powered by electrical means, while 56% relied on gasoline in 2014.

Petroleum fuels are made from crude oil and liquids from hydraulic fracturing of natural gases. The petroleum fuels used for transportation include gasoline, diesel fuel, jet fuel, residual fuel oil, and liquid petroleum gases. In 2014, those fuels made up 92% of the total energy consumed by the U.S. transportation sector. Within the transportation sector, Figure 3 breaks down energy consumption by mode of transportation. In 2014, light trucks[2], car, and motorcycles consumed roughly 60% within the transportation sector.

U.S. transportation energy use has increased, despite fuel economy improvements in cars and light trucks. The national average fuel economy for passenger cars and for light trucks has improved over time mainly because of fuel economy standards set by the federal government for those types of vehicles. However, total transportation fuel consumption has generally increased because of an increase in the number of vehicles (especially light pickup trucks, sport utility vehicles, and heavy duty freight trucks). Fuel consumption has generally increased because of the number of miles traveled per vehicle **[2].** Thus, given the increase in fuel consumption, now is the time to shift the market towards EVs and PHEVs.

This report discusses the importance of EVs and PHEVs. In 2008, President Obama set a goal to have one million EVs on the road by 2015. However, given high battery costs required for the necessary electrical energy storage, the market penetration of EVs has been quite low. In fact, by the end of 2015, there were roughly 400,000 EVs on the road, with 25% of them in California alone **[3].**

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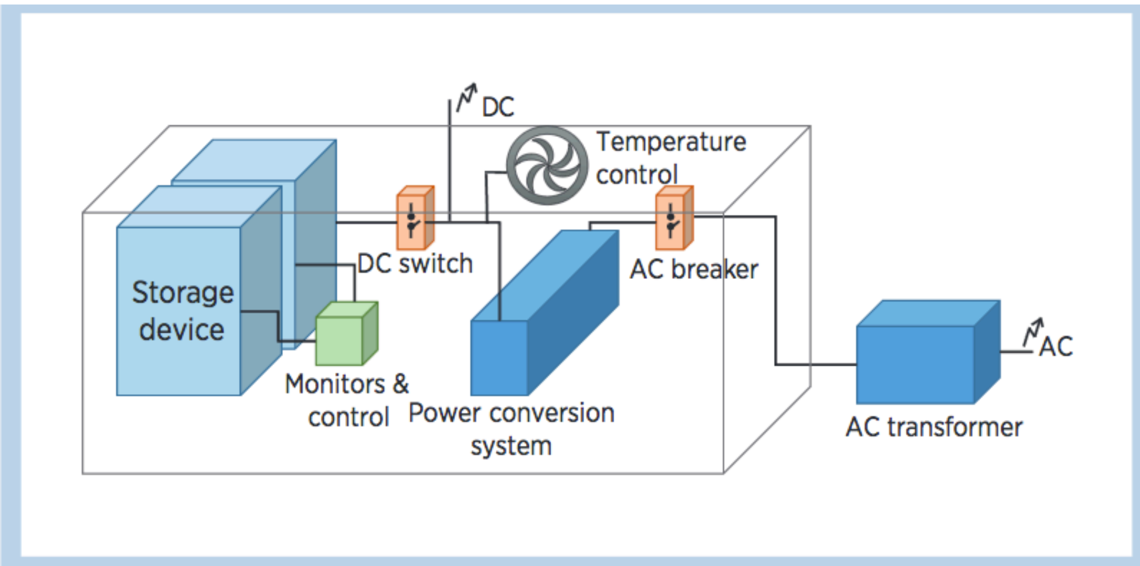
[2] A light truck is defined as a truck with a payload capacity of less than 4000 lbs (according to Title 40 of the Code of Federal Regulations created by the EPA).

To be competitive, policies and incentives must be put in effect for both EVs and PHEVs, particularly to bring down the cost of batteries.

BACKGROUND

Given the current Energy Revolution in North America and the advancement of renewable energy, the array of storage technologies is rapidly growing to accommodate these renewables.



Source: Based on EPRI and DOE, 2013

Figure 4: Battery Storage System with its primary power components

A battery storage system contains several primary components as shown in **Figure 4**, including the battery, monitoring and control systems, and a power conversion system. Cell based batteries consist of individual cells connected into modules and then into packs. Flow batteries consist of external tanks filled with an electrolyte, which flows through a reaction stack. Monitoring and control systems, referred to as the battery management system, ensure safety and maximize performance. The battery management system prevents individual cells from overcharging, and controls charge and discharge of the battery. This is important for safety and performance. Battery cells and component monitoring may vary to some degree, in that different types require emphasis on particular issues. For instance, lithium-ion battery packs must emphasize thermal monitoring and controls, given a tendency to overheat[3].

TYPES OF BATTERIES

A battery, by definition, is a device consisting of one or more electrochemical cells that convert chemical energy into electrical energy. The positive terminal of the cell is the cathode and the negative terminal is the anode. Electrolytes allow ions to move between the terminals, and current then flows through the battery to do work, and provide electrical energy.

Lithium Ion (Li-ion) batteries [10] are very prevalent in today's society. They are used in electric vehicles, cell phones, laptops, photovoltaic (PV) applications, and even megawatt (MW) containerized batteries for grid storage. Li-ion batteries are categorized by the transfer of lithium ions between the electrodes during the charge and discharge reactions. Typically, li-ion batteries have high cell voltages (3.6 V to 3.7 V), which correspond to high energy density.

Lead-acid batteries [11] are high power, inexpensive, safe, and reliable. However, low specific energy, poor cold-temperature performance, and short calendar and cycle life are the main barriers to entry. Advanced high-power lead-acid batteries are being developed, but these batteries are only used in commercially available EVs for ancillary loads.

Nickel Metal Hydride (Ni-MH) batteries [11] offer realistic specific energy and specific power capabilities. Ni-MH batteries have a much longer lifecycle than lead-acid batteries and are safe and cannot be abused, which makes them great for EVs. However, the main challenges with Ni-MH batteries are their high cost, high self-discharge and heat generation at high temperatures, and the need to control hydrogen loss.

[3] Hence the recent backlash with hover boards.

Ultracapacitors [11] are storage devices that store energy in a polarized liquid between an electrode and an electrolyte. To be clear, ultracapacitors are not batteries, but are highly used in the EV/hybrid vehicle industry. They increase storage capacity as the liquid's surface area increases. Ultracapacitors are useful in offering more power to vehicles during acceleration and hill climbing, as well as recycling and recovering braking energy. They may also be useful as secondary energy-storage devices in electric drive vehicles because they help electrochemical batteries level load power.

TYPES OF ENGINES

INTERNAL COMBUSTION ENGINE (ICE)

Combustion is a basic chemical process that releases energy by essentially burning fuel. The ignition and combustion of the fuel occurs inside the ICE, which then converts energy to work to power the engine. An ICE is a piston/cylinder, which is simply a reciprocating engine. The burned fuel creates gases that push the piston to rotate the crankshaft. The crankshaft then powers a series of gears to then drive and power the vehicle **[16]**.

The two prevalent kinds of ICEs are spark ignition gasoline engines and compression ignition diesel engines (simply gasoline vs. diesel vehicles). Most of these are four-stroke cycle engines, meaning four piston strokes are needed to complete a cycle **[16]**. The four components of the engine process include intake, compression, combustion and power stroke, and exhaust.

Gasoline and Diesel engines differ in how they handle fuel. In a gasoline engine, fuel and air are mixed and inducted into the cylinder during the intake process. After the piston compresses the mixture, the spark combusts the mixture of gases. The expansion of the combusted gases powers the cylinder during the power stroke phase. In a diesel engine, only air is inducted into the engine and then compressed. Diesel engines spray hot compressed airs with the fuel to ignite and combust it **[16]**.

ELECTRIC MOTOR

EVs use electricity stored in a battery pack to power an electric motor and turn the wheels. When depleted, the batteries are recharged using grid electricity, either from a wall socket or a dedicated charging unit. Since they don't run on gasoline or diesel and are powered entirely by electricity, EVs do not have any tailpipe emissions **[19]**.

The battery is the main component of an electric vehicle. The controller is the connecting factor between battery and the motor, monitoring how much energy is transmitted. When the driver presses down on the gas pedal, the controller sends the power to the engine to accelerate. The controller in EVs is either operating on alternating current (AC) or direct current (DC) **[20]**.

With an AC controller, the DC voltage from the battery is pulsed through the system. A typical AC controlled vehicle motor operates on 240 volts. A DC controlled vehicle operates from 96-192 volts **[20]**.

CURRENT LEGISLATION

CLEAN ENERGY INVESTMENT INITIATIVE

The White House passed a Clean Energy Investment Initiative **[3]** to reduce carbon emissions. President Obama announced a $4 billion goal to catalyze private sector investment in solutions to climate change, including innovative technologies with breakthrough potential to reduce carbon pollution. These technologies include solar voltaics, advanced batteries, lighting, and fuel cells.

EXECUTIVE ACTIONS TO INCREASE CHARGING INFRASTRUCTURE

In July 2016, the Obama Administration announced an unprecedented coalition to add and deploy more EV charging infrastructure, which will add more EVs on the road. This coalition includes the Federal government, private sector, and states, as well as a new framework for collaboration for vehicle manufacturers, electric utilities, electric vehicle charging companies, and states. President Obama's plan highlights a $4.5 billion loan guarantee from the DOE in order to invest in charging station infrastructure. The FAST Act is also part of the plan, which will identify zero emission opportunities for electric vehicle charging across the country. The Administration has an ambitious, yet accessible, goal to develop a national network of EV infrastructure by 2020.

Additionally, the Office of Energy Efficiency and Renewable Energy (EERE), a subset of the DOE, will bring forth a Memorandum of Understanding (MOU) with the American Public Power Association (APPA) to collaborate on EV infrastructure and access in municipalities across the United States. EERE and APPA will provide information to increase education and awareness of the benefit of EVs to public power utilities and local officials, and develop a community action plan focused on smaller communities with fewer than 200,000 electric customers. The partnership will also work to enhance workplace charging efforts at public power utilities, study the impacts of EVs in public power communities, and share insights regarding infrastructure installation and EV interaction with the modern grid.

CLEAN ENERGY INVESTMENT CENTER

The Department of Energy (DOE) launched a Clean Energy Investment Center to focus on four goals:

1. **Single Point of Access for Information** to allow investors to access clean energy reports and companies funded by the DOE.

2. **Technical Assistance for National Laboratories** to share research and analysis produced by DOE and its 17 national laboratories on relevant developments in clean energy technology.
3. **Information on Early-Stage Projects and Companies** including the Advanced Research Projects Agency-Energy (ARPA-E), Small Business Innovation Research (SBIR), Small Business Technology Transfer (STTR), and others that help fund and accelerate emerging early-stage technology projects and companies. The center will aggregate and make available public information on entities currently engaged in partnerships with DOE.
4. **Connections to Additional U.S. Federal Government Programs** that include information about energy and climate programs at other government agencies including the U.S. Department of Agriculture, U.S. Department of Housing and Urban Development, U.S. Department of Transportation, U.S. Department of Treasury, U.S. Environmental Protection Agency, U.S. Small Business Administration and the National Science Foundation.

CLEAN ENERGY TAX INCENTIVE

Additionally, Senator Martin Heinrich (D-NM) **[4]** will introduce a bill that provides a clean energy tax incentive. The legislation would give businesses and homes a 30% credit, but the credit would taper off starting in 2020. The bill would create incentives for both business and residential deployments. The business incentive applies to systems of at least 5 kilowatt-hours from any of the available technologies, including batteries, flywheels, pumped hydro, thermal energy and compressed air. The credit only applies to battery storage for residential applications, and the systems must have at least 3 kilowatt-hours of capacity. For comparison, the Tesla Powerwall has 6.4 kilowatt-hours of capacity.

H.R. 8 NORTH AMERICAN ENERGY SECURITY ACT AND INFRASTRUCTURE ACT OF 2015

A section of H.R.8 aims to amend the Energy Policy Act of 2005 to require electric utilities to make an interconnectivity service and net metering available to an electricity consumer for community solar facilities, consisting of a solar PV system. These facilities have a panel rating of 2 megawatts or less and allocate electricity to multiple consumers as well as meeting other standards. H.R.8. also states that each state regulatory commission is allowed to set rate making standards for non-regulated utilities.

S.2012 NORTH AMERICAN ENERGY SECURITY AND INFRASTRUCTURE ACT OF 2016

Section 3114 of S.2012 is a battery storage report that poses the following questions regarding the outlook for the storage industry:

1) How do existing Federal standards impact the development and deployment of battery storage systems?
2) What are the benefits of using existing battery storage technology, and what challenges exist to their widespread use? What are some examples of existing battery storage projects providing these benefits?
3) What potential impact could large-scale battery storage and behind-the-meter battery storage have on renewable energy utilization?
4) What is the potential of battery technology for grid-scale use nationwide?
5) What is the potential impact of battery technology on the national grid capabilities?
6) How much economic activity associated with large-scale and behind-the-meter battery storage technology is located in the United States? How many jobs do these industries account for?

7) What policies other than the Renewable Energy Investment Tax Credit have research and available data shown to promote renewable energy use and storage technology deployment by State and local governments or private end-users?

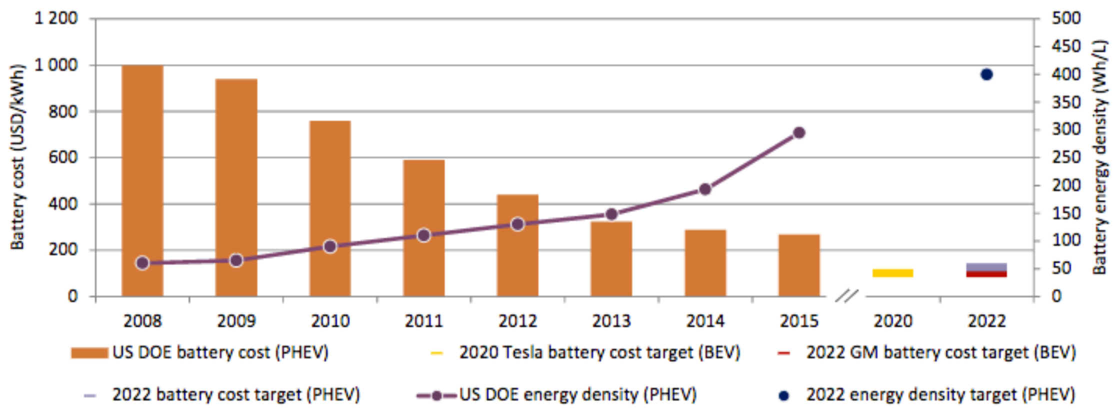
These questions serve as a backbone to what's left to address in the storage industry.

H.R.4584 ELECTRIC CARS ACT

Electric Credit Access Ready at Sale Act of 2014 **[8]**, or the Electric CARS Act, amends the Internal Revenue Code to increase the maximum amount of the tax credit for new qualified PHEVs to $7,500 and to extend the termination date of such credit to December 31, 2020. It permits the assignment of the credit to the sellers of such vehicles. However, this bill has only been introduced, and has not seen any activity since its introduction in May 2014.

DISADVANTAGES

Many of the hurdles to common usage of EVs/PHEVs over the past years include range on a full charge and car costs, both of which are likened to the high cost of advanced battery technologies. However, **Figure 5** illustrates the associated projected and current costs and energy densities of EV batteries. Costs have consistently gone down year-to-year, while energy densities have gone up year-to-year. While costs are still high, with the right policies, these costs can significantly decrease further. Additional barriers relate to the need to access recharging facilities, costs and other challenges associated with their installation, as well as the lack of awareness or confidence in the technology **[9]**. However, the Obama administration recently allocated over $4 billion to the DOE in order to invest in infrastructure for charging stations.



Notes: USD/kWh = United States dollars per kilowatt-hour; Wh/L = watt-hours per litre. PHEV battery cost and energy density data shown here are based on an observed industry-wide trend, include useful energy only, refer to battery packs and suppose an annual battery production of 100 000 units for each manufacturer.

Sources: US DOE (2015 and 2016) for PHEV battery cost and energy density estimates; EV Obsession (2015); and HybridCARS (2015).

Figure 5: Target and actual costs and energy densities of EV/PHEV batteries.

POLICY RECOMMENDATIONS

1. **Reform the $7,500 tax incentive for EVs/PHEVs to accommodate the middle class [6].**
   This report proposes a reform of the tax incentive laid out in the Internal Revenue Code (IRC) 30D. Instead of consumers waiting a year (or more) to receive the rebate and pay money up front, it is imperative that this incentive is actually a point-of-sale refund for consumers up to $10,000.

   The current policy in place for EVs and PHEVs is a tax rebate ranging from $2,500 to $7,500 **[5]**. According to the American Recovery and Reinvestment Act, "the base tax credit is $2,500 and above 5 kilowatt-hours taxpayers may claim on their IRS return $417 per kilowatt-hour not to exceed $5,000." This is where the "$7,500" tax credit comes from. However, cars with bigger batteries like the 24-kwh Nissan Leaf or 60-85-kwh Tesla Model S still are only eligible for the $7,500 tax credit, which isn't attractive to consumers **[12]**. Further, each manufacturer is capped at a selling limit of 200,000 PHEVs it could sell in the U.S., and this tax credit applies only to leases.

In order to implement this policy, the following measures must be addressed:

- Raising the federal fuel excise tax to offset the cost of the newly implemented point-of-sale refund.
- Manufacturers would administer the refund, and then apply for reimbursement from the federal government. This will, in the long run, drive down the upfront cost of the EVs and PHEVs.

2. **R&D Tax incentive for early stage energy storage developers**

This report proposes piloting a tax-free operation for battery startups that focus on EV/PHEV battery applications. This program would be a five-year federal tax break for startup battery developers and researchers in order to stimulate less expensive, long-range batteries that can power EVs and PHEVs. Moreover, the five-year-tax-break can be linked to a mandatory kWh goal, set by the EPA or DOE, that these startups have to meet.

This incentive is modeled after Start Up NY, which states: "*START-UP NY offers new and expanding businesses the opportunity to operate tax-free for 10 years on or near eligible university or college campuses in New York State.*" **[7]**

While START-UP NY costs New York State $323 million **[15]**, this federal incentive would reach the billions. Thus, while this sounds like an expensive policy, this report proposes an off-setting decrease in oil subsidies. According to *Oil Change International*, as of July 2014, U.S. fossil fuel subsidies reached $37.5 billion annually, including $21 billion in production and exploration subsidies **[14]**. While these subsidies are justified by increasing energy security in the United States, the oil industry is mature and has made significant advances in exploration, particularly in hydraulic fracturing.

The benefits of implementing a five-year-tax-free plan would include the following:

- Increased United States Energy Security by diversifying energy storage, given the volatile nature of oil and gas markets and global political instability
- Spurring innovation at the university level and bridging the gap between industry and academia. This will give researchers (at Stanford's Energy Labs, City University of New York's Energy Insistute, MIT's start-up hub, etc.) the opportunity to apply their research to industry and accelerate innovation in battery storage to drive down costs and increase ranges to be comparable to internal combustion engines.

3. **Raise standards to protect and encourage consumer usage of EVs/PHEVs**

Much of drawback of integrating EVs into the market is the lack of consumer awareness, and consumer uncertainty about safety, range, and cost. According to report published by Accenture **[21]**, vehicle range control, and charging infrastructure are main consumer concerns. In order to combat this, a policy alternative could be to introduce climate-friendly standards, in addition to state and local incentives to promote consumer purchase and usage of EVs/PHEVs.

For example, the Netherlands allows road tax exemption for zero-emission cars. In 2015, this also applied to PHEVs emitting less than 50 g CO_2/km. In 2016, they are subject to charges that are only 50% of the road tax for an internal combustion engine car **[13]**. Other countries in

Europe have proposed similar incentives for consumers. This report suggests the following policy alternatives with these benefits:

- Regulatory standards that regulate tailpipe emissions and fuel economy standards
- Financial incentives that include the following[4]:
    - Consumer access to restricted lanes (traditionally carpool lanes)
    - Parking preferences in municipal lots, garages, and meter-free parking in metered lots
    - Toll reductions: the best way to introduce this is a system like the Netherlands. Highway officials can offer up to 75% discounts on tolls for EVs/PHEVs, which will reduce emissions in congested areas with expensive tolls (i.e. Tri-State area)

CONCLUSION

Given the current state and legislation of battery technology and EVs, electric vehicles can potentially be commonplace in the global automotive market. Whether or not they do lead the auto industry depends on the future of policy surrounding EVs and battery technology—particularly government subsidies and incentives.

Policy reform of tax incentives, combined with policy proposals for startup incentives, and consumer protection and encouragement will foster innovation cost reduction, energy security and independence in the United States, and long-range targeting that will pose a viable threat to the traditional internal combustion engine.

[4] These financial incentives are on the State and Local levels, in collaboration with the Department of Transportation.

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[3] (Shepardson, 2016)

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[10] H.R.4584

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