State of New Mexico Fleet Electrification: Team Lightning

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EMS 593 – Applied Project

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July 7, 2021

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Introduction

The New Mexico Department of Transportation and General Services Department has embraced the initiatives outlined in Executive Order 2019-003 toward "statewide reduction in greenhouse gas emission of at least 45% by 2030 as compared to 2005 levels" (Lujan Grisham, M., 2019). The NM Climate Change Task Force evaluated policies and regulatory strategies to achieve reductions in greenhouse gas pollution and identified that the transportation sector was the second leading cause of greenhouse gas emissions in the state. They developed an initial Fleet Electrification Action Plan and are now in the process of electrifying their fleets with the goal of electrifying at least 70% of their vehicles by 2030 to address GHG emissions in the transportation sector (Cotton & Kamper 2021).

New Mexico has 35 AEVs and 32 charging stations installed in only Santa Fe. As electric vehicles gain traction with the automobile purchasing consumer focused on reducing their energy utilization and emissions footprint, manufacturers have taken notice. The value proposition of electric transportation is both economical and environmental. Reducing costs related to fuel can be had in both Hybrid electric vehicles (HEV) and Battery electric vehicles (BEV), which are often also referred to as all-electric vehicles (AEV). BEVs and HEVs can run solely on electricity, but HEVs can also switch to their second powertrain, an internal combustion engine. Innovations in lithium-ion battery knowledge and technologies are essential to the expanding adoption of electric vehicles.

The rise of the electric vehicle is pivoting from its nascent phase to widespread adoption. Most of the world's car manufacturers have seemingly announced pledges to commit to being either fully net-zero or electric. While the industry has been slow to cement its future in electrification, a new phase has come upon us. With this being said, electric vehicle adoption and transformation will come with significant hurdles and barriers.

Goals

This report addresses four of the next steps identified in the State of New Mexico Fleet Electrification Report prepared by Arizona State University students Sibley Cotton and Meghan Kamper (Cotton & Kamper, 2021).

- Cost comparison of what New Mexico is paying for gas and what emissions are versus what it would be for electric
- Electrification success stories and review of federal programs for potential sources of funding
- Comparative analysis: Investigate the differences between life cycle emission levels for HEVs and AEVs to determine the best models for the state
- Barriers to electric vehicle adoption

Cost Comparison of Gas vs. Electric

Existing Fleet

New Mexico currently has 30 HEVs and 35 EVs in the fleet. The fleet of over 2,000 vehicles ranges from the model years 1998 through 2000. (Cotton & Kemper, 2021). About 30% of the current NM fleet is older than ten years. The GSD is challenged with transitioning this aging fleet to EVs and securing the funding to do so.

Fleet Year Demographics	
Model Year	**HEV and EV Replacements**
1998 - 2006 All Gas-Powered Vehicles	
2007	Honda Accord HEVs Honda Civic HEVs
2008	Ford Escape HEV Honda Civic HEVs
2009	Honda Civic HEV Ford Escape HEV Chevy Tahoe HEV
2010	Ford Escape HEVs
2011	Ford Fusion HEVs
2014	
2015	Ford Fusion HEV
2016	Ford Fusion HEV
2017	
2018	
2019	Nissan Leaf EV
2020	Nissan Leaf EVs Chevy Bolt EVs

Demographics of NM Fleet

GSD Price Agreements

In 2020, the New Mexico General Services Department purchasing division awarded their first price agreements to vendors to purchase All-Electric Vehicles (AEVs) and Hybrid Electric Vehicles (HEVs). The vehicles approved for purchase within this price agreement included the Nissan Leaf and Chevy Bolt AEV sedans and HEVs, including the Ford Fusion, Honda Accord, and Ford Explorer. The price agreement allotted a budget of $1 million to update the fleet (New Mexico General Services Department, 2021). The current GSD Statewide Price Agreements for the fiscal year beginning July 1, 2021, allocate $750,000 to purchase all-electric, plugin hybrid, traditional hybrid, and gas-powered vehicles (New Mexico General Services Department, 2021).

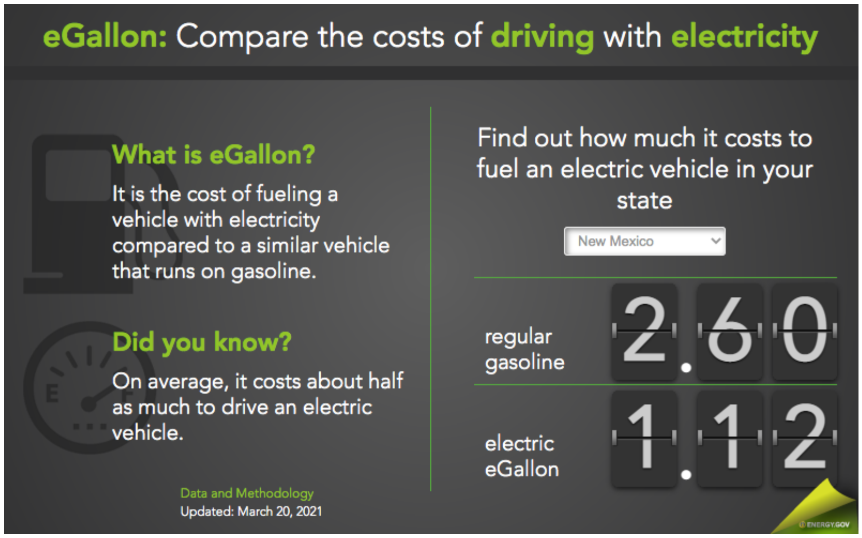
Emissions Commitment

New Mexico Laws and Regulations have been established for Alternative Fuel Vehicle (AFV) and Hybrid Electric Vehicle (HEV) Acquisitions. The requirements state that "a minimum of 75% of state government and educational institution fleet light-duty vehicles purchased must be HEVs or bi-fuel or dedicated AFVs. Vehicles must meet or exceed the federal corporate average fuel economy standards. The New Mexico Energy, Minerals and Natural Resources Department may grant additional exemptions based on the availability and suitability of vehicles, as well as fuel availability and cost" (US DOE, Alternative Fuels Data Center, n.d.). The current cost for most EVs is about $19,000 higher than gas-powered vehicles (Palmer, 2020). Nearly half of the cost of today's EVs are the batteries. Bloomberg New Energy Finance Research suggests that battery prices will drop by 77% by 2030 (Bloomberg, 2017). As the EV technology and market continue to evolve, New Mexico is tasked with replacing the aging gas-powered fleet with price-conscious HEVs and EVs.

Cost Comparison

The current GSD price agreement approved the acquisition of about 200 1/2-ton 4X4s (aka light-duty pickups. The two approved vehicle models include the Dodge Ram 1500 4x4 1/2 ton, HEV, 4-door, Rear Wheel Drive at the cost of $27,483 each and the Dodge Ram 1500 4x4 1/2 ton, HEV, 4-door, All Wheel Drive at the expense of $30,551 each (New Mexican General Services Department, 2021.) The budget needed to fulfill the acquisition of 200 vehicles, 100 of each model, would be $5.8 million. The combined overall average MPG for these pickups is 22 MPG. The anticipated lifespan of an EV is 15 years, with the actual battery forecasted to outlive the electric vehicle life. (Palmer, 2020).

For comparison purposes, a fifteen-year lifespan is used to analyze what the GSD is paying for gasoline versus electricity with the current light-duty fleet. The U.S. Department of Energy created an online tool capable of analyzing the cost of driving using gasoline versus driving with electricity. This tool enables the user to obtain a recent cost of gasoline by state. As of March 2021, the cost of gasoline in New Mexico was $2.60 per gallon. The electric vehicle comparison point is the eGallon. The eGallon "represents the cost of fueling a vehicle with electricity compared to a similar vehicle that runs on gasoline (eGallon, 2021). The eGallon tool (Figure 2) demonstrates that for $1.12 of electricity, a comparable vehicle can drive the same distance as using $2.60 in gasoline (eGallon, 2021).



Cost of gas per gallon versus eGallon in NM https://www.energy.gov/maps/egallon

The New Mexico fleet has over 250 light-duty pickup trucks ranging from model years 2000 through 2020. Of that total, about 150 of the light-duty pickup trucks are model years 2000 through 2015 (General Services Department, 2021). The following analysis considers 120 light-duty fleet trucks with model years 2000 through 2005. The fleets' light-duty pickups create about 8,887 grams per gallon of CO2 emissions based on the average annual CO2 emissions for a vehicle achieving 22MPG (US EPA, 2018). By replacing older light-duty trucks with HEV or EVs, NM could save over $126,000 in fuel per year. The environmental benefit of these 120 light-duty trucks would result in negating 758 metric tons of C02 annually.

Model Year Range	# Light-Duty Fleet	Total Annual Mileage	Avg MPG	Total Gallons of Gas	NM Gas $2.60	Electric $1.12
2000 – 2015	150	1,875,957	22	85,270	$221,704	$95,502

Emissions per Gallon of Gas	Total Emissions Annually
8,887 grams of CO2	758 metric tons of CO2

Analysis of cost of gas vs. electricity for 120 light-duty pickups

Maintenance

In addition to the savings between electricity and gas, there are cost savings to be realized to maintain EVs. New York City has reported spending between $204 and $386 in 2019 to maintain electric cars in their fleet. In comparison, New York City spent at least $1,600 in maintenance for the average gas-powered vehicle (Palmer, 20200. One study looked at projections with increased electricity and gas costs. While electricity and gas may increase, wind and solar power are projected to decrease (Werber et al., 2009). This shift of the expenses for renewable energy will benefit EV usage both by using renewable resources for electricity and reduced emissions. There have been concerns raised about emissions generated during the EV battery manufacturing process. Dr. Jessika Tranick, professor of energy studies at M.I.T., conducted research identifying that emissions generated during production would be offset within 6-18 months of EV usage (Penney, 2021).

Future Vehicles

The planning and production of new EVs will continue to evolve. The research and development departments for automobile manufacturers are working toward designing vehicles to reach the U.S. established standard for automobiles to have an average of 54.6 MPG by 2025 (Huo, et al., 1994). Today, it is not viable to replace the light-duty pickup trucks in the fleet with EVs. A challenge facing truck manufacturers is to produce lighter-weight vehicles to accommodate the weight of the battery. One study of light-duty trucks indicated that heavier EVs could produce the same GHG emissions as their gas-powered equivalents (Timmers, et al., 1994). About 13% of the NM fleet are light-duty pickup trucks. Two comparative models that could be contenders for fleet replacement are the Ford F-150 and Chevy Silverado. The all-electric Ford F-150 is expected to start production in mid-2020, while the Chevy Silverado is not expected in the market until 2025 (Car and Driver, 2021).

Data Evaluation and Analysis

The GPS tracking implemented in the NM fleet cars in January 2020 can provide beneficial data for evaluating and analyzing the transitioned fleet. Part of the GPS tracking includes the ability "to run reports on miles driven, time spent idling, greenhouse gas emissions, and fuel economy (New Mexico General Service Department, 2020). The GPS data, along with resources from the U.S. Department of Energy and the U.S. Environmental Protection Agency, can be used to review EV performance and evaluate options for future fleet transition.

Comparison of Gas vs. Electric: Next Steps

- Research new EV models in development with associated in-market timelines
  -Car and Driver.com is a good resource for identifying models, range, efficiency, and price (Oldham & Irwin, 2021)
- Develop a strategy for integration of new electric vehicles to coincide with the oldest models with the least efficient gas mileage within the period of each General Service Agreement
  -Department of Transportation Fleet Data (General Services Department, 2021).
- Utilize GPS tracking data to evaluate and validate miles per gallon for eGallon expectations, greenhouse gas emissions, fuel, and electricity economy
  -Add GPS data to the Department of Transportation Fleet Data (General Services Department, 2021).

Success Stories

Electrification Success Stories

The State of New Mexico can benefit from the following examples of the experiences and successes with electrification initiatives from other states and countries.

Columbus, Ohio

In 2016, the City of Columbus, Ohio, home to American Electric Power (AEP) 's corporate headquarters, won the U.S. Department of Transportation's (DOT) Smart City Challenge. Smart Columbus has a vision that starts with the reinvention of mobility, positioning central Ohio for a future beyond what anyone has yet imagined. The goals include improving people's quality of life, driving growth in the economy, providing better access to jobs and job opportunities, becoming a world-class logistics center, and fostering sustainability ("Columbus, Ohio, Provides a Replicable Model for Smart Electrification for Social Good - GSEP," 2021). AEP was one of several partners to sign on to the challenge with the City of Columbus. AEP Ohio has invested approximately $1.5 million in fleet electrification since 2016 and installed nearly 60 EV charging stations. In 2017, AEP also pursued a plan to invest approximately $175 million. In April 2018, the Public Utilities Commission of Ohio (PUCO) approved AEP Ohio's Electric Security Plan (ESP). Under the ESP, a program was created to expand EV charging station availability with up to 300 level 2 charging stations and 75 DC Fast charging stations. The $10 million program offers rebates for site owners to install charging stations, with 10 percent of the stations to be located in low-income areas ("Columbus, Ohio, Provides a Replicable Model for Smart Electrification for Social Good - GSEP," 2021).

Western Reserve Transit Authority

In Ohio, the Western Reserve Transit Authority was among the projects selected to receive funding from the Accelerating Innovative Mobility Grants announced by the Federal Transit Administration. In the fiscal year 2019, funds of $2.3 million were awarded to partner with the Santa Clara Valley Transportation Authority to deploy automated electric vehicles designed for accessibility in Mahoning Valley, Ohio, and Santa Clara Valley, California, to augment fixed route bus and paratransit services. The two locations will test the ability of the AVs to provide more efficient and cost-effective service under different climates and operating conditions. The Accelerating Innovative Mobility Initiative supported projects leading to the development and testing of innovative mobility, such as planning and developing business models, obtaining equipment and service, acquiring or developing software and hardware interfaces to implement the project, operating or implementing the new service model, and evaluating project results ("Accelerating Innovative Mobility | FTA," 2021).

Québec, Canada

The province of Québec, Canada, has about 5 million cars for 8 million consumers. The government had an ambitious Action Plan, which targeted having 100,000 plugin hybrid and electric vehicles by the end of 2020, resulting in a reduction of 150,000 tons in greenhouse gas emissions. The province provides subsidies to citizens for purchasing a new vehicle and installing a charging station at home. Some of these investments are based on partial funding by the federal government under Phase II of the Public Transit Infrastructure Fund (PTIF II) ("Transporting Québec towards modernity, Action Plan 2018-2023", 2021).

Australia

The Origin Energy Electric Vehicles Smart Charging Trial project in Australia started in July 2020, funded by the Australian Renewable Energy Agency (AREA) and the lead organization Origin Energy Ltd including partnerships with United Energy Distribution Pty Limited, Ausgrid Operator Partnership, Nissan Motor Co. (Australia) Pty. Ltd, Hyundai Motor Company Australia Pty Limited, Custom Service Leasing Pty Ltd, Schneider Electric (Australia) Pty Limited, and GreenFlux Assets B.V. Origin Energy commenced the trial in August 2020 and has so far engaged with both residential and business participants. The project aims to gain insight into EV charging patterns and behaviors of residential and business customers and demonstrate the value created in managing EV charging to respond to signals from the energy markets. A total of 103 (70 residential and 33 business) smart chargers have been installed, providing meaningful baseline charging data. EV smart charging can not only aid in managing grid load but can also enable customers to optimize charging based on the lowest cost ("Origin Energy Electric Vehicles Smart Charging Trial Project," 2021a; "Origin Energy Electric Vehicles Smart Charging Trial Project," 2021b).

The Energy Freedom Solar Electric Vehicle Pilot project is funded by the Australian Renewable Energy Agency (AREA) and Applied Electric Vehicles (AEV) organization in Australia. The project represents a sustainable EV solution where AEV produced lightweight, energy-efficient, autonomous electric vehicles that incorporate solar photovoltaic (PV) roofs and lithium-ion battery systems ("Energy Freedom Solar Electric Vehicle Pilot," 2021).

Funding Opportunities

Federal Funding Programs

One of the biggest problems facing the State of New Mexico is finding suitable grants, especially federal funding opportunities. Listed below are the grants, incentives, and other funding sources through federal programs:

CLEAN Future Act

The CLEAN Future Act introduced in March 2021 aims to help states, cities, communities, and companies transition to a clean economy by authorizing $565 billion over ten years to meet those targets. For the transportation sector, the act presented solutions that include authorizing $500 million to deploy electric vehicle supply equipment, building the infrastructure needed for a clean transportation system, deploying electric vehicles and charging stations by authorizing funding for State Energy Transportation Plans, and formally authorizing a Clean Cities Coalition Program (*The CLEAN Future Act*, 2021). Each state must submit a climate plan to EPA for its review and approval. To ensure that states have ample guidance and expertise at their disposal, the bill directs the EPA to develop a set of model greenhouse gas control strategies that states can incorporate into their plans. The bill authorizes $200 million to help states prepare their plans (*The CLEAN Future Act*, 2021).

Department of Transportation FY 2022 Budget

The RAISE (Rebuilding American Infrastructure) Grant for $88 billion: includes $1 billion for the Rebuilding American Infrastructure with Sustainability and Equity (RAISE) grants – formerly known as TIGER/BUILD Grants – to assist localities that are undertaking innovative infrastructure projects ("U.S. DOT 2022 Budget Highlights", 2021).

The maximum grant award is $25 million for the current RAISE grants, and no more than $100 million can be awarded to a single State. Up to $30 million will be awarded to planning grants, including at least $10 million to Areas of Persistent Poverty. Projects for RAISE will be evaluated based on criteria that include safety, environmental sustainability, quality of life, economic competitiveness, state of good repair, innovation, and partnership. The DOT is hosting a series of webinars during the FY 2021 RAISE grant application process. The deadline to submit an application is July 12, 2021, at 5 pm Eastern. To register for the webinars, visit http://www.transportation.gov/RAISEgrants/outreach.

American Jobs Plan

In addition to the base amounts included in the FY 2022 President's Budget request, the President's proposed plan invests an additional $621 billion in transportation infrastructure and resilience to include:

- $10 billion for the Carbon Reduction Bonus Program: this program would direct funds to help States reduce greenhouse gas emissions. States that achieve significant reductions in carbon dioxide emissions would receive additional flexibility in project Federal share and program transferability, while States making the least progress in emissions reduction would be required to dedicate additional Federal funds to projects that will reduce emission ("U.S. DOT 2022 Budget Highlights", 2021).

- $5 billion for the Congestion Mitigation Air Quality Improvement Program: this proposal would add funding to the existing Congestion Mitigation Air Quality Improvement (CMAQ) program to specifically pay for projects that reduced greenhouse gas emissions. This funding will be separate from and in addition to funding authorized for projects that reduce criteria pollutants under the existing CMAQ program ("U.S. DOT 2022 Budget Highlights", 2021).

- Create Good Jobs Building Electric Vehicles: President Biden is proposing a $174 billion investment to win the EV market, of which $140 billion will be at the Department of Transportation. His plan will enable automakers to spur domestic supply chains and support American workers to make batteries and EVs. It will give consumers point-of-sale rebates and tax incentives to buy American-made EVs ($100 billion) while ensuring that these vehicles are affordable for all families and manufactured by workers with good jobs. It also establishes grant and incentive programs to rapidly build a national network of 500,000 EV chargers ($15 billion) by 2030, including a comprehensive corridor charging network along the national highway system to support longer trips and community-based deployment of chargers where people live, work, and shop, to support drivers without access to charging at home and provide a general safety net for the general public ("U.S. DOT 2022 Budget Highlights", 2021).

- Transformational Projects Fund: Accelerate Transformational Infrastructure Projects $25 billion: This proposal would issue competitive grants for projects that are too complex, large, or innovative to achieve with existing programs such as RAISE (formerly BUILD) or INFRA. There would be broad eligibility across modes and project types – including greenfield and brownfield projects. Funding could be used for planning, design, construction, and implementation ("U.S. DOT 2022 Budget Highlights", 2021).

- Predevelopment and Planning Program: $2 billion (Accelerate Transformational Projects). Under current programs, there are limited Federal funds available for early-stage development and planning for potential projects; providing the opportunity to develop longer-term, more innovative, and more complex infrastructure projects that will help State, local, and Tribal governments incorporate emerging technologies and other innovations, and ensure equity, sustainability, and resiliency are built in from the start ("U.S. DOT 2022 Budget Highlights", 2021).

- Infrastructure Grand Challenge: $5 billion (Accelerate Transformational Projects). The plan would launch a new infrastructure grand challenge to plan, procure, and develop exciting projects, with innovations, financing, and organizational structures to transform how infrastructure is built fundamentally. The grand challenge would provide resources and technical assistance to offer capabilities to governors, mayors, and local transportation, and other infrastructure leaders to propose advanced projects and overcome barriers created by traditional infrastructure development ("U.S. DOT 2022 Budget Highlights", 2021).

- RAISE and INFRA Grants $8 billion (Accelerate Transformational Projects). This proposal will expand funding for the existing RAISE and INFRA discretionary grant programs to support projects that emphasize safety, climate, and resilience, and economic strength will foster innovation and will invest in historically underinvested communities ("U.S. DOT 2022 Budget Highlights", 2021).

Office of the Secretary, Department of Transportation

- Electric Fleet Vehicles: $11 million is requested to purchase electric vehicles (EV) for the Department's-owned vehicle fleet or as part of a transition to GSA's currently leased fleet.
- Research and Technology: $43 million will ensure coordination across the Department for transportation research, development, and technology activities and funds several specific efforts to address climate change, transportation equity, and the safety and resiliency of the transportation network ("U.S. DOT 2022 Budget Highlights", 2021).

Department of Transportation: Federal Transit Administration Grant Programs

- Climate Resilience and Adaptation Program: $50 million will fund competitive grants to improve the resilience of transit assets to climate-related hazards by protecting transit stations, tunnels, tracks, and other infrastructure from flooding, extreme temperatures, and other climate-related threats. This program funds can be utilized to improve the resilience of installed infrastructure.

Department of Transportation: Federal Highway Administration – Federal-Aid Highway Program

- Highway Safety Improvement Program (HSIP): $2.7 billion is requested to improve safe and accessible travel for all users inside and outside vehicles.
- Congestion Mitigation and Air Quality Improvement Program (CMAQ): $2.5 billion is requested to make transportation investments that reduce highway congestion and harmful emissions.
- National Highway Freight Program (NHFP): $1.5 billion is requested to invest in infrastructure and operational improvements on the National Highway Freight Network that reduce congestion, improve safety and productivity, and strengthen our Nation's economy ("NHPP -

Federal-aid Programs - Federal-aid Programs and Special Funding - Federal Highway Administration," 2021) ("U.S. DOT 2022 Budget Highlights", 2021).

Advanced Technology Vehicle (ATV) and Alternative Fuel Infrastructure: Manufacturing Federal Incentives

The Loan Program office has $17.7 billion to support the manufacture of eligible light-duty vehicles and qualifying components. To date, the program has loaned $8 billion for projects that have supported the production of more than 4 million advanced technology vehicles ("Advanced Technology Vehicles Manufacturing Loan Program," 2021).

Through the Advanced Technology Vehicles Manufacturing Loan Program, manufacturers may be eligible for direct loans for up to 30% of the cost of re-equipping, expanding, or establishing manufacturing facilities in the United States used to produce qualified ATVs, ATV components, or alternative fuel infrastructure, including associated hardware and software. Qualified ATVs are light-duty or ultra-efficient vehicles that meet specified federal emission standards and fuel economy requirements. Ultra-efficient vehicles are fully closed compartment vehicles, designed to carry at least two adult passengers, which achieve at least 75 miles per gallon while operating on gasoline or diesel fuel, as hybrid electric vehicles operating on gasoline or diesel fuel, or as fully electric vehicles. Qualified components must be designed for ATVs and installed to meet ATV performance requirements, as determined by the U.S. Department of Energy ("Alternative Fuels Data Center: Advanced Technology Vehicle (ATV) and Alternative Fuel Infrastructure Manufacturing Incentives," 2021).

Electric Vehicle Supply Equipment (EVSE) Funding

The New Mexico Environment Department (NMED) may provide funds up to 100% of the cost to purchase, install, and maintain eligible light-duty EVSE. The program is funded by New Mexico's portion of the Volkswagen Environmental Mitigation Trust ("Alternative Fuels Data Center: Electric Vehicle Supply Equipment (EVSE) Funding," 2021).

Alternative Fuel Vehicle (AFV) Loans

The New Mexico Energy, Minerals, and Natural Resources Department's Alternative Fuel Acquisition Revolving Loan Program provides loans to state agencies, political subdivisions, and educational institutions for AFV acquisitions. Funds must be used for the purchase of vehicles that operate on natural gas, propane, electricity, or hydrogen ("Alternative Fuels Data Center: Alternative Fuel Vehicle (AFV) Loans," 2021).

The DOE Announced $162 Million to decarbonize cars and trucks in April 2021. SuperTruck 3 will fund projects to electrify medium and heavy-duty freight Trucks; Additional Investment Will Boost Vehicle

Efficiency, Expand EV Infrastructure ("DOE Announces $162 Million to Decarbonize Cars and Trucks", 2021).

Improved Energy Technology Loans

The Department of Energy (DOE) provides loan guarantees through the Loan Guarantee Program to eligible projects that reduce air pollution and greenhouse gases and support early commercial use of advanced technologies, including biofuels and alternative fuel vehicles. The Department of Energy may issue loan guarantees for up to 100% of the loan amount for an eligible project like deploying alternative fueling infrastructure ("Alternative Fuels Data Center: Improved Energy Technology Loans," 2021).

The Loan Program Office (LPO) has more than $40 billion in loans and loan guarantees available to help deploy large-scale energy infrastructure projects in the United States. Over the past decade, LPO has closed more than $30 billion of deals across various energy sectors ("Loan Programs Office," 2021).

Alternative Fuel Infrastructure Tax Credit

Many fueling types of equipment, including those for electricity, installed through December 31, 2021, are eligible for a tax credit of 30% of the cost, not to exceed $30,000. Fueling station owners who install qualified equipment at multiple sites can use the credit towards each location. Consumers who purchase qualified residential fueling equipment before December 31, 2021, may receive a tax credit of up to $1,000 ("Alternative Fuels Data Center: Alternative Fuel Infrastructure Tax Credit," 2021).

Surface Transportation Block Grant

This program provided flexible funding that may be used by states for projects to preserve and improve the conditions and performance on any Federal-aid highway, bridge and tunnel projects on any public road, pedestrian and bicycle infrastructure, and transit capital projects, including intercity bus terminals ("STBG - Federal-aid Programs -Federal-aid Programs and Special Funding - Federal Highway Administration," 2021).

Additional Funding Opportunities

The state should leverage different funding types; to benefit from the funds that support innovative ideas and techniques, researches, and technologies.

Federal Transit Administration

The Federal Transit Administration (FTA) announced the availability of $11 million in the Fiscal Year 2019 research funds for Accelerating Innovative Mobility (AIM) Challenge Grants, 25 projects were selected in 24 states and one territory to receive a share of approximately $14 million to support mobility and innovation in the transit industry through projects that can accelerate the development, implementation, and adoption of innovative technologies, practices, and service models to improve mobility and enhance the rider experience, with a focus on innovative service delivery models, creative financing, novel partnerships, and integrated payment solutions ("Accelerating Innovative Mobility | FTA," 2021).

Among the projects selected to receive funding was Western Reserve Transit Authority in Ohio that will receive $2.3 million to partner with the Santa Clara Valley Transportation Authority to deploy automated electric vehicles designed for accessibility in Mahoning Valley, Ohio, and Santa Clara Valley, California, to augment fixed-route bus and paratransit services. The two locations will test the ability of the AVs to provide more efficient and cost-effective service under different climates and operating conditions. Other opportunities should also be considered to create sustained funding for the project.

Sustainability and Circularity

The state can also utilize circularity as a source of funding during and after implementation; for instance, they can utilize used EV batteries after reaching the end of their useful first life; batteries' life cycle can be optimized by reusing them in stationery applications where reduced performances capabilities are still valuable through the repurposing or refurbishing technologies of battery packs ("GSEP Storage community," 2021). Repurposing EV batteries is more cost-effective than refurbishing them; repairing, replacement, and extraction of individual cells within modules is unlikely to be economically feasible; however, both technologies will stay more cost-effective than first life batteries (1LB); 30-70% less expensive than 1LB ("Second life batteries: Enabling sustainability for electric mobility - WHITE PAPER RELEASE - GSEP," 2021).

Taxes on Gasoline

According to Jenn et al. (2015), one significant source of revenue generation for transportation infrastructure is the use of fees charged through taxes on gasoline both on a federal and state level. Taxes rates can also gradually increase to generate more revenue for transportation infrastructure, especially fast-charging to address consumers' high-level anxiety toward traveling long distances with EVs (Zhang et al., 2021), where level 1 (L1) chargers provide charging through a 120 V AC plug and does not require installation of additional charging equipment. For light-duty vehicles can deliver 2 to 5 miles of range per hour of charging. While level 2 (L2) chargers provide charging through a 240 V (for residential) or 208 V (for commercial) plug and require installation of additional charging equipment, they can deliver 10 to 20 miles of range per hour of charging for light-duty vehicles. And DC Fast Charge (DCFC) provides charging through 480 V AC input and requires specialized, high-powered equipment and special equipment in the vehicle itself. Plugin hybrid electric vehicles typically do not have fast-charging capabilities.

Cost of Charging EVs

It costs 12.6 cents/kWh, and the annual energy use of, for instance, a Chevy Volt is 2,520 kWh, which costs $317.52 compared to $1,500 per average passenger conventional car (eGallon, 2021). Charging on the road is more expensive than at home (double), yet the cost of charging is still cheaper than fuel for conventional vehicles ("Charging at Home," 2021). Moreover, the cost of charging is way cheaper if compared to premium gas; it is important to address consumers' concerns and ensure they are aware of these facts that imply the benefits of saving over the long term with EVs, it would be beneficial to use advertisements and social media platforms as tools in doing so.

Transition Plan: Technologies and Techniques

The state of New Mexico can consider creating an effective, comprehensive, realistic yet quick electrification transition plan to decrease GHG emissions significantly. The state has the opportunity of utilizing all the available EV types (Battery EVs, Plug-in hybrid EVs, Hybrid EVs, and Fuel-cell EVs) in its transition plan. They should consider dividing the state according to the number and locations of charging stops available in each area, determining the area and distance that can be traveled using AEV solely, and whether the consumers can use AEV or hybrid vehicles.

Utilizing Renewable Energy Resources

The state should make efforts to reduce carbon emissions from the electricity sector. The carbon footprint of EVs will only improve with the increasing penetration of a low-carbon electricity supply. And like what California, New York, and Hawaii did, they have the opportunity of utilizing renewable energy resources in doing so (Howard et al., 2021); however, New Mexico has the gap of oil and gas as their primary industry. Schuller et al. (2015) suggested that the usage of variable renewable generation (utilize a mix of PV and wind generation) can double the share of EV electricity demand covered by renewable energy sources compared to uncoordinated charging. Utilities will be an essential component of this transition. With targeted rates and managed charging, utilities can influence when EVs are plugged in, helping to make more efficient use of variable renewable resources.

Charging Demand

- Lin et al. (2019) suggested that trip information is essential in determining and managing EV flexibility. They developed an agent-based trip chain model ABTCM by simulating the charging patterns and the heterogeneous travel patterns of 1000 EVs for 77 days, including 55 weekdays and 11 weekends (22 days), determining the distributions of charging demand at three types of location. They used reliable, detailed loop travel models capable of simulating the travel patterns of a large fleet of EVs and their charging demand at different locations while considering both the energy consumption and the variations in EVs location and temporal distribution. The study models accounted for the time of departure from home, time of arriving at home and daily travel distance, the number of daily trips, also the possibilities of charging and trip purpose transition at different locations, the influence of traffic flow on charging demand, and the uncertainty of charging demand (Lin et al., 2019).

- NM can consider using/developing a predictive system that utilizes routes' speed profiles and the total battery energy consumption produced by the Heating, Ventilation, and Air Conditioning to minimize energy consumption (Medina et al., 2020). Medina et al. (2020) presented a predictive Energy Management System that can reduce total battery energy consumption by using available up-coming route information such as traffic flow, speed limits, and road slope. The results showed potential energy savings of 7.1% compared to a non-predictive energy management system.

- To improve the performance of vehicles, NM can consider utilizing simplified optimization-based techniques/models as proposed by Yan et al. (2018) for better fuel efficiency and emission reduction. Yan et al. (2018) optimized the power split of the internal combustion engine and the battery while considering the impact of the transmission system for plugin hybrid electric vehicles. The optimization process can be expressed as a 2D map. Any vehicle speed and traction force give the optimal value of the transmission ratio; such a map can be easily implemented in real vehicular applications.

- Vehicle-to-Grid (V2G) is a technology that enables energy to be pushed back to the power grid from the battery of an electric car. Additionally, a bonus point can be awarded to states that are piloting vehicle-to-grid technologies. A car battery can be charged and discharged with vehicle-to-grid technology based on different signals — such as energy production or consumption nearby.

- New Mexico can consider using vehicle-to-grid (V2G) and vehicle-to-vehicle (V2V) technologies and using optimization methods for developing EV charging and discharging scheduling algorithms; as linear programming (LP), mixed-integer linear programming (MILP), and binary linear programming (BLP) to maximize revenue and EV users' satisfaction, and manage congestion (Li et al., 2020). The charging and discharging power scheduling algorithm proposed by Li et al. (2020) decreased the cost of electric vehicle charging by almost 50% in a certain confidence level of photovoltaic forecasting compared with an uncoordinated method. The state should support utility management of EV charging and allow utilities to make investments, to help EV charging infrastructure, and to implement EV rates or managed charging programs that encourage the integration of EVs into the grid to maximize reliability and minimize costs and greenhouse gas (GHG) emissions.

- New Mexico can consider using the EV charging scheduling method based on the Lyapunov optimization technique to reduce charging costs and mean delay time of fulfilling EV charging requests (Jin et al., 2014). To allocate energy from renewable sources to EVs cost-efficiently, the group formulated a stochastic optimization problem based on the queuing model to minimize the time average cost of using non-renewable energy sources (Jin et al., 2014). The developed dynamic control algorithm does not require knowledge of the statistical distribution of the time-varying renewable energy generation, EV charging demand, or extra energy pricing.

- A statistical analysis of a large travel survey dataset was carried out by Dixon & Bell in the UK to support the hypothesis that car use is likely to vary according to population demographics, hence affecting the energy peak demand (increasing battery capacities and the establishment of more widespread charging opportunities may reduce the peak demand from EV charging or shift it to a timeless likely to coincide with peak domestic demand, making it easier for the network to cope with an increase in demand) (Dixon & Bell, 2020). First-generation EVs such as the 2011–2015 Nissan Leaf and the 2009–2016 Mitsubishi i-MiEV (16 kWh) could only accept 'slow' AC charging. However, when charging new generation EVs at home, it is more likely that consumers will opt for a high power rating that is hypothesized to increase the charging demand peak, as there is generally no difference in price between a 'slow' and a 'fast' AC charger. While switching to DC charging and consequential removal of onboard AC/DC converters could (i) reduce the up-front cost of the vehicle and (ii) increase charging efficiency (Dixon & Bell, 2020).

- Yao et al. (2017) proposed an energy storage system (ESS) in parking stations and exploited the power dispatches of the power grid and the charging and discharging scheduling of EVs (formulated using mixed-integer linear programming) to achieve better utilization of intermittent PVS for EV charging and minimize the overall operational cost of the parking stations.

Funding - Next Steps

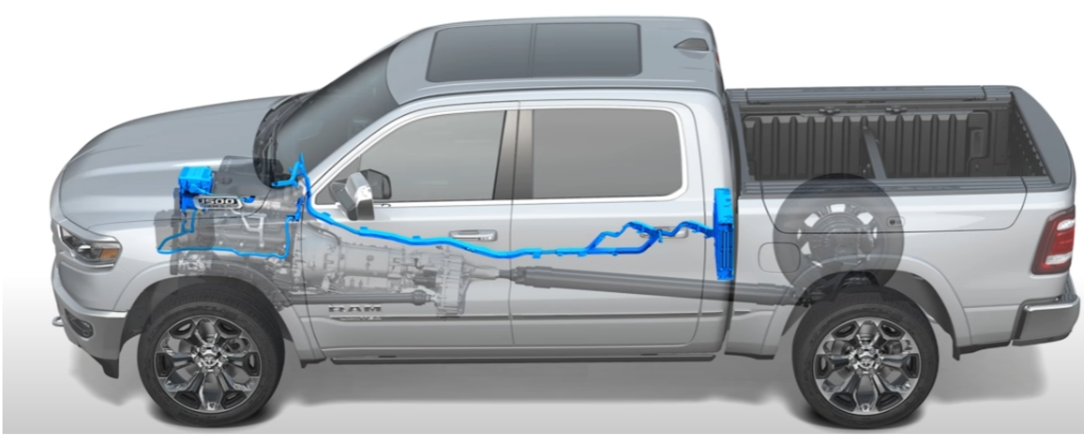
- Leverage funds that support innovative ideas, technologies, and research.
- Encourage utilities to invest in supporting EV charging infrastructure and implement EV rates or managed charging programs that encourage integrating EVs into the grid.
- Encourage grid-scale decarbonization to reduce the life-cycle emissions of EVs reducing GHG emissions from the transportation sector.

Life Cycle Emission Levels for HEVs and AEVs

Alternative Electric Vehicles

As manufacturers attempt to meet demand and promise clean, energy-efficient electric transportation, BEVs and HEVs have evolved to produce better power and travel greater distances. The two electric options do, however, offer different technologies and methods of efficiency. While BEVs require range and power to be provided by the battery, HEVs need comparable power but considerably less energy. As such, the battery cells in HEVs are adjusted to produce short surges of power for acceleration versus enduring energy for greater range capacity in BEVs. HEVs, therefore, have a far different power-to-energy ratio that attempts to balance range and power (Tingwall, 2016); this is noticeable when comparing the internal combustion engine (ICE) version of a vehicle to its HEV brethren. The HEV will have the same engine in the ICE vehicle. Still, the added hybrid component improves torque and horsepower to improve fuel efficiency and lower emissions.

HEVs can be broken down into MHEV (Mild hybrids), full hybrids, and PHEV (Plug-in hybrids). MHEVs use fewer batteries than both PHEVs, full hybrids, and BEVs, as MHEV batteries and motors are designed for acceleration assistance to the gasoline engine. Vehicles such as the Ram 1500 eTorque (hybrid) are considered MHEVs and cannot drive themselves along the road using only electricity. The eTorque technology aids in reducing fuel usage by deploying the stop/start system and assists the gas-powered engine in accelerating up to 1500 RPM. The hybrid effectively provides torque at low RPMs, stop/start and smoothing out shifts while slightly increasing fuel economy. Operating the Ram 1500 eTorque as with most mild hybrids in hotter climates will not produce the same savings on fuel due to the lack of electric-powered air conditioning; the gasoline engine must be active to run the AC (Alex on Autos, 2018). MHEVs have fewer emissions during the production stage due to smaller batteries involved in the build phase; see below, the battery pack is at the front of the pickup bed.

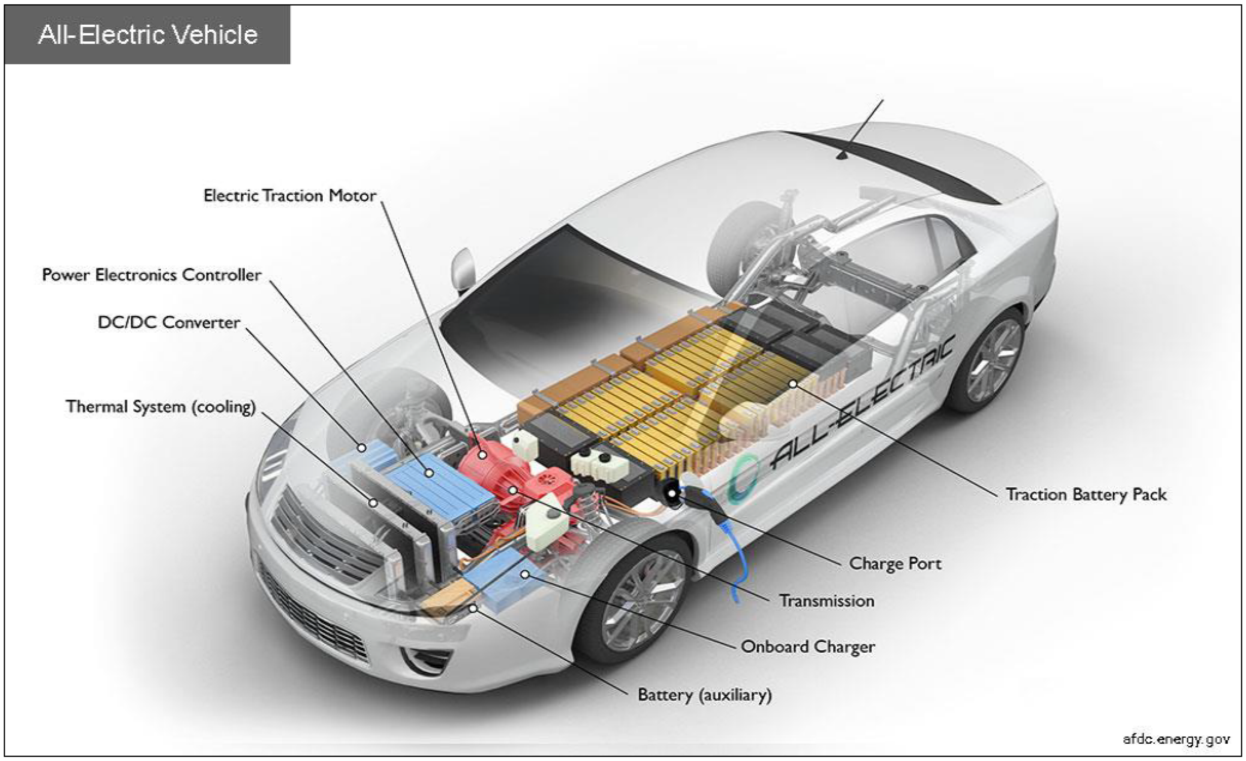


Full hybrids can drive short distances on all-electric power. The hybrid technology automatically cuts the gas engine used to reduce fuel utilization when feasible and deliver more power when acceleration is necessary. When braking and motionless, the internal combustion engine (ICE) shuts down, and the electric power system activates to save fuel consumption. A full hybrid will have the same total driving range as the equivalent ICE vehicle.

Ford Escape Hybrid Battery

PHEVs (Plug-in hybrids) act like BEVs, with the internal combustion gasoline engine effectively inactive while a charge remains in the battery. PHEVs have larger battery packs to allow for an increased electric driving range before the gasoline engine activates. They can travel on electric-only power, about 15 to 55 miles, with mileage varying based on mode. The plugin hybrids are designed with the knowledge that most people will not travel more than 30 – 35 miles per day in completing their everyday travel. The range traveled, falling between 30 – 35 miles, can only be accomplished on electric power and ultimately save fuel cost while lowering emissions. When the need arises to drive longer distances, the electric engine works in concert with the gas or diesel engine to garner a comprehensive range comparable to an ICE car. As a result, there is no so-called 'range anxiety' that can sometimes be experienced with a fully electric vehicle (Edmunds, 2021). PHEVs have the largest battery packs of the hybrid class and, for this reason, are responsible for the most significant percentage of GHG emissions in the production phase for HEVs.

BEVs (Battery electric vehicles) have large battery packs that store enough energy to propel the vehicle from 80 up to over 400 miles at the top of the range. A midsize, midrange (84 miles per charge) BEV typically introduces more than 1 ton of emissions to the aggregate production emissions, resulting in 20 percent greater emissions than manufacturing a similar gasoline vehicle (hereinafter Kim et al., 2016). Using electricity over gasoline can more than makeup for the 20% increase in emissions once the cars are in use on the road, reducing total emissions by 51% during the vehicle's useful life.



Source: Reproduced from U.S. Department of Energy, Alternative Fuels Data Center, https://afdc.energy.gov/vehicles/how-do-all-electric-cars-work.

Cradle-to-Gate

According to Zackrisson et al. (2010), the potential savings in the GHG range is between 25% for hybrid EVs, up to 49, 50-80% for plugin hybrid EVs and about 90% for battery EVs. The emission savings for the hybrid and plugin hybrid cars are contingent on electricity utilization for short trips. All the potential emission savings are reliant on batteries, and battery production may be the most significant barrier to fully realizing the environmental benefits of HEVs and BEVS. While batteries are a challenge, some of the world's largest lithium manufacturers, including Albemarle, a U.S.-based chemical firm, are ramping up sustainability efforts to clean up the EV battery supply chain. Albemarle CEO Kent Masters has spoken of how the firm will meet its environmental goal of net-zero carbon emissions for its enterprise by 2050. The importance of batteries in EV manufacturing and, more significantly, the greenhouse gas (GHG) emission related to EV production cannot be understated. The use of mined metals for battery production, the source of electricity used for charging, and the end of useful life disposal of batteries are crucial characteristics of an electric vehicle's life cycle assessment (Tagliaferri et al., 2016). From material sourcing and transportation to-site to fabrication of the battery packs and casings, production is energy and water-intensive. The lithium-ion batteries that power BEVs and account for the electric-powered range of HEVs have three primary components, the anode, which utilizes graphite, the electrolyte composed of lithium salts, and the cathode, which can have many compositions each demanding minerals (The World Bank, 2019). EV batteries are reliant on other minerals in addition to graphite and lithium, including cobalt, many of which come from developing countries with abundant deposits of vital minerals. The below world map displays the location of some of the largest deposits of minerals used in battery manufacturing.

(The World Bank, 2019).

Mining is an energy, water, and emission-intensive field as equipment must be brought to bear, and drilling and clearing out of areas to get to the metals can spew toxins into the air and water tables. Transportation of heavy metals to facilities that will process and manufacture batteries for EVs also increases the emissions related to the EV life cycle. Extraction of heavy metals habitually occurs in Latin America and Africa, India, and parts of Asia, where health and safety precautions are considered mainly eased compared to the United States. Mining generates GHG, particulate matter 2.5 and 10, and NOx emissions; these toxins occur due to the use of fossil fuel to run equipment or produce energy.
On a worldwide basis, the primary use of cobalt is in rechargeable battery electrodes, as a critical component of EVs. The large majority (more than 70%) of the world's cobalt is mined in the Democratic Republic of Congo (DRC). China was the world's leading consumer of cobalt, with more than 80% of its consumption being used by the rechargeable battery industry (U.S. Geological Survey, 2020). In addition to environmental effects at the mining site, the recovery of cobalt (and nickel) from ores requires smelting, which without pollution controls can raise air quality concerns with the emission of sulfur oxides in addition to other air pollutants (Dunn et al., 2015). Lithium, another primary material in battery production, depends on brine mining; however, hard rock mining spodumene can also produce lithium. Some have argued for further research to evaluate the environmental effects of lithium mining, including establishing a baseline for water consumption and understanding potential impacts on wildlife and

ecosystems. Also vital to battery manufacturing is graphite, the mining of which can lead to soil contagion and other environmental impacts. A study of graphite mining in Luobei County in Heilongjiang, China, found farmland and residential areas within the watershed of the mining area to be affected by impacts from mining activities (Lifeng et al., 2014). There have been numerous other reports that connect graphite extracting and processing with both air and water contamination.

The chemical makeup of the battery provides a point of differentiation. A decade ago, nickel-metal hydride (NiMH) batteries utilizing rare-earth metals dominated the market as HEVs deployed the batteries, and PHEVs and BEVs were rare. Two Li-ion battery types: nickel cobalt manganese lithium-ion (NCM) and iron phosphate lithium-ion (LFP), use virtually no rare-earth, reducing emissions related to rare-earth extraction. As Li-ion (lithium-ion) chemistries have come online, they have been proven to be more efficient and less harmful to the environment than NiMH. The battery types have had different use cases as NiMH was designed for hybrid technology as "HEV batteries are used mostly as assistance during accelerations and thus require greater power densities, PHEVs and BEVs use batteries as their primary energy source and require optimal energy densities" (Majeau-Bettez et al., 2011). PHEVs and BEVs utilize Li-ion battery technology as the batteries provide greater storage capacity and useful life. Ultimately the NiMH batteries proved to be responsible for the greatest percentage of negative externalities related to the environment, trailed by NCM and then LFP, except when the aspect studied was ozone depletion potential.

One study estimates that the steps for extracting and processing critical minerals are responsible for approximately 20% of the total GHG emissions from battery production (hereinafter Kim et al., 2016). The GHG emissions from extraction and processing depend upon the resource used to generate the energy used during these activities. The production phase comprises materials mining, processing, and the manufacturing of batteries and the entire vehicle. Yet, many of the emissions and environmental effects are related to the disposal of waste from mining. For this reason, cars such as BEV that run strictly off electric powered with larger battery banks tend to have a significant impact on emissions and may take more years and miles of driving to make up for the extra emissions than their HEV/PHEV counterparts.

As the electric vehicle life cycle progresses to battery and vehicle production, and fabrication process occurs. When it comes to HEVs, PHEVs, MHEVs, and BEVs, many components of the vehicles are the same. However, more than a few crucial parts and materials differentiate the technologies; some examples are motors, energy storage components, regenerative braking, and connectors. The greatest difference resides in the fabrication of batteries. At the same time, the chemical makeup has become more similar; the production factor with the greatest effect on the environment has become the size of the battery packs used to deliver an ever-increasing range. During the production process, much of the different environmental impacts are attributable to the greater demand for electricity and other forms of energy required for battery production (Ellingsen et al., 2018); this is exacerbated by the fact that the most recent electric cars come with much larger batteries. The Chevrolet Bolt has a range of 238 miles powered by a 60kWh battery. Tesla's 400+ mile range battery has a 100kWh capacity as these new larger batteries are produced, more energy is utilized to manufacture them.

As battery production is the primary differentiator of GHG emissions in vehicle production, the vehicle with the largest battery pack is most responsible for the largest percentage of emissions. This means that large PHEVs and BEVs prove to be the most harmful to the environment during the production phase (cradle to gate). BEVs deploy far larger battery packs between PHEVs and BEVs to store energy for a more extended range; for this reason, BEVs are responsible for more emissions in the manufacturing phase.

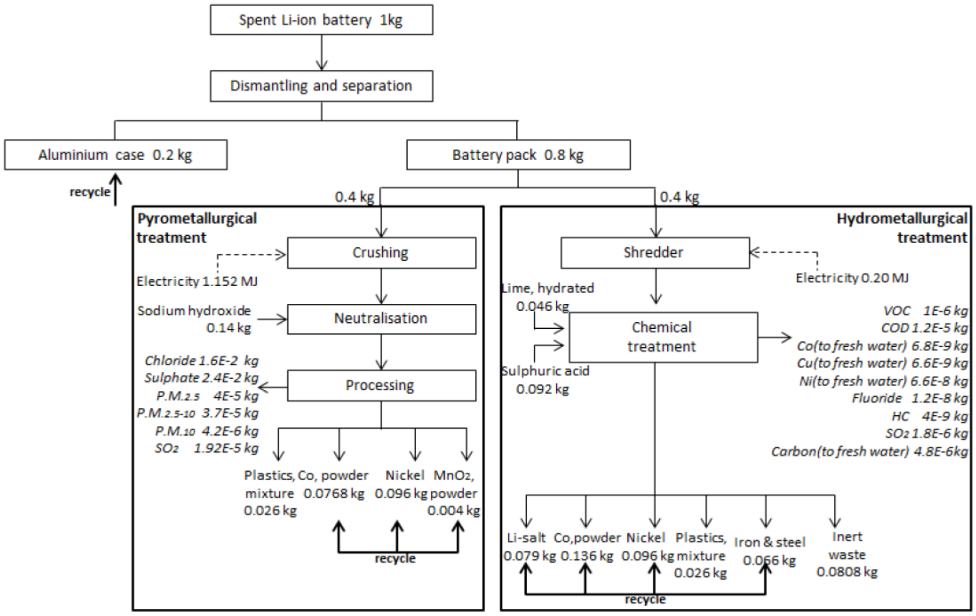
Well-to-Wheel

HEVs and MHEVs, while having onboard battery technologies, use gasoline to power the vehicles. Both vehicles charge their batteries using the ICE and regenerative braking, providing the HEV with a short electric range. PHEVs, if driven judiciously, can be very efficient; the daily driving range is paramount to this efficiency and reduced emissions. If the PHEV driver drives around 30 miles daily and charges at home during off-peak hours, they are essentially driving the car in the same manner as a fully electric vehicle. As the BEV only uses electricity, there is no gasoline emissions component; the BEV can make up ground lost in the production phase.

The source of energy that powers the charging station determines GHG emissions associated with electric vehicles. Electricity generation is responsible for differing environmental effects depending on the source. Nuclear, hydroelectric, and renewable energy have reduced emissions, while coal-fired power plants generate the greatest life cycle GHG, particulate matter (PM), and SOx emission concentrations. Each power option has a unique energy and water depletion and usage that determines the negative externalities related to power generation. The energy source is even more critical for hybrids as the environmental value proposition is based on the limited use of fossil fuels. If fossil fuels provide the energy charging the battery and the hybrid drive often depletes the battery and relies on the internal combustion engine, the efficiency is greatly diminished. The PHEV and BEV over the useful operating life of the vehicles will be the least harmful to the environment, with the BEV reducing emissions by as much as 51%. Overall, the BEV will be responsible for the least emissions while providing a lower operation and maintenance cost.

Grave-to-Cradle

End of useful life emissions, like cradle-to-gate, is primarily about the battery packs. The larger the batteries are, the greater the emissions. The chemical makeup of the battery can allow for some level of capture and recycling, which can reduce the need for extraction processes years down the line when more significant amounts of batteries are being processed for disposal. There are two methods for the disposal of EV batteries. Pyrometallurgical (more common in the United States) expels toxins into the air, while Hydrometallurgical expels toxins to freshwater.

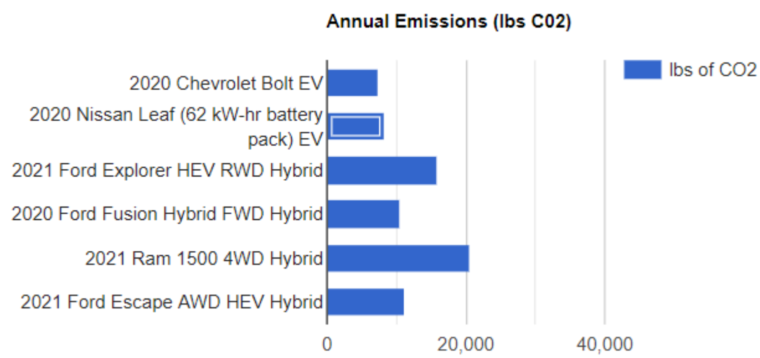


BEVs contain larger batteries and, for this reason, would be responsible for more GHG emissions in the disposal process than any version of the hybrids. The larger batteries will use more resources to dismantle, separate, and break down. The larger batteries will also produce more usable recycled materials that lessen the need for extraction activities.

Vehicle Recommendations

State Fleet Options

The current price agreement has options that can meet different use purposes. Still, for general use without considerable seating capacity or payload, the Chevrolet Bolt is the best option. The Bolt provides more range and capacity than the Nissan Leaf and will be responsible for less GHG emissions over the useful life. The Bolt will also have lower lifetime emissions than the hybrid options as the all-electric nature will more than makeup for the increased emissions expelled during production and disposal. The Ford Fusion, while a capable hybrid, is no longer being produced by Ford as they have decided to remove sedans and all car models outside of the Mustang from the North American market.
When looking at the current agreement, the Ford Explorer and Escape HEV SUVs and the Ram 1500 eTorque have specific use cases requiring larger vehicles with interior capacity and payload requirements that continue to make them viable alternatives to the Chevrolet Bolt when the additional utility is needed.



Future Options to Consider

Several new electric vehicles should be considered as the new pricing agreement is negotiated and signed. As technology has advanced, newer hybrid technology has greatly increased MPGs to meet new regulations and standards. Electric batteries have moved more toward lithium-ion technology and chemistry, increasing longevity and range. These advancements require a review of the current options. The Ram 1500 eTorque has specific use cases that keep it a viable option until a new agreement is approved. With Ford's F-150 hybrid having similar capabilities with better MPG ratings, greater towing, acceleration and amenities, and similar cost, it is an option to look at the hybrid market. For an electric opportunity, the Ford F-150 Lightning available in 2022 (limited to an estimated 500,000 units in year 1) will have emissions impacts above that of the Bolt but with a drastically different use. In its most basic spec, the Lightning will enter the market at $41,000.00 but will provide the state with the utility to include onboard power generators to power a work site or other items for as much as three days on a full charge.

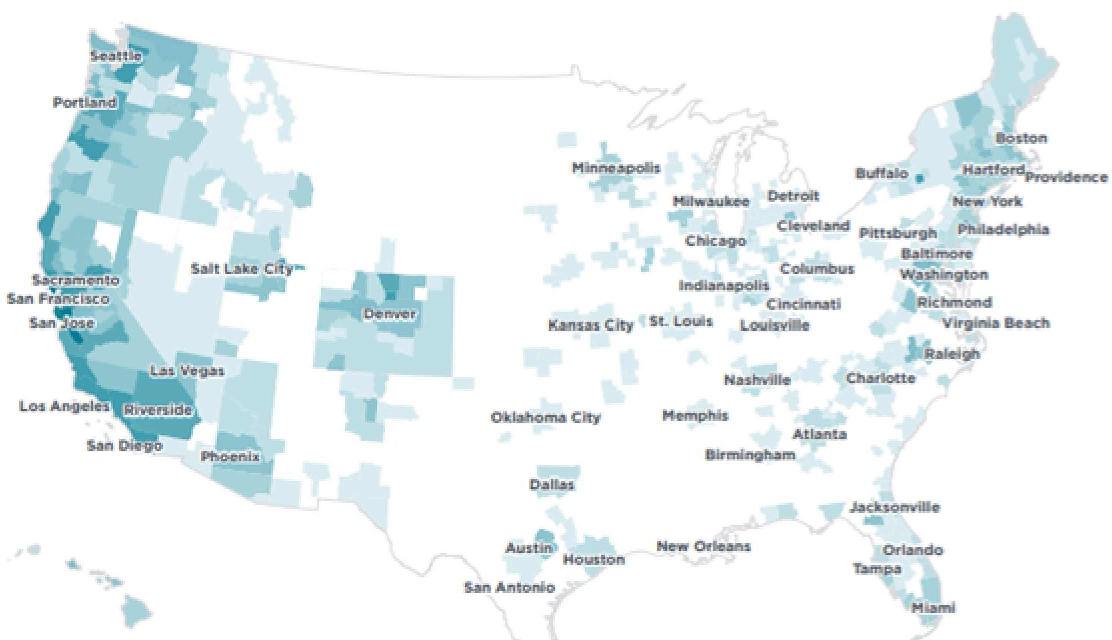
SUV options for full electrification can include the Volkswagen I-4, Chevrolet Bolt UEV (compact SUV), and the Ford Mustang Mach-E. The Bolt UEV looks to have a slightly lower price, but information on these three options is still recent and trickling out.

As power grids decarbonize, emissions related to EVs will further decrease. As the lithium-ion battery manufacturing supply chain is improved and made more efficient and clean, batteries will produce fewer negative externalities. Clean energy and advances in production will help realize the true value proposition of electric vehicles. Choosing the right vehicles for the specific duty is vital to New Mexico taking full advantage of this value while mitigating climate issues.

Barriers to Electric Vehicle Adoption

The United States has long been the land of the automobile. These vehicles symbolize liberty and freedom for our citizens. Yet, with EV's, this paradigm is challenged in the mindsets of many Americans. Charge and range anxiety stems largely from EV's lack of range, though improvements have become the new selling point. But add to that the absence of a charging grid as efficient as convenient gas stations and no federal and state mandates that would, among other things, dictate a one-size-fits-all plugin requirement (Tesla, for example, has charge stations only sized for Teslas), and adoption obstacles remain worrisome. The ability to drive the many roads laid out In America and not have to worry about finding a place to fill up or be stranded is a headspace that goes against the current state of EV infrastructure. Greater investment in infrastructure, paired with consumer engagement and education, can alleviate charging and range anxiety.

Another barrier in the current state of electrification adoption comes down to the inequity of buying an electric car. This barrier has three key tenets: the initial cost of purchase, lack of price parity, and access to charging stations in multi-unit apartments. High electric vehicle use is centered around affluent areas of the country and is firmly positioned on the coasts. In particular, the West Coast has a strong lead for this new technology, where "electric vehicle uptake on the West Coast of the United States was three-and-a-half times the national average. California alone was home to just under half of all new 2019 electric vehicle sales." (Bui, Anh, and Peter Slowick. "Update on Electric Vehicle Adoption across U.S. Cities.")



(Breakdown of shares of EV's across the US)

To achieve true electrification, inequity must be addressed by municipalities, utilities, and the private sector as a whole. Currently, there are several avenues local governments can pursue to mitigate these barriers of adoption and incentive usage. An example is to deploy financial incentives, such as rebates or tax breaks. California, the current U.S. leader in EVs, offers consumer rebates for electric vehicles. (Heart Auto Research, 2020) This analysis will further explain and extrapolate the barriers of EV adoption and illuminate mechanisms that states and cities can take to mitigate them. Highlighting these different points can help pave a path for New Mexico to navigate these obstacles and, in turn, drive public buy-in to achieve their electrification goals.

Barrier #1: Charging Anxiety

As stated earlier, charging anxiety remains one of the most potent and palpable barriers to entry for EV's to reach widespread adoption. This barrier is defined as "the worry that the battery will run out of power before the destination or a suitable charging point is reached." (Virta, 2019). The sponsor for our project, Thom, alluded to this dynamic being detrimental to the state's electrification goal. No one wants to be stuck worrying about where and if they will be able to fill up their car. According to a study conducted by Volvo, "58 percent of drivers are afraid that they will run out of power before being able to charge their vehicle". (Stumpf, Rob,2019) With this factor being the defining barrier, understanding the dimensions of this dynamic is imperative to reach adoption for the public market. Without buy-in, this challenge will continue to plague electrification transformation. In New Mexico, this concern is particularly present, being a largely rural state. However, what is interesting about this paradigm is that drivers only average around 20-30 miles driven per day. Even with short commutes, charging anxiety remains the strongest barrier of entry. (Wagner, I, 2021)

Consequently, range anxiety is much less a concern for individuals that own electric cars. A German study found that "range anxiety correlates with the level of experience drivers have with electric vehicles. A greater experience in driving an electric vehicle leads to less range anxiety." (Burkert, 2021) Additionally, only 28 percent of current owners state that they have any sort of range anxiety. These owners' anxiety comes more from the lack of public charging infrastructure in their regions.

A Deloitte study mentions that "even though drivers only drove 27 miles (45 km) on average per day, over 60% said they would like their fully-electric vehicle to have a minimum range of 200 to 400 miles (320 to 640 km)." (Geotab, 2021) With this fact in mind, consumer education at the point of purchase will be a strong indicator of overcoming this hurdle. Showing potential customers that most of their concerns about range anxiety are overblown will help the industry move forward and bring hesitant customers to the EV market. This can be done through local government engagement with car dealerships. Having dealerships inform potential buyers about how and where to charge their vehicles in places like Santa Fe and Albuquerque is an avenue the state can take to alleviate anxiety. It is a way to leverage existing infrastructure in the state and instruct consumers on utilizing it. Local governments can also engage consumers and auto dealerships with highlighting platforms like EV Connect. This application gives drivers real-time locational services on where charging stations are located. Doing so can mitigate the hesitancy of buying an EV car.

Barrier #2: Inequity of Electric Vehicles

Electric vehicles are still considered a luxury good, especially in comparison to internal combustion cars. The upfront cost presents a major hurdle for everyday consumers in the market. According to a study, the "average sticker price on an electric car is $19,000 higher than an average gasoline-powered vehicle." (Palmer, 2021) This is no trivial number and illuminates the economic disparities of EV adoption in the current marketplace. Understanding this hurdle, economies of scale, and technological advancements will help drive down the costs in coming years. Price parity is crucial for widespread electrification, and it could be coming sooner than later. According to a study by Bloomberg, "upfront cost parity for U.S. electric and internal combustion vehicles will arrive in 2024." (Bloomberg, 2021) In just three years, there may be virtually no price differential between EV's and ICE cars. While costs illuminate a crucial barrier in today's market, the commitments set by major companies to help achieve economies of scale on top of advancements in battery technology will help the everyday American tap into the EV market.

Another economic disparity for EV adoption revolves around the ability for Americans to charge their EV while living in a multi-family apartment. Individuals often lack, 1. A garage where they can charge their car, and 2. A parking garage equipped with optimal charging stations. (Geotab, 2021). This poses a significant barrier of entry for those who live in multi-family apartments to have an EV. They simply do not have access to a viable charging location. While those living with their private parking spot, "current or potential electric vehicle drivers who live in multi-unit dwellings typically do not have the option to independently install charging infrastructure." Combatting this will require engagement with property owners to install proper charging equipment. This being said, costs of installation will likely be passed down to tenants.

State and Local Government Engagement with EV Proliferation

With these barriers highlighted and accentuated, there are numerous avenues that state and local governments are taking to navigate them. These different avenues take place in a variety of forms, tending to revolve around implementing financial incentives such as rebates, offering electric car-sharing programs, streamlining EV registration, and benefits such as priority parking. Two countries that provide a case study for EV proliferation and government engagement in the market are Norway and the Netherlands. In regard to parking, "Oslo has designated 1,300 of its 6,500 parking spaces in municipal car parks for BEVs – they are free to use and have free charging points. Cities like Amsterdam and Bergen give priority for highly coveted residential parking permits to EVs." (C40, Knowledge Hub) These perks offer benefits to potential consumers to help convince the buyer to choose an EV.

Along with parking perks, making buildings equipped to handle EVs will help garner public support for electrification. Chicago presents a strong example of preparing for electrification, as the City Council "passed an ordinance to ensure that more residential and commercial developments are equipped to support electric vehicles. At least 20% of parking spots must be ready for EV chargers in new residential buildings with five or more dwelling units and commercial buildings with 30 or more parking spaces." (Berman, 2020) A similar blueprint would greatly help to bolster New Mexican's cities with proper charging infrastructure in optimal and convenient locations for citizens.

In addition to parking perks, there are numerous mechanisms that local governments can take to lower the barrier of entry for lower-middle-income consumers. In Los Angeles, "the BlueLA EV car-sharing fleet serves low-income communities with poor transit access. It has helped to improve economic prospects by improving mobility options for residents in these areas. Low-income drivers receive a 25% discount for the service. "(C40, Knowledge Hub). To achieve proper electrification, these targeted schemes should be implemented to allow holistic and widespread adoption across different economic levels of our society.

In regard to helping convince and incentivize car dealerships to sell, a key stakeholder in adoption, Denver offers a strong plan for New Mexico to use as a blueprint. The city passed a law that "forces car dealers to more than double their EV sales by 2030 — from 2.6% to 6.2% of statewide sales." (Berman, 2020) Doing so will help get EV's in the forefront of potential buyers' eyes and help push car salespeople to become more well versed in the benefits of EV's for the Public. One of the key pinpoints to consumer education on EV's will lie in the hands of dealerships. Moving forward with a sales mandate could help buffer the electrification plan and get more New Mexicans on board.

Additionally, California offers a 2,000 dollar rebate for those who meet the low-middle income criteria, helping mitigate the steep upfront cost of EVs. Lastly, streamlining EV registration can help sway potential consumers to buy EVs instead of standard ICE vehicles. In numerous Chinese cities, customers receive a streamlined license plate and fast-tracked car registration, avoiding long waiting periods that ICE vehicle owners must endure. (C40, Knowledge Hub) California isn't alone in states offering financial incentives. New Jersey went big with their rebate and will offer a $5,000 per vehicle rebate over the next ten years. (Berman,2020)

Once again, local governments providing market incentives, financial support, and perks have shown to help proliferate adoption in their cities and regions. These mechanisms can be examined by local governments and, in turn, implemented in numerous ways for the state of New Mexico. Doing so will propel the state's electrification goal forward.

Barriers to Adoption: Conclusion

All in all, barriers remain steep for the electric car market. Electrification goals set forth by New Mexico are ambitious in nature, and thus these barriers to adoption must be identified and navigated for the goal to come to fruition. With that being said, the EV market's potential is contingent on charging infrastructure to be deployed in a significant way. This deployment relies on strong buy-in and engagement from federal, state, and local governments, along with the private sector.

Significant strides can be made through local government engagement. Fostering financial incentives and perks can help alleviate the inequity around purchasing these cars and mitigate charging anxiety. Doing so will generate buy-in from the public, offering pipelines of incentivizing purchasing of EV's. When convenience and personal benefits can be associated with an electrification transition, the public will feel more inclined to support the state's mission. With this being said, I hope my analysis of barriers to adoption for the public and state and local government engagement to navigate these obstacles offer a potential blueprint for the State of New Mexico to follow.

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