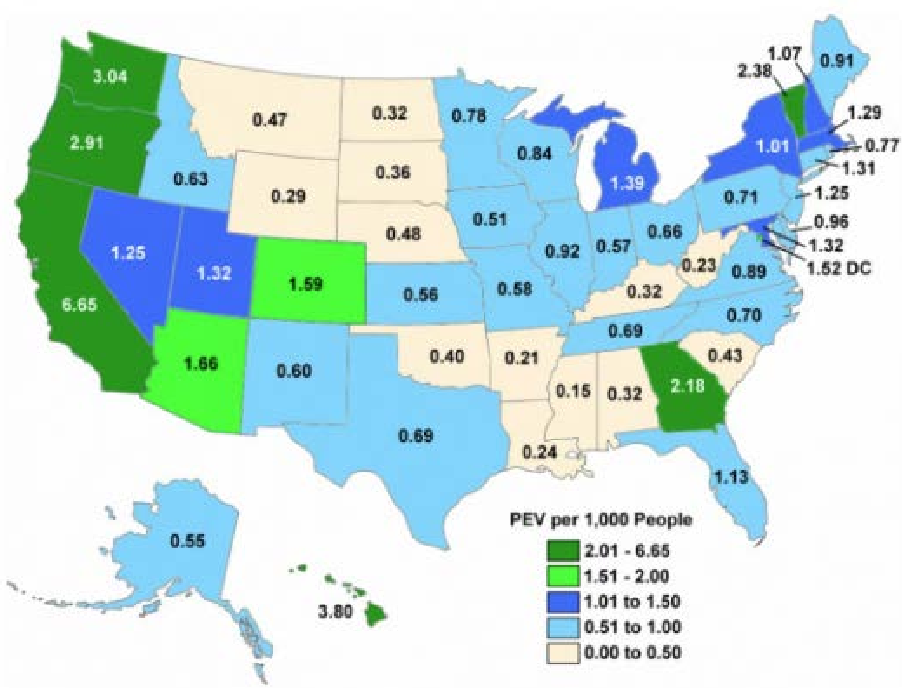
FINAL MEMO: THE ECONOMIC CONTRIBUTION OF THE CONSTRUCTION OF A STATEWIDE NETWORK OF FAST CHARGING ELECTRIC VEHICLE STATIONS IN MINNESOTA AND MEASURING THE ECONOMIC CONTRIBUTION OF THE ADOPTION OF ELECTRIC VEHICLES

INTRODUCTION

Electric vehicle adoption is increasing in the United States. In the first half of 2017, the number of electric vehicles sold increased 40 percent as compared to 2016. If treated as one model, the number of plug-in electric vehicles would have together been the 24th highest selling vehicle in the United States. In the first half of 2017, market share of electric vehicles increased to 1.07 percent (Klippenstein, 2017).

When it comes to electric vehicle adoption rates, Minnesota has largely been following national trends. There has been a slow, but steady, increase in the number of people buying electric vehicles. In 2016, Minnesota had 0.78 plug-in vehicle (PEV) registrations per 1,000 people (Voelcker, 2017). Registration data from the Minnesota Department of Public Safety shows there were 6,200 registered PEVs in Minnesota as of January 2018 (B. Jordan, personal communication, July 11, 2018). While lower than adoption rates on the West and East Coasts, it is one of the higher rates in the Midwest, particularly the Upper Midwest (Map 1).

Map 1: Plug-In Vehicles (PEV) Registrations Per 1,000 People by State, 2016



Source: U.S. Department of Energy via Green Car Reports

Increased adoption of electric vehicles will affect the economy. This memo explores two ways in which this could happen. First, the adoption of electric vehicles relies, in part, on the availability of electric charging stations. Construction of a network of fast charging stations would generate economic activity in the state during the construction phase. The first section of this research memo quantifies the economic contribution of the construction activity.

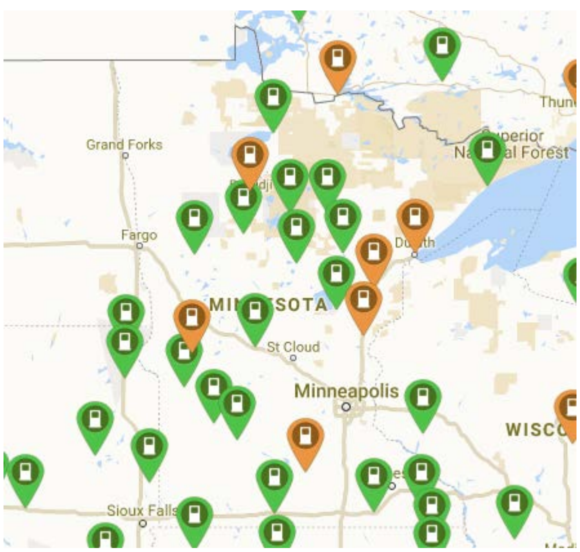
Second, adoption of electric vehicles by consumers can lead to economic shifts. This analysis explores the economic changes associated with representative households trading an average vehicle for an electric vehicle. The second section of this research memo quantifies this potential impact.

ECONOMIC CONTRIBUTION OF STATEWIDE NETWORK OF FAST-CHARGING ELECTRIC VEHICLE CHARGERS

Adoption of electric vehicles relies, in part, on the availability of electric vehicle chargers. While Minnesota has a network of chargers (Map 1), Minnesota has been slower to develop a network of fast-charging electric vehicle chargers. These are known as direct current fast-charging stations (DCFCs). DCFCs save drivers significant time, enhancing the appeal of electric vehicles. Minnesota currently has some DCFCs, primarily along major freeways (I-94 in the south and west and I-35 in the north).

Map 2: Electric Vehicle Chargers in Minnesota, 2018

(Includes J-1772, CHAdeMO, CCS/SAE, and NEMA 14-50 Chargers)



Source: PlugShare.com

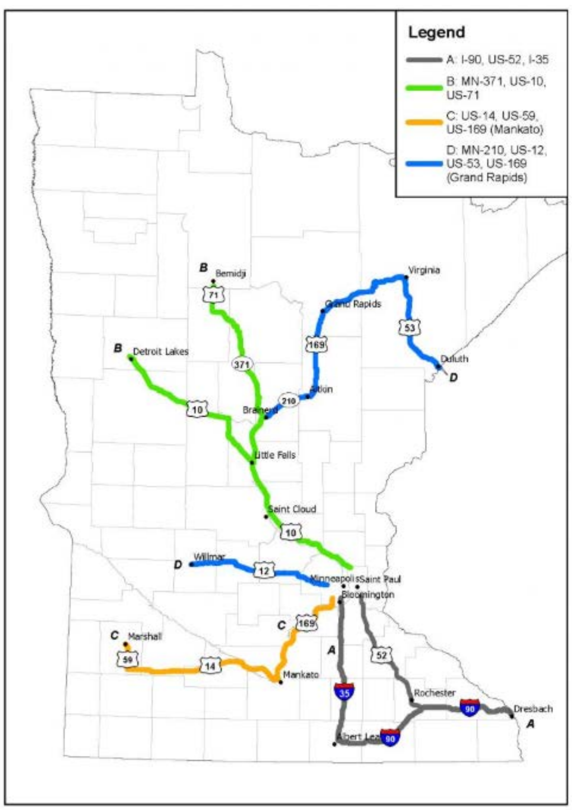
Policymakers are considering the role an expanded network of DCFCs would have on Minnesota's economy. Minnesotans' interests are driving the idea of an expanded network. In 2016, Volkswagen Corporation admitted to modifying vehicles, which in turn violated air pollution standards. In October 2017, the United States and Volkswagen Corporation signed an agreement for a $15 billion settlement. Minnesota received $47 million of the settlement.

To determine how to use the settlement funds, the Minnesota Pollution Control Agency (MPCA) conducted a series of activities to receive public input. Support for the development of the fast-charging electric vehicle chargers was clear in the public input. In fact, the MPCA concluded, "support for more electric vehicles was by far the most common comment the MPCA received during its public engagement efforts" (Smith, Sisk, Sulzbach, & Crotty, 2018). When Minnesota's draft plan for using the Volkswagen Corporation settlement funds was released for comment, 91% of all commenters and 45% of individual commenters wrote in support of the proposed electric vehicle-charging program.

The need for chargers in Greater Minnesota was also clear. In a survey with 507 responses, "respondents expressed a strong preference for charging along highway corridors to allow long-range travel between cities" (Smith, Sisk, Sulzbach, & Crotty, 2018).

Based on the information gathered from the public, the MPCA settlement plan includes three phases. In the first, phase, the plan designates $1,762,500 for the installation of DCFCs in Minnesota. The majority, $1.4 million, is for fast-charging electric chargers in Greater Minnesota. (The balance can be used for Level 2 or slower charging).

Map 3: Minnesota Pollution Control Agency Designated Fast Charging Electric Vehicle Charger Corridors, 2018



Source: Minnesota Pollution Control Agency

In its request for proposals in the first round, the MPCA designated DCFC corridors, or areas targeted for the development of chargers (Map 3). The first round of funding intends to fund the construction of 22 chargers along the corridors. Of those, the plan calls for 21 50kW chargers and one 150 kW charger. The MPCA plans for two additional funding rounds. Assuming 15 percent of the funds allocated go to electric vehicle chargers, 88 chargers could be installed with the settlement funds.[1]

Developing a network of DCFCs would generate economic activity in the state during the construction phase. Construction companies, electric workers, utilities, and equipment manufacturers would all see increased demand during build-out. As those businesses have additional demand, they will increase demand on their suppliers, creating a ripple of economic effects. These effects can be measured and quantified. Together, they are the total economic contribution.

Methods

Total economic contribution is composed of direct, indirect, and induced effects. Calculating total economic contribution begins with determining direct effects. Indirect and induced effects are then calculated using input-output models. This analysis uses the input-output model IMPLAN, version 3.0 with SAM multipliers and 2016 data.[2] Since the chargers will be built in Greater Minnesota, this analysis focuses on the impact in Greater Minnesota.

Direct Effects

The direct effect of the construction of a network of DCFCs includes the spending to purchase, install, and maintain the network. This analysis focuses only on the construction effects, making it a conservative analysis. The analysis does not include any potential benefits of an increase in the number of electric vehicles or an increase in electricity costs and use.

To quantify the direct effect, Extension worked with project partner Drive Electric Minnesota. Drive Electric Minnesota provided costs estimates from two companies. The estimates included costs for equipment, installation, engineering and design, and project management. Extension also consulted estimates from the United States Department of Energy (Smith & Castellano, 2015).[3] Extension prepared the budget for installing one fast-charging electric vehicle chargers from the cost estimates. Cost estimates can vary significantly. Extension created a single cost estimate from a range.

The cost estimates were grouped into four areas: charger-related equipment (including the direct current fast-charging unit and related switchgears and panels), engineering, design, and permitting, installation and upgrades (including necessary utility upgrades), and maintenance costs (Table 1). The cost estimates were then mapped to the appropriate IMPLAN sectors.

Fast-charging electric vehicle charging units are highly specialized. Greater Minnesota does not have a major manufacturer in the industry. Thus, purchases of the units will not generate much activity in Greater Minnesota. To account for this, the model's local purchase coefficient was set to the model default. This is shown in the percent local column of Table 1. Construction, however, is 100 percent local, since it is done at the site of the unit.

[1] Phase one of the settlement plan calls for 15 percent of the total spending to be on electric vehicle chargers. Other projects include a school bus replacement program and programs to replace heavy-duty equipment (both on and off road) with more efficient vehicles.
[2] www.implan.com
[3] Estimates from the Department of Energy are cited by MPCA in the settlement proposal plan.

Table 1: Fast-Charging Electric Vehicle Charger Cost by Category and Corresponding IMPLAN Sector

	IMPLAN Sector (s)	Percent Local (Greater MN)
Charger-related equipment	332 (Power, distribution, and specialty transformer manufacturing)	1.0%
	334 (switchgear and switchboard apparatus manufacturing	2.7%
Engineering, design, permitting	449 (Architectural, engineering, and related services)	37.9%
Installation and upgrades	49 (Electric power transmission and distribution)	88.9%
	54 (Construction of new power and communication structures)	100%
Annual maintenance costs	62 (Maintenance and repair construction of nonresidential structures)	74.5%

Extension then considered multiple scenarios for the build-out of the network. The first three scenarios focused on adding 150 fast-charging electric chargers. The estimation of 150 chargers was based on work done by the National Renewable Energy Laboratory (NREL) examining the potential for direct current fast-charging expansion in Colorado (Wood & Rames, 2017). In that analysis, the authors develop a formula for determining the number of DCFCs needed per number of PEVs. Their formula states there is a need for five DCFC plugs per 1,000 vehicles. The current average plugs per station is 2.5.

Minnesota had 7.1 million registered vehicles in 2017 (D. Neville, personal communication, July 18, 2018). Assuming Minnesota were to increase its electric vehicle ownership to one percent of all registered vehicles; there would be 71,000 PEVs in the state. The one percent was selected because current market share for electric vehicles is slightly more than one percent, so it seems feasible total ownership would eventually approach new market share. Using NRELs formula, this would lead to a need for 150 DCFCs in the state.

The first scenario measures the contribution of adding 150 50kW fast-chargers. The second scenario examines the contribution of adding 150 150kW fast-chargers. The third scenario looks at adding 75 of the 50kW chargers and 75 of the 150kW chargers.

The fourth scenario measures the contribution of adding 88 chargers. Of those, four would be 150kW chargers and 84 would be 50kW chargers. This reflects the potential if the MPCA settlement plan were to extend 15 percent investment over all three-project phases.

Indirect and Induced Effects

Input-output models trace the flow of dollars throughout a local economy and capture the indirect and induced, or secondary, effects of an economic activity. To quantify the indirect and induced effects of the construction of the network, the direct effects were entered into the input-output model IMPLAN.

Indirect effects are those associated with a change in economic activity due to spending for goods and services directly tied to the direct effect. In this case, these are the changes in the local economy occurring due to the purchases of goods (e.g., direct current fast-chargers, electric panels and switchgear, and utility upgrades) and related services (e.g., engineering, project management). As purchases are made for the construction of the network, this creates an increase in purchases across the supply chain. Indirect effects are the summary of these changes across an economy.

Induced effects are those associated with a change in economic activity due to spending by the employees of businesses (labor) and by households. These are economic changes related to spending by people directly employed to construct, install, and maintain the network. They create effects as they make purchases for things like health care, housing, and food. Induced effects also include household spending related to indirect effects.

Total Effects

Economic contribution effects can be measured in terms of output (sales), labor income, and employment. Output is typically the most common result of an economic contribution study. Labor income is also recommended as a measure, because it indicates the economic benefits that accrue for study area residents. Employment includes full-time, part-time, and seasonal employment, not full-time equivalents.

This analysis looks at construction effects, which are short-term in nature. The impact of construction will occur in the economy during the construction phase. When construction is complete, the effects will dissipate.

Potential for Development

As displayed in Table 1, inputs into the construction of DCFCs are not widely available from Greater Minnesota businesses. The model estimates only 1 percent of the DCFC units and 3 percent of the switchgear apparatus could be purchased in Greater Minnesota. This indicates an economic opportunity. If Greater Minnesota companies were to produce the necessary equipment, the economic impact would increase. To illustrate, Extension modeled with effects of an increase in local purchases to 25 percent for both DCFC and switchgear apparatus.

Further, the construction of fast chargers provides an opportunity for increased employment in the state. Construction and installation companies may need to hire and train additional employees. This may prove difficult. Currently, Minnesota's labor market is tight. The state's seasonally adjusted unemployment rate was 3.1 percent in May 2018. While the rate varies by county across Greater Minnesota, unemployment is still at the lowest rates in more than a decade.

At the same time, efforts are underway across the state to train clean energy workers. A 2014 report (Melville, Steichen, & Kaiser) on Minnesota's clean energy economy indicate the number of jobs in the clean energy sector increased by 78 percent between 2000 and 2014. During the same period, Minnesota's overall employment grew by 11 percent.

To explore this issue, Extension used the EMSI database to explore trends in the electrical and electronic equipment mechanics, installers, and repairers industry. In addition, Extension examined previous research on potential training programs.

Results

This section of the report explains the results from the analysis.

Direct Effects

For purposes of this project, Extension had to establish an average cost per charger. While the estimates should reflect an "average" charger, costs can vary significantly. Factors affecting cost include location and complexity of site, utility availability, distance of site from current utilities, and design. Of particular note related to design is the plan for future use. Options that fit today's needs only are often cheaper. Costs are higher if the project builds in room for future upgrades, which may cost less in the longer-run. In all likelihood, the construction of the network will involve some chargers being built on the low-end of the range and others being built on the high-end of the range.

Extension estimates a 50kW DCFC would cost $88,000 to install and maintain (Table 2). This is an average based on three cost estimates available. However, Extension estimates construction costs could range from $50,500 to $124,500. The average used in the analysis is not the mid-point of the cost range. This is because Extension had multiple estimates and considered the mid-point of all three in the determination of the average.

Table 2: Estimated Cost to Construct One 50 kW Fast-Charging Electric Vehicle Charger

	"Average"	Range	Factors Affecting Cost
Charger-related equipment	$30,000	$25,000-$50,000	High range reflects equipment that could be upgraded to higher power without requiring a new unit.
Installation, engineering, and electrical upgrades	$51,400	$20,000-$67,000	Highly variable depending on complexity of site for development, location, distance from current utility structures, and current status of electrical availability
Annual maintenance costs (does not include electric costs)	$6,600	$5,500-$7,500	Less variability, primarily covers warranty and network fees
Total	$88,000	$50,500-$124,500	

Estimates based on cost estimates provided to Extension by Drive Electric Minnesota and the Department of Energy

A 150kW DCFC would cost an estimated average of $131,900 to install and maintain (Table 3). The higher construct costs result from both higher costs for the individual units and from higher installation costs.

Table 3: Estimated Cost to Construct One 150 kW Fast-Charging Electric Vehicle Charger

	"Average"	Range	Factors Affecting Cost
Charger-related equipment	$55,500	$40,000-$70,000	Range depends on size and scale of unit
Installation, engineering, and electrical upgrades	$69,800	$55,000-$125,000	Variable depending on complexity of site for development, location, and costs of utility upgrades
Annual maintenance costs (does not include electric costs)	$6,600	$5,500-$7,500	Less variability, primarily covers warranty and network fees
Total	$131,900	$100,500-$202,500	

Estimates based on cost estimates provided to Extension by Drive Electric Minnesota and the Department of Energy

Annual maintenance costs include installation warranty, maintenance, and network fees. The costs are limited maintenance costs directly associated with the installation. They do not include the annual operating costs, such as electricity costs.

Total Effects

In total, the addition of 150 50kW DCFCs in Greater Minnesota would generate $12.1 million in economic activity (Table 4). This includes $4.0 million in labor income. The activity would create 80 jobs. The short-term construction effects will dissipate when construction is completed.

The direct effect in the table reflects direct spending in Greater Minnesota. For example, each unit on average will cost $30,000. The spending in Greater Minnesota will be around $300-$500, since the units are not manufactured in the region.

Table 4: Total Economic Contribution, Construction of 150 50kW Fast-Charging Electric Vehicle Chargers in Greater Minnesota

	Output (millions)	Employment	Labor Income (millions)
Direct	$7.9	50	$2.9
Indirect	$2.1	10	$0.5
Induced	$2.1	20	$0.6
Total	$12.1	80	$4.0

Estimates by University of Minnesota Extension

In total, the addition of 150 150kW DCFCs in Greater Minnesota would generate $16.3 million in economic activity (Table 5). This includes $5.2 million in labor income. The activity would create 90 jobs. The short-term construction effects will dissipate when construction is completed.

Table 5: Total Economic Contribution, Construction of 150 150kW Fast-Charging Electric Vehicle Chargers in Greater Minnesota

	Output (millions)	Employment	Labor Income (millions)
Direct	$10.5	60	$3.7
Indirect	$3.1	10	$0.7
Induced	$2.7	20	$0.8
Total	$16.3	90	$5.2

Estimates by University of Minnesota Extension

In total, the addition of 75 50kW and 75 150kW DCFCs in Greater Minnesota would generate $14.2 million in economic activity (Table 6). This includes $4.6 million in labor income. The activity would create 80 jobs. The short-term construction effects will dissipate when construction is completed.

Table 6: Total Economic Contribution, Construction of 75 50kW and 75 150 kW Fast-Charging Electric Vehicle Chargers in Greater Minnesota

	Output (millions)	Employment	Labor Income (millions)
Direct	$9.2	50	$3.3
Indirect	$2.6	10	$0.6
Induced	$2.4	20	$0.7
Total	$14.2	80	$4.6

Estimates by University of Minnesota Extension

In total, the addition of 84 50kW and four 150kW DCFCs in Greater Minnesota would generate $7.3 million in economic activity (Table 7). This includes $2.4 million in labor income. The activity would create 45 jobs. The short-term construction effects will dissipate when construction is completed.

Table 7: Total Economic Contribution, Construction of 84 50kW and 4 150 kW Fast-Charging Electric Vehicle Chargers in Greater Minnesota

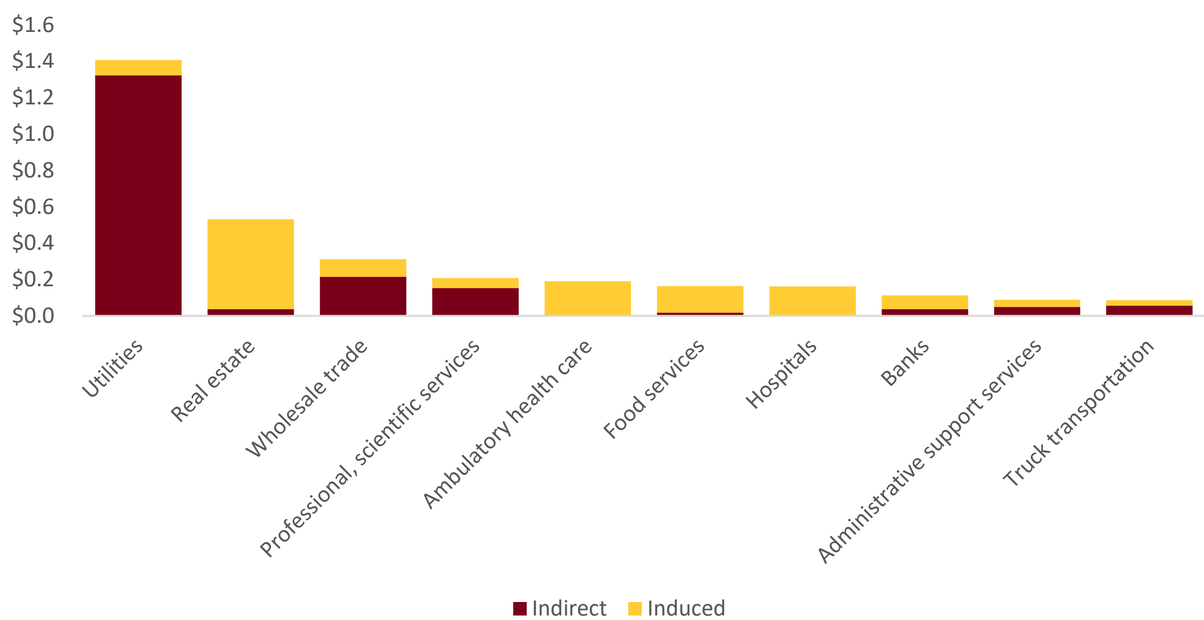
	Output (millions)	Employment	Labor Income (millions)
Direct	$4.7	30	$1.7
Indirect	$1.3	5	$0.3
Induced	$1.3	10	$0.4
Total	$7.3	45	$2.4

Estimates by University of Minnesota

Top Industries Affected

Of the $14.2 million in activity generated during construction of 75 50kW and 75 150 kW DCFCs, $9.2 million will be for the construction itself. However, $5.0 million will be in other industries in Greater Minnesota. The industries feeling the largest impacts include utilities, real estate, and wholesale trade (Chart 1). The indirect effects are high in the utilities, wholesale trade industries, and professional services as these are all suppliers into the construction process. Induced effects are high in real estate and health care, as these are major components of a household budget.

Chart 1: Top Industries Affected, Construction of 75 50kW and 75 150kW Fast-Charging Electric Vehicle Chargers, Greater Minnesota



The impacts on utilities are noteworthy. Construction of DCFCs will place demand on utilities, first as construction upgrades are made and then as power is provided to electric vehicles. As changes are made to Minnesota's energy portfolio, the types of utility impacts will also shift. Xcel Energy, for example, plans to add wind capacity and close its two of its Sherco coal generators by 2026. Coal's share of electric power generation is expected to decline from 34 percent to 15 percent by 2030 (McFarlane 2017).

Potential for Development

Currently, the model estimates only a slight portion of the fast charger unit will be purchased in Greater Minnesota, as it is not home to a manufacturer. This presents an opportunity. Increased manufacturing in the region will create a higher economic impact. To demonstrate, Extension increased the local purchasing of the units from one percent to 25 percent.

Correspondingly, the total economic contribution increased. In total, the addition of 75 50kW and 75 150kW DCFCs in Greater Minnesota (with 25 percent local purchasing) would generate $16.1 million in economic activity (Table 8). This includes $5.1 million in labor income. The activity would create 90 jobs.

Table 8: Total Economic Contribution, Construction of 75 50kW and 75 150 kW Fast-Charging Electric Vehicle Chargers in Greater Minnesota with 25 Percent Local Manufacturing Purchases

	Output (millions)	Employment	Labor Income (millions)
Direct	$10.7	60	$3.6
Indirect	$2.8	10	$0.7
Induced	$2.6	20	$0.8
Total	$16.1	90	$5.1

Estimates by University of Minnesota Extension

Given Minnesota's low unemployment rates, it is likely the jobs created to construct and install the fast-chargers will require hiring and training. Many workers needed are likely to belong to the electrical and electronic equipment mechanics, installers, and repairers' occupation. According to the EMSI database, this occupation in Minnesota has "aggressive hiring competition over a thin supply of regional talent." In an average month over the last 12 months, there were 355 unique job postings in the occupation (Table 9). However, businesses only filled 165 positions, indicating difficulties in hiring. The national average of postings per month is 81. Greater Minnesota has 176.

Table 9: Occupational Data, Electrical and Electronic Equipment Mechanics, Installers, and Repairers, Greater Minnesota, July 2018

Category	Value
Unique job postings	355
Positions filled	165
Postings per month, national average in U.S.	81
Postings per month, Greater Minnesota	176

Source: EMSI, Inc.

This makes the argument that training will be essential to hiring new positions. Previous research by Extension indicates there are training opportunities being developed. Renewable Energy Partners is one example. Renewable Energy Partners is exploring the option to open a clean energy training facility in North Minneapolis. The training facility would focus on providing training opportunities to diverse and underserved audiences in the neighborhood. Potentially, these workers could be trained to install and construct the fast-chargers.

Discussion

Minnesotans are purchasing electric vehicles. Continued adoption of the technology in Minnesota will require the addition of DCFCs across the state. In particular, a network of chargers will provide access and allow for travel across the state. The construction of fast-charging electric vehicle chargers has the potential to add to Minnesota's economy.

While the potential contribution of the construction of the chargers is clear from this analysis, opportunities exist to enhance the contribution. Currently, a significant portion of expenditures would go to companies based outside of Minnesota. Economic contribution could be higher if the companies manufacturing the units were located within the state. Second, given the state's low unemployment rate, training opportunities could be designed and focused to help underserved and diverse audiences gain valuable technical skills and jobs in the clean energy economy.

Construction effects are short-term in nature. The impacts will be in the economy during the construction phase. Once the construction is complete, the effects will dissipate. Since this portion of the analysis only examines the construction effects, it is by nature a conservative analysis. Construction events are by nature, job creators. Changes in the economy can result in the offset of job losses in other industries. The infusion of construction jobs to develop the network, however, is anticipated to only add jobs.

MEASURING THE ECONOMIC CONTRIBUTION OF THE ADOPTION OF ELECTRIC VEHICLES

The economic contribution of adopting electric vehicles is a complex and nuanced analysis. There are both micro- and macroeconomic considerations. Microeconomic considerations include the shifts in spending patterns by car owners. Changes start with the type of vehicle purchased and continue with different fuel purchases (electricity versus gasoline), maintenance (battery and vehicle), and registration and licensing fees. On the macro-level, large-scale shifts to electric vehicles could potentially affect national prices for gasoline and electricity. There are also environmental considerations. Evidence indicates electric vehicle usage can decrease greenhouse gas emissions (McFarlane, 2017). Decreased emissions may also prove to have long-term, macroeconomic consequences.

Methods

Given the complexity of issues around electric car adoption, any study needs to be clear in its focus. This analysis focuses on microeconomic changes. It measures how a small change in the number of electric vehicles being operated in Minnesota will affect the economy. The goal is to explore how the adoption of electric cars could affect households and regional economies. It also establishes a methodology. Future research can then focus on scaling up the analysis and exploring macro-level economic effects.

This research quantifies the impact of a small number of households (1,000) trading a medium-sized sedan for an electric vehicle. The number of 1,000 households was selected for illustrative purposes. Ideally, the analysis would have considered the impact of one representative household. However, the change of one household was minor enough to make the results difficult to interpret; scaling to 1,000 improves interpretation.

Total economic contribution is composed of direct, indirect, and induced effects. Calculating total economic contribution begins with determining direct effects. Indirect and induced effects are then calculated using input-output models. This analysis uses the input-output model IMPLAN, version 3.0 with SAM multipliers and 2016 data.[4] This analysis focuses primarily on the impact in Minnesota. The impact on Greater Minnesota is also explored.

[4] www.implan.com

Direct Effects

The direct effect of adopting electric vehicles includes the positive spending associated with operating an electric vehicle. However, it also has to include the loss of spending associated with a standard gasoline-powered vehicle (a medium-sized sedan).

To quantify the direct effect, Extension used the AAA's driving cost analysis. Annually, AAA uses proprietary methods to quantify the cost of driving different sizes and types of automobiles, including small sedans, medium sedans, large sedans, minivans, pickup trucks, hybrid cars, and electric cars (AAA 2017). Driving costs are calculated per mile for fuel, maintenance, repairs, and tires. They are calculated per year for insurance, registration, licensing, and fees, depreciation, and finance charges.

AAA averages costs over several models in each class size. Medium sedan models considered in their calculations include the Chevrolet Malibu, the Ford Fusion, the Honda Accord, the Nissan Altima, and the Toyota Camry. Electric vehicle models include the BMW i3, Chevrolet Bolt, Fiat 500e, Kia Soul, and Nissan Leaf.

For this analysis, Extension assumed the 1,000 households would exchange a medium-sized sedan for an electric car. Extension also assumed the households were driving 15,000 miles per year (the mid-point in the AAA data). The analysis includes three scenarios.

According to AAA, a medium-sized sedan cost $8,171 to drive 15,000 miles in 2017 (Table 10). The largest components of the cost were depreciation ($3,187) and fuel ($1,355). To measure economic contribution, the expenditures need to be mapped to the appropriate IMPLAN model code.

In input-output modeling, depreciation is not included in an analysis. This is because depreciation is an accounting technique, used to account for the decreasing value of an asset. However, it does not represent an actual purchase (or expenditure) occurring in the year. The cost to operate a medium sized sedan, excluding depreciation, is $4,984 per year.

Table 10: Annual Medium Sedan Vehicle Cost (15,000 Miles Driven) and Corresponding IMPLAN Sector

Type of Cost	Cost	IMPLAN Sector (s)
Fuel	$1,355	402 Gasoline stations (retail)
Maintenance, repair, and tires	$1,191	396 Motor vehicle and parts dealers
		504 Automotive repair and maintenance
Insurance	$1,202	437 Insurance carriers
License, registration, and fees	$639	526 Other local government enterprises
Depreciation	$3,187	Not included
Finance charge	$597	433 Monetary authorities and depository credit
Total	**$8,171**	
Total Without Depreciation	**$4,984**	

Source: AAA Driving Costs

An electric vehicle, driven 15,000 miles, cost $8,439 to drive in 2017 (Table 11). Major expenditures include depreciation ($5,704) and insurance ($1,185). According to AAA, electric vehicle owners had negative license, registration, and fee costs. This is due to the current federal incentive of $2,500 to $7,500 available to electric vehicle owners.[5] However, in Minnesota, electric vehicles owners actually pay more than a traditional vehicle, due to a $75 electric vehicle registration fee, on top of all other license and registration fees.

Cost comparisons show that electric vehicles have higher depreciation due to the higher cost of the initial vehicle. However, fuel and maintenance costs were lower compared to a medium-sized sedan in 2017.

As with the medium-sized sedan, depreciation is not included in the analysis. Further, AAA's estimate of negative registration, licensing, and fees stems from the federal tax incentive. However, Minnesota electric vehicle owners pay full fees, plus an additional electric vehicle fee, to license and register in the state. Therefore, this analysis uses a total of $714 for license, registration, and fees in Minnesota. This brings the full cost of operating an electric vehicle to $4,105.

Table 11: Annual Electric Vehicle Cost (15,000 Miles Driven) and Corresponding IMPLAN Sector

Type of Cost	Cost	IMPLAN Sector (s)
Fuel	$552	49 Electric power transmission and distribution
Maintenance, repair, and tires	$983	396 Motor vehicle and parts dealers 504 Automotive repair and maintenance
Insurance	$1,185	437 Insurance carriers
License, registration, and fees	-$656	526 Other local government enterprises
Depreciation	$5,704	Not included
Finance charge	$671	433 Monetary authorities and depository credit
Total	**$8,439**	
Total Without Depreciation	**$2,735**	
Total Without Depreciation, Adjusted Registration	**$4,105**	

Source: AAA Driving Costs

The first scenario in this analysis looks at 1,000 medium-sized sedans being replaced by 1,000 electric vehicles. In the model, this is reflected as an increase in spending of $4,105,000 by households for electric vehicle operation. It also includes a decrease in spending of $4,984,000 by households for medium-sized sedan operation.

Under the first scenario, an electric vehicle costs slightly less to drive 15,000 miles than a medium-sized sedan. However, the first scenario does not consider the implications for household spending. In reality, decreased spending on annual vehicle costs would translate into increased funds available for other household spending. Under the 2017 driving cost estimates, a medium sized sedan costs $879 more to drive (Table 12). Thus, the second scenario includes an increase in spending by households equal to the savings associated with operating an electric vehicle. In the model, this is reflected as an increase in spending of $4,105,000 by households for electric vehicle operation, a decrease in spending of $4,984,000 by households for medium-sized sedan operation, and an increase of household spending of $879,000 from cost savings.

[5] https://www.energy.gov/eere/electricvehicles/electric-vehicles-tax-credits-and-other-incentives

Table 12: Household Income Differentials, Medium Sized Sedan Compared to Electric Vehicle

Category	Cost	Difference from medium sedan
Cost to operate medium sedan	$4,984	N/A
Cost to operate electric vehicle	$4,105	-$879

Source: AAA Driving Costs and Extension Estimates

Currently, electric vehicle adoption rates are higher in the Twin Cities metro. Shorter average driving distances and availability of chargers drive this trend. The adoption of electric vehicles, however, will have impacts on both the Twin Cities metro and on Greater Minnesota. The input-output model can estimate how a change in one regional economy (the Twin Cities) will affect another regional economy (Greater Minnesota). The third scenario will quantify the effect of electric vehicle adoption in the Twin Cities on Greater Minnesota.[6]

AAA uses proprietary methods to calculate the total cost to operate a vehicle. To verify accuracy, Extension compared AAA's costs to the Alternative Fuels Data Center operated by the United States Department of Energy. The Alternative Fuels Data Center features a vehicle costs calculator. Extension selected the same medium sized sedan and electric vehicle models and calculated the average cost, based on the calculator. The Department of Energy calculator and the AAA cost estimates are relatively similar for both fuel and operations costs for electric vehicles (Table 13). Costs estimates are also close for fuel and operations of a medium-size sedan. Overall, the Department of Energy's costs are five percent higher for both electric vehicles and medium sized sedans. Thus, Extension is relatively confident the AAA estimates are valid.

Table 13: AAA Cost Estimates Compared to the Department of Energy, Vehicle Cost Calculator

Category	AAA Estimate	Department of Energy Estimate	Difference from AAA	Percent Difference
Electric vehicles				
Fuel	$552	$604	$52	9%
Operations	$2,735	$2,839	$105	4%
Total	$3,287*	$3,443	$156	5%
Medium sized sedan				
Fuel	$1,355	$1,392	$38	3%
Operations	$3,629	$3,821	$192	5%
Total	$4,984	$5,213	$229	5%

Source: AAA Driving Costs and U.S. Department of Energy Vehicle Cost Calculator; * does not include fees, so to be consistent with Department of Energy estimates

[6] Extension used the multi-regional input-output (MRIO) feature of IMPLAN for this scenario.

Indirect and Induced Effects

Input-output models trace the flow of dollars throughout a local economy and capture the indirect and induced, or secondary, effects of an economic activity. To quantify the indirect and induced effects of the adoption of electric vehicles, the direct effects were entered into the input-output model IMPLAN.

Indirect effects are those associated with a change in economic activity due to spending for goods and services directly tied to the direct effect. In this case, these are the changes in the local economy occurring due to the purchases of goods (e.g., electricity, car batteries, and tires) and related services (e.g., licensing, insurance). As purchases are made for during the adoption of electric vehicles, this creates an increase in purchases across the supply chain. Indirect effects are the summary of these changes across an economy.

Induced effects are those associated with a change in economic activity due to spending by the employees of businesses (labor) and by households. These are economic changes related to spending by people directly employed to staff the gasoline stations, repair automobiles, and provide the insurance. They create effects as they make purchases for things like health care, housing, and food. Induced effects also include household spending related to indirect effects.

Total Effects

Economic contribution effects can be measured in terms of output (sales), labor income, and employment. Output is typically the most common result of an economic contribution study. Labor income is also recommended as a measure, because it indicates the economic benefits that accrue for study area residents. Employment includes full-time, part-time, and seasonal employment, not full-time equivalents.

Results

This analysis has three scenarios. The results are presented here.

Economic Contribution of the Adoption of 1,000 Electric Vehicles

Overall, 1,000 households converting from a medium-sized sedan to an electric vehicle would generate an estimated $607,900 of new economic activity (output) in Minnesota (Table 14). However, the transition would lead to a decline of an estimated 3.3 jobs and $28,400 in labor income.

Table 14: Total Economic Contribution, Conversion of 1,000 Vehicles from Medium Sized Sedans to Electric Vehicles

	Output	Employment	Labor Income
Direct	$298,700	-3.6	-$72,600
Indirect	$328,900	0.4	$50,900
Induced	-$19,700	-0.1	-$6,700
Total	$607,900	-3.3	-$28,400

Estimates by University of Minnesota

This mixed results (positive output, negative employment impacts) stem from the shift in industry spending patterns. The industries with increased spending (electric utilities and banks) have higher output per person compared with industries with decreased spending (gasoline stations and repair and maintenance). Increasing spending in an industry with high output per worker will create fewer jobs. Thus, the increased number of jobs does not mitigate the lost jobs in sectors with lower output per person.

The industries gaining jobs as the result of electric vehicle adoption include utilities (electric), monetary authorities, and securities and other financial instruments (Table 15). The electricity purchases are driving increases in utilities. The increase for monetary authorities results from higher monthly payments for electric vehicles, due to the higher purchase price.

Table 15: Top Industries Impacted, Sorted by Employment Conversion of 1,000 Vehicles from Medium Sized Sedans to Electric Vehicles

	Job Change
Top Job Gaining Industries	
Utilities	0.7
Monetary authorities (banks)	0.3
Securities and other financial instruments	0.1
Top Job Loss Industries	
Gasoline stations	-3.1
Repair and maintenance	-1.1
Motor vehicle and parts dealers	-0.2

Estimates by University of Minnesota

Industries with job losses include gasoline stations, repair and maintenance, and motor vehicle and parts dealers. The decreases result from lower spending by electric vehicle owners on gasoline and repairs and maintenance. The decrease in gasoline station jobs is partially driven by model classification. Right now, consumers purchase gasoline at stations, driving activity. Electric charging stations could be installed at gasoline stations, which would substitute for lost gasoline stations. However, the analysis did not model this potential shift.

In terms of output, the utilities, monetary authorities, and state and local government industries are the top three industries with output increases (Table 16). Industries with the highest output losses are gasoline stations, repair and maintenance, and insurance carriers.

Table 16: Top Industries Impacted, Sorted by Output Conversion of 1,000 Vehicles from Medium Sized Sedans to Electric Vehicles

	Output Change
Top Output Gaining Industries	
Utilities	$866,600
Monetary authorities (banks)	$81,200
State and local government	$13,300
Top Output Loss Industries	
Gasoline stations	-$198,000
Repair and maintenance	-$105,200
Insurance carriers	-$26,700

Estimates by University of Minnesota

Currently, utility sectors experiencing the largest impacts from an increase in electric usage would mirror Minnesota's energy portfolio. However, Minnesota is emphasizing the use of renewable energy in power generation for electric vehicles. As this occurs, demand from electric vehicles will drive increased purchases of wind, hydroelectric, biomass, and solar energy.

Economic Contribution of Conversion of 1,000 Vehicles and Increased Household Income

Electric vehicles, excluding depreciation, cost an owner less to operate per year. The operational savings translate into additional income for household spending. This scenario looks at the economic contribution of the adoption of electric vehicles and includes the positive economic impact of increased household spending.

Under this scenario, the economic contribution of the conversion to electric vehicles would create $1.8 million in economic activity (Table 17). This includes $366,900 in labor income and five jobs. The direct employment and labor income effects are negative, due to the shifting patterns of spending. However, the higher induced effects from household spending offset the decreases.

Table 17: Total Economic Contribution, Conversion of 1,000 Vehicles from Medium Sized Sedans to Electric Vehicles, Including Household Income

	Output	Employment	Labor Income
Direct	$298,700	-3.6	-$72,600
Indirect	$328,900	0.4	$50,900
Induced	$1,136,400	7.9	$388,600
Total	$1,764,000	4.7	$366,900

Estimates by University of Minnesota

In this scenario, the top industries gaining jobs include food services and drinking places, utilities, and ambulatory health care (Table 18). Job losses accrue at gasoline stations, repair and maintenance services, and motor vehicle and parts dealers. The health care increase reflects household spending, as health care is a major component of every household's spending. A household may now be able to have an elective operation or seek treatment for a condition.

Table 18: Top Industries Impacted, Sorted by Employment Conversion of 1,000 Vehicles from Medium Sized Sedans to Electric Vehicles, Including Household Income

	Job Change
Top Job Gaining Industries	
Food services and drinking places	1.0
Utilities	0.8
Ambulatory health care	0.6
Top Job Loss Industries	
Gasoline stations	-3.0
Repair & maintenance	-0.9
Motor vehicle & parts dealers	-0.1

Estimates by University of Minnesota

The largest output gains are in the utilities, real estate, and monetary authorities industries (Table 19). The increase in real estate likely results from households having additional income to spend on housing. The largest output losses are in the gasoline stations, repair and maintenance, and motor vehicle and parts dealers industries.

Table 19: Top Industries Impacted, Sorted by Output Conversion of 1,000 Vehicles from Medium Sized Sedans to Electric Vehicles, Including Household Income

	Output Change
Top Output Gaining Industries	
Utilities	$900,500
Real estate	$169,100
Monetary authorities	$124,200
Top Output Loss Industries	
Gasoline stations	-$193,000
Repair & maintenance	-$87,100
Motor vehicle & parts dealers	-$9,800

Estimates by University of Minnesota

Economic Contribution of on Twin Cities and Greater Minnesota

Currently, electric car adoption rates are higher in the Twin Cities. The adoption of the electric cars, however, has an impact on Greater Minnesota. This analysis assumes all the households adopting electric vehicles are in the seven-county Twin Cities metro.

Adoption of electric vehicles by metro area households would increase output in Greater Minnesota by $246,000 (Table 20). It would add 0.7 jobs and $44,600 of labor income. Approximately 14 percent of the total output and employment gains would accrue to Greater Minnesota.

Table 20: Total Economic Contribution, Conversion of 1,000 Vehicles from Medium Sized Sedans to Electric Vehicles, Including Household Income on Greater Minnesota

	Output	Employment	Labor Income
Direct	$0	0	$0
Indirect	$202,500	0.4	$33,600
Induced	$43,500	0.3	$11,000
Total	$246,000	0.7	$44,600

Estimates by University of Minnesota

Discussion

Overall, the adoption of electric vehicles has the potential to increase economic activity in Minnesota. Adoption is predicted to add output and jobs in the utilities, banking, and food services industries. However, adoption will also potentially lead to job losses, particularly in the gasoline stations, automobile repair and maintenance, and motor vehicle and parts industries. Job losses in the gasoline station industry could be offset by installing electric vehicle chargers at current gasoline stations, thus encouraging purchases from those businesses. This analysis did not model this potential shift.

The analysis uses the 2017 costs to operate a vehicle. Clearly, changes in costs could significantly affect the results. Gas and electricity prices, for example, are based on 2017. Either price could vary, depending on supply and demand. This analysis does not consider impacts on the automobile manufacturing industry. Minnesota does not have significant employment or output in the industry, therefore, the effects on the state would be minor. However, if this analysis were to be conducted in a state with high automobile manufacturing, including a measure of the impact on that sector would be critical.

This analysis explores the micro-level effects of adoption of electric vehicles. It provides a framework for modeling the change on a smaller-scale. However, it does not account for potential macro-level changes. Widespread adoption of electric vehicles has the potential to alter gasoline (with decreased demand) and electricity (with increased demand) prices. The IMPLAN model used here does not account for price changes. The results would not be expected to hold given large fluctuations in prices. Future research could explore how demand changes would affect prices.

Further, the widespread adoption of electric vehicles has potential to affect the environment. If electric vehicles reduce emissions by a significant level, this would have positive economic effects not measured in this analysis. Further research could measure how emissions reductions would affect economic activity in Minnesota.

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