414 Nicollet Mall
Minneapolis, MN 55401

January 11, 2021

—Via Electronic Filing—

Mr. Will Seuffert
Executive Secretary
Minnesota Public Utilities Commission
121 7th Place East, Suite 350
St. Paul, MN 55101

RE: SUPPLEMENT
ELECTRIC VEHICLE PROGRAMS AS PART OF COVID-19 RELIEF AND RECOVERY
DOCKET NO. E002/M-20-745

Dear Mr. Seuffert:

Northern States Power Company, doing business as Xcel Energy, submits to the Minnesota Public Utilities Commission (Commission) this Supplement on the costs and benefits of electric vehicle (EV) adoption. In our October 30, 2020 Reply Comments in this docket, we indicated that we would work expeditiously with a third-party to file a detailed analysis.[1]

The Company worked with consulting firm, Energy+Environmental Economics (E3), to prepare the analysis. E3 is an energy consulting firm that helps utilities, regulators, and policy makers make the best strategic decisions possible as they implement new public policies, respond to technological advances, and address customers' shifting expectations. E3 has conducted similar studies for EVs for Hawaii, Washington, Oregon, Ohio, New York, New Mexico, Arizona, Massachusetts, California, and Colorado. This letter provides a high-level overview of the process that was used to prepare the analysis, along with some context around the results. The full report can be found as Attachment A.

E3's report incorporated Minnesota-specific data, including EV adoption scenarios, electricity supply costs, the Commission's approved environmental cost

[1] See pages 2-3 of our *Reply Comments*, also filed in Docket Nos. E002/M-18-643 and E002/M-20-711

values for pollutants[2], and electric rates. The report evaluated the net benefits to EV drivers, Company customers (i.e., non-participant ratepayers), and the citizens of Minnesota from the adoption of EVs in our service territory. Given the upfront and direct incentives that the proposed EV rebate proposals would have on EV adoption, in addition to a growing network of public DCFC stations, this analysis considered increases in EV adoption that we expect to occur as the result of the EV programs we have proposed.

The results of the analysis show that EV adoption paired with managed charging is a net benefit for the drivers through lower fuel and maintenance costs, even when the higher initial cost is factored in. The study also supports the expectation that the expansion of EV adoption could place downward pressure on overall electric rates in the Minnesota service territory. EV charging can be a beneficial new load to all customers, as the study identifies that the largest benefits will accrue to society as a whole when factoring in the estimated societal benefit of emissions reductions.

Table 1 below shows the estimated net present values, broken down by vehicle type and group receiving the benefit amount. The amounts shown in the table represent the benefits from general EV adoption and assume the use of managed charging programs.

Table 1
NPV for All Vehicles Adopted - 2020 through 2030
($ in Millions)

Vehicle Type	Ratepayers	Participants	Society
Light-Duty with Managed Charging	$339	$26	$366
Medium-Duty with Managed Charging	$1	$45	$50
Heavy-Duty with Managed Charging	$21	$44	$82
Total	**$361**	**$116**	**$497**

Beyond general EV adoption shown in Table 1, the E3 study also assessed the costs and benefits of a larger Public DCFC network and the proposed rebate programs detailed in this docket. The E3 analysis shows that, in aggregate, increasing Public DCFC access and the rebate programs show a net benefit to ratepayers, participants, and society. When viewed from a marginal benefits

[2] The report uses the Commission's current environmental externality values for carbon and criteria pollutants in compliance with Order Point No. 7 of the Commission's February 1, 2019 *Order Making Findings and Requiring Filings* in Docket No. E999/CI-17-879.

perspective, the Public DCFC and light-duty rebate programs together can be reasonably expected to increase net benefits to ratepayers compared to the status quo, as upfront EV incentives and increased public charging access can help spur light-duty EV adoption while encouraging managed charging and hastening the arrival of the benefits from transportation electrification. Table 2 below summarizes the NPV results for these programs.

Table 2
NPV for EV Adoption Related to Proposed Programs
($ in Millions)

Vehicle Type	EV Program	Ratepayers	Participants	Society
Light-Duty	Public DCFC[3]	$346	$41	$391
Light-Duty	Rebate	$411	$43	$335
Heavy Duty	Bus Rebate	($51)	$14	($35)

For the rebate programs, the study shows significant benefits in total, but shows that the bus rebate program is expected to be a net cost for ratepayers. However, when looking at all vehicles being adopted and across all vehicle types, the rebate programs can deliver a positive benefit to ratepayers and facilitate the growth of transportation electrification benefits to a large part of the population. In addition, the Company maintains that there are intangible benefits of the bus rebate program that are not captured in the analysis, including broader economic, societal, and equity benefits that the program aims to promote. The bus rebate program will help facilitate a needed public service, public transportation.

An expansion of bus electrification can open the benefits of transportation electrification to a much larger number of users through an expansion of public transit service with electric buses. These benefits will accrue to groups that currently do not often have access to electric vehicles, including lower-income communities, communities impacted by higher transportation-related emissions, and communities with predominately black, indigenous, and people of color (BIPOC) residents.[4]

Last, the E3 study very conservatively assumes that rebates supporting the electrification of public transit vehicles would not adjust heavy-duty electric vehicle

[3] E3 analysis for this program is based on 70 new DCFC plugs, not 21 stations mentioned in our initial proposal. The number of plugs at each station may vary. 70 new DCFC plugs would approximately double the current DCFC infrastructure in Minnesota.
[4] BIPOC and low-income populations are more likely to live close to transit service than non-BIPOC and non-low-income populations in Metro Transit's service Area, Metropolitan Council Title VI Program, January 2020, Page 38, https://www.metrotransit.org/Data/Sites/1/media/about/titlevi/2020%20Title%20VI%20Program%20Update.pdf

adoption rates above the existing forecast. Rather, the rebates would help make those forecasts a reality. However, it is important to underscore the uncertainty surrounding this assumption given the lack of data on electric vehicle adoption among fleets, as the E3 study notes.

In quantifying the future costs and benefits, the report analyzes the long-term ratepayer and societal benefits, stemming from grid management, public health, and societal impacts.[5] This includes the risk of stranded investments, given that the E3 report assesses costs and benefits over the useful life of EVs and their associated infrastructure and finds positive net benefits from transportation electrification and the Company's proposed light-duty rebate and Public DCFC station proposals.

We have electronically filed this document with the Minnesota Public Utilities Commission and copies have been served on the parties on the attached service list.

Please contact Holly Hinman at Holly.R.Hinman@xcelenergy.com or 612-330-5941 or Martha Hoschmiller at Martha.E.Hoschmiller@xcelenergy.com or 612-330-5973 if you have any questions regarding this filing.

Sincerely,

/s/

HOLLY HINMAN
REGULATORY MANAGER

Enclosures
c: Service List

[5] As prescribed in Order Point No. 7 of the Commission's February 1, 2019 *Order Making Findings and Requiring Filings* in Docket No. E999/CI-17-879

Cost-Benefit Analysis of Transportation Electrification in the Xcel Energy Minnesota Service Territory

January 2021

Energy+Environmental Economics

Cost-Benefit Analysis of Transportation Electrification in the Xcel Energy Minnesota Service Territory

January 2021

Energy and Environmental Economics, Inc.
44 Montgomery Street, Suite 1500
San Francisco, CA 94104
415.391.5100
www.ethree.com

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Executive Summary

Study Aims and Methodology

This work aims to inform Xcel Energy, Minnesota policymakers, and other stakeholders on the impacts of transportation electrification in Xcel Energy's Minnesota service territory. To achieve these aims Energy and Environmental Economics, Inc. (E3) conducted cost-benefit modelling to evaluate the economic and electric grid impacts of plug-in electric vehicle (PEV) adoption.

E3 employed its EVGrid model to capture key interactions between drivers, vehicles, chargers, utility costs, incentives, and gasoline costs. In this study, we consider the impacts of PEV adoption from 2020 to 2030 and costs and benefits are analyzed from ratepayer, driver, and societal perspectives that are captured through three cost tests:

+ Ratepayer Impact Measure (RIM): the costs and benefits to non-participating ratepayers in Xcel Energy's Minnesota territory – will average utility rates increase or decrease?
+ Participant Cost Test (PCT): the costs and benefits to the vehicle driver or fleet owner – is the total cost of ownership higher or lower for the driver?
+ Societal Cost Test (SCT): the costs and benefits to Minnesota State – do EVs provide net benefits for the state as a whole?

Vehicle Types and Scenarios

The study explored how costs and benefits vary under different vehicle types, charging control, charging infrastructure deployment, and utility program scenarios. The base case for each vehicle type studied:

- **Managed Personal Light-Duty Vehicle (LDV) base case:** This case calculates the costs and benefits arising from personal light duty PEV drivers. We simulate 4 different PEV types and assume charging is managed to minimize electric bills in the base case.
- **Medium Duty Vehicles:** Parcel vans are assumed to only charge at their depot location where each van has access to a fast charger. Charge management occurs to minimize electricity bills.
- **Heavy Duty Vehicles:** Transit buses are modelled very similarly to parcel vans assuming they only charge at their depot location and that charging is managed.

Four sensitivity cases were also performed to evaluate the impact of unmanaged charging and programs Xcel Energy has proposed to accelerate EV adoption and increase benefits to Minnesota drivers, Xcel Energy's non-participating ratepayers, and the State:

- **Unmanaged Personal Light-Duty Vehicle (LDV):** This case calculates the costs and benefits arising from personal light duty PEV drivers who charge in an uncontrolled or unmanaged manner.
- **Personal LDV high DCFC:** This scenario tests the impact of deploying 70 DCFCs across Xcel Energy's Minnesota territory. The scenario assumes adoption is increased relative to the personal LDV case to account for the indirect network effects of reducing range anxiety and increasing consumer awareness from having a denser DCFC network. The scenario assumes that charging is managed to minimize customer bills.

- **Personal LDV rebate:** This case models the impact of Xcel Energy's proposed LDV rebate. In this sensitivity we model the impact the rebate has on personal LDV adoption and assume charging is managed to minimize customer bills.
- **HDV Transit Bus rebate:** This scenario models Xcel Energy's proposed transit bus rebate using Metro Transit bus cost data.

Base Case Results

Overall, this study finds that under the base scenarios for all vehicle types *ratepayers stand to benefit by nearly $361 million* in net present value from PEV adoption between 2020 and 2030. *Drivers or fleet owners would benefit by $116 million* in lower total cost of ownership and *Minnesota would benefit by $497 million* from avoided gasoline, reduced O&M, emission reductions, and federal tax credits. Table 1 summarizes the total Net Present Value (NPV) of all cases. These values represent the total costs and benefits over each vehicle's 12-year lifetime, summed for every vehicle adopted from 2020 to 2030 and discounted using Xcel Energy's weighted average cost of capital (WACC).[1]

Table 1. Total Net Present Value (NPV) for all vehicles adopted between 2020 – 2030 in ($ Million)

Case	Ratepayer	Driver	Societal
Personal LDV – managed charging	$339	$26	$366
Parcel Trucks (MDV) – managed charging	$0.6	$45	$50
Transit Buses (HDV) – managed charging	$21	$44	$82
Total Base Case Impacts	**$361**	**$116**	**$497**

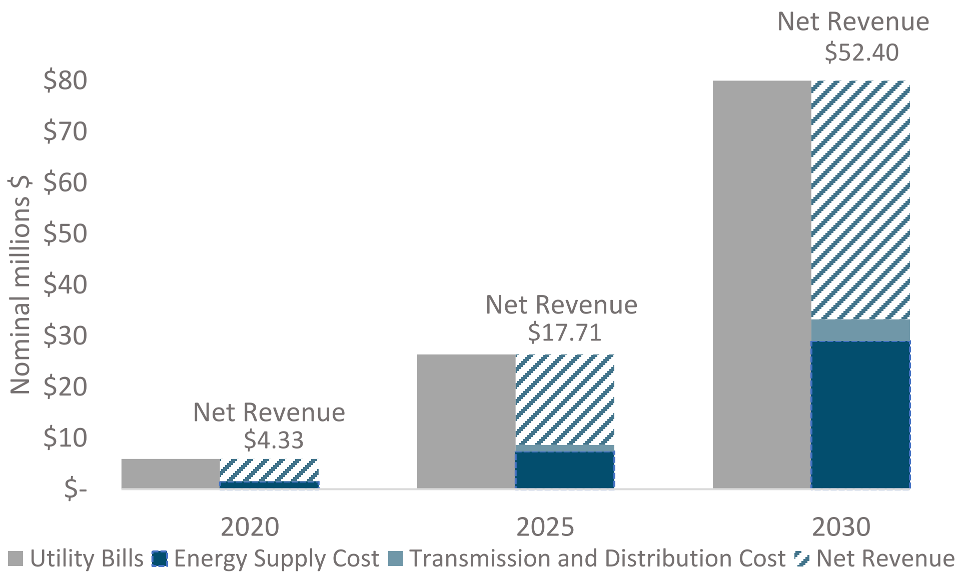
[1] Note that the costs and benefit streams that contribute to the NPV values calculated extend out to 2042 since all vehicles adopted in the last year of the study period, 2030, would continue to provide costs and benefits over their full lifetime which is assumed to be 12 years.

EV Programs and Sensitivities			
Personal LDV – Unmanaged charging	$346	-$10	$336
Personal LDV – High DCFC, managed charging	$346	$41	$391
Personal LDV – Rebate program, managed charging	$411	$43	$335
Transit Bus Rebate Program, managed charging[2]	-$51	$14	-$35

As seen in figure 1 below, in 2030, revenue collected from tariffs is over $85 million or an average of $0.13/kWh (in 2030 nominal dollars) which exceeds the total cost to serve PEV charging load at $33 million ($0.05/kWh). Under almost all scenarios explored, non-participating ratepayers benefit substantially from PEV adoption. Note that in all base cases we assume all charging is managed to minimize electric bills which generally results in lower net benefits to other ratepayers but higher benefits for both the participant and society, relative to when charging is unmanaged.

[2] The transit bus rebate case only included vehicles that received a rebate instead of all vehicles adopted between 2020 and 2030, like all other cases presented in this table.

Figure 1. Annual utility net revenue from transportation electrification ($ nominal)



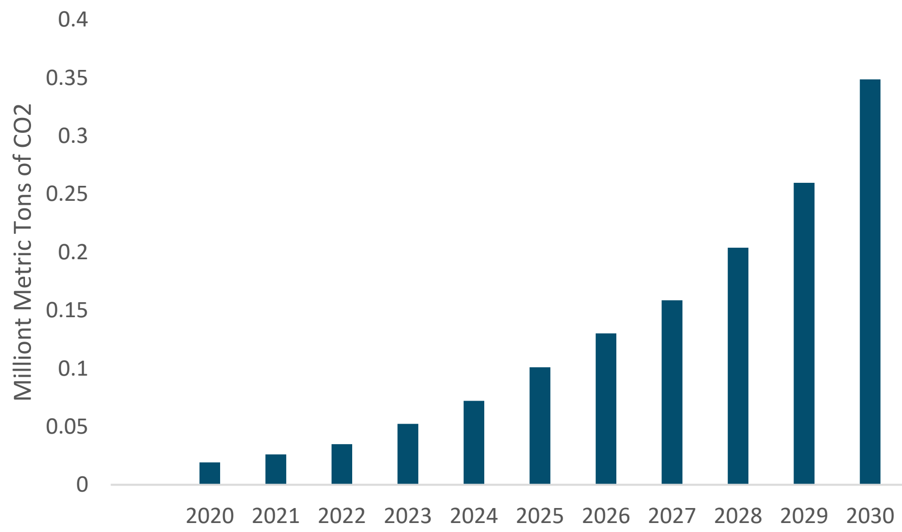
Driver or fleet owner benefits, as reported in the vehicle results sections on a per vehicle basis, show that for nearly all cases PEVs are cheaper in total cost of ownership than ICE vehicles. This is primarily from reduced gasoline or diesel consumption and reduced operation and maintenance (O&M) costs. Over the vehicle lifetime, these savings outweigh the higher upfront cost of PEVs, the charger installation costs, battery replacements, and charging costs. Federal tax credits also help the economics for drivers until they expire in the early 2020s.

The societal benefits to Minnesotans in Xcel Energy territory amount to nearly $497 million for all PEVs adopted between 2020 and 2030 over each vehicles' lifetime. The benefits from avoided gasoline, O&M costs and emission savings far exceed the charging infrastructure, electric supply, and incremental vehicle costs. Emissions savings account for the social cost of increasing electric sector emissions through vehicle charging and the social benefit of reduced tailpipe emissions. The study includes CO_2, $PM_{2.5}$, NO_x, and SO_2 emissions which are converted to social costs using externality costs adopted by the Minnesota Public Utilities Commission. Energy security value from lower reliance on fossil fuels, job creation, equity and other indirect benefits were not included in this study.[3]

For all vehicle types and scenarios explored in this study, the CO_2 emissions from electricity generation to meet charging load were lower than the emissions from gasoline or diesel combustion. Total CO_2 emission reduction for all PEVs adopted between 2020 and 2030 sum to 2 million metric tons (MMTons) over vehicle lifetimes, with annual CO_2 emission savings peaking in 2030 at 0.35 MMTons /year. Emissions from the criteria pollutant's NO_x and $PM_{2.5}$ were found to decrease with PEV adoption by 800 and 174 metric tons respectively, while SO_2 emissions are projected to increase by 72 metric tons relative to the adoption of new ICE vehicles. Criteria pollutant emission impacts are strongly dependent on how close the emissions occur to population centers. This report does not attempt to characterize the impact of shifting criteria pollutant emissions from vehicle tailpipes to generator smokestacks, but this should certainly be considered when interpreting these results. A detailed study on criteria pollutants with geographic emission modelling would be needed to understand these effects more fully.

[3] Some studies have provided monetized value of indirect benefit streams. For example, for the Federal Transit Administration provides published monetized values for the economic development impacts of transit investment for use in cost-benefit studies (FTA, 2016)

Figure 2. Annual avoided CO_2 emissions from all vehicle types



Sensitivity Case Results

The table below summarizes the cost-benefit impact of each personal LDV sensitivity relative to the personal LDV base case.[4]

Table 2. The change in Net Present Value (NPV) for personal LDV sensitivity cases relative to the total NPV for the base case in ($ Million)

Total NPV of Base Case	Ratepayer	Driver	Societal
Personal LDV – managed charging - Base	**$339**	**$26**	**$366**
NPV impact of each sensitivity [5]			
Personal LDV – Unmanaged charging	+ $7	- $36	- $30
Personal LDV – High DCFC, managed charging	+ $7	+ $15	+ $25
Personal LDV – Rebate program, managed charging	+ $72	+ $17	- $31

[4] The transit bus rebate sensitivity was performed using different costs to the base HDV case and over a shorter modelling horizon and the team therefore chose not to include it in the relative impact table to avoid mischaracterization.

[5] The total NPV of the sensitivity case subtracted by the total NPV of the base case.

Key findings from the sensitivity cases include:

+ The unmanaged charging sensitivity demonstrates that if charging were completely unmanaged over the 2020 – 2030 period drivers would see their costs increase by $36 million or $428 per EV while Minnesota would see net benefits decrease by $30 million. Unmanaged charging increases utility supply costs but also increases utility revenue as driver charging bills are higher. This results in a slight increase in ratepayer benefits of $7 million over the study period compared to the base scenario where 100% of charging is managed to minimize participants' electricity bills.
+ Deploying 70 DCFC more charging plugs by 2025 beyond the current expected DCFC network growth trends could incentivize an additional 5,850 BEVs to be adopted in Minnesota by 2030. Under this adoption impact scenario ratepayers would see an increase in net benefits of $7 million and Minnesota state would see net benefits grow by $25 million (7%) to $391 million. Although it should be noted that adoption impacts from DCFC network growth are highly uncertain.
+ Xcel's proposed rebate program would provide $50 million in benefits to drivers through lower upfront vehicle costs which E3 projects would lift adoption by 38,847 vehicles over the modelling period. This scenario results in driver net-benefits growing by $17 million and ratepayer net-benefits growing by $72 million for all vehicles adopted from 2020 to 2030. The growth in ratepayer net-benefits is due to increased adoption which offsets the program costs.
+ Finally, E3 also evaluated Xcel's proposed bus rebate program finding that under Metro Transit cost assumptions the program could result in between $43,772 and $142,311 per bus in fleet owner benefits but a net cost to ratepayers between $51 million and $63 million depending on the size of the rebate allocated to transit buses. Note that the cost-test framework used in this study does not include broader economic and

societal benefits of electrifying transit that the rebate program primarily aims to promote. Prior studies have shown that investment in public transit has positive impacts on job growth, affordable housing, land use, and economic development which should be considered alongside the results presented here. Also note that only cost inputs from Metro Transit were used but other parameters such as annual mileage, battery size, bus schedules, and other fleet data can vary significantly across transit agencies and have a strong impact on cost-benefit results.

1 Study Aims

This study evaluates the costs and benefits of PEV adoption in Xcel Energy's Minnesota territory and examines the impact of proposed rebate and fast-charging network programs to accelerate PEV adoption and provide economic relief and recovery from the impacts of COVID-19. Specifically, this study aims to support Xcel Energy, policymakers, and other stakeholders in understanding:

+ the costs and benefits of plug-in electric vehicle (PEV) adoption, from a non-participating ratepayer, driver, and broader societal perspective,
+ potential CO_2, $PM_{2.5}$, NO_x, and SO_2 impacts of electrified transportation, and
+ potential impacts of electric vehicles on utility planning, specifically electricity consumption and planning loads.

This cost-benefit methodology seeks to evaluate direct impacts of transportation electrification through the lens of regulatory cost test frameworks. However, it is important to note that various indirect benefits arise from transportation electrification such as job creation, fuel security, health impacts, and greater equity which can bring substantial benefit to Minnesota.

2 Methodology

2.1 Cost-Benefit Overview

To perform a Cost-Benefit Analysis (CBA) of transportation electrification in Xcel Energy's Minnesota service territory, E3 compared the costs and benefits accrued over the lifetime of each PEV adopted against an equivalent Internal Combustion Engine (ICE) vehicle. Defining a particular value stream as a cost or a benefit depends on the perspective taken. E3 performed CBA from the perspective of EV owners (drivers), other utility customers or non-participating ratepayers, and Minnesota state. Each perspective offers distinct insights that help describe the overall impact of EV adoption in Xcel Energy's Minnesota territory and inform development of policy and programs. The three perspectives are as follows:

+ Ratepayer Impact Measure (RIM): the costs and benefits to all non-participating ratepayers in Xcel Energy's Minnesota territory – will average utility rates increase or decrease?
+ Participant Cost Test (PCT): the costs and benefits to the vehicle driver or fleet owner in the case of buses – is the total cost of ownership higher or lower for the driver?
+ Societal Cost Test (SCT): the costs and benefits to Minnesota State – do EVs provide net benefits for the state?

The cost and benefit components that constitute each perspective were originally defined in the standard practices of cost-effectiveness for California (CALMAC, 2002). These methods are well established and used to evaluate other nationwide distributed energy resource programs (EPA, 2008). The PCT measures benefits and costs to participating customers. The benefits include any reduction in customer's bills and any tax incentives received, while the costs include costs of any equipment purchased plus any increase in customer's bills. Only charging infrastructure costs directly paid by drivers are included in the PCT (e.g., residential charging infrastructure costs for personal LDV drivers with home charging). The RIM compares utility revenues and supply costs associated with charging loads. The SCT measures the net costs of a program to both customers and the utility, including the effects of environmental externalities but excluding tax credit benefits. The effect of electricity bills cancels out after the summation of benefits and costs to both customers and the utility. Table 3 provides an overview of the various costs and benefits analyzed under each perspective[6]:

Table 3. Cost and benefits associated with each cost test perspective

Cost/Benefit Component	PCT	SCT	RIM
Incremental EV cost	Cost	Cost	
Federal & State EV tax credit	Benefit		
EV O&M savings	Benefit	Benefit	
Fuel savings	Benefit	Benefit	
Electricity Supply Costs for EV charging		Cost	Cost
Charging infrastructure cost	Cost	Cost	
Electricity Bill for EV charging	Cost		Benefit
Emission savings		Benefit	

[6] For more information on how cost and benefit components are assigned please refer to the Environmental Protection Agency best practice manual for cost effectiveness (EPA, 2008).

For this analysis Xcel Energy's Weighted Average Cost of Capital (WACC) was used to discount cost and benefit streams to calculate a Net Present Value (NPV) for all three cost tests due to modelling limitations. In other cost-benefit studies a higher discount rate for the PCT is often used (typically around 9%) and a lower discount rate for the SCT (typically 3%). Given net-benefits tend to grow over time with transportation electrification, had this analysis been conducted with these discount rates we would expect to see slightly lower participant net-benefits, and much higher societal net-benefits.

2.2 Modelling methodology

E3's EVGrid model performs CBA from each of the perspectives described above and uses various input streams that are described in detail in the Inputs and Assumptions section. The model calculates the net present value of EV adoption relative to gasoline vehicles across a region of interest. Accurate forecasting of electricity supply costs and electricity bills depends strongly on the hourly load shape from PEV charging. Charging load shapes in turn vary substantially across the driver population and depend on several factors such as vehicle type, charging access, cost of charging, and many others.

To model charging behavior E3 has developed a bottom-up modelling approach that simulates driving and charging of thousands of PEV drivers. Driving behavior is captured using travel survey data and converted to 15-minute driving patterns though a Markov-Chain Monte Carlo method. The driving population is characterized by drivers' access to charging and the type of EV they drive. For personal Light-Duty Vehicle (LDV) cases there are 4 PEV types and 6 charging access types, resulting in 24 combinations or customer types. Potential charging locations are categorized into residential, workplace, and public areas and drivers choose where and when to charge by minimizing their charging cost through linear optimization subject to various constraints. This generates a normalized load shape for each customer type which are then scaled by the portion drivers representing that customer type. The final load shape therefore captures the diversity of driving behavior, charging access, and PEV adoption across the driving population.

In addition, charging sessions can then be further managed to minimize peak loads or demand charges at each location through a heuristic cost minimizing method. This modelling framework enables PEV charging load shapes to be generated under various scenarios for Vehicle-Grid Integration (VGI), charging infrastructure deployment, and adoption scenarios. PEV charging load shapes output from EVGrid's load shape module have been benchmarked and calibrated using real world charging session data.

2.3 Modelling Scenarios

This study calculates the lifetime costs and benefits for every PEV adopted between 2020 – 2030. Personal LDV, parcel van, and transit bus vehicle types were modelled encompassing a majority of future PEV adoption in Xcel Energy's Minnesota territory. There were three sensitivities conducted for the LDV, which E3 expects will make up 97% of PEV adoption and 69% of forecasted PEV charging load by 2030. In addition, a sensitivity was conducted for transit buses modelling the effect of the transit bus rebate. Each case is described below:

- **Personal LDV – Managed Charging:** This case calculates the costs and benefits arising from personal light duty PEV drivers. We simulate four different PEV types. In this scenario, charging is performed to minimize the driver's cost of charging. Charging is managed on a 15-minute basis to minimize energy and demand charges. In addition, for residential charging, it is assumed that additional charge management is performed by Xcel Energy to mitigate the impact of rebound peaks when the off-peak TOU period begins. This is performed by a combination of cascading charging start times over a 45-minute interval and peak 'flattening' where charging is further staggered throughout the period the vehicle is parked.
- **Transit Buses – Managed Charging:** Transit buses are modelled as only charging at their bus depot location where each bus has access to a fast charger. It is assumed electric transit buses are only assigned shorter routes where daily mileage is less than the vehicle range. Charge management minimizes demand and energy charges.
- **Parcel Vans – Managed Charging:** Similar to transit buses, parcel vans are assumed to only charge at their depot location. Charging is also assumed to be managed.

Four sensitivities were explored to evaluate additional electrification scenarios:

- **Personal LDV – Unmanaged Charging:** This scenario models the cost and benefits of personal PEV adoption when charging is unmanaged. Drivers are still sensitive to the average cost of charging in each location and choose where to charge based on this cost, but when they arrive at a location that they plan to charge, charging begins immediately, and the vehicle is charged at the maximum rate until the battery is full or the vehicle leaves the charging premises.
- **Personal LDV high DCFC:** This scenario tests the impact of deploying 70 DCFCs across Xcel Energy's Minnesota territory. The scenario assumes adoption is increased by 5% relative to the personal LDV case to account

for the indirect network effects of reducing range anxiety and increasing consumer awareness from having a denser DCFC network.

- **Personal LDV rebate:** This case models the impact of Xcel Energy's proposed LDV rebate, which starts at $2,500 and $1,250 for new and used EVs in 2021 and declines to $1,500 to $750 in 2025. The rebate program is capped at $50M. A 13% increase in adoption from 2021 to 2025 is modelled in this case as a result of this incentive.
- **HDV Transit Bus rebate:** This scenario models Xcel Energy's proposed transit bus rebate, which starts at $1M in 2021 and declines to $250,000 in 2025. The case caps the rebates offered at $65M, the amount Xcel Energy is earmarking for Metro Transit, the largest transit operator in its Minnesota territory. A sensitivity is also run assuming the rebate cap is $100M – the total allotted for all bus types.

3 Inputs and Assumptions

3.1 Driving and Charging Behavior

To simulate PEV driving and charging behavior the team utilized thousands of vehicle trips from detailed trip datasets. For the personal LDV case, trip data was extracted from the 2017 National Household Travel Survey (NHTS) (Federal Highway Administration, 2017). For parcel van and transit bus, the NREL Fleet DNA database (NREL, 2019) and the national transit database (Federal Transit Administration, 2019) were used. Each dataset was cleaned, filtered for the specific vehicle of interest, and where possible filtered for Minnesota trips only. The origin and destination locations were categorized, and the mileage was adjusted slightly to align with Minnesota specific annual VMT sources as shown in Table 4.

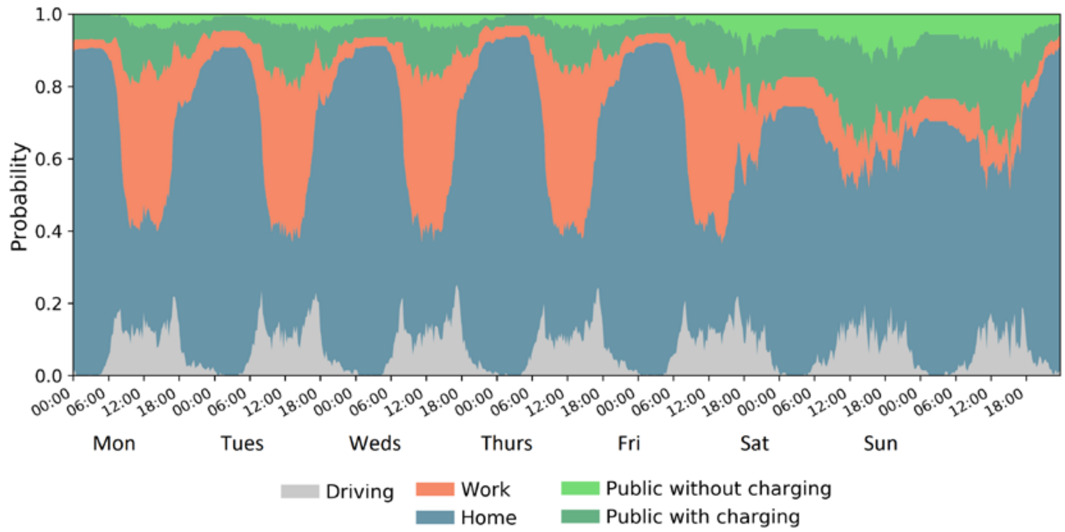
Table 4. Annual VMT for each vehicle class

PEV category	Annual VMT
Personal LDVs	12,021[7]
Transit buses	42,500[8]
Parcel vans	14,175[9]

[7] Minnesota personal LDV mileage from the National Household Travel Survey 2017 (Federal Highway Administration, 2017)
[8] Taken from (Federal Transit Administration, 2019)
[9] Taken from (NREL, 2019)

A random sample of trips is then drawn from the dataset covering 500 driver days to construct driving profiles through a Markov-Chain Monte Carlo approach. An example weekly driving pattern for a group of drivers is shown in Figure 3

Figure 3. A weekly driving profile generated for personal LDV drivers using 2017 NHTS data and the Markov Chain methodology



Drivers who had travel days that could not be completed using the EV and charging access options assigned to them were deemed to have 'unserved driving energy' and were dropped from the sample to generate the final aggregated charging loads. This implies that drivers with driving patterns where they cannot complete their travel day with the EV and charging access they were assigned would not purchase this EV type and would not therefore contribute to the final load. A minimum dwell time of 15 minutes was set for charging, if the driver was parked at a destination for less time than this time, no charging was assumed to occur.

Due to the computational intensity of simulating driving and charging behavior only a winter and summer week in 2025 was simulated, the resulting load shapes were scaled based on PEV adoption and interpolated for adoption forecast between 2020 – 2030.

3.2 EV Adoption

EV adoption assumptions for the base case are based on forecasts by Xcel Energy for its Minnesota territory. Personal LDVs are expected to grow cumulatively to 126,801 vehicles in Xcel Energy's territory in 2030. For parcel vans and transit buses, we follow the growth rate of Xcel Energy's EV forecast assumptions for Medium-Duty and Heavy-Duty Vehicles. This results in a gradual increase toward 2,036 parcel vans and 1,714 electric transit buses in 2030 in Xcel Energy's Minnesota territory. Note that the electric transit bus adoption forecast is based on generic cost estimates rather than specific costs estimates for transit agencies in Minnesota. This forecast was also developed prior to the COVID-19 pandemic and the associated economic impacts which have affected transit agencies. The forecast therefore represents an optimistic scenario for the future of electrification for Heavy Duty Vehicles.

The team also used a simple in-house bass diffusion model to understand the adoption impacts of the rebate and the deployment of DCFC infrastructure. More details on this methodology are described in Section 3.10.

Table 5. Overview of EV adoption per vehicle category

PEV category	2020 PEV	2025 PEV	2030 PEV
Personal LDVs - base	12,198	48,783	126,801
Personal LDVs – Rebate	12,198	87,630	165,648
Personal LDVs – high DCFC	12,198	49,542	132,651
Parcel vans - base	0	300	2,036
Transit buses - base	13	207	1,714

3.2.1 CHARGING ACCESS

To model charging behavior the driving population is segmented by where they have access to charging and by PEV type. For personal LDV cases, six charging access types are used. For parcel van and transit bus cases, it is assumed that charging access is limited to the depot.

For personal LDVs the team used information on population and housing type from the American Community Survey (ACS) to estimate the number of households by type, the percentage of each household type that own a car, and the percentage of car owners that drive to work (U.S. Census Bureau, 2016). The team then used a report from University of California, Davis to estimate the availability of home charging at each type of housing and the percentage of vehicles that would charge at home, at work, and on public chargers (Nicholas & Tal, 2017).

3.2.2 PEV TYPES

The driving population was also segmented by the type of PEV driven, for LDV cases four PEV types were used distinguishing long- and short-range BEVs and

PHEVs. Parcel van and transit bus cases only assume 1 type of BEV. The split between BEV and PHEVs is based on the Bloomberg New Energy Finance EV outlook for 2025 (BNEF, 2019) while the split between long and short range PEV types were used to ensure the average BEV and PHEV range was aligned with forecasts from NREL (Kontou, et al., 2018). The percentage of the vehicle population represented by each vehicle type in the model is shown in Table 6.

3.3 Vehicle and Charger Parameters

This study includes an analysis of three driver types: personal LDVs, parcel vans and transit buses. As described in section 3.2.2 for personal LDVs four vehicle types were modelled, for which vehicle and charger parameters are shown in Table 6. Note that as described in section 3.1, only charging profiles for 2025 were simulated. The normalized charging profiles for each of the four LDV types were scaled using their relative proportion by year over the modelling period to represent growth in average BEV and PHEV ranges over time. Therefore, the range of BEVs and PHEVs selected represent the lower and upper end of potential vehicle ranges that may be on the market by 2030.

LDVs are expected to have an efficiency of 0.35 kWh/miles based on the weighted average of the LDV market in Minnesota (U.S. Department of Energy, 2020; Auto Alliance, 2020).

Table 6. Vehicle and charger parameters of LDVs

Vehicle type	Electric range (miles)	Battery size (kWh)	Max DC charging power (kW)	Max AC charging power (kW)	% of Modelled Population
BEV – long range	400	140	20	105	25.3%
BEV – short range	150	52.5	20	50	42.8%
PHEV – long range	60	21	3.6	n/a	7.8%
PHEV – short range	25	8.75	3.6	n/a	24.2%

Class 5 Parcel Trucks were used to represent the MDVs and Transit buses were the representative vehicle type for HDVs. Transit buses require large daily mileage with few in-between charging stops, whereas parcel vans have lower daily mileage and more flexibility to charge. The vehicle efficiencies of both vehicle types are derived from (Eudy & Jeffers, 2018).

Table 7. Vehicle and charger parameters of buses

Vehicle type	Effective electric range (miles)	Battery size (kWh)	Max charging power (kW)	Vehicle efficiency (kWh/miles)
Transit buses	176	500	50	2.84
Parcel vans	119	80	50	0.67

3.4 Utility Tariffs and Charging Costs

Rates applied to the unmanaged and managed charging scenarios are different. For the unmanaged charging scenario, residential locations were assigned Xcel Energy's A01 and commercial rate A15 was applied to workplace, public, and depot locations. For the managed charging scenario, the time-of-use (TOU) residential rate A72 is applied to charging at residential locations and the proposed commercial rate A25 is applied to charging at workplace, public and depot locations (Northern State Power Company, 2020). The team also assumed 25% of EV drivers have access to free charging at workplace. It was assumed that all EV chargers were separately metered and therefore building loads were not included when calculating demand charges for the commercial rate since the intention is to measure the impact of EV charging on utility bills versus a counterfactual where an ICE vehicle is owned. Energy and demand charges are assumed to grow at the inflation rate of 2%/year.

For personal vehicles, the rates paid by the drivers are distinguished from the electricity bills paid by charging station site hosts for public locations, see Table 8. Commercial charging prices for L2 and DCFC chargers were selected from a publicly available source[10] to reflect the charging costs EV drivers pay at public locations, which are often much higher than the commercial rate paid by charging station site hosts or owners. This difference will be reflected in the cost of charging to drivers in the Participant Cost Test (PCT) and the utility revenue for ratepayers in the Ratepayer Impact Measure (RIM).

[10] Blink member charging fees for Minnesota taken from (Blink, 2020)

Table 8. Charging fees paid by EV drivers versus charging site hosts or owners

	Home	Workplace	Public	Depot
Drivers, Unmanaged	A01	75% A15 25% free	Blink L2 or Blink DCFC	-
Drivers, Managed	A72	75% A25 25% free	Blink L2 or Blink DCFC	A25
Charging Site Hosts, Unmanaged	-	A15	A15	-
Charging Site Hosts, Managed	-	A25	-	A25

	Season	Peak	Shoulder	Off-peak
A01	Winter	0.12	0.12	0.12
	Summer	0.14	0.14	0.14
A72	Winter	0.22	0.11	0.06
	Summer	0.26	0.12	0.06
A15	All	0.04	-	0.02
A25	All	0.07	0.05	0.03
Blink L2	All	0.44	0.44	0.44
Blink DCFC	All	0.54	0.54	0.54

The rates above (with riders included[11]) were used to simulate PEV charging in EVGrid by minimizing the driver's electric bill.

[11] For the fuel clause rider the team assumed a flat rate throughout the year of 0.025 $/kWh that was escalated with the inflation rate of 2%/year.

3.5 Incremental Vehicle Costs

On average, electric vehicles are currently more expensive in purchase price than their ICE counterparts, mostly due to battery costs. E3 used the base assumptions on the purchase price for both electric and ICE LDVs in the US from recent projections by the ICCT (ICCT, 2019). These were specified for vehicle mix and battery packages as used in this analysis, resulting in average incremental vehicles costs of an EV over an ICE vehicle of $14,661 in 2020. As battery costs are forecasted to decline towards 2030, EV and conventional vehicles are close to reach a breakeven point in 2030.[12]

For transit buses, E3 used incremental vehicle costs based on Bloomberg's report on electric buses in cities, corrected for the battery pack size (625kWh) for transit buses used in this analysis (BNEF, 2018). Transit buses are also expected to need battery replacements because of high annual mileage. E3 estimated a frequency for battery replacements in transit buses of 4 years, compared to ICE vehicle replacements of 12 years. This brings the total incremental vehicle costs for transit buses at $237,435 in 2020, declining to $125,820 in 2030 due to declining battery costs.

E3 also used incremental transit bus costs provided by Metropolitan Council and Metro Transit. Metro Transit provided the current incremental vehicle cost of $490,000 in 2020 and E3 assumes a cost decline trajectory similar to Bloomberg's study such that the incremental vehicle cost reaches $370,760 in 2030 (The

[12] In nominal dollars - based on battery costs projections by ICCT (2019)

Metropolitan Council, 2020). While Bloomberg's cost assumption includes the cost of battery replacement, Metro Transit's costs do not.

For parcel vans incremental vehicle costs are projected to decrease from $29,727 in 2020 to $2,000 by 2030 (Kuhn, 2013). Costs of charging infrastructure to serve transit buses and parcel vans are discussed further in Section 3.9.2.

Table 9. Incremental vehicle costs per vehicle category (Nominal $)

PEV category	2020	2030
Personal BEV LDVs	14,661	40
Personal PHEV LDVs	7,585	2,472
Transit buses (BNEF)	237,436	125,820
Transit buses (Metro Transit)	490,000	370,760[13]
Parcel vans	29,727	2,000

3.5.1 TAX CREDITS

To reduce the impact of upfront incremental vehicle costs, all EV drivers in Minnesota benefit from federal tax credits. Federal tax credits amount up to $7,500 per BEV purchased, phasing out when at least 200,000 vehicles have been sold by each manufacturer in the U.S which E3 assumed would occur by 2023 (Internal Revenue Services, 2020).

[13] Cost is extrapolated using the decline rate of BNEF vehicle cost adjusted for battery replacement

3.6 Avoided Electric Vehicle Miles Travelled (eVMT)

Avoided electric Vehicle Miles Travelled (eVMT) costs in our analysis are based on two factors: avoided fuel costs and avoided operation and maintenance (O&M) costs. For avoided fuel costs, we calculate the amount of fuel an ICE vehicle would have used under the same circumstances over the lifetime of the vehicle, multiplied by the costs of fuel in each year. The average annual fuel consumption avoided per EV per year is assumed to decrease over time according to the relative improvement in ICE vehicle fuel efficiency projected by NREL in their Light-Duty Vehicle Attribute Projections prepared for the California Energy Commission (Kontou, et al., 2018). Fuel economy data for other vehicle types was taken from the Transportation Energy Efficiency tables of EIAs Annual Energy Outlook for 2020 (EIA, 2020). The assumed fuel efficiencies per vehicle category are shown in Table 10.

Table 10. Fuel economy assumptions

Year	LDVs (miles/gallon gasoline)	Parcel Vans (miles/gallon gasoline)	Buses (miles/gallon diesel)
2020	32.9	10.3	7.4
2025	36.5	10.9	7.8
2030	37.4	11.6	8.2

Gasoline and diesel forecasted prices are derived from the EIA Short Term Energy Outlook and Annual Energy Outlook 2020 and include an inflation rate of 2%/year to convert them to nominal dollars. The EIA's current Short-Term Energy Outlook considers COVID price impacts and shows the impacts are largest in the second quarter of 2020 and then dissipate over the following 18 months (U.S. Energy Information Administration, 2020). Table 11 shows the projected fuel costs for both gasoline and diesel for several end years (U.S. Energy Information Administration, 2020).

Table 11. Fuel price forecast (Nominal $)

Year	Gasoline (nom $/gallon)	Diesel (nom $/gallon)
2020	1.96	2.44
2025	2.72	3.16
2030	3.18	3.68
2035	3.76	4.30
2040	4.34	4.92

To calculate annual O&M savings, E3 multiplied annual mileage of different vehicle categories by an estimation of the per mile difference between maintenance costs for ICE and electric vehicles. To inform these estimates for LDVs, E3 used data provided by the International Council on Clean Transportation, estimating conventional vehicle maintenance costs for LDVs at $0.061 per mile versus $0.026 per mile for their electric counterparts (ICCT, 2019).

For electric transit buses, their maintenance costs are considered significantly less expensive due to the relatively simple drive system compared to diesel buses. E3 assumed maintenance costs of $0.47 per mile for battery buses and $0.72 per mile for diesel buses, averaged from multiple sources of data. Electric bus maintenance costs were derived from an NREL study finding the maintenance cost of $0.39 per mile (NREL, 2018b) and from a recent study on 16 electric buses assuming $0.55 per mile (Frontier Group, US Pirg Education Fund, 2019). For diesel buses, NREL estimated $0.44 per mile (NREL, 2018b), while the Bus

Lifecycle Cost Model developed by US Department of Transportation estimated the maintenance costs of conventional diesel transit buses at a relatively conservative estimate of $1.00 per mile (US DOT Volpe Center, 2019). For parcel vans, E3 estimated an O&M cost saving of $2,505 per year (around $0.18 per mile).

3.7 Electricity Supply Costs

Utility electricity supply costs are calculated by multiplying the hourly marginal electricity supply costs with hourly electric PEV charging load. Recall that this study focuses only on adoption between 2020 – 2030 but to account for costs and benefits over each PEVs' 12-year lifetime, electric supply costs are calculated for charging load out to 2042, when it is assumed all EVs adopted by 2030 will have been retired.

The marginal electricity supply cost used in this analysis is comprised of four components. Xcel Energy provided marginal energy costs ($/MWh), avoided distribution cost ($/kW-year) and avoided transmission cost ($/kW-year) from 2020 to 2045.

Table 12. Marginal Electricity Cost Components

Component[14]	Description
Energy	Increase in costs due to change in production from the marginal generator
Generation Capacity	Increase in fixed costs of building new generator to meet the incremental EV load
Transmission Capacity	Increase in fixed costs of building or maintaining transmission lines to meet the incremental EV load
Distribution Capacity	Increase in fixed costs of building or maintaining distribution lines to meet the incremental EV load

To allocate the kW-year generation and transmission capacity costs to hourly values in $/kWh the PCAF (Peak Capacity Allocation Factor) methodology was used[15]. Using hourly net system load from 2020 to 2045 a threshold (MW) corresponding to the top 250 net load hours was selected. In hours where the net load exceeds the threshold, the exceeded load is divided by the total exceeded load for the 250 hours to create an hourly PCAF allocation factor that sums to 1 over the year. For years beyond 2035, the team used the 2035 PCAF shape.

$$\text{Exceeded load}_t = \min(0, \text{load}_t - \text{the } 250^{th} \text{ top load in a year})$$

$$\text{PCAF}_t\ (\%) = \text{Exceeded load}_t \,/\, \text{total exceeded load in a year}$$

$$\text{Capacity value}_t\ (\$/\text{kWh}) = \text{PCAF}_t\ (\%) * \text{capacity value } (\$/\text{kW-year})$$

[14] All cost components have loss factors included.

[15] The methodology was first developed by PG&E in 1993 (California Public Utilities Commission, 2016) and has since been used in various regulatory reports, for example see (Energy & Environmental Economics, 2012)

This same methodology was applied to allocate the distribution capacity value using a typical 2019 residential distribution load provided by Xcel Energy.

3.8 Avoided Emissions

Avoided carbon emissions are calculated based on the difference between electric vehicle emissions from charging load and gasoline or diesel combustion. E3 calculated avoided emissions for ICE vehicles based on 0.0085 metric ton/gallon of gasoline and 0.01098 metric ton/gallon of diesel.[16] Emissions from electric vehicles are expected to decrease over time following the growth of renewables in Xcel Energy's generation mix. For this study, E3 looked at average hourly electricity emissions provided by Xcel Energy between 2019 and 2042 which decline by more than 70% over the period. Annual carbon costs were provided by Xcel Energy and from the 2020-2034 Upper Midwest Resource Plan[17]. To convert avoided emissions to costs, E3 calculated an average societal cost of carbon, weighted by vehicle population, using the Minnesota Public Utility Commission's adopted CO_2 environmental cost and regulatory cost values for each year.[18]

E3 also calculated avoided criteria pollutant emissions using average hourly emissions provided by Xcel Energy and the emissions intensity of gasoline and diesel. E3 assumed emissions intensities for gasoline of 0.0031 kg/gallon for NO_x, 0.00011 kg/gallon for SO_2, and 0.00043 kg/gallon for PM. For diesel, the emissions

[16] Derived from the Argonne GREET Model
[17] Carbon Cost scenario: "PVSC – High Environmental/Regulatory Costs"
[18] To align with the base assumptions used in Xcel Energy's 2020-2034 Upper Midwest Resource Plan, we used the Commission's High CO2 environmental cost value through 2024, then High CO2 regulatory value thereafter.

intensities used were 0.0051, 0.00005, and 0.0016 kg/gallon for NO_x, SO_2, and PM, respectively. Avoided emissions were monetized using externality costs provided by the Minnesota Public Utility Commission.

3.9 Charging Infrastructure

3.9.1 CHARGER NETWORK DENSITY

E3 calculated the required number of EVSE chargers to support the vehicle adoption forecasts using NREL's EVI-Pro Lite model (NREL, 2018). EVI-Pro Lite can provide a state specific estimation of the number of workplace, public and DCFC chargers required to meet a given adoption forecast. Note that this model only provides a value for meeting personal LDV adoption, does not account for the impacts of managed charging, and only provides values for a maximum PEV market penetration of 10% of total LDV stock. The EVI-Pro model also does not account for charging required along transit corridor, therefore the E3 assumed a larger DCFC charger network to serve vehicles. For transit buses, E3 assumes a ratio of 2 transit bus per DC fast charger due to limited time available for charging and for parcel trucks, E3 assumes 10 vehicles per DCFC. Under these assumptions, the PEV adoption forecast for the Xcel Energy Minnesota territory requires the installation of 109,432 EVSE charging ports by 2030, 93% of which are L2 home chargers. Table 13 provides an overview of the number of EVSE chargers for 2020, 2025 and 2030.

Table 13. Number of required charging ports in Xcel Energy's Minnesota territory

EVSE type	2020	2025	2030
Home L2	9,758	39,026	101,441
Public L2	258	1,030	2,677
Workplace L2	370	1,481	3,851
DCFC	45	289	1,464
Total	**10,432**	**41,826**	**109,432**

For personal LDVs the team also explored the impacts of expanding Minnesota's public DCFC network which is described in section 3.10.

3.9.2 CHARGER COSTS

Charging infrastructure costs in this analysis are based on two components: EVSE hardware costs and installation costs ("make-ready" costs). The latter component includes all *behind the meter* costs required to get the charging unit working. We assume that infrastructure costs "in front of meter" are paid for by the utility and therefore included under electricity supply costs.

The costs of charging infrastructure are outlined in Table 14. These costs are based on data provided by the International Council on Clean Transportation, with installation costs of home charging averaged based on the proportion of existing types of homes (ICCT, 2019). Installation costs for public DCFC chargers are based on costs per charger assuming 2 chargers per site, whereas installation costs for DCFC 20 and 50 kW chargers in parcel van and transit bus depos are based on costs per charger with multiple chargers on site (since these chargers are assumed to be installed at large-scale bus depots). For the transit bus rebate sensitivity cost data from Metro Transit was used (The Metropolitan Council, 2020). The Metro Transit depot charging cost assumes a 150 kW charger and includes all planning, design, hardware, construction, installation, testing, and commissioning costs. The Metro Transit on route charger cost similarly considers all costs from design to commissioning and assumes the charger would have a 300 kW capacity.[19]

Table 14. Charging Infrastructure Costs

	Hardware	Installation	Total
Home L2	$ 742	$ 1,299	$ 2,040
Public L2	$ 3,127	$ 3,020	$ 6,147
Workplace L2	$ 3,127	$ 3,020	$ 6,147
DCFC (20 kW)	$ 11,360	$ 10,786	$ 22,146
DCFC (50 kW)	$ 28,401	$ 26,964	$ 55,365
DCFC (150 kW)	$ 75,000	$ 38,047	$ 113,047
Depot Charger for Metro Transit	-	-	$ 250,000
On Route Charger for Metro Transit	-	-	$ 1,250,000

For DCFCs, the analysis includes the costs a utility is required to make to upgrade transformer capacity. These costs are utility specific and therefore provided by Xcel Energy.

[19] Note that E3 modelled bus depot charging occurring using a 50 kW under all cost assumptions considered and did not model on route charging.

For cases involving managed charging we assume there is an additional upfront cost of $100 per charger for networking and communication between the charger and the utility.

3.10 Minnesota EV Programs

In addition to the impacts of transportation electrification in Minnesota under expected trends and forecasts the E3 team also investigated other scenarios based on the EV programs proposed by Xcel Energy in their COVID Relief & Recovery filing.[20] The programs put forward by Xcel include a rebate for both personal LDVs and Transit Buses and an expansion of public fast-charging charging infrastructure. The personal LDV rebate program also enrolls participating customers onto time-of-use rates or a managed charging program. This section describes the extra assumptions and inputs needed to model these scenarios. It is important to note that we model these programs to show the impacts from the narrow perspective of regulatory cost test frameworks but do not attempt to calculate the wider economic and social benefits that these programs also hope to achieve. Benefits like job creation, fuel security, health impacts, and greater equity are not included but can bring substantial benefit to Minnesota.

[20] Xcel Energy Minnesota also provides other EV programs in addition to those proposed in the COVID Relief & Recovery filing. For example, Xcel Energy provides residential EV charging tariffs and has several pilot projects including its Residential EV Service, Residential EV Subscription Service, Fleet EV Service and Public Charging pilots.

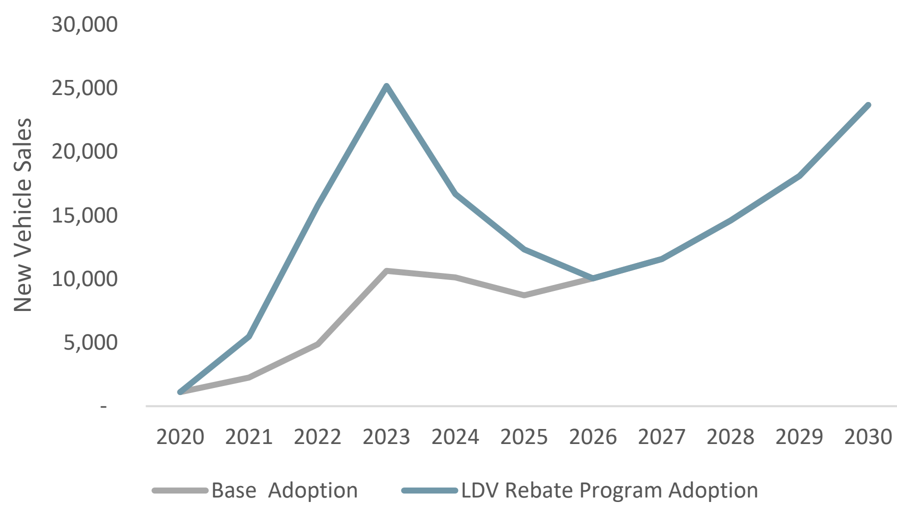
3.10.1 ELECTRIC VEHICLE REBATES

Xcel Energy proposed providing rebates to customers for the purchase of light-duty EVs and buses, including transit and school buses, to kickstart the growth of EV adoption. The LDV program is available to residential and commercial customers and non-profits or governments seeking to electrify their vehicle fleets. Xcel Energy proposes to offer LDV rebates of $2,500 for a new vehicle and $1,250 for a used vehicle in 2021 declining to $1,500 and $750 for new and used vehicles respectively in 2025. These rebates are only eligible if the vehicle base manufacturer's suggested retail price is below $50,000, and Xcel proposes offering up to $50 million in total for LDV rebates. Xcel Energy's bus rebate program totals $100 million with $65 million dollars designated for Metro Transit, the largest transit operator in the Xcel Energy's Minnesota territory. This analysis modelled transit buses for the HDV category and rebates for these vehicles start at $1 million in 2021 and decline to $250,000 in 2025 and assumes the full $65 million designated for transit buses would be used. Receiving the rebate for both LDVs and buses requires enrollment in a managed charging program, therefore this analysis considered managed charging profiles in its assessment of costs and benefits.

E3 modelled the rebate programs as proposed with rebates being allocated to each vehicle adopted until the program ends or the total rebate funding for the vehicle type is exhausted. For simplicity, the team assumed personal LDV rebates are only allocated to new vehicles but did not consider the price cap for eligibility.

The primary benefit of rebate programs is the accelerated adoption that arises from a lower upfront cost. The team used a simple two stage bass diffusion framework to understand the adoption impacts based on how the rebate affects the payback period of the vehicle. Bass diffusion models are a well-established framework to forecast the adoption of products in a population (Bass, 1969). The model was first developed in the 1960s to correctly predict the color television sales and subsequently widely applied across different industries and disciplines. Bass models are based on a simple differential equation parameterized by coefficients that represent imitation and innovation in an economy. The team used a two stage Bass diffusion approach similar to the method developed by NREL for their Distributed Generation Market Demand (dGen) model (NREL, 2020). First the maximum achievable market potential is calculated based on the payback period and then adoption is modelled based on the market potential and the maturity of the technology. The team used Bass coefficients derived from a study into adoption forecasting for residential appliances (Daim, et al., 2010) and total personal LDV sales in Minnesota scaled to the proportion of the population served by Xcel Energy. This approach was chosen for its wide use in literature and its simplicity which allows the impacts of rebate programs to be quickly modelled. The overall adoption impact can be seen in Figure 4.

Figure 4. Annual New Vehicle Sales in Base case and LDV Rebate Case



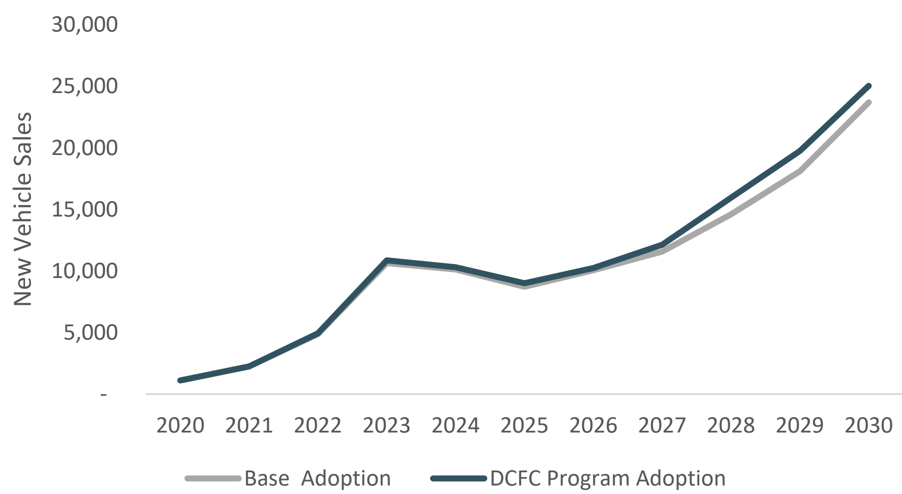
For the HDV rebate program we do not assume any change in adoption from the base case. This is a conservative assumption but a lack of data on adoption for fleets and the specific focus of the rebate program on a single transit agency means there would be large uncertainty and the bass diffusion approach employed to model adoption impacts for personal LDVs would not be appropriate.

3.10.2 DCFC PROGRAM

As part of its COVID Relief & Recovery filing Xcel Energy has also proposed to develop, install, own, and operate 21 DCFC stations throughout its service area to encourage adoption and reduce barriers to transportation electrification, including access to public charging and range anxiety. The team chose to model a larger program in which 70 DCFC plugs would be constructed (roughly the size of the DCFC network in Xcel Energy's Minnesota territory in 2019) over 4 years to understand the impact of DCFC deployment. The team assumed the costs for all 70 plugs are still borne by the Xcel Energy despite the actual proposed program being smaller. As with rebates, the main benefit of DCFC programs is their impact on EV adoption. A denser network of public fast charger stations increases EV adoption by reducing range anxiety and increasing consumer awareness. These indirect impacts are often referred to in economic literature as indirect network effects. Based on a survey of the literature the team assumed that increasing DCFC deployment by 10% causes an increase in adoption of 3.5% but that VMT for each vehicle remained the same as the base case.[21] The team assumes a lag effect of 1 year from when the extra DCFCs are built to when it impacts EV adoption and that the impact that DCFCs have on adoption declines with time. It was also assumed that DCFC deployment has no impact on PHEV adoption since most PHEVs on the market today cannot charge from DCFCs and range anxiety is much less for PHEV drivers. It should be stressed that the impact of denser DCFC networks on adoption and driving behavior is highly uncertain, so the assumptions used here are deliberately more conservative than most effects observed in studies and research.

[21] For a detailed review of evidence for network effects see (Li, et al., 2016; Sierzchula, et al., 2014; Slowik & Lutsey, 2017) for an example of network effect theory being used to inform a transportation electrification plan see (PGE, 2017)

Figure 5. Annual New Vehicle Sales in Base case and DCFC Program Case



4 Results

The first results section describes the total system impacts for all PEVs adopted between 2020 and 2030 and focuses on the respective base cases for each vehicle type. We quantify the total energy consumption, non-participating ratepayer benefits, and emission savings for Xcel Minnesota's service territory through 2030. In the remaining sections the results for each vehicle type and their respective sensitivities are explored in greater detail. Cost-benefit results are shown on both a total net present value and an average per vehicle adopted basis. The total value results show the magnitude of costs and benefits from all PEVs adopted in Xcel Energy's Minnesota service territory, but these results are heavily influenced by PEV adoption forecasts. The average value per vehicle results are more robust to uncertainty in forecasted vehicle population and can be useful in PEV program design since an incentive or program cost per-vehicle can be directly compared to the per vehicle net benefit.

4.1 Total Transportation Electrification Results

The aggregated results for all PEVs adopted in Xcel's Minnesota service territory show transportation electrification could generate significant benefits to ratepayers, drivers, and the state. This study finds that under the base scenario *the state could benefit by $497 million* for electric personal LDVs, MDVs and HDVs adopted between 2020 and 2030. *Drivers or fleet owners would benefit by $116 million* from total cost of ownership savings and *Xcel ratepayers in Minnesota* *would benefit by $361 million* in avoided gasoline, reduced O&M and emission reductions.

Table 15 summarizes the total Net Present Value (NPV) of all cases. These values represent the total costs and benefits over each vehicles' 12-year lifetime, summed for every vehicle adopted from 2020 to 2030 and discounted using Xcel Energy's weighted average cost of capital.[22]

Table 15. Net Present Value of net benefits for all vehicles adopted between 2020 – 2030 in ($ Million)

Case	RIM	PCT	SCT
Personal LDV – managed charging	$339	$26	$366
Parcel Trucks (MDV) – managed charging	$0.6	$45	$50
Transit Buses (HDV) – managed charging	$21	$44	$82
Total Base Case Impacts	**$361**	**$116**	**$497**
EV Programs and Sensitivities			
Personal LDV – Unmanaged charging	$346	-$10	$336
Personal LDV – High DCFC, managed charging	$346	$41	$391
Personal LDV – Rebate program, managed charging	$411	$43	$335
Transit Bus Rebate Program, managed charging[23]	-$51	$14	-$35

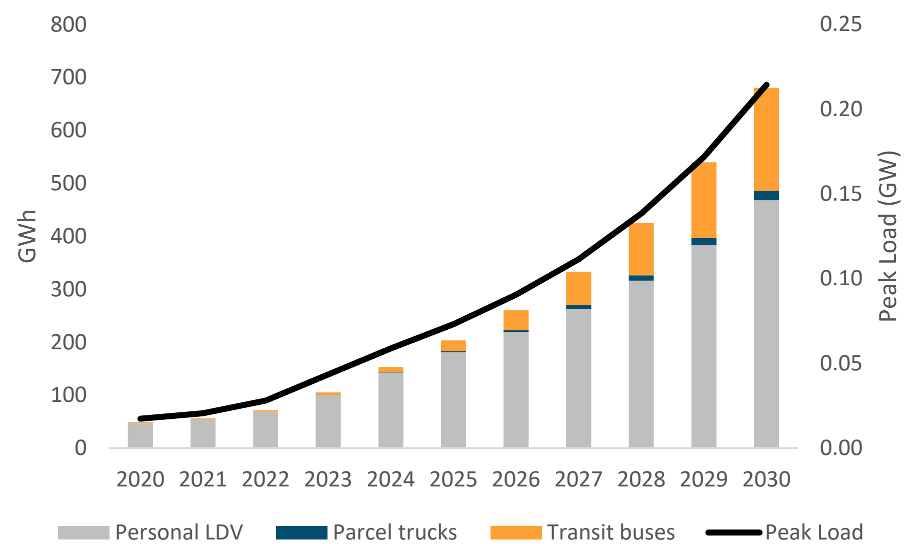
Annual electricity consumption of PEV charging from the three vehicle types studied rises from 56 GWh / year in 2021 to 680 GWh / year in 2030, as shown in Figure 5. By 2030 charging load from all vehicle types could contribute around 0.21 GW to Xcel Energy's Minnesota peak load. Under the base charging scenario, in which most vehicle charging is assumed to occur outside of peak hours, 27% of

[22] Note that the costs and benefit streams that contribute to the NPV values calculated extend out to 2042 since all vehicles adopted in the last year of the study period, 2030, would continue to provide costs and benefits over their full lifetime which is assumed to be 12 years.

[23] This case was only conducted for participating vehicles rather than all vehicles between 2020 and 2030

load occurs between 12pm and 9pm on weekdays and the remaining 73% of load is either on weekends or outside of these hours on weekdays where its generally cheaper for Xcel Energy to supply the load.

Figure 5. Annual Load of All Vehicle Types: 2020-2030 (GWh)



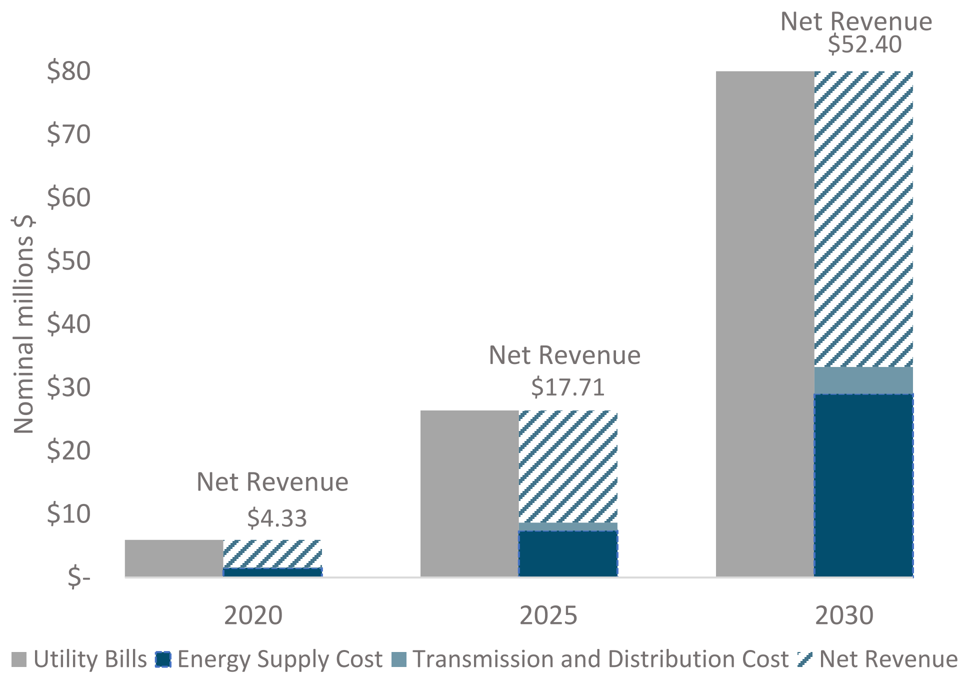
As shown in Figure 5, the vast majority of load and consequently the impact, arises from personal LDV vehicles. It should be noted that the load shape and timing of peak load does vary substantially across vehicle type.

Results for the Societal Cost Test (SCT) reveal that PEV adoption in Xcel Energy territory can generate $497 million in net-benefits for Minnesota in lifetime vehicle benefits aggregated across all PEVs adopted between 2020 and 2030. The benefits from avoided diesel and gasoline, reduced O&M costs, and emission savings far exceed the charging infrastructure, electric supply, and incremental vehicle costs in all cases. It is important to highlight that the societal cost-benefit results presented in this study do not include other indirect impacts such as job creation, energy security value from lower reliance on fossil fuels, financial impacts of reduced criteria pollutants, and lifecycle emissions.

The Participant Cost Test (PCT) results show that when averaged over all EVs adopted between 2020 and 2030 *all PEV types are cheaper for drivers or fleet owners than equivalent ICE vehicles in total cost of ownership*. These PCT results arise from significant savings from reduced gasoline or diesel consumption and lower O&M costs which outweigh the higher upfront cost of PEVs, the charger installation costs, battery replacements, and charging costs. Drivers also benefit from tax credits at the federal and state level although these benefits only apply to PEVs adopted prior to 2027. It is important to note that, as with all cost tests, the results shown here are averaged over the lifetime of each vehicle adopted between 2020 and 2030, but cost-test results for a vehicle adopted in 2020 may vary significantly from a vehicle adopted in 2030. For example, declines in upfront vehicle costs and charging infrastructure increase net-benefits for vehicles adopted later while the federal tax credits that roll off in the mid-2020s increase net-benefits for early adopters.

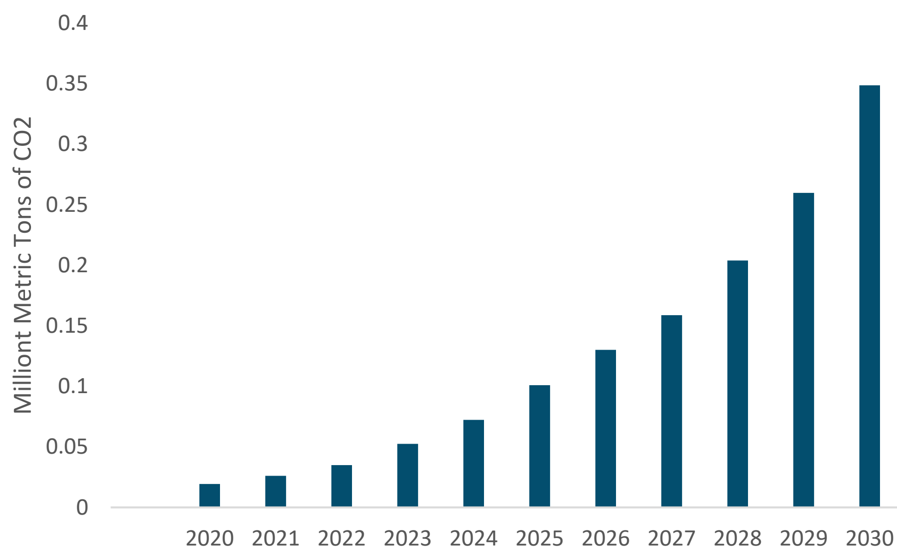
The aggregate impact on Xcel Energy ratepayers under the base case scenario is summarized in Figure 6, and shows that by 2030 revenue collected from tariffs is over $85 million or an average of 0.13 $/kWh (in 2030 nominal dollars) which exceeds the total cost to serve PEV charging load at $33 million (0.05 $/kWh). Under the base case for all vehicle types ratepayers benefited substantially from PEV adoption. Benefits generally scale directly with electricity consumption since bill revenue outweighs supply costs, although tariffs and load shape do play a role as described in subsequent result sections on each case.

Figure 6. Annual utility net revenue from transportation electrification ($ nominal)



For all vehicle types and scenarios explored in this study, the total carbon emissions generated from providing electricity to charge vehicles were lower than the tailpipe emissions from gasoline or diesel combustion. The total carbon emission reduction impacts of all PEVs adopted between 2020 and 2030 sum to 2 MMTons over their lifetime, with annual carbon emissions savings peaking in 2030 at 348,619 metric tons /year. As with the annual energy consumption results, personal LDVs make up nearly a large proportion of the carbon emissions savings at 1.5 MMtons, while parcel trucks and transit buses contribute 0.1 and 0.4 MMtons respectively. Carbon emission savings vary based on the timing of charging throughout the day as grid emissions fluctuate depending on the marginal generator. Consequently, emission savings vary by vehicle type and whether managed charging occurs which is explored in the vehicle result sections.

Figure 7. Annual avoided CO_2 emissions from all vehicle types



The emissions of NO_x and $PM_{2.5}$ were found to decrease with PEV adoption by 800 and 174 metric tons, respectively, while SO_2 emissions increase by 72 metric tons relative to the use of ICE vehicles. The results show that new efficient ICE vehicles tend to have lower emission intensities for SO_2 than the average emissions from Xcel Energy's generation mix for Minnesota. Using externality costs provided by the Minnesota Public Utilities commission, the avoided NO_x emissions represent a value of \$5.2 million and the avoided $PM_{2.5}$ emissions a value of \$3.7 million.[24] The increase in SO_2 has a societal externality cost of \$888 thousand. This results

[24] Emissions externality costs calculated using the Minnesota Public Utilities Commission mid externality cost scenario for urban areas.

in an overall net benefit of $8 million dollars from reduced criteria pollutants.[25] However note that this report does not attempt to characterize the differences in externality costs for emissions at the tailpipe and emissions from a point source such as a generator smokestack, but this should be taken into consideration when interpreting these results. For example, while SO_2 emissions may increase on net, the externality cost of tailpipe SO_2 may be greater than the externality cost of SO_2 emissions occurring at a smokestack if they are in closer proximity to the population. For a full understanding of these impacts pollution dispersion modelling would be required that accounts for the geographic location and timing of emissions.

4.2 Personal Light Duty Vehicles

Personal LDVs are by far the largest contributor to vehicle electrification benefits in Minnesota simply because they make up 97% of vehicles adopted over the study horizon. A range of sensitives were therefore explored for this vehicle type and are presented in this section. The first personal LDV case presented, the base case, involves managed charging and no EV rebates or programs to support adoption. The unmanaged charging sensitivity, which involves no EV programs, is presented to demonstrate the change in costs and benefits when charging is uncontrolled resulting in higher charging load during on-peak periods. The managed charging case serves as the base case for the personal LDV rebate and DCFC program sensitivities as the team felt this is the more appropriate charging

[25] Note that under these emission calculations average emissions were used rather than marginal emissions. The average hourly electric system emission intensity tends to be lower than the emission intensity of the marginal generator and therefore these results may be a slight overestimate of the emission savings from PEVs.

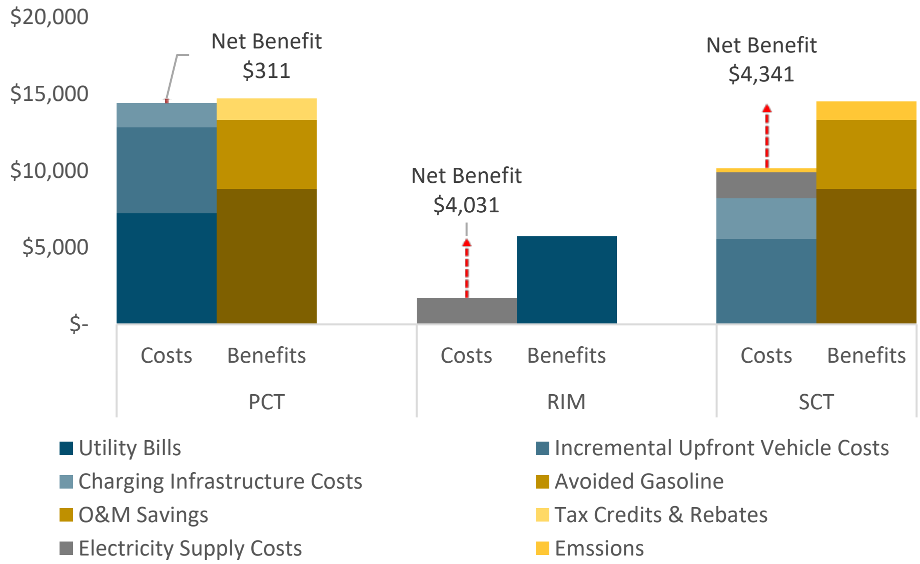
behavior to model for the long time horizon of this study. Xcel's proposed rebate program for personal LDVs also requires participating drivers to enroll on a managed charging program or a time-of-use tariff which also led the team to choose the managed charging case as the base case.

4.2.1 MANAGED CHARGING (BASE CASE)

In the managed charging case charging was timed to minimize the electric bill at home and work locations. Under this scenario electric personal LDVs adopted between 2020 and 2030 could provide $339 million in NPV of benefit to non-participating ratepayers in Xcel Energy's Minnesota territory and $366 million in benefits to the state. The benefits on a per vehicle basis for the state of Minnesota and Xcel Energy ratepayers are $4,341 per vehicle and $4,031 per vehicle, respectively (see Figure 8). Under this scenario drivers see a net benefit of going electric of $311 per vehicle over the vehicle's 12-year lifetime.

The state of Minnesota sees substantial benefits from electrifying personal LDVs given the large eVMT cost savings, low electric supply costs, and reduced carbon and criteria pollutant emissions. Ratepayers see a significant net benefit from electrification as Xcel Energy's cost to serve a PEV averages $1,706 per vehicle over its lifetime while the utility collects $5,737 per vehicle in revenue, as shown in Figure 8 below.

Figure 8 Average Costs and Benefits of Personal LDV electrification per vehicle adopted from 2020 to 2030 – Managed Charging Case (Base case)



In this scenario, electrifying personal LDVs avoids 553 metric tons of NO_x and 94 metric tons of $PM_{2.5}$ emissions. As discussed previously, electrifying transportation results in a slight increase in SO_2 emission of 59-metric tons due the higher average SO_2 emissions intensity of the electric grid than gasoline. Applying Minnesota PUC externality costs shows avoided criteria pollutant emissions result in $1.5 to $7.2 million dollars in avoided damages.[26] The table below presents the societal externality benefit value for the modelled criteria pollutants.

[26] Range based on the low rural externality cost and high urban externality cost developed by the Minnesota PUC.

Table 16. Net Present Value of Total Avoided Criteria Pollutant Emissions

	Net Present Value of Total Emissions Cost	
	Low[27]	High[28]
SO2	-$247,869	-$1,040,191
NOX	$1,337,747	$5,319,288
PM2.5	$393,550	$2,877,955
Total	$1,483,428	$7,157,051

This approach assumes the externality costs applied to criteria pollutant emissions at vehicle tailpipes are the same as generator smokestacks. If the geographic effects of criteria pollutants were accounted for the externality costs for emissions at smokestacks and vehicle tailpipes could be very different depending on their proximity to population centers. This may result in a greater reduction in environmental damages from transportation electrification, but this is beyond the scope of this study.

It is important to be aware of the uncertainties in these cost-benefit projections. As discussed in the Inputs and Assumptions section, this study is not a detailed feeder by feeder level analysis of the distribution impacts from PEV charging. Our method uses marginal distribution impact costs provided by Xcel Energy and allocated using a single generalized residential feeder load. Higher resolution analysis of distribution grid impacts with greater EV penetrations, EV clustering, and higher-powered charging could result in higher utility costs that would reduce ratepayer benefit. Furthermore, Xcel Energy's electric tariffs may evolve substantially over the next decade, which would have strong implications for

[27] These values are based on the low rural externality cost developed by the Minnesota PUC.
[28] These values are based on the high urban externality cost developed by the Minnesota PUC.

these results. This analysis assumes tariffs stay constant in real terms but if rates were to decline, ratepayer benefits could decrease.

4.2.2 UNMANAGED CHARGING

In the unmanaged charging case, drivers are sensitive to the average cost of charging in each location and choose where to charge based on this cost, but when they arrive at a location that they plan to charge, charging begins immediately, and the vehicle is charged at the maximum rate until the battery is full or the vehicle leaves the charging premises. In comparison, in the managed charging case (discussed in section 4.2.1), the team optimized charging behavior of each driver to *minimize utility bills* at both residential and workplace locations. The team assumed further charge management is also performed by Xcel Energy at residential locations to mitigate sharp 'rebound peaks' that can occur when drivers begin charging as soon as the peak period ends causing very large peak loads. This additional charge management is through cascading or staggering the start time of different residential locations over a 45-minute period, and through 'load flattening' where the timing of each drivers' charging is adjusted to flatten peak load as much as possible whilst ensuring the vehicle is sufficiently charged before departure. Figure 9 shows the charging load when charging is uncontrolled or unmanaged, and Figure 10 shows the managed charging load which assumes 100% of drivers in Xcel Energy Minnesota territory have their charging managed. Under both the managed and unmanaged scenarios the average EV consumes 4,071 kWh with BEVs consuming slightly more and PHEVs slightly less.

Figure 9.Unmanaged Personal LDV Charging Load in 2030 – Summer Week

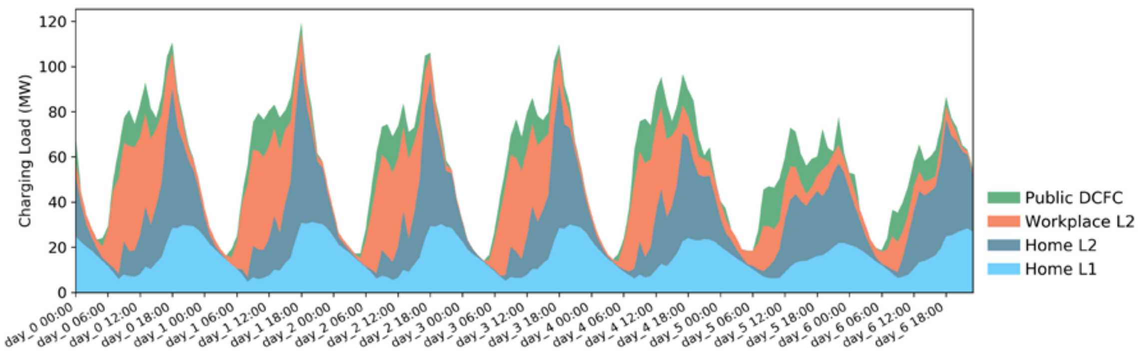
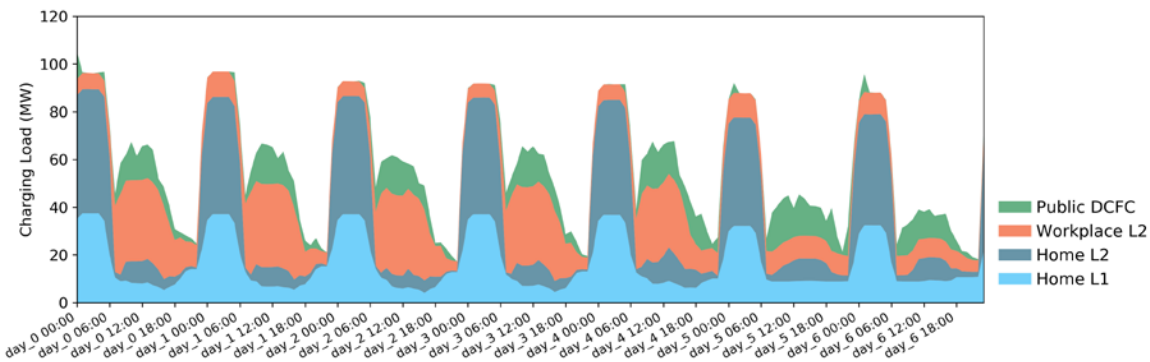


Figure 10. Managed Personal LDV Charging Load in 2030 – Summer Week

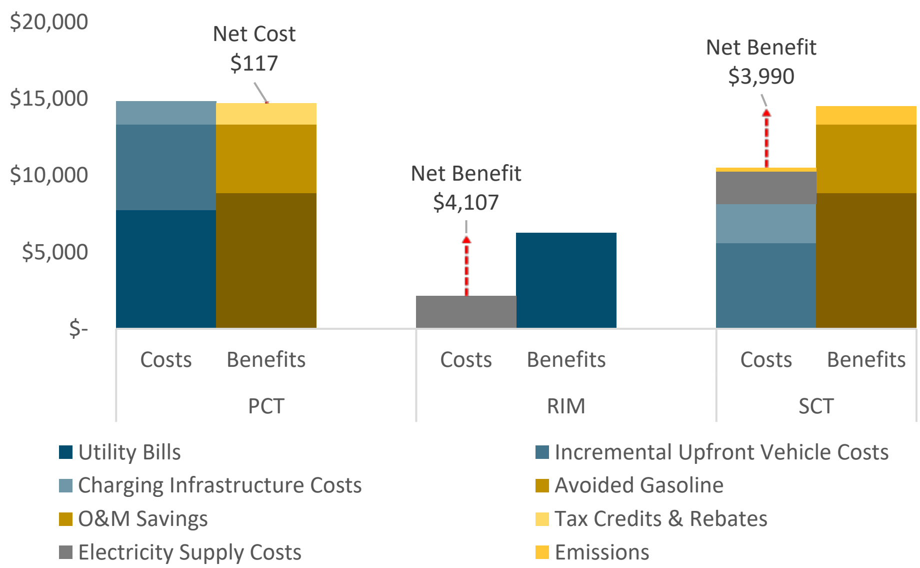


The way a managed charging program impacts the hourly PEV charging load, and therefore a utility's costs to serve that load, is strongly dependent on the price signal used to manage charging. In the managed charging scenario for this study, the price signal is the customers' time-of-use (TOU) tariff, and therefore the objective is to minimize the electricity bill at work and residential locations. This results in substantially lower charging load during TOU peak periods at residential and workplace locations in the managed charging case (Figure 10) compared to the unmanaged charging case (Figure 9). Under the managed charging case, as much charging as possible is squeezed into the off-peak period (10pm to 6am) and peak load management ensures charging is spread evenly over this period resulting in a reduction in peak charging load from 119 MW to 101 MW in 2030. It is important to note that managed charging could also be performed using different price signals, for example using hourly marginal energy costs or through a demand response program. These price signals would have a large impact on the hourly load shape and may better align with hourly system costs resulting in greater benefits for the utility and ratepayers, as discussed later.

For the unmanaged charging case, as in the managed case, results show a significant benefit to the state and non-participating ratepayers from PEV adoption. The unmanaged case results show that electric personal LDVs adopted between 2020 and 2030 could provide $346M in NPV of benefit to non-participating ratepayers in Xcel Energy's Minnesota territory and $336M of benefit to the state. This results in NPV per vehicle benefits of $3,990 and $4,107 for the state of Minnesota and Xcel Energy ratepayers, respectively (see Figure 11).[29]

[29] As mentioned, the average NPV per vehicle values are calculated by taking the total NPV result for all vehicles adopted between 2020 – 2030 and dividing it by the total number of vehicles adopted during this period.

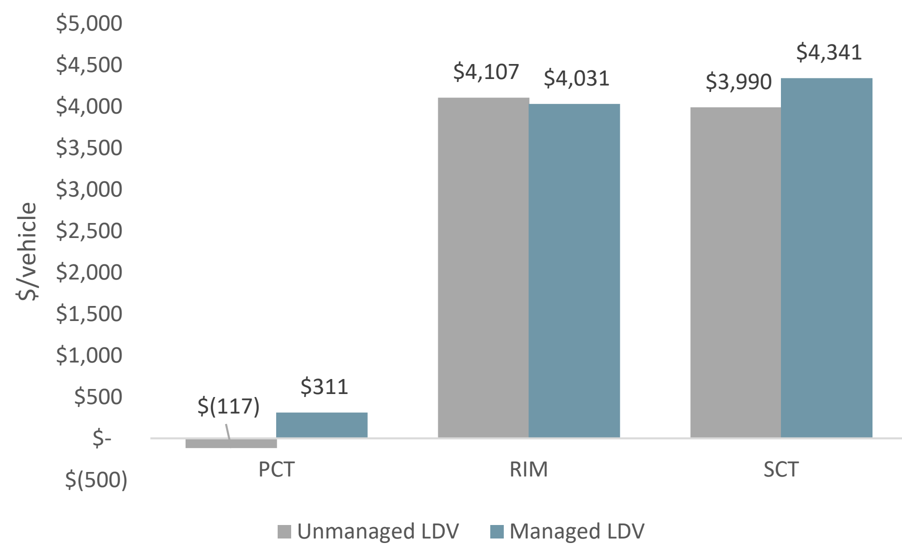
Figure 11. Average Costs and Benefits of Personal LDV electrification per vehicle adopted from 2020 to 2030 – Unmanaged Charging Case



These results show that if drivers charged in an uncontrolled fashion under current residential rates, the average driver across all vehicles adopted between 2020 and 2030 would pay slightly more in total cost of ownership by purchasing a PEV instead of an ICE vehicle. While drivers would enjoy large cost savings from reduced O&M and gasoline over the lifetime of the vehicle, these benefits along with tax credits would not outweigh the higher upfront cost of PEVs, the cost of charging infrastructure, and increased electricity bills from charging. This result is lower than prior cost-benefit studies for other jurisdictions across the US such as California, Hawaii, New York, and Massachusetts. High gasoline prices in these states result in large gasoline savings relative to charging costs. Furthermore, near term gasoline price forecasts have been revised downward this year due to reduced demand from the economic effects of COVID-19 which has reduced gasoline savings compared with earlier studies.

Comparing the unmanaged and managed charging cases we see that unmanaged charging results in driver benefits declining substantially leading to PEV adoption being a net cost to drivers, societal benefits also decline by 8%, and ratepayer benefits narrowly increase by 2% ($76 per EV over the vehicles' 12 year lifetime), as shown in Figure 12.

Figure 12 Net Benefit Comparison of Personal LDV Unmanaged Charging vs. Managed Charging



Moving from a managed to an unmanaged charging paradigm alters the shape of the hourly charging load which primarily affects electric supply costs and utility bills. As discussed previously, the objective of the managed charging case is to minimize customer bills, hence electricity bills (and therefore utility revenue) are $498 lower per EV in the managed case compared to the unmanaged case. Managed charging therefore results in benefits for drivers increasing by $428 per EV after including the cost of installing smart charging network communications.

Managed charging also decreases electricity supply costs by approximately 20% or $420 per EV on average across all vehicles adopted between 2020 and 2030 compared to the unmanaged charging case. In the unmanaged charging case, generation capacity and transmission and distribution capacity costs compose 28% and 6%, respectively, of the total cost to serve PEV load, while in the managed charging case generation capacity is 17% of the cost to serve PEV load and transmission and distribution capacity upgrades is 5% of the cost to serve load. This indicates that moving load to off-peak periods and managing peak PEV loads reduces the capacity costs borne by Xcel ratepayers. However this reduction in supply costs does not offset the revenue loss from lower electric bills leading to slightly smaller ratepayer benefits in the managed charging scenario.

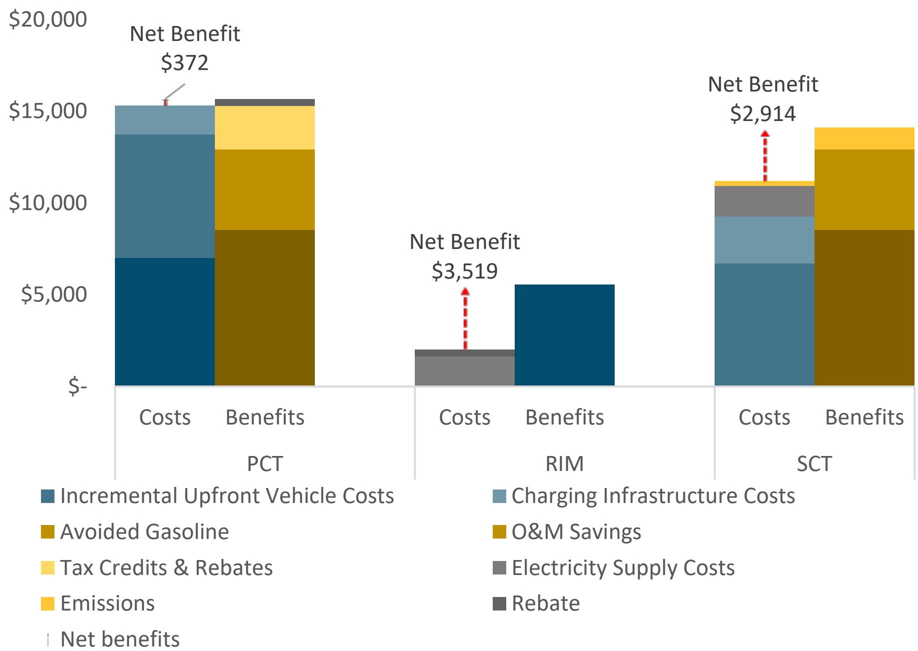
It is important to highlight that when comparing managed and unmanaged charging the results are very sensitive to the price signal used to manage charging. If an alternate price signal were used to manage charging such as a demand response signal or hourly system costs, system costs could decline even further relative to the unmanaged case but at the expense of drivers who would not receive as large bill savings. It should also be noted that for this case the team assumed no difference in adoption between the two scenarios despite the unmanaged scenario showing a higher total cost of ownership in comparison to an ICE vehicle and the managed charging case showing a lower cost of ownership. There is likely to be greater adoption when purchasing an EV presents a significant total cost of ownership benefit as in the managed case due to price elasticity effects, but these are not modelled here. Finally, we assume no change to the structure of electricity tariffs across all years that charging occurs (2020 to 2042).

4.2.3 PERSONAL LDV PURCHASE REBATE

This scenario explored the impacts of Xcel Energy's personal LDV rebate which offers $2,500-1,500 or $1,250-750 on the purchase of new personal LDVs (under $50,000) or used personal LDVs, respectively, from 2021-2025. As a simplifying assumption E3 assumed personal LDV rebates are only allocated to new vehicles and did not consider the price cap for eligibility. Based on the bass-diffusion adoption modeling described in section 3.10.1, the rebate was assumed to increase adoption over the base case assumption by a total of 38,847 vehicles over the 2021-2025 period. However, the rebate program is expected to be fully subscribed by mid-2022.

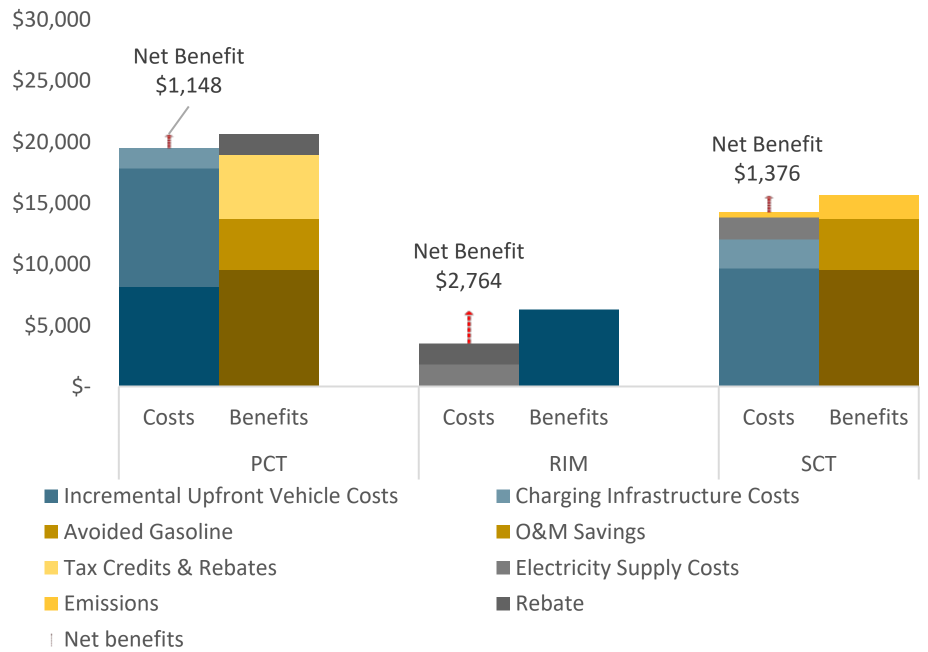
The NPV of the rebate offered to LDV drivers in Xcel Energy's Minnesota Territory is $44M. Over all vehicles adopted between 2020 and 2030 the average NPV of benefits to drivers increases to $372 per vehicle, an increase of $61 over the managed LDV case. Ratepayers see net present benefits increase to $411 million for all PEVs adopted between the 2020 – 2030 over the vehicle lifetime. Adding $44 million in rebates and greater EV adoption increases utility costs but overall revenue from electricity consumption increases due to the greater adoption, which still leads to net benefits for ratepayers. The total benefits to Minnesota state decrease due to the rebate program from a NPV of $366M in the managed LDV case to $335M when the rebate is offered.

Figure 13. per vehicle results for the LDV rebate sensitivity averaged over all vehicles adopted between 2020 and 2030



E3 believes rebate programs should be assessed in the wider context of long-term electrification plans since the adoption impacts of these programs are uncertain and net-benefits of electrification are projected to grow substantially over time as technology improves and costs decline. However, as a sensitivity E3 conducted another EVGrid modelling run to understand the impact of the program just for vehicles that receive the Xcel rebate. As expected, when dividing rebate costs and benefits over a smaller number of vehicles, the per vehicle impacts are larger resulting in larger PCT net benefit and lower RIM net benefits. The societal benefits decline since this sensitivity covers only vehicles adopted through 2022 which have higher upfront vehicle costs.

Figure 14 - NPV of lifetime net benefits for vehicles receiving a rebate under the Xcel energy LDV rebate program

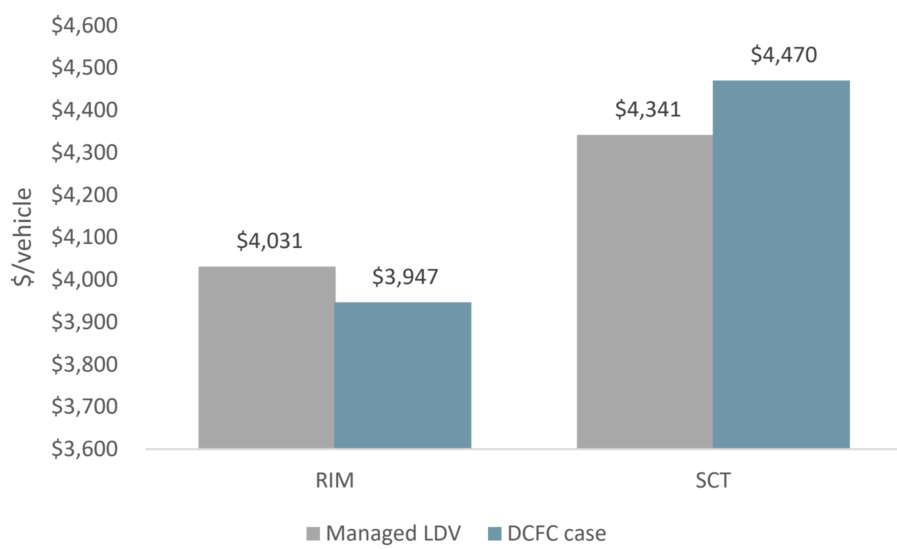


4.2.4 DCFC PROGRAM

In this sensitivity the DCFC charging network in Xcel Energy's Minnesota territory is expanded by adding an additional 70 DCFC chargers between 2021 and 2025 (equivalent to doubling the size of the DCFC charging network in Xcel Energy's Minnesota territory in 2019). Based on E3 cost estimates for DCFC infrastructure the total combined cost for all charging stations is just under $8M in total. The team assumed as a simplifying assumption that all DCFC charging stations were built by Xcel Energy, although the program proposed by Xcel Energy includes just 21 DCFC stations or 42 plugs. As shown in section 3.10.2, the team projects adoption to increase by a total of 5,850 BEVs over the study horizon or around 84

BEVs per DCFC deployed. As described in the methodology section the team assumed the DCFCs have no impact on PHEV adoption.

Figure 15. Net Benefit Comparison of Personal LDV Managed Case vs. High DCFC Case between 2020 and 2030



Since more vehicles are adopted in this scenario and ratepayers benefit by around $3,947 for each vehicle, total ratepayer benefits increase to $346 million for all vehicles adopted between 2020 – 2030. The ratepayer benefit on a per vehicle basis decreases slightly because the additional DCFC charging increases utility supply costs and DCFC infrastructure by 8% but only increases utility revenue by 4%. Minnesota state also sees an overall rise in net-benefits of 7% over the managed case, due to an increase in avoided gasoline costs, avoided O&M, and emissions benefits. Note that the scenario modelled here is a larger program than the one proposed by Xcel Energy. Impacts are also shown for EVs adopted between 2020 and 2030 and while the period over which adoption effects from

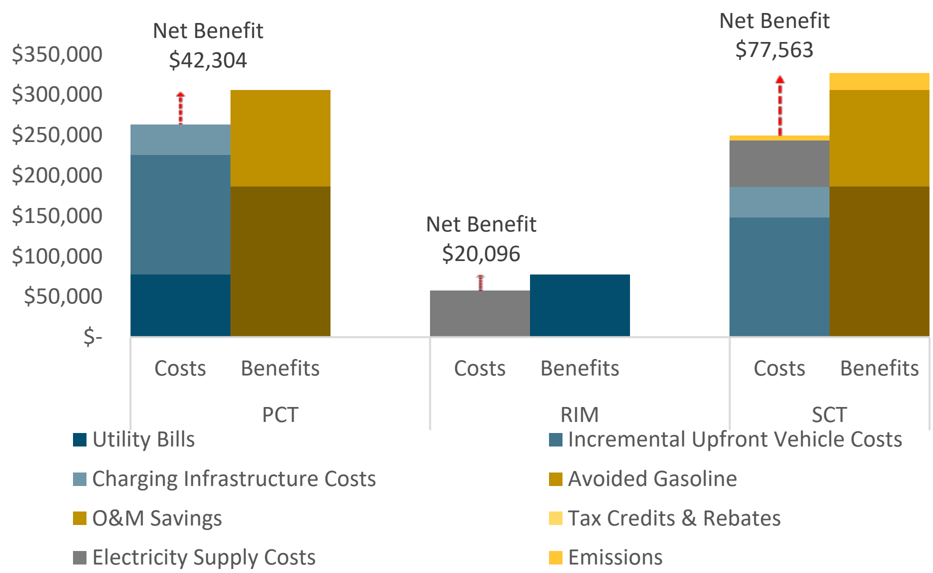
DCFC deployment occur remains highly uncertain, they could continue beyond 2030 which would increase benefits further.

It is important to emphasize that while total ratepayer benefits from this scenario appear high there is great uncertainty around indirect network effects and the causal effect of DCFC deployment on PEV adoption. Indirect network effect studies rely on empirical data and therefore are based on today's PEV market conditions. Studies show that the size of the effect depends strongly on a host of factors such as PEV range, home and workplace charging access, socioeconomics, geography, and others, many of which are rapidly evolving. This sensitivity therefore presents one potential high-level analysis and actual adoption impacts will vary. However, the team has used conservative assumptions compared to the limited available literature. To get a fuller understanding of how the DCFC deployment could impact PEV sales further study on this subject that is specific to Minnesota would be required.

4.3 Transit Buses

For the analysis of HDV electrification in Minnesota the team chose to use transit buses as the representative vehicle type. To model transit buses, it was assumed the vehicles are operated by a fleet owner and only charged at their depot locations, where they would always be parked outside of shift hours. Transit buses have demanding schedules with high mileage and little downtime and therefore need a lot of fast charging infrastructure to ensure batteries can adequately be replenished between shifts. Only daily bus schedules that cover fewer miles than the effective range of the electric transit bus were electrified in the analysis, leading to a lower annual VMT of 42,500 miles. Charging was assumed to be managed to mitigate large demand charges under the proposed A25 rate from fast charging.

Figure 16. Average lifetime vehicle costs and benefits for all transit buses adopted in Xcel Energy Minnesota territory between 2020 and 2030



Using our base assumptions for electric transit bus adoption, these vehicles can provide significant net benefits for transit fleet operators, Minnesota, and Xcel Energy ratepayers on average over all vehicles adopted between 2020 and 2030. Ratepayer net benefits of approximately $44 million could be obtained by 2042 for all buses adopted between 2020 – 2030, or an average of $42,304 per bus. Assuming charging is well managed to minimize the electricity bills for the fleet owner, the cost of supplying the new charging load is offset by the revenue collected under the proposed A25 tariff. Note that if charging were less optimally managed, particularly without demand charge management, electric bills could be substantially higher resulting in greater ratepayer benefits per bus, but lower fleet owner benefits. Also note that these results assume all infrastructure costs in front of the meter are entirely borne by ratepayers. However, some distribution costs such as transformer upgrades would be shared between the utility and the fleet owner under current interconnection rules and tariffs which would lead to higher ratepayer benefits (and lower participant benefits) than presented here.

Using E3 cost estimates, transit agencies or transit bus fleet owners would see net benefits of $21 Million for all electric buses adopted between 2020 and 2030, an average lifetime benefit of $20,096 per bus. Despite the higher up-front cost of electric buses compared to diesel, the cost of installing a DCFC per two buses, and the cost of battery replacements every 200,000 miles, these costs are still outweighed by the diesel and O&M savings for ICE buses as a result of high annual mileage, resulting in net benefits for transit agencies.

The significant O&M and diesel savings along with the net emissions benefit far exceed the incremental vehicle cost, charger costs and battery replacement costs leading to a societal benefit of $82 million for the Minnesota population in Xcel Energy's territory over the lifetime of all buses adopted between 2020 – 2030. In addition, a net CO_2 reduction of approximately 0.44 MMT is achieved by 2042 for all vehicles adopted between 2020 – 2030.

As noted in the methodology section these transit bus costs, and projected declines are taken from BNEF and are not specific to the US. The transit agency, Metro Transit, provided cost estimates for electrification of their transit fleet. In 2020, Metro Transit reports the cost of an electric bus at $990,000 and the cost of an equivalent diesel bus at $500,000. This results in an incremental vehicle cost of $490,000 for an electric bus in 2020 according to Metro Transit, compared to the incremental vehicle cost of $237,000 from the BNEF study.[30]

To project cost estimates through 2030, the team applied the same rate of cost decline as the BNEF bus cost estimates. Using these adjusted costs, and the same inputs as the base HDV case[31], results in fleet owners seeing a net cost for electrification of $353 Million for all buses adopted through 2030 or $336 thousand per bus. The higher incremental upfront vehicle and charger costs projected by Metro Transit are too large to be offset by lifetime gasoline and O&M savings which alters the results substantially. Note that for this estimate E3 did not assume on-route charging was installed which would increase the infrastructure cost even further. E3 chose to use its original source for presenting the base case as BNEF is a widely cited and highly respected source for cost projections and market research into electric vehicle technology. However, the BNEF cost estimates are worldwide averages and assume economies of scale that may only be available for large purchase orders rather than smaller first-time orders such as in Metro Transits case.

It should also be noted that transit bus schedules can vary regionally, and this study utilized NREL's fleetDNA database for bus travel data but local Minnesota transit agencies like Metro Transit may have quite different bus block schedules that would alter the results (NREL, 2019). Finally, a reminder that the HDV class could include other vehicle types such as long-haul trucking which have very

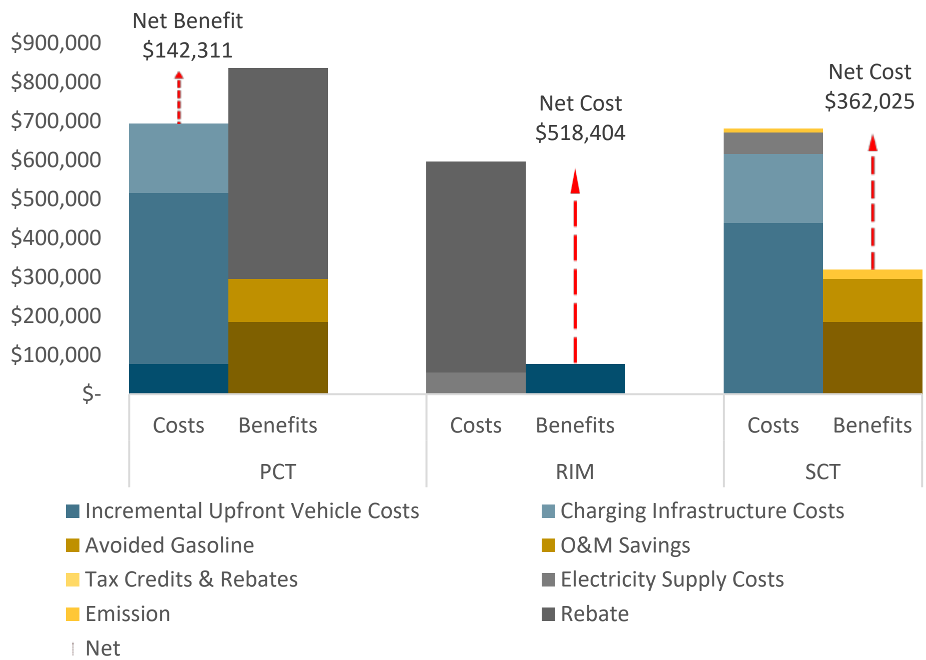
[30] Note that the BNEF cost estimates include both the incremental upfront capital cost of an electric bus compared to a diesel bus and the cost of battery replacement over the vehicle's lifetime. Metro Transit's cost estimate does not include midlife battery replacement.
[31] This analysis uses the same forecast as was assumed in the base HDV case which was developed based on lower incremental upfront costs for electric buses than those reported by Metro Transit.

different driving patterns and vehicle characteristics than transit buses. Other HDVs may have very different cost-benefit results to what is presented here.

4.3.1 TRANSIT BUS PURCHASE REBATE

As discussed in section 3.10.1 Xcel Energy has proposed a rebate program to support electrification of buses in Minnesota. Metro Transit's cost estimates assume the incremental upfront vehicle cost of an electric transit bus is $490,000 in 2020 and under these inputs E3 projects that electrification of a transit buses in Minnesota would be a significant net cost to fleet owners. The rebates proposed by Xcel which start at $1 million in 2021 declining to $250,000 by 2025 would therefore make electrification of Metro Transit's fleet significantly more economically feasible. Since the Xcel electric bus rebates were designed with local transit agency costs in mind, the team chose to use Metro Transit cost assumptions for the rebate program analysis. The rebate program was also evaluated only for participating vehicles (i.e., vehicles that receive a rebate by the program end year of 2025) rather than all vehicles adopted between 2020 and 2030. The team felt it would not be appropriate in this instance to model the full-time horizon since the Metro Transit cost and bus data was only available for 2020. E3 assumed that buses would be adopted following the trajectory of the forecast used in the base case analysis, which was not developed using Metro Transit specific costs and was developed prior to the economic impacts of COVID-19 which have affected transit agencies severely.

Figure 17 - Average lifetime costs and benefits for all Transit Buses Receiving a total of $65 Million in Rebates in Xcel Energy Minnesota territory between 2020 and 2025



The $65 Million earmarked for Metro Transit would support the adoption of new electric buses with the funds being exhausted early in 2025 according to E3 estimates. If the full $100 Million bus rebate were allocated to Metro Transit, it would support further adoption through the end of 2025. Under the base assumption of a $65 Million rebate, Metro Transit[32] would see net benefits of $142,311 per bus on average between 2020 and 2025 while ratepayers would see a significant net cost of $518,404 per bus. E3 assumed transit bus adoption followed the same trajectory as the base case with more participating buses being

[32] It is important to be cognizant that while the PCT in this sensitivity the PCT reflects the perspective of Metro Transit, any net benefits generated may also pass onto the users of public transit as well

adopted in later years leading to an NPV of the average bus rebate of $436,770. Each bus adopted under the program generates $78 thousand on average in ratepayer benefits but this is significantly outweighed by the program costs. As mentioned for the base HDV case, the ratepayer net-benefit would likely be slightly larger since distribution upgrades for a charging load of this size would be shared between ratepayers and the fleet owner while these results assume it is borne entirely by ratepayers. However, the program would still be a large net cost to ratepayers with distribution upgrade cost sharing.

Under the $100 Million rebate program scenario, rebates would be available to support the adoption of more buses through 2025. Since transit bus costs will decline over time (see section 25), the extra buses adopted would be cheaper than buses adopted earlier in the program. Under the program the rebate per vehicle is also lower in 2025 at $250,000 per bus. These two factors mean the net benefits for fleet owners are reduced to $43,772 per bus in the $100 Million rebate program scenario. The ratepayer costs increase overall to a net present value of $63 million but since more buses are included in the program the average ratepayer costs per bus also declines to $415,001 per bus.

It is important to note that for simplicity this analysis assumed the program would not affect the adoption trajectory of electric transit buses in Minnesota but this is highly unlikely to be true in practice. As described in the COVID Relief & Recovery filing, in the absence of a reliable funding source for electrification, Metro Transit currently plans for all bus purchases between 2021 to 2026 to be diesel powered due to budget constraints. Given the high incremental cost that Metro Transit reports for an electric bus and the expected rate of cost decline for electric vehicles, the agency may not purchase any electric buses even beyond

2026 without the support of a rebate. Furthermore, rebates are known to support adoption of new technologies which can increase ratepayer benefits as each vehicle brings additional revenue from charging. Rebates would help build institutional knowledge of transit electrification and the accelerated adoption may also help drive further cost declines through larger orders for buses and infrastructure.

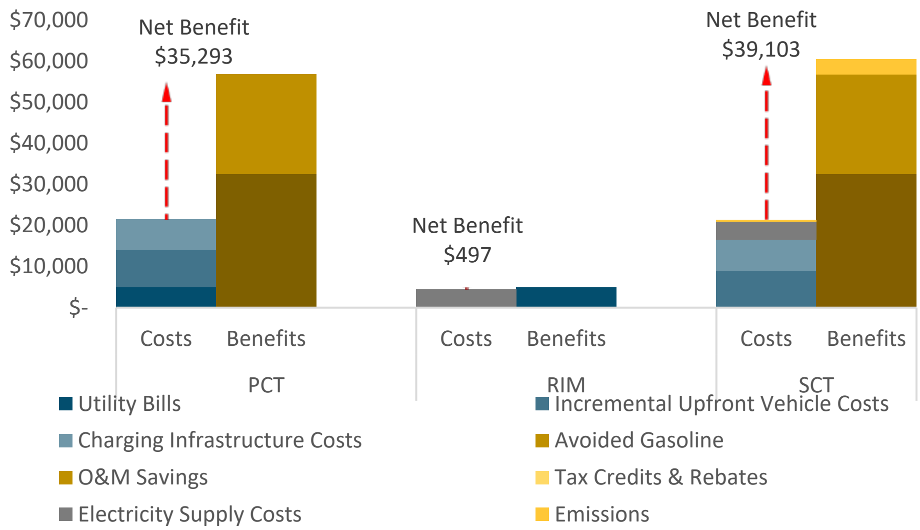
As with the other results there are many benefit streams that are not fully captured through the narrow lens of regulatory cost-benefit tests and this is perhaps most apparent for public transit. For example, studies have found that 50,000 jobs are created per $1 Billion of investment in transit (APTA, 2020). The cost tests also do not provide much detail on who bears the costs and who reaps the benefits of transportation electrification. Transit bus electrification would enable lower income communities to enjoy the benefits of cleaner transportation and increased economic opportunities whereas the electrification of other vehicle types, such as personal LDVs, tend to benefit wealthier consumers who more readily adopt new technologies with high upfront costs. The Federal Transit Administration (FTA) has developed measures to evaluate the indirect benefits of transit investment and electrification including impacts on affordable housing, job creation, land use, and economic development (FTA, 2016). These measures should be considered alongside the results presented here and could be incorporated into future studies that explore the broader benefits of transit electrification.

4.4 Parcel Trucks

Parcel trucks were chosen as a representative class for Medium Duty Vehicles and were modelled as a vehicle fleet which only charge at their depot locations where they are assumed to always be parked when not driving. Parcel trucks cover less mileage than transit buses and have longer charging windows so have lower energy consumption and charging infrastructure needs. Like transit buses it was assumed that fleet owners managed their charging to mitigate large demand charges under the proposed A25 rate.

Cost test results show that electrifying parcel trucks generates lifetime net benefits of $39,103 for Minnesota State and $35,293 for the fleet owner on average per vehicle versus an equivalent gasoline truck. Xcel Energy ratepayers see benefits totaling $634 thousand for all vehicles adopted over the modelling period or an average of $497 per vehicle.

Figure 18. Average lifetime costs and benefits for all Parcel Trucks adopted in Xcel Energy Minnesota territory between 2020 and 2030



It is important to note that, as with the transit bus results, fleet owners are assumed to optimize their charging to reduce their electric bill as much as possible which reduces per vehicle ratepayer benefits. As with the HDV case, the team also used the conservative assumption that the cost for extra distribution upgrades to meet the large depot charging load are borne entirely by the utility (currently an average of $2,294 per vehicle). However, under Xcel's current interconnection rules and tariffs in many cases for upgrades such as these, around a third of costs would be paid for by the site owner. Also note that the adoption forecast for MDVs assumes these vehicles are not adopted until 2023 by which point upfront vehicle and charging infrastructure costs have declined somewhat.

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CERTIFICATE OF SERVICE

I, Crystal Syvertsen, hereby certify that I have this day served copies of the foregoing document on the attached list of persons.

<u>xx</u> by depositing a true and correct copy thereof, properly enveloped with postage paid in the United States mail at Minneapolis, Minnesota

<u>xx</u> electronic filing

Docket Nos. E002/M-20-745

Dated this 11th day of January 2021

/s/
____
Crystal Syvertsen
Regulatory Administrator

First Name	Last Name	Email	Company Name	Address	Delivery Method	View Trade Secret	Service List Name
Tamie A.	Aberle	tamie.aberle@mdu.com	Great Plains Natural Gas Co.	400 North Fourth Street Bismarck, ND 585014092	Electronic Service	No	OFF_SL_20-745_Official
Michael	Ahern	ahern.michael@dorsey.com	Dorsey & Whitney, LLP	50 S 6th St Ste 1500 Minneapolis, MN 554021498	Electronic Service	No	OFF_SL_20-745_Official
Michael	Alvarez	Michael.Alvarez@longroadenergy.com	Community Wind North, LLC	c/o Longroad Development Company, LLC 330 Congress Street, 6th Fl Boston, MA 02210	Electronic Service	No	OFF_SL_20-745_Official
Kristine	Anderson	kanderson@greatermngas.com	Greater Minnesota Gas, Inc.& Greater MN Transmission, LLC	1900 Cardinal Lane PO Box 798 Faribault, MN 55021	Electronic Service	No	OFF_SL_20-745_Official
Alison C	Archer	aarcher@misoenergy.org	MISO	2985 Ames Crossing Rd Eagan, MN 55121	Electronic Service	No	OFF_SL_20-745_Official
Thomas	Ashley	tom@greenlots.com	Greenlots	N/A	Electronic Service	No	OFF_SL_20-745_Official
Kevin	Auerbacher	kauerbacher@tesla.com	Tesla, Inc.	1050 K Street NW, Suite 101 Washington, DC 20001	Electronic Service	No	OFF_SL_20-745_Official
Anjali	Bains	bains@fresh-energy.org	Fresh Energy	408 Saint Peter Ste 220 Saint Paul, MN 55102	Electronic Service	No	OFF_SL_20-745_Official
Max	Baumhefner	MBAUMHEFNER@NRDC.ORG	Natural Resources Defense Council	111 Sutter St 21st Fl San Francisco, CA 94104	Electronic Service	No	OFF_SL_20-745_Official
Carolyn	Berninger	cberninger@mncenter.org	Minnesota Center for Environmental Advocacy	26 E Exchange St Ste 206 Saint Paul, MN 55101	Electronic Service	No	OFF_SL_20-745_Official
James J.	Bertrand	james.bertrand@stinson.com	STINSON LLP	50 S 6th St Ste 2600 Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official

First Name	Last Name	Email	Company Name	Address	Delivery Method	View Trade Secret	Service List Name
Brenda A.	Bjorklund	brenda.bjorklund@centerpointenergy.com	CenterPoint Energy	505 Nicollet Mall Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official
James	Canaday	james.canaday@ag.state.mn.us	Office of the Attorney General-RUD	Suite 1400 445 Minnesota St. St. Paul, MN 55101	Electronic Service	No	OFF_SL_20-745_Official
Cody	Chilson	cchilson@greatermngas.com	Greater Minnesota Gas, Inc. & Greater MN Transmission, LLC	1900 Cardinal Ln PO Box 798 Faribault, MN 55021	Electronic Service	No	OFF_SL_20-745_Official
Ray	Choquette	rchoquette@agp.com	Ag Processing Inc.	12700 West Dodge Road PO Box 2047 Omaha, NE 68103-2047	Electronic Service	No	OFF_SL_20-745_Official
John	Coffman	john@johncoffman.net	AARP	871 Tuxedo Blvd. St, Louis, MO 63119-2044	Electronic Service	No	OFF_SL_20-745_Official
Generic Notice	Commerce Attorneys	commerce.attorneys@ag.state.mn.us	Office of the Attorney General-DOC	445 Minnesota Street Suite 1400 St. Paul, MN 55101	Electronic Service	Yes	OFF_SL_20-745_Official
Riley	Conlin	riley.conlin@stoel.com	Stoel Rives LLP	33 S. 6th Street Suite 4200 Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official
Brooke	Cooper	bcooper@allete.com	Minnesota Power	30 W Superior St Duluth, MN 558022191	Electronic Service	No	OFF_SL_20-745_Official
Grace	Corbin	G.Corbin@mpls-synod.org	Eco-Faith Network	122 W Franklin Ave Ste 600 Minneapolis, MN 55404	Electronic Service	No	OFF_SL_20-745_Official
Heidi	Corcoran	Heidi.Corcoran@CO.DAKOTA.MN.US	Dakota County	N/A	Electronic Service	No	OFF_SL_20-745_Official

First Name	Last Name	Email	Company Name	Address	Delivery Method	View Trade Secret	Service List Name
Hillary	Creurer	hcreurer@allete.com	Minnesota Power	30 W Superior St Duluth, MN 55802	Electronic Service	No	OFF_SL_20-745_Official
George	Crocker	gwillc@nawo.org	North American Water Office	PO Box 174 Lake Elmo, MN 55042	Electronic Service	No	OFF_SL_20-745_Official
Timothy	DenHerder Thomas	timothy@cooperativeenergyfutures.com	Cooperative Energy Futures	3500 Bloomington Ave. S Minneapolis, MN 55407	Electronic Service	No	OFF_SL_20-745_Official
Carrie	Desmond	carrie.desmond@metrotransit.org	Metropolitan Council	560 6th Avenue North Minneapolis, MN 55411	Electronic Service	No	OFF_SL_20-745_Official
Elizabeth	Dickinson	eadickinson@mindspring.com	Community Power	2720 E 22nd St Minneapolis, MN 55406	Electronic Service	No	OFF_SL_20-745_Official
Bridget	Dockter	Bridget.Dockter@xcelenergy.com		N/A	Electronic Service	No	OFF_SL_20-745_Official
Marie	Doyle	marie.doyle@centerpointenergy.com	CenterPoint Energy	505 Nicollet Mall P O Box 59038 Minneapolis, MN 554590038	Electronic Service	No	OFF_SL_20-745_Official
Michelle	Dreier	mdreier@electricalassociation.com		N/A	Electronic Service	No	OFF_SL_20-745_Official
Ron	Elwood	relwood@mnlsap.org	Mid-Minnesota Legal Aid	2324 University Ave Ste 101 Saint Paul, MN 55114	Electronic Service	No	OFF_SL_20-745_Official
James C.	Erickson	jericksonkbc@gmail.com	Kelly Bay Consulting	17 Quechee St Superior, WI 54880-4421	Electronic Service	No	OFF_SL_20-745_Official

First Name	Last Name	Email	Company Name	Address	Delivery Method	View Trade Secret	Service List Name
John	Farrell	jfarrell@ilsr.org	Institute for Local Self-Reliance	2720 E. 22nd St Institute for Local Self-Reliance Minneapolis, MN 55406	Electronic Service	No	OFF_SL_20-745_Official
Eric	Fehlhaber	efehlhaber@dakotaelectric.com	Dakota Electric Association	4300 220th St W Farmington, MN 55024	Electronic Service	No	OFF_SL_20-745_Official
Sharon	Ferguson	sharon.ferguson@state.mn.us	Department of Commerce	85 7th Place E Ste 280 Saint Paul, MN 551012198	Electronic Service	No	OFF_SL_20-745_Official
Daryll	Fuentes	dfuentes@usg.com	USG Corporation	550 W Adams St Chicago, IL 60661	Electronic Service	No	OFF_SL_20-745_Official
Brian	Gardow	bgardow@greatermngas.com	Greater Minnesota Gas, Inc. & Greater MN Transmission, LLC	1900 Cardinal Ln PO Box 798 Faribault, MN 55021	Electronic Service	No	OFF_SL_20-745_Official
James	Garness	james.r.garness@xcelenergy.com		N/A	Electronic Service	No	OFF_SL_20-745_Official
Edward	Garvey	edward.garvey@AESLconsulting.com	AESL Consulting	32 Lawton St Saint Paul, MN 55102-2617	Electronic Service	No	OFF_SL_20-745_Official
Bruce	Gerhardson	bgerhardson@otpco.com	Otter Tail Power Company	PO Box 496 215 S Cascade St Fergus Falls, MN 565380496	Electronic Service	No	OFF_SL_20-745_Official
Janet	Gonzalez	Janet.gonzalez@state.mn.us	Public Utilities Commission	Suite 350 121 7th Place East St. Paul, MN 55101	Electronic Service	No	OFF_SL_20-745_Official
Anita	Grace	anita@gracemulticultural.com	GRACE Multicltural	12959 196th LN NW Elk River, MN 55330	Electronic Service	No	OFF_SL_20-745_Official

First Name	Last Name	Email	Company Name	Address	Delivery Method	View Trade Secret	Service List Name
Bill	Grant	billgrant@minncap.org	Minnesota Community Action Partnership	MCIT Building 100 Empire Dr Ste 202 St. Paul, MN 55103	Electronic Service	No	OFF_SL_20-745_Official
Todd J.	Guerrero	todd.guerrero@kutakrock.com	Kutak Rock LLP	Suite 1750 220 South Sixth Street Minneapolis, MN 554021425	Electronic Service	No	OFF_SL_20-745_Official
Joe	Halso	joe.halso@sierraclub.org	Sierra Club	1536 Wynkoop St Ste 200 Denver, CO 80202	Electronic Service	No	OFF_SL_20-745_Official
Matthew B	Harris	matt.b.harris@xcelenergy.com	XCEL ENERGY	401 Nicollet Mall FL 8 Minneapolis, MN 55401	Electronic Service	No	OFF_SL_20-745_Official
Erik	Hatlestad	erik@cureriver.org	Cure River	117 1st St Montevideo, MN 56265	Electronic Service	No	OFF_SL_20-745_Official
Kim	Havey	kim.havey@minneapolismn.gov	City of Minneapolis	350 South 5th Street, Suite 315M Minneapolis, MN 55415	Electronic Service	No	OFF_SL_20-745_Official
Annete	Henkel	mui@mnutilityinvestors.org	Minnesota Utility Investors	413 Wacouta Street #230 St.Paul, MN 55101	Electronic Service	No	OFF_SL_20-745_Official
Shane	Henriksen	shane.henriksen@enbridge.com	Enbridge Energy Company, Inc.	1409 Hammond Ave FL 2 Superior, WI 54880	Electronic Service	No	OFF_SL_20-745_Official
Corey	Hintz	chintz@dakotaelectric.com	Dakota Electric Association	4300 220th Street Farmington, MN 550249583	Electronic Service	No	OFF_SL_20-745_Official
Michael	Hoppe	lu23@ibew23.org	Local Union 23, I.B.E.W.	445 Etna Street Ste. 61 St. Paul, MN 55106	Electronic Service	No	OFF_SL_20-745_Official

First Name	Last Name	Email	Company Name	Address	Delivery Method	View Trade Secret	Service List Name
MJ	Horner	mj.horner@xcelenergy.com		N/A	Electronic Service	No	OFF_SL_20-745_Official
Samantha	Houston	shouston@ucsusa.org	Union of Concerned Scientists	1825 K St. NW Ste 800 Washington, DC 20006	Electronic Service	No	OFF_SL_20-745_Official
Lori	Hoyum	lhoyum@mnpower.com	Minnesota Power	30 West Superior Street Duluth, MN 55802	Electronic Service	No	OFF_SL_20-745_Official
Holmes	Hummel	Holmes.Hummel@CleanEnergyWorks.org	Clean Energy Works	925 French St NW Washington, DC 20001	Electronic Service	No	OFF_SL_20-745_Official
Travis	Jacobson	travis.jacobson@mdu.com	Great Plains Natural Gas Company	400 N 4th St Bismarck, ND 58501	Electronic Service	No	OFF_SL_20-745_Official
Alan	Jenkins	aj@jenkinsatlaw.com	Jenkins at Law	2950 Yellowtail Ave. Marathon, FL 33050	Electronic Service	No	OFF_SL_20-745_Official
Richard	Johnson	Rick.Johnson@lawmoss.com	Moss & Barnett	150 S. 5th Street Suite 1200 Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official
Sarah	Johnson Phillips	sarah.phillips@stoel.com	Stoel Rives LLP	33 South Sixth Street Suite 4200 Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official
Brendan	Jordan	bjordan@gpisd.org	Great Plains Institute & Bioeconomy Coalition of MN	2801 21st Ave S Ste 220 Minneapolis, MN 55407	Electronic Service	No	OFF_SL_20-745_Official
Stacey	Karels	skarels@local563.org	Mankato Area Bldg & Construction Trades Council	310 McKinzie St Mankato, MN 56001	Electronic Service	No	OFF_SL_20-745_Official

First Name	Last Name	Email	Company Name	Address	Delivery Method	View Trade Secret	Service List Name
Mark J.	Kaufman	mkaufman@ibewlocal949.org	IBEW Local Union 949	12908 Nicollet Avenue South Burnsville, MN 55337	Electronic Service	No	OFF_SL_20-745_Official
Thomas	Koehler	TGK@IBEW160.org	Local Union #160, IBEW	2909 Anthony Ln St Anthony Village, MN 55418-3238	Electronic Service	No	OFF_SL_20-745_Official
Frank	Kohlasch	frank.kohlasch@state.mn.us	MN Pollution Control Agency	520 Lafayette Rd N. St. Paul, MN 55155	Electronic Service	No	OFF_SL_20-745_Official
Michael	Krikava	mkrikava@taftlaw.com	Taft Stettinius & Hollister LLP	2200 IDS Center 80 S 8th St Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official
Nicolle	Kupser	nkupser@greatermngas.com	Greater Minnesota Gas, Inc. & Greater MN Transmission, LLC	1900 Cardinal Ln PO Box 798 Faribault, MN 55021	Electronic Service	No	OFF_SL_20-745_Official
Douglas	Larson	dlarson@dakotaelectric.com	Dakota Electric Association	4300 220th St W Farmington, MN 55024	Electronic Service	No	OFF_SL_20-745_Official
Peder	Larson	plarson@larkinhoffman.com	Larkin Hoffman Daly & Lindgren, Ltd.	8300 Norman Center Drive Suite 1000 Bloomington, MN 55437	Electronic Service	No	OFF_SL_20-745_Official
James D.	Larson	james.larson@avantenergy.com	Avant Energy Services	220 S 6th St Ste 1300 Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official
Amber	Lee	Amber.Lee@centerpointenergy.com	CenterPoint Energy	505 Nicollet Mall Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official

First Name	Last Name	Email	Company Name	Address	Delivery Method	View Trade Secret	Service List Name
Annie	Levenson Falk	annielf@cubminnesota.org	Citizens Utility Board of Minnesota	332 Minnesota Street, Suite W1360 St. Paul, MN 55101	Electronic Service	No	OFF_SL_20-745_Official
Ryan	Long	ryan.j.long@xcelenergy.com	Xcel Energy	414 Nicollet Mall 401 8th Floor Minneapolis, MN 55401	Electronic Service	No	OFF_SL_20-745_Official
Susan	Ludwig	sludwig@mnpower.com	Minnesota Power	30 West Superior Street Duluth, MN 55802	Electronic Service	No	OFF_SL_20-745_Official
Kavita	Maini	kmaini@wi.rr.com	KM Energy Consulting, LLC	961 N Lost Woods Rd Oconomowoc, WI 53066	Electronic Service	No	OFF_SL_20-745_Official
Nick	Mark	nick.mark@centerpointenergy.com	CenterPoint Energy	505 Nicollet Mall Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official
Pam	Marshall	pam@energycents.org	Energy CENTS Coalition	823 7th St E St. Paul, MN 55106	Electronic Service	No	OFF_SL_20-745_Official
Brian	Meloy	brian.meloy@stinson.com	STINSON LLP	50 S 6th St Ste 2600 Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official
Joseph	Meyer	joseph.meyer@ag.state.mn.us	Office of the Attorney General-RUD	Bremer Tower, Suite 1400 445 Minnesota Street St Paul, MN 55101-2131	Electronic Service	No	OFF_SL_20-745_Official
Kevin	Miller	kevin.miller@chargepoint.com	ChargePoint, Inc.	254 E. Hacienda Avenue Campbell, California 95008	Electronic Service	No	OFF_SL_20-745_Official
Stacy	Miller	stacy.miller@minneapolismn.gov	City of Minneapolis	350 S. 5th Street Room M 301 Minneapolis, MN 55415	Electronic Service	No	OFF_SL_20-745_Official

First Name	Last Name	Email	Company Name	Address	Delivery Method	View Trade Secret	Service List Name
David	Moeller	dmoeller@allete.com	Minnesota Power	30 W Superior St Duluth, MN 558022093	Electronic Service	No	OFF_SL_20-745_Official
Marc	Monbouquette	marc.monbouquette@enel.com	Enel X North America, Inc.	846 Bransten Rd San Carlos, CA 94070	Electronic Service	No	OFF_SL_20-745_Official
Andrew	Moratzka	andrew.moratzka@stoel.com	Stoel Rives LLP	33 South Sixth St Ste 4200 Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official
Mark	Nabong	mnabong@nrdc.org	Natural Resources Defense Council	20 N. Wacker Drive #1600 Chicago, IL 60606	Electronic Service	No	OFF_SL_20-745_Official
David	Niles	david.niles@avantenergy.com	Minnesota Municipal Power Agency	220 South Sixth Street Suite 1300 Minneapolis, Minnesota 55402	Electronic Service	No	OFF_SL_20-745_Official
Michael	Noble	noble@fresh-energy.org	Fresh Energy	Hamm Bldg., Suite 220 408 St. Peter Street St. Paul, MN 55102	Electronic Service	No	OFF_SL_20-745_Official
Samantha	Norris	samanthanorris@alliantenergy.com	Interstate Power and Light Company	200 1st Street SE PO Box 351 Cedar Rapids, IA 524060351	Electronic Service	No	OFF_SL_20-745_Official
Nate	OReilly	nate@iron512.com		851 Pierce Butler Route St Paul, MN 55104	Electronic Service	No	OFF_SL_20-745_Official
Matthew	Olsen	molsen@otpco.com	Otter Tail Power Company	215 South Cascade Street Fergus Falls, MN 56537	Electronic Service	No	OFF_SL_20-745_Official
Debra	Opatz	dopatz@otpco.com	Otter Tail Power Company	215 South Cascade Street Fergus Falls, MN 56537	Electronic Service	No	OFF_SL_20-745_Official

First Name	Last Name	Email	Company Name	Address	Delivery Method	View Trade Secret	Service List Name
Carol A.	Overland	overland@legalectric.org	Legalectric - Overland Law Office	1110 West Avenue Red Wing, MN 55066	Electronic Service	No	OFF_SL_20-745_Official
John	Pacheco	johnpachecojr@gmail.com		N/A	Electronic Service	No	OFF_SL_20-745_Official
Greg	Palmer	gpalmer@greatermngas.com	Greater Minnesota Gas, Inc. & Greater MN Transmission, LLC	1900 Cardinal Ln PO Box 798 Faribault, MN 55021	Electronic Service	No	OFF_SL_20-745_Official
Ben	Passer	Passer@fresh-energy.org	Fresh Energy	408 St. Peter Street Ste 220 Saint Paul, MN 55102	Electronic Service	No	OFF_SL_20-745_Official
Jose	Perez	jose@hispanicsinenergy.com		1017 L Street #719 Sacramento, CA 95814	Electronic Service	No	OFF_SL_20-745_Official
Jennifer	Peterson	jjpeterson@mnpower.com	Minnesota Power	30 West Superior Street Duluth, MN 55802	Electronic Service	No	OFF_SL_20-745_Official
Catherine	Phillips	Catherine.Phillips@wecenergygroup.com	Minnesota Energy Resources	231 West Michigan St Milwaukee, WI 53203	Electronic Service	No	OFF_SL_20-745_Official
Marcia	Podratz	mpodratz@mnpower.com	Minnesota Power	30 W Superior S Duluth, MN 55802	Electronic Service	No	OFF_SL_20-745_Official
Kevin	Pranis	kpranis@liunagroc.com	Laborers' District Council of MN and ND	81 E Little Canada Road St. Paul, Minnesota 55117	Electronic Service	No	OFF_SL_20-745_Official
David G.	Prazak	dprazak@otpco.com	Otter Tail Power Company	P.O. Box 496 215 South Cascade Street Fergus Falls, MN 565380496	Electronic Service	No	OFF_SL_20-745_Official

First Name	Last Name	Email	Company Name	Address	Delivery Method	View Trade Secret	Service List Name
Generic Notice	Residential Utilities Division	residential.utilities@ag.state.mn.us	Office of the Attorney General-RUD	1400 BRM Tower 445 Minnesota St St. Paul, MN 551012131	Electronic Service	Yes	OFF_SL_20-745_Official
Kevin	Reuther	kreuther@mncenter.org	MN Center for Environmental Advocacy	26 E Exchange St, Ste 206 St. Paul, MN 551011667	Electronic Service	No	OFF_SL_20-745_Official
Susan	Romans	sromans@allete.com	Minnesota Power	30 West Superior Street Legal Dept Duulth, MN 55802	Electronic Service	No	OFF_SL_20-745_Official
Richard	Savelkoul	rsavelkoul@martinsquires.com	Martin & Squires, P.A.	332 Minnesota Street Ste W2750 St. Paul, MN 55101	Electronic Service	No	OFF_SL_20-745_Official
Tim	Schaefer	tschaefer@environmentminnesota.org	Environment MN	211 N 1st St Ste 480 Minneapolis, MN 55401	Electronic Service	No	OFF_SL_20-745_Official
Thomas	Scharff	thomas.scharff@versoco.com	Verso Corp	600 High Street Wisconsin Rapids, WI 54495	Electronic Service	No	OFF_SL_20-745_Official
Larry L.	Schedin	Larry@LLSResources.com	LLS Resources, LLC	332 Minnesota St, Ste W1390 St. Paul, MN 55101	Electronic Service	No	OFF_SL_20-745_Official
Elizabeth	Schmiesing	eschmiesing@winthrop.com	Winthrop & Weinstine, P.A.	225 South Sixth Street Suite 3500 Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official
Kevin	Schwain	Kevin.D.Schwain@xcelenergy.com	Xcel Energy	404 Nicollet Mall Minneapolis, MN 55401	Electronic Service	No	OFF_SL_20-745_Official

First Name	Last Name	Email	Company Name	Address	Delivery Method	View Trade Secret	Service List Name
Will	Seuffert	Will.Seuffert@state.mn.us	Public Utilities Commission	121 7th Pl E Ste 350 Saint Paul, MN 55101	Electronic Service	Yes	OFF_SL_20-745_Official
Timothy	Sexton	Timothy.Sexton@state.mn.us	Minnesota Department of Transportation	395 John Ireland Blvd #620 St. Paul, MN 55155-1899	Electronic Service	No	OFF_SL_20-745_Official
Janet	Shaddix Elling	jshaddix@janetshaddix.com	Shaddix And Associates	7400 Lyndale Ave S Ste 190 Richfield, MN 55423	Electronic Service	No	OFF_SL_20-745_Official
Colleen	Sipiorski	Colleen.Sipiorski@wecenergygroup.com	Minnesota Energy Resources Corporation	700 North Adams St Green Bay, WI 54307	Electronic Service	No	OFF_SL_20-745_Official
Anne	Smart	anne.smart@chargepoint.com	ChargePoint, Inc.	254 E Hacienda Ave Campbell, CA 95008	Electronic Service	No	OFF_SL_20-745_Official
Ken	Smith	ken.smith@districtenergy.com	District Energy St. Paul Inc.	76 W Kellogg Blvd St. Paul, MN 55102	Electronic Service	No	OFF_SL_20-745_Official
Peggy	Sorum	peggy.sorum@centerpointenergy.com	CenterPoint Energy	505 Nicollet Mall Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official
Jamez	Staples	jstaples@renewablenrgpartners.com	Renewable Energy Partners	3033 Excelsior Blvd S Minneapolis, MN 55416	Electronic Service	No	OFF_SL_20-745_Official
Byron E.	Starns	byron.starns@stinson.com	STINSON LLP	50 S 6th St Ste 2600 Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official

First Name	Last Name	Email	Company Name	Address	Delivery Method	View Trade Secret	Service List Name
Richard	Stasik	richard.stasik@wecenergygroup.com	Minnesota Energy Resources Corporation (HOLDING)	231 West Michigan St - P321 Milwaukee, WI 53203	Electronic Service	No	OFF_SL_20-745_Official
Kristin	Stastny	kstastny@taftlaw.com	Taft Stettinius & Hollister LLP	2200 IDS Center 80 South 8th St Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official
Cary	Stephenson	cStephenson@otpco.com	Otter Tail Power Company	215 South Cascade Street Fergus Falls, MN 56537	Electronic Service	No	OFF_SL_20-745_Official
James M	Strommen	jstrommen@kennedy-graven.com	Kennedy & Graven, Chartered	150 S 5th St Ste 700 Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official
Eric	Swanson	eswanson@winthrop.com	Winthrop & Weinstine	225 S 6th St Ste 3500 Capella Tower Minneapolis, MN 554024629	Electronic Service	No	OFF_SL_20-745_Official
Lynnette	Sweet	Regulatory.records@xcelenergy.com	Xcel Energy	414 Nicollet Mall FL 7 Minneapolis, MN 554011993	Electronic Service	Yes	OFF_SL_20-745_Official
Dean	Taylor	dtaylor@pluginamerica.org	Plug In America	6380 Wilshire Blvd, Suite 1000 Los Angeles, CA 90048	Electronic Service	No	OFF_SL_20-745_Official
Stuart	Tommerdahl	stommerdahl@otpco.com	Otter Tail Power Company	215 S Cascade St PO Box 496 Fergus Falls, MN 56537	Electronic Service	No	OFF_SL_20-745_Official
Karen	Turnboom	karen.turnboom@versoco.com	Verso Corporation	100 Central Avenue Duluth, MN 55807	Electronic Service	No	OFF_SL_20-745_Official

First Name	Last Name	Email	Company Name	Address	Delivery Method	View Trade Secret	Service List Name
Andrew	Twite	twite@fresh-energy.org	Fresh Energy	408 St. Peter Street, Ste. 220 St. Paul, MN 55102	Electronic Service	No	OFF_SL_20-745_Official
Thomas	Tynes	jjazynka@energyfreedomcoalition.com	Energy Freedom Coalition of America	101 Constitution Ave NW Ste 525 East Washington, DC 20001	Electronic Service	No	OFF_SL_20-745_Official
Ana	Vang	avang@mnpower.com	Minnesota Power	30 W Superior St Duluth, MN 558022093	Electronic Service	No	OFF_SL_20-745_Official
Lisa	Veith	lisa.veith@ci.stpaul.mn.us	City of St. Paul	400 City Hall and Courthouse 15 West Kellogg Blvd. St. Paul, MN 55102	Electronic Service	No	OFF_SL_20-745_Official
Dwight	Wagenius	dwagenius@gmail.com	Minnesota Interfaith Power & Light	4407 E Lake St Minneapolis, MN 55406	Electronic Service	No	OFF_SL_20-745_Official
Francesca	Wahl	fwahl@tesla.com	Tesla	3500 Deer Creek Rd Palo Alto, CA 94304	Electronic Service	No	OFF_SL_20-745_Official
Darrell	Washington	darrell.washington@state.mn.us	DOT	N/A	Electronic Service	No	OFF_SL_20-745_Official
Samantha	Williams	swilliams@nrdc.org	Natural Resources Defense Council	20 N. Wacker Drive Ste 1600 Chicago, IL 60606	Electronic Service	No	OFF_SL_20-745_Official
Justin	Wilson	justin.wilson@chargepoint.com	ChargePoint	240 East Hacienda Ave. Campbell, CA 95008	Electronic Service	No	OFF_SL_20-745_Official
Joseph	Windler	jwindler@winthrop.com	Winthrop & Weinstine	225 South Sixth Street, Suite 3500 Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official

First Name	Last Name	Email	Company Name	Address	Delivery Method	View Trade Secret	Service List Name
Patrick	Zomer	Patrick.Zomer@lawmoss.com	Moss & Barnett a Professional Association	150 S. 5th Street, #1200 Minneapolis, MN 55402	Electronic Service	No	OFF_SL_20-745_Official