

Electric Grid Impacts and Benefits of Off-Road and Commercial Transportation Electrification in California

Eric Cutter¹, Jeff Rosenfeld², Brendan Schneiderman¹, Dr. Nancy E. Ryan¹, Luke Lavin¹

¹*Energy and Environmental Economics 101 Montgomery Street, Suite 1600, San Francisco, CA 94104; for questions contact eric@ethree.com*

²*ICF International, 620 Folsom St, Suite 200, San Francisco, CA 94107, Jeffrey.Rosenfeld@icfi.com*

Summary

We quantify the electric grid impacts and benefits for electrification of several off-road and commercial transportation technologies in California, including: forklifts, truck stop electrification (TSE), electric transport refrigeration units (e-TRU), transit buses and light, medium, and heavy heavy-duty trucks (LHD, MHD, HHD). We find regional economic benefits of \$2.9 million for commercial transport electrification and the potential for reduced utility rates due to EV adoption. Despite clear regional economic benefits, several barriers to adoption remain and can be addressed by government and utility programs.

Keywords: Business Model, Heavy-Duty, Policy, Public Transport, Utility

1 Introduction

Federal and state policies aimed at regional air quality and climate change mitigation are major drivers for transportation electrification (TE) in California. Electrified transportation technologies have near-zero or zero tailpipe emissions, and electricity generated in California has lower carbon intensity than gasoline and diesel. Furthermore, the transportation sector's petroleum dependency continues to be a national security concern while exposing consumers and businesses to price volatility. Despite the environmental benefits of transportation electrification, the technologies still face many barriers. Most notably, electrified technologies often have higher upfront costs and/or require significant infrastructure investments such as electric vehicle supply equipment (EVSE), high load transformers and new electrical interconnections. This analysis presents evidence that these high initial investment costs may be offset by broad societal benefits. Encouraging flexible charging, ongoing charger maintenance, and expansion of governmental and utility programs will be critical to realizing these benefits.

Transportation electrification technologies reviewed in this paper include commercial on-road vehicles as well as off-road technologies such as forklifts, truck stop electrification (TSE), transport refrigeration units (TRUs), and medium- and heavy-duty (MD/HD) trucks (collectively Medium and Heavy Duty Vehicles, MDV/HDV). This analysis was conducted as part of the California Transportation Electrification Assessment for the California utilities Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas and

Electric (SDG&E), and Sacramento Municipal Utility District (SMUD) and builds on previous E3/ICF work on light-duty vehicle electrification costs and benefits for these utilities [1],[2]. Results of detailed modeling and quantification of grid benefits are presented using California Public Utilities Commission (CPUC) Standard Practice Manual (SPM) cost-tests with E3’s Distributed Energy Resources Avoided Cost Framework. These technologies and E3/ICF’s approach to modelling their electrification impacts are discussed further in sections 1&2.

Figure 1 below shows the combined results from the Total Resource Cost test (TRC) and Societal Cost Test (SCT) for all of the on-road and off-road EV technologies analyzed. The TRC evaluates monetized resource expenditures and savings for the region as a whole, and the SCT includes additional environmental and societal benefits that are not directly monetized. Positive TRC results suggest regional electric MDV/HDV adoption can yield monetary savings given optimal program design, while the SCT indicates there are further non-monetized societal benefits to electric MDV/HDV adoption.

Figure 1 shows \$2.9 billion and \$3.8 billion (2014\$) in TRC and SCT benefits, respectively, for the “In Between” adoption scenario, which has adoption levels in between the “In Line with Current Adoption” and “Aggressive Adoption” scenarios (see section 1.1.2 for scenario descriptions). Cost results are discussed further in Section 3.

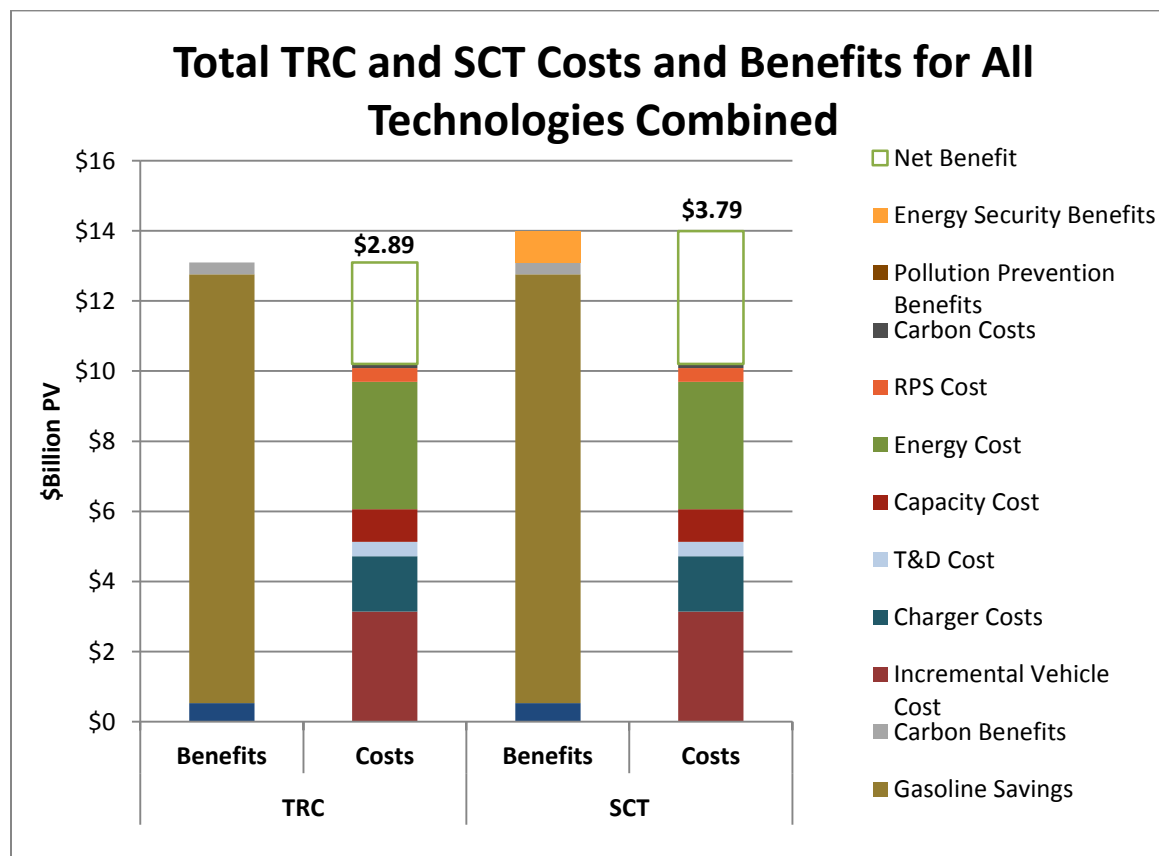


Figure 1. Total TRC and SCT Costs and Benefits for All Technologies Combined, “In Between” Case (see section 1.1.2)

However, the benefits shown in Figure 1 will not be realized at current low levels of MDV/HDV EV adoption. To realize these potential long-term grid benefits of commercial and off-road transportation electrification, it is

necessary to increase EV market penetration in the near-term. ICF and E3 identified the following major obstacles and barriers to achieving this near-term market penetration, discussed further in Section 5:

- Incremental up-front costs relative to conventional vehicles
- Limited vehicle options
- Customer bill impacts including demand charges and rate structures
- Cost to provide appropriate charging infrastructure

In section 6, E3/ICF discuss opportunities for utilities to address these obstacles through education and outreach, vehicle purchase incentives, electric tariff redesign, and load management coaching.

2 Study Technologies and Charger Costs

We include adoption and energy consumption scenarios for forklifts, TSE, TRUs, and MD/HD trucks and costing for forklifts, TSE and TRUs. These technologies and their incremental costs are characterized further in the Appendix.

2.1 Charger Installation Costs

In addition to the vehicle-specific charging equipment costs shown in the Appendix, we also include generic estimates of installation costs for Level 2 and DC fast charging at commercial sites. Cost estimates are provided for installing five commercial L2 EVSEs and two DC fast charger EVSEs at each site. The estimates include trenching, conduit, engineering & design, breakers, fuses, panels, signs and permitting. The total installation cost for five commercial L2 chargers used in our analysis is \$19,075 and for two DC fast chargers is \$11,095, though more recent estimates show costs may be substantially higher than these numbers. These estimates are used as representative average costs for commercial and workplace installations, though actual customer costs will vary substantially from site to site.

2.2 Adoption Levels

E3/ICF evaluated three adoption scenarios: “In Line with Current Adoption,” “Aggressive Adoption,” and “In Between.” Adoption level assumptions by year and vehicle type for the “In Between” scenario are shown in Table 1.

Table 1: Technology Adoption Levels

Technology	2010	2020	2025	2030
eTRU (25-50 hp)	36	7,581		49,312
eTRU (11-25 hp)	3,595	8,245		17,401
eTRU (<11 hp)	0	106		538
TSE (spaces)	262	1,523		2,452
Forklifts (Class 1&2)	42,905	62,936		101,176

MDV/LHD (Class 2&3) *.01	3	627	5,035	5,035
MHD (Class 4-7)	1	157	1,139	4,118
HHD (Class 8)	1	179	3,563	17,979
Buses	0	46	385	1,400

2.3 Vehicle Electricity Consumption and Load Shapes

Electricity consumption assumptions by vehicle type are shown in Tables 2 and 3.

Table 2. Forklift, TSE and eTRU Electricity Consumption

Technology	Annual kWh
Forklifts - <120 hp	18,312
Forklifts – 120-175 hp	52,080
TSE (per space)	7,305
eTRU – 25-50 hp	10,600
eTRU – 11-25 hp	8,160
eTRU - <11 hp	2,720

Table 3. MD/HD Electricity Consumption by Vehicle Class and Type

Vehicle Class	PHEV Annual kWh	BEV Annual kWh
MDV/LHD	6,080	14,720
MHD	11,520	40,000
HHD	19,520	107,840 - 160,000
Buses	51,840	103,680

We also developed normalized load profiles for each of these technologies by charger type. Load profiles for forklifts, TRU/TSE, LHD/MHD vehicles, and buses are shown below:

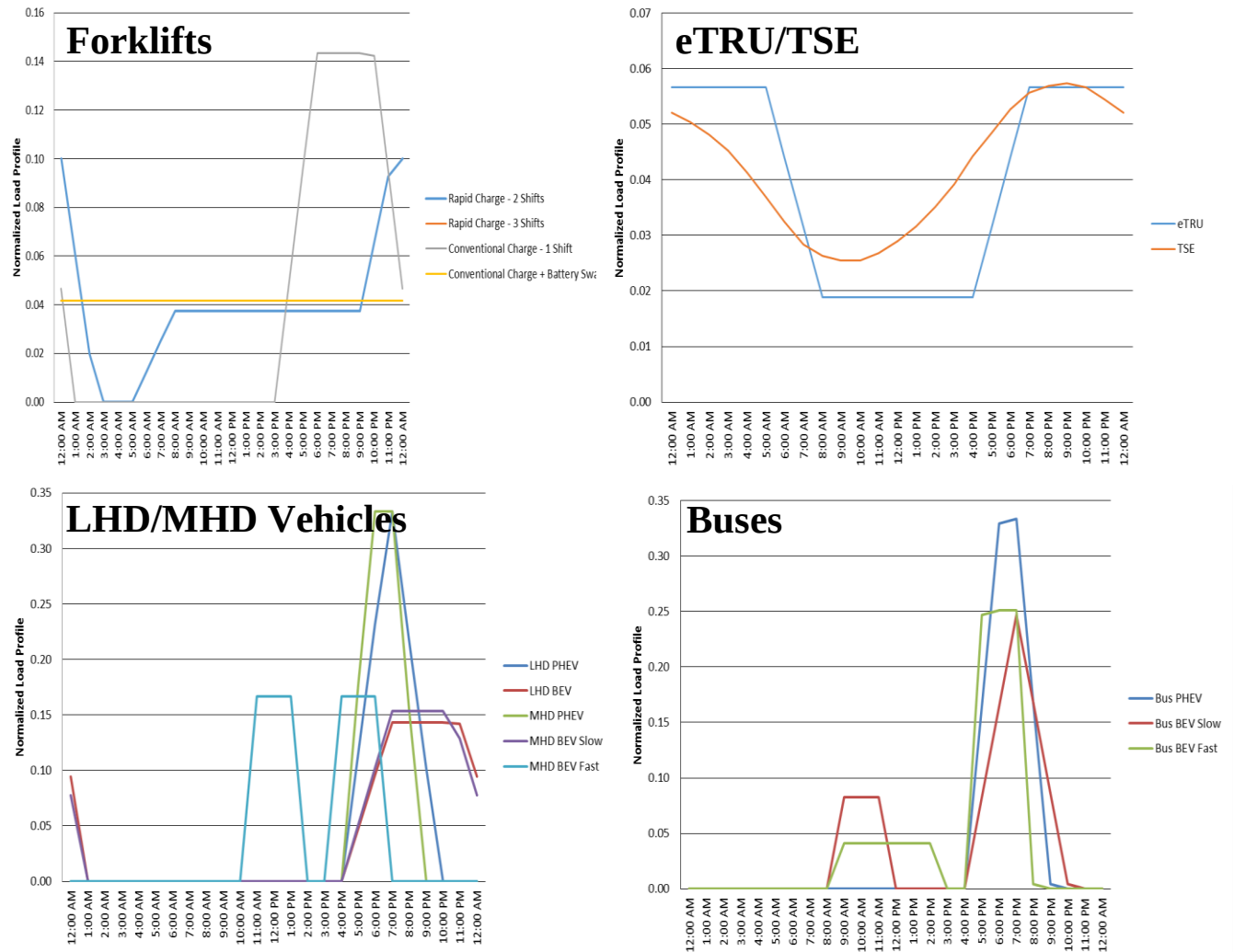


Figure 2. Forklift, eTRU/TSE, LHD/MHD Vehicles, and Bus Load Shapes

3 Grid Impact Analysis

We calculated the distribution grid impacts and upgrade costs for the MDV/HDV sector. We calculate the PEV-related peak load growth that would occur at each location on the distribution system and calculated the PEV-related distribution upgrade costs.

3.1 Spatial Adoption Patterns

Light duty electric vehicle (LDV) adoption analyses are often based on hybrid electric vehicle (HEV) adoption patterns. However, for the MDV/HDV sector there is no record of prior HEV, so a different approach is required. Further, MDV/HDV technologies are typically owned by businesses and governments rather than residential consumers, and are mostly used for transporting goods rather than passengers (with the exception of buses). Some of the technologies, like TSE and eTRUs, are not even vehicles.

As a result of these differences to LDVs, our MDV/HDV model uses a random distribution approach. The annual number of incremental units for each technology is taken from adoption forecasts and randomly

distributed across all utility distribution feeders. The unit of analysis is the customer, since vehicles such as forklifts are assumed to operate as a fleet rather than individual vehicles. Since the distribution process is stochastic, each run of the model produces a different distribution pattern. We tested a range of distributions and found similar distribution system upgrade costs (see section 2.2) associated with the different adoption scenarios. These distribution system costs are a relatively small portion of costs in the TRC/SCT, as seen in Figure 1.

3.2 Distribution System Upgrade Costs

The California utilities PG&E, SCE, SDG&E, and SMUD provided E3/ICF with distribution-level feeder data. Each utility specified the level of utilization that would trigger a circuit, feeder or substation upgrade. For each type of upgrade, the utilities also provided average upgrade sizes and costs representative of their respective systems. In each modeled year, upgrade costs are added when load increases cause loads to exceed rated capacity. The cost of distribution system upgrades is added to each utility's rate base and included in the cost-effectiveness analysis. The model looks forward several years to determine whether a single (larger) new substation or substation upgrade or several (smaller) feeder upgrades are more cost-effective. The utilities also estimated the percentage of existing substation locations at which upgrades could feasibly be performed (e.g., have sufficient high-side capacity and land area to add a new low-side bus). In some cases, this upgrades feasibility constraint results in lower-cost options being unavailable and results in higher cost upgrades.

3.2.1 PEV-Related Distribution Upgrades

We combined adoption scenarios, load shapes, and geographic distribution of EVs to calculate peak load growth that would occur at each location on the distribution system for each scenario as a result of EV adoption. With the utility distribution system data, we are able to calculate utilization at each point with the total forecasted load growth, including incremental EV charging load. To examine the grid impacts specific to EV charging, we first model distribution upgrades required to meet the base case forecasted load growth provided by each utility. We then add the hourly EV charging load for each adoption scenario to the base case load forecast and model the required distribution upgrades. We count the incremental distribution upgrades in the EV charging case as being EV-related. The additional distribution upgrade cost with EV charging is due to both a greater number of required upgrades and some upgrades being required earlier than they are in the base case without EVs. The distribution upgrade costs are included in the cost-effectiveness results presented in the next section.

4 Cost-Effectiveness Results

We use the cost tests developed in the California Practice Manual to evaluate the cost-effectiveness of electrifying medium- and heavy-duty vehicles. These costs tests are the same tests the California Public Utilities Commission (CPUC) uses to evaluate energy efficiency measures. Each of the cost tests evaluates cost-effectiveness from a different stakeholder perspective. We focus here on the Total Resource Cost test (TRC), which looks at monetized resource expenditures and savings for the region as a whole, and the Societal Cost Test, which includes additional environmental and societal benefits.

This study includes the territories of the four utilities that contributed data and evaluates the regional perspective of the state of California as a whole. Federal tax credits are included as a benefit but state tax

credits are not included: federal tax credits add to the resource base in the state by bringing in money from outside the study area, while state tax credits merely redistribute resources within the state.

As shown in Figure 1 on page 2, the largest cost components are the incremental vehicle costs and the energy costs; the majority of the benefit comes from fossil fuel savings. The analysis includes all the costs associated with vehicles adopted between 2015 and 2030 and all the costs and benefits of operating those vehicles for their respective useful lives (including beyond 2030 until the last vehicles are retired). The present value net TRC benefits for all vehicle types over this time frame are \$2.9 billion in \$2014. The net benefits for the SCT for all vehicle types are \$3.8 billion, primarily due to addition energy security benefits. The results for buses, forklifts, TSE, and TRUs are each shown below in Figure 3. Buses have the lowest net benefits, while TRUs and TSE provide opportunities to achieve large net benefits due to lower incremental vehicle and energy costs.

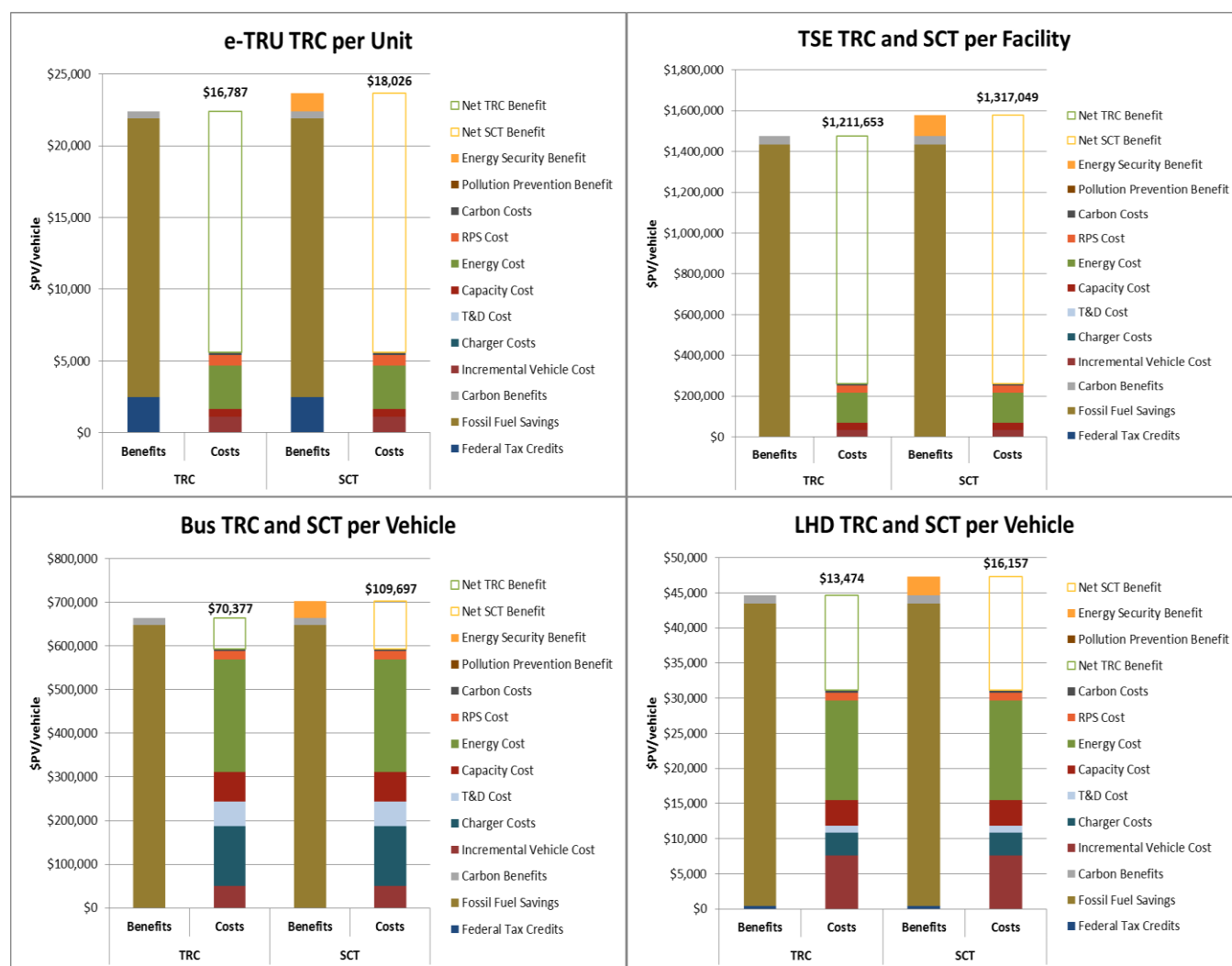


Figure 3. e-TRU, TSE, Bus, and LHD Cost Test Results

5 Obstacles to Deployment and Utility Role High Vehicle Prices and Limited Options

Electrified forklifts, TSE and TRUs have achieved relative cost maturity and are extremely cost effective to the consumer, as seen in Figure 3. Even though there are lifecycle cost benefits to these technologies, their

incremental up-front cost over conventional technologies is still limiting their deployment. MDV/HDVs and buses, on the other hand, are still extremely expensive compared to the conventional alternative and have limited lifecycle savings, especially at the current low diesel prices. In addition, there are currently very few companies and vehicle models to choose from.

5.1 Customer Electric Bill Impacts

Though most of the vehicles studied produce net positive TRC and SCT results, this does not automatically guarantee financial benefit for the individual adopter of these technologies. Some EV adopters may see their utility bills increase enough to at least partially negate savings relative to conventional MDV/HDVs. The extent to which this happens depends largely on two factors: customer daily load profile and utility rate schedule. Methods for managing and lowering these costs to ensure benefits are realized are discussed further in Section 6.

5.2 Cost of Providing Appropriate Charging Infrastructure

Another potential obstacle to adoption of electrified MDV/HDV technologies is the cost to adopters of providing charging infrastructure for their vehicles. These technologies (with the exception of TSE and TRUs) are all commercial and/or industrial vehicles. Unlike LDVs, these vehicles will have little to no access to public charging infrastructure. Owners must take responsibility for ensuring that enough chargers are available. This responsibility can inhibit adoption via both the costs themselves and uncertainty about how large those costs will be.

6 Utility Opportunities to Address Obstacles

There are several measures utilities can take to help overcome the above obstacles to commercial and industrial transportation electrification. They include:

- Education and outreach
- Vehicle incentives
- Tariff redesign
- Load management coaching

6.1 Education and Outreach

Many users of ICE forklifts, trucks, and buses may simply be unaware that electrification is now a viable and potentially cost-effective option. Utilities could partner with vehicle manufacturers to educate ratepayers about the types of electric vehicles available and how they could impact adopters' electricity bills. Outreach efforts could also clarify more obscure costs like potential distribution system upgrade charges. A particularly useful resource could be a checklist that guides potential adopters through all the issues they need to consider when deciding whether to electrify their fleet. To raise awareness and confidence in MDV/HDV electrification cost savings, utilities might consider supporting larger scale deployments that would achieve sufficient scale to realize cost savings and economic benefits.

6.2 Vehicle Incentives

Incremental vehicle and infrastructure costs are still the main hurdle for implementation of electrified off-road and commercial sector technologies. Utility incentives could take the form of either rebates or limited-time discounts on electricity rates. In California, Proposition 1B provides funding for new BEV and hybrid trucks [3]. Further, the California Air and Resources Board's Hybrid and Zero-Emission Truck and Bus Voucher

Incentive program (HVIP) includes vouchers for electrified trucks [4]. Funding varies with vehicle type, but is generally in the \$50,000-\$200,000 per vehicle range.

This funding can provide the necessary incentives for vehicle purchases, but utilities need to be intimately involved in the costing and implementation of infrastructure upgrades to support electrified off-road and commercial sector technologies. Making sure that upgrades are necessary and cost effective will be important for implementation and maximizing the economic benefits for operators.

6.3 Tariff Redesign

Another option for utilities to consider is developing rate schedules specifically for MDV/HDV fleets. In this case, utilities should strive to strike a balance between helping make MDV/HDV transportation electrification affordable and minimizing cross subsidization. Minimizing cross-subsidization entails designing cost-based rates, a key component of which is proper demand charges. Demand charges send a price signal discouraging electric vehicle charging in hours coincident with system peak load (when electric vehicle charging could drive costly grid upgrades and thus rate increases).

6.4 Load Management Coaching

The efficacy of the tariff redesign options described in section 5.3 relies on customers avoiding or reducing charging during high-price, system peak times. While a price signal alone may induce modest change, some customers may need further information on how managing charging loads can maximize savings under new rate schedules. Utilities could offer a service advising customers on the trade-off between reduced fleet charging time flexibility and maximizing savings. This service might be especially useful for small to medium commercial and industrial (C&I) customers for whom demand management has not previously been imperative. This advice could be mutually beneficial by saving EV owners money and helping the utility delay distribution upgrades.

6.5 Conclusion

Our analysis finds significantly increased EV adoption in the MDV/HDV sector can yield regional and societal economic benefits. However, these benefits will not be fully realized through demonstration projects or at current low adoption levels. As for any nascent technology, reducing the upfront costs of switching to electric MDV/HDVs through incentives during early-stage adoption, increasing awareness of electric MDV/HDV options, and expanded electric MDV/HDV product offerings are crucial components of realizing increased adoption. Vehicle electrification also requires charging infrastructure, with attendant attention and investment from utilities and governments. In addition to vehicle and charger cost reductions and awareness, the electric grid impacts of loads associated with MDV/HDV electrification will require C&I electric fleet-specific tariff designs to avoid costly distribution upgrades and maximize system benefits. Some customers may require load management education in addition to demand or time-of-use price signals in their rates to ensure these system benefits are realized.

7 Appendix

Table 4. Technology Types Reviewed in Study

Technology Category	Technology Type	Technology Displaced	Incremental Cost of Electric Vehicle	Vehicle Charger Cost & Other Costs	Other Notes
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Forklifts	8,000 lb forklifts	<120 horsepower Gasoline and propane forklifts	\$12,500- \$27,500	Slow (11kW): \$3,500-\$4,650 Fast (35kW): \$10,000-\$15,000	
Forklifts	19,800 lb forklifts	120-175 horsepower gasoline and propane forklifts	\$30,500- \$33,500	Slow (11kW): \$3,500-\$4,650 Fast (35kW): \$10,000-\$15,000	No existing electric forklift technology can displace >175 horsepower forklifts
Truck Technologies – Truck Stop Electrification (TSE)	Plug-in APUs/Shorepower	Gasoline and diesel trucks	\$328-\$600 (side cost)	\$2,600 - \$6,000 facility cost	Driver plugs into parking stall to power onboard technologies
Truck Technologies – Truck Stop Electrification (TSE)	IdleAir	Gasoline and diesel trucks	\$328-\$600 (side cost)	\$5,000 - \$10,000 facility cost	Electricity provided through unit that attaches to truck cab window, no plug-in needed
Truck Technologies – Transport Refrigeration Unit (TRU)	Semi in-state	Gasoline and diesel truck refrigeration unit	25-50hp - \$3,700-\$5,000 11-25hp - \$550 - \$650	25-50hp - \$4,300 facility cost 11-25hp - \$1,500 facility cost	California based
Truck Technologies – Transport Refrigeration Unit (TRU)	Semi out-of-state	Gasoline and diesel truck refrigeration unit	25-50hp - \$3,700-\$5,000 11-25hp - \$550 - \$650	25-50hp - \$4,300 facility cost 11-25hp - \$1,500 facility cost	Non-California based
Truck Technologies – Transport Refrigeration Unit (TRU)	Bobtail	Gasoline and diesel truck refrigeration unit	25-50hp - \$3,700-\$5,000 11-25hp - \$550 - \$650	25-50hp - \$4,300 facility cost 11-25hp - \$1,500 facility cost	Bobtails do not have a trailer
Truck Technologies – Transport Refrigeration Unit (TRU)	Bobtail <11 hp	Gasoline and diesel truck refrigeration unit	25-50hp - \$3,700-\$5,000 11-25hp - \$550 - \$650	25-50hp - \$4,300 facility cost 11-25hp - \$1,500 facility cost	Bobtails do not have a trailer
Medium-duty and light heavy- duty	Classes 2 and 3	Gasoline and diesel LHD/MHD vehicles	PHEV: \$14,122 BEV: \$22,012		Incremental vehicle costs are for 2015 and decrease through 2030

Medium-heavy duty (MHD)	Classes 4-7	Gasoline and diesel MHD vehicles	PHEV: \$27,245 BEV: \$60,524		Incremental vehicle costs are for 2015 and decrease through 2030
Heavy-heavy duty (HHD)	Classes 8/8b	Gasoline and diesel HHD vehicles	PHEV: \$39,533 BEV: \$134,851		Incremental vehicle costs are for 2015 and decrease through 2030
Buses		Gasoline and diesel buses	PHEV: \$90,033 BEV: \$144,851		Incremental vehicle costs are for 2015 and decrease through 2030

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Authors



Mr. Eric Cutter, Senior Managing Consultant, E3. Mr. Cutter is a lead analyst at E3 on the costs and benefits of energy storage, distributed generation, and customer load management, working with the Electric Power Research Institute (EPRI), utilities, regulators and technology companies to assess their value for the integration of renewable and distributed generation. Mr. Cutter's prior experience includes 5 year as independent consultant working on energy and water resources and 10 years at Pacific Gas and Electric Company. Mr. Cutter earned a B.A. in Economics and German from Tufts University and an M.B.A. and an M.S. in Energy and Resources from the University of California, Berkeley.



Mr. Jeff Rosenfeld, Manager, ICF. Mr. Rosenfeld is an expert in lifecycle analysis (LCA) of conventional and alternative fuels and regulations, including conventional oil and oil sands. His expertise includes modeling well-to-tank greenhouse gas (GHG) emissions for gasoline and diesel from conventional and oil sands, crude oils, biofuels from various feedstocks and production methods, and conventional and renewable natural gas. Mr. Rosenfeld has an M.S. in Civil and Environmental Engineering from Stanford University and a B.S. in Chemical Engineering from Georgia Institute of Technology.



Mr. Brendan Schneiderman, Senior Associate, E3. Mr. Schneiderman has contributed to E3's work on distributed energy resource cost effectiveness, transport electrification, and natural gas market analysis. He recently completed a publication in The Energy Journal with E3 Senior Partner Dr. C.K. Woo on the drivers of profitability in natural gas markets. He received his B.A. in Mathematics and Philosophy from Pomona College.



Dr. Nancy E. Ryan, Partner, E3. Dr. Ryan is a partner at Energy and Environmental Economics (E3), where she leads the electric transportation practice area. She is an economist with over two decades of experience in energy and environmental policy. Prior to joining E3, Dr. Ryan held several high-level appointed positions at the California Public Utilities Commission including Deputy Executive Director for Policy and External Relations (2011-2013), Commissioner (2010-2011), and Chief of Staff to President Michael R. Peevey (2007-2009). During her tenure at the CPUC, Dr. Ryan guided development of California's policies in electric transportation, renewable energy, smart grid, energy storage, and long term planning and procurement. She also worked closely with senior officials from the California Air Resources Board, the California Energy Commission, the California ISO and the Governor's Office to devise strategies to achieve California's ambitious Greenhouse Gas reduction targets and develop regulations implementing California's cap and trade program for the electric sector. Dr. Ryan's career path has also included positions in environmental advocacy and academia. She was a Senior Economist at the Environmental Defense Fund from 2001-2005 and taught applied economics at UC Berkeley's Richard and Rhoda Goldman School of Public Policy from 1996-2007. Dr. Ryan received her Ph.D. in Economics from the University of California at Berkeley and a BA in Economics from Yale University.



Mr. Luke Lavin, Associate, E3. Mr. Lavin has contributed to E3's work on distributed energy resource cost effectiveness, renewable integration, and transport electrification, including co-authoring an Electricity Journal publication on the economic benefits of electric vehicle adoption. He received his B.A. in Physics and Anthropology from Amherst College.