U.S. Department of Transportation
Federal Transit Administration

Peak Demand Charges and Electric Transit Buses

White Paper

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Executive Summary

In 2009, Foothill Transit purchased three on-route opportunity charging electric transit buses to provide fixed-route bus service in their operating fleet of 300 transit buses (Figure ES-1). This first electric transit bus deployment led to an additional purchase of twelve more buses to fully electrify Foothill Transit Route 291. During the early bus deployment, peak demand charges incurred as a result of charging the buses were identified as a major barrier to the deployment of electric transit buses.

Figure ES-1: Foothill Transit on-route opportunity charging electric transit bus (photo courtesy: Foothill Transit)

In order to support and increase the adoption of electric transit buses, CALSTART (under the U.S. Federal Transit Administration cooperative agreement CA26-7075) researched and analyzed potential options that would mitigate the impact of peak demand charges on the operation of electric transit buses. The first goal of this white paper is to better understand how the peak demand charges levied by electric utilities on their commercial and industrial customers impact the business case for electric transit buses. The second goal is to research and analyze potential technical and policy options and recommend for consideration a pathway that will support and increase the adoption of electric transit buses.

Our review of commercially available electric transit buses reveals a dynamic industry, with a least 12 serious manufacturers and several electric transit bus deployments all around the world. It also reveals at least two different ways of recharging electric transit buses:

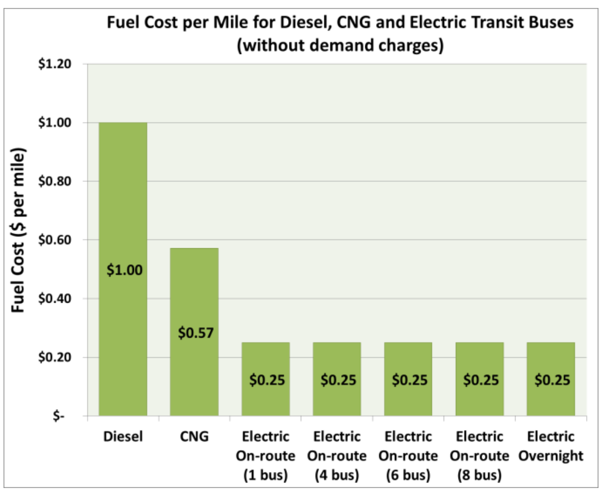
- **On-route opportunity charging**, where the electric transit bus recharges while the vehicle is operating.
- **Overnight charging**, where the electric transit bus recharges at night or when the vehicle is not in operation.

Peak demand charges are levied by electric utilities on their commercial and industrial customers to recover their capital costs and are calculated based on the maximum amount of electrical power (in kW) the electric transit bus draws from the grid during a charging event. Demand charges can have a significant impact on a customer electricity bill. To better understand demand charges in the United States, we reviewed the electric rate schedules of 26 major electric utilities in Arizona, California, Colorado, Florida, Georgia, Illinois, New York, Oregon, Texas and Washington. The findings of our review are listed below.

- **21 out of the 26 electric utilities** that we reviewed **levy demand charges** on their commercial and industrial customers.
- **Three utilities indirectly include peak demand** to calculate the total customer charge.

- Demand charges vary widely from **$0.00/kW to $23.65/kW**.
- In some optional Time-Of-Use (TOU) rates, demand charges can go **up to $59.24/kW**.
- The states with the **highest** demand charges are **California and New York**.
- The states with the **lowest** demand charges are **Oregon and Washington**.
- **Five utilities vary their demand charges seasonally** (summer versus winter).
- **Four utilities include Time-Of-Use demand charges**.
- **19 utilities include Time-Of-Use pricing for energy charges** (12 as an option).
- **Four utilities** have **specific electric vehicle pricing** for commercial and industrial customers.
- Some utilities have **specific public transit pricing** for light and heavy rail transportation.

Among the 26 electric utilities that we reviewed as part of this project, 24 include peak demand charges (directly or indirectly) in their commercial and industrial electric rate schedules. Public transit agencies deploying electric transit buses around the country are bound to experience the impact of peak demand charges. Figure ES-2 below compares the fuel costs per mile of a diesel, CNG and two types of electric transit buses: charging on-route (with four different bus deployment strategies) and charging overnight.[1] In the first case, no demand charges are included and in the second case, low demand charges at $5 per kW are included.



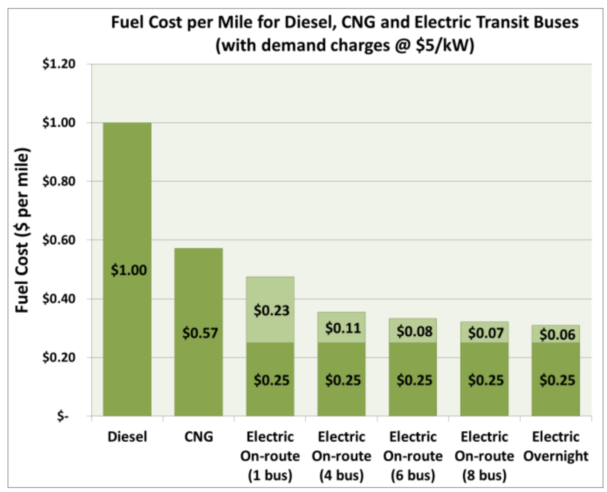


Figure ES-2: Fuel cost for diesel, CNG and electric buses with no and low demand charges

Electric transit buses show a clear advantage over diesel and CNG-powered transit buses when no demand charges are included. When low demand charges are included, fuel cost increase by $0.06 per mile for one electric bus charging overnight and by $0.23 per mile for one electric bus charging on-route. However, as the number of electric transit buses using a single on-route fast charger is optimized (up to 8 buses using one single fast charger), demand charges can be spread over more buses and greatly reduced. In Figure ES-3 below we look at the impact of medium ($10/kW) and high ($20/kW) demand charges.

[1] We assume each bus drives 40,000 miles per year. The diesel bus has a fuel economy of 4 MPG and diesel is priced at $4.00 per gallon. The CNG bus has a fuel economy of 3.5 MPDGE and CNG is priced at $2.00 per DGE. The electric transit buses have an efficiency of 2.5 AC kWh / mile and electricity is priced at $0.10/kWh. One electric bus charging on-route draws 150 kW from the grid, 4 draw 280 kW, 6 draw 330 kW and 8 draw 380 kW. The electric bus charging overnight draws 40 kW from the grid.

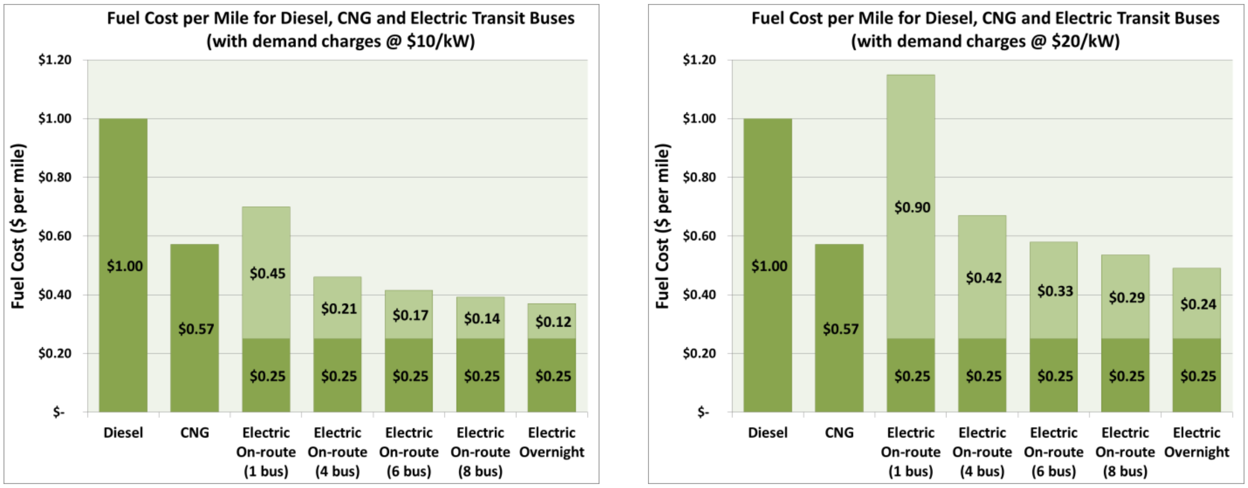


Figure ES-3: Fuel cost for diesel, CNG and electric buses with medium and high demand charges

When medium demand charges are included, fuel cost increase by $0.12 per mile for one electric bus charging overnight and by $0.45 per mile for one electric bus charging on-route. In that case, the fuel cost for one electric bus charging on-route is higher than the fuel cost for a CNG-powered bus. However, as the number of electric transit buses using a single on-route fast charger is optimized, demand charges can be spread over more buses and electric transit buses charging on-route regain their advantage over CNG-powered buses.

When high demand charges are included, fuel cost increase by $0.24 per mile for one electric bus charging overnight and by $0.90 per mile for one electric bus charging on-route. In that last case, the fuel cost for one electric bus charging on-route is higher than the fuel cost for a diesel-powered bus. However, as the number of electric transit buses using a single on-route fast charger is optimized, demand charges can be spread over more buses and electric transit buses charging on-route regain their advantage over diesel and even over CNG-powered buses.

Peak demand charges have a significant impact on the business case of electric transit buses charging on-route and overnight. In areas where demand charges are high, fuel cost is more than doubled although it still stays below the fuel cost of a diesel-powered bus and remains competitive with a CNG-powered bus.

Demand charges will have a greater impact on small pilot deployments of electric transit buses charging on-route than on small pilot deployments of electric transit buses charging overnight. However, for bus deployments of 6 to 8 buses (the optimum number of buses that can use a single fast charger in the conditions), demand charges can be spread over more buses and greatly reduced.

TOU rates are another form of peak demand charges. Figure ES-4 below compares the fuel costs per mile of a diesel, CNG and electric transit bus.[2] We consider three different electricity prices: $0.10 / kWh, $0.05 / kWh corresponding to off peak rate and $0.20 / kWh corresponding to on-peak rate.

[2] We assume each bus drives 40,000 miles per year. The diesel bus has a fuel economy of 4 MPG and diesel is priced at $4.00 per gallon. The CNG bus has a fuel economy of 3.5 MPDGE and CNG is priced at $2.00 per DGE. The electric bus has an efficiency of 2.5 AC kWh / mile.

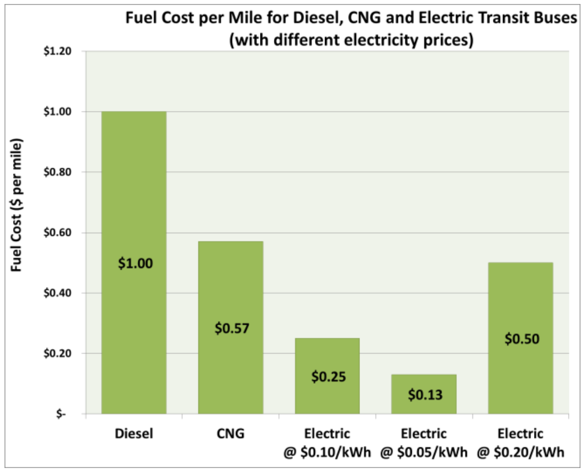


Figure ES-4: Impact of TOU pricing on electric transit bus fuel cost

The price of the electricity used to recharge an electric transit bus is an important component of its fuel costs. Charging off peak when electricity prices are low can lead to significant savings. On the other hand, charging on peak when electricity prices are high can dramatically increase fuel costs per mile.

Lastly, we researched and analyzed potential options that would mitigate the impact of peak demand charges on the operation of electric transit buses charging on-route and overnight. The list below summarizes these potential technical and policy options:

- **Increasing electric bus efficiency** (use range extender, fuel-fired HVAC / APU).
- **Managing electric bus charging** (for on-route opportunity charging buses: increase the number of charging stops, use overhead power or wireless charging - for overnight charging buses: charge at lower charging power, stagger night-time charging).
- **Employing energy transfer technology** (for on-route opportunity charging buses: use battery swapping, energy storage system or auxiliary generator, manage charging with load management system - for overnight charging buses: manage charging with load management system).
- **TOU pricing option** (for on-route opportunity charging buses: use single flat rate - for overnight charging buses: use TOU pricing).
- **Energy charge / power charge pricing option** (for on-route opportunity charging buses: use higher energy charge / lower power charge option - for overnight charging buses: use lower energy charge / higher power charge option).
- **Temporary suspension of peak demand charges.**
- **Optimize deployment of electric transit buses charging on-route**

This white paper confirms that peak demand charges are a barrier to the deployment of electric transit buses. But it also identifies several potential technical and policy options that could help mitigate the impact of peak demand charges and ultimately promote further adoption of electric transit buses in public transit agencies across the country.

Chapter 1: Introduction

In 2013 there were only 24 battery electric transit buses in service in the United States. While this represents less than 0.1% of the more than 35,000 public transit buses in service in 2013,[3] this number is expected to grow in the next few years pushed by stricter ozone regulations, growing concerns over climate change and energy security and strong federal and state regulations.

In 2009, Foothill Transit purchased three on-route opportunity charging electric transit buses to provide fixed-route bus service in their operating fleet of 300 transit buses (Figure 1). This first electric transit bus deployment led to an additional purchase of twelve more buses to fully electrify Foothill Transit Route 291. During the early bus deployment, peak demand charges incurred as a result of charging the buses were identified as a major barrier to the deployment of electric transit buses. Peak demand charges are levied by electric utilities on their commercial and industrial customers to recover their capital costs. They are calculated based on the maximum amount of electrical power (in kW) the electric transit bus draws from the grid during a charging event.

Figure 1: Foothill Transit on-route opportunity charging electric transit bus (photo courtesy: Foothill Transit)

In order to support and increase the adoption of electric transit buses, CALSTART (under the U.S. Federal Transit Administration cooperative agreement CA26-7075) researched and analyzed potential options that would mitigate the impact of peak demand charges on the operation of electric transit buses. The first goal of this white paper is to better understand how the peak demand charges levied by electric utilities on their commercial and industrial customers impact the business case for electric transit buses. The second goal is to research and analyze potential technical and policy options and recommend for consideration a pathway that will support and increase the adoption of electric transit buses.

This white paper is divided in six chapters. Chapter 1 is the present introduction. In Chapter 2, we review commercially available electric bus models and deployments. We also look at how electric transit buses are recharged. Chapter 3 presents background information about peak demand charges and analyzes how they impact the business case of electric transit buses under different operating assumptions. Chapter 4 and Chapter 5 analyze potential technical and policy options to peak demand charges. Finally, Chapter 6 summarizes the findings and potential technical & policy options developed in the report.

[3] American Public Transportation Association. *2013 Public Transportation Vehicle Database.* August 2013.

Chapter 2: Electric Transit Buses

2.1 Commercially Available Electric Transit Buses

Electric transit buses are manufactured and operated all over the world; the following non-exhaustive list includes models from China, Europe and North America. These vehicles have unique powertrain and charging configurations. Some buses are already in mass production while others are still prototypes in pilot deployment. The variety in vehicle and charging infrastructure technology indicates a dynamic global supplier pool of electric transit buses.

- **ABB TOSA**

The Trolleybus Optimisation Système Alimentation (TOSA) bus is the first full electric articulated bus that runs without overhead lines and is currently in a pilot deployment on the Geneva airport transit route in Switzerland. With relatively small Lithium-Ion battery packs, it receives flash charges at each stop along the route, running with essentially unlimited range.[4]

Table 1: ABB TOSA Super-Fast Charge Electric bus specifications

Parameter	Detail
Dimensions	61.4' L
Capacity	135 total passengers
Battery Type	Lithium Titanate Oxide
Battery Capacity	38kWh
Charging	40kW – 30 minutes, 200kW – 3/4 minutes, 400kW – 15 seconds
Advertised Range	Unlimited along route
Deployment Locations	Geneva, Switzerland

Figure 2: The ABB TOSA articulated electric bus charging at a stop (photo courtesy ABB)

- **BYD**

BYD Motors Inc. is an American manufacturing company and a wholly-owned subsidiary of BYD Company Ltd, the largest Chinese domestic auto-manufacturer and electric-bus manufacturer in the world. In October 2011, BYD Motors established its headquarters in downtown Los Angeles and has hired over 60 Americans to support BYD Electric Bus and Energy Module factories in Lancaster, California. BYD manufactures the Buy America compliant BYD Electric Bus, which can meet roughly 80% of urban transit needs with its minimum driving range of 155 miles.[5] As of August 2014, BYD had

[4] Projet TOSA – Informations *Générales*. http://www.tosa2013.com/wp-content/uploads/2014/03/Informations_generales_tosa.pdf. Accessed 05-22-2014.
[5] For more information: http://www.byd.com/na/auto/ElectricBus.html

deployed 13 40-ft, battery electric buses at Stanford University with many in demonstration across North America including two in Edmonton, Canada.

Table 2: BYD Electric Bus specifications

Parameter	Detail
Dimensions	40.2' L x 8.4' W x 11.4' H
Capacity	40 seated passengers
Battery Type	BYD Iron Phosphate
Battery Capacity	324 kWh and 360 kWh (600Ah)
Charging	Option 1: 40kW or 80kW (480V 3 phase AC) Option 2: 100kW or 200kW (480V 3 phase AC)
Advertised Range	155 miles
Deployment Locations	Worldwide

Figure 3: The BYD Electric bus (photo courtesy BYD)

BYD Motors has additionally designed and manufactured the world's first 60-foot articulated, battery-electric bus, a high-load vehicle that produces zero emissions, runs over 170 miles on a single charge and delivers an impressive 3,000 Nm of torque with a 547.5 kWh / 750 Ah battery pack for up to 24 hours of service. The 60-foot bus will enters Altoona testing in 2015.

- **Complete Coach Works**

Complete Coach Works remanufactures transit buses with their all-electric Zero-Emission Propulsion System (ZEPS). The ZEPS can drive up to 150 miles using overnight charging and over 200 miles using wireless opportunity charging.

Table 3: ZEPS All Electric Remanufactured Transit Bus Specifications[6]

Parameter	Detail
Dimensions	40'/35'/30' L x 8.5' W
Capacity	37/32/25 seated passengers + standees
Battery Type	Lithium-Iron Phosphate
Battery Capacity	213 kWh/242 kWh
Charging	Overnight charging 48kW (100A, 480V 3-Phase AC) Wireless charging 50kW
Advertised Range	85-95 miles (213kWh) / 120-150 miles (242kWh) Over 200 miles (wireless charging)
Deployment Locations	Washington, Oregon, Indiana and Utah

[6] The Remanufactured All-Electric Transit Bus. http://www.completecoach.com/wp-content/uploads/2013/07/ZEPS-Brochure.pdf. Accessed on 05-22-2014.

Figure 4: CCW ZEPS bus in Washington (photo courtesy www.greenerideal.com)

- **EBusco**

EBusco, a Dutch company, has deployed over 300 YTP-1 Electric Buses for the Chinese market. The YTP-1 has a maximum range of 187 miles and is well suited for operating in extreme temperatures; buses are currently part of a pilot deployment program in Finland testing their operation in cold climates.[7]

Table 4: EBusco YTP-1 electric bus specifications

Parameter	Detail
Dimensions	39.4' L
Capacity	76 total passengers
Battery Type	Lithium-Iron Phosphate
Battery Capacity	242kWh – 311kWh
Charging	2.5 hours
Advertised Range	155 miles – 187 miles
Deployment Locations	China, Veolia Transport – Finland

Figure 5: The EBusco YTP-1 electric bus (photo courtesy motorpasionfuturo.com)

- **Hengtong EBus**

The Ultrafast Charging Pure Electric Bus made by Hengtong uses a super-fast charger located at route terminals that can provide a full charge in ten minutes; good for up to 31 miles of operation. The bus is currently being exclusively used by Chongqing Transit in China.

[7] http://www.ebusco.eu/en/. Accessed on 05-22-2014.

Table 5: Hengtong Pure Electric bus specifications

Parameter	Detail
Dimensions	39.4' L
Capacity	70 total passengers
Battery Type	Lithium Titanate
Battery Capacity	60.9 – 77.6kWh
Charging	400kW
Advertised Range	24 – 31 miles
Deployment Locations	Chongqing Transit, China

Figure 6: The Hengtong electric bus charging (left) and en-route (right) (photo courtesy en.htebus.com)

- **New Flyer**

New Flyer is a Canadian company producing zero-emission buses based off the proven Xcelsior chassis. Buses have been or are in the process of being deployed in two U.S. locations and in Winnipeg, Canada.

Table 6: New Flyer all-electric transit bus specifications

Parameter	Detail
Dimensions	40' L x 102" W
Capacity	Up to 40 seated
Battery Type	Lithium-Ion (Nickel Manganese Cobalt)
Battery Capacity	120kWh
Charging	Overhead 500kW (0 to 95% SOC in 6 minutes)
Advertised Range	Up to 45 miles
Deployment Locations	Illinois, Connecticut & Winnipeg, Canada

Figure 7: The New Flyer zero-emissions electric bus (photo courtesy New Flyer)

- **Power Vehicle Innovation (PVI)**

PVI is a French company that has developed the WATT system, a fast on-route charging system allowing for nearly unlimited range. Ultra-capacitors in charging poles at fixed stops along a bus route are powered by low-voltage grid electricity and can transfer energy to recharge a bus in 20 seconds and allow the vehicle to run on electricity for approximately a kilometer. The charging pole layout along the route is optimized to provide enough power to the bus at each stop for it to travel to the next stop.[8]

Figure 8: PVI Watt system with deployed charging arm (photo courtesy busworld.org)

- **PRIMOVE**

PRIMOVE, the e-mobility unit within Bombardier Transportation specializes in wireless charging options for all types of rail and road electric vehicles.[9] The PRIMOVE technology has been integrated into transit buses and tested in passenger service in Mannheim, Germany on a 6-mile route. In addition to two inductive charge points located at each bus terminal, five additional inductive charge points are located along the route to provide opportunity charging.[10]

Table 7: Hess Swiss PRIMOVE 12.0m Specifications

Parameter	Detail
Dimensions	39.4' L
Capacity	36 seated, 44 standing
Battery Type	Lithium-Ion
Battery Capacity	60kWh (Voltage: 660V)
Charging	200kW (Grid connection: AC 400V or DC 750V) using inductive charging platforms
Advertised Range	Unlimited en-route
Deployment Locations	Germany

[8] PVI. *PVI Présente WATT, une solution unique pour des bus urbains zéro émission et sans limite d'autonomie.* http://www.pvi.fr/pvi-presente-watt-r-une-solution,139.html?lang=fr and Veolia Transport & Transdev. *Electric Vehicles: A new generation of shared mobility.* http://www.transdevlab.com/Pointdevue_Vehicules_electriques_An.pdf. Accessed on 05-22-2014.
[9] For more information: http://primove.bombardier.com/
[10] PRIMOVE E-Bus, 100% e-mobility on demanding city route. http://primove.bombardier.com/fileadmin/REDAKTION/downloads/documents/PT_PRIMOVE_Datasheet_2013_Mannheim_final_110dpi_SP.pdf . Accessed on 05-22-2014.

Figure 9: Transit bus with PRIMOVE technology in Mannheim, Germany (photo courtesy: www.noz.de)

- **Proterra**

As of August 2014, Proterra deployed 56 Proterra EcoRide BE35 in 9 transit agencies across the United States.[11] Coupled with Proterra's Fast Fill charge system, this 35-foot transit bus can be rapidly recharged in 5-10 minutes while passengers load and unload.[12]

Table 8: Proterra EcoRide BE35 specifications

Parameter	Detail
Dimensions	35' L x 8.5' W x 11.2' H
Capacity	35 seated passengers
Battery Type	Lithium-Titanate
Battery Capacity	74kWh at 368V
Charging	Overhead 500kW (0 to 95% SOC in 6 minutes)
Advertised Range	>26 miles per charge
Deployment Locations	United States

Figure 10: The Proterra EcoRide BE35 (left) and deployed super-fast charger (right)

In addition, Proterra recently released an additional product offering with their next-generation 40-foot bus. This new electric transit bus is equipped with a larger battery pack (104 versus 74 kWh for the EcoRide BE35).[13]

[11] San Joaquin Regional Transit District and Foothill Transit in California, Regional Transportation Commission of Washoe County in Nevada, VIA Metropolitan Transit in Texas, Transit Authority of River City in Kentucky, Worcester Regional Transit Authority in Massachusetts, City of Seneca in South Carolina, StarMetro in Florida, Nashville Metropolitan Transit Authority in Tennessee.
[12] For more information: http://www.proterra.com/index.php
[13] Next-Generation 40-Foot Bus, Technical Specifications. http://www.proterra.com/wp-content/uploads/2014/07/Proterra-Specifications.pdf. Accessed on 08-11-2014.

- **Siemens**

The eBus by Siemens is currently operated in Vienna, Austria. It is charged in the depot and at the terminal bus station through a 2-pole current collector which draws electrical power from the available overhead lines of the Vienna tram.[14]

Table 9: Siemens eBus specifications

Parameter	Detail
Dimensions	25.3' L x 7.2' W x 10' H
Capacity	40 total passengers
Battery Type	Lithium-Iron Phosphate
Battery Capacity	96kWh
Charging	10 minutes per hour of operation through overhead catenary
Range	Unlimited along route
Deployment Locations	Vienna, Austria

Figure 11: Siemens eBus charging (photos courtesy bmvit.gv.at)

- **Sinautec**

Sinautec manufactures ultra-capacitor powered buses in partnership with the Shanghai Aowei Technology Corporation. Sinautec Ultra-Capacitor buses have been in-service in Shanghai since 2006. The bus is recharged on-route through an overhead catenary. In addition, a backup battery storage system can power the vehicle for 50 miles if ultra-capacitor charging is unavailable.[15]

Table 10: Sinautec Ultra-Capacitor bus specifications

Parameter	Detail
Dimensions	37.5' L x 8.2' W x 11.1'H
Capacity	41 seated passengers
Battery Type	Ultra-capacitor + Battery
Battery Capacity	5.9 kWh ultra-capacitors
Charging	120kW (200A, 600V) using overhead catenary
Advertised Range	Unlimited en-route
Deployment Locations	Shanghai, China

[14] Wiener Linien Electric Bus. http://www.siemens.com/press/pool/de/events/2013/infrastructure-cities/2013-03-UITP-PK/background-ebus-wiener-linien-e.pdf. Accessed 05-22-2014.
[15] For more information: http://www.sinautecus.com/products.html

Figure 12: The Sinautec bus charging (left) and en-route (right) (photo courtesy media.treehugger.com)

- **Volvo**

The Volvo 7900 Plug-In Hybrid Electric Bus is capable of recharging using a collector installed on the roof. It has a Lithium-Ion battery pack which allows approximately 7 km of electric-only operation, after which the 215 bhp 5-liter diesel engine powers the vehicle. The batteries are charged at route terminals for six to ten minutes.[16]

Table 11: Volvo 7900 Plug-In Hybrid Electric bus specifications

Parameter	Detail
Dimensions	39.6' L x 8.4' W x10.6 'H
Capacity	102 total passengers
Battery Type	Lithium-Ion
Battery Capacity	4.8kWh
Charging	Up to 100kW 6 to 10 minutes using plug-in charger at route terminals
Advertised Range	4.3 miles all-electric
Deployment Locations	Gothenburg, Sweden

Figure 13: The Volvo 7900 series hybrid-electric bus (photo courtesy gizmag.com)

[16] Volvo launches noiseless electric buses in Gothenburg. http://www.volvogroup.com/group/global/en-gb/_layouts/CWP.Internet.VolvoCom/NewsItem.aspx?News.ItemId=143388&News.Language=en-gb. Accessed 05-22-2014.

2.2 Electric Transit Buses Charging

Our review of commercially available electric transit buses reveals a dynamic industry, with a least 12 serious manufacturers and several electric transit bus deployments all around the world. It also reveals at least two different ways of recharging electric transit buses:

- **On-route opportunity charging**, where the electric transit bus recharges while the vehicle is operating (ABB TOSA, Hengtong, New Flyer, PRIMOVE, Proterra, PVI, Siemens, Sinautec, Volvo).
- **Overnight charging**, where the electric transit bus recharges at night or when the vehicle is not in operation (BYD, CCW, EBusco).

In the following sections, we discuss these two different ways of recharging electric transit buses in greater details. We believe these two different ways of recharging electric transit buses each have their place in the electric transit bus market. We also believe both options will be impacted by peak demand charges.

2.2.1 On-route opportunity charging

Several electric transit bus manufacturers opted to recharge on-route while the vehicle is operating and carrying passengers. Table 12 below presents the main advantages and drawbacks associated with on-route opportunity charging.

Table 12: On-route opportunity charging advantages and drawbacks

Advantages	Drawbacks
Smaller battery size can reduce vehicle curb weight, potentially increasing vehicle efficiencies and can take less space	Lower vehicle assignment flexibility as buses are dedicated to on-route charging infrastructure
Possibility to operate indefinitely without long interruption for charging	Demand charges can be high without energy storage
Smaller battery may be easier and cheaper to service and replace	Charging infrastructure costs can be high and grid connection complex
	Charging is done generally during daytime and thus on peak
	Bus operation is not possible when grid power is not available

Electric transit buses charging on-route are designed to meet a short driving range. Thus, batteries need to be sized in order to store enough energy to get to the next charging point. Table 13 shows battery weight and volume for one electric transit bus charging on-route and one electric transit bus charging overnight (assuming same battery energy densities).

Table 13: Battery weight and volume as a function of battery size

	On-route	Overnight
Battery Size	50 kWh	250 kWh
Battery Weight @ 100 Wh/kg	500 kg	2500 kg
Battery Volume @ 200 Wh/l	0.25 m^3	1.25 m^3

With identical battery energy densities, the electric transit bus charging on-route has a much lighter and smaller battery pack compared to the electric transit bus charging overnight. However, different battery chemistries may have different energy densities and it is important to also look at vehicle curb weight.

On-route opportunity charging is generally done at a high power rate (up to 500 kW) and if no energy storage is used to buffer the impact on the electricity grid, demand charges can be high. On-route opportunity charging is also done on peak when grid utilization is high and energy prices are generally higher.

On-route opportunity charging can be done in several different ways: conventional charger located at terminals or on-route, magnetic induction, catenary or overhead charging systems at bus stops.

2.2.2 Overnight charging

Several electric transit bus manufacturers opted for the solution to recharge overnight while the vehicle is not in operation. Table 14 below presents the main advantages and drawbacks associated with overnight charging.

Table 14: Overnight charging advantages and drawbacks

Advantages	Drawbacks
Bus is designed to replace conventional diesel bus without accommodating on-route charging	Larger battery size can increase vehicle curb weight and could decrease passenger capacity
Charging is done generally at night and thus off peak	Longer charging time
Charging infrastructure costs can be lower	Decreased maintenance time while charging at night
Grid connection can be simpler and may not require grid upgrades	Grid impact if multiple buses need to charge at the same time and at the same location

Electric transit buses charging overnight are designed to meet the daily range of a conventional diesel bus. Thus, batteries need to be sized in order to store enough energy to cover over 100 miles. As Table 13 shows, larger batteries may take more space and increase vehicle curb weight, potentially decreasing vehicle efficiencies. In addition, recharging a large battery pack will immobilize the bus for long periods of time and thus decrease the time available to service and use the vehicle.

On the other hand, battery charging will be done at a lower power rate (below 100 kW), potentially reducing demand charges, and off peak when grid utilization may be low (see Figure 14). As a result, overnight charging will generally not increase peak demand on the grid and thus, will not require grid upgrades since it is making use of available grid capacity unused at night.

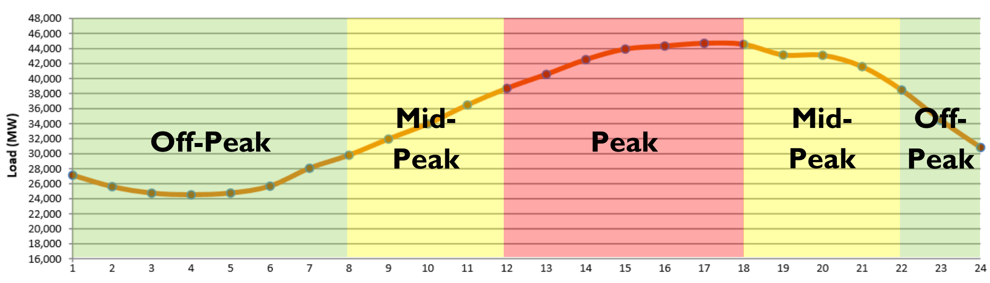


Figure 14: Average load for California ISO grid on 09/15/2014[17]

Lastly, overnight battery charging is generally done through a conventional charger located at the bus depot.

[17] California ISO. Renewables Watch, Monday, September 15, 2014. http://content.caiso.com/green/renewrpt/20140915_DailyRenewablesWatch.pdf. Accessed on 09/30/2014.

Chapter 3: Peak Demand Charges

3.1 Background

Electricity demand fluctuates depending on the time of day, day of the week (weekends or weekdays) and seasonally. To meet this demand, electric utilities build their electricity generation infrastructure in order to meet the highest peak demand plus a reserve margin for contingency. Every day, electric utilities dispatch power plants to meet total demand in the most economical way. Power plants are categorized in three groups:

- **Baseload** power plants (for example nuclear and coal power plants) are expensive to build but cheap to operate. As a result, they should be operated continuously.
- **Peaking** power plants (for example natural gas and oil power plants) are cheaper to build but more expensive to operate. Thus, they are generally operated only during periods of highest demand.
- **Intermediate** power plants (for example natural gas power plants) are in between baseload and peaking power plants and are generally operated during the day and as necessary to follow demand.

Figure 15 shows a typical demand curve showing how baseload, intermediate and peaking power plants are dispatched.

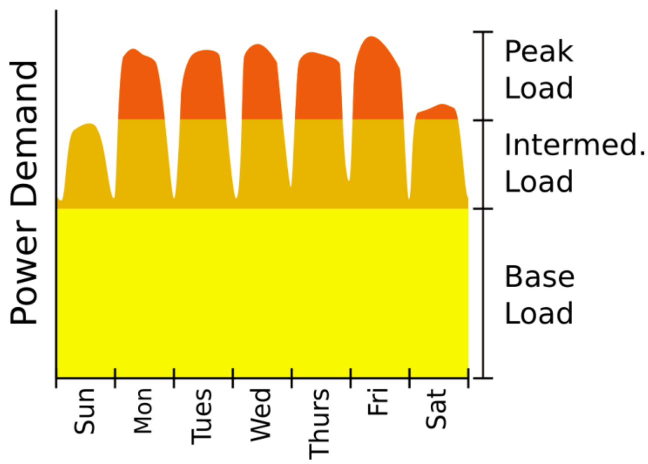


Figure 15: Typical demand curve, showing base, intermediate, and peak-level power plant[18]

In addition to charging for the total amount of energy used (in kWh), electric utilities levy peak demand charges or demand charges (in kW) on commercial and industrial customers to repay the fixed costs associated with the peaking power plants used to provide the maximum level of power. Demand charges are also used to encourage customers to shift electrical usage from peak hours to non-peak hours.

Demand charges can have a significant impact on a customer electricity bill. For example, Table 15 shows two customers with identical monthly energy consumption (5,000 kWh) but Customer A has a maximum monthly peak demand of 500 kW and Customer B, 50 kW.

[18] Bogdanowicz, Nate. Introduction to Smart Grid Concepts. November 16, 2011. http://large.stanford.edu/courses/2011/ph240/bogdanowicz1/. Accessed on 05/19/2014.

Table 15: Impact of Demand Charges

	Customer A	Customer B
Peak Demand	500 kW	50 kW
Demand Charges	*500 kW x $15.00/kW = $7,500*	*50 kW x $15.00/kW = $750*
Energy Usage	5,000 kWh	5,000 kWh
Energy Charges	*5,000 kWh x $0.10/kWh = $500*	*5,000 kWh x $0.10/kWh = $500*
Total Charges	**$8,000**	**$1,250**

We see that Customer A's total monthly charges are over six times greater than Customer B's. While demand charges represent 60% of total charges for Customer B, they represent 94% of total charges for Customer A.

Demand charges are generally charged monthly based on the highest average kW measured in a 15-minute interval during the billing period.[19] For example, if the power demand reaches 50 kW for a period of 15 minutes or more, the meter will record a peak demand of 50 kW ($50kW \times \frac{15\,minutes}{15\,minutes}$). On the other hand, if the demand reaches 100 kW for the first 7.5 minutes and is at zero for the next 7.5 minutes, the meter will record a peak demand of 50 kW ($100kW \times \frac{7.5\,minutes}{15\,minutes}$).

Some electric utilities do not apply demand charges on commercial and industrial customers whose peak demand remains under a potential threshold. However, this demand threshold varies considerably between electric utilities.

Monthly demand charges can also be ratcheted to the annual peak demand (Figure 16). For instance, if a customer reaches an annual peak demand of 120 kW, then for a period of 12 months the demand charge will be based on 120 kW, regardless of the actual monthly demand. As a result, demand charges can greatly impact a customer electricity bill.

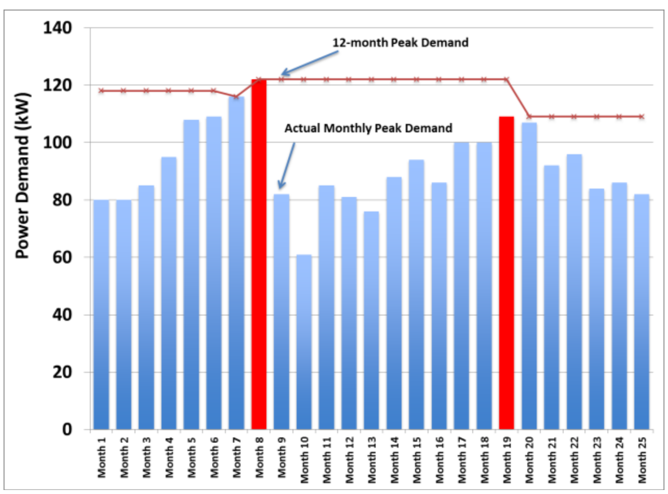


Figure 16: Example of demand charges with a ratchet adjustment

[19] National Grid. Understanding Electric Demand. 2005. www.nationalgridus.com/niagaramohawk/non_html/eff_elec-**demand**.pdf. Accessed on 08/12/2014.

Demand charges are expected to increase in the future. For instance, average demand charges in California increased by 19.5% between 2010 and 2013. The factors driving this increase are an aging grid and peaking plants, the proliferation of renewable energy (solar and wind) leading to greater grid volatility, the growth in electric vehicle charging station and higher temperatures due to climate change.[20]

Electricity providers set the electricity rates they charge their customers according to a complex ratemaking process that is regulated by public utility commissions. Electric rates vary considerably, depending not only on the utility itself, but also on the electrical characteristics of the specific customer purchasing the power.[21] With over 3,200 electricity providers in the United States in 2011, demand charges vary widely all across the United States.[22]

To better understand demand charges in the United States, we reviewed the electric rate schedules of 26 major electric utilities in Arizona, California, Colorado, Florida, Georgia, Illinois, New York, Oregon, Texas and Washington. The findings of our review are listed below. For more information about the electric rate schedule of the electric utilities reviewed, see Appendix A.

- **21 out of the 26 electric utilities** that we reviewed **levy demand charges** on their commercial and industrial customers.
- **Three utilities indirectly include peak demand** to calculate the total customer charge.
- Demand charges vary widely from **$0.00/kW to $23.65/kW**.
- In some optional Time-Of-Use (TOU) rates, demand charges can go **up to $59.24/kW**.
- The states with the **highest** demand charges are **California and New York**.
- The states with the **lowest** demand charges are **Oregon and Washington**.
- **Five utilities vary their demand charges seasonally** (summer versus winter).
- **Four utilities include Time-Of-Use demand charges**.
- **19 utilities include Time-Of-Use pricing for energy charges** (12 as an option).
- **Four utilities** have **specific electric vehicle pricing** for commercial and industrial customers (Southern California Edison, Los Angeles Department of Water & Power, Georgia Power Company, Portland General Electric).
- Some utilities have **specific public transit pricing** for light and heavy rail transportation.

[20] Stem, Inc. Tackling peak demand charges. 2013. http://www.slideshare.net/stem_marketing/20130514-demand-charges-overview-for-slideshare. Accessed on 05/19/2014.
[21] Masters, Gilbert. *Renewable and Efficient Electric Power Systems*. ISBN 0-471-28060-7. Hoboken, NJ: John Wiley & Sons, Inc., 2004.
[22] American Public Power Association. 2013-14 Annual Directory & Statistical Report. http://www.publicpower.org/files/PDFs/USElectricUtilityIndustryStatistics.pdf. Accessed on 05/15/2014.

3.2 Electric Transit Bus Charging and Peak Demand

Demand charges will affect both on-route and overnight charging technologies. In the following sections, we look at the peak demand associated with both on-route and overnight charging if one bus or multiple buses are deployed.

3.2.1 On-route opportunity charging

On-route opportunity charging allows an electric transit bus to recharge in a short amount of time while at a bus stop for instance. This short charging duration requires a high power rate (up to 500 kW) to transfer a large amount of energy. However, several factors (such as route distance and battery size) come into play to actually make the peak demand lower than the maximum input power of the charger.

In the case of the Proterra EcoRide BE35, the maximum input power is 500 kW; however, nominal power is 450 kW. Thus, if the bus is charged continuously for all 15 minutes, it would generate 450 kW of demand.

In addition, electric transit buses charging on-route have small batteries that will limit the amount of energy transferred when charging, and thus, limit the peak demand from the grid. For instance, while the Proterra Fast Fill charge system is capable of replenishing 112.5 kWh in a 15-minute window, in the absolute worst-case, the Proterra EcoRide BE35 only needs 70 kWh. At a nominal power of 450 kW, it would take about 9.3 minutes to transfer 70 kWh. This would result in a maximum peak demand of 280 kW ($450\ kW\ \times \frac{9.3\ minutes}{15\ minutes}$).

Lastly, in real-world transit operation, it is unlikely that an electric transit bus charging on-route would use 80% or more of its total battery capacity. Proterra analyzed a large sample of transit routes indicating that the average transit route serviceable by a single on-route charger would be 16 miles long.[23] With an efficiency of 2.5 AC kWh / mile, this translates into about 40 kWh of energy used between charges. At a nominal power of 450 kW, it would take about 5.3 minutes to transfer 40 kWh. This would result in an average peak demand of 160 kW ($450\ kW\ \times \frac{5.3\ minutes}{15\ minutes}$).

Table 16 below summarizes these different power levels for a single bus deployment.

Table 16: On-route opportunity charging power levels for a single bus deployment

	Maximum Input Power	Nominal Power	Maximum Peak Demand	Average Peak Demand
Power from the grid	500 kW	450 kW	280 kW	160 kW

High power chargers are generally very expensive and require significant and costly utility infrastructure upgrades. Demand charges will have a greater impact on small pilot deployments of electric transit buses charging on-route. Since demand charges are calculated based on the maximum power demand on the grid, greater utilization of a fast charger will not increase demand charges. That is why optimizing the number of electric transit buses using a single fast charger can maximize charger usage and spread demand charges over more electric transit buses. Figure 17 shows four different bus deployment cases that make use of the same fast charger without increasing the peak demand charges associated with this charger.

[23] Dmitriy Konyrev (Proterra), personal communication, August 2014.

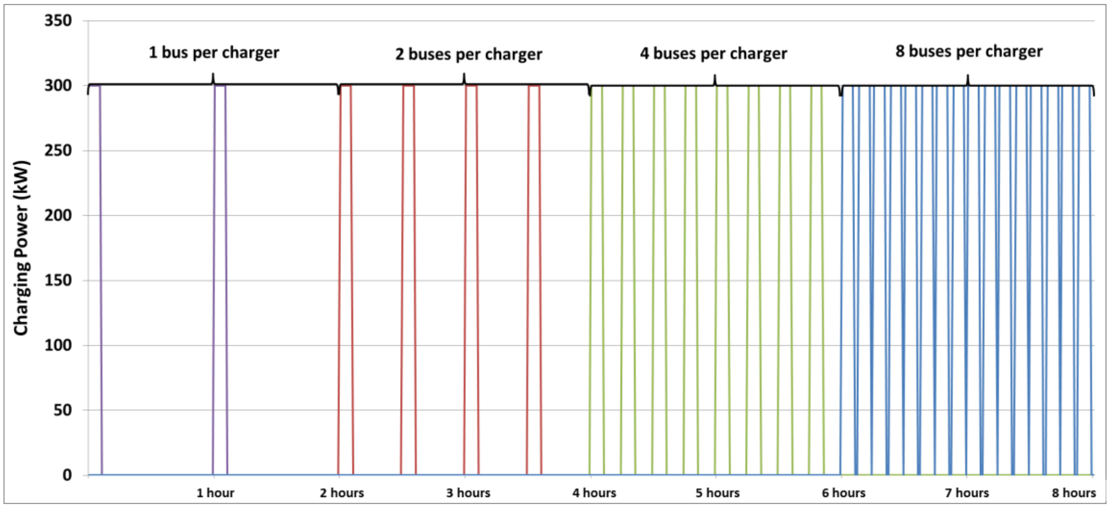


Figure 17: Charging power profile for 4 different electric transit bus deployment cases

For the first two hours, only one bus uses the charger. The maximum power demand on the grid is 300 kW. For the next two hours, two buses use the charger. Although a bus charges every 30 minutes, the maximum power demand on the grid is still 300 kW. The next two cases show the same results with 4 and 8 buses using the same charger, the maximum power demand on the grid remains 300 kW.

Even with large bus deployments, the fast charger will not be transferring energy continuously as there will be periods when buses dock and/or undock from the fast charger. It is estimated that it takes at least 1.5 minutes to dock/undock. In the absolute worst case, the fast charger would be transferring energy at a nominal power of 450 kW for 13.5 minutes out of 15 minutes. This would result in a maximum peak demand of 405 kW ($450\ kW \times \frac{13.5\ minutes}{15\ minutes}$).

In addition, in real-world transit operation, it is unlikely that an electric transit bus charging on-route would use 80% or more of its total battery capacity. Over more than 400,000 miles of transit operation, Proterra was able to develop a good picture of the average peak demand for multiple bus deployments.[24] Table 17 below summarizes these different power levels for multiple bus deployments.

Table 17: On-route opportunity charging power levels for multiple buses deployments

Power from the grid	Maximum Input Power	Nominal Power	Maximum Peak Demand	Average Peak Demand
4 buses	500 kW	450 kW	405 kW	280 kW
6 buses	500 kW	450 kW	405 kW	330 kW
8 buses	500 kW	450 kW	405 kW	380 kW

[24] Dmitriy Konyrev (Proterra), personal communication, August 2014.

3.2.2 Overnight charging

Overnight charging happens while the vehicle is not in operation (usually at night) and thus over longer charging duration than on-route opportunity charging. This long charge duration means that the demand charges associated with an overnight charger will be equal to the nominal power of the charger (generally less than 100 kW).

Although on-route opportunity charging requires high-power chargers, these chargers could be spread over various locations throughout the city. On the other hand, overnight chargers may be located at a single bus depot where the buses reside when not in use. For multiple bus deployments, the power demand from the grid can be large and a significant infrastructure investment at the bus depot may be required.

Table 18 below compares the average peak demand for different bus deployments charging on-route and overnight. For on-route opportunity charging, we use the results that we presented in Section 3.2.1 and for overnight charging, we assume a charger with a 40 kW nominal power is assigned to each bus.

Table 18: Comparison of average peak demand for different bus deployments

	On-route	Overnight
Nominal Power	450 kW	40 kW
Average Peak Demand (1 bus)	150 kW	40 kW
Average Peak Demand (4 bus)	280 kW	160 kW
Average Peak Demand (6 bus)	330 kW	240 kW
Average Peak Demand (8 bus)	380 kW	320 kW

We can see that for one bus, the average peak demand is over three times higher for on-route than for overnight charging. However, as more electric transit buses are deployed, demand charges for on-route opportunity charging can be spread over more buses as they will use the same fast charger, whereas demand charges will increase by increments of 40 kW for each new bus charging overnight.

However, there is a limit to the number of buses that can use a fast charger. Using the example in Section 3.2.1, we saw that an average bus would need about 5.3 minutes to charge at a nominal charging rate of 450 kW. Including the time it takes to dock/undock from the fast charger, it would take an average of 7 minutes per bus to charge. In one hour, a maximum of 8 buses could use the fast charger in these conditions and for more than 8 buses a new fast charger would be required. For bus deployments of 6 to 8 buses (the optimum number of buses that can use a single fast charger in the conditions presented in Section 3.2.1), average peak demands are comparable between on-route opportunity charging and overnight charging.

3.3 Business Case of Electric Transit Buses

Peak demand charges have been a surprise to some commercial electric vehicle users, and in some few cases have been quite substantial. In the following sections, we look at how peak demand charges and Time-Of-Use pricing impact the business case of electric transit buses.

3.3.1 Impact of Peak Demand Charges

Among the 26 electric utilities that we reviewed as part of this project (see Section 3.1), 24 include peak demand charges (directly or indirectly) in their commercial and industrial electric rate schedules. Public transit agencies deploying electric transit buses around the country are bound to experience the impact of peak demand charges. Figure 18 below compares the fuel costs per mile of a diesel, CNG and two types of electric transit buses: charging on-route (with four different bus deployment strategies) and charging overnight.[25] In the first case, no demand charges are included and in the second case, low demand charges at $5 per kW are included.

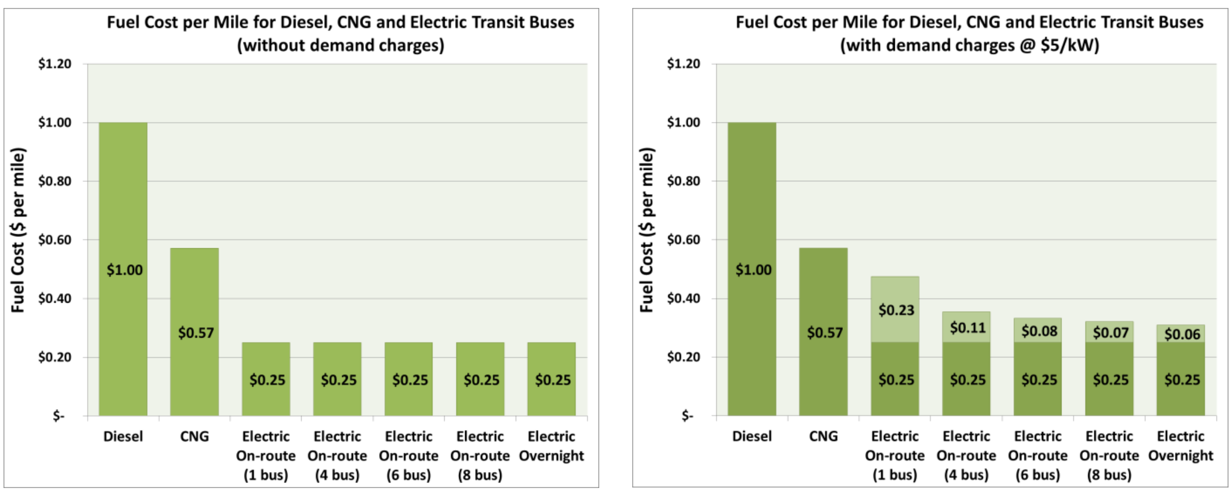


Figure 18: Fuel cost for diesel, CNG and electric buses with no and low demand charges

Electric transit buses show a clear advantage over diesel and CNG-powered transit buses when no demand charges are included. When low demand charges are included, fuel cost increase by $0.06 per mile for one electric bus charging overnight and by $0.23 per mile for one electric bus charging on-route. However, as the number of electric transit buses using a single on-route fast charger is optimized (up to 8 buses using one single fast charger), demand charges can be spread over more buses and greatly reduced.

[25] We assume each bus drives 40,000 miles per year. The diesel bus has a fuel economy of 4 MPG and diesel is priced at $4.00 per gallon. The CNG bus has a fuel economy of 3.5 MPDGE and CNG is priced at $2.00 per DGE. The electric transit buses have an efficiency of 2.5 AC kWh / mile and electricity is priced at $0.10/kWh. One electric bus charging on-route draws 150 kW from the grid, 4 draw 280 kW, 6 draw 330 kW and 8 draw 380 kW. The electric bus charging overnight draws 40 kW from the grid.

In Figure 19 below we look at the impact of medium ($10/kW) and high ($20/kW) demand charges.

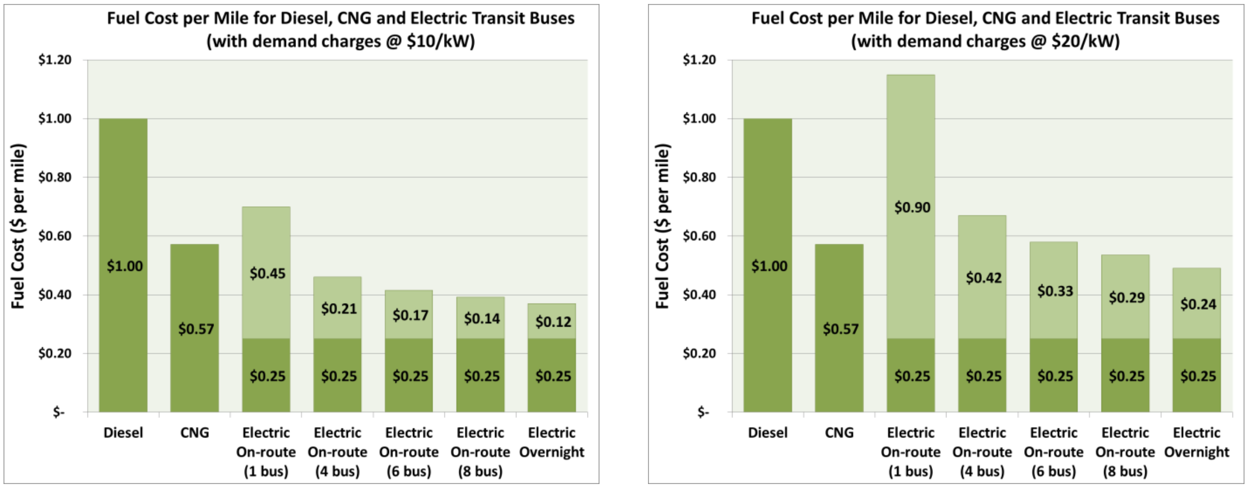


Figure 19: Fuel cost for diesel, CNG and electric buses with medium and high demand charges

When medium demand charges are included, fuel cost increase by $0.12 per mile for one electric bus charging overnight and by $0.45 per mile for one electric bus charging on-route. In that case, the fuel cost for one electric bus charging on-route is higher than the fuel cost for a CNG-powered bus. However, as the number of electric transit buses using a single on-route fast charger is optimized, demand charges can be spread over more buses and electric transit buses charging on-route regain their advantage over CNG-powered buses.

When high demand charges are included, fuel cost increase by $0.24 per mile for one electric bus charging overnight and by $0.90 per mile for one electric bus charging on-route. In that last case, the fuel cost for one electric bus charging on-route is higher than the fuel cost for a diesel-powered bus. However, as the number of electric transit buses using a single on-route fast charger is optimized, demand charges can be spread over more buses and electric transit buses charging on-route regain their advantage over diesel and even over CNG-powered buses.

Peak demand charges have a significant impact on the business case of electric transit buses charging on-route and overnight. In areas where demand charges are high, fuel cost is more than doubled although it still stays below the fuel cost of a diesel-powered bus and remains competitive with a CNG-powered bus.

Demand charges will have a greater impact on small pilot deployments of electric transit buses charging on-route than on small pilot deployments of electric transit buses charging overnight. However, for bus deployments of 6 to 8 buses (the optimum number of buses that can use a single fast charger in the conditions presented in Section 3.2.1), demand charges can be spread over more buses and greatly reduced.

3.3.2 Impact of Time-Of-Use Pricing

TOU rates are another form of peak demand charges. Instead of a single flat rate for energy use, TOU rates are higher when electric demand is higher (Figure 20). This means when you use energy is just as important as how much you use.[26]

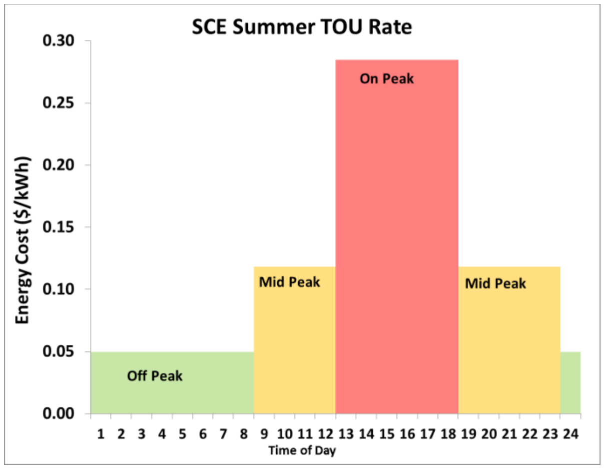


Figure 20: Example of TOU pricing[27]

Figure 21 below compares the fuel costs per mile of a diesel, CNG and electric transit bus.[28] We consider three different electricity prices: $0.10 / kWh, $0.05 / kWh corresponding to off peak rate and $0.20 / kWh corresponding to on-peak rate.

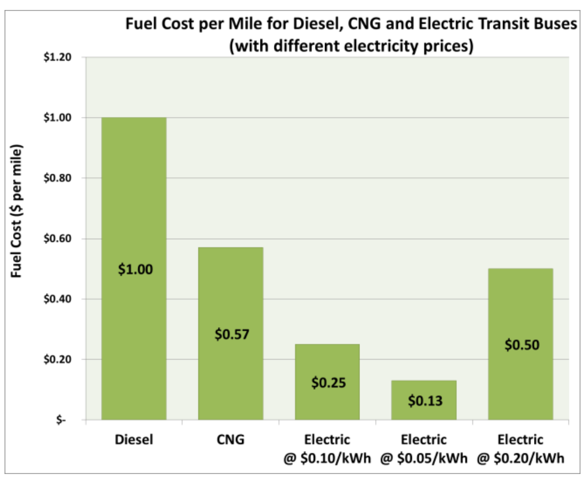


Figure 21: Impact of TOU pricing on electric transit bus fuel cost

The price of the electricity used to recharge an electric transit bus is an important component of its fuel costs. Charging off peak when electricity prices are low can lead to significant savings. On the other hand, charging on peak when electricity prices are high can dramatically increase fuel costs per mile.

[26] Pacific Gas & Electric. Time-Of-Use Rates. http://www.pge.com/en/mybusiness/rates/tvp/toupricing.page. Accessed on 05/19/2014.
[27] Southern California Edison. Schedule TOU-GS-2 / Time-Of-Use – General Service – Demand Metered. https://www.sce.com/AboutSCE/Regulatory/tariffbooks/ratespricing/default.htm. Accessed on 07/16/2013.
[28] We assume each bus drives 40,000 miles per year. The diesel bus has a fuel economy of 4 MPG and diesel is priced at $4.00 per gallon. The CNG bus has a fuel economy of 3.5 MPDGE and CNG is priced at $2.00 per DGE. The electric bus has an efficiency of 2.5 AC kWh / mile.

Chapter 4: Technical Options

This chapter discusses potential technical options that could mitigate the impact of peak demand charges on the operation of electric transit buses. While we did not look at every technical option available today or in the near future, we considered several of interest for electric transit buses. These technical options are grouped in three different areas of improvement:

- Increasing electric transit bus efficiency,
- Managing electric transit bus charging,
- Employing energy transfer technology.

4.1 Increasing Electric Transit Bus Efficiency

Increasing the overall efficiency of electric transit buses can reduce peak demand charges. Table 19 below highlights the impact of better electric transit bus efficiency on peak demand charges.

Table 19: Impact of better efficiency on peak charging power

	On-route opportunity charging bus		Overnight charging bus	
Distance between charges	15 miles		150 miles	
Bus efficiency	2.5 kWh/mi	2.0 kWh/mi	2.5 kWh/mi	2.0 kWh/mi
Charge energy needed	37.5 kWh	30 kWh	375 kWh	300 kWh
Charging time	*@ 450 kW* 5 minutes	*@ 450 kW* 4 minutes	6 hours	
Average Peak Demand	**150 kW**	**120 kW**	**63 kW**	**50 kW**

We see that a more efficient electric transit bus will use less energy between charges and will require a lower charging power (120 kW instead of 150 kW for a bus charging on-route and 50 kW instead of 63 kW for a bus charging overnight). Both charging methods would benefit from increased bus efficiency, although electric transit buses using on-route opportunity charging would benefit more as indicated by the larger charging power decrease.

Increasing electric transit bus efficiency can be achieved through several different ways. We looked at two different technologies of interest for electric transit buses.

- *Range Extender*

A range extender is an auxiliary power unit consisting of a small internal combustion engine coupled with an electric generator which is used to recharge the battery pack.[29] Range extenders are compact and lightweight and can increase the energy stored on-board and ultimately the driving range of electric vehicles. Integrated on electric transit buses, a range extender could decrease the amount of electricity needed between two charging events and ultimately the required charging power. However, integration of range extenders can be complex and adds cost. In addition, if they consume conventional fossil fuels, they will produce emissions. To keep operating with zero-emissions, hydrogen fuel cell range extender could be used.

Figure 22 below compares the operation of two electric transit buses: one operating on pure electricity alone and one operating on electricity and gasoline using a range extender.

[29] MAHLE Compact Range Extender Engine. http://www.mahle-powertrain.com/C1257126002DFC22/vwContentByKey/W28HLDYB580STULEN. Accessed on 06/12/2014.

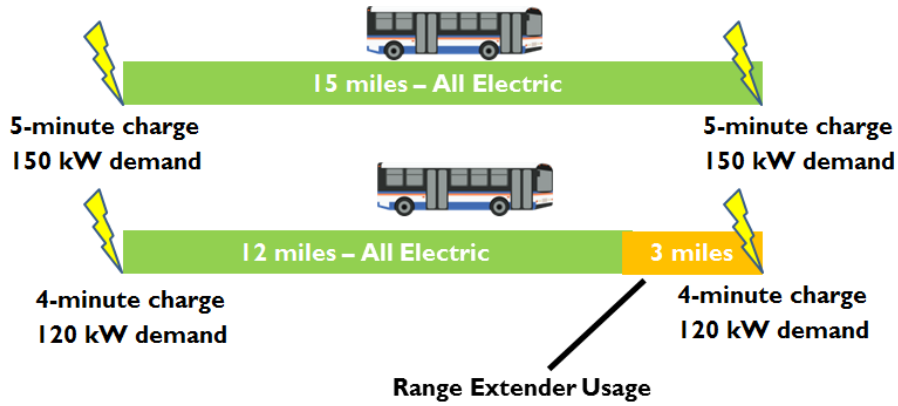


Figure 22: Comparison of all-electric and range extended transit bus operation

In pure electric mode, the bus would consume 37.5 kWh of electricity to drive 15 miles and would require a 5-minute charge at 450 kW (150 kW demand) to be able to drive the next 15 miles.[30] With a range extender, the bus could drive 12 miles in pure electric mode, consuming 30 kWh of electricity. It would then switch to range extended mode to cover the last three miles, consuming 2.1 L of gasoline.[31] It would require a 4-minute charge at 450 kW (120 kW demand) to be able to drive the next 15 miles. Daily fuel requirement to cover about 150 miles would be 5-6 gallons of gasoline.

- *Fuel-fired HVAC / APU*

Accessory loads (heating, ventilation and air conditioning) consume a large amount of energy on transit buses. Using fuel-fired heaters or auxiliary power units (APU) would reduce the load on the vehicle traction batteries and increase the electric transit bus efficiency. Fuel-fired systems or APUs are very efficient systems but if they consume conventional fossil fuels, they will produce some emissions. To keep operating with zero-emissions, battery-powered air-conditioners or hydrogen-powered APUs could be used.

Fuel-fired heating is currently in use on one of the electric transit bus model manufactured in North America. Coupled with an electric heating source, a diesel heating source heats up water, which then passes to the passenger compartment. The system increases the overall efficiency of the electric transit bus and guarantees that it operates with consistent performance in cold weather operation.

4.2 Managing Electric Transit Bus Charging

In addition to improving the efficiency of electric transit buses, significant effort should be focused on managing charging to achieve operational goals without being impacted too severely by peak demand charges. In this section we considered four different technologies to better manage charging.

[30] Assuming electric transit bus efficiency of 2.5 kWh / mile.
[31] Assuming the range extender consumes 240 grams of gasoline per kWh.

- *Charge at Lower Charging Power*

The simplest way to decrease the impact of demand charges is to charge at a lower charging power. Table 20 below shows how the required charging power decreases as the charging time increases.

Table 20: Impact of charging time on peak charging power

	Overnight charging bus		
Distance between charges	150 miles		
Bus efficiency	2.5 kWh/mi		
Charge energy needed	375 kWh		
Charging time	4 hours	6 hours	8 hours
Required charging power	**94 kW**	**63 kW**	**47 kW**

There is of course a trade-off between charging time and required charging power as transit buses will not be able to park for extended periods of time and meet their operating requirements.

- *Increase Number of Charging Stops*

On-route opportunity charging is based on providing just enough energy during charging to reach the next charging stop. As transit buses frequently stop to pick-up and drop-off passengers, they can charge frequently at lower power rates instead of charging only a few times along the route at high power rates. Figure 23 below shows how the same bus could operate on the same route while charging once every 30 miles or once every 15 mile.

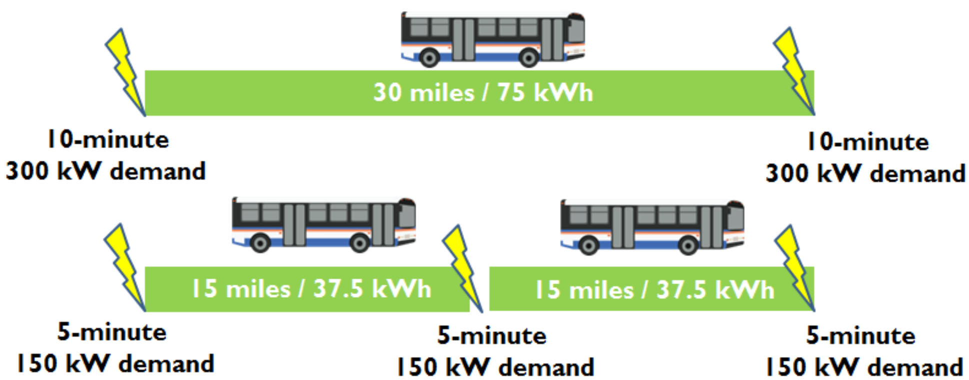


Figure 23: Comparison of charging power demand for two different charging configurations

Charging stops should be located on-route to ensure bus operation and minimize peak demand charges. Electric transit buses should also recharge anytime it is possible even if they have enough energy to get to the next charging stop.

- *Overhead Power*

Overhead power has been in use for many years in the transit industry. These systems use overhead power lines either throughout the entire route or at specific points in order to provide power to electric transit buses. In the former, a power transfer device (pantograph or trolley) connects the moving vehicle with the power lines, providing electricity to the traction motor in order to move the vehicle (Figure 24). In the latter, the electric transit bus stops or drives through specific charging points along the route in order to recharge batteries.

Figure 24: Trolley bus from San Francisco MTA (photo courtesy www.sanfrancisco.net)

Using overhead power has the advantage to recharge more or less continuously and thus at lower power rates. In addition, passenger space is maximized and vehicle weight minimized as it can operate without large energy storage. However, the overhead infrastructure can be costly and unsightly power lines may be needed for much of the route.

- *Wireless Charging*

Wireless charging allows the charging of electric vehicles through conduction or induction and thus without a physical connection between charger and vehicle. The charging infrastructure is embedded in the road surface and either connects with the electric transit bus while the bus is at a stop or through magnetic induction to recharge without any contact. Figure 25 below presents a shuttle bus powered by WAVE technology, a wireless power charging system that is being introduced in several locations in the United States.[32] Using magnetic induction, the WAVE system recharges at bus stops at a maximum power of 50 kW.

Figure 25: Shuttle bus powered by WAVE technology (photo courtesy Utah State University)

Like overhead power, wireless charging technology can increase the frequency of charging events and thus lower the power demand on the grid. It also has the advantage of minimizing visual impact of the charging infrastructure and can maximize passenger space as it can operate without large energy storage.

Inductive charging is generally less efficient that conductive charging and can vary significantly depending on the distance between the charging device and the vehicle and how well the vehicle is positioned over the inductive charger.

[32] For more information: http://www.waveipt.com/blog/wirelessly-charged-electric-bus-unveiled.

4.3 Employing Energy Transfer Technology

The last technology that we considered to reduce the impact of peak demand charges on the operation of electric transit buses makes use of energy transfer technologies such as battery storage. The demand on the grid can be reduced by trickle charging batteries or ultracapacitors to later fast charge electric transit buses without pulling large amounts of power from the grid. Other technologies could use auxiliary generators to directly recharge electric transit buses or offset the demand from charging through load management systems.

- *Battery Swapping*

With battery swapping, electric transit buses can operate throughout the day and replace empty batteries with recharged ones when needed. Empty batteries can then be recharged at lower power throughout the day. Figure 26 presents a battery swapping system operating in Beijing, China. About 50 electric transit buses swap battery packs several times a day at this facility. An automated system provided by Dianba Technology and funded by State Grid, swaps the battery packs in 8 to 10 minutes per bus.

Figure 26: Battery swapping system in Beijing, China

The 144 kWh battery packs are charged throughout the day and can also provide grid support. It takes about four hours at a charging power of 36 kW to recharge a battery pack. Table 21 below compares the maximum charging power of battery swapping with a fast charge system that would recharge the same electric transit bus in the 10 minutes it takes to swap the battery packs.

Table 21: Comparison of charging power for battery swapping and fast charge

	Battery Swapping	Fast Charge
Energy transferred	144 kWh	144 kWh
Charging duration	4 hours	10 minutes
Required charging power	36 kW	864 kW

In this case, battery swapping significantly reduces the required charging power from 864 kW to 36 kW. However, battery swapping requires a significant upfront investment and is better suited for larger deployment of electric transit buses. In addition, the space required for the battery swapping station can be a major barrier for adoption in dense urban areas where cheap real estate is scarce.

- *Energy Storage System*

Energy storage systems (such as batteries, ultracapacitors or flywheels) can be used as buffers between the grid and fast chargers to smooth out peak load. This technology is currently in use in the ABB TOSA demonstration project in Geneva, Switzerland (Figure 27).

Figure 27: The ABB TOSA articulated electric bus charging at a stop (photo courtesy ABB)

Ultracapacitors integrated into the charging stations are recharged from the grid for a duration of 2.5 minutes at 40 kW. When the bus is connected to the charging station, the ultracapacitors transfer their stored energy in about 15 seconds at a 400 kW charging power (Table 22).

Table 22: Description of ABB TOSA bus charging system

	Grid to Charger	Charger to Bus
Maximum charging power	40 kW	400 kW
Charging duration	2.5 minutes	15 seconds
Energy transferred	1.7 kWh	1.7 kWh

The use of ultracapacitors decreases the maximum charging power from 400 kW to 40 kW while maintaining the benefits of on-route opportunity charging. In addition, lower charging power allows for easier siting of the charging infrastructure as it may not require complex and expensive upgrades to the electric infrastructure.

Adding an energy storage system will increase the cost and complexity of the charging infrastructure and decrease the overall efficiency of the system as it adds energy conversion losses. But it represents an interesting option to implement on-route opportunity charging of electric transit buses without the high power demand that can be associated with fast charging.

- *Auxiliary Generator*

Instead of pulling power from the grid, electric transit buses could be recharged directly using an auxiliary generator. As auxiliary generators are generally better suited for continuous operation, this technology could be coupled with energy storage systems to store energy while no electric transit bus is charging. Excess electricity produced by the auxiliary generator could also be fed back to the grid or used to power transit agency buildings.

An example of auxiliary generator is produced by Bloom Energy. Their Bloom Box Energy Server (Figure 28) consists of a scalable solid-oxide fuel cell fed by pipeline-delivered natural gas.

Figure 28: Bloom Box Energy Server (photo courtesy Fast Company)

Although the Bloom Box does not operate without emissions, it runs efficiently to provide reliable and clean energy. While the high cost and complex integration of this technology may not suit every electric transit bus deployments, it may show a good business case in applications where demand prices are high.

- *Load Management System*

Transit agencies implementing electric transit buses in their fleet could use load management systems to accommodate some or all of the added demand from electric transit bus charging. For example, when an electric transit bus is charging, non-essential lighting could be automatically shut off or air conditioning temperature modified by a few degrees at the facility associated with the utility meter. This would offset some or all of the power demand associated with electric bus charging.

By knowing the typical load profile of the facility associated with the utility meter, transit agency could also determine the best time to recharge electric transit buses. For example, Figure 29 below shows the load profile of a typical parcel delivery facility. It usually shows two main periods of activities: in the morning between 6 and 8am when packages are loaded onto the delivery trucks and between 6 and 10pm when trucks are unloaded.

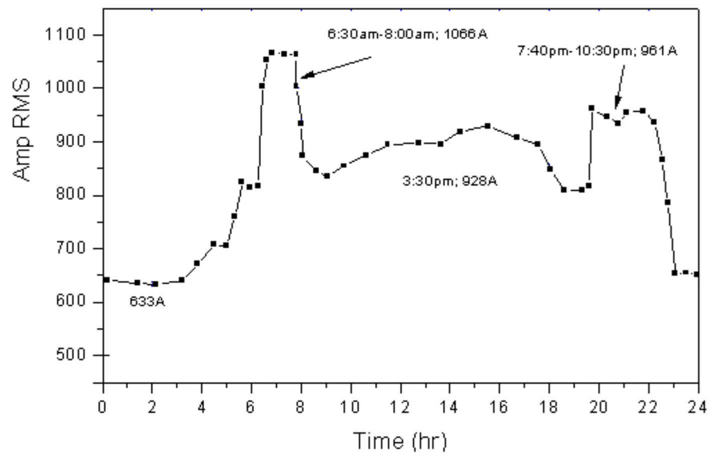


Figure 29: Building load in ampere from a typical day at a 120-vehicle parcel delivery facility[33]

Charging electric vehicles right upon returning to the facility can mean adding electrical load to a facility already drawing a large amount of power from the grid. In the worst case scenario, electric vehicles charging can increase the peak load of the facility and thus increase peak demand charges. On the other hand, electric vehicles could easily be charged at night (between 11pm and 6am) without increasing the maximum demand of the facility. Load management systems could automate the process, by choosing to allow charging at the most favorable time or by staggering charging between several buses while still ensuring that the vehicles will be charged when needed.

[33] Sondhi, Keshav. *Talking Freight Webinar, National Clean Fleets Partnership.* http://www.fhwa.dot.gov/planning/freight_planning/talking_freight/february_2013/03_talkingfreight_02_20_2013_ks.pptx. Accessed on 2013-07-18.

Chapter 5: Policy Options

5.1 Current Policy Context

Strong federal and state regulations are currently in place to help expand the market for electric transit buses in the United States. We review below three key regulations and policy instruments that have spurred early deployments of electric transit buses and will help grow their number on the road. While the reviewed state policy and regulations focus on the State of California, we strongly believe that the results and findings developed in the following sections are relevant for other parts of the nation.

Transit Investments for Greenhouse Gas and Energy Reduction (TIGGER)

The TIGGER Program provides capital grants to public transit agencies for the purpose of reducing energy use or greenhouse gas emissions of public transportation systems.[34] This program enabled the demonstration and rapid adoption of hybrid-electric buses, electric buses, and fuel cell buses for urban fleets.

ARB Zero Emission Bus Regulation[35]

Recognizing the importance of zero emission buses in meeting California's criteria pollutant and greenhouse gas emission reduction goals, the California Air Resources Board adopted the Zero Emission Bus regulation that would mandate that 15% of new bus purchases in California would have to be zero emission. Although the Zero Emission Bus regulation is currently on hold, it remains an important driver for the development and implementation of zero emission buses in California.

California ZEV Action Plan

The Zero-Emission Vehicle (ZEV) Action Plan identifies specific strategies and actions that state agencies will take to meet the milestones of the Governor's ZEV Executive Order, whose goal is to put 1.5 million ZEV on California roadways by 2025. In order to accelerate the commercialization of medium and heavy-duty ZEVs, the ZEV Action Plan recommends the following specific strategies and actions: [36]

- **Help to expand ZEVs within bus fleets**

Specifically for electric transit buses, the ZEV Action Plan recommends to monitor technology and market progress and update Zero-Emission Bus (ZBus) regulation, taking into consideration technology and market development, to expedite use of ZBuses.

- **Reduce cost barriers to ZEV adoption for freight vehicles**

Specifically for electric transit buses, the ZEV Action Plan recommends to continue to provide incentive funding to reduce up-front purchase costs and assess need for incentive funding to include an infrastructure cost component. In addition, the ZEV Action Plan recommends the development of electricity tariffs that encourage electrification, promote efficient utilization of grid resources and allow for recovery of utility capital costs.

[34] U.S. DOT, Federal Transit Administration. TIGGER Program Overview. http://www.fta.dot.gov/documents/TIGGER_Overview_r3_w150.pdf. Accessed on 05-29-2014.

[35] California Air Resources Board. Zero Emission Buses. http://www.arb.ca.gov/msprog/bus/zbus/zbus.htm. Accessed on 07-22-2014.

[36] Governor's Interagency Working Group on Zero-emission Vehicles. 2013 ZEV Action Plan. http://opr.ca.gov/docs/Governor's_Office_ZEV_Action_Plan_(02-13).pdf. Accessed on 07-22-2014.

5.2 Review of Current CPUC Activities

The California Public Utilities Commission (CPUC) has been working closely with industry stakeholders to consider alternative-fueled vehicle programs, tariffs, and policies that would encourage the adoption of cleaner vehicles in California. Particularly interesting to this white paper, the California ZEV Action Plan asked the CPUC to explore how electric rates can be used to support the adoption of EVs in fleets, public transit and freight sectors.[37] The Order Instituting Rulemaking (OIR) R.13-11-007 drew significant interest from EV industry stakeholders as seen in the number of comments submitted to the CPUC. In order to get a better understanding of the multiple perspectives regarding the issue, we summarized below the comments regarding medium and heavy-duty electric vehicles and demand charges from EV charging. As the issue of peak demand charges first arose from the specific case of Foothill Transit in California, the CPUC has been the first state agency to look into the issue. We strongly believe the comments and opinions summarized below, while originating from California, are relevant to the industry and other states looking at electric transit buses.

Proterra, the sole medium and heavy-duty electric vehicle manufacturer who provided comments, "strongly support[ed] establishing predictable and uniform statewide rate structures that fully recognize the public benefits offered by deploying zero-emission, fast charge public transit buses". Specifically they supported "the elimination of demand and time of use charges" and the "[adoption of] favorably lower rates for zero-emission public bus transit that are comparable to other forms of electrified transportation". Lastly, they "also support[ed] the proposed inclusion of financing programs to help public transit agencies".[38]

The interest of California electric utilities in the electrification of medium and heavy-duty vehicles was not as important as for the electrification of light-duty passenger vehicles. For instance, San Diego Gas & Electric (SDG&E) believes that the topic "should be covered after the more immediate and higher priority subject areas are addressed in the light duty PEV markets."[39] In general, California electric utilities recommended the CPUC not to take action that would disturb the current model of cost recovery, create "perverse incentives" and shift costs to "non-participating customers".[40] [41]

Contrary to Proterra's wishes, Southern California Edison (SCE) recommended that the "resolution granting government agencies adopting zero-emission electric buses a subsidy to help early deployments should not be expanded".[42]

None of the three California investor-owned utilities recommended the elimination of demand charges. Pacific Gas & Electric (PG&E) advised the CPUC to "treat the use of demand charges for PEVs the same way it would treat other residential and non-residential loads and customers".[43] According to PG&E, "demand charges are used to correctly reflect the fixed and variable costs of serving all customers, including PEV charging customers".[44] SDG&E believes that "recovery of grid costs are appropriately done through demand charges" as it ensures that "the customer has the ultimate flexibility of deciding service demands based on the utility price signals".[45] Lastly, SCE recommended the CPUC to

[37] CPUC. Order Instituting Rulemaking to Consider Alternative-Fueled Vehicle Programs, Tariffs, and Policies. http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M081/K996/81996327.PDF. Accessed on 06-03-2014.
[38] CPUC. Opening comments of Proterra Inc on the OIR to consider alternative-fueled vehicle programs, tariffs, and policies. http://delaps1.cpuc.ca.gov/CPUCProceedingLookup/f?p=401:57:1543034934426::NO. Accessed on 06-03-2014.
[39] CPUC. Response of San Diego Gas & Electric Company (U 902 M) to the OIR to consider alternative-fueled vehicle programs, tariffs, and policies. http://delaps1.cpuc.ca.gov/CPUCProceedingLookup/f?p=401:57:1543034934426::NO. Accessed on 06-03-2014.
[40] CPUC. Opening comments of Pacific Gas and Electric Company (U 39E) on alternative-fueled vehicle rulemaking. http://delaps1.cpuc.ca.gov/CPUCProceedingLookup/f?p=401:57:1543034934426::NO. Accessed on 06-03-2014.
[41] CPUC. Southern California Edison Company's (U 338-E) reply to parties' comments on OIR. http://delaps1.cpuc.ca.gov/CPUCProceedingLookup/f?p=401:57:1543034934426::NO. Accessed on 06-03-2014.
[42] See footnote 41.
[43] See footnote 40.
[44] See footnote 40.
[45] See footnote 39.

"explore rate structures that recover […] costs through a combination of fixed and variable rate components."[46]

Several environmental groups also weighed in. The Green Power Institute recommended the CPUC to "[reduce] demand charges for [DC] Fast Charging stations", which "can be prohibitively costly […] when utilization is relatively infrequent".[47] The Environmental Defense Fund echoed Proterra's wish to enact rates that encourage adoption of alternative-fueled vehicles, calling out the electrification of fleets as "an important step in meeting emission reduction goals, supporting the grid, and producing […] environmental benefits […]".[48]

Two Electric Vehicle Supply Equipment (EVSE) suppliers contributed differing opinions. ChargePoint noted that "demand charges on some heavy-duty customers such as transit agencies may discourage electrification" and recommended the CPUC to "thoroughly explore the alternatives to demand charges, and involve [municipal transit agencies] in the discussion of rate options and solutions."[49] On the other hand, NRG Energy recommended the CPUC to avoid creating "application-specific rates that are simple rate-payer cross subsidization" and that could "stifle market innovations in alternatives that are economically viable". It recommended instead pursuing V2G revenue, which could have "the potential to substantially offset demand charges for medium and heavy-duty plug-in electric vehicles".[50]

Finally, The Utility Reform Network (TURN), a utility consumer advocate group, opined that it was "not the responsibility of utility ratepayers to provide incentives to commercialize PEVs in California" and that utilities should be "supporting and facilitating" rapid commercialization of PEVs and not "causing" such commercialization.[51]

Following the review of the submitted comments, the CPUC has recently signaled that the "proceeding will allow for more input to determine whether to mitigate current demand charges levels and if so, how to do so."[52]

5.3 Policy Options to Support Electric Transit Buses

Peak demand charges are generally considered as the appropriate way to allow recovery of utility capital costs. In addition, the application of demand charges gives an appropriate price signal that pushes for market innovation promoting economically viable alternatives. However, medium and heavy-duty electric vehicles face unique rate challenges. Demand charges in these cases may discourage transportation electrification if loads cannot be shifted to off-peak periods or to periods with low load factors.[53]

Electric transit buses may need to be considered differently than light-duty electric vehicles. While concerns about "perverse incentives" and "shifting cost to non-participating customers"[54] are legitimate for privately owned light-duty electric vehicles, they may not recognize the specific business constraints of public transit agencies and the public benefits offered by deploying electric transit buses. Displacing fossil-fuel powered buses that can drive over 50,000 miles per year at a fuel economy of less than 4

[46] See footnote 41.
[47] CPUC. Green Power Institute and Community Environmental Council opening comments on OIR. http://delaps1.cpuc.ca.gov/CPUCProceedingLookup/f?p=401:57:1543034934426::NO. Accessed on 06-03-2014.
[48] CPUC. Comments of Environmental Defense Fund on the OIR in the alternative-fueled vehicle docket. http://delaps1.cpuc.ca.gov/CPUCProceedingLookup/f?p=401:57:1543034934426::NO. Accessed on 06-03-2014.
[49] CPUC. Comments of Chargepoint, Inc. on OIR to Consider Alternative-Fueled Vehicle Programs, Tariffs, and Policies. http://delaps1.cpuc.ca.gov/CPUCProceedingLookup/f?p=401:57:1543034934426::NO. Accessed on 06-03-2014.
[50] CPUC. Reply comments of NRG Energy, Inc. on OIR. http://delaps1.cpuc.ca.gov/CPUCProceedingLookup/f?p=401:57:1543034934426::NO. Accessed on 06-03-2014.
[51] CPUC. Comments of the Utilty Reform Network in response to OIR and scoping memo. http://delaps1.cpuc.ca.gov/CPUCProceedingLookup/f?p=401:57:1543034934426::NO. Accessed on 06-03-2014.
[52] CPUC. Order Instituting Rulemaking to Consider Alternative-Fueled Vehicle Programs, Tariffs, and Policies. http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M098/K861/98861048.PDF. Accessed on 07-22-2014.
[53] See footnote 52.
[54] See footnote 40.

MPG can offset significant amounts of greenhouse gases, criteria pollutants and foreign oil as Figure 30 shows.

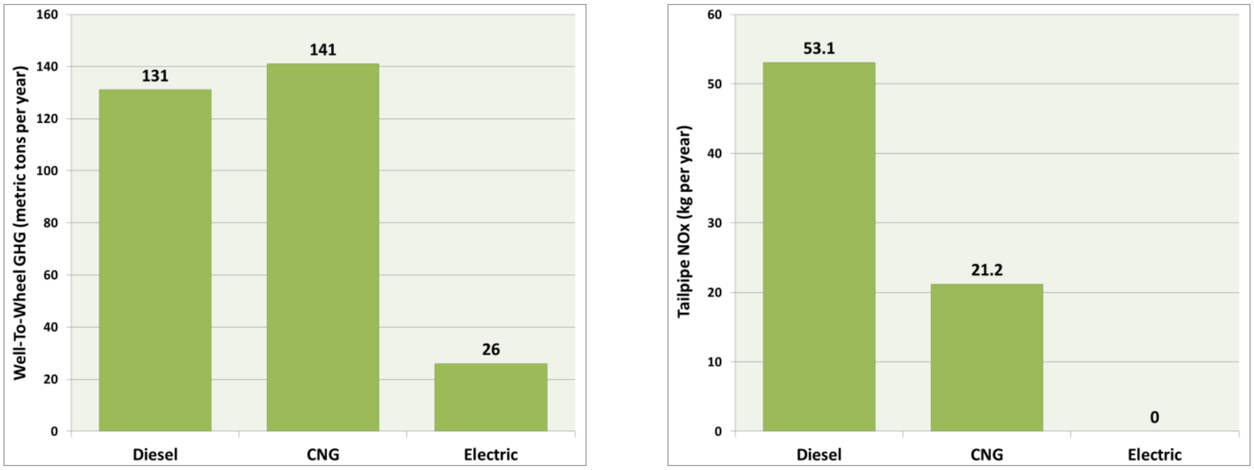


Figure 30: Environmental benefits of electric transit buses compared to diesel and CNG buses[55]

In order to support and increase the adoption of electric transit buses, we recommend considering the creation of a specific electric transit bus rate to support the electrification of public transit buses. In the following sections, we look at the characteristics that this specific electric transit bus rate should have to be effective. We also look at how direct support to transit agencies to encourage optimum deployment of electric transit buses charging on-route could help reduce peak demand charges.

5.3.1 Time-Of-Use Pricing Option

Instead of a single flat rate for energy use, TOU rates are higher when electric demand is higher. Figure 31 below shows daily energy charges in the summer season for Southern California Edison General Service TOU – EV Charging Demand Metered.

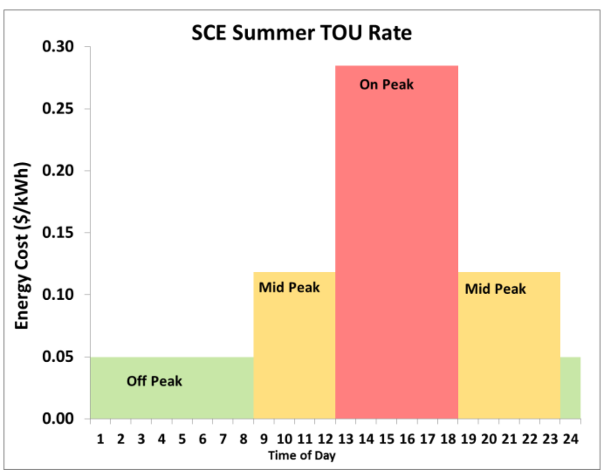


Figure 31: Example of TOU pricing[56]

[55] WTW GHG numbers from the GREET Fleet Footprint Calculator. Other assumptions: 40,000 miles/yr, Diesel fuel economy = 4 MPG, CNG fuel economy = 3.25 miles per DGE, Electric bus efficiency = 2.5 kWh/mile. WECC annual CO_2 equivalent total output emission rate = 513.31 lb./MWh (from eGRID 9th edition version 1.0), Diesel NO_x emission rate = 1.18 g/mile and CNG NO_x emission rate = 0.47 g/mile (average from numbers published in MJB&A, Comparison of Modern CNG, Diesel and Diesel Hybrid-Electric Transit Buses: Efficiency & Environmental Performance, 2013)

In that case, energy prices fluctuate from \$0.28454/kWh on-peak (from noon to 6pm) to \$0.04991/kWh off-peak (from 11pm to 8am). Transit buses generally operate during the day, loosely matching business hours (8am to 8pm) which generally corresponds to on-peak and mid-peak periods. If recharging is done on-peak, the operating costs of electric transit buses can be very high. For more information, please see Section 3.3.2.

Given the non-flexible nature of transit bus operation, **we recommend consideration of optional TOU pricing for electric transit buses**. Buses using on-route opportunity charging during the day would benefit from a single flat rate for energy use. Electric transit buses capable of recharging overnight could opt in for TOU pricing and take advantage of lower off-peak energy prices.

5.3.2 Higher Energy Charge / Lower Power Charge Pricing Option

As we identified in Section 2.2, electric transit buses are generally recharging on-route through fast charging technology (up to 500 kW) or overnight during longer periods of time (less than 100 kW). We believe these two different ways of recharging electric transit buses each have their place in the electric transit bus market.

In order to foster a dynamic and innovative electric transit bus market that does not favor one charging solution over another, **we recommend consideration of a higher energy charge / lower power charge pricing option** that charges more per kWh and less per kW. Some electric utilities already provide this option for commercial customers. For instance, the General Service Demand rate proposed by Tampa Electric Company has 2 different options: a Standard rate with a low energy charge (\$0.01583/kWh) and a high power charge (\$9.16/kW) and an Optional rate with a high energy charge (\$0.05879/kWh) and a low power charge (\$0.00/kW).

Table 23 below presents the monthly electricity charge of two pricing options: Option 1, a higher energy charge / lower power charge option applied to an electric transit bus charging at 280 kW and Option 2, a lower energy charge / higher power charge option applied to an electric transit bus charging at 60 kW.

Table 23: Comparison of total monthly electricity charge for 2 different energy/power options

	Option 1 *"Lower demand / Higher energy"*	Option 2 *"Higher demand / Lower energy"*
Daily driving distance	120 miles / day	
Bus efficiency	2.5 AC kWh/mi	
Charging Power	280 kW	60 kW
Energy charge	\$0.15/kWh	\$0.05/kWh
Demand charge	\$2.00/kW	\$20.00/kW
Total Monthly electricity charge	**\$1505**	**\$1515**

We can see that the two options provide flexibility for both charging solutions and do not favor one charging option over another as monthly electricity charges are similar.

[56] Southern California Edison. Schedule TOU-GS-2 / Time-Of-Use – General Service – Demand Metered. https://www.sce.com/AboutSCE/Regulatory/tariffbooks/ratespricing/default.htm. Accessed on 07/16/2013.

5.3.3 Temporary Suspension of Peak Demand Charges

We look at a transit agency deciding to introduce one electric transit bus on a route with the following characteristics: 150 miles/day, 5 days/week and 4 weeks/month. The electric transit bus has the following performance on this route:

- Efficiency of 2.5 AC kWh/mile,
- Energy cost of $0.10/kWh,
- Demand charges of $10/kW, and
- Charging rate of 280 kW.

Monthly energy charges would be equal to:

$$150\, miles/day \times 2.5\, AC\, kWh/mile\ \times \$0.10/kWh \times 20\ \ days/month = \$750$$

Monthly demand charges would be equal to:

$$\$10/kW \times 280kW = \$2{,}800$$

The transit agency would then have to pay $1.18/mile to operate the electric transit bus, compared to $1.00/mile for a diesel bus and $0.57/mile for a CNG bus.[57] With demand charges, the electric transit bus would not be economically viable for the transit agency. If demand charges were temporarily suspended, the transit agency would only pay $0.22/mile to operate the electric transit bus. As the transit agency gains experience with electric transit buses and is able to purchase more buses, demand charges could be reintroduced. Table 24 below summarizes four cases where 1, 2, 4 or 8 buses charge using a single fast charger.

Table 24: Examples of fast charging electric transit bus deployment and their operating costs

	1 bus	2 buses	4 buses	8 buses
Total Energy Charges	$750	$1500	$3000	$6000
Total Demand Charges	$2800	$2800	$2800	$2800
Total Charges	$3550	$4300	$5800	$8800
Per bus	***$3550***	***$2150***	***$1450***	***$1100***
Per mile	***$1.18***	***$0.72***	***$0.48***	***$0.37***

We can see that as the number of electric transit buses using a single on-route fast charger is optimized, the cost per mile to operate electric transit buses decreases. If 8 buses use the same fast charger, the peak demand will not increase, but demand charges can be spread on 8 buses, achieving a cost of $0.37/mile to operate an electric transit bus, competitive with diesel and CNG buses.

Similar to the CPUC resolution granting transit agencies adopting electric transit buses no restriction on demand level for a period of three years, **we recommend considering the temporary suspension of peak demand charges for a period of up to three years.** This would encourage early deployment of electric transit buses charging on-route that may not be economically feasible with demand charges. As transit agencies purchase more electric transit buses, they could spread the demand charges associated to one fast charger over more buses and achieve a viable business case.

[57] See Section 3.3.1.

5.3.4 Optimize Deployment of Electric Transit Buses Charging On-Route

The Green Power Institute mentioned in their comments to the CPUC Order Instituting Rulemaking (OIR) R.13-11-007 that “demand charges can be prohibitively costly for site owners, particularly when [fast charger] utilization is relatively infrequent”. [58]

Since demand charges are calculated based on the maximum power demand on the grid, greater utilization of a fast charger will not increase demand charges. The results presented in Table 24 of Section 5.3.3 and Sections 3.2.1 and 3.3.1 clearly show that optimized deployments of electric transit buses charging on-route can lead to lower operating costs per bus.

Transit agencies interested in deploying electric transit buses charging on-route should be encouraged to deploy the optimum number of buses using a single fast charger in order to maximize fast charger usage and spread demand charges over more electric transit buses.

[58] CPUC. Green Power Institute and Community Environmental Council opening comments on OIR. http://delaps1.cpuc.ca.gov/CPUCProceedingLookup/f?p=401:57:1543034934426::NO. Accessed on 06-03-2014.

Chapter 6: Conclusion

This chapter summarizes the findings and potential technical & policy options developed in the report that have the potential to help support and increase the adoption of electric transit buses in the United States.

We saw that with at least 12 serious manufacturers and already several electric transit bus deployments all around the world, the electric transit bus industry is dynamic. We also saw that there are at least two different ways of recharging electric transit buses: on-route opportunity charging and overnight charging.

Peak demand charges, the charges levied by electric utilities on their commercial and industrial customers to recover their capital costs, have a significant impact on the business case of electric transit buses charging on-route and overnight. In areas where demand charges are high, fuel cost is more than doubled although it still stays below the fuel cost of a diesel-powered bus and remains competitive with a CNG-powered bus. Demand charges will have a greater impact on small pilot deployments of electric transit buses charging on-route than on small pilot deployments of electric transit buses charging overnight. However, when the number of electric transit buses using a single fast charger is optimized (6 to 8 buses per fast charger), fast charger usage can be maximized and demand charges spread over more electric transit buses. In addition, TOU rates are another form of peak demand charges. Instead of a single flat rate for energy use, TOU rates are higher when electric demand is higher. This means when you use energy is just as important as how much you use. Charging off peak when electricity prices are low can lead to significant savings. On the other hand, charging on peak when electricity prices are high can dramatically increase the fuel costs per mile of electric transit buses.

Lastly, we researched and analyzed potential options that would mitigate the impact of peak demand charges on the operation of electric transit buses charging on-route and overnight. The list below summarizes these potential technical and policy options:

- **Increasing electric bus efficiency** (use range extender, fuel-fired HVAC / APU).
- **Managing electric bus charging** (for on-route opportunity charging buses: increase the number of charging stops, use overhead power or wireless charging - for overnight charging buses: charge at lower charging power, stagger night-time charging).
- **Employing energy transfer technology** (for on-route opportunity charging buses: use battery swapping, energy storage system or auxiliary generator, manage charging with load management system - for overnight charging buses: manage charging with load management system).
- **TOU pricing option** (for on-route opportunity charging buses: use single flat rate - for overnight charging buses: use TOU pricing).
- **Energy charge / power charge pricing option** (for on-route opportunity charging buses: use higher energy charge / lower power charge option - for overnight charging buses: use lower energy charge / higher power charge option).
- **Temporary suspension of peak demand charges.**
- **Optimize deployment of electric transit buses charging on-route.**

This white paper confirms that peak demand charges are a barrier to the deployment of electric transit buses. But it also identifies several potential technical and policy options that could help mitigate the impact of peak demand charges and ultimately promote further adoption of electric transit buses in public transit agencies across the country.

Appendix A: Review of Electricity Rate by State

- **Arizona**

Table 25: Arizona Electricity Profile, 2012[59]

Primary Energy Source	**Coal**
Top Three Retailers of Electricity, 2012	1. Arizona Public Service Co 2. Salt River Project 3. Tucson Electric Power Co
Average Retail Price (cents/kWh), 2012	Residential: 11.29 Commercial: 9.53 Industrial: 6.53 Transportation: 0.00

aps	**Arizona Public Service Company** http://www.aps.com/en/ourcompany/ratesregulationsresources/serviceplaninformation/Pages/business-sheets.aspx	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**E-32 Small – Secondary / Bundled Standard**	**E-32 Medium – Secondary / Bundled Standard**
Time-of-Use Pricing	Optional	Optional
Energy Charge	Summer: $0.10337/kWh for the first 200kWh, plus $0.06257/kWh for all additional kWh Winter: $0.08718/kWh for the first 200kWh, plus $0.04638/kWh for all additional kWh	Summer: $0.09884/kWh for the first 200kWh, plus $0.06091/kWh for all additional kWh Winter: $0.08378/kWh for the first 200kWh, plus $0.04586/kWh for all additional kWh
Demand Pricing	Yes	Yes
Demand Charges	$9.828/kW for the first 100kW, plus $5.214/kW for all additional kW	$10.235/kW for the first 100kW, plus $5.385/kW for all additional kW
Electric Vehicle Pricing	No	No
Notes	- Summer: May – Oct. - Winter: Nov. – Apr. - For billing purposes, including determination of Monthly Maximum Demands, the kW used in this rate schedule shall be based on the average kW supplied during the 15-minute period of maximum use during the month as determined from readings of the Company's meter.	

SRP®	**Salt River Project** http://www.srpnet.com/prices/business/	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**General Service Price Plan (E-36)**	
Time-of-Use Pricing	Optional	
Energy Charge	Summer: $0.0989/kWh for the first 350kWh, $0.0988/kWh for the next 180kWh/kW, $0.0816/kWh for the next 155kWh per kW, $0.0597/kWh for all additional kWh Summer Peak: $0.1211/kWh for the first 350kWh, $0.1203/kWh for the next 180kWh/kW, $0.0943/kWh for the next 155kWh per kW, $0.0714/kWh for all additional kWh Winter: $0.0785/kWh for the first 350kWh, $0.0778/kWh for the next 180kWh/kW, $0.0690/kWh for the next 155kWh per kW, $0.0522/kWh for all additional kWh	
Demand Pricing	Yes	
Demand Charges	$3.33/kW (over 5kW)	
Electric Vehicle Pricing	No	
Notes	- Summer: May, June, September and October - Summer Peak: July and August - Winter: November through April - The billing demand, when applicable, is the maximum fifteen-minute integrated kW demand occurring during the billing cycle, as measured by meter.	

[59] U.S. Energy Information Agency. Arizona Electricity Profile 2012. http://www.eia.gov/electricity/state/arizona/. Accessed on 5/16/14.

TEP	Tucson Electric Power Company https://www.tep.com/customer/rates/	
	Case 1 (<100 kW)	Case 2 (>300 kW)
Reference	**Small General Service (GS-10)**	**Large General Service (LGS-13) - Secondary**
Time-of-Use Pricing	Optional	Optional
Energy Charge	Delivery Charges (first 500kWh) $0.111911/kWh Summer - $0.088332/kWh Winter Delivery Charges (all remaining kWh) $0.132711/kWh Summer - $0.110332/kWh Winter	$0.054311/kWh Summer - $0.044932/kWh Winter
Demand Pricing	No	Yes
Demand Charges	N/A	$15.25/kW
Electric Vehicle Pricing	No	No
Notes	- Summer: May – Sep. - Winter: Oct. – Apr. - The monthly billing demand shall be the greatest of the following: 1. The maximum 15 minute measured demand in the billing month; 2. 75 % of the maximum demand used for billing purposes in the preceding 11 months; or 3. The contract demand amount, not to be less than 200 kW.	

- ## California

Table 26: California Electricity Profile, 2012[60]

Primary Energy Source	Natural Gas	
Top Five Retailers of Electricity, 2012	1. Pacific Gas & Electric Co 2. Southern California Edison Co 3. Los Angeles Department of Water & Power	
Average Retail Price (cents/kWh), 2012	Residential: Commercial: Industrial: Transportation:	15.34 13.41 10.49 7.17

PG&E	Pacific Gas & Electric Company http://www.pge.com/tariffs/ERS.SHTML#ERS	
	Case 1 (<75 kW)	Case 2 (>300 kW)
Reference	**Small General Service – A1**	**Medium General Demand-Metered Service – A10**
Time-of-Use Pricing	Yes	Yes
Energy Charge	Peak Summer: $0.24756/kWh Part-Peak Summer: $0.23875/kWh Off-Peak Summer: $0.21195/kWh Part-Peak Winter: $0.16801/kWh Off-Peak Winter: $0.14881/kWh	Peak Summer: $0.17479/kWh (Secondary) Part-Peak Summer: $0.16711/kWh (Secondary) Off-Peak Summer: $0.14377/kWh (Secondary) Part-Peak Winter: $0.12798/kWh (Secondary) Off-Peak Winter: $0.10796/kWh (Secondary)
Demand Pricing	No	Yes
Demand Charges	N/A	Summer: $13.87/kW (Secondary) Winter: $6.46/kW (Secondary)
Electric Vehicle Pricing	No	No

Notes	- Does not include Peak Day Pricing Charges and Credits
	- Summer: May – Oct.
	  - Peak; noon to 6:00pm, M to F
	  - Partial Peak: 8:30am to noon and 6:00pm to 9:30pm, M to F (except holidays)
	  - Off-Peak: 9:30pm to 8:30am, M to F and All day, Sat., Sun. and holidays
	- Winter: Nov. – Apr.
	  - Partial Peak: 8:30am to 9:30pm, M to F (except holidays)
	  - Off-Peak: 9:30pm to 8:30am, M to F and All day, Sat., Sun. and holidays
	- The customer will be billed for demand according to the customer's "maximum demand" each month. The number of kW used will be recorded over 15-minute intervals; the highest 15-minute average in the month will be the customer's maximum demand.
	- If the customer's use of energy is intermittent or subject to severe fluctuations, a 5-min. interval may be used.	

[60] U.S. Energy Information Agency. California Electricity Profile 2012. http://www.eia.gov/electricity/state/california/. Accessed on 5/16/14.

	Southern California Edison Company https://www.sce.com/AboutSCE/Regulatory/tariffbooks/ratespricing/default.htm	
Reference	**General Service TOU-GS-1 / Option B**	**General Service TOU - EV Charging Demand Metered**
Time-of-Use Pricing	Yes	Yes
Energy Charge	On-Peak Summer: \$0.16259/kWh Mid-Peak Summer: \$0.07813/kWh Off-Peak Summer: \$0.05684/kWh Mid-Peak Winter: \$0.12856/kWh Off-Peak Winter: \$0.09104/kWh	On-Peak Summer: \$0.28454/kWh Mid-Peak Summer: \$0.11812/kWh Off-Peak Summer: \$0.04991/kWh On-Peak Winter: \$0.10315/kWh Mid-Peak Winter: \$0.08988/kWh Off-Peak Winter: \$0.05879/kWh
Demand Pricing	Yes	Yes
Demand Charges	Facilities Related Demand Charge: \$7.08/kW, plus Time Related Demand Charge: On-Peak Summer: \$7.76/kW Mid-Peak Summer: \$2.95/kW	\$13.00/kW
Electric Vehicle Pricing	Yes (exemption from demand limit)	Yes (special rate)
Notes	- Does not include Peak Day Pricing Charges and Credits - Summer: May – Oct. / Winter: Nov. – Apr. - On-Peak; noon to 6:00pm, M to F (except holidays) - Mid-Peak: 8:00am to noon and 6:00pm to 11:00pm, M to F (except holidays) - Off-Peak: all other hours - The Billing Demand shall be the kilowatts (kW) of Maximum Demand, determined to the nearest kW. The Demand Charge shall include the following billing components. The Time Related Component shall be for the kW of Maximum Demand recorded during (or established for) the monthly billing period for within the Summer season Time Periods. The Facilities Related Component shall be for the kW of Maximum Demand recorded during (or established for) the monthly billing period.	

	Los Angeles Department of Water & Power https://www.ladwp.com/ladwp/faces/ladwp/aboutus/a-financesandreports/a-fr-electricrates/a-fr-er-electricrateschedules?_adf.ctrl-state=1bc6c9zvqz_43&_afrLoop=55570123708270	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**Schedule A-2 – Primary Service**	
Time-of-Use Pricing	Yes	
Energy Charge	\$0.05690/kWh, plus High Peak Period: \$0.04473/kWh Low Season - \$0.05107/kWh High Season Low Peak Period: \$0.04473/kWh Low Season - \$0.04380/kWh High Season Base Period: \$0.02680/kWh Low Season - \$0.02307/kWh High Season	
Demand Pricing	Yes	
Demand Charges	Facility Charge: \$7.48/kW High Peak Period: \$4.75/kW Low Season - \$10.00/kW High Season Low Peak Period: \$0.00/kW Low Season - \$3.75/kW High Season Base Period: \$0.00/kW	
Electric Vehicle Pricing	Yes, discount at -\$0.02500 / kWh	
Notes	- High Season June – Sep. / Low Season Oct. – May - High Peak Period: 1:00 pm – 5:00pm, M through F - Low Peak Period: 10:00 am – 1:00pm, M through F, and 5:00pm – 8:00pm, M through F - Base Period: 8:00 pm – 10:00am, M through F, all day Sat. and Sun. - The Facility Charge shall be based on the highest demand recorded in the last 12 months. - The Demand Charge shall be based on the Maximum Demands recorded within the applicable Rating Periods during the billing month. - Reactive energy charge applied if demand is greater than 250 kW	

- **Colorado**

Table 27: Colorado Electricity Profile, 2012[61]

Primary Energy Source	Coal
Top Five Retailers of Electricity, 2012	1. Public Service Co of Colorado 2. City of Colorado Springs - (CO) 3. Intermountain Rural Elec Assn
Average Retail Price (cents/kWh), 2012	Residential: 11.46 Commercial: 9.39 Industrial: 6.95 Transportation: 9.69

Xcel Energy	**Public Service Company of Colorado** https://www.xcelenergy.com/About_Us/Rates_&_Regulations/Rates,_Rights_&_Service_Rules/CO_Regulatory_Rates_and_Tariffs	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**Secondary General Service - SG**	
Time-of-Use Pricing	Optional	
Energy Charge	$0.04279/kWh	
Demand Pricing	Yes	
Demand Charges	Base Demand: $8.19/kW Generation and Transmission Demand – Summer Season: $10.96/kW Generation and Transmission Demand – Winter Season: $8.00/kW	
Electric Vehicle Pricing	No	
Notes	- Summer Season June – Sep. / Winter Oct. – May - Billing demand, determined by meter measurement, shall be the maximum 15 minute integrated kilowatt demand used during the month. - The billing demand for the Generation and Transmission Demand Charge and for the Distribution Demand Charge, determined by meter measurement each month, shall be the maximum fifteen (15) minute integrated kilowatt demand used during the month. - The Distribution Demand Charge billing demand for the current month will be not less than fifty percent (50%) of the highest fifteen (15) minute measured demand occurring during the preceding eleven months.	

Colorado Springs Utilities It's how we're all connected	**Colorado Springs Utilities** https://www.csu.org/pages/rates-tariffs-r.aspx	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**Industrial Service – Time-of-Day Service 1,000kWh/Day Minimum (ETL)**	
Time-of-Use Pricing	Yes	
Energy Charge	On-Peak: $0.0517/kWh Off-Peak: $0.0231/kWh	
Demand Pricing	Yes	
Demand Charges	On-Peak: $0.6068/kW Off-Peak: $0.3944/kW	
Electric Vehicle Pricing	No	
Notes	- On-Peak: Oct. to Mar. / 4 to 10pm, M to F - On-Peak: Apr. to Sep. / 11am to 6pm, M to F - Off-Peak: all other hours plus legally-observed holidays - Maximum Demand is the greatest fifteen (15) minute load during any time in the billing period adjusted upward by one percent (1%) for each one percent (1%) that the power factor of Customer is below ninety-five percent (95%) lagging or leading. - On-Peak: The greatest fifteen (15) minute load during On-Peak hours in the billing period adjusted upward by one percent (1%) for each one percent (1%) that the power factor of Customer is below ninety-five percent (95%) lagging or leading. - Off-Peak either A or B, whichever is greater: A. The greatest fifteen (15) minute load during Off-Peak hours in the billing period adjusted upward by one percent (1%) for each one percent (1%) that the power factor of Customer is below ninety-five percent (95%) lagging or leading, minus the On-Peak billing Demand. Such demand will not be less than zero. B. Sixty-eight percent (68%) of the Maximum Demand during the last twelve (12) billing periods, minus the On-Peak Billing Demand. Such demand will not be less than zero.	

[61] U.S. Energy Information Agency. Colorado Electricity Profile 2012. http://www.eia.gov/electricity/state/colorado/. Accessed on 5/16/14.

- **Florida**

Table 28: Florida Electricity Profile, 2012[62]

Primary Energy Source	Natural Gas	
Top Five Retailers of Electricity, 2012	1. Florida Power & Light Co 2. Duke Energy Florida, Inc. 3. Tampa Electric Co	
Average Retail Price (cents/kWh), 2012	Residential: Commercial: Industrial: Transportation:	11.42 9.66 8.04 8.45

	Florida Power & Light Company http://www.fpl.com/customer/rates_and_bill/rules_tariffs.shtml	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**General Service Demand GSD-1**	
Time-of-Use Pricing	Optional	
Energy Charge	$0.05405/kWh	
Demand Pricing	Yes	
Demand Charges	$11.36/kW	
Electric Vehicle Pricing	No	
Notes	- The Demand is the kW to the nearest whole kW, as determined from the Company's thermal type meter or, at the Company's option, integrating type meter for the 30-minute period of Customer's greatest use during the month as adjusted for power factor.	

	Duke Energy Florida, Inc. http://www.duke-energy.com/rates/progress-energy-florida.asp	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**General Service – Demand GSD-1**	
Time-of-Use Pricing	Optional	
Energy Charge	$0.06884/kWh	
Demand Pricing	Yes	
Demand Charges	$10.50/kW	
Electric Vehicle Pricing	No	
Notes	- The billing demand shall be the maximum 30-minute kW demand established during the current billing period.	

	Tampa Electric Company http://www.tampaelectric.com/company/ourpowersystem/tariff/	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**General Service Demand - GSD**	
Time-of-Use Pricing	Optional	
Energy Charge	Standard: $0.07635/kWh – Optional: $0.10816/kWh	
Demand Pricing	Yes	
Demand Charges	Standard: $9.76/kW – Optional: $0.00/kW	
Electric Vehicle Pricing	No	
Notes	- The customer may select either standard or optional. - The billing demand is the highest measured 30-minute interval kW demand during the billing period.	

[62] U.S. Energy Information Agency. Florida Electricity Profile 2012. http://www.eia.gov/electricity/state/florida/. Accessed on 5/16/14.

- **Georgia**

Table 29: Georgia Electricity Profile, 2012[63]

Primary Energy Source	Natural Gas
Top Five Retailers of Electricity, 2012	1. Georgia Power Co 2. Jackson Electric Member Corp – (GA) 3. Cobb Electric Membership Corp
Average Retail Price (cents/kWh), 2012	Residential: 11.17 Commercial: 9.58 Industrial: 5.98 Transportation: 7.65

	Georgia Power Company http://www.georgiapower.com/pricing/
Reference	**Electric Transportation Service Schedule – ET-15**
Time-of-Use Pricing	Yes
Energy Charge	June-Sep., Mon to Fri, 5am to Noon: $0.040039/kWh June-Sep., Mon to Fri, 8pm to 1am: $0. 040039/kWh June-Sep., Mon to Fri, Noon to 8pm: $0.079086/kWh Jan.-Dec., Mon to Sun, 1am to 5am: $0.00000/kWh Jan.-Dec., Sat to Sun, 5am to 1am: $0.017731/kWh Oct.-May, Mon to Fri, 5am to 1am: $0.037282/kWh Fuel Cost Recovery: $0.03923/kWh from June through September, $0.032584/kWh from October through May
Demand Pricing	No
Demand Charges	N/A
Electric Vehicle Pricing	Yes (specific rate)

	Jackson Electric Member Corporation http://www.jacksonemc.com/ **Case 1 (<100 kW)** / **Case 2 (>300 kW)**
Reference	**Schedule GS-14 / General Service**
Time-of-Use Pricing	Optional
Energy Charge	First 15000kWh per month @ $0.1215/kWh Next 185000kWh per month @ $0.0967/kWh Over 200000kWh per month @ $0.0834/kWh All consumption (kWh) in excess of 200 hours and not greater than 400 hours times the billing demand @ $0.0429/kWh All consumption (kWh) in excess of 400 hours and not greater than 600 hours times the billing demand @ $0.0323/kWh All consumption (kWh) in excess of 600 hours times the billing demand @ $0.0301/kWh
Demand Pricing	Indirect
Demand Charges	N/A
Electric Vehicle Pricing	No
Notes	- The minimum bill shall be the greater of $7.50 per kW of (a) the highest demand measured during the billing months June through September or (b) 65% of the highest demand measured during the billing months October through May. - **Determination of Billing Demand:** By measurement of the highest 30-min. kW demand during the current month and the preceding eleven (11) months. For the billing months June through September, the Billing Demand shall be the greatest of: 1. The current actual demand, or 2. Ninety percent (90%) of the highest actual demand occurring in any previous applicable summer month, or 3. Sixty-five percent (65%) of the highest actual demand occurring in any previous applicable winter month (October-May). For the billing months of October through May, the Billing Demand shall be the greater of: 1. Ninety percent (90%) of the highest summer month (June- September), or 2. Sixty-five percent (65%) of the highest winter month (including the current month).

[63] U.S. Energy Information Agency. Georgia Electricity Profile 2012. http://www.eia.gov/electricity/state/georgia/. Accessed on 5/16/14.

COBB EMC	Cobb Electric Member Corporation http://www.cobbemc.com/	
	Case 1 (<100 kW)	Case 2 (>300 kW)
Reference	**Large General Service Schedule / CS-14A Rate 40**	
Time-of-Use Pricing	No	
Energy Charge	First 10000kWh @ $0.1417/kWh Next 190000kWh @ $0.1171/kWh Over 200000kWh @ $0.0875/kWh All consumption in excess of 200kWh per kW of demand, which is also in excess of 1000kWh @ $0.0650/kWh All consumption in excess of 400kWh per kW of demand, which is also in excess of 2000kWh @ $0.0494/kWh	
Demand Pricing	No	
Demand Charges	Indirect	
Electric Vehicle Pricing	No	

Notes	- The minimum bill shall be the greater of:
	  - $21.00 per meter plus $6.65/kW of demand plus Wholesale Power Adjustment
	  - Contract minimum, plus Wholesale Power Adjustment
	- **Determination of Billing Demand:** The Demand shall be based on the highest 30-minute kW measurement during the current month and the preceding eleven (11) months. For the billing period of June 20 through October 20, the kW demand shall be the greater of:
	1. The current actual demand or, 2. 90 percent of the highest demand occurring in any previous applicable summer month or, 3. 65 percent of the highest demand occurring in any previous applicable winter month (October 21 through June 19)
	For the billing period of October 21 through June 19, the kW demand shall be the greater of: 1. 90 percent of the highest summer month (June 20 through October 20) or, 2. 65 percent of the highest winter month (including the current month) In no case shall the demand be less than the contract minimum.	

- ## Illinois

Table 30: Illinois Electricity Profile, 2012[64]

Primary Energy Source	Nuclear
Top Five Retailers of Electricity, 2012	1. Commonwealth Edison Co 2. Constellation New Energy, Inc. 3. Ameren Illinois Company
Average Retail Price (cents/kWh), 2012	Residential: 11.38 Commercial: 7.99 Industrial: 5.80 Transportation: 6.15

ComEd. An Exelon Company	Commonwealth Edison Company https://www.comed.com/customer-service/rates-pricing/rates-information/pages/current-rates.aspx	
	Case 1 (<100 kW)	Case 2 (>300 kW)
Reference	**Small Load / Retail Delivery Service**	**Medium Load / Retail Delivery Service**
Time-of-Use Pricing	Optional	Optional
Energy Charge	$0.0393/kWh	$0.0393/kWh
Demand Pricing	Yes	Yes
Demand Charges	$5.72/kW	$5.89/kW
Electric Vehicle Pricing	No	No

[64] U.S. Energy Information Agency. Illinois Electricity Profile 2012. http://www.eia.gov/electricity/state/illinois/. Accessed on 5/16/14.

Ameren Illinois Utilities	Ameren Illinois Company https://www.ameren.com/sites/aiu/Rates/Pages/NonResidentialRates.aspx	
	Case 1 (<100 kW)	Case 2 (>300 kW)
Reference	**DS-2 Small General Delivery Service**	**DS-3 General Delivery Service**
Time-of-Use Pricing	Optional	Optional
Energy Charge	Summer: $0.08701/kWh Non-summer, first 2000kWh: $0.07016/kWh Non-summer, over 2000kWh: $0.06281/kWh	Summer: $0.03599/kWh Non-summer: $0.04144/kWh
Demand Pricing	No	Yes
Demand Charges	N/A	$3.95/kW
Electric Vehicle Pricing	No	No

MidAmerican Energy	MidAmerican Energy Company http://www.midamericanenergy.com/rates1.aspx	
	Case 1 (<100 kW)	Case 2 (>300 kW)
Reference	**Rate No. 42 Commercial and Industrial Service**	
Time-of-Use Pricing	Yes	
Energy Charge	For the first 300 hours' use per month of the kilowatt billing demand applicable for the month: Jun thru Sep: First 6000kWh: $0.0503/kWh All over 6000kWh: $0.0399/kWh Oct thru May: First 6000kWh: $0.0442/kWh All over 6000kWh: $0.0338/kWh For the excess over 300 hours' use per month of the kilowatt billing demand applicable for the month: $0.0269/kWh Energy Efficiency Cost Recovery Adjustment: $0.00315/kWh	
Demand Pricing	Yes	
Demand Charges	Jun thru Sep: First 300kW: $8.91/kWh All over 300kW: $8.21/kWh Oct thru May: First 300kW: $6.14/kWh All over 300kW: $5.44/kWh	
Electric Vehicle Pricing	No	

- ## New York

Table 31: New York Electricity Profile, 2012[65]

Primary Energy Source	Natural Gas
Top Five Retailers of Electricity, 2012	1. Consolidated Edison Co-NY, Inc. 2. Long Island Power Authority 3. New York Power Authority
Average Retail Price (cents/kWh), 2012	Residential: 17.62 Commercial: 15.06 Industrial: 6.70 Transportation: 14.20

conEdison	Consolidated Edison Co-NY, Inc. http://www.coned.com/rates/	
	Case 1 (<100 kW)	Case 2 (>300 kW)
Reference	**SC 09 General - Large**	
Time-of-Use Pricing	Optional	
Energy Charge	Low Tension Service: $0.04846/kWh	
Demand Pricing	Yes	
Demand Charges	Low Tension Service: $22.15/kW over 5kW in June, July, August and September Low Tension Service: $17.55/kW over 5kW all other months	
Electric Vehicle Pricing	No	

[65] U.S. Energy Information Agency. New York Electricity Profile 2012. http://www.eia.gov/electricity/state/newyork/. Accessed on 5/16/14.

LIPA Long Island Power Authority	Long Island Power Authority http://www.lipower.org/papers/tariff.html	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**General Service - Large**	**Large General & Industrial Service with Multiple Rate Periods (Secondary 285)**
Time-of-Use Pricing	Optional	Yes
Energy Charge	Jun. to Sep.: $0.16648/kWh Oct. to May.: $0.15158/kWh	Off-Peak (all year, midnight to 7am) $0.13638/kWh On-Peak (Jun-Sep, except Sundays 10am to 10pm) $0.16118/kWh Intermediate (all other hours) $0.15048/kWh
Demand Pricing	Yes	Yes
Demand Charges	Jun. to Sep.: $10.84/kW Oct. to May.: $9.63/kW	Off-Peak (all year, midnight to 7am) Demand Charge: none On-Peak (Jun-Sep, except Sundays 10am to 10pm) Demand Charge: $22.09/kW Intermediate (all other hours) Demand Charge: $5.26/kW
Electric Vehicle Pricing	No	No
Notes	How Demand is Determined a) The Authority will furnish and maintain a demand meter of standard type to determine the demand. The demand is the maximum 15-minute integrated demand during the month, taken to the nearest one-half (1/2) kilowatt. b) For billing purposes, the Authority will establish the monthly demand for the period ending on the date the meter is read or estimated, and it will be the greater of: (1) The recorded demand, or (2) 85% of the maximum recorded demand for the summer months (June through September) during the last eleven (11) months or (3) 70% of the maximum recorded demand for the winter months (October through May) during the last eleven (11) months. c) Only the recorded demand will apply to Customer-generators eligible for net billing.	

New York Power Authority	New York Power Authority http://www.nypa.gov/trustees/2011%20minutes/June/5-Govt%20Cust%20Rate%20Structure%20Redesign%20-%20Exhibit%20A.pdf.	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**Transit Substation No. 85**	
Time-of-Use Pricing	No	
Energy Charge	Summer (Jun. to Sep.): $0.08050/kWh Winter (Oct. to May): $0.07006/kWh	
Demand Pricing	Yes	
Demand Charges	Production: $7.39/kW + Delivery: $16.26/kW (low tension)	
Electric Vehicle Pricing	No	

- **Oregon**

Table 32: Oregon Electricity Profile, 2012[66]

Primary Energy Source	Hydroelectric
Top Five Retailers of Electricity, 2012	1. Portland General Electric Co 2. PacifiCorp 3. City of Eugene – (OR)
Average Retail Price (cents/kWh), 2012	Residential: 9.80 Commercial: 8.31 Industrial: 5.59 Transportation: 8.24

PGE	Portland General Electric Company http://www.portlandgeneral.com/our_company/corporate_info/regulatory_documents/tariff/rate_schedules.aspx	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**Large Nonresidential Optional Time-of-Day Standard Service – Schedule 38**	
Time-of-Use Pricing	Yes	
Energy Charge	On Peak: Mon to Fri, 7am to 8pm: $0.06383/kWh Off Peak: Mon to Fri, 8pm to 7am, Sat and Sun: $0.05383/kWh Transmission Charge: $0.00237/kWh Distribution Charge: $0.06078/kWh	
Demand Pricing	No	
Demand Charges	N/A	
Electric Vehicle Pricing	Yes (specific rate)	
Notes	A large Nonresidential Customer wishing to charge EV's may do so either as part of an integrated service or as a separately metered service billed under the TOU Option. In such cases, the applicable Basic, Transmission and Related Services, and Distribution charges will apply to the separately metered service as will all other adjustments applied to this schedule. If the Customer chooses separately metered service for EV charging, the service shall be used for the sole and exclusive purpose of all EV charging. The Customer, at its expense, will install all necessary and required equipment to accommodate the second metered service at the premises. Such service must be metered with a network meter as defined in Rule B (30) for the purpose of load research, and to collect and analyze data to characterize electric vehicle use in diverse geographic dynamics and evaluate the effectiveness of the charging station infrastructure.	

PACIFICORP A MIDAMERICAN ENERGY HOLDINGS COMPANY	PacifiCorp https://www.pacificpower.net/rates	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**General Service Large Nonresidential Delivery Service – Schedule 28**	**General Service Large Nonresidential Delivery Service – Schedule 30**
Time-of-Use Pricing	No	No
Energy Charge	Base Supply Service Charge: First 20,000kWh: $0.0381/kWh All Additional kWh: $0.02999/kWh Low Income Bill Payment Assistance Fund: $.0005/kWh J.C. Boyle Dam Surcharge: $0.00036/kWh Copco 1 and 2, Iron Gate Dams Surcharge: $0.00107/kWh Solar Incentive Program Adjustment: $0.00027/kWh Energy Conservation Charge: $0.00217/kwh Rate Mitigation Adjustment: $0.00113/kWh Distribution Energy Charge: $.00393/kWh System Usage Charge: $0.0075/kWh	Base Supply Service Charge: First 20,000kWh: $0.02667/kWh All Additional kWh: $0.02313/kWh Low Income Bill Payment Assistance Fund: $.0005/kWh J.C. Boyle Dam Surcharge: $0.00035/kWh Copco 1 and 2, Iron Gate Dams Surcharge: $0.00105/kWh Solar Incentive Program Adjustment: $0.00025/kWh Energy Conservation Charge: $0.00201/kwh Rate Mitigation Adjustment: $0.00039/kWh System Usage Charge: $.0067/kWh
Demand Pricing	Yes	Yes
Demand Charges	Load Size Charge: ≤ 50kW: $1.15/kW 51 – 100kW: $0.90/kW 101 – 300kW: $0.55/kW > 300kW: $0.35/kW Demand Charge: $3.88/kW	Base Supply Service Demand Charge: $1.75/kW Load Size Charge: 201 – 300kW: $1.65/kW > 300kW: $0.80/kW Demand Charge: $3.98/kW

[66] U.S. Energy Information Agency. Oregon Electricity Profile 2012. http://www.eia.gov/electricity/state/oregon/. Accessed on 5/16/14.

	Transmission & Ancillary Services Charge: $1.49/kW	Transmission & Ancillary Services Charge: $1.71/kW
Electric Vehicle Pricing	No	No
Notes	kW Load Size: The kW Load Size shall be the average of the two greatest non-zero monthly demands established during the 12-month period which includes and ends with the current billing month.	

	Eugene Water & Electric Board http://www.eweb.org/electricrates	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**Medium General Service – Schedule G-2 (31kW – 500kW)**	
Time-of-Use Pricing	No	
Energy Charge	$0.06084/kWh	
Demand Pricing	Yes	
Demand Charges	$7.25/kW	
Electric Vehicle Pricing	No	
Notes	Power Cost Recovery Adjustment: At the discretion of the Board, the rates may be adjusted for 12 months to reflect the variance between budgeted and actual power cost for the previous calendar year. BPA Power Cost Recovery Adjustment: Electric rates may be automatically adjusted for up to 12 months to reflect a future variance in projected power costs due to changes in Bonneville Power Administration (BPA) wholesale rates. These adjustments are determined by dividing the amount to be rebated or recovered by the projected kilowatt-hour sales for the appropriate period and then decreasing or increasing the energy or power component of the rate accordingly.	

- ## Texas

Table 33: Texas Electricity Profile, 2012[67]

Primary Energy Source	Natural Gas
Top Five Retailers of Electricity, 2012	1. Reliant Energy Retail Services 2. TXU Energy Retail Co LP 3. City of San Antonio – (TX)
Average Retail Price (cents/kWh), 2012	Residential: 10.98 Commercial: 8.16 Industrial: 5.57 Transportation: 10.54

	CPS Energy (City of San Antonio) http://www.cpsenergy.com/Commercial/Billing_Payments/Rates/index.asp	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**Commercial General Service Electric Rate**	
Time-of-Use Pricing	No	
Energy Charge	Fuel/Regulatory Adjustment Factor: $0.02393/kWh $0.0719/kWh for the first 1600 kWh* (200kWh are added for each kW of Billing Demand in excess of 5kW) $0.0332/kWh for all additional kWh Peak Capacity Charge: Summer (Jun. to Sep.) $0.0198/kWh per kWh for all kWh in excess of 600kWh Non-Summer Billing (Oct. to May.) $0.0100/kWh per kWh for all kWh in excess of 600kWh	
Demand Pricing	No	
Demand Charges	N/A	
Electric Vehicle Pricing	No	
Notes	- Minimum Bill: $8.75 plus $4.00 per KW of Billing Demand in excess of 5 KW. - The Demand will be the KW as determined from the reading of the CPS Energy demand meter for the 15 minute period of the Customer's greatest Demand reading during the month.	

[67] U.S. Energy Information Agency. Texas Electricity Profile 2012. http://www.eia.gov/electricity/state/texas/. Accessed on 5/16/14.

- **Washington**

Table 34: Washington Electricity Profile, 2012[68]

Primary Energy Source	Hydroelectric	
Top Five Retailers of Electricity, 2012	1. Puget Sound Energy, Inc 2. City of Seattle – (WA) 3. Bonneville Power Administration	
Average Retail Price (cents/kWh), 2012	Residential: Commercial: Industrial: Transportation:	8.53 7.68 4.13 8.06

PUGET SOUND ENERGY	Puget Sound Energy, Inc. https://pse.com/aboutpse/Rates/Pages/Electric-Rate-Schedules.aspx?Schedule_x0020_Type=Rate%20and%20Adjusting%20Schedules	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**Small Demand General Service – Schedule 25 (50kW – 350kW)**	**Small Demand General Service – Schedule 26 (> 350kW)**
Time-of-Use Pricing	Yes	Yes
Energy Charge	Oct to Mar: $0.098263/kWh for the first 20,000kWh $0.072349/kWh for all over 20,000kWh Apr to Sep: $0.089976kWh for the first 20,000kWh $0.071358kWh for all over 20,000kWh	$0.064033/kWh
Demand Pricing	Yes for load > 50kW	Yes
Demand Charges	Oct to Mar: $9.02/kW Apr to Sep: $6.02/kW	Oct to Mar: $12.14/kW Apr to Sep: $8.09/kW
Electric Vehicle Pricing	No	No

Seattle City Light	Seattle City Lights http://www.seattle.gov/light/rates/	
	Case 1 (<100 kW)	**Case 2 (>300 kW)**
Reference	**Medium Standard General Service – City (50kW – 1000kW)**	
Time-of-Use Pricing	No	
Energy Charge	$0.0606/kWh	
Demand Pricing	Yes	
Demand Charges	$2.42/kw	
Electric Vehicle Pricing	No	

[68] U.S. Energy Information Agency. Washington Electricity Profile 2012. http://www.eia.gov/electricity/state/washington/. Accessed on 5/16/14.