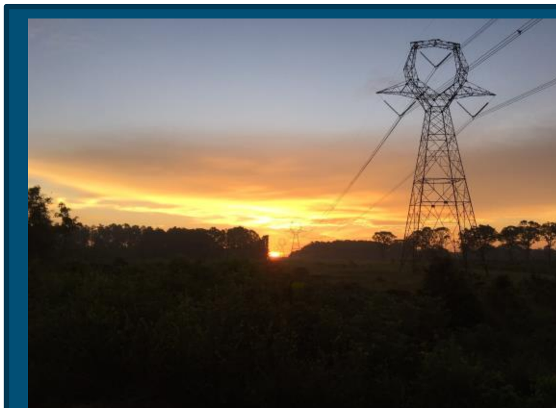
Energy Storage, Electric Vehicles & EV Charging



21st Century Strategic Direction

Comprehensive Study and Key Considerations

NC CLEAN ENERGY TECHNOLOGY CENTER

March 31, 2020

PWC Fayetteville's HOMETOWN UTILITY

Prepared For

Fayetteville PWC Officers and Commissioners

Prepared By

Fayetteville PWC Development & Marketing

NC Clean Energy Technology Center, NCSU

The following individuals provided research and/or contributed content to this document:

Fayetteville Public Works Commission, Development & Marketing

Kathy Miller, Marketing Manager
Maureen O'Connor, Market Planning Specialist
Josie Titus, Customer Programs Analyst
Janelle Rockett, Key Accounts Agent
Kimberly Rodriguez, Key Accounts Agent

North Carolina Clean Energy Technology Center, NCSU

Heather Brutz, Clean Transportation Finance and Operations Manager
Kimberly Conley, Project Manager
Qinling Li, Duke University, Master's Environmental Management '19
Isaac Panzarella, P.E., Assistant Director for Technical Services
Autumn Proudlove, Senior Manager of Policy Research
Danny Sodano, NC State University, Student, Master's Environmental Engineering '20
Ted Spencer, Senior Extension Specialist
Alexander Yoshizumi, NC State University, Student, Ph.D. Geospatial Analytics '22

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Executive Summary

Process

In the preparation of this document, Fayetteville Public Works Commission (PWC) Development & Marketing created an open and inclusive process to engage community stakeholders and industry experts. Participants included subject matter experts from Sustainable Sandhills, local car dealerships, North Carolina Auto Dealers Association (NCADA), ElectriCities of North Carolina, Plug-In NC, energy storage vendors, community leaders, internal authorities, and customers. The North Carolina Clean Energy Technology Center (NCCETC) assisted with written content and research. Research from the NC Clean Energy Plan, NC ZEV Plan, and Motor Fleet ZEV Plan completed in October 2019 as directed by NC Executive Order No. 80 and Energy Storage Options for North Carolina completed November 2018 tasked under House Bill 589 were used as technical references. American Public Power Association (APPA) Electric Vehicle Blueprint for Your Community Public Power Strategies produced 2018, APPA Behind-the-Meter Energy Storage produced 2019, and APPA Getting Involved in Fleet Electrification produced November 2019 provided examples of factors, programs, and resources to consider.

Current Situation

PWC understands the value of storage technology and has led the way with the recent installation of the first municipally owned solar/battery storage site in North Carolina. While solar doesn't operate at its peak capacity during coincident peak (CP) hours, an effectively managed battery can provide CP capacity at its rated nameplate capacity. To date, the PWC output summary from the 1 MW_{AC} solar/ 500kW_{AC} battery site is as follows:

Butler Warner Generation Plant Community Solar & Battery Storage

Month	Panel kWh	Panel CP kW	Battery kWh	Battery CP kW	CP Day/Hr.	
Sep-19	120,913	440	-2,849	-4	9/12 @1700	*Battery controls not complete*
Oct-19	122,810	584	-1,208	-6	10/3 @1600	*Battery controls not complete*
Nov-19	108,053	1	-2,980	248	11/14@0700	*260 kW module inoperable*
Dec-19	92,399	11	-3,752	480	12/20 @0800	
Jan-20	101,157	12	-3,954	499	1/22@0800	
Feb-20	111,324	58	-3,965	499	2/22@0800	

Adding storage capacity to the PWC distribution grid makes economic sense; however, PWC is bound by a full-requirements Power Supply and Coordination Agreement (PSA) with Duke Energy Progress (DEP). The current PSA allows PWC to install, own and operate up to 2 megawatts (MW) battery storage together with a solar facility to store and discharge the solar energy.

Energy storage ownership benefits not only PWC but also customers when rates are designed to reflect the hourly and seasonal variability of the cost of electric service. Pricing that reflects actual cost variability encourages customers to efficiently time their electricity use. DEP's PSA does not limit PWC's ability to design rates that send a price signal to encourage customer response, nor does it limit demand response activities; yet, it does limit signaling a customer and it appears to limit a customer's ability to export to the grid. Commercial and industrial customers who value renewable procurement, heightened reliability with back-up generation, electrification of fleet services, and demand response storage systems could take advantage of tariff offerings to meet their needs and/or environmental goals. Residential customers who desire a plug-in electric vehicle (EV) or want to pair their rooftop solar with battery storage may also see advantages from rates that reflect the variable cost of energy. Variable rates can offer benefit to individual customers without requiring subsidization from non-participating customers, if correctly structured.

Across the state, utility-scale energy storage development is expected to rise quickly. Since 2011, investor owned, municipal and cooperative utilities in NC have installed 2,287 kW of battery storage capacity. The 2018 latest Integrated Resource Plans (IRPs) filed by NC investor owned utilities (IOUs) indicated that the capacity of IOU operated energy storage is planned to increase from the current level of 1 MW to 246 MW by 2025 (NCDEQ 2019). Likewise, state-wide EV sales are expected to exceed 80,000 electric and hybrid vehicles in the next five years.

In contrast to these trends, there has been little interest in behind-the-meter (BTM) energy storage or EVs in this service territory despite the rate variability offered by our current retail time-of-use and coincident peak rates. Some of the larger industrial customers are considering peak shaving Tier IV compliant diesel generation assets but have not approached PWC about energy storage options. According to local area auto dealers, the penetration of EVs in this area is extremely low. In Fayetteville, the sale of plug-in EVs and hybrid EVs is less than 1%, leading dealers to omit electric options from their lots. According to Jay Wyatt, Chairman of the North Carolina Auto Dealers Association and owner of Valley Auto World, Fayetteville, "customer preference in Fayetteville/ Cumberland County is typically high-performance vehicles and trucks."

Drivers of Transformation

There are drivers of transformation for both EVs and energy storage adoption that are largely supported by NC legislative policy, the evolution of NC electric utilities, and future EV and battery storage manufacturing output increases and cost reductions. These drivers are expected to significantly influence customer adoption in the coming years. Environmental concerns also continue to spur momentum behind EV and energy storage adoption. Governor Cooper's Executive Order 80: North Carolina's Commitment to Address Climate Change and Transition to a Clean Energy Economy directed North Carolina to execute a Clean Energy Plan, Zero Emissions Plan, and Motor Fleet ZEV Plan published October 2019. The NC Policy Collaboratory was also tasked with conducting a study to evaluate energy storage in North Carolina, *Energy Storage Options for North Carolina 2018*. The report outlines a variety of recommended approaches and tactics available to State policy makers as a starting point for further development of a statewide coordinated energy storage policy. Without endorsing any policy changes, the North Carolina Utilities Commission (NCUC) agreed with the report that there is a need to prepare for increased storage deployment; therefore, they are conducting a series of educational presentations from experts on various discrete energy storage-related topics in order to provide informed policy endorsement.

The car industry is also undergoing transformation, with most every automaker planning to introduce more EVs. Established car manufacturers like Volkswagen, Ford, and Volvo intend to have an electric or hybrid version of every vehicle in their lineup in the near future. Incentives, laws, and regulations related to EVs and EV charging in North Carolina designed to advance EV adoption are beginning to emerge.

Key Considerations for Strategic Direction

Facilitating the ownership of energy storage and EVs meets PWC's strategic plan. It is our vision to be a leader in sustainability and to be a valued community partner. It is our mission to provide information to our customers and to help them make informed choices. It is our goal to provide the lowest responsible rates and the most reliable service. Recent analysis in the *Energy Storage Options for North Carolina 2018* by a team of experts from North Carolina State University, the NCCETC, and North Carolina Central University indicated that batteries have the most potential for exponential growth over the next decade. It is the appropriate time to consider options to facilitate BTM opportunities, including commercial charging stations, battery storage (both solar connected and stand-alone), EV charging, and thermal storage. Advanced metering, intelligently managed storage resources and distributed generation combined, create a vision of a community where response to peak demand can lower the cost of electric service. Developing a comprehensive road-map to include energy storage, EV acceleration and EV charging as part of our strategic plan, as allowed by the DEP PSA, will require us to (1) understand the benefits of various storage and charging solutions, (2) be aware of current market trends, (3) be aware of the impact of legislative policy and restrictions/allowances afforded by the DEP PSA, (4) understand how both storage and charging can impact revenue, (5) evaluate responsive pricing structures and incentive programs that are economically viable and encourage customer participation, and (6) assess impact to the grid.

Thermal Storage and Battery Storage Key Considerations

There are two specific categories of BTM storage addressed in this study, thermal and battery. Thermal storage solutions such as ice and hot water have fewer participation barriers than do battery storage because of the nature of the technology, allowing customers to chill or heat water when rates are lower and use it onsite when electricity rates are higher. Thermal storage is generally incorporated into existing mechanical systems. Battery storage, charged during off-peak hours on a lower rate, can provide similar grid curtailment and can also be used to dispatch power to the grid, if permitted. Currently, PWC electric customers who are on a large power coincident peak (CP) rate or TOU rate can take advantage of storage opportunities to reduce electric consumption during more costly billing hours. Starting in January 2021, medium power electric customers, with demand in excess of 200 kW, who elect to be on a medium power CP rate can also benefit from these technologies.

Consider Demand Response Philosophy for Thermal Storage

Demand response (DR) programs can offer considerable benefit to the customer as well as the utility. There are varying philosophies or approaches on how this can and should be achieved. These include:

- Change electric usage by end-use customer from normal consumption patterns in response to changes in the price of electricity over time.

- Change electric usage through direct load control compensated by incentive payments or rebates.
- A combination of both customer and utility control.

There are advantages and disadvantages to be considered. For instance, if a customer has a wi-fi enabled water heater that they control, they may control water heating during on-peak hours, as well as night-time hours, thereby reducing overall electrical consumption in addition to managing the peak. However, direct load control switches which are used to curtail load prevent the customer from making changes to the utility-controlled peak event and limit curtailment to anticipated coincident peak hours only, thereby reducing the potential for lost revenue. This type of control device requires administration by the utility and is typically tied to an incentive payment. In contrast, ice storage may reduce kilowatt hours (kWh) by allowing the customer to install a smaller chiller to help meet customer peaks, as well as curtail load during the CP hour. This type of technology is most often controlled by the end-user.

At what level can PWC engage directly with devices/control systems to conduct DR response? If we can aggregate residential water heaters to limit heating during an event hour, can we also control ice storage to provide cooling from a thermal storage system during peak hours? What is PWC's DR philosophy – do we want to leave it in the hands of the customer and provide TOU and CP rates to elicit response or do we want utility control that limits revenue erosion derived from more conservative customer control? Should we incentivize a hybrid approach that allows customer control in addition to utility control to best manage capacity and voltage reduction? Should PWC diversify the DR program offerings, assuming not one approach suits all, and flexibility encourages participation?

Policy Regarding Charging to the Grid and/or Net Metering for Solar + Battery Storage

The DEP PSA does not allow discharge of non-PURPA (Public Utility Regulatory Policies Act of 1978) qualified facilities to the grid. The current buy-all sell-all rate and interconnection procedures do not address interconnection of battery storage to a solar array. However, from our procedures we can derive that all power produced by the array should be metered separately and exported to the grid at the wholesale cost and the battery storage should be powered from the grid to charge the home during peak hours. Because the savings value would only be the difference between the peak and off-peak rate, this technology is not currently economically viable for customers on a PWC TOU rate.

- Consider amending the current interconnection procedures to address the potential for solar/battery interconnection and manage the charge and discharge of batteries when installed with a solar array, or
- Consider a rate structure and interconnection procedures to allow net-metering and charge of the battery storage from the solar array, with discharge of excess solar production to the grid through a bi-directional meter. Many states are establishing an expedited interconnection process for storage systems with only "inadvertent export."
- It is important to note; a customer could install a solar array plus battery storage tied directly to a house with a non-export relay device. This could go undetected and the customer would benefit from the value of kilowatt hour reduction at the full retail rate. Since some of the fixed cost of providing service to a customer is embedded in the kWh charge, other customers would be subsidizing the cost of service to the solar/battery customer.

Energy Storage Incentives and Rates

- Battery storage and thermal storage are most often driven by rate variability and/or incentive programs. Utilities that do not have variable rate offerings incentivize load control which they often manage through a third-party aggregator to support capacity and voltage reduction. DR philosophy dictates rate design and incentive offerings. Do both incented programs and variable rates have a place in our DR program?

Education and Communication

- What level of education and awareness do we want to provide to customers?
- As we begin moving our medium power customers to a variable rate and introduce a medium power CP rate, it will become necessary to educate our customers on available DR solutions; to become their trusted advisor. This requires a level of education on our part.
- Some of these customers are considered Key Accounts and will be supported through the Key Accounts Program. Would PWC include additionally identified customers as another tier of our Key Accounts Program? Would PWC expand the Key Accounts staff to support these additional customers?

Electric Vehicles and EV Charging Key Considerations

Electrification

U.S. Energy Information Administration (EIA) 2019 Annual Energy Outlook predicts a 22% decrease in annual delivered energy use per household from 2018 to 2050 (Partain 2019). As appliances, lighting, and HVAC systems become more efficient and customers embrace technology that give them more control of their home's energy use, the demand for electricity will decline. Conversely, there is potential for growth through increased electrification.

- Consider the value electrification provides to PWC and the community.
  - Reduces greenhouse gas emissions by increasing use in off-peak electricity supplied by a larger composite of clean energy sources.
  - Improves system load thereby improves marginal revenue. Pasi Miettinen, Sagewell's CEO, stated that operating leverage in the electric utility business is so significant that the marginal profitability of extra kilowatt-hours sold in the off-peak hours has huge impacts.
- Does the promotion of electrification meet our strategic objectives?
- If so, does PWC promote and support EV adoption?

Policy Regarding Customer Installation of Level 2 and Direct Current Fast Charger (DCFC) Stations

- Consider separate metering for Level 2 and/or DCFC stations to meet potential future rate application.
- Consider the impact of multiple commercial Level 2 chargers installed at the same location. Should PWC establish a power share demand ceiling for grouped chargers or DC fast chargers?

Policy Regarding Discharging to the Grid

- Consider policy to manage discharge of batteries. The DEP power supply agreement does not allow discharge to the grid. There are some emerging car/bus battery technologies that will allow discharge for demand response.

EV Incentives

- Consider bill credit or incentive to residential customers installing or those who have installed Level 2 chargers so that it is known where they are installed. PWC can utilize load profile analysis to provide information and insights into consumer charging patterns.
- Consider offering an incentive to current commercial customers with a Level 2 ChargePoint to acquire the ChargePoint data for load/use analysis.
- Should PWC plan or pilot managed charging programs, passive and or active and integrate with DR efforts? Passive programs include EV time-varying rates, communication to solicit voluntary response, and incentive programs rewarding off-peak charging. Active programs include direct load control via the charging device, direct load control via automakers telematics, and direct load control via a smart circuit breaker or panel.

EV Rates

- Should PWC offer a super TOU or CP rate for customers with EVs? PWC could utilize the rate to identify EV customers and study load profiles/charging habits while simultaneously encouraging off-peak charging.
- Should a rate for residential customers owning EVs be more reflective of the cost of service or should it be structured to incent customers to charge off-peak while allowing some share in the increase in contribution margin among residential rate payers? Argument for sharing the increase in contribution margin among all residential customers would be the shared cost of supplying charging equipment, promotion, education, etc.
- What type of rate structure/load control should be established for public charging to support EV adoption, yet manage system peaks? Do we establish a per minute or per kWh cost?
- Consider a rate for the transit authority and other heavy-duty electric fleet operators that requires active management of smart chargers to manage coincident peak charging.

PWC Public Charging Stations

- Should PWC consider installing additional charging stations as is DEP and the NC Electric Membership Cooperative (NCEMC)?
- Should PWC consider incenting home charger installations to accelerate local EV growth? Over 80% of the time, EV drivers charge their EVs at home.
- At what point should PWC charge customers for the electricity on existing and future public charging stations?
- Should PWC manage potential peak hours on PWC owned stations? ChargePoint can help manage usage, including limiting power of each charger on a routine schedule or for individual events, delaying charging based on TOU structure, charging variable rates based on time of use, and charging a premium for lane occupancy without charge (parking fee).

Education and Communication

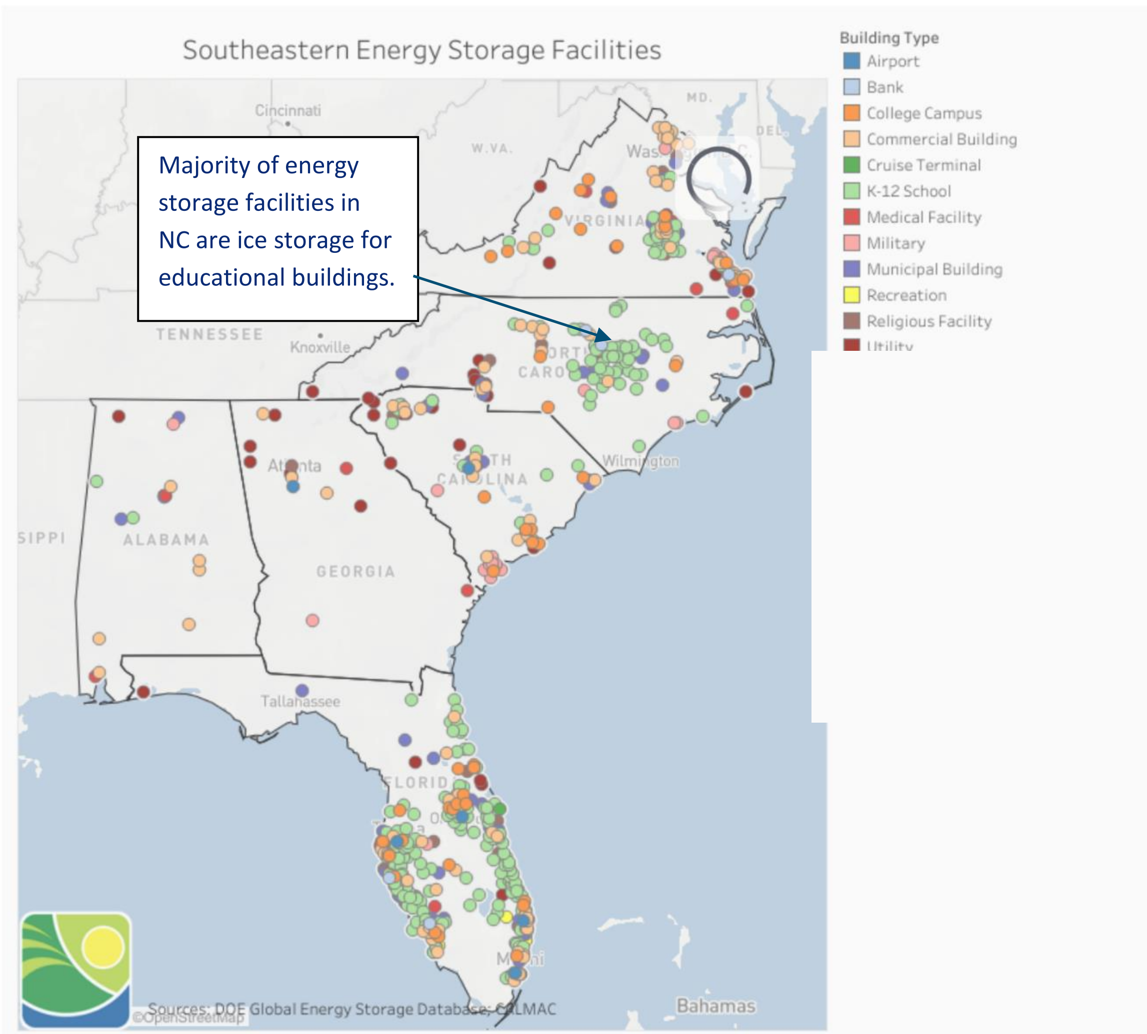
- What level of education and awareness do we want to provide to customers?
- Should PWC consider using a third party for website integration such as PlugShare or Plug-in NC? Do we want to partner with Advanced Energy for branded educational materials or Sagwell for Strategy Plan (Appendix 11: Education and Marketing EVs)?
- Consider including an eGallon calculator on the website to provide cost information to EV owners and potential owners? A calculator could be developed to reflect various charging methods/pricing.

The following Detailed Report is provided to assist PWC decision makers in making informed future decisions about these emerging technologies.

Detailed Report - Energy Storage

Forms of energy storage include compressed air, thermal storage, battery storage, and pumped hydro storage. Energy storage can be used by utilities to reduce the cost of peak capacity or it can be used behind-the-meter (BTM) to reduce customer demand during peak hours and shore up resiliency. This report will focus on the market trends, applications, and value of three viable BTM storage options: **lithium-ion battery storage, water heater storage, and ice storage**. The impact of state and federal policy, contractual obligation, and rate design in relation to energy storage will be included.

Energy storage systems are described by their power output and energy capacity (EIA 2018). The power output is represented in kilowatts (kW) or megawatts (MW) and the energy capacity is represented in kilowatt hours (kWh) or megawatt hours (MWh) and denotes the amount of energy that can be stored and discharged over a designed period of time. Value to the customer is dependent on retail electric rate design, market and policy conditions.



South Eastern Storage Facilities Interactive Map - https://energync.org/maps/

Key cost and performance indicators are provided for the energy storage technologies considered. "System cost" represents the total installed cost and all other costs required to make the storage technology ready for deployment (DeCarolis et al. 2018).

Cost analysis summary of energy storage technologies:

Technology	System Cost[a] $/kWh	Duration (hr)	Lifetime (yr)	FOM[b] ($/kWyr)	R.T.E.[c] (%)	Source(s)
Ice	$310	6	30	$180	97%	Ingersoll Rand (2018)
Water Heaters	$100	4	12	$15.8	92%	DOE (2018a), Hledik et al, 2016, Alliant Gas (2018)
Li-ion Battery Commercial	$561 $551	2 4	10 10	83 83	85% 85%	Zakeri and Syri (2015)

[a] *Includes total installed cost, which includes the equipment cost, balance of system cost, engineering procurement cost, and any other cost required to make the storage technology ready for deployment.*

[b] *Fixed Operations and Maintenance*

[c]*Roundtrip Efficiency*

Energy storage is not new in the United States. Many thermal energy storage systems, such as ice or chilled water storage, as well as pumped hydro storage facilities, have existed nationwide for decades (Whittingham 2012). Recent cost breakthroughs in battery energy storage systems, which are modular and not geographically limited, have given way to the eruption of nationwide installations of energy storage systems, as well as media interest around the subject. 1.08 Gigawatt hours (GWh) of energy storage capacity was installed from 2013-2017, more than 94% of which was lithium-ion batteries (GTM 2018). Smart Electric Power Alliance found that between 2016 and 2017, residential storage deployment in MW increased by over 200%, while non-residential deployment increased 9% and utility-scale deployment decreased by 3% (SEPA 2018). Most of these installations come from specific states, namely ones with favorable energy storage policies, such as Massachusetts and California.

Energy Storage Quarterly Growth

(Wood Mackenzie 2019)

Energy Storage Applications and Services

Electricity is the world's largest commodity that generally lacks an ability to store the commodity. However, the rise of cost-effective technologies to store electricity - or more broadly, energy - is beginning to overhaul the electricity sector at all scales. Energy storage is now routinely discussed for residential or commercial solar projects, and states have begun to pass energy storage mandates, or introduce energy storage incentive programs. The majority of U.S. front-of-the-meter and BTM energy storage installations are battery energy storage systems. Batteries have the versatility and modularity to be used in a variety of applications and provide service to both the utility and end-user of electricity. With the proper policies in place, batteries can provide grid stability, accelerate the deployment of renewable or carbon-free electricity, and save consumers money on their utility bills.

Energy Arbitrage

Energy storage technologies can shift the net load of customers to take advantage of TOU pricing or other incentives by adjusting when electricity from the grid is consumed (DeCarolis et al. 2018). TOU pricing refers to rate schedules where charges are dependent on the time in which electricity is consumed. Storage has the potential to decrease electricity bills by charging during low-cost hours and discharging during high-cost hours.

Demand Charge Management

In addition to being charged for electricity in $/kWh, many large commercial and industrial customers are also charged for a period of peak demand in $/kW, known as coincident peak pricing. Energy storage can charge during off-peak hours to shift electricity consumption and reduce peak consumption, reducing demand charges. The high cycle life and versatility of energy storage systems allows most storage systems to participate in both energy arbitrage and demand charge management. This or any combination of services a single storage unit provides can increase the total benefits of a storage system; most battery providers call this "value stacking."

Backup Power

Storage can play an important role in increasing the resilience of a facility or home. Energy storage can provide emergency backup power in the event of power outages for a set period of time. Backup power may be particularly important for commercial and industrial customers with "critical load," such as hospitals or food processing plants that rely on constant power.

Distributed Energy Resource Management

Energy storage is often used in tandem with variable energy resources to increase their reliability. By charging variable energy resources when they are in excess, energy storage can alleviate concerns with dispatchability of these resources. Storage is often used with solar technologies to provide electricity at night.

Power Quality Management

Energy storage can interact with the microgrid to reduce reliance on and disturbance of grid power quality. Decreases in power quality may come from voltage fluctuation, voltage drop, or frequency variation, sometimes to avoid system-wide power outages (DeCarolis et al. 2018). During "brownouts," energy storage can maintain the quality of power for critical pieces of equipment. Power quality management is particularly important for specific industrial customers.

Butler Farm Microgrid – White Oak, NC
(Appendix 3: Butler Farm Microgrid)

Lithium-ion Batteries

Li-ion batteries of various chemistries currently dominate the market for new energy storage installations. Nearly 100% of new grid-scale battery projects in the past several years have used li-ion chemistry (GTM 2018), and most battery chemistries that show potential for market penetration for nearly any application are first compared to li-ion. System costs have continued to decrease throughout the decade, thanks to advancements in battery design, increased experience deploying and operating modular systems, and several large manufacturers achieving economies of scale (DeCarolis et al. 2018). The technology is not without limitations however, including safety concerns around operation and decommissioning. In addition, long-term storage is typically limited, and most battery systems do not exceed four hours of storage capacity. This electrochemical technology is characterized by fast response times, high cycling efficiency, and high energy density. Li-ion are also popular due to the versatility of applications and flexibility of performance. Li-ion have high DC round trip efficiency (typically > 85) but experience annual degradation and have a rated service life of ten years (dependent on the charge/discharge cycle).

In North Carolina, only about 1 MW of battery storage capacity was installed prior to 2018. In 2019, Cypress Creek, a large NC solar developer, installed 12 MWh of battery storage facilities coupled with solar for the Brunswick Electric Membership Cooperative and as part of the Community Solar Project, PWC installed a 560 kW li-ion battery. Duke Energy Carolinas (DEC) has three battery-backed microgrids: two near its Charlotte headquarters and one in the mountains. DEC and Duke Energy Progress (DEP) are planning a combined total of 291 MW of battery storage to be installed by 2033 (Appendix 2: North Carolina Battery Storage Installations, NCCETC 2019).

The declining cost of li-ion battery technology is driving market growth. Since 2013, prices have dropped by nearly 73%; in the first quarter of 2019, the market achieved a record-breaking 232% growth. Forecasted price projections by Bloomberg New Energy Finance indicate continued decline in cost; the average battery pack at $94/kWh by 2024 and $62/kWh by 2030.

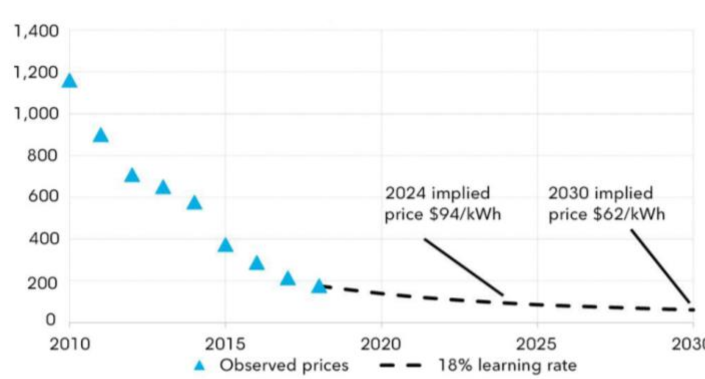


FIGURE 3.4 – Li-ion Battery Module Costs Trend & Outlook (2018 $/kWh)
Source: Bloomberg New Energy Finance, "A Behind the Scenes Take on Lithium-ion Battery Prices", March 2019

When looking at the possible usage of li-ion battery storage, it is necessary to be aware of the advantages and disadvantages of this type of technology. There are other chemical storage options available on the market but in terms of cost, market availability, life cycle, and round-trip efficiency li-ion is the operative choice. Despite its overall advantages, li-ion has its drawbacks. It is fragile and requires protection. Some capacity deterioration is noticeable after one year, whether the battery is in use or not. Batteries can fail after two or three years but most last ten years. More than 99% of storage capacity installed in the third quarter of 2019 used li-ion batteries (Wood Mackenzie 2019). U.S. storage companies engineer the projects and install them, but the batteries at the core of the systems almost exclusively come from overseas factories. Tesla provides a rare exception, because it brought in a foreign partner, Panasonic, to manufacture cells within its Nevada Gigafactory. The cobalt required for most li-ion storage technology is mined in the Congo by young boys and significant water resources are required for producing lithium. In addition, disposal is an obstacle not yet resolved; at this juncture, the cobalt is the only cost-effective recyclable material (Gyuk 2020). It is important to note that challenges remain, including developing sustainable business and financing models, overcoming performance uncertainty, integration of battery energy storage with existing systems, disposal, and long-term procurement as the battery market continues to grow.

Summary Table of Battery Storage Technologies

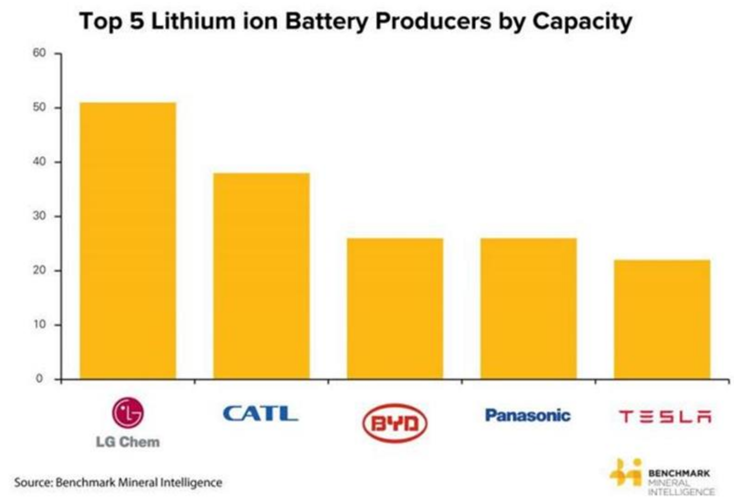
Table 4.3. Summary of Compiled Findings by Technology Type – BESS[(a)]

Parameter	Sodium Sulfur	Li-Ion	Lead Acid	Sodium Metal Halide	Zinc-Hybrid Cathode	Redox Flow
Capital Cost – Energy Capacity ($/kWh)	661 (465)	271 (189)	260 (220)	700 (482)	265 (192)	555 (393)
Power Conversion System ($/kW)	350 (211)	288 (211)	350 (211)	350 (211)	350 (211)	350 (211)
Balance of Plant ($/kW)	100 (95)	100 (95)	100 (95)	100 (95)	100 (95)	100 (95)
Construction and Commission Cost ($/kWh)	133 (127)	101 (96)	176 (167)	115 (110)	173 (164)	190 (180)
Total Project Cost ($/kW)	3,626 (2,674)	1,876 (1,446)	2,194 (1,854)	3,710 (2,674)	2,202 (1,730)	3,430 (2,598)
Total Project Cost ($/kWh)	907 (669)	469 (362)	549 (464)	928 (669)	551 (433)	858 (650)
O&M Fixed ($/kW-yr)	10 (8)	10 (8)	10 (8)	10 (8)	10 (8)	10 (8)
O&M Variable Cents/kWh	0.03	0.03	0.03	0.03	0.03	0.03
System Round-Trip Efficiency (RTE)	0.75	0.86	0.72	0.83	0.72	0.675 (0.7)
Annual RTE Degradation Factor	0.34%	0.50%	5.40%	0.35%	1.50%	0.40%
Response Time (limited by PCS)	1 sec	1 sec	1 sec	1 sec	1 sec	1 sec
Cycles at 80% Depth of Discharge	4,000	3,500	900	3,500	3,500	10,000
Life (Years)	13.5	10	2.6 (3)	12.5	10	15
MRL	9 (10)	9 (10)	9 (10)	7 (9)	6 (8)	8 (9)
TRL	8 (9)	8 (9)	8 (9)	6 (8)	5 (7)	7 (8)

(a) An E/P ratio of 4 hours was used for battery technologies when calculating total costs.
MRL = manufacturing readiness level; O&M = operations and maintenance; TRL = technology readiness level.

Mongrid et al, Energy Storage Technology and Cost Characterization Report. http://energystorage.pnnl.gov/pdf/PNNL-28866.pdf

The li-ion energy storage market has grown at a much higher rate than projected. Cell capacity expansion at LG Chem saw the South Korean li-ion battery producer rise to the number one spot with a capacity of 51 GWh in 2018. Tesla and Panasonic have the world's largest li-ion battery factory in Nevada reaching an annualized rate of 20 GWh. Tesla projects that the cost of battery cells will significantly decline through economies of scale, innovative manufacturing, reduction of waste, and optimization of locating manufacturing processes under one roof.



https://seekingalpha.com/article/4289626-look-top-5-lithium-ion-battery-manufacturers-in-2019
https://www.benchmarkminerals.com/who-is-winning-the-global-lithium-ion-battery-arms-race/

Available Residential Batteries

Manufacturer	Battery Type	Capacity	RTE	Cost	Warranty
Tesla Powerwall	Lithium-Ion	13.5 kWh	92.5%	$6,700 (before installation)	10 years
Sonnen Eco	Lithium-ion	Starts at 4 kWh	>= 86%	$9,950 (before installation)	10 years @ 70% capacity
LG Chem RESU	Lithium-Ion	3.3-9.8 kWh	>=90%	~$6,000 - $7,000 (before installation)	10 years @ 60% capacity
Smart Harbor	Lithium-Ion	10.6-15.9 kWh	96.5%	$12,000 - $20,000 (including installation)	10 years
ElectrIQ PowerPod	Lithium-Ion	10 kWh	92%	$8,999 (before installation)	10 years @ 60% capacity
BYD B-Box	Lithium Iron Phosphate	2.45-9.8 kWh	≥95.3 %	~$8,750 (before installation)	10 years @ 60% capacity
SimpliPhi Power (CivicSolar partner)	Lithium Ferro Phosphate	160 W – 200+ kWh	98%	$3,000 - $3,500 (before installation)	10 years
Sunverge One	Lithium-Ion	6-23 kWh	95.7%	$8,000 - $20,000	10 years
Panasonic EverVolt	Lithium-Ion	6-17 kWh	84% (AC) / 89% (DC)	$5,000 to $7,000+ (before installation)	10 years
Samsung SDI ESS	Lithium-Ion	6.3-8.8 kWh	95%	~$2,000+	10 years @ 65% capacity
Enphase Encharge	Lithium Iron Phosphate	3.36-10.08 kWh	89%	$6,000-$20,000 (including installation)	10 years
Powervault (UK only)	Lithium-Polymer	4.1-20.5 kWh	>90%	$3,000+ (before installation)	3-10 years (depends on model)
Eaton/Nissan x Storage (UK only)	Lithium-Ion	4.2-9.6 kWh	89% (AC) / 91.8% (DC)	~$8500+	5-10 years
Aquion Aspen* (chpapter 11 in 2017)	Saltwater Electrolyte	2.2 kWh (stackable)	80-90%	~$1,000 (before installation)	8 years, 70% capacity
Vivent/Mercedes (2017-2019)	Lithium-Ion	2.5 kWh (stackable up to 20 kWh)	unknown	$5,000 - $13,000 (including installation)	10 years
BMW (production unknown)	Lithium-Ion	22 kWh or 33 kWh	unknown	Unknown	8 years

(PWC Development & Marketing 2019)

BTM storage opportunities are expected to expand, particularly as shifts in rate tariffs, net energy metering policies, and state programs allowing storage to provide grid services push the markets ahead. The total U.S. market is expected to reach 3.9 GW by 2023 (GTM 2018). Utilities across the nation are beginning to offer battery storage programs that either incent battery purchase, provide long-term payment options for the purchase of batteries, provide battery deployment incentives, or offer rates that provide monetary benefit for deployment and low pricing during off-peak periods.

Utility Incentives/Rates for Battery Storage

Utility	Battery Purchase Option/Incentives	Deployment Incentives	Rate
NHPU	Tesla Powerwall - Ten-year bill charge $25/month or $2,433 upfront. Utility operates battery		Off-Peak $.0683 - $.1302 Mid-Peak $.1526 - $.1668 Critical Peak $.3644 - $.3567 Differs by time of year
Green Mountain Power	BYOD Energy Storage (batteries, resistant water heaters, Level 2 chargers). Utility operates. One-time up-front incentive for battery of $850	Bill credit based on kW and kWhs made available during peak events/ 5-8 times month 3-6 hours. Flat incentive for water heaters and Level II chargers	
Arizona – Salt River Project	$300 per DC kWh up to $3,600 (Research study limited to 4,500)	Customers must agree two uses – 1) back-up power, and 2) peak reduction	Must be on solar price plan (TOU export, EV Export, Avg. Demand, or Customer Generation)
PG&E	Declining Incentives: Residential: <=10kW .35/Wh - .25 Wh Commercial: >10 kW .50/Wh - .25/Wh	Dispatch no more than 52 times per year	
SMUD	Residential: 1 kW – 10 kW $300, 11 kW+ $600 Commercial: 15 kW – 30 kW $600, 30.1 – 75 kW $1,000, 75.1 kW – 150 kW $2000, 150.1+ kW $5,000	Residential - $10 - $20 bill credit per month – for cycling by SMUD (not more than 120 times per year) Commercial – additional compensation during peak	
JEA	30% of the cost of energy storage system up to $2,000/customer. At least 6 kWh usable capacity/ charged by renewable energy		

(PWC Development & Marketing 2019)

Battery Energy Storage System Lifetime Extension

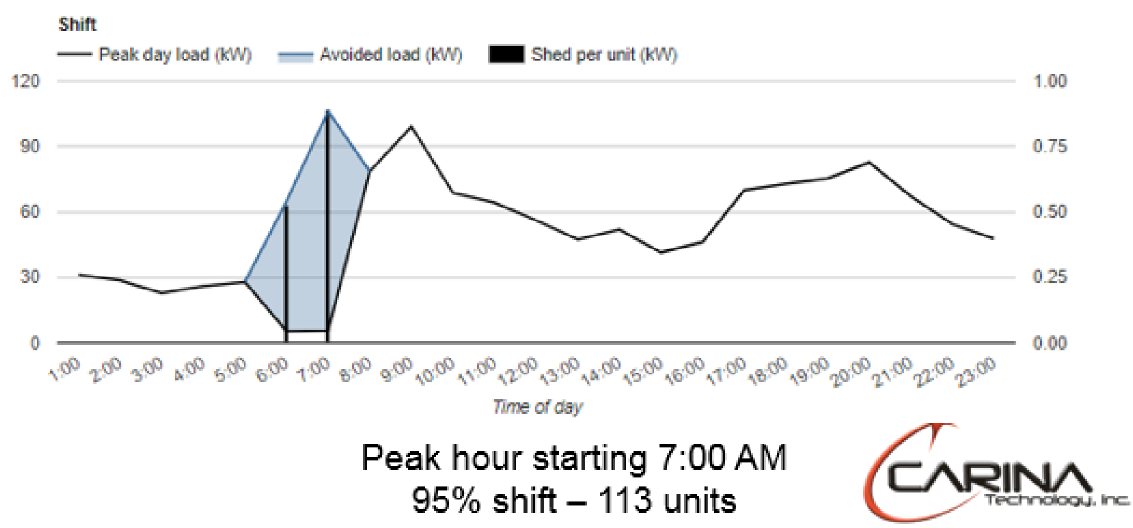
Recent contracts for battery energy storage systems have promised 15 to 20-year lifetimes with very low to zero variable operation & maintenance (VOM) costs. In these contracts, battery cells are replaced periodically to maintain battery performance over time, preventing degradation (Cole 2018, Lazard 2018). Included in these contracts instead are "augmentation costs," detailed as yearly fixed costs. This can reduce the uncertainty of maintenance costs for battery operators and project owners, incentivizing operators to increase throughput to and from the battery system during the system's lifetime.

Energy Storage as a Transmission Asset

Recently, CAISO and MISO have studied the classification of energy storage as a non-wires alternative (NWA) transmission asset and to alleviate transmission congestion (MISO 2019). This could be a unique method for Independent System Operators (ISO) to provide transmission services and other front-of-the-meter services without investing tens of millions of dollars into transmission lines. Many states are also considering possibilities for energy storage to serve as alternative transmission or distribution system upgrades (NCUC 2019a).

Water Heater Storage

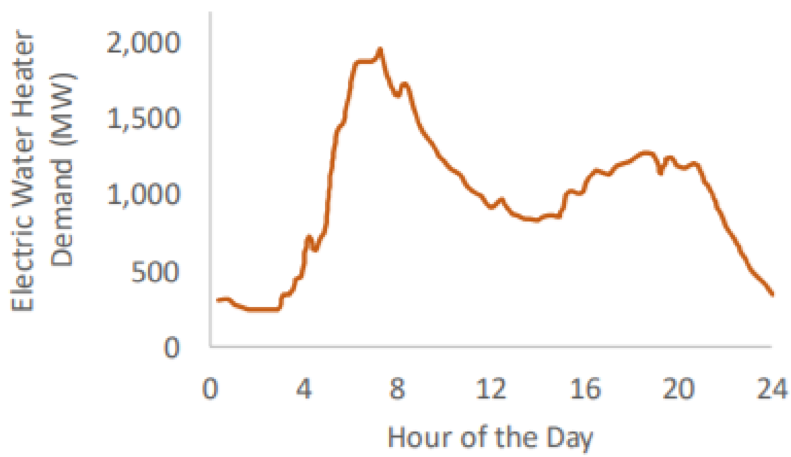
Grid-interactive electric water heaters are a form of thermal storage that allow both residential and commercial customers to store hot water and shave peak demand through load control shifting. Existing water heaters can become interactive with a control retrofit or new wi-fi interactive water heaters can be installed. The North Carolina Electric Membership Corporation (NCEMC) are currently offering Wi-Fi/4G-LTE connected devices that shift energy-intensive water heating to off-peak times with no impact to the member. An initial pilot with Carina Technologies demonstrated that the



average savings per water heater was .45 kW during the summer and .9 kW during the winter. This savings was realized without sacrificing comfort for the member. The selected control device comes with a built-in override feature that prevents the tank temperature from dropping below a preset temperature during a demand response event. Another retail-sourced control device, Aquanta advertises average summer savings of .4 kW and winter savings of .7 kW. This type of BTM control device is most beneficial to customers that can utilize it to manage peak pricing periods and to the utility when it can be curtailed in-aggregate to avoid peak hour(s) consumption. PWC is in the process of initiating a Wi-Fi connected pilot program for water heater control and is working with Sensus to develop a pilot for load control switches that communicate through our regional network interface. This type of load control was successfully piloted by PWC in the past; however, the vendor support for the technology was discontinued. The ratio between capacity savings and revenue loss from electricity sales favors direct load control. However, many consumers like to be in control and are willing to invest in smart technology to achieve savings when it can be justified by a cost-effective TOU rate offering (DOE 2016).

The U.S. Energy Information Administration's Residential Energy Consumption Survey found that 71% of the households in the South Atlantic Region, which includes North Carolina, have electric water heaters and the annual average consumption is 3,043 kWh per household. The daily consumptive pattern varies significantly, with most electric water demand occurring in the morning between 7 am and 8 am. A secondary peak occurs in the evening. This suggests that there is potential to shift peak demand through water heater demand response.

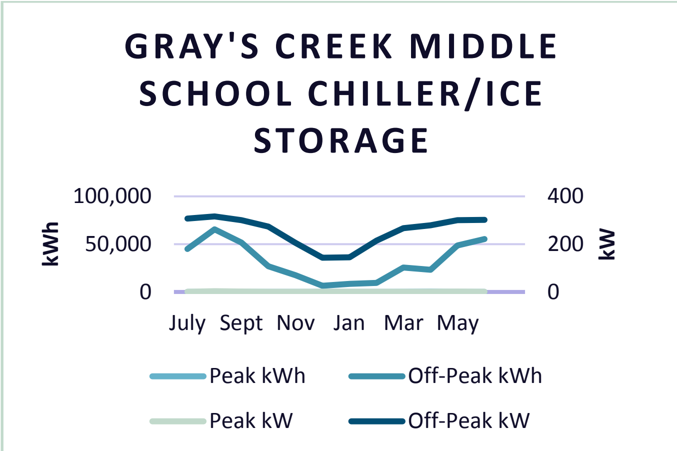
Estimated electricity demand from NC residential electric water heaters on a typical day (DeCarolis et al. 2018)



Ice Storage

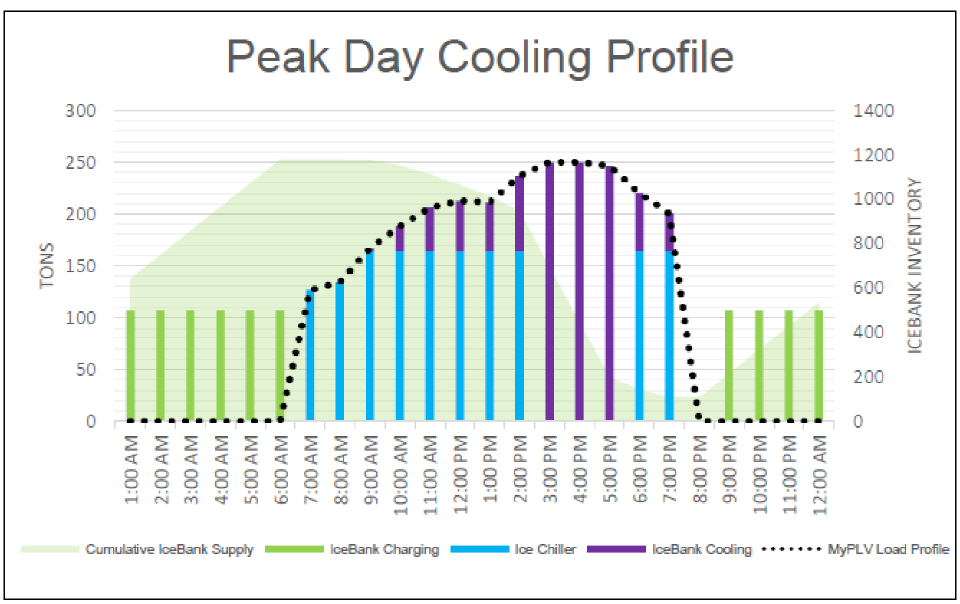
Ice storage technology involves freezing water during off-peak hours to use during peak hours to supply cool air and reduce chiller load. Storage banks are typically sized to eliminate peak demand during on-peak hours or eliminate coincident peak demand during potential coincident peak hours, in addition to lowering the daily customer peak. Over 80 projects exist around the state, totaling 99 MWh of storage (DeCarolis 2018). Two projects exist in Cumberland County, Gray's Creek Middle School served by South River Electric Membership Cooperative (SREMC) and New Century Elementary School served by Lumbee River Electric Cooperative. Each school defers 150 kW - 300 kW to off-peak hours each month (Cumberland County Schools). The chill water system for Gray's Creek Middle is served by a separate electric meter; thereby, providing usage data specific to the chill water/ice storage plant. As indicated in the graph below, little usage or demand is registered during the SREMC peak hours 2:00 pm – 7:00 pm.

In addition to on-peak curtailment, thermal storage can provide some back-up resiliency, and improved temperature stability. It requires no additional energy and has no-round trip energy losses. Chiller size in new applications can be reduced to meet base load.



Gray's Creek Middle School is served by South River Electric Cooperative on a rate schedule that encourages off-peak usage. Ice is made during the night during the off-peak hours and used for chill water during the daytime peak hours.

Gray's Creek Middle School Calmac Ice Storage Units



Ice storage tanks paired with an optimally sized chiller and used to shave a 250-ton coincident peak chiller load and flatten customer peak demand, is estimated to save $54,832 (with PWC Coincident Peak Rate) in annual operating cost and offer a payback in less than six years (Appendix 3: CALMAC/Trane Ice Storage Estimation – December 2019).

What is Duke Energy Doing?

The ability of energy storage to support distributed energy resource management is highlighted in the 2019 DEP Integrated Resource Plan. DEP foresees "solar + storage" coupled systems playing a role in alleviating growing electricity demand in the balancing territory. DEP expects the deployment of 100 MW of storage coupled with solar in its service territory by the end of 2034. DEP assumes storage is DC coupled with solar, has a four-hour duration, and has a maximum capacity of 25% of the maximum output of the solar setup (DEP 2019a).

DEP does not have a rate specific for battery storage but offers TOU, interruptible, and curtailment rates and riders that could incent the use of BTM storage. DEP also offers a thermal energy storage rate for contract demand less than 4,000 kW. This schedule is available to non-residential customers who would use the thermal storage mediums to reduce HVAC load. A basic customer charge of $35.50 is applied to contract demands less than 1,000 kW and $200.00 for demands in excess of 1,000 kW.

Duke Energy Progress Time Varying Rates as of January 1, 2020

Rate	Fixed Rate ($/month)	Cost per kWh and kW	
Residential with TOU	16.85 23.85	$0.23520/kWh (on-peak) + $0.12009/kWh (shoulder) + $0.07076/kWh (off-peak) (Jun-Sep)	$0.22369/kWh (on-peak) + $0.11721/kWh (shoulder) + $0.07076/kWh (off-peak) (Oct-May)
Residential with TOU + Demand	16.85 23.85	$4.88/kW (on-peak) + $0.07185/kWh (on-peak) + $0.05745/kWh (off-peak) (Jun-Sep)	$3.90/kW (on-peak) + $0.07185/kWh (on-peak) + $0.05745/kWh (off-peak) (Oct-May)
SGS-TOU – less than 30 kW	21.00 28.00	$0.21691/kWh (on-peak) + $0.11282/kWh (shoulder) + $0.06077/kWh (off-peak) (Jun-Sep)	$0.19609/kWh (on-peak) + $0.10762/kWh (shoulder) + $0.06077/kWh (off-peak) (Oct-May)
SGS-TOU-Demand	$35.50	$.06148/kWh (on-peak) $.04923/kWh (off-peak)	$10.24/kW (on-peak) $1.22/kW (off-peak) (Jun – Sept) $8.56/kW (on peak) $1.22/ kW (off-peak) (Oct – May)
LGS TOU	$200	$.05125/kWh (on-peak) $.04625/kWh (off-peak)	$20.30 - $18.30/kW tiered (Jun – Sept) $15.16 - $13.16/kW tiered (Oct – May) $.89 excess
Thermal Energy Storage	35.50 200.00	$12.02/kW (on-peak) + $1.22/kW (off-peak) + $.04998/kWh on-peak + $.04745/kWh off-peak	$10.75/kW (on-peak) + $1.22/kW (off-peak) + $.04998/kWh on-peak + $.04745/kWh off-peak

- On-peak hours: 1:00-6:00 p.m. Monday-Friday, excluding holidays.
- Shoulder hours: 11:00 a.m.-1:00 p.m. and 6:00-8:00 p.m. Monday-Friday, excluding holidays.
- Off-peak hours: All other hours, plus holidays defined as off-peak.

In addition, DEP has an interruptible standby service rider for customers having generation equipment not held solely for emergency use and for which DEPs service may be substituted either directly or indirectly or used as an additional power supply, a large load curtailable rider for contracts in excess of 1,000 kW of curtailable load, and a demand response rider for contracted curtailable demand of 75 kW or greater during summer peak periods.

Policy and Contractual Obligations

Duke Energy Progress Power Supply Contract

The DEP Power Supply Contract allows PWC to participate in DR opportunities. Therefore, the aggregation of load control devices by PWC for the purposes of DR would be allowed, as would customer incentives/rebates and optional pricing. However, providing DEP System CP timing information or PWC owned DR equipment is not allowed.

In accordance with Federal Energy Regulatory Commission (FERC), battery storage is considered a generator and as such, DEP explicitly prohibits injection of power into the grid from battery stored energy. There is a limited variance for utility solar tied storage which may not apply to customer owned battery/storage systems.

North Carolina Legislative Policy

North Carolina House Bill 589 - 2018 called for a study to potentially help develop a statewide coordinated energy storage policy in North Carolina. Certain NC legislative policy is currently unclear how it pertains to storage assets. For example:

(1) Ownership and leasing, NCGS §62-126.5, .7 and .9 authorize leased solar energy generation, limited to a maximum equal to 1% of the utility's previous five-year average of the state retail contribution of their coincident peak demand. There is also attending clarification that lessors are not public utilities. While this mainly was meant with DEP/ DEC in mind, municipal utilities also have the option to allow leasing of solar generation.

(2) Though municipal utilities and electric cooperatives can employ demand side management for REPS compliance, NCGS §62-133.8(c)(2)(b), it is unclear as to the role storage specifically can play in satisfying existing regulatory obligations. Aside from the cases set up by HB589, there are examples of NC Electric Cooperatives where assets appear to be shared between the co-op and end user; these are characterized as microgrid-based systems (https://www.ncelectriccooperatives.com/energy-innovation/microgrids/).

(3) NCGS §62-110.1(a) requires that the NCUC issue a Certificate of Public Convenience and Necessity (CPCN) prior to the construction of a "facility for the generation of electricity." Under the current interpretations of the statute, battery storage systems may fall outside the definition of a generator. However, supply contracts between generation utilities and municipal utilities and electric cooperatives classify battery storage as a generation asset and currently influence the storage projects undertaken by these utilities.

It is certain that policy and regulatory reform can influence the deployment of energy storage. Linking energy storage to other pre-existing planning efforts, programs, and objectives can facilitate the integration of this technology. The incorporation of storage into resiliency or energy assurance plans is one area to consider (NGA 2016). Another consideration is how to link storage to state renewable energy portfolio standard (REPS) programs, particularly the mechanisms by which renewable energy certificates are issued. To the extent that established regulations create value for various storage applications or services, there is inherent overlap with improvement in cost competitiveness (DeCarolis et al. 2018).

Interconnection standards in NC already consider the potential for energy storage but potential revisions are underway, with multiple provisions for storage being debated. While standards, regulations, and policies remain unclear, the 2019 NC Clean Energy Plan recommends that utilities be required to develop innovative rate design pilots to encourage customer behavior that helps achieve clean energy goals, such as peak demand reduction, better utilization of renewable resources, and strategic storage deployment (NCDEQ 2019). Navigating the deployment of energy storage beyond what can be achieved by the utilities under their current supply contracts or policy provisions, seems to bear uncertainty for customers who may want to export power to the grid, at this juncture.

Federal Investment Tax Credit for Standalone Energy Systems

For the past few years, the energy storage industry has suggested a standalone federal investment tax credit for energy storage systems. Dozens of energy storage-related bills have been introduced in Congress since 2017, many of which discuss tax credits for energy storage systems (Gheorghiu 2019). However, none have been signed into law. An example of energy storage legislation discussing tax credits is H.R. 5409 - Incentivizing New and Valuable Energy Storage Technology (INVEST) Act of 2019. The resolution introduces a technology-agnostic federal tax credit for standalone energy storage systems with capacity greater than 5 kWh. It also introduces a credit for residential energy storage systems known as the residential energy efficiency property credit. This bill was introduced on December 12, 2019. A very similar pair of bills were introduced to the House and Senate in April 2019, known as S. 1142/H.R. 2096 - Energy Storage Tax Incentive and Deployment Act of 2019. However, these bills died in committee.

A standalone federal investment tax credit for energy storage systems would almost certainly accelerate the energy storage industry throughout the U.S. Many applications of storage are on the cusp of economic viability and are agnostic to what energy generation source they are charged with (DeCarolis et al. 2018). These include frequency and voltage regulation, demand response, coincident peak shaving, power quality management, and others. Currently, if an energy storage system were commissioned with intention of contributing to any of these services, as well as taking advantage of a federal tax credit, the storage system would need to be charged with renewable energy at least 75% of the time.

For a listing of regulatory activity related to energy storage, see Appendix 4: North Carolina and Federal Regulatory Activity.

Grid Impact

BTM energy storage can bring benefits and new opportunities for utilities. For some utilities BTM energy storage can reduce peak demand and alleviate stress on the system, potentially providing opportunity to defer or avoid investment in infrastructure upgrades. BTM energy storage can also help address the challenge of renewable energy intermittency by charging during times of excess generation and discharging during periods of high demand. Many utilities offer demand response programs to help manage peak demand, and BTM energy storage can be another technology option for customer participation in such programs. If BTM energy storage reduces peak demand, it can consequently improve the utility's load factor, increasing system efficiency.

BTM energy storage can be simply used as a DR tool without discharging back to the grid; this would be typical of any type of thermal storage. However, battery storage can act as both a load during its charging state and an energy generator by injecting stored energy into the grid. In 2013, the Federal Energy Regulatory Commission (FERC) revised the definition of “small generating facilities” to explicitly include energy storage systems. FERC’s interconnection process directs utilities to assume less than the maximum capacity if the applicant can demonstrate that it can limit the export so as not to “adversely affect” the safety and reliability of the electric system.

A photovoltaic (PV) array, a battery, and a battery-based inverter are the fundamental components of all PV plus storage systems. Additional component requirements are determined by whether the system is DC or AC coupled: a DC-coupled system often requires a charge controller to step down the PV output voltage to a level that is safe for the battery, whereas an AC-coupled system requires a grid-tied inverter to feed PV output directly to the customer’s load or the grid (Figure 1). AC-coupled systems typically achieve a higher system efficiency than DC-coupled systems where the customer frequently consumes the PV output directly at the time of generation. DC-coupled systems are generally more efficient than AC-coupled systems in applications where the customer will more frequently store the PV output for use at a later time (Ardani et al. 2017).

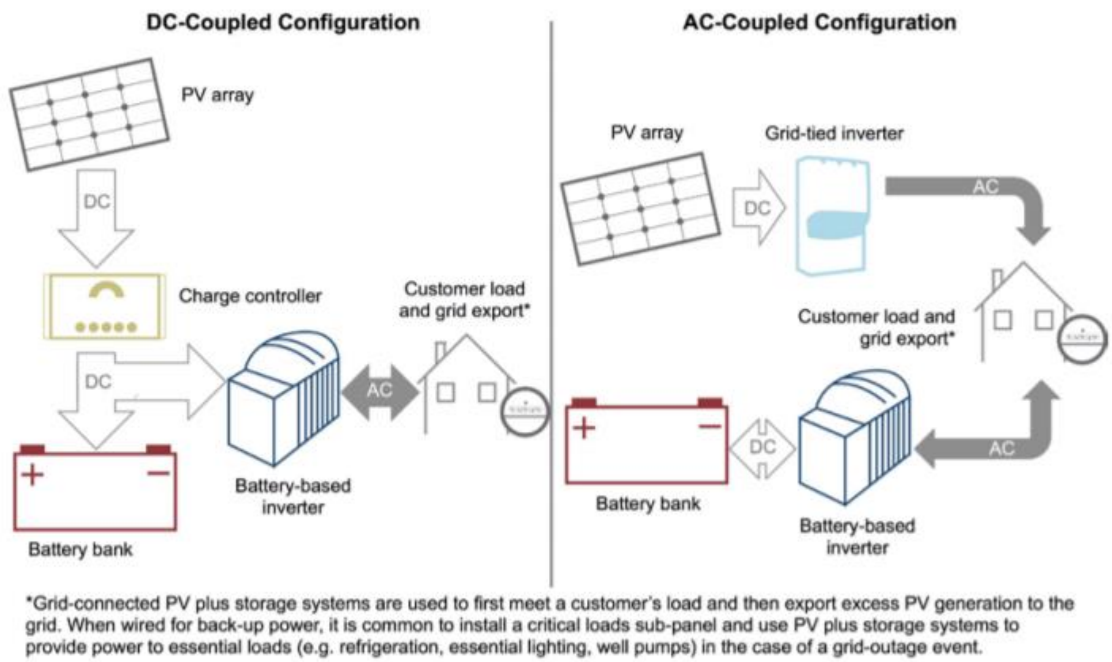


Figure 1. Modeled DC- and AC-coupled system configurations (simplified for illustrative purposes)

In some states, utilities allow customers to store PV electricity and then sell it to the grid during high-rate periods while others require a non-export relay device or a secondary meter on the battery. In North Carolina, the adoption and acceleration of BTM stand-alone energy storage and PV + storage is highly dependent on the creation of energy storage policies to address uncertainty about generation, ownership, net-metering rules, interconnection rules, and local code and permitting standards. Interconnection standards exist in NC for non-utility owned generation resources qualified by the Public Utility Regulatory Policies Act of 1978 (PURPA) to connect to the electric grid. However, until interconnection standards address battery storage, uncertainty will serve as a barrier to widespread BTM implementation.

Codes and Standards

Electric energy storage systems that connect in parallel with the grid must meet applicable interconnection standards and safety codes, which currently consist of the standard *North Carolina Interconnection Procedures, Forms, and Agreements for State-Jurisdictional Generator Interconnections,* and the *National Electric* Code, along with specific requirements determined by the utility with which the facility is interconnecting.

Under the Renewable Energy and Energy Efficiency Portfolio Standard provision in Chapter 62 of the NC General Statutes, the Utilities Commission was charged to "Establish standards for interconnection of renewable energy facilities and other nonutility-owned generation with a generation capacity of 10 MW or less to an electric public utility's distribution system; provided, however, that the Commission shall adopt, if appropriate, federal interconnection standards." This led to the creation of the NC standard in Commission docket E-100 sub 101, which was revised in 2015 to add storage to the definition of a Generating Facility for the purposes of interconnection. The NC standard includes reference to the IEEE 1547 standard for "Standard for Interconnecting Distributed Resources with Electric Power Systems." Essentially, the requirements apply at the point of connection, and since batteries and other DC power based distributed resources, such as solar PV, connect through a power inverter, the requirements are very similar.

A revised NC interconnection standard was approved by the Commission in 2019, with minor changes related to storage, such as addition of storage to the energy and capacity fields of the standard interconnection application. One question that was raised in the 2019 revision process was how to handle the addition of energy storage to existing solar energy facilities. Due to differences between parties on whether addition of energy storage without a change in generating output constituted a material modification, the Commission ordered a stakeholder process, that is currently underway, to establish a streamlined process for handling such applications.

Installation of energy storage requires attention to fire and life safety, and generally discriminates between type of storage and whether storage is located indoors or outdoors. In response to increased interest in deployment of energy storage, the U.S. Department of Energy contracted with Pacific Northwest National Laboratory and Sandia National Laboratories to work on identifying any gaps and to build confidence in the safety of storage systems. In 2016, the team published a document titled *Energy Storage System Guide for Compliance with Safety Codes and Standards,* which helps to establish a process for ensuring acceptability of storage projects. There is also a working group facilitated by the team that is coordinating the development of new or revised standards for all types of storage, and ten major codes and standards organizations are involved, including IEEE, NEMA, UL, and the International Code Council (ICC).

For indoor storage consisting of electric batteries, several different codes apply. The State of North Carolina has adopted the International Building Codes, which includes by references the *National Electric Code* (NFPA 70) and the *National Fire Code* (NFPA 1). Key provisions of the *North Carolina Building Code* that address storage are:

- Building Code – Chapter 5 – Section 509 – Incidental Uses – Table 509: Rooms or areas defined as storing "Stationary storage battery systems having a liquid electrolyte capacity of more than 50 gallons for flooded lead-acid, nickel cadmium or VRLA, or 1,000 pounds for lithium-ion and lithium metal polymer of used for facility standby power, emergency power or uninterrupted power supplies" and requires one-hour fire separation from other uses in in Business, Factory & Industrial, Mercantile, Storage and Utility occupancies and two-hour fire separation in Assembly, Educational, Institutional and Residential occupancies.

- Fire Code – Chapter 6 – Section 608 – Stationary Storage Batteries: This section has requirements for spill control and neutralization using approved methods and materials, as well as ventilation requirements, including supervisory alarms upon fault detection. Lithium-ion, lithium metal polymer or other types of sealed batteries with immobilized electrolytes do not require spill control or ventilation.

The 2018 version of the International Fire Code, which has not yet been adopted by North Carolina, adds a new Chapter 12 - Energy Systems. This chapter includes Section 1206 - Electrical Energy Storage Systems, provides requirements for indoor installations of storage batteries. For indoor batteries with capacities below the threshold shown in Table 1206.2 below, the section does not apply. Above the threshold capacities listed in Table 1206.2, the section applies and includes requirements for construction of building space, clearances, emergency egress, spill control, thermal runaway protection fire-extinguishing, and ventilation.

TABLE 1206.2
BATTERY STORAGE SYSTEM THRESHOLD QUANTITIES.

BATTERY TECHNOLOGY	CAPACITY[a]
Flow batteries[b]	20 kWh
Lead acid, all types	70 kWh
Lithium, all types	20 kWh
Nickel cadmium (Ni-Cd)	70 kWh
Sodium, all types	20 kWh[c]
Other battery technologies	10 kWh

For SI:1 kilowatt hour = 3.6 megajoules.

a. For batteries rated in amp-hours, kWh shall equal rated voltage times amp-hour rating divided by 1000.
b. Shall include vanadium, zinc-bromine, polysulfide-bromide, and other flowing electrolyte-type technologies.
c. 70 kWh for sodium-ion technologies.

For outdoor storage of electric batteries, the requirements for indoor batteries also apply, and additionally, there is a requirement for a minimum distance of five feet from lot lines, separation from means of emergency egress by no less than ten feet and for batteries to be in a secure location to prevent unauthorized entry.

Most of the requirements in the ICC reflect the requirements of NFPA 1 – the National Fire Code. The National Fire Protection Association (NFPA) is in the process of developing Standard 855 – Standard for the Installation of Energy Storage Systems, which is expected to be released in 2020. This standard consolidates and reflects much of what is in the other NFPA standards, and notably adds a distinction between storage that is outdoors, vs remote, defined as more than 100 feet from a building.

Where thermal storage is installed, safety codes are generally needed to ensure protection where high temperatures and pressure are part of the design. The American Society of Mechanical Engineers is developing a TES-1 Safety Standard for Thermal Energy Storage Systems. This standard will regulate higher temperature thermal energy storage, including molten salt thermal storage, and the developing document does not include chilled water storage.

Incentives

Energy storage systems may be eligible for two federal incentives: the Investment Tax Credit (ITC) and Modified Accelerated Cost Recovery System (MACRS) depreciation. Energy storage as a standalone technology is currently not covered by the ITC. However, energy storage systems that are charged from at least 75% of a renewable energy source would be eligible for the ITC. Battery systems that are charged with 75% or more, but less than 100% renewable energy, are eligible for 30% of the ITC incentive. This will decrease to 10% from 2022 onwards. Systems charged with renewable energy 100% of the year can claim the full benefit of the ITC (Cole 2018). As a standalone technology, energy storage systems can qualify for seven-year MACRS depreciation schedules, about a 20% reduction in upfront capital costs. With renewable energy, systems can qualify for five-year MACRS depreciation schedules, about a 21% reduction in upfront capital costs (Cole 2018).

North Carolina does not currently offer any state incentives for energy storage systems, such as tax credits or property tax abatements. DEP currently does not offer explicit incentive programs for residential or non-residential electric customers to utilize energy storage. However, customers with CP or TOU rate structures can use batteries for energy arbitrage and demand reduction to reduce their monthly electricity bills. A few utilities outside of North Carolina are offering customer incentive for li-ion storage as a means to enhance grid operations by maintaining balance between solar generation and the load as well as smooth short-term variations in voltage and frequency. The utility typically will have the capability to dispatch the battery as needed.

A number of utilities offer incentives for thermal storage for both water heater storage and ice/water storage. In North Carolina, Roanoke Electric Cooperative offers a monthly bill credit of $1 to allow the Cooperative to install and manage a load control device on the customer’s water heater. Austin Energy will pay up to $12,000 for a feasibility study if a commercial customer can provide 100 kW or more of load shift by using thermal storage. In addition, the customer can qualify for a thermal energy storage rebate of $350 per kW shifted.

Tariffs

While batteries are typically paired with home solar energy systems, they can also be useful to homeowners without solar panels. Batteries can be discharged to mitigate peak energy or demand charges. Discharging cycles for battery storage are not 100% efficient. To be economically viable, there must be a lengthy off-peak period and a high rate differential. As controls advance, customer response will improve. Tesla Powerwall 2 offers accompanying software to optimize discharge for time varying rates, detect grid outages and automatically becomes the home’s main energy source. For back-up power, Tesla recommends three Powerwalls to run a 2,200 square foot grid-powered house, to include air conditioning, for one day (Tesla 2020). At an initial installed cost of approximately $25,000, the annual savings achieved by curtailing grid-load during peak hours would not recover upfront system costs. If peak load shaving/load shifting/TOU arbitrage are the primary objectives, a smaller battery storage system could suffice and potentially be cost-effective.

A Tesla 2 battery has an approximate install cost of $10,000, a maximum discharge rate of 7 kW, and full discharge of 13.75 kWh. Potentially, a customer could shave 7 kW from the coincident peak. If that was the case, a PWC customer on a CP rate could also shave approximately $140 from their electric bill each month. However, the average energy efficient home may not exceed 2 – 3 kW during the coincident peak hour. To be economically viable, a customer may need battery storage sized to meet the average CP demand.

Ability to control the heating elements in a water heater storage system, can either reduce usage during the coincident peak hour if the utility manages the load control device, the energy during on-peak hours if the customer manages the load control device, or both if it is mutually managed by both the customer and the utility. The advantage of the utility installing a direct load control switch is that it allows the utility to curtail load during the coincident peak hour without eroding revenue. However, there is no mechanism for the customer to opt out of events or manage water heating. The advantage of the customer managed wi-fi connected or time-clock integrated control device is that the customer can manage load during the TOU hours, at night when hot water is not needed, and when on vacation. Electric water heaters account for 12% of residential consumption (ENERGY STAR 2017); this type of management can be very advantageous to the customer but may or may not benefit the utility. A wi-fi connected control device that gives both the utility and the customer control is another option to consider.

North Carolina Municipal Electric Utilities offer a variety of rate structures for both residential and non-residential customers (Appendix 5: North Carolina Municipal Rate Structures). Some TOU and CP rate options are voluntary while others are mandatory for specific rate classes. For any storage option, price signals that are more closely aligned with the utility's wholesale power purchase structure generally provide the greatest value to the customer and to the utility.

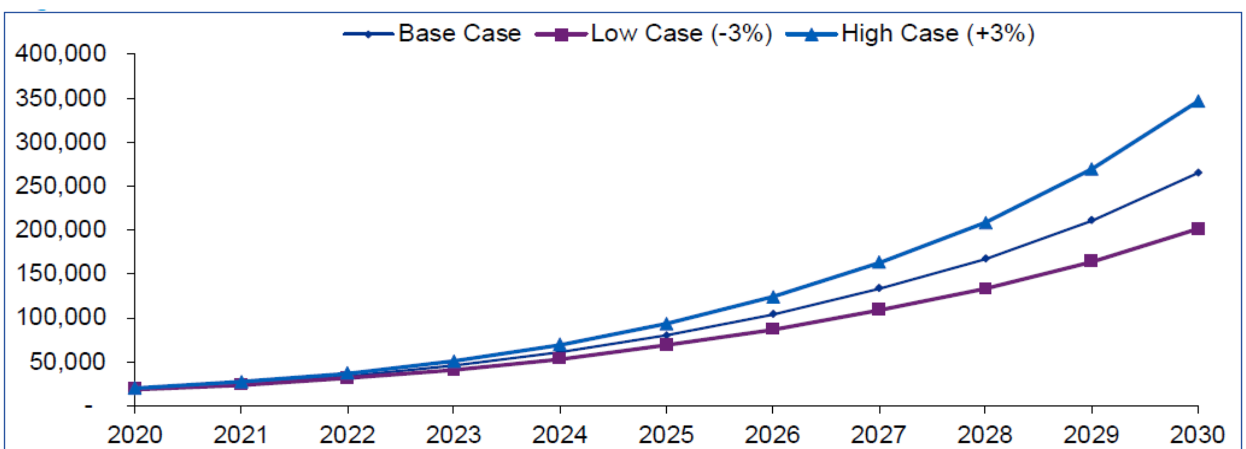
Detailed Report - Electric Vehicles and EV Charging

Both plug-in hybrid electric vehicles (PHEV) and electric motored fueled electric vehicles (EVs) are considered Zero Emissions Vehicles (ZEVs). The average driver covers between 30-35 miles per day (USDOT 2020). Because most plug-ins generally achieve ranges near 30 miles before switching to the gas, the majority function like EVs for typical driving scenarios; therefore, are regarded as ZEVs. For the balance of this study both PEVs and EVs will be referred to as EVs.

ICE – Internal combustion engine fueled with gas or diesel 	Hybrid - Gas engine and electric motor, only fueled by gas; very short battery range 
PHEV – Plug-in hybrid electric vehicle has both gas engine and electric motor; is fueled by both electricity and gas; medium range battery 	EV – Electric motor fueled with electricity; long range battery 

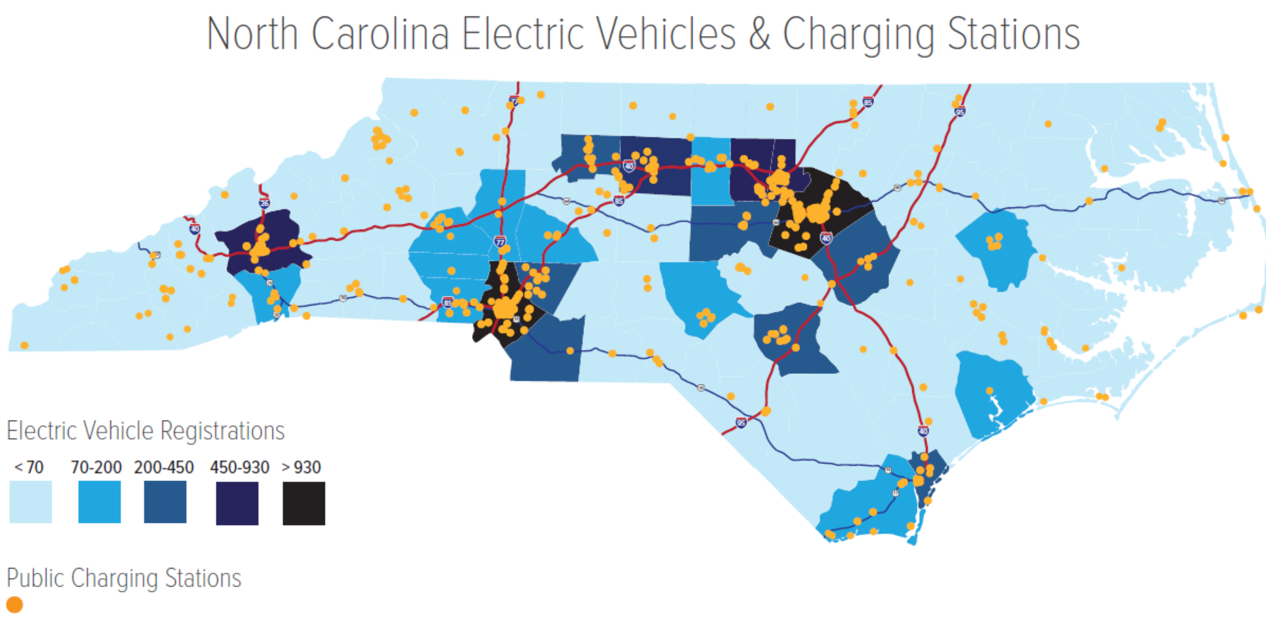
Current Status and Market Trends

Nearly every automaker is planning to introduce more EVs and models in the coming years. While projections differ, some experts believe that light-duty EVs will reach price parity with gasoline vehicles within the next ten years (Bloomberg NCF 2019). Once EVs reach price parity with gasoline vehicles, adoption is expected to skyrocket. The figure below is from an analysis completed by KPMG for the North Carolina Department of Transportation for the 2019 North Carolina Zero-Emission Vehicle Plan. This analysis estimates that North Carolina will have between 50,000 and 100,000 EVs



Source(s): Data received from NCDOT; https://www.afdc.energy.gov/evi-pro-lite; KPMG Analysis by 2025 and between 150,000 and 350,000 EVs by 2030. As of August 31, 2019, 9,614 cars were registered in the state. North Carolina's Transportation sector accounts for 32% of the greenhouse gas emissions (NCDOT 2019).

Currently, adoption of EVs is not evenly spread between all regions and demographics within North Carolina. The Fayetteville region does not have the same level of adoption as the largest metropolitan areas in the state, but has higher levels of adoption than rural areas, as shown in the map below (Saxton 2018). As the EV ranges continue to improve and the difference between the price of an EV and a similar internal combustion engine (ICE) vehicle decreases, it is reasonable to assume that adoption will increase in all areas of the state.



Electric Vehicle Models Available in North Carolina

The number and type of EV models available vary dramatically across states. It is also important to note that most available EV models are light duty sedans, so customers who prefer trucks and SUVs may not have access to a desirable EV option. NCCETC researchers compiled a database of available makes and models of plug-in vehicles (both all electric and plug-in hybrids) that are available for sale in North Carolina. The researchers called dealers within 100 miles of Fayetteville to confirm that these makes and models are available for sale. A vehicle was considered available for sale if it could be ordered and delivered to a dealership; there is no guarantee that a given dealer will have these vehicles on the floor on any given day. The table below lists basic information about the available makes and models. Additional details about the vehicles, including vehicles that are available in other parts of the U.S. outside of North Carolina, are available in the full spreadsheet, which can be accessed at https://docs.google.com/spreadsheets/d/1BYllth2XrSJBrsoFFgeIQ_95r89FnvszcOR8-yQwJdc/edit?usp=sharing and Plugincars.com provides a list of electrically powered cars, along with pricing and other details.

North Carolina Electric Vehicle Forecast November 2019

Make	Model	Year	Electric Range [miles]	Total Range [miles]	EPA Size Class	EV Type	Time to Charge Battery	Battery Capacity [kWh]	Base Model MSRP [2019 USD]
Audi	e-tron	2019	204	204	Standard Sport Utility Vehicle 4WD	BEV	10 hrs at 240V	95.0	74800
BMW	530e	2020	21	350	Compact Cars	PHEV	3 hrs at 240V	12.0	53900
BMW	745e xDrive	2019	16	290	Large Cars	PHEV	4 hrs at 240V	12.0	96545
BMW	i3	2019	153	153	Subcompact Cars	BEV	5 hrs at 240V	42.0	44450
BMW	i3 with Range Extender	2019	126	200	Subcompact Cars	PHEV	7 hrs at 240V	42.0	48300
Chevrolet	Bolt EV	2020	259	259	Small Station Wagons	BEV	10 hrs at 240V	60.0	42110
Chrysler	Pacifica Hybrid	2020	32	520	Minivan - 2WD	PHEV	2 hrs at 240V	16.0	39995
Ford	Fusion Energi Plug-In Hybrid	2019	26	610	Midsize Cars	PHEV	2.6 hrs at 240V	9.0	36595
Jaguar	I-PACE	2020	234	234	Small Sport Utility Vehicle 4WD	BEV	13 hrs at 240V	90.0	69850
Kia	Niro Plug-in Hybrid	2019	26	560	Small Station Wagons	PHEV	2.25 hrs at 240V	9.0	28500
Mini	Cooper SE Countryman ALL4	2019	12	270	Midsize Cars	PHEV	3 hrs at 240V	8.0	36900
Mitsubishi	Outlander PHEV	2020	22	310	Small Sport Utility Vehicle 4WD	PHEV	3.5 hrs at 240V	12.0	36095
Nissan	Leaf (40 kWh battery pack)	2019	150	150	Midsize Cars	BEV	8 hrs at 240V	40.0	29990
Nissan	Leaf (62 kWh battery pack)	2019	226	226	Midsize Cars	BEV	11 hrs at 240V	62.0	36550
Nissan	Leaf SV/SL (62 kWh battery pack)	2019	215	215	Midsize Cars	BEV	11 hrs at 240V	62.0	38510
Porsche	Panamera Turbo S e-Hybrid	2020	14	450	Large Cars	PHEV	3 hrs at 240V	14.1	187700
Porsche	Taycan 4S	2020	242	242	NA	BEV	9 hrs at 11 kW AC	93.4	103800
Tesla	Model 3 Long Range AWD	2019	310	310	Midsize Cars	BEV	10 hrs at 240V	74.0	47990
Tesla	Model 3 Standard Range Plus	2019	240	240	Midsize Cars	BEV	9.5 hrs at 240V	50.0	38990
Tesla	Model S Long Range	2019	370	370	Large Cars	BEV	12 hrs at 240V	100.0	79990
Tesla	Model X Long Range	2019	325	325	Standard Sport Utility Vehicle 4WD	BEV	12 hrs at 240V	100.0	84990
Tesla	Model Y Long Range	2020	273	273	NA	BEV	8 hrs at 11 kW AC	75.0	48000
Toyota	Prius Prime	2020	25	640	Midsize Cars	PHEV	2 hrs at 240V	9.0	27600
Volvo	S60 AWD PHEV	2020	22	510	Compact Cars	PHEV	3 hrs at 240V	10.4	55400
Volvo	S90 AWD PHEV	2020	21	490	Midsize Cars	PHEV	3 hrs at 240V	10.4	63200
Volvo	XC60 AWD PHEV	2020	19	520	Small Sport Utility Vehicle 4WD	PHEV	3 hrs at 240V	10.4	53950
Volvo	XC90 AWD PHEV	2020	18	520	Standard Sport Utility Vehicle 4WD	PHEV	3 hrs at 240V	11.6	67000

Links to corresponding fact sheets can be found here:
BEV Marketplace
PHEV Marketplace

Local Dealership Information

PWC Development and Marketing performed on-site surveys of local dealerships and interviewed several sales managers, general managers, and the North Carolina Association of Auto Dealers (NCAAD) Chairman, Jay Wyatt, Dealer Principal Valley Auto World Volkswagen, Fayetteville. This provided insightful information about the car purchasing habits of the community, general barriers to the EV market in this region, reasons customers choose to purchase EVs, future market trends, and drivers of EV expansion. Most relevant information is recapped below:

- **Bryan Honda**
  Charging Stations
  Three charging stations on-site; of which two are for public charging and available without charge upon request.
  Vehicles
  Year-to-Date vehicle sales: one PHEV Clarity, Customers are given a charger with purchase.
  Trend
  Not planning to order EVs in 2020
- **Crown Ford**
  Charging Stations
  None
  Vehicles
  None on the lot, none sold
  Trend

Not planning to order EVs in 2020

- **Fayetteville Automall (Volvo, Acura, Mitsubishi, Kia)**
  Charging Stations
  Two public charging stations available without charge upon request.
  Vehicles
  KIA #1 hybrid dealer in U.S. in 2016; sold 150. There was $6,250 federal rebate at that time. Since rebate money has expired, they have not stocked any EVs. Mitsubishi does not have EVs on the lot.
  Trend
  By 2025, Volvo will only offer hybrid and EVs in their product line.
- **Flow Nissan**
  Charging Stations
  One 50 kW public charging station that is available without charge during business hours.
  Vehicles
  Three – four Nissan Leafs sold this past year. None currently on the lot.
  Trend
  Leaf sales on a downward trend. Nissan plans to launch 12 electric or electrified vehicles by 2022, including a delivery van.
- **Lafayette Ford and Lincoln**
  Charging Stations
  Two public charging stations with two more being installed at the request of Lincoln.
  Vehicles
  25-40 ZEVs sold per year
  Trend
  Ford has presold all Mustang Mach Es and is spending significant money on EV development and promotion. Ford is planning to offer a hybrid option for every vehicle.
- **Lee Hyundai**
  Charging Stations
  None
  Vehicles
  Kona EV, Ioniq EV and Ioniq PHEVs are only available in ten states. North Carolina dealers cannot order at this time.
  Trend
  No perceived trend, states get approved for sale of Hyundai EVs based on ZEV Plan and legislation.
- **Power Swain Chevrolet**
  Charging Stations
  None
  Vehicles
  All electric Bolt is available, no longer make Volt, two Bolts on the lot with $12,000 mark-down. Two-three ZEVs sold a year.
  Trend
  No imminent change in this market.

- **Reed-Lallier Chevrolet**
  Charging Stations
  One public charging station available without charge during business hours.
  Vehicles
  Volt PHEV no longer available. Have two Bolt EVs on the lot. Sold one Bolt last year.
  Trend
  It will be three - five years before we see an appreciable increase in EV sales. Manufacturers have made a commitment to build electric, states are making plans to increase EV sales to include consumer rebates and tax incentives.
- **Rick Hendrick Toyota**
  Charging Stations
  None
  Vehicles
  Two Prius Prime PHEVs sold in 2019.
  Trend
  Slow adoption in Fayetteville
- **Valley Auto World**
  Charging Stations
  One public charging station, billed through ChargePoint.
  Vehicles
  20-25 EVs sold per year
  Trend
  See more interest in larger cities but all manufacturers are developing EV technology. Ford and Volkswagen are collaborating with Argo Al to share the cost of EV and self-drive development. There is a global push for EV development and manufacturing to meet environmental mandates. Valley expects to have new EVs available on the lot in 2021.

In summary, most dealerships site upfront cost, culture and education, charging infrastructure and charging convenience, battery life, depreciation, and high fuel efficiency of ICE vehicles as key barriers to EV sales in Fayetteville. However, most are alert and preparing for future change in the marketplace. To quote one sales manager, "*We are leaning forward in a foxhole*."

Local electric rates do not seem to be a purchasing factor for most customers. The majority purchase an EV because they have a concern about the environment. However, there are a few who consider fuel and operational savings as top priority and are stimulated to purchase when tax incentives and rebates are available.

National Trend

National market trends indicate that U.S. electric vehicle sales will require incentive support for the next three years. Despite lower costs and improvements in charging infrastructure, the U.S. will be the slowest major market to electrify, according to Boston Consulting, largely because of low gasoline prices and the brisk demand for SUVs. However, EVs currently account for 8% of global sales. Sales projections are expected to increase to 30% by 2025 and over 50% by 2030 (Automotive News

2020). Automakers have committed $300B in global development and continue to invest in vehicle charging infrastructure. This uptick in sales and investment in electric vehicle models by automakers will place pressure on all automakers, supplies and government leaders to support electric vehicles.

Cost to Own and Operate an Electric Vehicle

Currently, the purchase price of EVs tends to be notably more expensive than that of comparably sized ICE vehicles (IEA 2019). That said, the operational expenses of EVs are typically cheaper due to savings from lower fuel (Sivak & Shoettle 2018) and maintenance costs (CARB NDa, Palmer et al. 2017). Thus, when comparing the economic value of electric and ICE vehicles, it is important to evaluate both their upfront costs as well as their long-term operating costs. Taken together, these components form the Total Cost of Ownership (TCO) of a vehicle.

TCO is useful for understanding all asset-related costs over a designated period of time, and it can help consumers compare between options when considering which vehicle might be the best investment. Of course, consumers do not make purchase decisions based on cost alone, and studies that have sought to forecast market trends have demonstrated that consumer choice is also affected by consumer characteristics, vehicle characteristics, and contextual factors (Wu et al. 2015). Still, TCO is a useful concept for understanding when an electric vehicle might make economic sense. In fact, it has been suggested in the literature that customers "should be educated about the TCO fitting to their respective vehicle preference and driving distance" (Wu et al. 2015). In line with this, several utilities – including Southern California Edison and PG&E – offer simplified vehicle TCO calculations on their respective websites (SCE 2019, PG&E 2019), and the California Air Resources Board has organized a list of notable TCO calculators (CARB NDb).

Vehicle Cost

Purchase costs are currently seen as the main barrier to wider adoption of EVs (IEA 2019, Baik et al. 2019). In the *Global EV Outlook 2019* report, the International Energy Agency (IEA 2019) found that "purchasing a standard medium size EV is approximately 40% more expensive than a conventional ICE vehicle of similar size" (IEA 2019). Importantly, despite this current price gap, the downward trajectory of battery costs is expected to significantly decrease the purchase price of EVs in coming years (Soulopoulos 2017).

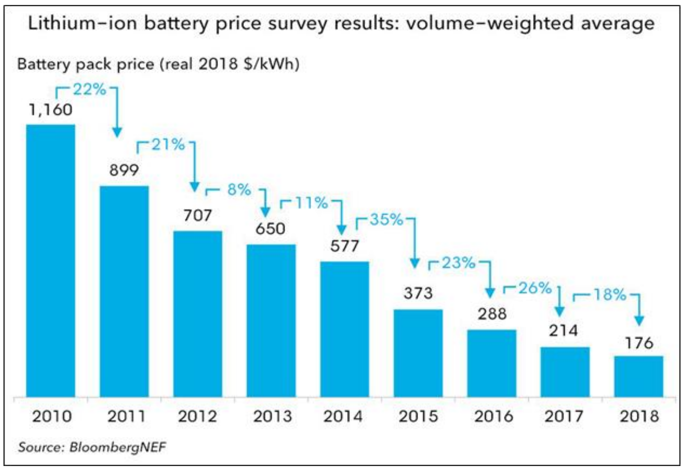
Looking forward, Bloomberg New Energy Finance (BNEF) projected that the purchase price of electric vehicles will reach price parity with ICE vehicles sometime around 2025 (Soulopoulos 2017). And, by 2030, they project that the average EV in US and European markets will be "cheaper than a comparable ICE [vehicle] in all market segments" (Soulopoulos 2017). More recent analyses from McKinsey & Company and the ICCT respectively have similarly found that EVs will likely reach purchase price parity by sometime in the mid-2020s (Baik et al. 2019, Lutsey and Nicholas 2019).

Importantly, price parity will likely occur at different times for different market segments and geographic regions (Soulopoulos 2017, Lutsey and Nicholas 2019). Additionally, financial incentives at the state and federal level can and do make a difference in offsetting the upfront cost of EV options. Most notably, the federal IRS tax credit can offset each per vehicle EV purchase by $2,500 to $7,500 depending on vehicle size and battery capacity (EERE ND). Currently, the Office of Energy Efficiency & Renewable Energy provides a comprehensive list of EV-related tax credits and other incentives available at both the state and federal level on their website [Electric Vehicle Tax Credits & Other Incentives] (EERE ND).

Battery Prices

Of all the various cost components that form EV purchase prices, batteries are expected to change the most drastically over the next decade. As of 2017, the battery made up approximately 48%-55% of the purchase price of a "mass manufactured EV" (Soulopoulos 2017); however, by 2030, the battery share of the purchase price may drop as low as 18%-23% (Soulopoulos 2017). These projections are informed by rapidly decreasing prices of li-ion battery packs. From 2010 to 2018, the volume-weighted average price of a battery pack fell approximately 85% from 1,160 $/kWh to 176 $/kWh as shown by Figure 1 (Goldie-Scot 2019). This represented an average decline in price of 20.5% per year (Goldie-Scot 2019).

Figure 1: Lithium-ion volume weighted average battery price survey results from Bloomberg NEF.



Into the future, BNEF estimated that li-ion battery pack prices will hit 94 $/kWh by 2024 and as low as 62 $/kWh by 2030 (Goldie-Scot 2019). Forecasts from other technical reports have also suggested that there will be large decreases in the price of EV battery packs throughout 2020 to 2030 (Lutsey and Nicholas 2019).

Electric Vehicle Supply Equipment Costs

For residential EV owners, purchase and installation of electric vehicle supply equipment (EVSE) will typically be small compared to the purchase cost of the vehicle. Project cost data collected by HomeAdvisor indicated that typical upfront EVSE costs – including both purchase and installation – ranged from $435 to $987 with an average price of $708 (HomeAdvisor 2019). Assuming a vehicle purchase cost of $30,000 to $50,000, costs associated with EVSE might only represent 1% to 2% of the total upfront costs associated with vehicle purchase.

For fleets, medium-duty and heavy-duty (MDHD) vehicle owners, EVSE costs can be substantial. Depending on what is required, non-residential upfront EVSE costs can vary tremendously, but it is not unreasonable for per unit purchase and installation costs to be many thousands of dollars more expensive than in residential set-ups (Smith and Castellano 2015). For example, if free-standing units are required, both the unit and installation will be more expensive, and DC fast charging required for MDHD vehicle fleets can be in excess of $50,000 per EVSE unit (Smith and Castellano 2015). Given the context-dependent price differences, EVSE expenses can be an especially important consideration when assessing TCO of non-residential-use vehicles.

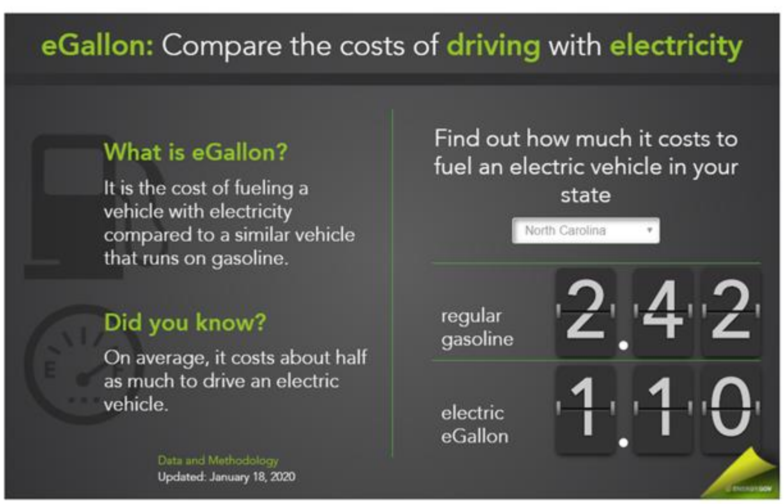
Maintenance and Repair Costs

Maintenance and repair can include a wide array of costs and can vary significantly depending on the assumptions that TCO modelers make. In general, maintenance costs for EVs – all electric motor fueled especially – are typically thought of as lower than those of their ICE vehicle counterparts. This cost difference is attributable to EVs applying less wear on brakes and having fewer moving parts (Palmer et al. 2017). ICE vehicles have more moving parts that require ongoing and frequent maintenance. Items that do not need to be replaced in a battery powered EV include oil, fan belts, air filters, timing belts, head gaskets, cylinder heads, and spark plugs. In addition, regenerative braking can extend the life of the brakes on electric cars. Although the annual difference in maintenance costs may be fairly small – Palmer et al. measured it to be roughly $100 to $150 per year depending on the region – it can contribute to a notable savings over the lifetime of the vehicle. However, the battery in an EV may need to be replaced within eight - ten years and may cost $1,000 - $6,000.

If modelers understand maintenance costs to include major repairs – such as battery replacement in the case of EVs or engine rebuilds in the case of ICE vehicles – the lifetime cost projections for vehicle ownership can increase substantially. For residential vehicle owners, it could make sense to assume that an EV is resold or scrapped before any major repairs are needed when modeling TCO. A 2016 report from the Department of Energy indicated that most EV manufacturers offered an eight-year warranty on their vehicle battery (EERE 2016), and there are many examples of TCO calculations that assume vehicle ownership lifetimes shorter than eight years (Palmer et al. 2017). For fleet operators that have vehicle repair technicians on staff, it could make sense to explore longer periods of ownership and include cost accounting for major vehicle part failures due to the reduced cost of in-house vehicle maintenance.

Fuel Costs

Fuel costs represent expenses associated with the refueling of a vehicle and typically account for a large portion of a vehicle's yearly operating expenses. Annual fuel cost of EVs is reported to average $1.10/gallon in North Carolina (Energy.gov 2019). However, EV drivers charge at work or from free public charging stations, in addition to charging from their home; therefore, fuel costs may be much lower. In Cumberland County, Level 1 and Level 2 charging is typically free. One dealership in Fayetteville charges $4.95/session + $2.11/hour energy fee and an additional $25/hour after four hours.



https://www.energy.gov/articles/egallon-how-much-cheaper-it-drive-electricity

In a comprehensive study of fuel costs across every state in the US, it was found that the average annual cost of fueling a typical new gasoline vehicle was $1,117 while the average annual cost of fueling a typical new EV was $485 (Sivak and Schoettle 2018). Over a five-year ownership window, owning an EV would then correspond to a total fuel savings of $3,160.

Dealerships typically assume an average kWh cost when comparing fuel savings on EVs. The Department of Energy's eGallon allows EV drivers to see how much they can save on fuel by using electricity instead of gasoline. The price of an eGallon tells consumers how much it costs to drive an EV the same distance you could go on a gallon of unleaded gasoline in a similar car. This difference varies from state to state and between utility territories. This savings is based on state averages and does not consider utility price signals that may offer greater savings potential or free charging opportunities. The "eGallon" is measured as an "implicit" cost of a gallon of gasoline. It is calculated by multiplying the average residential electricity price (EP) in the state by the average comparable passenger car adjusted combined fuel economy (FE) by the average fuel consumption of popular EVs (EC), as follows: eGallon ($/gal) = FE * EC * EP.

Given that EVs rely on electricity for fuel, their savings can be highly sensitive to utility rate structures. Using the assumptions below, NCCETC conducted multiple sensitivity analyses to assess the impact of rate design, consumer behavior, fleet size, and demand-side management on electricity costs:

EV assumptions for fuel cost sensitivity analyses:

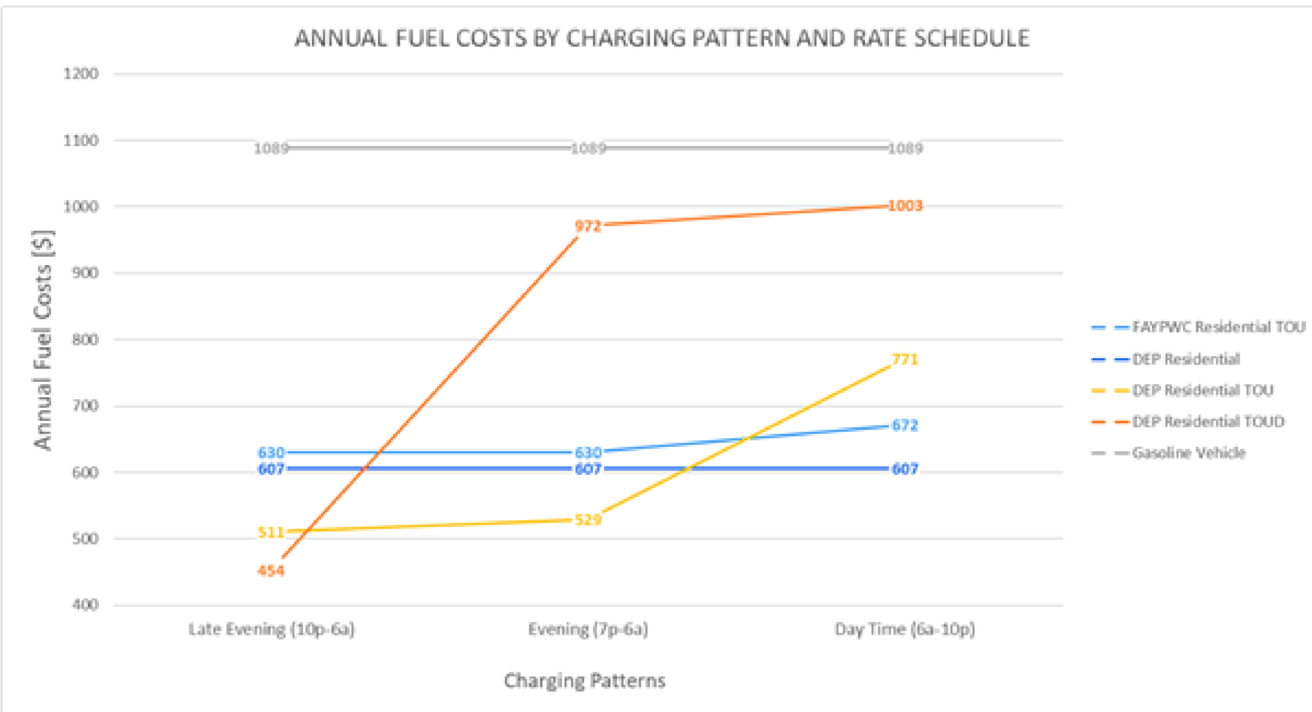
Parameter	Value	Notes	Source
Charger Rating	$10\ [kW]$	Designated "Level 2 – Standard" in the rate calculator.	CARB 2019
Daily Miles per Vehicle	$31.08 \left[\frac{miles}{day}\right]$	Estimated using average annual VMT by light-duty vehicles: $11,346 \left[\frac{miles}{year}\right] \cdot \frac{1}{365} \left[\frac{year}{days}\right] = 31.08 \left[\frac{miles}{day}\right]$	AFDC 2019
Vehicle Fuel Economy	$0.32 \left[\frac{kWh}{mile}\right]$	Mean fuel economy of light-duty BEVs of model years 2019 and/or 2020.	EERE 2019
Charging Efficiency	85%	Efficiency losses can vary widely depending on a variety of factors. In a study by Sears et al. using 1008 charge event observations, overall charge efficiency was measured at 85.1%.	Sears et al. 2014
Taxes and Other Fees	0%	Taxes and percent-based fees were not considered.	NA

ICE vehicle assumptions for fuel cost analysis:

Parameter	Value	Notes	Source
Daily Miles per Vehicle	$31.08 \left[\frac{miles}{day}\right]$	Estimated using average annual VMT by light-duty vehicles: $11,346 \left[\frac{miles}{year}\right] \cdot \frac{1}{365} \left[\frac{year}{days}\right] = 31.08 \left[\frac{miles}{day}\right]$	AFDC 2019
Vehicle Fuel Economy	$24.9 \left[\frac{miles}{gal}\right]$	Value corresponds to model year 2017 average estimated real-world fuel economy of vehicles in the US market.	EPA 2019

Fuel Cost	$2.383\left[\frac{\$}{gal}\right]$	**Value corresponds to the average price of regular gasoline reported by EIA for the Lower Atlantic East Coast as of 02 December 2019.**	**EIA 2019**

Electricity rates can be constructed in many different ways, and changes in rate designs can modify vehicle TCO significantly. In the chart below, fueling costs are compared between (1) FAYPWC's residential rate, (2) DEP's residential rate, (3) DEP's residential TOU rate, (4) DEP's residential TOU + demand rate, and (5) a gasoline fuel vehicle (Annual Fuel Costs). As indicated by DEP's rate options, TOU rates incentivize EV owners to charge at off-peak times. In comparing DEP's normal volumetric rate with their TOU offerings, we see that heeding price signals can contribute to an annual savings of approximately $78 to $153. In this way, savings from alternative rate designs can be helpful in keeping fuel costs low. That said, ignoring the TOU pricing signal can result in drastically more expensive bills. This is especially true for rate designs that include demand charges such as the DEP Residential TOUD rate. Still, it is worth noting that – under the assumptions provided – the most expensive residential electricity costs are still less than projected gasoline fuel costs.

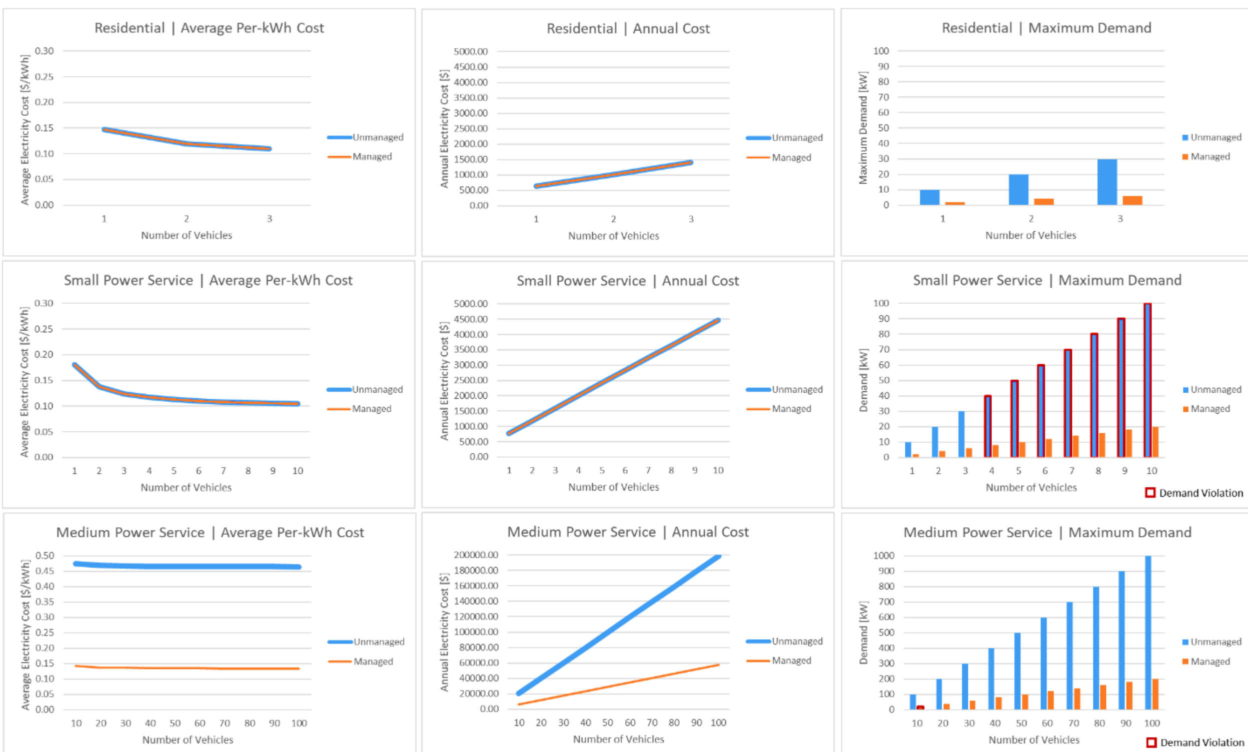


Annual Fuel Costs: Annual fueling costs based on the FAYPWC residential rate, the DEP standard residential rate, the DEP TOU residential rate, the DEP TOU + Demand residential rate, and a gasoline-fuel vehicle. Calculations follow assumptions found in above tables. Additionally, calculations correspond to a single vehicle and assume unmanaged charging. Due to model limitations, DEP TOU rates assume March-September on-peak and mid-peak timing for the entire year.

Two other important concerns when considering rate costs are the total number of vehicles owned and whether charging is managed. Managed charging here refers to the use of smart EVSE to control the level of power delivered during a charging period. For example, an operator using a managed charging strategy would use smart EVSE to intentionally minimize demand across charging periods. Thus, if a vehicle required 50 kWh of charge and an operator owned a charger rated at 10 kW with ten hours allotted for charging, they would choose to charge at 5 kW for ten hours instead of charging at 10 kW for five hours. In this way, the operator's peak demand would only be 5 kW. A 10 kW monthly peak may seem trivial, but what if the operator owned a fleet of 20 vehicles? Under those conditions, a managed charging strategy would curtail 100 kW of demand rather than just 5 kW.

Of course, demand is only of concern for consumers if they are in a rate schedule that applies demand charges. Most residential service rates do not have demand charges, and so most residential EV owners are unlikely to benefit from managed charging. However, as indicated by the example in the previous paragraph, fleet operators should absolutely consider managed charging when contemplating EV adoption.

The chart panel below shows average per-kWh costs, annual costs, and maximum demand expected under various rate schedules for both unmanaged and managed charging strategies. Modeled rates correspond to FAYPWC's residential service, small power service, and medium power service schedules (FAYPWC 2019).



Panel of figures detailing average per-kWh costs, annual costs, and maximum demand for FAYPWC's residential, small power service, and medium power service rates. Evening charging from 7pm to 6am is assumed for all scenarios (NCCETC 2020)

Note that, without managed charging, a fleet operator under a small power service agreement would violate the demand limits (0 – 30 kW) of their rate schedule after only four EVs (Small Power Service | Maximum Demand). With managed charging, they could operate many more vehicles before needing to switch to a different rate schedule. For larger fleet operators under a medium power service agreement, the need to manage charging would be even greater as FAYPWC's medium power service rate schedule includes demand charges. Even at only 20 EVs, savings from managed charging would exceed $28,000 annually. At 100 EVs, the annual cost savings would be over $140,000 (Medium Power Service | Annual Cost).

Other Costs

Other costs that are sometimes but not always considered include taxes, insurance, and vehicle registration costs (Palmer et al. 2017). While the differences between EVs and ICE vehicles with respect to these costs are typically very small, recent reporting from Consumer Reports indicated that of the 26 states that currently impose annual fees on EVs, “11 charge more than the amount owners of similar gas-powered cars pay in gas taxes, and three charge more than twice the amount” (Plungis 2019). This is especially pertinent because, among 12 additional states considering EV fee proposals, “10 would have fees greater than what a driver on average would pay in gas taxes” and “seven of those states would ratchet up the fees over time to twice the amount” (Plungis 2019).

As policies around EV fees continue to evolve, fees may become an increasingly important part of TCO calculations. For example, this past year, Illinois lawmakers proposed a $1,000 annual registration fee for EV owners. After being met with “pushback from EV manufacturers and owners alike,” the fee was reduced to $248 – just $100 more than what non-electric vehicle owners pay (Channick 2019). Not all states are taking such an aggressive approach, though. In an example from Vermont, state lawmakers backed away entirely from a plan to increase EV fees after the state’s Agency of Transportation concluded that fees should be postponed until “the market for EVs moves beyond the ‘early adopter’ phase” (Plungis 2019).

Considerations When Interpreting Total Cost of Ownership

TCO calculations offer a comprehensive means of comparing the full economic cost of differing vehicle options. That said, estimates can be very sensitive to assumptions. Given this, it is important to recognize and clarify potential limitations to promote better understanding and accurate interpretation of results. Some key considerations are provided below:

- TCO calculation methods are not standardized in the literature (Palmer et al. 2018). Neither the assumptions nor calculation methods used in one model are guaranteed to be the same as those used in another. For example, TCO models may vary in how they calculate:
    - The time-value of money,
    - The resale value of a vehicle,
    - Vehicle lifetime,
    - And more.
- The economics of vehicle ownership can change quickly over time (Palmer et al. 2018). Thus, it is important to recognize that estimates can also quickly become obsolete. It seems reasonable to expect that more current estimates will typically be more accurate than less current estimates.
- The true TCO of a vehicle can differ significantly by geography due to varying fuel prices, incentive opportunities, taxes, and average mileage (Palmer et al. 2018). This is not always represented in all TCO models. Given this, the best TCO estimates will likely be those tailored to the region in question.

Currently, EV charging stations – often called EV supply equipment (EVSE) – exist at one of three levels: Level 1, Level 2, or DCFC. Each EVSE level corresponds to a different maximum amount of power supplied, and higher maximum power translates to faster charge times (EERE 2019). EVs have varying power acceptance rates. If the EV charging station offers less power than the vehicle's maximum acceptance rate, the EV charging station is the limiting factor in charge time. If the vehicle's acceptance rate is lower than the EV charging station's maximum output rate, the vehicle is the limiting factor.

The table below details how different level EVSE vary based on power levels, range per hour of charge, and locations where these stations are typically installed (CSE 2016).

Charger Type	Voltage	Amps	Charging Loads	Miles of Range per Hour of Charge	Where to Charge
AC Level 1	120V 1-Phase AC	12-16 Amps	1.4 - 1.9 kW	4-6 miles/hour	At home or workplace
AC Level 2	208V or 240V 1-Phase AC	12-80 Amps (Typ 32 Amps)	3.3 kW (Low) @ 20 amps	8-12 miles/hour	At home, workplace, or public charging station
			6.6 kW (Med) @ 40 amps	16-24 miles/hour	
			9.6 kW (High) @ 50 amps	32-48 miles/hour	
			19.2 kW (Highest) @ 100 amps	> 60 miles/hour	
DC Fast Charge	208V or 480V 3-Phase AC	< 125 Amps (Typ 60 Amps)	< 90 kW (Typical 50 kW)	80% in < 30 minutes	Public or commercial

Electric vehicle charging levels with associated details (CSE 2016)

Level 1 charging corresponds to the use of a standard 120-volt wall outlet. As such, it is mainly suitable for residential charging, although many individuals now opt for Level 2 charging in their homes given the speed advantages that Level 2 provides (ChargeHub 2019). For those that have shorter commutes, charging at Level 1 overnight can represent a cost-effective solution. Unfortunately, it can also be limiting if one needs to drive longer distances for two consecutive days, as a nine-hour overnight charge might only restore approximately 40 – 50 miles of range (Saxton 2011, CSE 2016).

Level 2 charging provides a considerable boost in charging speed. Many in the industry recommend Level 2 charging for home charging, as it typically ensures that a vehicle will be ready for a longer commute when charged overnight (ChargeHub 2019, Bean 2019). For customers that own plug-in hybrids with comparatively small battery capacities, Level 1 charging will likely be sufficient. Level 2 charging requires a 240V or 208V circuit. A flexible home charger is one that can be set to an amperage that works best for the home.

As indicated by the table, DCFC is typically used to charge rapidly. It also tends to be significantly more expensive than Levels 1 and 2 (ChargeHub 2019). As a result, DCFC equipment is generally reserved for non-residential uses and is more frequently seen along heavy traffic corridors (EERE 2019b). In this way, it more closely fills the role that gas stations play for internal combustion engine vehicles.

Connector Plug Types

At charging Levels 1 and 2, most modern EVs make use of the SAE J1772 plug type (EERE 2019b). Although Tesla vehicles have a unique connector, they also come with adapters that allow use of the J1772 plug type (ChargeHub 2019). The standardization of this plug type across Level 1 and 2 charging systems has helped to ensure compatibility "with nearly all non-fast charging workplace and public chargers" (EERE 2019b).

DC fast charging does not currently have a standardized connector. Thus, connectors come in one of three variants: SEA Combo, CHAdeMO, and Tesla. The SEA Combo is actually a combination plug that builds upon the original architecture of the J1772 and allows "use of the same receptacle for all levels of charging" (EERE 2019b). Currently, BMW, Volkswagen, and Chevy, have adopted the SEA Combo for use in fast charging. CHAdeMO connectors are compatible with Nissan, Mitsubishi, and Kia models (Duke Energy 2019c). Fortunately, newer fast-charging stations tend to "have outlets for both SEA and CHAdeMO fast charging" (EERE 2019b). Tesla connectors only work with Tesla vehicles, but Tesla vehicles are able to make use of both SEA Combo and ChAdeMO connectors through use of adapters (Duke Energy 2019c).

EVSE Upfront Costs

Costs of EVSE purchase and installation can vary tremendously depending on a variety of factors. Core costs include, but are not limited to, the cost of the EVSE unit itself, connecting to electrical service, and required electrical service upgrades (Smith and Castellano 2015). EVSE units are sold by a variety of manufacturers and can come with a wide range of added functionality that affects the unit price. Examples of potential features include automated data collection, network-enabled phone and web-based control, and metering (Smith and Castellano 2015). Another key factor affecting unit cost is the charging level with Level 1 being the cheapest and DCFC being the most expensive. Project cost data collected by HomeAdvisor indicated that respondents payed between $300 and $600 for Level 1 EVSE units and between $500 and $700 for Level 2 EVSE units (HomeAdvisor 2019). Costs of installation similarly scaled upwards by charging level.

Notably, non-residential EVSE units can cost significantly more. In a 2015 report prepared for the U.S. Department of Energy's Clean Cities program, the authors observed that non-residential EVSE unit costs ranged from $300-$1,500 for Level 1, $400-$6,500 for Level 2, and $10,000-$40,000 for DC fast charging (Smith and Castellano 2015). The authors also indicated that installation costs varied greatly by site; ballpark installation costs could amount to $0-$3,000 for Level 1, $600-$12,700 for Level 2, and $4,000-$51,000 for DC fast charging (Smith and Castellano 2015).

From this, it becomes clear that installation costs can easily exceed unit purchase costs. This is especially true for non-residential installation where site-specific needs may call for significant landscape modification. In particular, if the charger site is not wall-mounted inside a building structure and new electrical lines must be installed underground, the costs of installation can be tremendous. Trenching and boring operations to lay underground line are costly, and this is especially true when hard surface like asphalt or concrete must be removed and then later repaved. Trenching through paved surfaces was found to cost between $100 and $150 per foot (Smith and Castellano 2015). Pedestal mounted systems – which are typically required for parking lots – also add cost when compared to wall mounted units. The study conducted for the Clean Cities program found that pedestal mounted units cost around $500 to $700 more by unit. Level 2 pedestal units were also found to be more than $1,000 more expensive to install on-average when compared to wall mounted units (Smith and Castellano 2015). Other possible installation costs include meeting Americans with Disabilities Act (ADA) requirements, traffic protection, signage, and lighting (Smith and Castellano 2015).

Most public charging stations are Level 2 AC chargers but DCFC is essential for high mileage/long distance driving and fleets. Charging times are dependent on battery size and dispenser output, but many vehicles are capable of getting 80% charged in less than an hour. Currently there are only three types of DCFC: CHAdeMO, Combined Charging System (CCS), and Tesla Supercharger.

Charging Companies and Rates

Chargepoint's business model is unique, as they don't own the stations in their network, but rather partner with 3rd party site-hosts (property owners) and leave the pricing formula up to the site-host. Owners of Chargepoint stations can charge by the minute/hour or kWh.

Electrify America and EVgo both own and operate their charging networks and set their own pricing. EVgo, with DCFC chargers (almost all offering speeds at a max of 50 kW) in 34 states, says that they are "the nation's largest and most reliable public fast-charging network." In most of the country, EVgo prices are at $0.30/per-minute for their 50 kW stations, and a few cents less if you sign up for their $8/month plan that also includes 29 free minutes (EVgo 2020).

Electrify America says that they "offer the largest number of public, high-powered, fast-charging stations on the market" with 140 stations (offering speeds up to 350 kW) across the country as of April 2019. The charging station at the Walmart in Lumberton offers 350 kW delivery @ $.89/min, 125 kW @ $.58/min, and .75 kW @ .21/min.; there is also a $40/min idle fee applied after a ten - minute grace period. Once plugged in, the car will tell the charger how much power it can accept; this will determine the power level and the associated per-minute cost for the session (Electrify America 2020).

Tesla's network of superchargers enables Tesla drivers to recharge their cars in as little as an hour. This charging infrastructure is viewed as a competitive advantage for Tesla drivers. Tesla has about 7,600 supercharger points in North America, compared to about 1,400 charging points for

Tesla Supercharging costs vary based on vehicle and location

- Cars purchased before January 1, 2017 receive free, unlimited Supercharging for the life of the vehicle
- Cars purchased between January 1, 2017 and November 2, 2018 receive 400 kWh of Supercharging credit before paying for Supercharging
- Cars purchased after November 2, 2018 are required to pay for all Supercharging

There are 2 structures for Supercharging costs:

1. Customers are billed per kWh
2. Customers are billed per minute of charging, broken down into Tier 1 and 2 based on charging kW
    a. Tier 1 charges apply when charging at or below 60 kW
    b. Tier 2 charges apply when charging above 60 kW

Actual charges are based on location and time of charging; average costs in the US are:

1. $0.28 per kWh
2. Tier 1 $0.13/min
3. Tier 2 $0.26/min

ChargePoint. However, Tesla's overall network of super/Level 2 chargers stands at 17,700, well behind ChargePoint's 34,000 charging connectors (Forbes 2020, Trefis Team 2020).

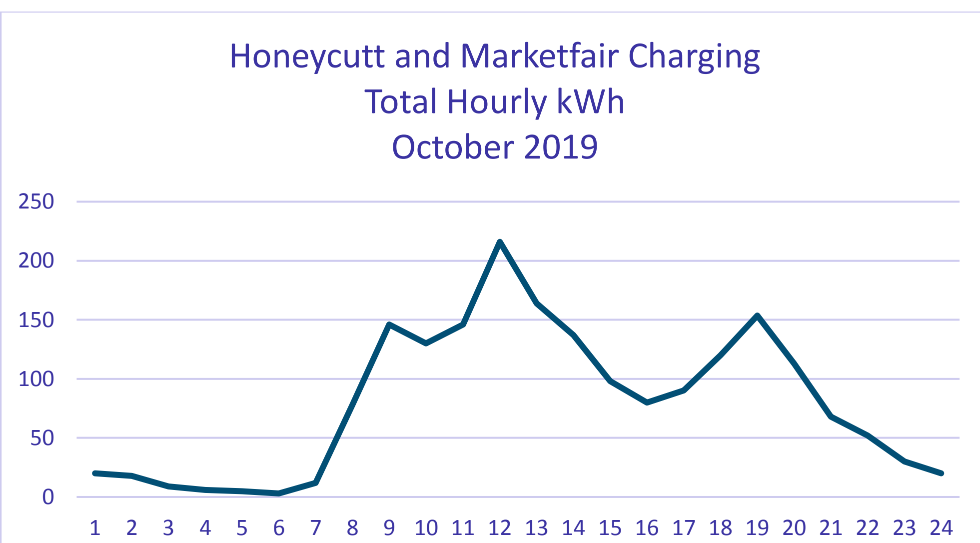
ChargePoint Level 2 Chargers in Fayetteville

PWC installed Level 2 chargers at four locations. Each charger has two charge ports. Each charge port can deliver a maximum of 40 amps of power, which equates to approximately 6.6 kW. The miles of range delivered per hour is 16-24 miles. The annual aggregate usage recorded by the PWC meters deviate less than 1% from the kWhs recorded by ChargePoint equipment. The total consumption for 12 months was 23,721, which equates to the annual electric consumption of two households.

PWC Level 2 ChargePoint Station kWh compared to MDM

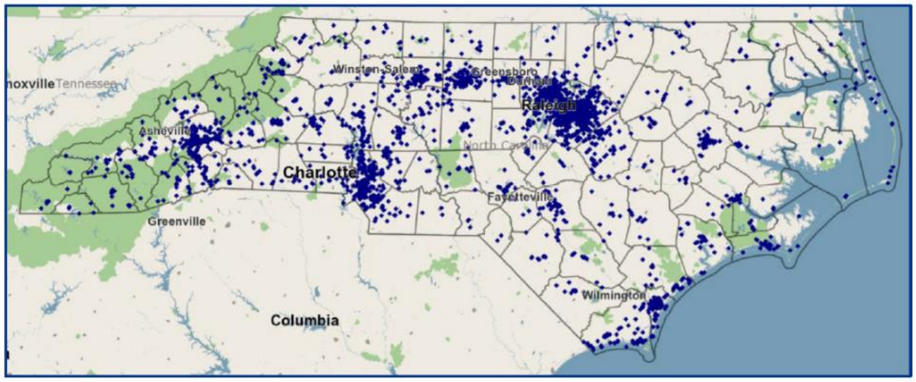
	Marketfair		Honeycutt		Clark Park		Lake Rim	
	ChargePoint	**MDM**	**ChargePoint**	**MDM**	**ChargePoint**	**MDM**	**ChargePoint**	**MDM**
Nov-18	826	834	601	605	5	5	98	99
Dec-18	948	954	286	288	4	7	19	19
Jan-19	997	1005	501	504	0	0	4	4
Feb-19	1108	1124	620	624	0	3	4	3
Mar-19	1072	1082	658	662	0	0	55	55
Apr-19	871	878	593	598	9	11	57	57
May-19	1157	1168	1070	1077	12	12	124	128
Jun-19	1002	1011	1315	1327	102	103	153	155
Jul-19	1179	1190	1325	1336	30	30	227	231
Aug-19	1087	1097	809	816	104	105	116	118
Sep-19	1316	1329	678	684	143	145	160	162
Oct-19	1148	1167	742	748	106	107	49	54
Total	**12712**	**12839**	**9196**	**9269**	**516**	**528**	**1065**	**1085**

Load analysis for the two most frequently used charging stations indicates a 68% probability that they will be used during coincident peak hours with an average peak of 5 kW.



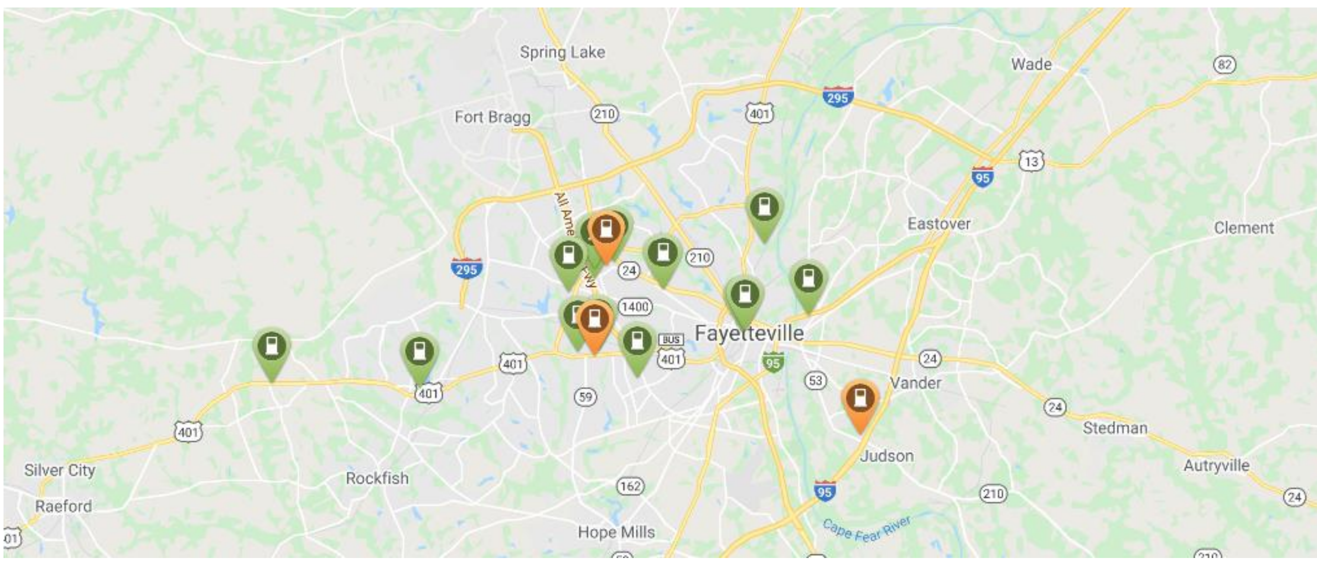
Cost on 2020 TOU Rate = $191.58 or $.10/kWh
Cost on 2020 CP Rate = $99.58 or $.052/kWh
CP: October 3, 2019 16:00 – 0 kW
Hourly kW during typical CP hours 0 – 14
CP @ 5 kW cost is $.1033/kWh

Electric Vehicle Readiness in North Carolina



In 2012 and 2013, several North Carolina Metropolitan Planning Organizations, Asheville, Charlotte, Piedmont Triad, Greater Triangle, and Raleigh developed EV readiness plans that helped spur charging station installation. Currently there are over 1,440 charging outlets across the state. North Carolina's share of the Volkswagen (VW) Settlement, an agreement between the German Automaker and the U.S. Department of Justice on behalf of the U.S. Environmental Protection Agency (EPA), will provide funds to expand the state's charging infrastructure.

Level II and DC Fast Charge locations across Cumberland County



***DCFC - Tesla Supercharger Cedar Creek Rd (DEP) 120 kW, Flow Nissan 50 kW, Harley Davidson 25 kW**

Utilities across the county are adding EV information to their web space and are participating in programs to educate the public and stimulate EV adoption. Some have contracted with a third party to supply interactive and evolving information. Apogee, PlugStar, and Plug-in NC provide white-label versions for utility marketing and branding. Functionality includes EV shopping assistance, incentives, chargers, local events, dealers, customized charging rates, and a list of local electricians.

UTILTIY	SLOGAN
Cape Hatteras Electric Cooperative	Be polite, charge at night
Duke Energy	Electric Vehicles - Shaping the future and promoting smarter, cleaner transportation
Alabama Power	Electric Transportation - Environmental Commitment
Tucson Electric Power	Electric Vehicles - Energize your ride
Pacific Gas & Electric	Save money and go green by driving an electric vehicle
Glendale Water & Power	Electric Vehicles - Clean Power = Green Future
Florida Power & Light	Electric vehicles are here to stay!

Braintree Electric Light Department	Save money. Save time. Save carbon.
Indiana Michigan Power	Driving electric cars into your future
Entergy	Driving towards a bright future
New Hampshire Electric Co-op	Plug-in to your Future - Drive Electric!
Eugene Water & Electric Board	Electric Vehicles - Fun to drive. Low carbon. Easy on your wallet.
Baltimore Gas & Electric	Skip the gas pump and live life, fully charged
Hawaii Electric Company	Electric Vehicles - Driving to a Greener Future
Delaware Electric Coop	Beat the Peak with Electric Vehicles
SMUD - Sacramento	Drive electric and save
CPS - San Antonio	Power Up with Electric Vehicles
North Carolina Cooperatives	Charge Ahead

In 2011, North Carolina received a $500,000 grant from the U.S. Department of Energy that helped to establish the North Carolina Plug-In Electric Vehicle (NC PEV) Taskforce (Duke Energy 2019e, Susser 2017, CCOG ND). The NC PEV Taskforce included a diverse array of partners "ranging from government, industry, electric utilities, non-profits, and other stakeholders." Originally headed up by Advanced Energy and the North Carolina Department of Commerce, the NC PEV Taskforce eventually transitioned into the Plug-in NC program headed up by Advanced Energy alone (Susser 2017).

Below is a list of all Plug-in NC steering committee members and their affiliations:

- Andrea Eilers, Triangle Clean Cities Coalition
- Bill Eaker, Land of Sky Clean Vehicles Coalition
- David Schatz, ChargePoint
- Diane Huis, North Carolina's Electric Cooperatives
- Jason Wager, Centralina Clean Fuels Coalition
- Joe Baum, Blue Ridge EV Club
- Lisa Poger, Duke Energy
- Marcy Bauer, EVgo
- Mike Waters, ChargePoint
- Stan Cross Brightfield Transportation Solutions
- Richard Sapienza, NC Clean Energy Technology Center

Currently, Plug-in NC has grown to include over 80 unique member organizations. These organizations can be found here: http://www.pluginnc.com/current-members/

What is Duke Energy Doing?

Currently, Duke Energy does not offer a specific electricity rate for EVs. That said, Duke Energy does offer general TOU rates which can potentially lower electricity costs if users charge during off-peak times (Duke Energy 2019b).

In Duke Energy's Electric Transportation (ET) Pilot application – currently under review by the North Carolina Utilities Commission – Duke Energy proposed offering "$1,000 rebates to as many as 800 residential customers for installation of vehicle-charging stations at their homes" as well as "rebates of up to $2,500 each to as many as 900 commercial and institutional customers to help with the costs of installing charging stations" (Downey 2019b). More details regarding Duke Energy's ET Pilot are listed below.

Proposed Electric Transportation Pilot Program

In March of 2019, Duke Energy submitted a request to the NCUC asking for approval of a $76 million investment in an ET Pilot. As indicated in Duke Energy's application, the main goals of the pilot would be to:

- Better understand EV charging behavior and the effects of charging multiple types of EVs on the Companies' bulk electric system;
- Install a foundational level of fast charging infrastructure across the Companies' service territories in North Carolina;
- Support the development of a competitive market for EV charging services and ensure customer choice in EV charging technology;
- Determine procedures to cost-effectively integrate vehicle charging by actively managing charging loads;
- Support public transit electrification and associated cost savings for public agencies in North Carolina;
- Ensure that electrification projects benefit all customers, including those who do not own EVs and low/moderate income customers; and
- Coordinate with the North Carolina Department of Environmental Quality on the Volkswagen Settlement Environmental Mitigation Trust funding, and to the extent practicable, leverage available funding streams for electrification projects (Duke Energy 2019a).

To meet these goals, Duke Energy proposed seven distinct programs: 1) the residential EV charging program; 2) the fleet EV charging program; 3) the EV school bus charging program; 4) the EV transit bus charging program; 5) the multi-family dwelling charging station program; 6) the public Level 2 charging station program; and 7) the direct current fast charging station program as a three-year pilot (Duke Energy 2019a). Below is a table that breaks down the structure and purpose of each program (Duke Energy 2019a):

Program	Details	Goals
Residential EV Charging Program	• EVSE rebates of up to $1,000 are provided for 500 DEC customers and 300 DEP customers. • Participants transmit charging load data. • Participants allow utility management of home charging during defined hours.	• Evaluate whether EVSE rebates encourage EV adoption. • Determine the value and viability of utility-managed charging.
Fleet EV Charging Program	• EVSE rebates of up to $2,500 are provided to 500 DEC customers and 400 DEP customers. • Participants must install EVSE behind a separate meter and adopt a TOU rate.	• Encourage adoption of EVs by public and private fleet operators. • Collect charging utilization data for a variety of EV types and weight-classes to better understand potential impacts.

EV School Bus Charging Station Program	• Rebates of $215,000 per bus are provided for 55 buses for DEC and 30 buses for DEP. • Participants transmit charging data. • Participants perform testing of load management and bi-directional charging capabilities. • Participants agree to hand over batteries at the end of a bus's vehicle life.	• Encourage replacement of older diesel buses with clean zero-emissions buses. • Facilitate market adoption by installing EVSE. • Collect charging utilization data to understand potential impacts • Explore potential for bi-directional power flow.
EV Transit Bus Charging Station Program	• EVSE for transit buses are installed at 60 stations for DEC and 45 for DEP. • Duke Energy contributes $75,000 per bus acquired in the last 24 months.	• Deploy charging stations to support BE bus adoption. • Collect charging utilization data to understand potential impacts.
Multi-Family Dwelling Charging Station Program	• Duke Energy installs, owns, and operates 100 EVSE for DEC and 60 for DEP near multi-family residences. • Duke Energy collects $0.02/kWh to cover network platform and transaction fees.	• Support EV adoption by residence of multi-family dwelling units.
Public L2 Charging Station Program	• Duke Energy installs, owns, and operates 100 EVSE for DEC and 60 for DEP at eligible public destination locations. • Duke Energy collects $0.02/kWh to cover network platform and transaction fees.	• Build EV driver confidence by increasing access to public charging. • Collect charging utilization data to understand potential impacts.
Fast Charging Program	• Duke Energy installs, owns, and operates 70 chargers at 35 locations for DEC and 50 chargers at 25 locations for DEP. • Duke Energy charges a fee consistent with the statewide average for fast charging offered by other stations that charge a fee and are publicly accessible. • Duke Energy calculates and updates the fee quarterly.	• Build EV driver confidence by increasing access to public charging. • Fill a market gap that might otherwise be economically impractical for non-utility operators.

Duke Energy estimated the breakdown of the ET Pilot costs to be as follows (Duke Energy):

	DEC	DEP
Residential Rebate	$ 1,175,000	$ 705,000
C&I Fleet Rebate	$ 1,925,000	$ 1,540,000
EV School Bus	$ 11,981,750	$ 6,535,500
EV Transit Bus	$ 4,671,000	$ 3,503,250
Multi-Family L2	$ 1,285,000	$ 771,000
Public L2	$ 1,285,000	$ 771,000
DC Fast Charge Network	$ 20,107,500	$ 14,362,500
Education and Outreach	$ 2,025,000	$ 1,350,000
Ongoing O&M (Project Mgmt., Networking, Charger O&M)	$ 1,125,000	$ 900,000
Sub-Total	$ 45,580,250	$ 30,438,250
Total		**$ 76,018,500**

In July of 2019, the Public Staff of North Carolina Utilities Commission recommended that regulators reject the proposal, arguing that "the three-year pilot amounted to pre-approval of EV infrastructure investments to be funded by customers" and that Duke Energy did not provide enough evidence to demonstrate that a new pilot was necessary (Walton 2019a). The North Carolina Sustainable Energy Association and the North Carolina Clean Energy Business Alliance have also called for at least partial rejection of the pilot program as it would result in "Duke privately owning a large number of charging stations" (Downey 2019b), citing the following issues:

- Disagreement over assumptions that Duke Energy used when calculating DCFC market size (NCSEA 2019) and concerns that Duke Energy mischaracterized the EV charging market (NCCEBA 2019),
- Concerns that Duke Energy would have an unfair market advantage due to their internal operational knowledge of the grid (NCSEA 2019),
- Concerns that Duke Energy is not actually prepared to "ensure that underserved communities have access to charging infrastructure" (NCSEA 2019),
- Concerns that Duke Energy's plans would grant them an unfair share in the market for vehicle charging (NCSEA 2019, NCCEBA 2019),
- Concerns that Duke Energy's application focuses too much on DCFC and not enough on Level 2 charging (NCSEA 2019),
- Concerns that Duke Energy is proposing to set electricity rates "outside the context of a general rate case pursuant to NC Gen. Stat. § 62-133" (NCSEA 2019),
- Lack of clarity regarding how Duke Energy "will bill EV drivers that charge their vehicles at Duke-owned charging equipment" (NCSEA 2019),
- Concerns over the amount of money allocated for education and outreach given Duke Energy's "track record on marketing pilot programs" (NCSEA 2019),
- Concerns that reporting should be more frequent than what is currently outlined in the Pilot application (NCSEA 2019),
- Failure to show "why… utility intervention is necessary" (NCCEBA 2019).

More recently, in October of 2019, eight automakers called upon the NCUC to urgently approve the EV Pilot "without delay" (Downey 2019b). Many non-manufacturer groups have also come out in either partial or full support the plan, including the North Carolina Justice Center, the Southern Alliance for Clean Energy, Greenlots, the City of Durham, and the City of Asheville (Walton 2019a). In total, more than 21 groups have filed comments to the NCUC in either partial or full support of the ET pilot (Downey 2019b). Notably, some partial supporting organizations have echoed concerns raised by dissenting groups. One common concern raised is that Duke is not proposing an EV-specific rate. By not addressing demand charges with an EV-specific rate, they claim that Duke is creating an unfair competitive environment where other charging companies will be forced to pay demand charges, whereas Duke will not. Currently, the proposal remains under review by the NCUC.

Full List of Organizations and Positions

Supporting Parties

- Sierra Club
- The Environmental Defense Fund ("EDF")

- The Southern Alliance for Clean Energy
- NC Justice Center
- EVBox
- Proterra Inc.
- SemaConnect
- Advanced Energy
- Adomani, Inc.
- CCOG (Centralina Council of Governments)
- Zeco System, Inc. d/b/a Greenlots ("Greenlots")
- Alliance for Transportation Electrification
- Brightfield Transportation Solutions
- Regional Transportation Alliance
- The Alliance of Automobile Manufacturers, the Association of Global Automakers, General Motors LLC, Ford Motor Company, Jaguar Land Rover North America, Daimler North America Corporation, Mitsubishi Motors R&D of America, Fiat Chrysler Automobiles, Nissan North America, American Honda Motor Company Inc, Kia Motors Corporation, and Hyundai Motor Company (collectively "Joint Automakers")
- Southeast Energy Efficiency Alliance
- ABB, Inc.
- Blue Horizons Project
- Electrify America, LLC
- GoDurham
- The City of Asheville
- The City of Charlotte
- The Natural Resources Defense Council

Opposing Parties

- The Public Staff of the North Carolina Utilities Commission
- North Carolina Sustainable Energy Association
- North Carolina Clean Energy Business Alliance

Other Parties

ChargePoint did not formally support or oppose the proposed ET Pilot. That said, most of their comments echoed concerns raised by the opposing parties.

Education

Duke Energy provides several online resources through their website that detail (1) the potential benefits of EVs, (2) EV charging considerations, (3) EV purchase options, and (4) EV initiatives being pursued by DEP. These four resources are summarized below:

Benefits of EVs

Duke Energy webpage corresponding to the benefits of EVs details considerations related to (1) performance and comfort, (2) fuel and maintenance savings, (3) convenience and practicality, (4) local economic benefits (5) environmental benefits, and (6) incentives and price (Duke Energy 2019b). Additionally, the webpage links to videos associated with these categories. These videos and their corresponding links are provided below:

- Benefits of Electric Vehicles (EVs)
- Electric vehicles (EVs) offer amazing performance.
- Electric vehicles (EVs) help you save on fuel costs.
- Electric vehicles (EVs) help you save on maintenance.
- Electric vehicles (EVs) are convenient.
- Electric vehicles (EVs) are cleaner for the environment.
- Electric vehicles (EVs) are affordable.
- Electric Vehicle Owner Testimonials

Duke Energy also provides an "Electric Vehicle Savings Calculator" that allows users to input daily miles driven, miles per gallon, and gas prices in order to calculate daily, monthly, and yearly savings. The tool assumes an average Duke Energy residential rate of $0.1117 per kWh and an average EV efficiency of 3.5 miles per kWh (Duke Energy 2019b).

Charging Your EV

The primary webpage corresponding to EV charging details general considerations as well as information about charging at home, charging on the road, and charging networks. The webpage also links to a separate page that provides information on types of chargers. This separate page details (1) things to consider when purchasing a charger, (2) Level 1, Level 2, and Level 3 charging, and (3) the types of charger connecters available (Duke Energy 2019c).

Duke Energy also provides an educational video on charging which is listed below:

- Charging an Electric Vehicle (EV)

Choosing Your EV

The webpage corresponding to EV purchase options contains a built-in "EV Selector Tool" that allows users to search through vehicle models according to body style, daily mileage needs, and price range. The page also details recent trends and sales reports in the EV market and provides a comparison chart between PHEVs and EVs (Duke Energy 2019d).

EV Initiatives

The webpage corresponding to Duke Energy's EV initiatives provides an overview of their work in the EV space (Duke Energy 2019e). The webpage details the following initiatives:

- Duke Energy's own EV fleet adoption
- A Florida-based three-year EV study entitled "Charge Florida" that is currently underway
- A Florida-based "Park & Plug" pilot program in which Duke Energy plans to add more than 530 EV chargers to public spaces and thoroughfares in Florida

- Duke Energy's stakeholder status in the federally funded North Carolina EV readiness plan entitled "NC Readiness Initiative: Plugging in from Mountains to Sea"
- Duke Energy's stakeholder status in the federally funded Ohio EV readiness plan
- Duke Energy's research group collaborations
- Duke Energy's EV tests in Kentucky

Duke Energy also provides a video on its commitment to EVs listed below:

- Why Duke Energy believes in electric vehicles.

Frequently Asked Questions

Across many of its webpages, Duke Energy provides answers to frequently asked questions. These questions include:

- What is an EV?
- Do you offer incentives or special rates for EVs?
- Is there a tax credit for plug-in EVs?
- How can I learn more about EV programs that may become available to nonresidential customers?
- Do I need a charging station?
- How long will it take to charge my EV?
- How much will it cost to charge an EV? Will my electricity bill go up?
- Are there public charging stations in my area?
- Are EV batteries tested for safety?
- I'm thinking about buying an EV. Which one should I buy?
- I'm interested in adding charging stations to my facility. Who should I contact about this?

Supporting Research Groups

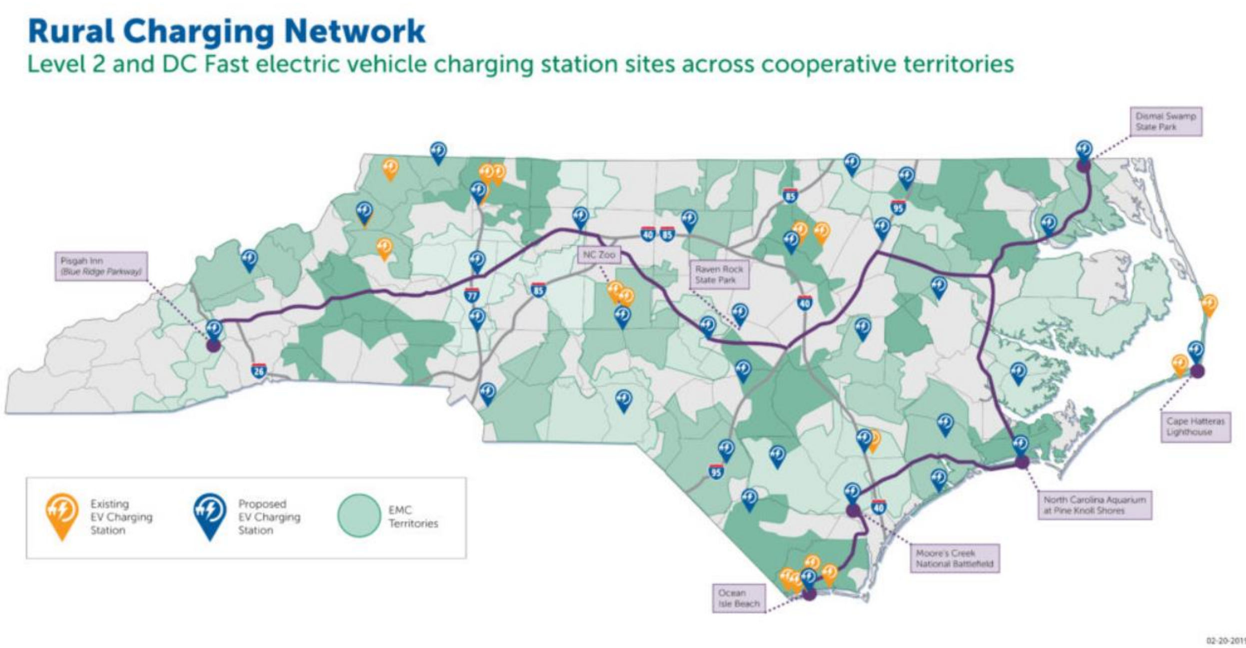
Duke Energy is also working to promote electric vehicle adoption through connections with research organizations. These organizations are listed on Duke Energy's website as affiliated research groups (Duke Energy, 2019e) and are provided here below:

- Advanced Energy
- Centralina Clean Fuels Coalition
- Charlotte Center City Partners
- Central Florida Clean Cities Coalition
- Clean Fuels Ohio
- Clemson University International Center for Automotive Research
- Edison Electric Institute
- Electric Drive Transportation Association (EDTA)
- Electric Power Research Institute (EPRI)
- Get Ready Central Florida
- Get Ready Tampa Bay
- Land of Sky Regional Council
- NC Department of Commerce

- NC Clean Energy Technology Center
- Palmetto State Clean Fuels Coalition
- Piedmont Triad Regional Council
- Project Get Ready Indianapolis
- Tampa Bay Clean Cities Coalition
- Tampa Bay Regional Planning Council
- Triangle Clean Cities Coalition
- Triangle Get Ready Initiative
- NC State Advanced Transportation Energy Center
- Ohio State Center for Automotive Research
- Purdue University State Utility Forecasting Group
- Rose Hulman Institute of Technology

What are the North Carolina Cooperatives Doing?

North Carolina Electric Cooperatives have already deployed 39 cooperative-owned charging stations to serve rural communities and intend on investing another $1 million in 2019-2020 (NCDOT 2019). The NC Cooperatives are "Charging Ahead" to provide consumer information on all websites and several Cooperatives offer associated programs and rates as reflected below (pluginnc@advancedenergy.org).



(https://www.ncelectriccooperatives.com/)

Utility	EV Program	On, Off, Super Off-Peak
Cape Hatteras EMC	$100 rebate on Level 2 ChargePoint home charger	$.3448/$.4876, $.0991/$.1402, $.0625
Central EMC	Super off-peak TOU rate for EVs	$.3435/$.4029, $.0758, $.0401

Edgecombe-Martin County EMC	$200 rebate for EV purchase; super off-peak TOU rate	$.0892, $.0768, $.0375 + $8.90 on-peak kW
Energy United	$500 rebate for Level 2 charger	
Piedmont EMC	$50 credit for notification of EV ownership; $50 credit for signing up for super off-peak TOU rate	$.2642/$.3369, $0614, $.0279
Randolph EMC	$500 rebate for Level 2 charger, super off-peak TOU rate	$.3642, $.0843, $.0302
South River Electric	Super off-peak TOU rate	$.3379/$.4388, $.0477, $.0397
Surry-Yadkin EMC	$500 rebate for Level 2 charger, super off-peak TOU rate	$.3575, $.0650, $.0375
Wake EMC	TOU rate with discount for overnight charging; purchase and retirement of renewable attributes associated with 5,000 kWh each year.	$.40, $.08, $.05

Electric Fleet and Buses

The cities of Greensboro and Asheville are currently operating fully electric buses in their transit fleets. Chapel Hill Transit and GoRaleigh bus service will also have electric buses in service by the winter of 2020. As EVs represent an increasing percentage of the consumer market, more businesses, organizations and government entities are looking to upgrade their fleets to include electric options. Manufacturers are meeting this demand, from light to heavy duty transportation, and the options available to fleet managers are higher than ever.

Organizations looking to upgrade their current ICE fleets are motivated by several factors. EVs present immediate budget savings, starting with fuel and maintenance costs. Depending on service territory, charging an EV can be significantly less than the traditional fuel costs. In addition, maintenance needs on EVs are much lower, eliminating the need for oil changes and increasing the time between tire and break replacements. EVs also positively impact operational costs. Most states offer incentives to purchase EVs and, in some locations, EVs are exempt from road tolls and can access HOV lanes without charge.

Businesses and government agencies can also be motivated by intangible factors. EVs are the face of sustainability and environmental consciousness, with lower emissions and elimination of fossil fuel consumption. Employee retention and overall job satisfaction can be positively impacted with an EV fleet; individuals who are passionate about sustainability may feel an increased connection to their employer who shows a commitment to the electrification movement, increasing loyalty and performance. Finally, an EV fleet may boost customer or consumer opinions of a business or government agency. Environmental responsibility may impact brand image and, consequently, public opinion.

Prior to purchase, organizations need to closely examine logistics of an electric fleet. This examination primarily relates to charging but can also include EV selection, staffing, and training. Daily driving needs pose the first question for fleet managers and will ultimately determine which EV and battery size is required. Multiple charging solutions exist and, depending on the size of the fleet and daily driving activities, vary in up-front and long-term costs.

Type of Station	Speed of Charge (miles per minute)	Estimated Installation Costs per Station (USD)	Minutes of charge for 100mi range
Level 1 (120V AC)	0.1	$500-$1000	1080 (18 hours)
Level 2 (240V AC)	0.4	$2000-$5000	240 (4 hours)

50 kW (DC)	2.9	$60,000-$100,000	35
150 kW (DC)	8.7	$100,000-$150,000	12
350 kW (DC)	20.4	$150,000+	5

(Schefter and Knox 2019)

In order to support fleet charging, businesses and agencies need to calculate the required electrical load and determine if additional services are warranted. Garages and parking areas may need to be redesigned to support daily/nightly charging. Organizations looking to install inductive charging will also need to include a location for the charging pad in their plans.

When evaluating an electric vs. ICE fleet, organizations may come across several barriers. While the cost of EVs has decreased in recent years, the initial investment is still higher than ICE transportation. Although state and federal tax incentives still exist to offset the additional cost, incentives are expiring and may be less than in years past. Proterra claims that the electric bus has the lowest operational lifecycle cost (TCO). The required charging infrastructure may present a large hurdle to overcome, both in capital cost and time and space required to complete. If additional services are needed from the electric utility, this could present additional costs and delays (Proterra 2019).

	Proterra EV	CNG Bus	Diesel Bus	Diesel Hybrid
Vehicle	$749	$470	$454	$650
Energy/Fuel	$81	$294	$378	$302
Maintenance	$238	$432	$389	$475
TCO	$1,067	$1,196	$1,221	$1,428
TCO $'s/Mile	$2.47	$2.77	$2.83	$3.30

Electric Bus Fleet

Brand	Model	Length (m)	Capacity (Seated)	Battery Capacity (kWh)	Charging Time (hrs.)	Range (Miles)
BYD		35	33	266	3.5-4	
BYD		40	38	352	4.5-5	
Greenpower	EV250	30-32	25	210		175
Greenpower	EV300	35	34	260		175
Greenpower	EV350	40	40	320		185
Greenpower	EV400	45	44	320		185
Xcelsior	CHARGE	35	32	311	2.2	195
Xcelsior	CHARGE	40	40	388	2.7	225
Xcelsior	CHARGE	60	52	466	3.2	135
Proterra	Catalyst	35	29	220-440	2.7-3.2	234
Proterra	Catalyst	40	40	220-660	2.7-4.5	328

Upfront cost and charging infrastructure aside, the other major barrier is range. While there are some EVs in the market that match the range of a typical ICE vehicle, most are below what the average gas tank affords. Traditional driving routes may not be possible with battery range and would need to be evaluated. EV users will also need to be trained on driving behaviors that impact range, as well as know the availability and location of public charging if the need arises.

It is up to each individual business or agency to decide if fleet electrification is the right choice for their organization and employees. Here in Fayetteville, Fayetteville Area System of Transit (FAST) is looking to utilize grant funds from the VW settlement to replace four of their diesel buses with electric options. Although the total cost of the project will not be covered by the grant, FAST plans to utilize federal and city-matched capital to cover the difference. Additional evaluations currently underway include route analysis and required charging infrastructure. These issues will need to be answered prior to implementation. The city has several examples to look to for answers, including nearby Greensboro, who has already implemented an EV bus fleet.

Policy and Contractual Obligation

Legislative Policy

Executive Order 80: North Carolina's Commitment to Address Greenhouse Gas Emissions and Transition to a Clean Energy Economy was signed by Governor Cooper on October 29, 2018. This proclamation sets a goal to reduce North Carolina's greenhouse gas emissions to 40 percent below 2005 levels by 2025 and increase the number of registered ZEVs to 80,000 by 2025. In addition to these goals, some legislative policies have been put in place that could impact EV acceleration:

1. High-occupancy vehicle (HOV) Lane Access: Qualified plug-in EVs, dedicated natural gas vehicles, and fuel cell EVs may use North Carolina HOV lanes, regardless of the number of occupants. NCGS §20-4.01 and 20-146.2.
2. Exempt from Emissions Inspection Requirements: Qualified PHEVs and fuel-cell electric vehicles (FCEV) are exempt from state emissions inspection requirements. Other restrictions may apply. NCGS §20-4.01 and 20-183.2.
3. Annual Electric Vehicle Fee: At the time of an initial registration or registration renewal, the owner of a plug-in EV that is not a low-speed vehicle and that does not rely on a nonelectric source of power shall pay a fee in the amount of one hundred thirty dollars ($130.00) in addition to any other required registration fees. NCGS §20-87. NC Senate bill S446, was introduced to provide road tax parity with that of ICE by increasing registration for PEVs that do not rely on a non-electric source of power to $230 and PHEVs to $115. The Senate bill, having passed three panels, was scheduled for floor vote April 17, 2019 but was referred back to the rules committee and hasn't moved since.
4. EVSE Payment Rules: A new North Carolina law allowing companies to charge EV drivers for power by the kWh was introduced by NC Rep. John Szoka and signed by Governor Cooper on July 19, 2019. HB 329, enacted in 2019 allows the owners of EV charging stations to resell electricity. The bill clarifies that the term "public utility" does not include a person who uses an electric vehicle charging station to resell electricity to the public for compensation. According to the bill, utility service to an electric vehicle charging station will be provided subject to the electric power supplier's terms and conditions. The backers believe that this will help create a free market, thus spurring third parties to install charging stations across the state and increase the number of North Carolinians driving EVs. North Carolina is now the 30th state to allow public EV charging companies to offer pricing by the kWh. Private providers, like Chargepoint – the nation's largest charging station owner – are expected to face competition from Duke Energy Carolinas (DEC).

5. Motor Vehicle Dealer Law: A substitute bill for S.B. 384 about Motor Vehicle Dealer Laws was enacted in 2019, allowing up to five motor vehicle dealership locations until December 31, 2020 for a manufacturer and seller of only plug-in EVs. After December 31, 2020, up to six such dealerships may be operated. The bill includes several criteria that these manufacturers must also meet in order to operate dealerships in the state.

One of the key recommendations outlined in the 2019 North Carolina Clean Energy Plan is to require utilities to develop innovative rate design pilots to encourage off-peak charging of vehicles and to test effectiveness of different rate structures at shifting customer usage and encouraging the adoption of EVs (NCDEQ 2019). As part of Executive Order 80, Gov. Roy Cooper asked the NC Department of Transportation to develop a strategic plan to significantly increase the number of zero emission vehicles in North Carolina. The NC ZEV Plan, completed October 2019, lays out several strategies for accelerating EV adoption in North Carolina from less than 10,000 in 2018 to 80,000 by 2025. The ZEV Plan identifies four action areas to support ZEV adoption:

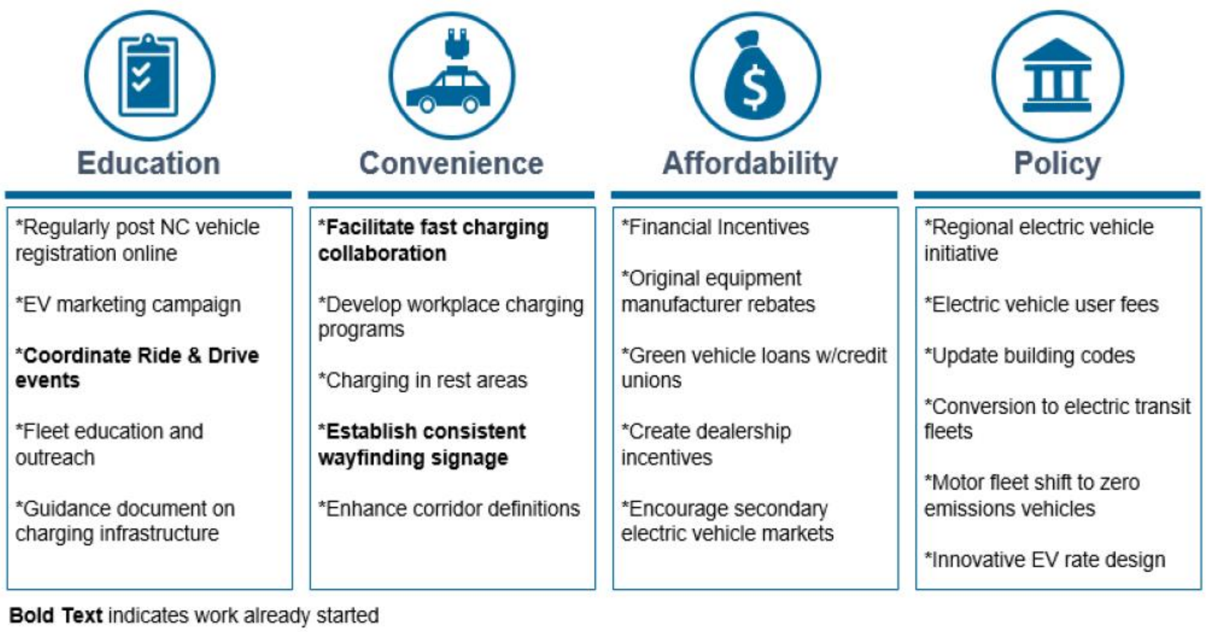


Figure xx. North Carolina strategies for increasing the number of ZEVs

NCCETC at NCSU reported that 43 states plus the District of Columbia have enacted changes in EV laws in the second quarter of 2019 alone. Most involve rebates for buyers, new vehicle registration fees, and programs to add new stations. One of the biggest trends is to exempt charging stations from state utilities law restrictions.

Federal Legislative Policy

Proposed Clean Energy Tax Package

On November 19, 2019, House Ways and Means Subcommittee on Select Revenue Measures Chairman Mike Thompson and Committee Democrats proposed a draft bill, Growing Renewable Energy and Efficiency Now Act of 2019 or GREEN Act of 2019 to extend and expand renewable energy use through the tax code. This draft bill is seen as a significant step towards reducing greenhouse gas emissions and addressing climate change. This proposal includes tax credits for qualified electric vehicles that may help increase the number of EVs and decarbonize the transportation sector. Here are summaries related to electric vehicles.

1. Modification of limitations on new qualified plug-in electric drive motor vehicle credit: The provision expands the qualified plug-in electric drive motor vehicle credit to apply a new transition period for vehicle sales of a manufacturer between 200,000 and 600,000 electric vehicles, under which the credit is reduced by $500. For manufacturers that pass the 200,000-vehicle threshold before the enactment of this bill, the number of vehicles sold in between 200,000 and those sold on the date of enactment are excluded to determine when the 600,000-vehicle threshold is reached. This policy was also proposed in the 2020 Appropriations bill, discussed below. The provision extends the two-wheeled plug-in electric vehicle credit through 2024. Starting in 2020, it also extends the three-wheeled plug-in electric vehicle credit through 2024.
2. New credit for qualified used plug-in electric drive motor vehicles: The provision creates a new credit for buyers of used plug-in electric cars from date of enactment through 2024. Buyers can claim a base credit of $1,250 for the purchase of qualifying used EVs, with additional incentives for battery capacity. The credit is capped at the lesser of $2,500 credit or 30% of the sale price. To qualify for this credit, used EVs must generally meet the eligibility requirements in the existing credit for new EVs, not exceed a sale price of $25,000, and be a model year that is at least two years earlier than the date of sale. Buyers with up to $30,000 ($60,000 for married couples filing jointly) in adjusted gross income can claim the full amount of the credit. The credit phases out so that buyers with below $40,000 ($70,000 for married couples) in adjusted gross income may be eligible for a reduced credit. Buyers must purchase the vehicle from a dealership for personal use and cannot claim the credit more than once every three years. The credit only applies to the first resale of a used EV and includes restrictions on sales between related parties.
3. New credit for zero-emission commercial vehicles and zero-emission buses: The provision creates a manufacturer credit for the sale of heavy, zero-emission vehicles starting after the date of enactment through the end of 2024. Eligible manufacturers may claim a credit of 10% of the sale price of an eligible vehicle, capped at a credit of $100,000. To be eligible, vehicles must be for domestic use, must weigh no less than 14,000 pounds, must not include an internal combustion engine, and must be propelled solely by an electric motor which draws electricity from a battery or fuel cell.
4. Qualified fuel cell motor vehicles: The provision extends the credit for the purchase of a qualified fuel cell motor vehicle through 2024.
5. Alternative fuel refueling property credit: The provision extends the alternative fuel vehicle refueling property credit through 2024. Starting in 2020, it also expands the credit for electric charging infrastructure by allowing a 20% credit for expenses above $100,000 (i.e., it allows a credit for expenses beyond the current limit if certain requirements are met). To qualify for this uncapped credit, the property must: 1) be intended for general public use and either

accept credit cards as a form of payment or not charge a fee, or 2) be intended for exclusive use by government or commercial vehicle fleets.

FY2020 Appropriations Bills

On December 16, 2019, two comprehensive appropriations packages containing all 12 appropriations measures were filed in the U.S. House of Representatives in an effort to complete funding for the Fiscal Year 2020 (FY20) process. With regards to electric vehicles, the bill provides $396,000,000 for vehicle energy technologies programs, which was well above the Administration request of $73,400,000.

Electric Vehicle Tax Credit

Also proposed but not ultimately included in the FY20 Appropriations bill was the federal electric vehicle tax credit. The tax credit is intended to encourage EV development and is thought of as an effort to advance electrification in the states. However, this tax credit extension failed to be included in the legislation that was signed in December 2019. Beginning on January 1, 2020, Tesla is the first manufacturer that is ineligible for the federal tax credit. In addition, the federal tax credit will be no longer available for General Motors starting from April 1, 2020. Other EV manufacturers, including Nissan, Ford, Toyota and BMW Group, will still be eligible for the full amount of federal tax credit ($7,500) until hitting the 200,000 eligible plug-in car sales limit in Q1 2020.

At this point, it remains unclear if EV sales will decline without the federal tax credit. Here are some opinions about the failure of tax credit extension.

- GM: “This is a missed opportunity to further advance electrification in the United States. The EV tax credit provides a proven pathway to establish the U.S. as a leader in electrification, helping make electric vehicles more accessible for all customers.”

- Tesla: “In the long run, we do not expect a meaningful impact to our sales in the U.S., as we believe that each of our vehicle models offers a compelling proposition even without incentives.”

- Melinda Pierce (Sierra Club Legislative Director): “The electric vehicle tax credit has helped to put more than a million clean cars on the road, creating thousands of jobs along the way. We must extend these investments for flourishing technologies like EVs to continue growing our economy and protecting the health of the planet.”

Grid Impact

When EVSE units are connected to the grid, there must be sufficient electrical capacity at the requisite voltage flowing to the service location. If this is not the case, electrical service upgrades are required beforehand to ensure safe and reliable service (Smith and Castellano 2015). This can range “from a simple electrical panel modification to more costly transformer upgrades or installations” (Smith and Castellano 2015). If significant upgrades are required, costs could be minimized by siting EVSE units closer to appropriate electrical services. Large upgrades – especially those that require new transformer installations – can cost tens of thousands of dollars (Smith and Castellano 2015).

Residential load profiles of homes with all EVs have been studied in recent years to evaluate the effect of EV on the power system. These studies indicate that smart-charging methods are needed to influence when charging occurs. Uncoordinated charging can lead to voltage problems in the distributed grid. Major factors impacting charging behavior include driving behavior, penetration of EVs and public charging stations, and technical demands of the vehicle. Figure 8 represents EVs' impacts on residential electric local profiles (Fischera et al. 2019).

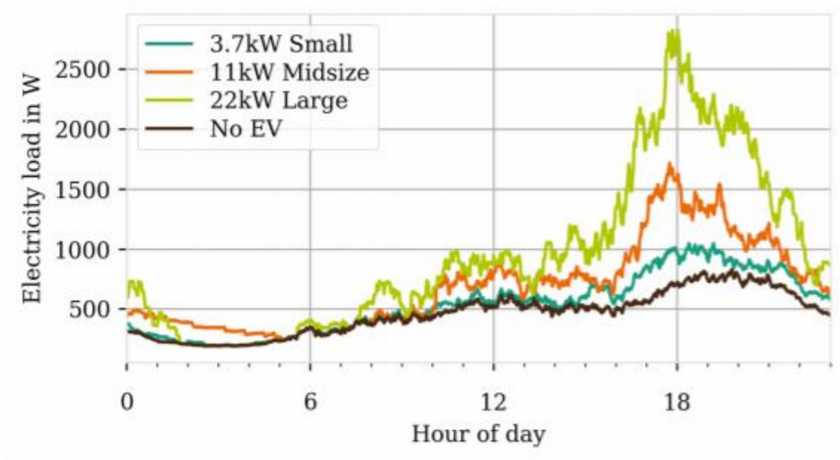
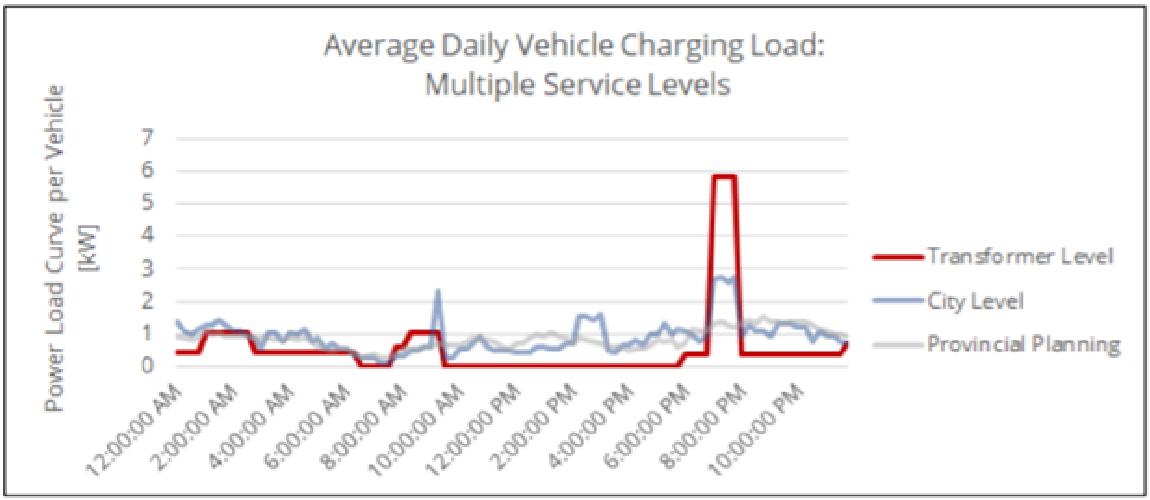


Figure 8: Comparison of mean day load trace for a family with different car types and home charging station.

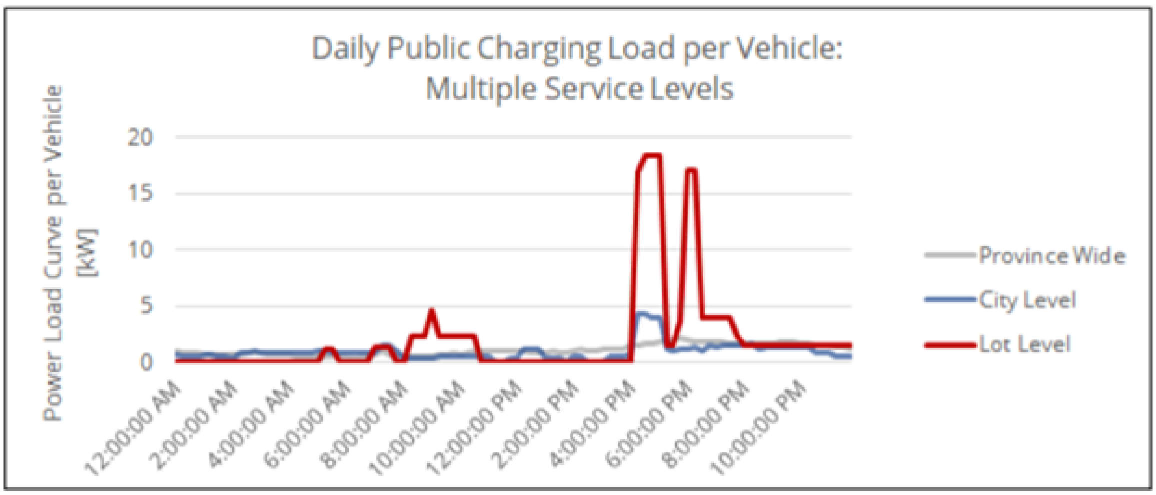
EV load can vary significantly from region to region. This is because "every electric service area has its own unique EV ecosystem with different adoption rates, vehicle specific market share, and geographic considerations" (Goody 2019). On top of this, the market for EVs is rapidly changing (Goody 2019). For example, the Tesla Model 3 has "only been in production since July 2017" yet accounted for "46% of 2019's plug-in electric sales for the US" (Goody 2019). Furthermore, recent research from the largest EV profiling study to date, *Charge the North*, indicates that charging behavior is also changing over time (FleetCarma 2019b). The authors found that over a five-year period home charging in Canada had decreased from an estimated 90% to just 72% of charging energy consumption (FleetCarma 2019b). This shift was coupled with "a rise in workplace charging" as well as increased public charging for specific vehicle types (FleetCarma 2019b).

Given that EV load in one service area is likely to be different than EV load in another, it is important to use caution when interpreting and leveraging data from other service areas. While data from other studies can provide useful information concerning important variables to consider or the efficacy of TOU rates, it is not recommended as a stand-in for region-specific data and/or analysis. Thus, this section will seek to pull general lessons from past EV load profiling work while refraining from trying to extend data from other service areas to this service area. General lessons cover (1) grid impacts, (2) vehicle type, (3) charger type, (4) commuting distance and geography, (5) seasonality and climate, and (6) TOU rates.

A primary long-term concern for many utilities is whether electric vehicles will negatively impact the grid. As EVs increase in overall vehicle market share and fast charging EVSE become more commonplace, how will grid infrastructure cope with increased load? In *Charge the North*, the authors found that, at the transmission and generation levels, per-vehicle load tends to be smoothed across a service area (FleetCarma 2019b). However, at the distribution level, per-vehicle electricity demand can peak sharply (FleetCarma 2019b). Consequently, this indicates a need to understand the geography of EV adoption and think about mechanisms to shape EV load so as to "avoid negative impacts on distribution assets" (FleetCarma 2019b). Figures 1 and 2 below demonstrate how, at the distribution level, the impact of individual vehicles could threaten grid reliability as EV adoption increases.

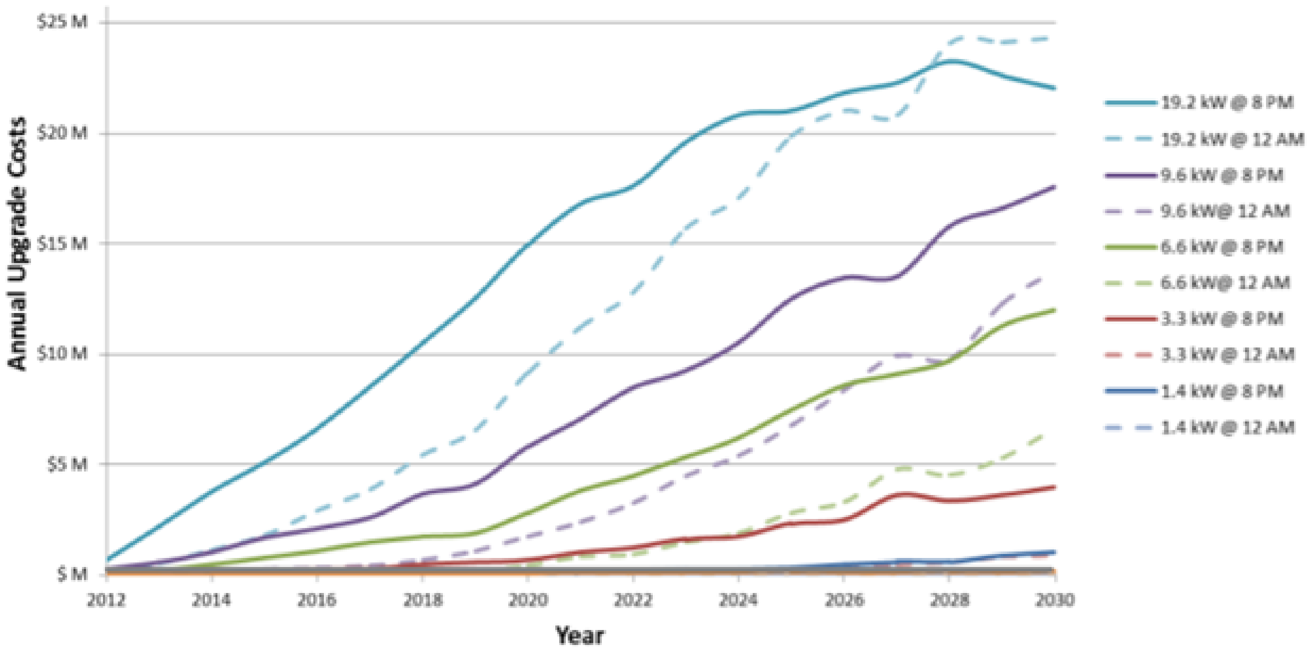


Average per-vehicle load demand on a single day at the transformer, city, and province (regional) levels (FleetCarma, 2019b).



Average per-vehicle public charging load demand at the lot, city, and province (regional) levels (FleetCarma 2019b).

In a separate study conducted for Sacramento Municipal Utility District (SMUD) in California, the authors projected that system upgrade costs could reach over $10 million in 2030 (Herter and Okuneva 2014). The authors assumed that there will be 140,000 EVs in their region by 2030 and found that incentivizing midnight charging in their 6.6 kW average EV demand scenario could cut 2030 annual costs in half – for a savings of approximately $6 million (Figure 3). In this 2014 analysis, the authors suggest that SMUD "has 5 to 8 years to develop good solutions to avoid significant peak and transformer issues" (Herter and Okuneva 2014).

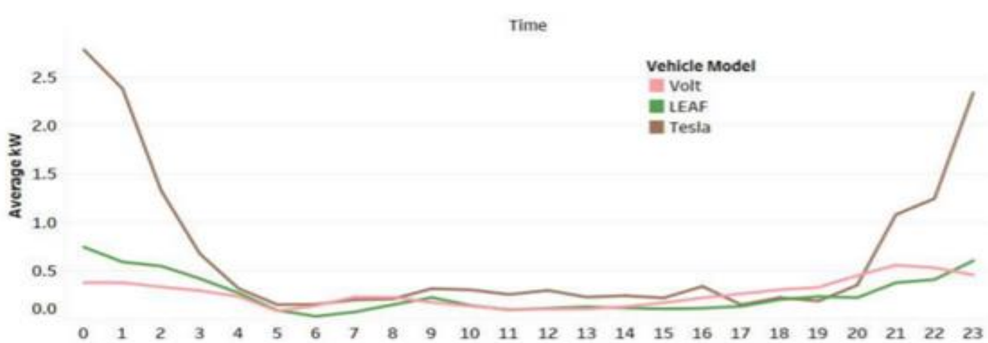


Estimated system upgrade costs for unmoderated residential EV charging (Herter and Okuneva 2014).

While lessons from other regions are not directly transferable, they can highlight general concerns about EV adoption and important considerations when evaluating load. In this section, the provided sources highlight a need to assess the long-term impacts that increased EV adoption could impose on distribution infrastructure. Additionally, this section highlights the value of understanding and tracking EV adoption at a fine spatial resolution to identify which distribution level infrastructure might be most at risk.

Vehicle Type

Another general takeaway from past load profile studies is that vehicle type can be important to understanding trends informing load shape. For example, in a 2018 report from the Electric Power Research Institute (EPRI) conducted in the Salt River Project (SRP) service region, load shape was seen to vary significantly by vehicle type (EPRI 2018). Differences in load shape were attributed to varying battery sizes and driving patterns. In particular, Tesla owners drove more miles daily and "prioritized charging at night and at higher rates" (EPRI 2018).



Average load shape for Volts, LEAFs, and Teslas (EPRI 2018)

In the *Charge the North* report, annual charging load across PHEV, short-range EV, and long-range EV were all found to vary considerably. As highlighted by Table 1, average annual charging load exhibited a disparity of over 3,000 kWh when comparing between short-range and long-range EVs. Load shape was also seen to vary across vehicle types with the authors noting that "some Tesla models are able to draw up to 17.2 kW at a residential Level 2 charger while many other makes and models of electric vehicles are able to draw a maximum power of 7.2 kW" (FleetCarma 2019b).

Annual distance traveled, annual load, and energy consumption by vehicle segment in Canada (FleetCarma 2019b).

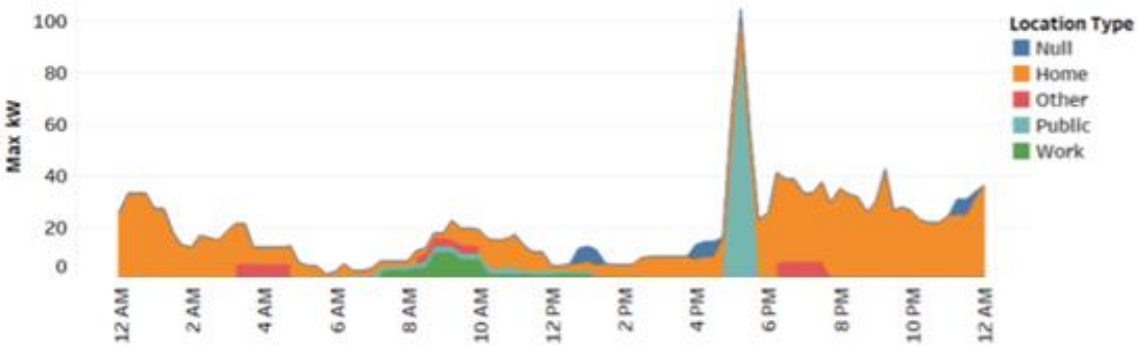
		Annual Distance Travelled (km)		Annual Charging Load (kWh)	Real-World Energy Consumption Including Charging Losses (Wh/km)
		Total	Electric		
Canada	PHEV	22,265	14,235	4,563	321
	SR BEV	17,520	17,520	3,942	225
	LR BEV	24,820	24,820	7,227	291

This section highlights how vehicle type can be an important consideration when trying to understand and explain load shape. Given that various vehicle models actually have different ceilings at which they can draw power from the grid, it will likely prove beneficial to track the market share of differing model types within a given service area. Additionally, both within the EPRI report and the *Charge the North* report, the authors recognized that driving distance behavior is related to vehicle type.

Charger Type

Another factor that can play a significant role in load shape is charger type and availability of non-residential chargers in the service area. In the *Charge the North* report, the authors noted a dramatic decrease in residential charger energy consumption from an estimated 90% of all energy to just 72% (FleetCarma 2019b). This was attributed in large part to an increase in workplace and public charger availability. It was also found that the cost – or lack thereof – for workplace charging played a role in charging behavior with participants with free Level 2 workplace chargers being more likely to charge during the day than those with paid charging options (FleetCarma 2019b). Taken together, this indicates that non-residential charger availability is likely to impact load curves.

This conclusion is supported by examples from the EPRI report in which the authors provide several single-day glimpses at recorded participant load. In the example from January 24, 2017, one can observe how workplace charging creates a small increase in demand as workers first arrive in the morning (Figure 5). The use of a public DC fast charging station later in the day also stands out in the load profile. During this EV peak load event, there was only one participant using a DC fast charger (EPRI 2018).

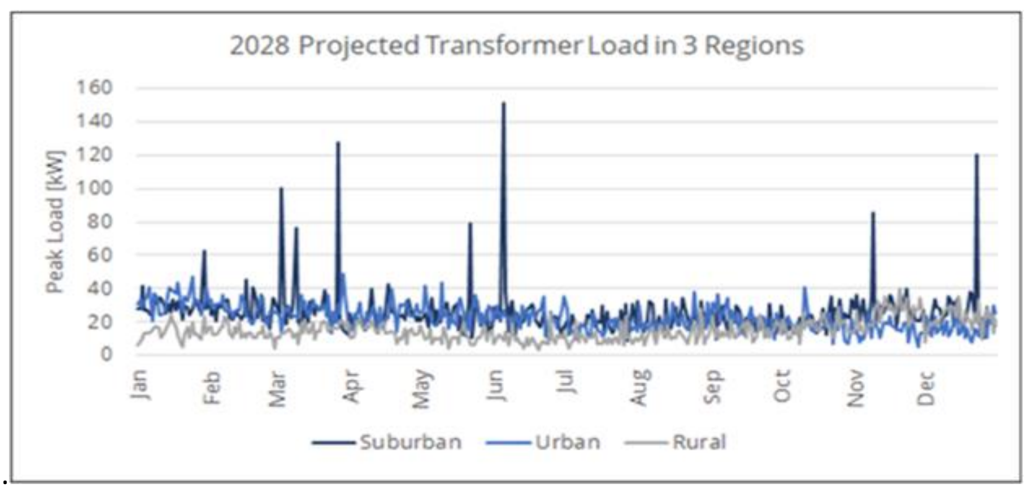


Example kilowatt load on January 24, 2017. Total load colored by charging type location (EPRI 2018).

As indicated by past studies, the availability of public and workplace charging is likely to shift load in the absence of off-peak charging incentivization. As non-residential EVSE infrastructure becomes increasingly available, it will be important for utilities to consider how consumer behavior might change as well as how rates and programs can be constructed to incentivize EV charging during off-peak times.

Commuting Distance and Geography

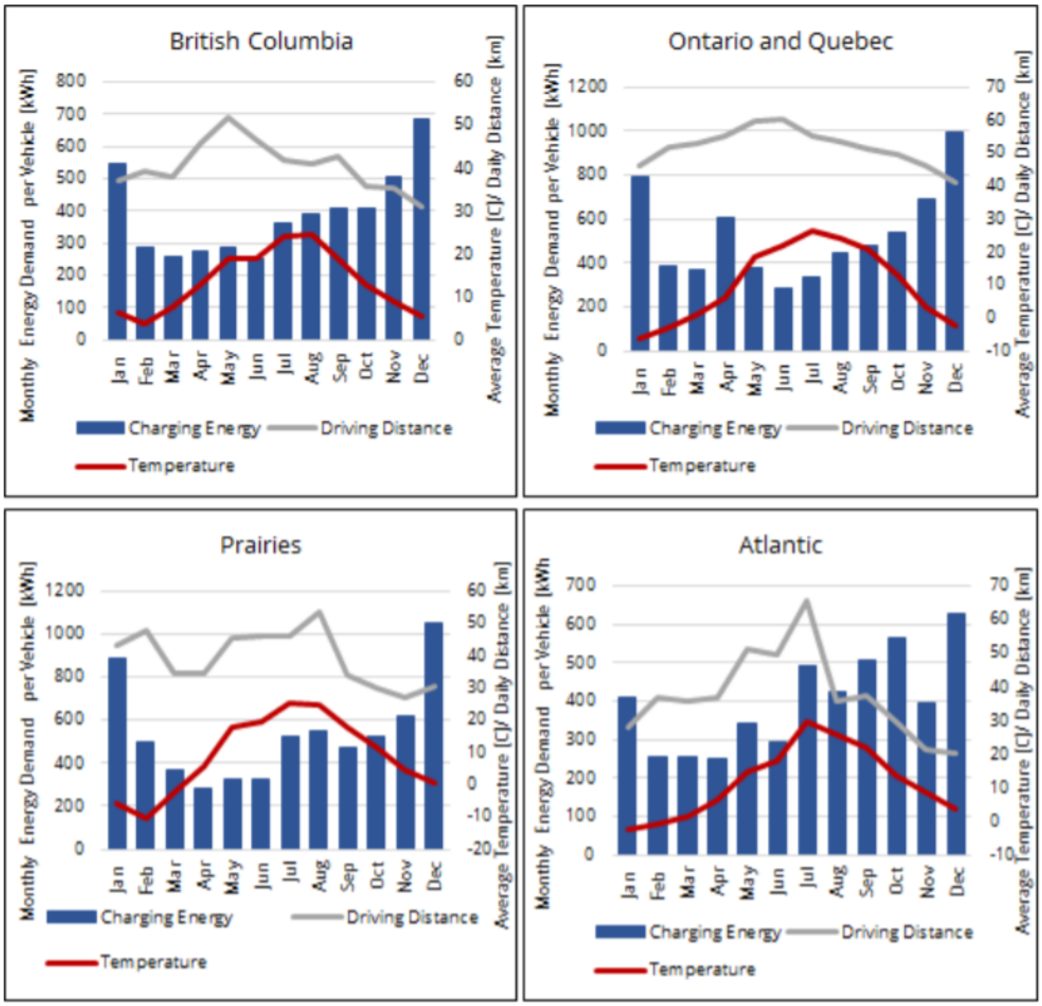
Given the size of the *Charge the North* study, the authors were able to explore factors that few others have. One factor that stood out was commuting distance and how it varied across rural-urban divides. In particular, the authors found that participants living in suburban areas were driving 80% farther daily than those living in urban areas (FleetCarma 2019b). In terms of how this translated to load, the timing of peak loads stayed fairly consistent across urban, suburban, and rural regions (FleetCarma 2019b). That said, the magnitude of loads tended to vary by development-level.



Importantly, the exact results from the *Charge the North* report regarding the impact of regional geography are likely not extendable to the Southeast US. That said, the results do highlight how considering geography and regional development-level in any EV load profile analysis would likely be beneficial. This is especially true given that urban sprawl in the Southeast US is projected to increase dramatically over the next 50 years (Terando et al. 2014). As sprawl and urbanization increase, so too will aggregate commuting time and energy demand.

Seasonality and Climate

The *Charge the North* report also highlighted how seasonal temperature variation can dramatically shift energy demand. Despite driving distances decreasing in the winter, decreasing temperatures were consistently associated with increased energy consumption (Figure 7). The authors asserted this was due to increased energy consumption of the vehicle (FleetCarma 2019b), which makes sense as cabin climate control can be energy intensive. In North Carolina, the pattern would likely be different, as cabin climate control is important both in the winter and the summer. Additionally, North Carolina winters are milder, so winter energy increases would likely not be nearly as dramatic.



Energy consumption, driving distance, and temperature by region. (FleetCarma 2019)

Seasonality also appeared to potentially play a role in charger choice. For example, in one studied vehicle set, public charging trended downward in the winter within British Columbia (FleetCarma 2019b). Interestingly, peak loads did "not show any consistent seasonal trends in the load curves of the residential charging section" (FleetCarma 2019b).

Incentives

The Plug-in Electric Drive Motor Vehicles Credit (26 U.S.C. 30D) provides a tax credit for the purchase of a new plug-in electric vehicle. Depending on the vehicle's battery capacity, the credit is worth at least $2,500, but no more than $7,500. The credit was created in the Energy Improvement and Extension Act of 2008 and is phased out for any vehicle manufactured by a manufacturer that has sold 200,000 or more qualifying EVs. Tesla and GM have been phased out and Nissan will likely sell its first 200,000 at some point this year. In the case of a tax-exempt entity that cannot make use of these tax credits, such as a public power utility, the tax credits instead can be claimed by the seller of the EV. For a full list: https://fueleconomy.gov/feg/taxevb.shtml

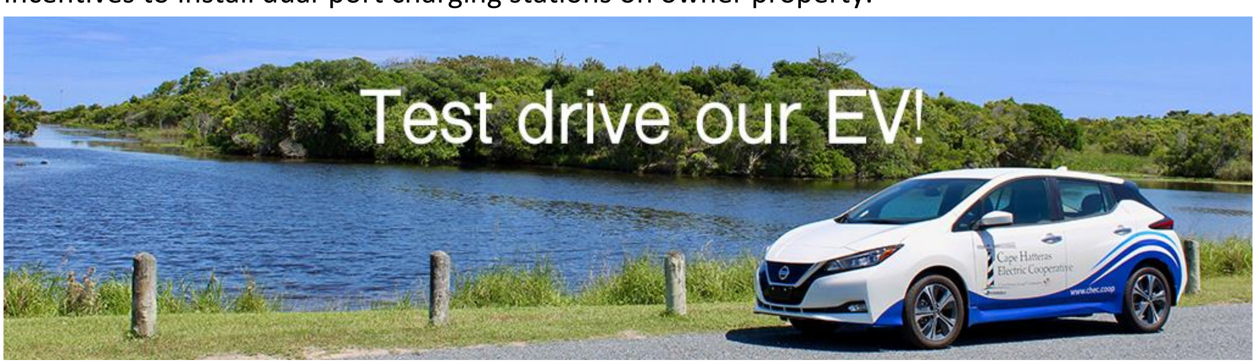
2020 Clean Fuel Advanced Technology (CFAT) funding, supported from federal Congestion Mitigation Air Quality (CMAQ) funds and provided by the NC Department of Transportation is available for EVSE installation. Applications are due by March 13, 2020. In 2020, up to $1,400,00 in federal funding with maximum per project award of $400,000 and minimum per project award of $5,000.

In addition, there is the Alternative Fuel Infrastructure tax credit which gives businesses 30% of the total cost of purchasing and installing an EVSE when purchased and installed by December 31, 2020. Maximum credit per address is $30,000.

As EV ownership is growing, utilities are responding by offering incentives and rates for a variety of reasons: (1) environmental stewardship, (2) support load data collection and evaluation, (3) promote EV acceleration, (4) engage customers, and (5) manage EV charging. Some utilities want to encourage ownership within their service territory and are more inclined to support ownership through rebates and incentives, rather than install utility owned charging which might support commuters and travelers. Others feel it is important to increase the infrastructure and are investing in Level 2 and DCFC sites.

According to DSIRE Insight, 19 municipal utilities and 19 investor-owned utilities with financial incentives in 23 states have been investigated. There were 52 actions ongoing related to incentives for electric vehicles and electric vehicle supply equipment. Of these, 47 actions were rebate programs, two were loan programs, and three were bill credits. 20 actions relate to electric vehicles, and 32 relate to electric vehicle supply equipment.

In North Carolina, the Cooperatives are leading the way. Several are now offering rebates; most with the requirement to share the charging data. Greenville Utilities has set aside $30,000 for $1,500 incentives to install dual-port charging stations on owner property.

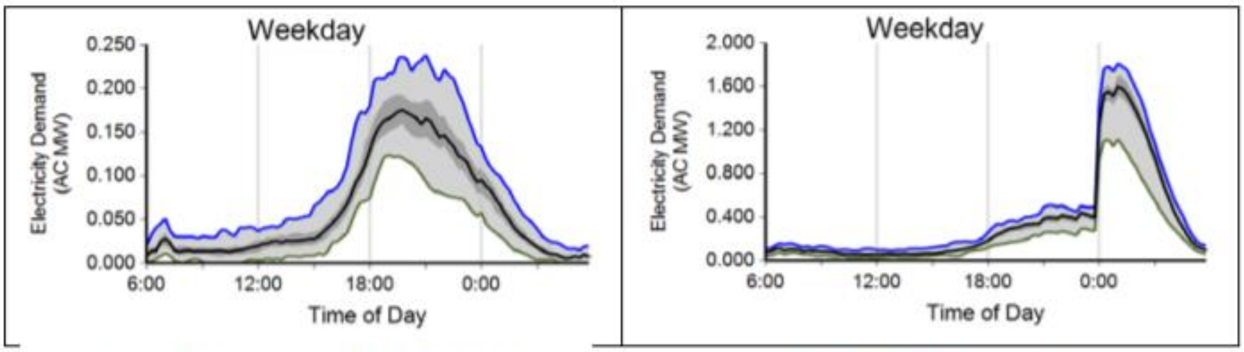


- Cape Hatteras - $100 rebate for Level 2 ChargePoint home charger. Must allow utility the ability to access ChargePoint data.
- Randolph - $500 rebate for wi-fi connected Level 2 charger and participation in the REVUP Pilot program. Agree to share data collected from charger and be on the Plug N2 Savings rate schedule (A-TOU-PEV)

- EnergyUnited - $500 rebate for Level 2 charger
- Greenville Utilities - $1,500 rebate for dual-port Level 2 charging station

Tariffs

Perhaps one of the most valuable takeaways from past studies: there seems to be consistent evidence for the efficacy of TOU rates. In a study by NREL looking at data from Pacific Gas and Electric's service territory, the authors found that TOU pricing very clearly shifted charging to off-peak times (Hodge 2017). Analyses from SMUD, EPRI, and FleetCarma all similarly found that TOU rate structures are successful at shifting charging demand to off-peak times (Herter and Okuneva 2014, EPRI 2018, FleetCarma 2019b).



Weekday residential charging demand in NES territory without TOU pricing, Q1 2013

Weekday residential charging demand in PG&E territory with TOU pricing, Q1 2013

Residential Charging demand (Hodge 2017)

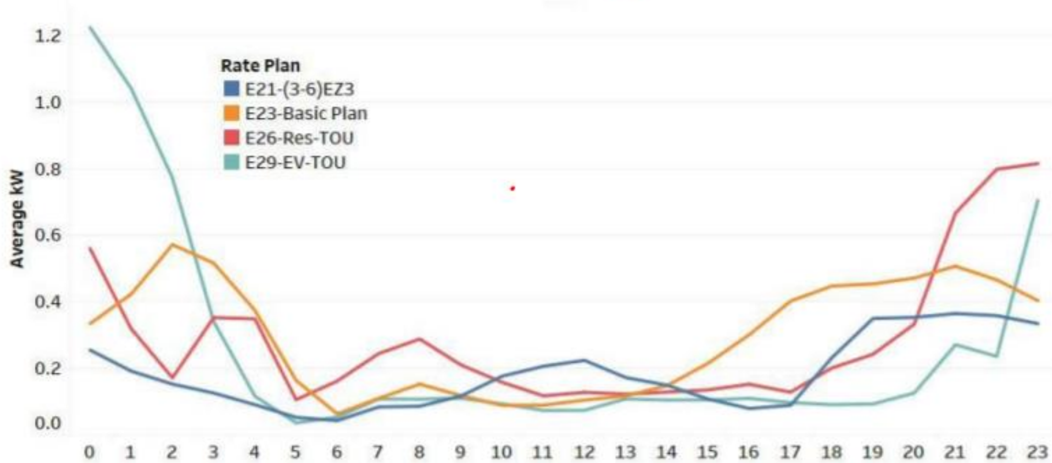
An in-depth study by the Electric Power Research Institute provides valuable insight into when, where, and how much drivers' charge allows utilities to adjust their load projections to include additional load from anticipated EV adoption (EPRI 2018). This study provides baseline information to help understand utility revenue opportunities and how EV load impacts the grid and how customers react to price signals. The report presents the results of a vehicle tracking study of 70 EVs from June 2016 through January 2018. Data loggers were placed on vehicles to show when, where, and how much and how frequently drivers charged their cars. The key findings included:

- EVs use approximately 2,700 – 3,300 kWh per year
- Utility TOU rates are very effective in shifting peak loads
- While DC fast charging comprised less than 3% of the total energy used in the study, DC fast charging was the cause of most of the peaks in the total project load
- Approximately 81% of charging occurred at home, while only ~3% of charging occurred in public charging locations
- The majority of charging occurred at Level 2 chargers (74%), followed by Level 1 chargers (23.4%) and DC fast chargers (2.5%)

The weekly average load shape shown below is derived from the data associated with this study. The basic plan, E23 shows an increase in charging from 3-10 pm, most likely caused by people arriving home from work or school and plugging in their cars. The values associated with these rate differences is not known.

Description of the EV charging rate plans associated with each load shape:

Rate Plan Name	Description
E21-(3-6) EZ3	Avoid 3-9 pm
E23 Basic Plan	All charging times are the same
E26-Res-TOU	Avoid 1-8 pm
E29-EV-TOU	Avoid 1-8 pm, Target 11-5 pm



Weekday average load shape colored by four rate plans (EPRI 2018)

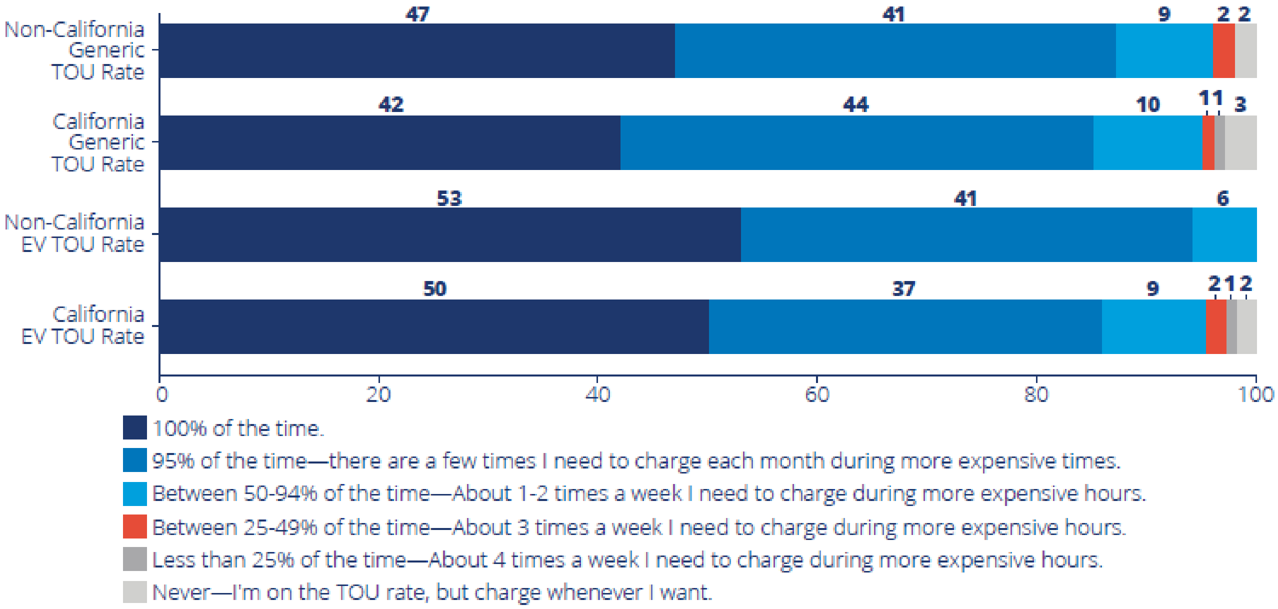
The Smart Electric Power Alliance (SEPA) coordinated a comprehensive overview of EV time-varying rates. SEPA collected information from 28 utilities. Brattle focused on factors that contributed to successful EV rate design. Enel X and SEPA surveyed 2,967 JuiceNet users. Time varying rates were placed in one of seven categories, TOU Rates, Subscription Rates, Off-Peak Credits, Real Time Pricing (RTP), Variable Peak Pricing (VPP), Critical Peak Pricing (CPP), and Critical Peak Rebate (CPR). The benefits of time-varying rates include:

- Reducing energy supply costs by making greater use of lower-cost resources and limiting the use of the highest cost energy;
- Reducing pollution by shifting demand to times when clean energy sources are generating electricity;
- Providing economic benefits to all utility customers through the grid efficiencies captured using off-peak charging;
- Avoiding or deferring capacity investments in generation, transmission, and distribution;
- Reducing the cost of infrastructure upgrades/replacement/repairs, particularly transformers;
- Responding to customer needs, incentivizing customer EV adoption, and influencing beneficial customer charging behavior; and
- Encouraging sustainable behavior changes, resulting in more reliable, predictable, and pronounced peak load reductions for utilities.

Utilities reported, on average, more than 90% of customers responded to the off-peak price signal and approximately 40% of the utilities surveyed reported persistent improvement in charging behavior after the introduction of EV time-varying rates, with a 95% retention rate. Peak to off-peak price differentials varied as did off-peak discounts.

The survey indicated that most rates were designed so that the customer’s bill would remain the same or increase if charging load was not shifted to the off-peak period. Metering configurations varied with the majority being applied to the whole home verses using EVSE specific secondary meters, submeters, or vendor telemetry.

TOU Enrolled EV Customer Charge Time Done Off-Peak by TOU Type, by percent (SEPA 2019).



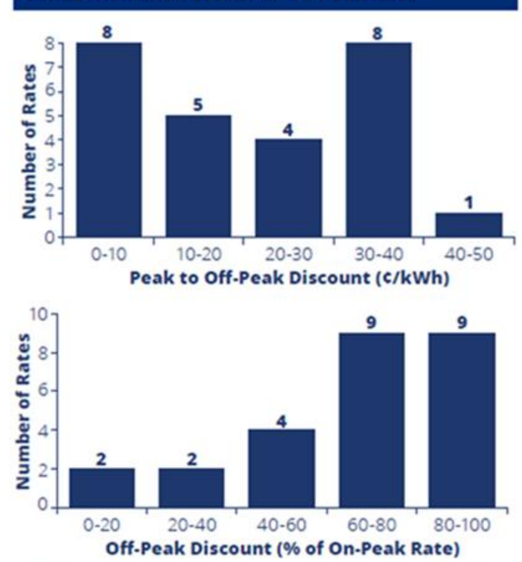
Source: Smart Electric Power Alliance & Enel X, 2019. N=1,167.

Some of the key recommendations presented in this report include:

- Minimize the up-front cost for customer enrollment
- Make the price differential between on-peak and off-peak significantly large to incentivize participation but not so large that it deters customers from enrolling
- Incorporate opt out rather than opt in passive electives
- Ensure adequate marketing funding
- Build a long-term strategy to transition from passive managed charging to active managed charging
- Work with ESVE providers to deliver unified standards (SEPA 2019)

As demonstrated by past studies, TOU rates can be an effective tool for shifting EV charging demand to off-peak times and many utilities in North Carolina have instituted a TOU rate. In the future, TOU rate structures will likely require oversight to avoid dramatic secondary peaks (Engel et al. 2018). Certainly, many areas in the US may not have current levels of EV adoption to where this is an immediate concern, but it will become increasingly relevant as EV adoption continues its upward growth into the future.

Figure 5: Peak to Off-Peak Discount by Cents/kWh and Percent of On-Peak Rate



Source: Smart Electric Power Alliance & The Brattle Group, 2019. N=26.

TOU EV offerings in North Carolina

Utility	Basic Facility	On-Peak	Off-Peak	Super Off-Peak
Central EMC	$34 $61	Summer $10.45/kW + $.0810/kWh Winter $7.55 kW + $.0606	$3.25/kW $.0606/kWh	$.0401
Surry-Yadkin EMC	$29.50	$.3575	$.0650	$.0375
Piedmont	$35 $80	Summer $.3369 Winter $.2642	$.0614	$.0279
Wake (PEV)	$15 $30	$.107	$.087	
Wake (EV)	$15 $30	$.40	$.08	$.05
South River + $20 bill credit	$27.50 $49.50	Summer $.4388 Winter $.3379	.0477	.0397
Roanoke Rapids	$50 per month subscription for up to 450 kWh/month free overnight charging + new professionally installed charging station valued at $1,700. (pilot)			

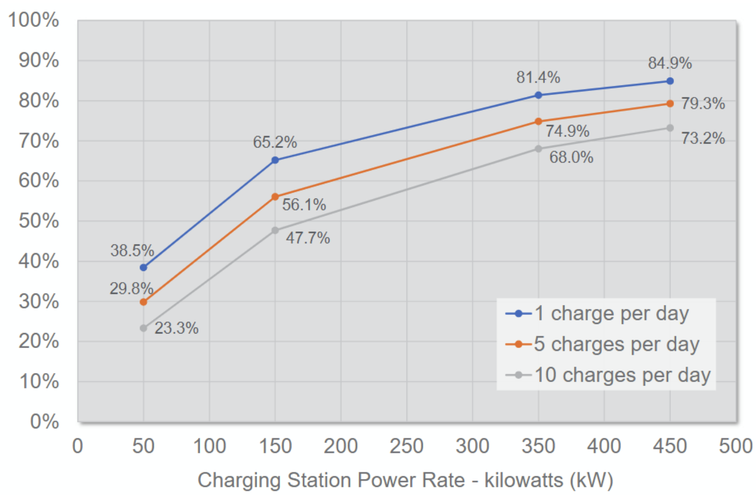
- For additional EV rates see Appendix 8: Other Residential EV Rates Collected by NCCETC, 2019
- NCCETC researcher compiled information on EV incentives and rate structures into a spreadsheet that can be accessed here at the following link: https://docs.google.com/spreadsheets/d/1rghxiphLgITdVpqD5_jX6KNJVaZ1FTr4Cf4Y62Qo20A/edit?usp=sharing
- A comprehensive list of available residential EV time-varying rates is available from SEPA: (https://sepapower.org/resource/residential-electric-vehicle-time-varying-rates-that-work-attributes-that-increase-enrollment/)

Utility rates also play an important role in the economics of public charging stations. Flexibility around demand charges can give owners of DC fast charging stations much greater potential to make a business case for their stations. DC fast charging stations and multiple Level 2 charging sites are most often subject to demand charges in addition to a per-kWh energy charge. Demand charges are generally based on the highest level of electricity demand (measured in kW) over a 15-minute period in a billing cycle. The fast charging nature of these stations results in high demand charges which can be a deterrent to developing this infrastructure. Utilities proposing demand charge alternatives for fast charging stations is listed as one of the top EV policy trends of the third quarter of 2018 (50 States of Electric Vehicles 2018) The Hawaiian Electric Company (HECO) offers commercial customers who provide EV charging two rates that remove or mitigate demand charges. The first, EV-C, does not have demand charges for off-peak use and offers TOU rates consumption. The second, EV-F, has higher per-kWh charges on a TOU schedule, but does not apply a demand charge at any time. Xcel Energy in Colorado offers a non-EV specific commercial rate (Secondary General Low-Load Factor, or SGL) which may be useful for entities such as DC fast charging stations that have high demand for brief periods but low total energy usage. This rate offers much lower demand charges during off-peak hours. For additional non-residential EV rates see Appendix 9: Non-Residential EV Rates, Collected by NCCETC, November 2019.

The Greater Plains Institute did a study in 2019 to assess how frequently a DCFC station must be used by customers, and how much do they need to pay in order for the station to break even each year. Cost factors such as electric rates, demand charges, cellular and data network costs, billing services, and customer charges were considered. An example of the findings included:

- If EV penetration eventually reaches the level for a charging station to see ten charging customers per day, 50 kW stations will break even at nearly all electric utility rates that GPI studied.
- For 150 kW chargers (which could include three 50 kW chargers or a single 150 kW charger), a DCFC station will break even for about half of the electric utility rates studied.
- Increasing power capacity beyond 150 kW makes it nearly impossible for a station operator to break even except in cases where the electric utility does NOT have a demand charge.
- Research indicates that ten charges per day is not happening anytime soon.

Total cost share of demand charges by DCFC power Capacity (50 kW – 450 kW)



"This is a chicken and egg scenario: more access to DCFC charging stations will help accelerate EV adoption; but DCFC charging stations will currently lose money every year until increased EV adoption results in more charging customers each day" (Walton 2019b).

Load Profile Study Design Recommendations

Many options exist for developing EV load profiles. Some options are more likely than others to yield accurate results, and each option comes with its own trade-offs. Additionally, even within one specific category of study design, there are many decisions and assumptions that can impact the final results. Given this, it is beyond the scope of this report to provide a full and comprehensive breakdown of every possible study design. That said, five potential study designs have been broadly identified for review and are detailed in following sections. These five study designs include [1] vehicle-side data collection, [2] charger-side data collection, [3] surveys and self-reporting, [4] extrapolation from travel survey data, and [5] extrapolation from existing charging behavior data. It should be noted that these five methods are not mutually exclusive, but each can be used independently to derive EV load profile estimates. For more information about each design option see Appendix 10: Data Collection.

Appendix 1: Butler Farm Microgrid, SREMC 2020

http://www.sremc.com/content/butler-microgrid

BUTLER MICROGRID

A microgrid is an electric system that combines local energy resources and control technologies to provide power to a defined area. Microgrids typically remain connected to the main grid but can also operate independently.

South River Electric Membership Corporation and its power supplier, North Carolina Electric Membership Corporation, are partnering with Butler Farms, a sustainability-focused hog farm in Lillington to develop a local microgrid.

This innovative project brings together resources owned by the farm with components owned by NCEMC to establish a unique partnership that benefits rural North Carolina by leveraging opportunities from two important industries— agribusiness and energy.

During normal conditions, the microgrid will connect to South River EMC's distribution system to supplement and diversify traditional power resources. During outages, it can also operate in island mode to power Butler Farms and surrounding homes.

The purpose of the Butler Farms microgrid:

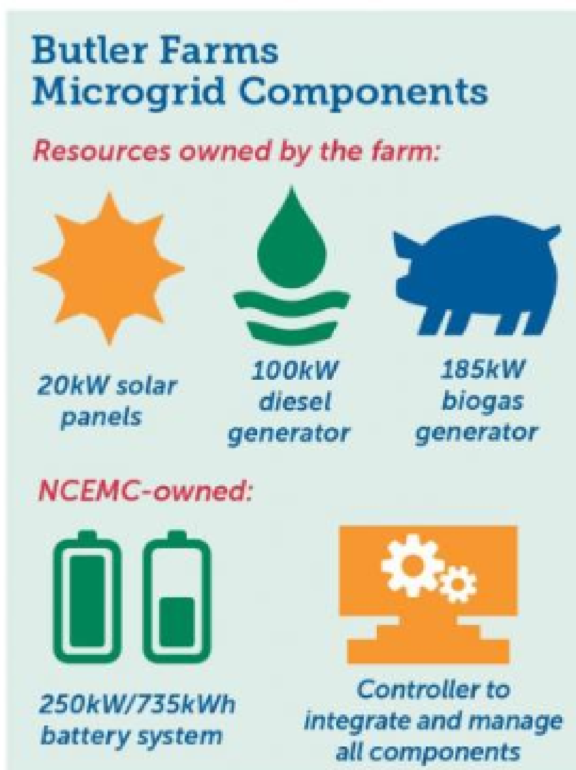
Integrate local renewable energy resources, including solar and biogas, with energy storage to supplement traditional power sources, diversify the electric grid and provide environmental benefits.

Improve the reliability of the electric system and farm operations by avoiding prolonged outages after storms or other events that interrupt grid power. The microgrid will also serve as a model for the integration of member-owned power generation that benefits the entire cooperative membership.

Explore the potential benefits of using microgrids as a demand response resource.

Serve as a case study for how agriculture and electric utilities— two of North Carolina's most important industries— can work together to promote sustainability and improve quality of life.

Provide a learning opportunity that will help discover future uses for microgrids and their components.



Appendix 2: North Carolina Battery Storage Installations, Collected by NCCETC, 2019

Organization Name	Facility Name	City	State	Application	OpYear	Output (kW)	Capacity (kWh)	Technology	Power Source
South River EMC	Butler Farms Microgrid	Lillington	NC	Microgrid	2017	250	735	Lithium-ion battery	180 kW Biogas CHP Generator + 20 kW Solar PV Array
Tideland EMC	Ocracoke Island Microgrid	Ocracoke	NC	Microgrid	2017	500	1,000	Lithium-ion battery	15 kW solar PV + 3 MW diesel generator
Brunswick EMC	various	Brunswick/ Columbus County	NC	DER Management	2018/2019	various	12,000	Lithium-ion	All solar + storage systems
Fayetteville PWC	Butler-Warner Station	Fayetteville	NC	Utility Distribution Grid	2019	560	1,020	Lithium-ion battery	1 MW solar PV
Duke Energy	Rankin Ave. Substation	Mount Holly	NC	Microgrid	2012	402	282	Sodium Nickel-Chloride	1.2 MW solar PV ~3 miles away
U.S. Army / Bosch	Fort Bragg	Fort Bragg	NC	Microgrid	2016	100	100	Lithium-iron phosphate	145 kW solar PV
Duke Energy	Mount Sterling	Haywood	NC	Microgrid	2017	10	95	Zinc-Air	10-kW solar PV
Duke Energy	Marshall Steam Station	Sherrills Ford	NC	Utility Distribution Circuit	2012	250	750	Lithium-polymer	1.0 MW solar PV
Duke Energy	McAlpine Creek Substation	Charlotte	NC	Microgrid	2012	200	500	Lithium-iron phosphate	50 kW solar PV
Duke Energy	Community Energy Storage	Charlotte	NC	McAlpine 24 kV circuits	2011	25	25	Lithium-ion	Grid power

Organization Name	Facility Name	City	State	Application	OpYear	Capacity (kW)	Duration (hr)	Technology	Power Source
Town of Benson	Wastewater Treatment Plant	Benson	NC	Microgrid	2020	500	2	Lithium-ion	500 kW solar PV
Duke Energy	Hot Springs	Hot Springs	NC	Microgrid	2020	4,000	4	Lithium-ion	2 MW(AC) Solar PV
Duke Energy	Asheville Plant	Asheville	NC	Utility-scale system in DEP-West		>=5000	4	Lithium-ion	
Duke Energy	Bad Creek Pumped Hydro Upgrades	Salem	NC	Utility Distribution Grid	2020-2023	260,000	8	Pumped Hydro	Bad Creek Hydroelectric Plant

Appendix 3: CALMAC/Trane Ice Storage Estimation, Mark Johnson, CALMAC Portfolio of Ingersoll Rand, December 2019

1/7/2020 FirstPass 2.0 Life Cycle Analysis Firstpass - CDF - 250c 170c

TRANE CALMAC

FirstPass ™ Analysis Of : 250 tons

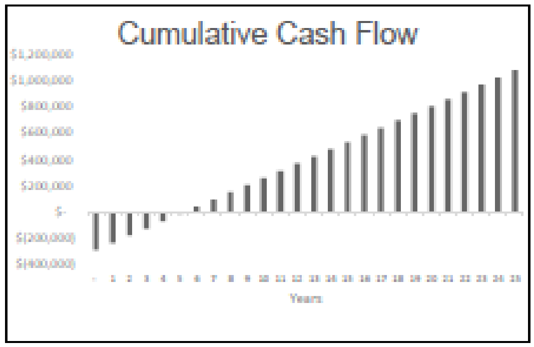
Ice Bank® Energy Storage Analyzer - A FirstPass Life Cycle Analysis

Building Profile	
City / Location	Fayetteville (3A), North Carolina (NC)
Building Type	Office
Chiller Type and Peak Load	Air Cooled @ 250 Tons

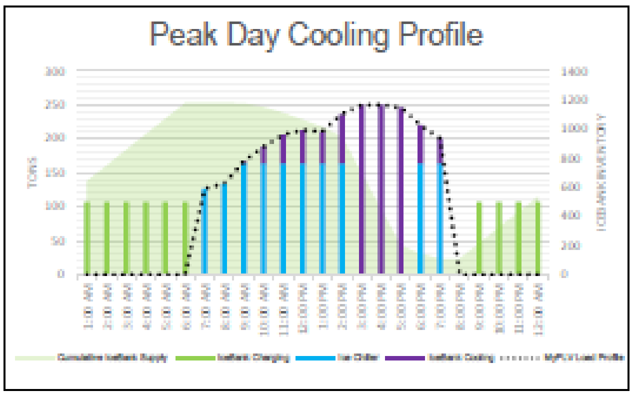
Energy Savings Summary	
Energy Demand Cost Savings	$54,832
Energy Utility Rate Savings	$0
Annual Operating Cost Reductions	$54,832

Conventional System	
Chiller Capacity	250 Tons
On-Peak Demand	325 kW

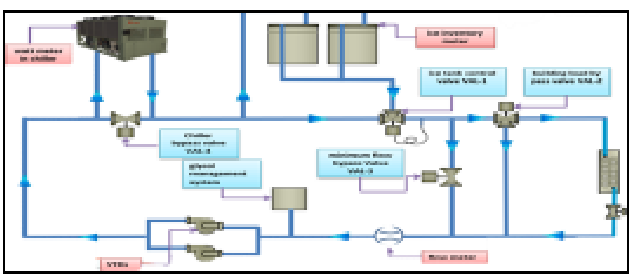
Business Case	
First Cost Premium	$292,868
Net Present Value	$186,222
Internal Rate of Return	18.8%
Payback Period	5 years 4 months



Ice Storage System	
Ice Chiller Nominal Capacity	165 Tons
Ice Chiller Ice Making Capacity	108 Tons
IceBank Energy Storage Capacity	1072 Ton-Hrs
On-Peak Cooling Load Reduction	250 Tons
Ice Chiller On-Peak Demand	0 kW
On-Peak Demand Reduction	325 kW



Ice System Architecture	
Storage Farm of 1190C Units	7
Approximate Square Footage	400
Pump Flow (GPM)	399
Pump Power (HP)	10
Pipe Size (in)	6



The data provided herein is a computer generated output from a mathematical model using data provided by or originated from you, and must not be relied upon as an accurate representation or prediction of current or future performance or construed as advice. The data is of a general nature and should not be construed as specific advice or relied upon in lieu of a full review of your HVAC and energy system and objectives. The data is current only as of the date of publication or supply and may change over time.

Trane disclaims all warranties that the data is accurate, complete, or up to date, and to the fullest extent permitted by law, excludes all liability for any loss or damage howsoever arising (including through negligence) or suffered by the recipient, whether as a result of any reliance on the accuracy of data or otherwise arising in connection with an evaluation by Trane.

Appendix 4: North Carolina and Federal Regulatory Activity, Collected by NCCETC 2020

North Carolina Regulatory Activity

In 2019, several North Carolina Utilities Commission dockets related to energy storage in NC were created or updated. Summaries of the actions undertaken in these proceedings are given below, as well as references to the documents themselves:

[Docket No. E-7 Sub 1156, Docket No. E-2 Sub 1159] Competitive Procurement of Renewable Energy (CPRE), 2019 - Market participants bid potential projects every year in order for Duke to reach the renewable procurement targets set in NC H.B. 589 of 2017. All of the proposals in the past year utilized solar PV technology, with three projects including battery storage as well. Of the 12 proposals submitted to Duke Energy Carolinas that the Independent Administrator (IA) for the CPRE approved (515 MW total), two had storage systems. CPRE requires these accompanying energy storage systems can only be charged with renewable energy (NCUC 2019).

[Docket No. E-100 Sub 157] Smart Grid Technology Plan (Duke Energy Progress, Duke Energy Carolinas, Dominion Energy), 2018 - Duke has proposed an Energy Storage Control System Project to remotely monitor and control all Duke Energy-owned battery energy storage systems. The batteries can participate in aggregate to provide energy arbitrage, frequency regulation, or grid islanding, both in the context of peak reduction and outage support. In addition, Duke proposes to continue their roll-out of advanced metering infrastructure (AMI), which are necessary for households to participate in net metering or time-of-use billing (DEC 2019a). The Smart Grid Technology Plan was conditionally approved in July 2019, with all control system proposals approved.

[Docket No. E-100 Sub 157] Integrated Resource Plans, 2018 and 2019 - In 2018, DEP's IRP included plans for113 MW of energy storage by 2033, and DEC planned for 120 MW of energy storage by 2033. In 2019, DEP's IRP included plans for 100 MW-AC of storage paired with solar and 140 MW-AC of grid-scale standalone storage by 2034, while DEC's IRP included plans for 200 MW-AC paired with solar by 2034. (DEC 2018, DEC 2019, DEP 2019).

[Docket No. E-100 Sub 157] Integrated System Operations Planning (ISOP) – In 2018, Duke Energy Progress released their latest Integrated Resource Plan (IRP), and began development of an Integrated System Operations Plan, to allow for a better solution to integrate generation, load, transmission, and distribution more effectively, with renewable generation and energy storage resources in mind (DEC 2019).

[Docket No. E-2 Sub 1219, Docket No. E-7 Sub 1214] Grid Improvement Plan – On September 30, and October 30, 2019 DEC and DEP, respectively, filed applications with the NC Utilities Commission requesting authority to increase its electrical service rates, a request driven in part by investments made since 2017 that included expanded smart metering infrastructure, costs incurred for restoration of service following Hurricanes Florence, Michael, and Dorian, and modernization of transmission and distribution infrastructure.

[Docket No. E-100 Sub 164] Investigation of Energy Storage in North Carolina, 2019 - In September, the NCUC began an initiative to provide an educational foundation on energy storage in the state as a follow-up to the energy storage study required by H.B. 589 of 2017. Docket E-100 Sub 164 was created as a repository for presentation transcripts, to "increase the Commission's awareness for addressing storage-related issues." Presentations have been given by an array of national experts on various topics, including integrated resource planning, storage valuation, interconnection, integration, and storage as a transmission asset (NCUC 2019a).

[Docket No. E-2 Sub 1185] Microgrid Solar and Battery Storage Facility in Madison County, 2019 - In Docket E-2 Sub 1185, Duke Energy Progress requested approval to develop a microgrid facility in Hot Springs, NC which would include a 4 MW lithium-based battery storage system. The Commission issued a decision in May 2019, approving the project and requiring that the utility conduct a study, or contract with a third party to conduct a study, estimating the ancillary service benefits battery storage can provide Duke's system, using sub-hourly modeling techniques. DEP has moved the commercial operation date of the project to September 2020 (DEP 2019a).

[Docket No. E-100 Sub 101] Study Process Report for Addition of Storage at Existing Generating Facilities, 2019- In Docket E-100 Sub 101, the Commission required Duke Energy to produce a report detailing a streamlined process to install energy storage at existing generating facilities (Energy Storage Retrofit Process), as well as how that storage would alter the System Impact Study of the generating facility. Duke broadly investigated adding energy storage to solar-only generating facilities, concluding that storage would very likely help solar-only facilities contribute to off-peak and winter peak hours on the grid. This would require additional study, since System Impact Studies for existing solar-only generating facilities only analyzed solar power flow between 9am and 5pm (DEC 2019b).

[Docket No. E-7 Sub 1146] Dynamic Price Pilot Tariffs- Although Duke Energy already offers time-of-use rate options to many of its customers, the NCUC directed Duke Energy to file a report on advanced metering infrastructure and customer connect-enabled rate design in its order on the utility's proposed PowerForward program. In July 2019, the Commission approved Duke's nine proposed dynamic price pilots, which include three different rate designs each for residential, residential all-electric, and small commercial and industrial customers.

<u>North Carolina Legislation</u>

The North Carolina General Assembly is not currently in session but is scheduled to reconvene for the 2020 short session on April 28, 2020. State lawmakers enacted one bill related to energy storage in 2019, while another significant storage bill did not advance.

<u>Recently Enacted Legislation</u>

H.B. 329 (2019) Renewable Energy Amendments - This bill was enacted in part to require rules for end-of-life management of standalone or paired solar photovoltaic and battery energy storage systems. This includes recycling of materials, reusing undamaged materials, safe disposal of any hazardous materials in these systems, and categorization of waste for landfilling. The stakeholder process for these rules is currently taking place.

<u>Other Recently Proposed Legislation Not Enacted</u>

S.B. 510 - Promotion of Energy Storage Investments (2019) - This bill would have helped promote investments and utilization of energy storage systems throughout North Carolina. This would have included, with public approval, a new tariff for small power producers that add energy storage to existing renewable energy facilities, review of any restrictions by public utilities on design, construction, or operation of energy storage facilities, and considering the recommendations from the 2018 Energy Storage Options for North Carolina study.

North Carolina Executive Action

Executive Order No. 80 - Within EO 80 which passed in 2018, the Department of Environmental Quality was tasked to develop a Clean Energy Plan with collaboration from several stakeholders. The goal of the Clean Energy Plan is to reduce state-wide greenhouse gas emissions by 40% below 2005 levels by 2030. Within this plan, investments in energy storage are recommended, including deployments of utility-scale solar + storage facilities. However, they caveat this with a need for additional cost reductions and research of these systems before solar + storage can be deployed cost-effectively. NRDC recommends 1.3 GW of battery energy storage by 2030, much higher than Duke Energy's proposal of 260 MW by 2030. NCSU's energy modeling team observed battery storage deployment in 2030 or later in all of the scenarios DEQ recommended, though the level of deployment was dependent on nuclear plant relicensing. https://files.nc.gov/ncdeq/climate-change/clean-energy-plan/5.-Modeling-Final.pdf

Federal Legislation

Federal programs and legislation mostly deal with research & development of energy storage systems to increase storage duration and/or reduce investment costs. Although several bills have proposed policies specific to batteries or energy storage as a whole, none have passed in the past few years. Below are a few examples of federal initiatives to study energy storage:

Energy Storage Grand Challenge - Department of Energy 2020 - The DOE hopes to create a domestic manufacturing supply chain for energy storage to utilize in the U.S. and export internationally. Emphasis will be placed on eliminating dependence on foreign sources of critical materials such as lithium, cobalt, and Rare Earth Elements.

In S. 1790 - National Defense Authorization Act for Fiscal Year 2020 - The Department of Defense was allocated at least $10 million to develop long duration on-site battery energy storage projects for distributed energy assets. The Department of Energy was also allocated research money for electrical energy storage systems in H.R.589 - Department of Energy Research and Innovation Act, 2018.

H.R. 2114 - Enhancing State Energy Security Planning and Emergency Preparedness Act of 2019 - allows the DOE to provide financial assistance to improve energy security for states that submit a state energy security plan. Energy storage can be considered as a technology to improve energy security and reliability. The bill has passed the House and is under consideration in the Senate Committee of Energy and Natural Resources. Similarly, S.79 - Securing Energy Infrastructure Act of 2017 would establish a two-year pilot program at DOE national laboratories to investigate the current security vulnerabilities of various aspects of the energy sector, and technology that can be used to isolate critical loads in the event of security attacks. The bill passed the Senate but has been in the House since December 2018.

https://www.appropriations.senate.gov/news/congress-works-to-fully-fund-government-ahead-of-deadline-files-two-fy20-packages

Appendix 5: North Carolina Municipal Rate Structures, Collected by NCCETC, October 2019

Residential Rate Structures

Municipality	Fixed Rate ($/month)	Energy Rate ($/kWh)	Notes
City of Albemarle	12.17	0.11315 first 500 kWh + 0.11998 (>500 kWh)	
Town of Apex non-TOU	15.05	0.1029 (first 800 kWh) + 0.0993 (>800 kWh) November-June	10.29/kWh flat rate for July-October
Town of Apex TOU	15.57	0.0636 (non-peak) + 0.27 (peak)	
Town of Ayden	11.50	0.111	
Town of Benson	26.50	0.1097	
Town of Belhaven	10.75	0.1511	
New River Light and Power	12.58	0.080027 + 0.003791 (coal ash cleanup)	
Town of Bostic	9.01	0.099335 (first 500 kWh) + 0.096679 (Jun-Sep) or 0.095182 (Oct-May)	
Town of Forest City	9.89	0.1102 (first 350 kWh) + .01233 (July-Oct) or 0.1224 (Nov-June)	
Town of Clayton	6.95	0.1283	
City of Concord	9.65	0.09748	
Town of Cornelius	11.54	0.10327 (June-Sept) or 0.0895 (Oct-May)	
Town of Dallas	10	0.091 (first 350 kWh) + 0.114 (next 950 kWh) + 0.10 (over 1.3 MWh)	
Town of Edenton	11.10	0.1133	
City of Elizabeth City	12.48	0.1094	
City of Elizabeth City TOU	14.65	0.0474	Demand Charge on-peak $19.50/kW, excess demand charge $3.15/kW
Town of Enfield	14.69	0.138690	
Town of Farmville	9.00	0.1219	

Town of Granite Falls	18.33	0.10653 (first 500 kWh) + see notes	$0.10406 (next 500 kWh) + $0.10174 (>1 MWh)
City of Gastonia	17.50	0.09765 (Oct-May)	0.10765 (Jun-Sept)
Greenville Utilities Commission	21.00	0.09414	
Greenville TOU	27.47	0.14228 (on-peak) + 0.03569 (off-peak)	$5.67/kW demand charge
City of High Point	12.91	0.108323 (first 350 kWh) + 0.113966 (>350 kWh) (Jul-Oct)	$0.108323 (first 350 kWh) + $0.096318 (>350 kWh) (Nov-Jun)
Town of Highlands	20.31	0.1146	
Town of Hobgood	17.00	0.135	
Town of Huntersville	11.54	0.10327 (Jun-Sep), 0.08950 (Oct-May)	
City of King's Mountain	9.00	0.0967 (first 350 kWh) + 0.0950 (next 950 kWh) + 0.0895 (>1.3MWh)	
City of Kinston	14.95	0.07433 + $9.35/kW	
Town of Landis	20	0.105	
City of Laurinburg	8.40	0.111 (first 1750 kWh) + 0.09338 (>1750 kWh)	
City of Laurinburg TOU	8.50	0.44 (on-peak) + 0.0530 (off-peak)	
City of Lexington	20	0.1125 first 500 kWh + 0.1084 next 500 kWh + 0.1052 over 1,000 kWh (Summer)	0.1059 first 500 kWh + 0.1018 next 500 kWh + 0.0986 over 1,000 kWh (Non-Summer)
City of Lincolnton	13.16	0.1093 (first 350 kWh) + 0.1179 (next 950 kWh) + 0.1232 (>1.3 MWh)	
Town of Lucama		0.112413	
Town of Louisburg	8.35	0.12095 (<800 kWh) + 0.11254 (>800 kWh)	
Municipality	Fixed Rate ($/month)	Energy Rate ($/kWh)	Notes
Town of Maiden	18.52	0.10877 (first 350 kWh) + 0.10032 (next 950 kWh) + 0.09385 (>1300 kWh)	Demand charge of $4.30/kW (>10 kW)
City of Monroe TOU	16.80	0.1592 (peak) + 0.0585 (off- peak)	
City of Monroe	12.00	0.122 (< 300 kWh) + 0.1149 (> 300 kWh)	
City of Morganton	12.75	0.1083 (Jun-Sep) + 0.1053 (Oct-May)	

City of Morganton TOU	14.25	0.0963 (peak) + 0.0806 (off- peak)	Demand charge $7.14/kW Jun-Sep or $3.27/kW Oct-May
City of New Bern	9.95	0.1017	
City of Newton	12.57	0.1061(<350 kWh)+ 0.1193(<950 kWh)+ 0.1074(>1.3 MWh)	
City of Rocky Mount	26	0.097077	
Town of Scotland Neck	20	0.126	
Town of Selma	8.50	0.1115	
City of Shelby	13.13	0.10974 (<1000 kWh) + 0.10719 (>1 MWh) (Summer)	0.10974 (<500 kW) + 0.10321 (<1 MW) + 0.10005 (>1 MW) (Winter)
Town of Smithville	10	0.1002	
City of Statesville	14	0.09140	
Town of Wake Forest	15.95	0.1131	
City of Washington	9.10	0.09617 (summer), 0.08814 (winter)	

Non-Residential Rate Structures - Collected October 2019 by NCCETC

Municipal Utility / Category	Basic Charge ($)	Energy Charge (¢/kWh)	Demand Charge ($/kW)	Coincident Peak Charge ($/kW)	Notes
Fayetteville PWC – Large Power	290	.052	2.00	19.63	Large scale customers exceed 1 MW at least 3 times during the year
Fayetteville PWC – Medium Power	37 52	.05	14.75		
Fayetteville PWC – Small Power TOU	30 45	.135 on-peak .096 off-peak			

Town of Apex non-TOU	124.60	6.3	9.34		
Town of Apex TOU	124.60	6.2	9.86 (on-peak)		
Town of Apex CP	311.51	4.78	2.59 (excess)	20.18	
City of Albemarle	25.87	9.069 first 25 MWh + 8.634 next 50 MWh + 7.616 next 75 MWh + 7.019 for extra kWh	5.83 above 30 kW		The City of Albemarle does not offer TOU rates. Large scale rate applies to customers who exceed 200 kW
Town of Ayden - General CP	350	5.28	6.00 (excess)	24.00	Demand >300 kW but less than 1 MW
Town of Ayden - Industrial	1000	5.629	6.00 (excess)	24.00	Demand >1 MW
Town of Belhaven	11.50	8.0	22		Demand >20 kW for one month
Town of Benson	251.50	5.29	3.25 (excess)	24.90	Demand >50 kW
New River (No Demand Charge)	23.22	4.4205 + .3791 (coal ash)			Large Commercial
New River (Demand Charge)	23.22	4.1783 + .3791 (coal ash)	10		Commercial Demand High Load Factor
Forest City Industrial	20.53	For first 125 kWh per kW per month: 14.54 (<3 MWh) + 9.116 (<90 MWh)+ 7.176 (>90 MWh)	4.34 (all over 30 kW)		For next 275 kWh per kW per month: 8.6320 (<140 MWh) + 8.0298 (>140 MWh); For all over 400 kWh per kW per month: 7.7904
Forest City Commercial	13.66	For first 125 kWh per kW per month: 14.76 (<3 MWh) +9.0230 (<90 MWh) + 7.3218 (>90 MWh)	4.37 (all over 30 kW)		For next 275 kWh per kW per month: 9.1866 (<6 MWh) + 9.0342 (<140 MWh) + 8.5442 (>140 MWh); For all over 400 kWh per kW per month: 8.2463

Town of Clayton Large Commercial	100	5.249	1.50 (excess)	17.50	Min demand 350 kW
Town of Clayton Coincident Peak	75	5.979	3.50 (excess)	18.00	Available to any non-residential customer with demand exceeding 50 kW for at least 3 months
City of Concord Industrial TOU	47.09	8.9654 (peak, June-Sept) 8.8235 (peak, Oct-May)	1.18	On-peak: 12.95 (June-Sept) 8.24 (Oct-May)	5.1312 (off-peak, June-Sept), 4.9891 (off-peak, Oct-May)
City of Concord Industrial	19.30	For first 125 kWh per kW per month: 11.5251 (<3 MWh) + 7.0911 (<90 MWh) + 6.9151 (>90 MWh)	3.80		For next 275 kWh per kW per month: 6.0471 (<140 MWh) + 5.8651 (>140 MWh); For all over 400 kWh per kW per month: 5.6751
City of Concord TOU	46.22	8.6719 (peak, June-Sept), 8.4153 (peak, Oct-May)	1.16	On-peak demand charge: 13.29 (June-Sept), 8.67 (Oct-May)	5.2081 (off-peak, June-Sept), 4.9515 (off-peak, Oct-May)
Town of Dallas Commercial		11.9 (first 3 MWh) +8.8 (next 87 MWh) +6.9 (>90 MWh)	14 (<30 kW) + 5 (>30 kW)		
Town of Dallas Industrial		11.7 (first 3 MWh) + 7.9 (next 87 MWh) + 6.1 (>90 MWh)	30 (<30 kW) + 5 (>30 kW)		
Town of Edenton Large Commercial	105	6.42	12.984		Min Charge $500/mo., demand >50 kW
Town of Edenton CP	105	5.92	4.275 (excess)	26.580	Voluntary for when demand >100kW
City of Elizabeth City Interactive TOU	175	5.27	3.25 (excess)	24.10	Industrial rate
City of Elizabeth City TOU	35	6.05	3.95 (excess)	20.25	

City of Elizabeth City General	25	10.93 (<3 MWh) +5.85 (>3 MWh)	15.40 (all over 30 kW)		
Town of Enfield Large Commercial	40.45	4.9578	26.56		
Town of Enfield Large Manufacturing	37.56	4.5996	24.65		
Town of Farmville Large Power	110	7.88	11.50		Customer demand >100kW
Town of Farmville CP	100	6.6616	4.39 (excess)	23.57	
City of Gastonia Large Commercial CP	850	5.005 (on-peak, June-Sept), 4.659 (off- peak, June-Sept)	5.00 (excess)	19.00 (on-peak)	Demand exceeds 750 kW but less than 4 MW. 4.765 (Oct-May, on- peak), 4.552 (Oct-May, off-peak)
City of Gastonia Large Industrial	160	6.551 (June-Sept), 6.051 (Oct-May)	14.00 (June-Sept), 13.00 (Oct-May)		Demand exceeds 500 kW
City of Gastonia Large Commercial	85	6.65 (June-Sept), 6.150 (Oct-May)	14.00 (June-Sept), 11.00 (Oct-May)		250 kW < Demand < 500 kW
City of Gastonia Large Industrial CP	850	4.635 (peak, June-Sept), 4.306 (off-peak, June-Sept)	17.1 (June-Sept), 5.50 (Oct-May)	5.00 (excess)	Demand >2 MW, 4.470 (peak, Oct-May), 4.196 (off-peak, Oct-May)
Town of Granite Falls Commercial	102.64	8.310 (first 300 kWh/kW), 7.830 (>300 kWh/kW)	8.98		
Town of Granite Falls Industrial	145.89	7.239 (first 100 kWh/kW), 6.571 (next 200 kWh/kW), 6.394 (>300 kWh/kW)	8.69		
Greenville Utilities Commission	50	9.592 (first 12.5 MWh) + 8.028 (>12.5 MWh)	4.17 (>35 kW)		Medium Commercial, Demand >35 but <750 kW
Greenville Medium Commercial CP	50	3.071	15.61 + 5.38 (excess)	17.40	Demand >35 but <750 kW, additional charge of 25 cents/rkVA

City of High Point Commercial	17.11	For the first 125 kWh/kW, 15.2846 (first 3MWh) + 7.6709 (next 87MWh) + 6.0829 (>90MWh)	5.65 (>30kW)		For next 275 kWh/kW, 10.5562 (first 6MWh) + 7.8176 (next 95 MWh) + 7.5619(>101MWh), for over 400 kWh/kW, all kWh are 6.996
City of High Point Industrial	26.62	For the first 125 kWh/kW, 15.1811 (first 3MWh) + 8.222 (next 87MWh) + 6.5119 (>90MWh	5.59 (>30kW)		For next 275 kWh/kW, 7.5741 (first 140MWh) + 6.8167 (>140MWh), for over 400 kWh/kW, all kWh are 6.4734
City of High Point TOU	78.37	8.7346 (peak) + 3.8322(off-peak)	16.83 (peak, Jun-Sep), 9.19 (peak, Oct-May)		
City of High Point CP	79.59	6.0829		21.85 (peak, Jun-Sep), 7.28 (peak, Oct-May)	
Town of Highlands	22.67	11.44 (first 3MWh) + 8.08 (next 6MWh) + 8.03 (>9MWh)	7.64		
Town of Hobgood	18.50	14 (first 2MWh) +12.7 (>2MWh)	9.00 (>10kW)		Seasonal Base Charge $20.00, $0.194/kWh +$9.30/kW (>5kW)
Town of Huntersville Medium Commercial	37.62	8.560 (<100 kWh/kW) + 6.312 (>100 kWh/kW) (Jun-Sep)	4.97 (>30 kW)		8.560 (<100 kWh/kW) + 4.768 (>100 kWh/kW) (Oct-May)
Municipal Utility / Category	Basic Charge ($)	Energy Charge (¢/kWh)	Demand Charge ($/kW)	Coincident Peak Charge ($/kW)	Notes
Town of Huntersville Medium Industrial	357.54	6.258 (on-peak) + 4.575 (off-peak) (Jun-Sep)	17.88 (summer peak), 3.57 (winter peak), 2.52 (excess)		5.583 (on-peak) + 4.177 (off-peak) (Oct-May)
City of King's Mountain Large Industrial	84.10	First 125 kWh/kW: 6.81 (<3MWh) +	8.42 (>30kW)		Next 275 kWh/kW: 5.60 (<140MWh) +

		6.59 (<90 MWh) + 6.37 (>90MWh)			5.35 (>140MWh) Over 400 kWh/kW: 5.19
City of King's Mountain Large Commercial	84.10	First 125 kWh/kW: 7.38 (<3MWh) + 7.15 (<90 MWh) + 6.81 (>90 MWh)	8.42 (>30kW)		Next 275 kWh/kW: 6.42 (<6MWh) + 6.14 (<140MWh) + 5.86 (>140MWh) Over 400 kWh/kW: 5.59
City of Kinston Medium Commercial	50	10.972 (<2MWh) + 8.773 (>2MWh)	7.20 (>12kW)		
City of Kinston Medium Commercial "ToU"	50	6.20	26.35 (on-peak) + 5.10 (off-peak)		
City of Laurinburg Large		5.9	15.50* (<1 MW) + 14.30 (>1MW)		Demand > 1MW *May be typo in rate schedule, 15,500 for (<1 MW) on electric rate schedule
City of Laurinburg Medium		6.989	300 (<30kW) + 9.25 (next 20 kW) + 9.10 (>50kW)		
City of Lexington Small Commercial	60	(Summer) First 100 kWh/kW: 9.77 (<3MWh) + 7.91 (>3MWh) Next 200 kWh/kW: 7.55 All over 300 kWh/kW: 6.50	3.50 (<10 kW) + 11.00 (>10 kW)		(Winter) First 100 kWh/kW: 9.12 (<3MWh) + 7.22 (>3MWh) Next 200 kWh/kW: 6.86 All over 300 kWh/kW: 5.81
City of Lexington Large Commercial	175	(Summer) First 100 kWh/kW: 9.24 Next 200 kWh/kW: 8.25 All over 300 kWh/kW: 6.96	11		(Winter) First 100 kWh/kW: 8.53 Next 200 kWh/kW: 7.54 All over 300 kWh/kW: 6.26
City of Lexington Industrial	430	First 100 kWh/kW: 6.60	11		Next 200 kWh/kW: 6.15 All over 300 kWh/kW: 5.90
City of Lincolnton Large	52.41	6.28	11.35		

Town of Louisburg Commercial	13.00	16.21 (<500 kWh) + 12.17 (<2 MWh) + 10.77 (>2 MWh)	5.20 (>5 kW)		
Town of Louisburg Large Power	81.00	8.75	9.20		Demand exceeds 150 kW
Town of Maiden Large Commercial	126.08	8.0591 (first 100kWh/kW) + 6.245 (next 200 kWh/kW) + 3.991 (>300 kWh/kW)	22.75 (>30 kW)		
Town of Maiden Large Industrial	132.50	5.543 (first 100 kWh/kW) + 5.113 (next 200 kWh/kW) + 4.114 (>300 kWh/kW)	22.82 (>30kW)		
City of Monroe Commercial TOU	50	8.55 (on-peak) + 6.11 (off-peak)	17.25 (on-peak) + 2.50 economy)		Demand is less than 500 kW
City of Monroe Commercial CP	500	7.29 (on-peak) + 4.74 (off-peak) (Jun-Sep)	2.45 (excess) + 1.50 (CP)	19.75 (Jun-Sep) + 11.15 (Oct-May)	6.19 (on-peak) + 4.16 (off-peak) (Oct-May)
City of Monroe Industrial CP	500	6.85 (on-peak) + 4.48 (off-peak) (Jun-Sep)	2.35 (excess) + 1.50 (annual CP)	19.75 (Jun-Sep) + 11.15 (Oct-May)	5.77 (on-peak) + 3.87 (off-peak) (Oct-May)
City of Morganton Large Commercial	83	6.19 (Jun-Sep) or 5.90 (Oct-May)	17.42 + 4.36 (excess) (Jun-Sep) 9.15 + 6.97 (excess) (Oct-May)		Demand between 150 and 500 kW
City of Morganton Large Industrial	83	5.41 (Jun-Sep) or 5.11 (Oct-May)	17.39 + 4.30 (excess) (Jun-Sep) 9.31 + 6.31 (excess) (Oct-May)		Demand between 500-1000 kW
City of Morganton Industrial CP Small	75	6.03 (Jun-Sep) + 5.63 (Oct-May)	17.60 + 2.18 (excess) (Jun-Sep) 4.09 + 2.18 (excess) (Oct-May)		Demand 100-500 kW

City of Morganton Industrial CP Medium	100	5.75 (Jun-Sep) + 5.57 (Oct-May)	17.60 + 2.18 (excess) (Jun-Sep) 4.09 + 2.18 (excess) (Oct-May)		Demand 500-300 kW
City of New Bern CP	1214	5.29 (first 1750 MWh) + 4.45 (>1750 MWh)	4.19 (excess)	26.84 (first 3.2 MW) + 14.94 (>3.2 MW)	Demand >2 MW
City of New Bern CP	166.06	5.61	4.43 (excess)	26.84	Demand between 750kW and 2 MW
City of Newton Small CP	72.18	5.463 (peak) + 5.128 (off-peak) (Summer)	2.17 (excess)	22.86 (summer) or 6.18 (winter)	5.191 (peak) + 5.066 (off-peak) Winter Demand between 100 and 500 kW
City of Newton Medium CP	354.37	5.645 (peak) + 5.326 (off-peak) (Summer)	2.17 (excess)	21.62 (summer) or 4.32 (winter)	5.424 (peak) + 5.282 (off-peak) Winter Demand between 500 and 3000 kW
Town of Red Springs	9.98		0.1421 (<1 MW) 0.1377 (<2.5 MW) 0.1271 (>2.5 MW) (Nov-May)		Demand charge flat rate of 0.14 (Jun-Oct)
Municipal Utility / Category	Basic Charge ($)	Energy Charge (¢/kWh)	Demand Charge ($/kW)	Coincident Peak Charge ($/kW)	Notes
City of Rocky Mount Industrial	1125	4.22	3.00	22.5	
Town of Scotland Neck Commercial	87	6.80	1024.50 (first 50 kW) + 20.96 (>50 kW)		
Town of Selma Large Commercial	40	7.648	10		
Town of Selma Commercial CP	510	5.145	2.70 (excess)	19	

Town of Smithville Commercial TOU	20	9.0 (peak) + 6.0 (non-peak)	13.67		
Town of Smithville General Service	513.95	6.16	19.00		
City of Statesville TOU	55.14	5.655	13.01		TOU is based on demand during peak periods, not energy use
City of Statesville Large Commercial	20.78	6.215 (summer) or 6.706 (winter)	10.85		
City of Statesville Industrial TOU	55.14	4.924 (summer) 5.4150 (winter)	14.29		TOU is based on demand during peak periods, not energy use
Town of Wake Forest Coincident Peak	75 (Demand <100 kW), 200 (Demand <500 kW), 475 (>500 kW)	5.12	3.75 (excess)	23	
City of Washington Industrial	0	4.561	13.03		Additional charge: 0.26/rKVA

Duke Energy Rate Structures – Collected by NCCETC November 2019

For legibility, the following table is abbreviated to only show summer pricing at single-phase:

Rate Description	Basic Charge ($)	Energy Charge (¢/kWh)	Demand Charge ($/kW)	Notes
Residential Standard [RES-56]	14.00	10.817	NA	
Residential TOU + Demand [R-TOUD-56]	16.85	7.569 (on-peak), 6.129 (off-peak)	4.88 (on-peak)	
Residential TOU [R-TOU-56]	16.85	23.904 (on-peak), 12.105 (mid-peak), 7.460 (off-peak)	NA	
Small General Service Tiered [SGS-56]	21.00	11.496 (tier 1), 9.826 (tier 2), 9.372 (tier 3)	NA	Tier 1: first 750 kWh Tier 2: next 1,250 kWh Tier 3: all additional kWh
Small General Service TOU [SGS-TOUE-56]	21.00	22.219 (on-peak), 11.810 (mid-peak), 6.605 (off-peak)	NA	

Small General Service TOU [SGS-TOU-56]	35.50	6.460 (on-peak), 5.235 (off-peak)	10.53 (on-peak), 1.22 (off-peak)	
Medium General Service [MGS-56]	28.50	7.379	6.15	
Large General Service [LGS-56]	200.00	5.796	12.96 (tier 1), 11.96 (tier 2), 10.96 (tier 3)	Tier 1: first 5,000 kW Tier 2: next 5,000 kW Tier 3: all additional kW
Large General Service TOU [LGS-TOU-56]	200.00	5.317 (on-peak), 4.817 (off-peak)	20.29 (p, t1), 19.29 (p, t2), 18.29 (p, t3), 0.89 (off-peak)	Tier 1: first 5,000 kW Tier 2: next 5,000 kW Tier 3: all additional kW

Appendix 6: EV/EV Charging Rebates and Incentives, Collected by NCCETC, November 2019

Sta	Utility Name	Utility Type	Incentive	Technology	Incentive Amount
AZ	Salt River Project	Municipal Utilitiy	Rebate	EVSE	$500 per Level 2 EVSE at businesses for workplace charging (limit
CA	Alameda Municipal Power	Municipal Utilitiy	Rebate	EVSE	Residential Customers: $800 for Level 2 EVSE
CA	Anaheim Public Utilities	Municipal Utilitiy	Rebate	EVSE	Residential, Commercial and Industrial Customers: Up to $500
CA	Burbank Water & Power	Municipal Utilitiy	Rebate	EVSE	Commercial Customers: $2,000 and 4 rebates per fiscal year
CA	Los Angeles Department of Water and Power	Municipal Utilitiy	Rebate	EVSE	Commercial Customers: $5,000 per Level 2 charger, with an
CA	Los Angeles Department of Water and Power	Municipal Utilitiy	Rebate	EV, PHEV	$450 rebate for the purchase of a used EV or PHEV
CA	Pacific Gas & Electric	Investor-owned Utility	Rebate	PEV	Residential Customers: $800 rebate
CA	Pasadena Water and Power	Municipal Utilitiy	Rebate	PEV	PEV: $250 bonus rebate
CA	Pasadena Water and Power	Municipal Utilitiy	Rebate	EVSE	Commercial Customers: $3,000 rebate for Level 2 EVSE or $6,000
CA	Sacramento Municipal Utility District	Municipal Utilitiy	Rebate	EVSE	Residential Customers: a $599 rebate or a free Level 2 PEV
CA	San Diego Gas & Electric	Investor-owned Utility	Bill Credit	PEV	2018 Credit: $500
CA	Sonoma Clean Power	Municipal Utilitiy	Rebate	EVSE	A free JuiceNet-enabled EVSE and a $250 rebate in JuicePoints to
CA	Southern California Edison	Investor-owned Utility	Rebate	PEV	Residential Customers: Up to $1,000
CT	Groton Utilities	Municipal Utilitiy	Rebate	PEV	$2,000 rebate for the first 20 EV purchases by Groton Utilities
CT	Groton Utilities	Municipal Utilitiy	Rebate	EVSE	Rebate up to $600 for an approved Level 2 charging station.
DE	Exelon	Investor-owned Utility	Rebate	PEV	Varies
DE	PECO	Investor-owned Utility	Rebate	PEV	Residential Customers: $50 rebate
FL	Duke Energy	Investor-owned Utility	Rebate	EVSE	Duke Energy will provide the equipment, installation, warranty
FL	Orlando Utilities Commission	Municipal Utilitiy	Rebate	PEV	Residential Customers: $200 rebate
FL	Jacksonville Electric Authority	Municipal Utilitiy	Rebate	PEV	Battery Capacity less than 15 kWh: $500
GA	Georgia Power	Investor-owned Utility	Rebate	EVSE	Residential Customers: $250 for Level 2 EVSE
IA	Alliant Energy	Investor-owned Utility	Rebate	PEV	New PEVs: $500 rebate
IA	Alliant Energy	Investor-owned Utility	Rebate	EVSE	Commercial and Industrial Customers:
IA	Alliant Energy	Investor-owned Utility	Rebate	EVSE	Residential Customers: $500 for networked Level 2 EVSE, $250 for
KS	Kansas City Power & Light	Investor-owned Utility	Rebate	PEV	$3,500 discount on a new Nissan Leaf
MD	Delmarva Power & Light	Investor-owned Utility	Rebate	EVSE	Residential Customers: $300 for Level 2 EVSE
MD	Pepco	Investor-owned Utility	Rebate	EVSE	Residential Customers: $300 for Level 2 EVSE
MD	Baltimore Gas & Electric	Investor-owned Utility	Rebate	EVSE	Residential Customers: $300 for Level 2 EVSE
MA	Braintree Electric Light Department	Municipal Utilitiy	Bill Credit	EVSE	Bill credit of $8 per month for customers that charge their PEVs
MA	Braintree Electric Light Department	Municipal Utilitiy	Rebate	EVSE	$250 for Level 2 charger
MA	Participating Municipal Light Plants	Municipal Utilitiy	Rebate	EVSE	Free Level 2 charger
MI	Consumers Energy	Investor-owned Utility	Rebate	EVSE	Residential Customers: $400 for Level 2 EVSE
MI	Indiana Michigan Power	Investor-owned Utility	Rebate	EVSE	Level 2 EVSE with a separate meter: $2,500 rebate
MO	Kansas City Power & Light	Investor-owned Utility	Rebate	PEV	$3,500 discount on a new Nissan Leaf
NE	Nebraska Public Power District	Municipal Utilitiy	Rebate	EV	Purchase of Lease of New Battery EV: $4,000
NE	Nebraska Public Power District	Municipal Utilitiy	Rebate	EVSE	Residential Charging Stations: $500
NE	Omaha Public Power District	Municipal Utilitiy	Rebate	EVSE	Level 2 Charger: $500
NE	Omaha Public Power District	Municipal Utilitiy	Rebate	PEV	$1,000 off new 2019 Audi e-tron
NV	NV Energy	Investor-owned Utility	Rebate	EVSE	Level 2 Charger: Lesser of $3,000 per charging port or 75% of
NJ	Exelon	Investor-owned Utility	Rebate	PEV	Varies
NY	Exelon	Investor-owned Utility	Rebate	PEV	Varies
NY	PSEG Long Island	Municipal Utilitiy	Rebate	EVSE	80% of the invoice price, up to $4,000 per port, for customers
OH	American Electric Power (AEP) Ohio	Investor-owned Utility	Rebate	EVSE	Local Government: Lesser of $50,000, 100% of costs, or $10,000
OR	Eugene Water & Electric Board	Municipal Utilitiy	Loan Program	EVSE	Commercial: 4% loan to cover the upfront costs, including
OR	Eugene Water & Electric Board	Municipal Utilitiy	Rebate	PEV	$300
PA	Duquesne Light Company	Investor-owned Utility	Bill Credit	PEV	One-time bill credit of $60 to residential customers who purchase
PA	Duquesne Light Company	Investor-owned Utility	Rebate	EVSE	Up to $32,000 to install publicly available Level 2 charging
PA	Exelon	Investor-owned Utility	Rebate	PEV	Varies
PA	PECO	Investor-owned Utility	Rebate	PEV	$50 for the purchase of a new PEV
TX	Austin Energy	Municipal Utilitiy	Rebate	EVSE	50% of cost, up to $1,200 for Wi-Fi-enabled Level 2 EVSE or $900
TX	Austin Energy	Municipal Utilitiy	Rebate	EVSE	50% of cost, up to $4,000 for Level 2 EVSE and/or EV Level 1
UT	Rocky Mountain Power	Investor-owned Utility	Rebate	EVSE	Level 2 EVSE (75% of equipment cost):
VT	Burlington Electric Department	Municipal Utilitiy	Loan Program	PEV	Low or no interest loans available for the purchase of a new EV.
VT	Burlington Electric Department	Municipal Utilitiy	Rebate	PEV, PHEV	All-Electric Vehicles or PHEVs: $1,200
VT	Green Mountain Power	Investor-owned Utility	Rebate	PEV, PHEV	Varies by dealer
VT	Green Mountain Power	Investor-owned Utility	Rebate	EVSE	Purchase a new All-Electric Vehicle: eligible for a free In-Home
VT	Green Mountain Power	Investor-owned Utility	Rebate	PEV, PHEV	New All-Electric Vehicle: $1,500
WI	Alliant Energy	Investor-owned Utility	Rebate	EVSE	Residential: $500 rebate for a networked Level 2 EVSE; $250 for a

Appendix 7: Pilot Programs of EV Managed Charging, 2020

Pacific Gas and Electric

Pacific Gas and Electric (PG&E) launched the ChargeForward program with BMW to support the electric grid and integrate renewable energy through smart charging. The pilot had two phases. In its first phase, 96 BMW i3 drivers were enrolled with a $1,000 incentive. BMW "utilized proprietary aggregation software to delay charging via cellular (GSM-based) telematics" and tested second-life stationary batteries for grid services to meet demand response (DR) requirements (Myers 2019).

During the 18-month trial, DR events were tested "in both Day Ahead (24-hour advance notification) and Real Time (four-minute advance notification) scenarios" (Myers 2019). BMW met the load requirements for 90% of events, with average contribution from vehicles being 20% and average contribution from the second-life battery system being 80% (Myers 2019). In a second phase, the study "expanded to over 350 participating vehicles and focused on the customer experience by giving users more managed charging information to make smart choices" (Myers 2019).

The pilot ultimately made a strong case for leveraging EVs in helping to optimize for load conditions (Myers 2019). For example, in a test conducted on Earth Day in 2017, "participants received more than 57% of their energy from renewable sources" (Myers 2019). This was accomplished by data sharing from PG&E to BMW. PG&E provided "data on the status of renewable energy generation as well as excess supply on the system", and BMW used that data to "[optimize] the EV charging by sending push notifications to participating drivers" (Myers 2019).

Because vehicle charging was controlled using telematics on-board the vehicle, vehicles were able to participate regardless of where they charged (Myers 2019). Into the future, an important challenge will likely be "estimating how much value there is to the utility with this kind of program so that it can ultimately become economically attractive or self-sustaining without subsidies" (Myers 2019).

Avista Corporation

Avista, a utility that services the Pacific Northwest, designed their pilot such that they would "own, maintain, and install EVSE on a residential or commercial customer premise and rate-base the assets" (Myers 2019). In order to participate in the project, customers had to allow "Avista to collect charging data and run DR events" (Myers 2019). Any time a DR event was to be run, customers were given the option to be notified a day in advance so that they could opt-out of an event if desired (Myers 2019).

According to one of Avista's EV engineers, Avista was able to curtail load "up to 75% and had no complaints from customers" (Myers 2019). The engineer also indicated that "as long as the vehicle is fully charged when they need it, customers don't care when the load is being shifted" asserting that Avista "saw about a 10% opt-out rate overall for the program for residential sessions" (Myers 2019).

That said, the pilot was not without challenges. In particular, reliance on customers' Wi-Fi connections was problematic at times "with 30-45% of systems losing connection with charging devices" (Myers 2019). Additionally, the costs of the program were determined to outweigh the grid benefits at the time of study. Thus, an important question remains, "at what EV penetration and with improved technology and costs will it make financial sense?" (Myers 2019).

Despite challenges, Avista is currently planning to expand DR experiments with a mind towards continued improvements. Possible next steps include expanding the program to test different control groups to determine customer impacts, adding additional EVSE models to the testing group, and exploring using the utility's advanced metering infrastructure (AMI) network for communications instead of customer Wi-Fi (Myers 2019).

Consolidated Edison

In New York, Consolidated Edison (ConEd) - in partnership with FleetCarma and ChargePoint - launched the SmartCharge New York program "to incentivize drivers to charge their vehicles at off-peak times and study customer response to non-tariff rebates" (Myers 2019). As part of the program, participants receive a FleetCarma C2 device and receive $150 upfront for simply installing and activating it (ConEd 2019). The C2 device "plugs into the vehicle's Onboard Diagnostic Port (OBDII), which then collects the customers charging data and makes it available to ConEdison and the customer via an online portal" (Myers 2019). Participants are also provided with the ability to compare their charging activity with that of other EV drivers nearby which acts as an additional gamified incentive to increase participation in the program and "improve the customer experience" (Myers 2019).

Rebates are awarded to participants when they join, keep the C2 device plugged in, and refer others to the program (Myers 2019). The program also rewards participants with $20 per month when they "avoid charging their EV's from 2 pm to 6 pm on weekdays from June through September" (Myers 2019). Additionally, participants are incentivized to charge off-peak as pricing is reduced by $0.10/kWh "between midnight and 8 am all year round" (Myers 2019).

Fleet-owning customers are also encouraged to participate. Fleets using ChargePoint infrastructure can request to send their per-vehicle charging data from ChargePoint to ConEd in order to qualify for incentives (Myers 2019). Savings can be especially substantial for fleets. For example, the NY Department of Citywide Administrative Services projected in 2019 that it could potentially "earn up to $150,000 per year for charging its EVs overnight by participating in the program" (Myers 2019).

Xcel Energy

Xcel Energy conducted an EV charging station pilot in Colorado from 2013 to 2014. The pilot was designed to help the utility better understand "customer charging patterns and behaviors, how charging load coincides with Xcel Energy's Generation System (System) peak in Colorado, how technically and operationally feasible it is to interrupt vehicle charging through DR, and how vehicles may impact the distribution system" (Xcel Energy 2015). To this end, Xcel Energy recruited 20 EV-owning customers.

Each customer was either provided a smart, Level 2 EVSE or a load control device to be "installed on their existing Level 2 charger" (Xcel Energy 2015). At the conclusion of the study, participants could keep their respective EVSE or load controllers. Participants were also given an additional $100 incentive "for each year they agreed to participate in DR events" (Xcel Energy 2015). Those that agreed to participate in DR events were subject to 12 control events per season. During control events, Xcel Energy could control demand from the chargers (Xcel Energy 2015).

In addition to providing DR capacity, participants also agreed to allow Xcel energy to monitor daily usage and download charging data (Xcel Energy 2015). Surveys conducted after the study indicated that participants were "happy overall with the pilot believing that communication was at an appropriate level and 12 control events per season were reasonable" (Xcel Energy 2015). With regard to DR events, most participants expressed that they were either "not inconvenienced" or only "mildly inconvenienced" by the events (Xcel Energy 2015). Most participants also indicated that a yearly incentive of $100 was sufficient compensation for the inconvenience of control events (Xcel Energy 2015).

Another key takeaway from the study was that EV owners "are an engaged group of customers and there is a high willingness to participate in future EV-related pilots" so long as the utility is paying for "equipment needed to participate" (Xcel Energy 2015).

Potomac Electric Power Company

In 2014, Potomac Electric Power Company (Pepco) started their Residential Pilot Program with the goals of "improving electric distribution system reliability and efficiency, and… decreasing the use of electricity at peak times" (EPRI 2016). The program ran for 22 months and enrolled 101 EV-owning customers to participate. While Pepco recognized that demand from EV adoption was "relatively minor" at the time, the utility expressed that "it was crucial… to proactively understand potential EV charging solutions" (EPRI 2016).

Through the pilot, Pepco offered two new rates: (1) a whole house TOU rate that allowed participants to manage their EV demand in with their house electricity needs and (2) an EV-only TOU rate designed to be calculated separately from other residential consumption (EPRI 2016). Those participants that chose the separately metered rate could either use their own existing Level 2 charging station and install a secondary meter, or they could purchase a qualifying smart Level 2 EVSE as specified by the utility. Results from the study indicated that "customers who signed up for a Pepco TOU offering took advantage of the off-peak rates" (EPRI 2016).

In addition to the rates, Pepco also conducted seven DR events. Across all seven events only three people were ever charging. One of those individuals opted out of the DR event, and the other two individuals reduced their charging in response to the event (EPRI 2016). For DR events, customers were "informed… hours prior" and few participants even attempted to charge during the events (EPRI 2016). Authors of the EPRI publication summarizing the study took this as a signal that "DR response events can influence customer behavior" (EPRI 2016).

Appendix 8: Other Residential EV Rates Collected by NCCETC, 2019

Utility Name	Rate Description	Basic Charge ($)	Energy Charge (¢/kWh)	Demand Charge ($/kW)	Notes
Alabama Power	TOU	25	26.9540 (on-peak) 6.9540 (off-peak)	NA	1.7155¢/kWh discount available during EV charging period
Alabama Power	TOU + Demand	14.5	22.6557 (on-peak) 7.6557 (off-peak)	1.5	
Salt River Project	EV	NA	Summer: 20.94 (on-peak) 7.65 (mid-peak) 6.11 (off-peak) Winter: 9.51 (on-peak) 7.37 (mid-peak) 5.75 (off-peak)	NA	
Anaheim Public Utilities	EV	5	Summer: 26.34 (on-peak) 11.17 (off-peak) Winter: 25.63 (on-peak) 10.56 (off-peak)	NA	separate meter for EV charging
Burbank Water & Power	TOU-EV	8.99	24.52 (on-peak) 16.34 (mid-peak) 8.17 (off-peak)	NA	
Riverside Public Utilities Department	EV	9.66	Summer: 26.44 (on-peak) 15.10 (mid-peak) 10.59 (off-peak) Winter: 19.83 (on-peak) 13.94 (mid-peak) 10.59 (off-peak)"	NA	separate meter for EV charging
Sonoma Clean Power	EV-B	NA	Summer: 24.055 (on-peak) 10.098 (mid-peak) 3.711 (off-peak) Winter: 6.941 (on-peak) 3.944 (mid-peak) 3.307 (off-peak)	NA	separate meter for EV charging
Sonoma Clean Power	EV2	NA	Summer: 14.822 (on-peak) 10.632 (mid-peak) 6.922 (off-peak) Winter: 9.449 (on-peak) 8.234 (mid-peak) 6.223 (off-peak)	NA	

Norwich Public Utilities	Tiered	14.02	13.750 (first 1000 kWh) 13.172 (all excess)	NA	
Georgia Power	TOU-PEV-6	10	20.3217 (on-peak) 6.5865 (off-peak) 1.4164 (super off-peak)	NA	
PSEG Long Island	TOU	16.2	Summer: 33.51 (on-peak) 5.29 (off-peak) Winter: 9.32 (on-peak) 3.44 (off-peak)	NA	
Stowe Electric	TOU & CPP	14.71	Summer: 64.47 (CPP peak) 18.52 (non-CPP peak) 11.68 (off-peak) Winter: 24.55 (on-peak) 14.31 (off-peak)	NA	
Dominion Virginia Power	TOU with EV	6.58	Varies in hours and seasons	NA	
Dominion Virginia Power	TOU-EV	2.73	13.5149 (on-peak) 4.6975 (off-peak) 1.626 (super off-peak)	NA	

Appendix 9: Non-Residential EV Rates, Collected by NCCETC, 2019

Note that all TOU rates presented only include summer pricing. These are examples of non-residential electric vehicle rates.

EV electricity rates available to non-residential EVSE operators.

Utility	Rate Description	Basic Charge [$/month]	Energy Charge [$/kWh unless otherwise stated]	Demand Charge [$/kW]	Notes
Southern California Edison	TOU-EV-7	11.53	0.41 (on-peak), 0.30 (mid-peak), 0.15 (off-peak)	NA	Does not include discounts. Demand < 20 [kW].
Southern California Edison	TOU-EV-8	117.96	0.50 (on-peak), 0.26 (mid-peak), 0.13 (off-peak)	NA	Does not include discounts or power factor adjustment charges. Demand > 20 [kW] and < 500 [kW].
Southern California Edison	TOU-EV-9	433.47	0.44 (on-peak), 0.22 (mid-peak), 0.11 (off-peak)	NA	Does not include discounts or power factor adjustment charges. Demand > 500 [kW]
San Diego Gas & Electric	Power Your Drive	NA	Hourly day ahead pricing	NA	Applies directly to public charging.
Consolidated Edison	Business Incentive Rate	Varies	32% - 49% rate reduction applied to monthly bill	Varies	Available to publicly accessible electric vehicle quick charging stations.
Alabama Power	Business Electric Vehicle TOU	100.00	0.21 (on-peak), 0.11 (mid-peak), 0.08 (off-peak)	NA	Does not include discounts.
Indianapolis Power & Light Company	EVP	NA	2.50 [$/charging session]	NA	Applies directly to public charging.

Alameda Municipal Power	EV Discount Rates	NA	-0.06 rate discount	NA	Limits customers to 150 – 350 [kWh/month] depending on vehicle size. Customers receive a discount of $9.00 - $21.00 depending on vehicle size.
Bear Valley Electric Service	TOU-EV-2	NA	0.18 (on-peak), 0.14 (mid-peak), 0.09 (off-peak)	NA	Demand < 20 [kW].
Bear Valley Electric Service	TOU-EV-3	NA	0.18 (on-peak), 0.14 (mid-peak), 0.09 (off-peak)	9.00	Demand > 20 [kW] and < 500 [kW].
CPS Energy	EV Flat Rate Program	NA	60.00 [$/year]	NA	Applies directly to public charging.
Otter Tail Power Company	Off-Peak EV	7.00 – 28.00	0.027 (authorized), 0.075 (penalty)	NA	The monthly charge varies depending on meter set-up. Customers may only receive electricity from 10:00 PM to 6:00 AM.

Appendix 10: Data Collection, Collected by NCCETC, 2020

Vehicle-Side Data Collection

Vehicle-side data collection involves connecting a data monitoring device to participants' vehicles and recording activity at a predetermined interval. In our review, some studies using vehicle-side data collection opted to only collect global positioning system (GPS) location data and estimated electricity consumption and demand using a combination of energy use calculations and behavioral assumptions (Liu 2015). That said, most studies in this category appeared to hire telematics services from companies like FleetCarma (FleetCarma 2019a, EPRI 2018). FleetCarma is a division of Geotab and has worked with many utilities to assess EV load as well as explore the impacts of TOU rate designs. FleetCarma's C2 monitoring device can provide high resolution data on GPS location, mileage, air temperature, voltage, current, and state of charge (EPRI 2018).

With the resulting data, utilities can construct load profiles for individuals and use them to estimate aggregate load. The data can be segmented by specific attributes such as vehicle type, rural versus urban residence, and driver demographics. In this way, individual load profiles might first be used to create a typology of EV driver behaviors, and then these behavioral load profiles would be used to estimate aggregate demand based on vehicle registration data and/or population demographic data. Understanding driver behavior is valuable as it allows the study designer to interrogate why drivers make certain decisions as well as how those decisions might change in the future. Recent data out of Canada suggests that charging behaviors are not fixed (FleetCarma 2019b). Over the past few years, average residential charging in Canada dropped from an estimated 90% to just 72% in part due to increased availability of workplace charging (FleetCarma 2019b).

Yet another option for estimating aggregate load using vehicle-side data could be Monte Carlo simulation. In this method, a secondary data set would be constructed from the empirical data. This secondary data set would be made to be proportionally representative of the study population. Then, values would be randomly drawn from this secondary data set and summed to provide a stochastic load estimate over a given period of time. If study designers wanted to explore potential future scenarios, they could intentionally change the proportions in the secondary dataset to explore possible shifts such as increased commuting behavior, increased public charging activity, or increased ownership of higher battery capacity EVs.

Based on our review of load profiling options, vehicle-side data collection has become increasingly popular over time and is currently being used by many different utilities in states across the US (FleetCarma 2019a). Vehicle-side data collection offers many advantages including but not limited to the following:

- it has high potential for accuracy if representative,
- it is easy to understand and defend,
- it requires fewer assumptions compared to other methods,
- it allows for assessment of distribution level impacts,
- it allows for construction of behavioral profiles,
- it can clarify where non-residential charging is taking place.

For most utilities, vehicle-side data collection is probably the best approach available for constructing load profiles. It requires far fewer assumptions than any other method and has few disadvantages outside of cost. From conversations with FleetCarma, it sounded as though vehicle-side data collection has the potential to be equivalent or even cheaper than some forms of charger-side data collection (Shin 2019). That said, this is likely highly variable depending on the scope and design of the study, and we were not able to acquire exact estimates from FleetCarma for comparison. Compared to methods that do not require digital data collection, vehicle-side data collection is likely more expensive than conducting surveys and/or extrapolating from existing data.

Charger-Side Data Collection

Charger-side data collection involves recording data from smart EVSE and/or sub-metered EVSE. The format of the data is typically similar to vehicle-side data with electricity withdrawals reported at a regular interval. For example, in a study completed by Xcel Energy, the authors reported using 15-minute interval load data from ChargePoint [EVSE] and 5-minute interval load data from Consert EVSE (Xcel Energy 2015). Notably, this study only tracked home charging.

If one is only interested in estimating residential EV load, charger-side data collection would likely compare equivalently to vehicle-side. However, if aggregate EV load (i.e., residential, public, and workspace charging) is of interest, vehicle-side data might typically be expected to provide greater value. This is primarily due to several key limitations of charger-side data. For one, charger-side data cannot be used to create robust behavioral profiles because it is generally not possible to tie charging outside of the home with specific individuals. Additionally, to get a fuller picture of non-residential charging, the study designer would need to enlist workplace and public charging infrastructure operators. In vehicle-side data collection, this hurdle is inherently bypassed.

As detailed in the previous section, charger-side data collection does not appear to be especially cost competitive with any other options (Shin 2019). Additionally, we noted that it was not uncommon for utilities in charger-side data studies to either provide free smart chargers or offer significant EVSE subsidies to study participants – further contributing to study costs (Xcel Energy 2015, Herter and Okuneva 2014, NCUC 2019). Perhaps, if a program were to target participants that already owned smart EVSE in their homes and request voluntary data handover, study costs might be reduced. That said, such a design might not provide a sufficiently large enough sample size to be useful in analysis.
All this said, if data collection is not an obstacle and/or if substantial charger-side data already exists and is readily accessible, charger-side data can be used to great success. For example, in the UK, the National Grid Electricity System Operator pulled data from major operators of charging infrastructure as well as existing data from the UK Office of Low Emission Vehicles and used this data to create demand profiles for various charger types (Element Energy Limited 2019). Importantly, the dataset included "over 8 million real-world charging events" and so was assumed to provide a fairly comprehensive look at charging behavior (Element Energy Limited 2019). Below is the workflow used to generate annual demand at the country-level (Figure 1):

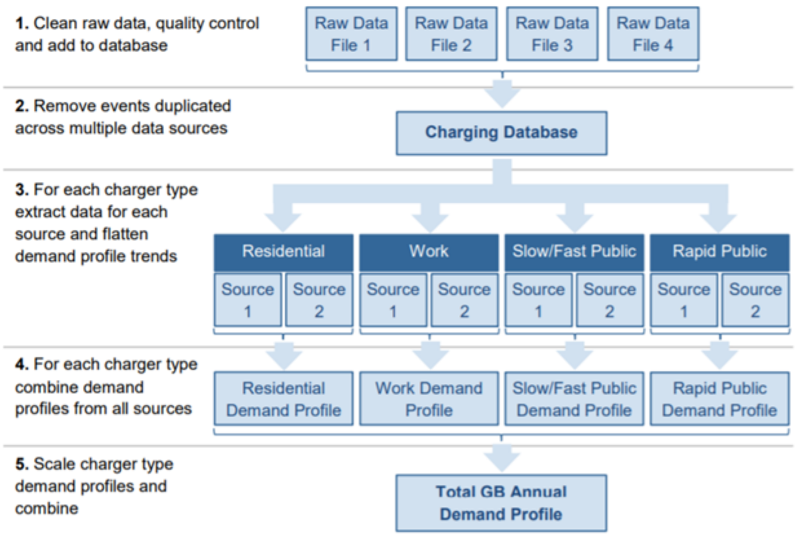


Figure 1: Flowchart of data processing method used by Element Energy Limited in their analysis of charging data from the UK. Source: Element Energy Limited, 2019

Surveys and Self Reporting

Surveys and self-reporting involve collecting data directly from EV-owning customers regarding their driving and charging habits. This could take the form of a simple survey, but it would likely benefit from greater involvement. For example, participants could commit to keep travel journals recording daily mileage, charging time, charging duration, and charging location. Because the journals would not contain explicit numeric values for energy consumption, assumptions would need to be made regarding the power rating and efficiency of EVSE used by participants. Still, this method comes with the advantage that creation of behavioral typologies is still possible as individuals' behaviors could be traced both inside and outside of the home.

An obvious limitation of this method is that it is subject to reporting errors. Even assuming that all participants are benevolent actors, it is possible that honest mistakes could still be made. Good study design could help reduce error, but it would never eliminate it. Several key factors that could potentially mitigate study error include the length of the survey period, the amount of information requested, the compensation for participating, and method of collection.

A longer survey period would undoubtedly provide more data, but participant fatigue increases with time and could increase the likelihood of reporting errors (Lavrakas 2008). For this reason, keeping survey period length short (e.g., perhaps a week or less) would likely be optimal. However, because activity-travel behavior is likely to be influenced by the weather (Cools and Creemers 2013) and weather patterns are related to seasonality, it would also make sense to conduct a longitudinal study that captures seasonality. For example, perhaps participants could be asked to record a week of survey data for each season. In this way, they would record four weeks of data in total, but there would be reprieves in which they do not collect data for a long period of time. Importantly, participants should not all collect data at the exact same time because any given week within a season may not be representative of the season as a whole.

Requesting too much information can also contribute to participant fatigue and potentially reduce interest in study involvement or increase reporting errors (Lavrakas 2008). If a participant is expected to log information every time they connect and disconnect from an EVSE, the information required of them should not unduly impede their daily activity. That is to say, they should not feel disproportionately inconvenienced by the data logging.

How inconvenienced a participant feels – and thus their engagement with the study – will also depend on their level of compensation. Compensating participants is important as it facilitates recruitment, enables participation, and can encourage participants to push through barriers like fatigue (Grady ND). Compensation communicates to participants that the study designer respects their time. Compensating participants can be accomplished in a variety of ways including direct payment, subsidizing EVSE, or discounting electricity bills.

The method of collection can reduce the opportunity for error and combat participation fatigue if used skillfully. For example, a digital journal accessible via phone application could standardize how data is collected. It could also reduce the time it takes to record charging activity as a phone application could collect time of day and GPS location at the push of a button. Of course, a digital platform might also alienate some users. So, the study design could allow for users to choose either a pre-formatted paper journal or a phone application. This flexibility would add work for analysts but may help to increase the accuracy of data reporting across the participant population.

Travel Survey Data

Travel survey data is typically required for transportation analyses conducted by regional planners. Travel survey data typically contains information on when, where, and how people travel. If data is acquirable for the region of interest, this method can significantly reduce the work required on the data collection side. That said, it would translate to increased work for those designing and conducting data analysis. Methods relying on travel survey data would likely require non-trivial data reformatting, and any analysis would have to rely heavily on a large number of assumptions.

In a study conducted by the European Commission, travel survey data was used to construct load profiles for EV charging (Pasaoglu et al. 2013). The data contained information on (1) individuals, (2) their vehicles, (3) the calendar days on which trips were recorded, (4) the time, distance, and purpose of trips, and (5) the municipalities in which individuals lived (Pasaoglu et al. 2013). Because the data was not explicitly for EV drivers, the authors had to make several critical assumptions:

- an individual's travel behavior is irrespective of the type of vehicle they drive,
- an individual uses an EV for all trips made in the day,
- energy consumption is explained only by the driving pattern of a single individual,
- one individual uses the same EV on all days of the week (Pasaoglu et al. 2013).

The data were first reformatted so that individual driving patterns were divided into five-minute intervals, and each five-minute interval [was] marked as either a driving period or a parking period for each sampled individual (Pasaoglu et al. 2013). In order to construct charging profiles, the authors had to estimate (1) energy use during driving periods and (2) electricity consumption during parking periods.

Energy use was estimated for driving periods based upon EV type and travel speed. EV type was randomly assigned based on market share, and a speed-dependent energy consumption function was used to estimate battery depletion during driving periods. Electricity consumption was far more complicated to estimate with the authors trying to account for several conditions:

First, the parking space should provide recharging facilities; second, the parking time should be long enough to allow completion of the recharge process or a reasonable top-up; and third, the car driver should actually want to recharge her or his car (Pasaoglu et al. 2013).

Electricity consumption estimates thus hinged on further assumptions including:

- recharging at home is always possible,
- availability of recharging at parking spaces at work refers to a share of drivers rather than to a share of spaces,
- drivers will not start to recharge unless they will be parked for at least 30 minutes,
- drivers will not spend money recharging outside of the home if they have enough power to get home,
- recharging can occur at either a normal or fast rate,
- recharge rates decline as the battery approaches its full capacity,
- chargers have an efficiency ratio of 0.8 (Pasaoglu et al. 2013).

Finally, load profiles were calculated by selecting individual charging profiles through constrained random selection. These selections were then summed with weights corresponding to the relationship between the composition of the reference population and the composition of the sample, and this resulted in population load profiles (Pasaoglu et al. 2013).

Reflecting on this study design more generally, the primary disadvantage of using travel survey data to construct load profiles is that it requires both a large number of assumptions and several potentially highly significant assumptions. As such, this methodology would likely provide less accurate results than other options that rely on EV-specific data. Additionally, building defensible assumptions and protocols for dealing with data can be laborious work for analysts. Still, if the cost of data collection is a major barrier and staff expertise is not, this option could be worth considering.

Charging Behavior Data

As evidenced by the above study design examples, many studies have already developed charging behavior data and constructed load profiles for their respective regions. Given this, one option could be to request data from other studies and try to extend it to a new study region of interest. Importantly, this method does come with several critical concerns. Aside from the possibility that others may be unwilling to share data, this method also entails the very significant assumption that behavior in one region is representative of behavior in another. This can be a very difficult assumption to justify as "every service area has its own unique EV ecosystem with different adoption rates, vehicle specific market share, and geographic considerations" (Goody 2019). Additionally, as stated previously, recent data out of Canada suggests that charging behaviors can change over time (FleetCarma 2019b).

Given the severe assumptions that this method entails, it is not generally recommended unless analysts can demonstrate that the two study regions in question are comparable. Additionally, it would be advisable to try to pull from studies conducted closer to the new region of interest rather than farther away. For example, it would be more defensible to use existing data if it were from a nearby city or if the geographies of the data overlapped and were not dramatically different in scale (e.g., if county data were used to inform analysis of a city within that county). These methods could still lead to inaccurate results without appropriate vetting, but they at least attempt to take into consideration Tobler's first law of geography that "everything is related to everything else, but near things are more related than distant things" (Tobler 1970).

If two regions were deemed similar enough, then behavioral data from the first region could just be reproportioned and/or rescaled so as to best represent the new study region of interest. The benefit of this type of study design is that it would likely be fairly easy to understand and would entail less overall work than any other method. However, as discussed, there are many circumstances under which this method is not advisable. Additionally, obtaining empirical data from other studies – especially private studies – may not be possible.

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Contact Kristi Brodd to learn more or to purchase the Electric Vehicle Marketing Toolkit for your utility.
kbrodd@advancedenergy.org or 919-857-9019

www.advancedenergy.org

Proposal for White-Label PlugStar site

- Plug In America will develop a white-labeled version of its PlugStar.com site for Fayetteville PWC
  - Suggested domain for registration: faypwc.plugstar.com designed with faypwc.com marketing and branding guidelines
- Included in build will be all tools and pages seen on PlugStar.com
  - EV Shopping Assistant
  - Cars
  - Incentives
  - Chargers
  - Events
  - Dealers
  - Customer Login

  with additions to Fayetteville PWC territory including:
  - Customized charging rates to be inserted into charging cost calculations
  - List of local incentives (if available)
  - List of local events
  - Local electricians for installation of charging equipment (coming January 2020)

PlugStar by Plug In America

2

Budget

White-Label Website
- One-year customized PlugStar.com licensing fee: $30,000
  - Site build
  - Domain upkeep
  - General maintenance plus data updates

Program Management
- One-year of ongoing Plug In America support: $19,000
  - Monthly site traffic/activity reports
  - Monthly communications/check-ins
  - Administration fee

EV Support Line:
- One-year access for Fayetteville PWC customers: $5,000

Total: $54,000

PlugStar by Plug In America

14

sagewell[SM]

1. Identify value of beneficial electrification opportunities	2. Design high-impact marketing programs to drive adoption	3. Grow utility revenues, lower rates and reduce emissions

EV Strategic Planning for Apex, NC - $5,000

EV Strategy includes:

Individualized EV value

- Use existing models to present the individualized value of EVs in Apex's territory

EV stock & sales

- Assess dealerships, existing stock and pricing. Provide roadmap for building relationships

Utility Marketing

- Keys to a successful EV informational website, guide on programs and events, specific organizations to contact

Utility investments

- What should Apex spend money on?

Bring Your Own Charger® (BYOC) EV Load Shifting Program

- Bring Your Own Charger® (BYOC) pays monthly incentives to customers for charging off peak
- Across more than 60,000 days of monitoring, BYOC has a 95% off-peak charging rate
- Non smart charger, in-car devices or other hardware required
- Turn-key solution
- Sagewell processes enrollment, provides customer service, and reporting

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