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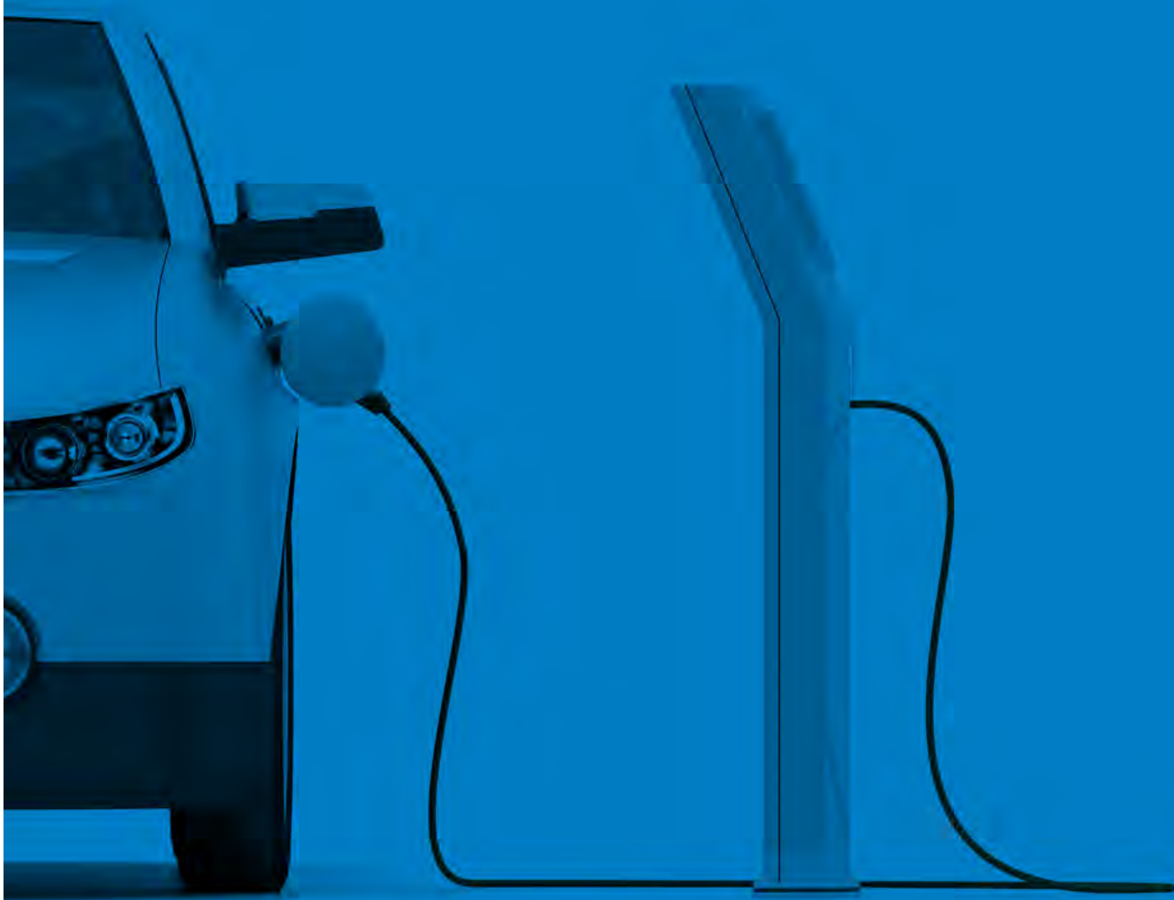
Running the Grid on Electric Vehicles



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Running the Grid on Electric Vehicles

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The NC Sustainable Energy Association (NCSEA) is a 501(c)(3) nonprofit membership organization of individuals, businesses, government, utility providers and nonprofits interested in North Carolina's sustainable energy future. NCSEA drives public policy and market development to create energy jobs, economic opportunities and affordable energy to benefit North Carolina.

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INTRODUCTION

On average, an electric vehicle ("EV") is driven for only 72 minutes per day.[1] For the remainder of the day, the vehicle is parked and generally is plugged into a charger. Traditionally, when EVs are plugged into a charger, there is a unidirectional flow of electricity from the electric grid to the vehicle. With electric vehicle to grid technology ("EV to Grid"), when EVs are plugged into a charger, there is a bidirectional flow of electricity between the electric grid and the vehicle. Through this bidirectional flow of electricity, EV to Grid allows EVs to be a resource that can provide stability and ancillary services to the electric grid and support the integration of intermittent generation resources, all while providing an income stream to owners of EVs.

Pilot Project: University of Delaware

A project at the University of Delaware marked the first time vehicle owners were paid to provide grid support. Researchers aggregated their fleet of 18 EV to Grid vehicles, located at two sites, for total connected power of 180 kW.

Source: Stephen Edelstein, Delaware V2G Test Lets Electric Cars Sell Power, Green Car Reports (October 20, 2014), http://www.greencarreports.com/news/1094990_delaware-vehicle-to-grid-test-lets-electric-cars-sell-power.

BENEFITS OF EV TO GRID

The electric grid is generally divided into three segments: generation, transmission, and distribution. However, the delivery of electricity would not be possible without the provision of **ancillary services**, which are defined as the "services that are necessary to support the transmission of capacity and energy from resources to loads while maintaining reliability operation" of the grid.[2] Ancillary services include: "(1) **Scheduling, System Control and Dispatch Service**; (2) Reactive Supply and Voltage Control from Generation Sources Service; (3) Regulation and Frequency Response Service; (4) Energy Imbalance Service; (5) Operating Reserve - Spinning Reserve Service; and (6) Operating Reserve - Supplemental Reserve Service."[3] EV to Grid is well-suited to serve some of these functions because it provides higher quality ancillary services than traditional resources and it has minimal operating costs.[4]

The Curious Case of Demand Response

Demand response can be used to vary the load of a charging EV, however, it involves the unilateral flow of electricity from the grid to the EV. Because demand response does not involve the bilateral flow of electricity between the grid and the EV, it is not discussed in this paper. However, demand response services provided by EVs can be beneficial to the grid.

[1] Adrene Briones, James Francfort, Paul Heitmann, Michael Schey, Steven Schey, & John Smart, *Vehicle-to-Grid (V2G) Power Flow Regulations and Building Codes Review by the AVTA*, IDAHO NATIONAL LABORATORY, Sept. 2012, at 31, 37.
[2] FERC Order 888-A, Appendix B (March 4, 1997).
[3] FERC Order 888-A, p. 186 (March 4, 1997).
[4] Sonia Aggarwal and Robbie Orvis, *Distribution Optimization: Ready for Takeoff*, Public Utilities Fortnightly (June 2015), *available at* http://www.fortnightly.com/fortnightly/2015/06/distribution-optimization-ready-takeoff.

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> *"I think EV to grid and renewables go hand in hand, especially because EVs are an enabling technology as far as being able to charge when you have the renewable online and switching it around."*
>
> ***Jeff Barghout, Principal Adviser, Nexus EMC***

While EV to Grid is capable of providing several different types of ancillary services, it is particularly well-suited to provide **reserve and regulation services**.[5] **Peaking reserves** are called upon to meet electricity needs during periods of high demand.[6] **Spinning reserves** are called upon to meet electricity needs when there is a generation, transmission, or distribution failure.[7] **Regulation services** correct instantaneous disparities between electricity supply and demand to ensure that the frequency and voltage of the electricity provided by the grid remain constant.[8]

Pilot Project: Los Angeles Air Force Base

The Los Angeles Air Force Base utilizes a fleet of 42 EV to Grid vehicles to that provide more than 700 kWh of power to the grid.

EV to Grid can also provide support for intermittent generation resources. Certain renewable energy resources, notably solar and wind, are intermittent in their generation and are not dispatchable by the grid operator. EV to Grid can provide support for intermittent generation resources by storing energy during periods of peak generation and low demand, and then returning it to the grid during demand spikes.[9] In doing so, EV to Grid levelizes the generation profile of these resources, allowing the grid to accommodate greater amounts of intermittent and non-dispatchable solar and wind generation.[10]

BARRIERS TO EV TO GRID

Barriers to EV to Grid adoption generally fall into three main categories: **financial**, **technological**, and **legal and regulatory**.

Financial Barriers. Simply put, the infrastructure necessary to implement EV to Grid can be expensive. The most universal financial barrier to EV to Grid is the cost associated with charging infrastructure. In order to support EV to Grid, charging infrastructure must allow the bidirectional flow of electricity and include certain safety features, such as anti-islanding measures that prevent the flow of electricity onto the local grid during times of service disruptions.[11]

Pilot Project: University of California, San Diego

The University of California at San Diego is home to one of the largest and most advanced microgrids in the world. In addition to supporting the microgrid, the pilot project will use 9 vehicles to develop new use cases for EV to Grid and test interconnection standards.

Source: Jeff St. John, UC San Diego and NRG to Test Electric Cars on a Solar and Storage Microgrid, Greentech Media (November 12, 2015), https://www.greentechmedia.com/articles/read/uc-san-diego-nrg-to-test-electric-vehicles-that-can-charge-the-grid.

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[5] Steven Letendre, Paul Denholm, and Peter Lilienthal, *Electric & Hybrid Cars: New Load, or New Resource?,* Public Utilities Fortnightly (December 2006), *available at* http://www.fortnightly.com/fortnightly/2006/12/electric-hybrid-cars-new-load-or-new-resource.

[6] Letendre, et al., *supra* note 5. Willett Kempton and Jasna Tomic, *Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy* at 3 (December 2004).

[7] Letendre, et al., *supra* note 5.

[8] Letendre, et al., *supra* note 5. Kempton and Tomic, *supra* note 6.

[9] Robert F. Kennedy, Jr., *Green Transition*, Public Utilities Fortnightly (May 2011), *available at* http://www.fortnightly.com/fortnightly/2011/05/green-transition.

[10] Michael T. Burr, *Edison Under the Hood*, Public Utilities Fortnightly (April 2012), *available at* http://www.fortnightly.com/fortnightly/2012/04/edison-under-hood. Kennedy, *supra* note 9.

[11] Mcdavis A. Fasugba and Philip T. Krein, *Cost benefits and vehicle-to-grid regulation services of unidirectional charging of electric vehicles*, Energy Conversion Congress and Exposition (ECCE), 2011 IEEE (September 2011), *available at* http://electricvehicle.ieee.org/battery-technologies/cost-benefits-and-vehicle-to-grid-regulation-services-of-unidirectional-charging-of-electric-vehicles/. Adam Langton and Noel Crisostomo, *Vehicle-Grid*

"Cost is tied to the technology and very much a barrier."

Richard Sapienza, Clean Transportation Specialist, NC Clean Energy Technology Center
Tommy Cleveland,Renewable Energy Project Coordinator, NC Clean Energy Technology Center

Where unidirectional charging infrastructure has already been installed, it will need to be replaced to support EV to Grid, leading to the possibility of stranded costs.[12] Depending on the location of the charging infrastructure, these costs will be borne by either individual EV owners, utilities, or third parties who own public chargers.

In addition to the costs associated with charging infrastructure, owners of EVs will likely need to upgrade their vehicles in order to provide EV to Grid services.[13] Few EVs are capable of providing EV to Grid services without modifications. Upgrades to EVs typically include replacing plugs and circuits, and usually cost around $2,000.[14]

In some states, there are concerns that other costs associated with interconnection, including necessary grid upgrades to facilitate distribution, will be borne by all ratepayers while only a few EV owners benefit.[15] These concerns have already been shown in the context of EV charging; the California Public Utilities Commission recently declined to approve an EV charging plan proposed by Pacific Gas & Electric.[16]

"The technology is there, but there are still a lot of issues surrounding widespread adoption. Most cars don't have bilateral capabilities built into the vehicle so you still have to wait until mainstream vehicles have that capability."

Jeff Barghout, Principal Adviser, Nexus EMC

Technological Barriers. If EV to Grid services are to be controlled by a third party other than the EV owner, such as the grid operator, there must be a communications network in place to allow for this control. At least two existing communications networks can be utilized to allow EV to Grid services. One option is the network already used by smart grid technologies such as advanced metering infrastructure ("AMI") electric meters. Another option for certain EVs is the cellular telephone network; a pilot project utilizing EVs for demand response is being implemented by BMW and Pacific Gas & Electric, which uses computers from both companies and the cellular telephone network to communicate with participating EVs.[17] However, the use of either communications network will likely require an investigation into the security of the network and cybersecurity threats.

Legal and Regulatory Barriers. Enabling EV to Grid may require clarifying statutory and regulatory provisions. Interconnection standards would apply to EV to Grid, because EVs would be selling electricity to the grid, but such standards have not been crafted with EV to Grid in mind.

The implementation of EV to Grid will also necessitate complex contractual relationships between EV owners, utilities, and possibly third parties. These contractual relationships will dictate when EVs must be available to provide services, as well as who controls when and how much electricity is drawn from the EV.

Integration, CALIFORNIA PUBLIC UTILITIES COMMISSION ENERGY DIVISION (October 2013), *available at* http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M081/K975/81975482.pdf.

[12] Fasugba and Krein, *supra* note 11.

[13] Langton and Crisostomo, *supra* note 11.

[14] Willett Kempton, Victor Udo, Ken Huber, Ken Komara, Steve Letendre, Scott Baker, Doug Brunner, & Nat Pearre, *A Test of Vehicle-to-Grid (V2G) For Energy Storage and Frequency Regulation in the PJM System*, UNIVERSITY OF DELAWARE, PEPCO HOLDINGS, PJM INTERCONNECT, & GREEN MOUNTAIN COLLEGE (November 2008), http://www.udel.edu/V2G/resources/test-v2g-in-pjm-jan09.pdf.

[15] Langton and Crisostomo, *supra* note 11.

[16] Julia Pyper, *Regulators Turn Down PG&E's $654 Million EV-Charging Station Proposal*, Greentech Media (September 28, 2015), *available at* http://www.greentechmedia.com/articles/read/Regulators-Turn-Down-PGEs-654-Million-EV-Charging-Station-Proposal.

[17] See generally, *Introducing the BMW i ChargeForward Program*, *available at* http://www.bmwichargeforward.com/.

"The most important aspect for implementing EV to grid is law, because have already figured out the technology, and because we have already put in a lot of work in getting the car companies moving on this."

Dr. Willett Kempton, Professor, University of Delaware's School of Marine Science and Policy within the College of Earth, Ocean, and Environment

However, such barriers can be overcome. Recently, the first tariff using stationary home batteries for grid services was proposed. San Diego Gas and Electric's "Bring Your Own Battery Tariff" utilizes customer-owned distributed energy storage to meet the utility's needs.[18] The tariff includes three major provisions: incentives, such as rebates for the purchase of batteries, to customers in locations that would benefit from services provided by distributed energy storage; time-varying rates designed to align charging and discharging with grid needs; and utility control of the battery's charge and discharge functions during certain periods of peak demand.[19] While this tariff only applies to stationary batteries, it is an application of utility control of customer-owned resources that could easily be adopted for EV to Grid.

HOW TO MAKE MONEY

EV owners are unlikely to allow their vehicles to be used for EV to Grid services unless they are compensated for the use of their personal property. Thus, the frequency at which certain ancillary services are needed and the monetary value of these services must be considered.

As discussed above, EV to Grid is well-suited to provide reserve capacity to the grid. While EV to Grid is capable of providing peaking reserves, these reserves are called upon for only a few hours per year, and thus revenue from providing peaking reserve services would be limited.[20] In comparison, while spinning reserves are only called upon around twenty times per year, providers are paid capacity payments simply for being available to provide the services when called upon.[21]

While instances when EV to Grid services would be called upon to provide reserve capacity are relatively infrequent, regulation services are called upon as many as 400 times per day.[22] Similar to spinning reserves, providers of regulation services are paid capacity payments to ensure their availability.[23] Thus, regulation services could be very profitable for EV to Grid services. Based on calculations of the value of spinning reserve and regulation services that EV to Grid could provide, one energy company CEO estimated that owners would be paid as much as $10 per day, per vehicle.[24] In one pilot project, researchers calculated the value of services provided by each vehicle to be $5 per day.[25]

[18] Jeff St. John, *SDG&E Proposes a 'Bring-Your-Own-Battery' Tariff*, Greentech Media (July 14, 2015), *available at* http://www.greentechmedia.com/articles/read/sdges-proposes-a-bring-your-own-battery-tariff.

[19] *Application of San Diego Gas & Electric Company (U 902 E) for Approval of Distribution Resource Plan,* California Public Utilities Commission Docket No. A.15-07-003 (July 1, 2015), *available at* http://www.sdge.com/regulatory-filing/14986/sdges-approval-distribution-resources-plan-drp.

[20] Letendre, et al., *supra* note 5. Kempton and Tomic, *supra* note 6.

[21] Letendre, et al., *supra* note 5.

[22] Michael T. Burr, *CEO Forum: Dealing with Disruption*, Public Utilities Fortnightly (June 2010), *available at* http://www.fortnightly.com/fortnightly/2010/06/ceo-forum-dealing-disruption. Letendre, et al., *supra* note 5. Kempton and Tomic, *supra* note 6.

[23] Burr, *supra* note 22. Letendre, et al., *supra* note 5. Kempton and Tomic, *supra* note 6.

[24] Burr, *supra* note 22. Michael T. Burr, *V2G Shuffle*, Public Utilities Fortnightly (June 2010), *available at* http://www.fortnightly.com/fortnightly/2010/06/v2g-shuffle.

[25] T. Markel, et. al.,*Multi-Lab EV Smart Grid Integration Requirements Study: Providing Guidance on Technology Development and Demonstration*, National Renewable Energy Laboratory (May 2015), *available at* http://www.nrel.gov/docs/fy15osti/63963.pdf.

With key services identified and valued, a profitable business model must next be identified.[26] In researching this paper, it became apparent that there are three general business models for EV to Grid services to be profitable. The first model, which this paper terms **Owner Control**, gives the owner of the EV control over when electricity from their EV is transmitted onto the electric grid. The second model, termed **Utility Control**, gives the utility control over when electricity from an EV is transmitted onto the electric grid. The third model, termed **Aggregator Control**, gives a third-party access to multiple vehicles and control over when electricity is transmitted from the vehicles to the electric grid.

Owner Control. The first identified model allows the owner of an EV to decide when to sell power to the grid. This model would give the EV owner full control of the flow of electricity. The EV owner would be compensated for the sale of electricity to their local utility. A variant of this model would have a utility or aggregator provide EV owners with optional plug-in times and inform them of the rates that would be paid for each time period.

Utility Control. The second model allows the utility to decide when to buy electricity from EV owners. This model would involve a contractual relationship between the utility and owners of EVs, which would include terms specifying dates and times when EVs must be connected, compensation for services, and penalties for not abiding.

Aggregator Control. In the third business model, a third-party aggregator combines the capacity and services of numerous EVs to participate in an existing energy market. A third-party aggregator can either pool the services of EVs that are charging at a single location (e.g., a business fleet of EVs that is parked at a single location) or pool the services of EVs that are dispersed and charging at many locations (e.g., consumer-owned EVs that are parked at many different homes). Aggregating EVs that are connected at a single location provides logistical ease, and has been used in pilot projects.[27]

HOW EV TO GRID WOULD WORK IN NC: CURRENT LANDSCAPE

Lack of Prerequisite Technologies. As a practical matter, North Carolina does not currently have a significant penetration of the EVs that would be necessary to make EV to Grid a success. In 2014, there were approximately 3,200 EVs registered in North Carolina, with vehicles registered in 92 of the state's 100 counties.[28] At that time, there were also only 284 public EV charging stations, with a total of 682 charging outlets.[29]

For the Utility Control and Aggregator Control business models to succeed, there must be communications infrastructure that allows third parties to control the charge and discharge EVs. However, North Carolina does not have a robust smart grid network, which is one of the communications networks that would enable EV to Grid. In North Carolina, the three major investor-owned utilities have installed AMI meters in only 8.7% of the 2,816,458 homes they

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[26] Kempton, et al., *supra* note 14.
[27] Markel, et. al., *supra* note 25. Stephanie Morse and Karen Glitman, *Electric Vehicles as Grid Resources in ISO-NE and Vermont*, Vermont Energy Investment Corporation (May 2014), *available at* https://www.veic.org/documents/default-source/resources/reports/evt-rd-electric-vehicles-grid-resource-final-report.pdf.
[28] North Carolina Plug-In Electric Vehicle Task Force, *2014 Annual Report*, p. 2, *available at* http://www.advancedenergy.org/portal/ncpev/resources/2014_Taskforce_Annual_Report_FINAL.pdf.
[29] *Id.*

service; in contrast, nationally approximately 43% of residential customers have AMI meters.[30] Without a robust smart grid network, the only available communications network would be the cellular telephone network, which is itself imperfect communications.

Communications infrastructure will not be a barrier to implementation in the Owner Control business model because individual EV owners will determine when to sell the electricity.

Market for Ancillary Services. The Aggregator Control model is only viable in locations where the grid operator allows third parties to provide ancillary services. However, in North Carolina, ancillary services are provided by utilities and there is not a market for third parties to provide such services. EV owners will demand compelling incentives and compensation to allow their vehicle to be used for EV to Grid services; because there is no market for third parties to provide ancillary services, it may be difficult for potential aggregators to create a workable business model.

Legal and Regulatory Environment. Enabling EV to Grid in North Carolina may require clarification of statutory and regulatory provisions. In order to enable the University of Delaware pilot project discussed above, the legislature needed to define certain terms in statute.[31]

In North Carolina, net metering at a full retail rate is not mandated by law; rather, it is required by Utilities Commission decisions, and therefore is subject to review and modification.[32] When enabling the University of Delaware pilot project, the legislature also statutorily required utilities to pay EV owners the full retail rate for electricity sold to the grid.[33]

> ***"At the state level, one really important thing is for the state governments to say if someone is providing a service to the grid like this, you need to give them net metering. If it's not in state law, it is going to be spotty and will not be reliable. No one is going to set up business in North Carolina if it can be yanked away."***
>
> ***Dr. Willett Kempton, Professor, University of Delaware's School of Marine Science and Policy within the College of Earth, Ocean, and Environment***

A recent revision of North Carolina's interconnection standards clarified how energy storage could interconnect to the electric grid.[34] While not explicitly stated in the interconnection standards, these requirements would likely also apply to EV to Grid. Because of their relatively small size, most EVs produce only around 12 kW of power, EV to Grid would generally qualify for the state's fast-track process, which requires a minimal application fee and speedy review by the utility.[35]

Consumer protections will also be necessary to ensure all parties participating in EV to Grid are treated fairly. North Carolina has robust consumer protections in place surrounding utilities. State agencies such as the Public Staff and the Attorney General are tasked with protecting consumers from unscrupulous transactions. Furthermore, utilities cannot offer tariffs to customers without approval by the Utilities Commission. While the precise contractual terms would need to be developed, there should be sufficient safeguards in place to protect consumers.

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[30] *Comments of NCSEA and EDF*, p. 14, n. 40, North Carolina Utilities Commission Docket No. E-100, Sub 141 (Jan. 9, 2015), *available at* http://starw1.ncuc.net/NCUC/ViewFile.aspx?Id=8e3dccc6-7e9e-4508-a829-ebf7016eba89.

[31] 77 Del. Laws 212 (2009).

[32] N.C. Gen. Stat. § 62-133.8(i)(6).

[33] 77 Del. Laws 212 (2009).

[34] "Generating Facility - The Interconnection Customer's device for the production and/or storage for later injection of electricity identified in the Interconnection Request, but shall not include the Interconnection Customer's Interconnection Facilities." *Order Approving Revised Interconnection Standard*, Attachment 1, p. 2, North Carolina Utilities Commission Docket No. E-100, Sub 101 (May 15, 2015), *available at* http://starw1.ncuc.net/NCUC/ViewFile.aspx?Id=bc4171f9-38ac-48ad-ba34-b02996856f60.

[35] Markel, et. al., *supra* note 25. *N.C. Interconnection Procedures*, DUKE ENERGY PROGRESS (2015), *available at* https://www.progress-energy.com/carolinas/business/renewable-energy/interconnect-nc.page.

CONCLUSION

The concept of large-scale EV to Grid implementation is still in its infancy and has not yet been attempted in North Carolina. The largest barrier to implementation of EV to Grid may be the identification of a business model that works for both utilities and consumers. Furthermore, the costs of necessary infrastructure and communications network upgrades are likely to be a major barrier to EV to Grid implementation in the State. Pilot projects and demonstrations of EV to Grid may reveal other barriers that must be addressed, such as statutory and regulatory clarification.

Despite these barriers, as consumers purchase more EVs, interest in EV to Grid from all parties will rise. While much can be learned from projects in other states, undertaking pilot projects in North Carolina would be the most beneficial way to gauge consumer and utility interest, identify specific barriers, and encourage EV to Grid adoption.

