Connecting Electric Vehicles and Green Energy

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Abstract. This paper discusses the interrelationship between the purchase of green energy (GE) and electric vehicles (EV) and the motivations for and values formed around the purchase of the combination of the two. The BMW Group completed a two-year EV and GE user study, a joint project with the PH&EV Research Center at UCDavis and multiple market research agencies. Through a focus group study of US East and West coast all-electric MINI E markets and a new car buyer online survey, the BMW Group assessed the value of offering GE with EVs. A follow-on user experience survey, assessed the success of two GE products in the US. 39% of MINI E and 29% of Active E respondents have purchased home solar. A vehicle design game revealed that adding GE options increased overall demand for EVs among conventional buyers by 23%, with technology interest, environment and cost savings reported as the motivation.

Keywords: Electric Vehicle, Green Energy, Solar, Environment.

1 Electric Vehicles Deliver a Positive User Experience

Vehicles with plug-in electric drive technologies deliver a positive user experience, according to published customer satisfaction surveys. More than 90% of BMW Active E, Nissan Leaf and GM Volt customers report being satisfied or very satisfied with their electric vehicle purchase. After two years with the car, 88% of respondents of the MINI E survey said that they would purchase an EV within the five years following the field trial. After one year with the BMW Active E, 91% of users responded "yes" to the question; "Do you plan on buying or leasing an electric vehicle in the next three years?" according to preliminary data from a recent survey.

EV customers report numerous advantages over vehicles with conventional drive trains. These include a quiet interior space, smooth and quick driving experience, compelling environmental benefits, the ability to refuel at home, increased energy independence and decreased fuel and operating costs. EV drivers form new values such as the intersection of clean and fun-to-drive, the ability to expand an electric driving territory and to master energy use, in and out of the car [1]. EV users discover that they can be independent from an energy system which is potentially unsustainable and are able use electricity from a portfolio of clean generation technologies, including GE, to fuel their car.

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2 BMW Group Electric Vehicle History

BMW Group has introduced 7 electric vehicle models since 1972, but only two EV field trials have been coupled with academic user research. The first, an all-electric MINI E field trial occurred from 2009 to 2011 with 450 vehicles in regular customer hands on U.S. East and West coast markets. The focus of the accompanying user study - which included multiple in-person and phone interviews, online surveys, focus groups and vehicle data logging - was driving and charging behavior, gauging the interest of the market in electric drive technologies and renewable energy, range preference and demands on the electricity grid.

BMW of North America is currently leasing 700 BMW Active E vehicles to customers in Boston, Hartford, New York City, New Jersey, Los Angeles, Sacramento, San Diego and San Francisco for a period of 24 months. The BMW Active E is unique compared to past BMW all-electric offerings, like the MINI E. First, the active E is equipped with a standard charging port (J1772), so customers can use tens-of-thousands of public charging stations which greatly enhances everyday usability. Second, Active E customers can purchase home solar through a preferred partnership with Real Goods Solar or a wind power renewable energy certificate package through Green Mountain Energy. Third, the Active E has an advanced telematics system, ConnectedDrive, and a smart phone application, MyBMWRemote, which allows the customer to connect to the car to see its status, like battery state-of-charge and remaining range, and set charging and preconditioning timers.

3 EV Charging and the Environment

The environmental benefits of driving an EV are linked to the timing, duration and location of charging. For example researchers at the Institute for Transportation Studies at UCDavis identified through an electricity supply model that emissions associated with generation vary greatly with hourly demand and power plant availability [2]. Green house gas (GHG) emissions associated with electricity generation also vary greatly across geographic regions. For example, the US South, Midwest, and Western Rocky states have more than 3 times greater EV GHG emission rates than the West Coast and Northeast [3]. An electric vehicle charged in California is likely to produce 60% less well-to-wheel GHG emissions than a conventional gasoline vehicle [4] because of the mix of electricity generation sources. In 45% of US regions, regardless of when it's charged, an EV produces less well-to-wheel GHG emissions than even the cleanest hybrid vehicles [5]. The BMW i-3 is expected to achieve a 50% reduction in well-to-wheel greenhouse gas emissions largely due to the integration of GE in both production and use phases of the vehicle.

When charged intelligently, electric vehicles can be grid assets, lowering electricity costs for all consumers and total emissions from the electricity sector. A fleet of plug-in vehicles can act as: 1. a virtual power plant, eliminating the need to turn on expensive natural gas power plants and reducing costly transmission and distribution system upgrades, which will lower the cost of electricity for all consumers, and 2. a large battery,

storing wind energy which may be produced in excess during the night when load is at its minimum or other renewable energy which is intermittent so that it can be used later, which will lower total grid emissions and enable the installation of more GE.

An ongoing BMW Group partnership with a major European energy service provider, Vattenfall, is demonstrating that intelligent charging of an EV can reduce costs and GHG emissions associated with EV charging. In a Berlin field trial, a cloud computing algorithm calculates and sends a charging profile to the MINI E based on a wind energy forecast, a customer mobility calendar, and battery state-of-charge and state-of-health information stored on BMW backend servers. Users are encouraged to plug in according to their mobility calendar through gamification of the smart phone application. Through intelligent charging of the MINI E, GHG emissions are reduced by 3%. Further economic and environmental benefits can be realized through a true vehicle-to-grid scenario; Excess wind electricity is purchased during off-peak hours and fed back into the grid during peak periods when electricity is often more expensive and polluting.

The BMW Technology Office USA, located in Mountain View CA, recently launched eMobility Lab, a new research and demonstration platform for the evolving ecosystem surrounding sustainable electric mobility. eMobility Lab is focused on five

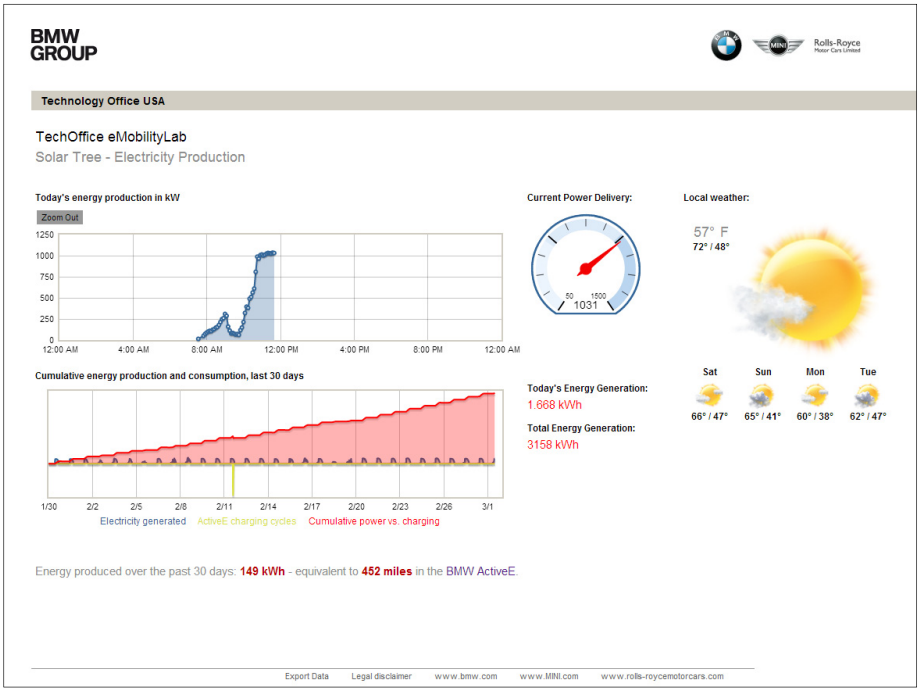

Fig. 1. BMW Group Technology Office USA solar and EV energy visualization tool

key research areas: 1. understanding the interaction between renewable sources of electricity and EV charging (Fig. 1), 2. communication pathways that allow the consumer and utility to visualize and interact with vehicle charging and home energy use, the "smart home", 3. second-life opportunities for EV batteries, 4. consumer studies and 5. electric vehicle grid services. BMW Technology Office USA is keeping an eye on emerging trends in technology innovation and learning from consumers about emerging markets through focus group and survey based studies.

4 Green Energy and EV Users

A survey of customers who participated in a two-year all electric MINI E US field trial revealed a strong user preference for charging EVs with solar (100%) and wind (98%) energy. The same survey of former US MINI E owners found that 37% owned solar by the end of the field trial. This result was re-confirmed by a recent survey of California EV owners (96% Nissan Leaf owners) which found that 39% have invested in home solar systems (n=1419), helping to "fuel" their vehicles with renewable solar energy [6]. Most recently, 29% of Active E respondents said that they have home solar according to preliminary results of a recent survey. An additional 25% responded that they intend to purchase solar within the next three years.

In order to gain a better understanding of the connections that EV drivers make with GE and the motivations for combining the two, BMW Group and the Plug-in Hybrid and Electric Vehicle Research Center at the Institute for Transportation Studies at UCDavis conducted eight focus groups in Beverly Hills, CA, Manhattan, NY, and Montvale, NJ in June of 2011. Participants were drawn from three sets of households: all-electric MINI E customers, people who bought GE through their local utility (ex. LADWP Green Power Program), and people who owned conventionally-fueled MINI vehicles and who had no obvious connection to GE or electric mobility.

By creating a comfortable environment in a focus group, the moderator enabled MINI E customers to tell a story about their common experience with owning, driving and charging an EV. The discussion began with MINI E users describing how they came to be an EV owner - how the MINI E made them feel at the start of the field trial along with initial like and dislikes - and moved to how they currently see the MINI E, electric mobility and fueling an EV. The moderator then asked if MINI E users knew about GE options available to them and if talking about GE enhanced their feelings about and experience with the MINI E. The group discussion was conducted four times in three locations so that the research team could identify themes and patterns. These themes were incorporated into the design of the survey component of the mixed-method GE and EV buyers study.

During the focus groups MINI E customer response to the combined offering of GE and EVs was truly mixed. Some participants had already made large investments in home solar photovoltaic (PV) systems or were participating in voluntary GE programs. Leasing the EV was an extension of a sustainable lifestyle which included GE.

I put SunPower panels on my barn so I have a 20-kilowatt solar system and the MINI E was kind of a segue to that.

Some customers for whom home solar was not accessible had thought about other innovative pathways for coupling solar or wind power and EV charging, like a power purchase agreement or intelligent charging.

I can buy a package of green power, renewable power, power generated from renewable sources that [makes me] feel good that a very healthy portion of my driving - if I didn't have solar - is covered by a program that's really easy for me to sign up on or with to drive basically in a non-emission-generating way.

A third group decided that because EVs were so clean, it was not necessary to charge them with GE. They believed that regardless of how it's produced, using coal or other sources, electricity must have a lower environmental impact than gasoline burned in an engine.

It would have to be a really compelling way in which you packaged whatever it is...I already feel great about driving the electric car. I don't need to feel great about paying Southern California Edison more money for the proper source, for me, just me.

The nationwide new car buyer online survey applied themes and language taken from the focus group sessions to assess consumer interest in PEVs and green electricity programs. Deployed in July of 2011, the survey contained an EV and GE design game. BMW Group and a market research agency recruited three U.S. samples to complete a web-based survey, including recent buyers of new conventional vehicles (CVB, n=1064), hybrid vehicles (HEVB, n=364) and plug-in electric vehicles, including the MINI E, Chevrolet Volt and Nissan Leaf (PEVB, n=74).

Respondents were asked to design a vehicle, choosing the make, model and engine type (conventional, hybrid, plug-in hybrid or electric). They then designed a home energy plan, choosing between no green program (or current "green" program if already enrolled), a monthly green program applied to at least 20 percent of home electricity use with a user defined electricity source, a 2-year green lease supporting wind or solar power through the voluntary purchase of renewable energy certificates (and requiring a two-year commitment) and purchasing and installing residential solar, financed as one monthly bill for 20 years (a power purchase agreement or PPA). The final section of the survey asked them to choose a vehicle and electricity plan side-by-side with an option to cover EV electricity use with GE. Respondents were asked to identify motivation for choices of vehicle, energy plan and combinations of the two.

Respondents that already have "green electricity" are more likely to design PEV in the game. Most hybrid and plug-in buyers design solar (18-35%), or already own solar (32-37%). Adding GE options increased overall demand for PEV designs among CVBs by 23%, HEVBs by 20%, and among PEVBs by 5% [7]. For PEVBs the most frequently designed combination (38%) is an EV with home solar; 86% combined an EV and GE and none designed a conventional vehicle and rejected GE (Fig. 2).

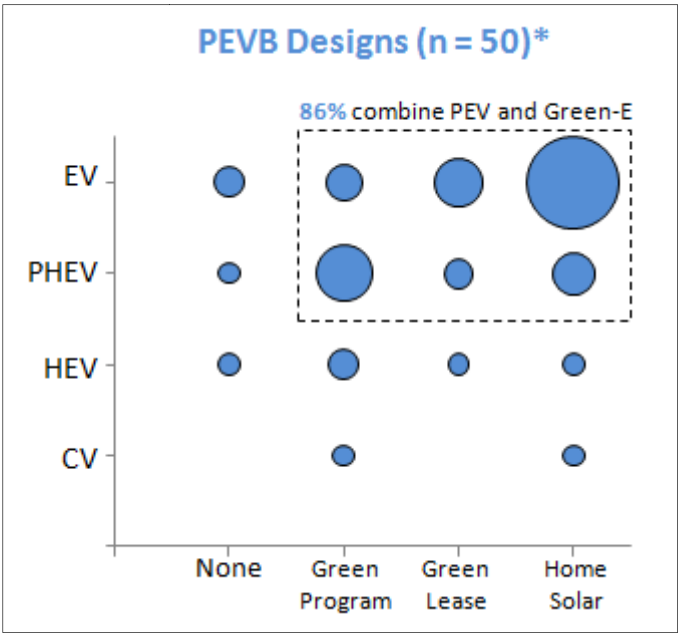

Fig. 2. EV buyers combine vehicle and energy plan (source: [7])

Motivations for combining GE and EVs vary within car buying groups. They include environment, total cost of ownership, energy independence, renewable energy support and control over electricity sources. Conventional and hybrid vehicle buyers are more likely to be motivated by cost savings. EV buyers are more strongly motivated by technology interest and as well as environmental benefits. Customers' reported motivations provide guidance on policy and marketing strategies to advance GE and EV demand.

5 Green E Product Offerings

In 2012 the BMW of North America offered Active E customers two GE options. One, a wind-energy renewable energy certificate (REC) package offered through Green Mountain Energy, provides a two-year green energy plan - approximately $48 - that corresponds to the amount of energy an Active E uses during the lease, 6400 kWh, with a mechanism for "topping up" at the end (Fig. 3). The second is a preferred partnership with Real Goods for a residential solar PV installation which is appropriately sized for home and EV. A portfolio approach to green energy allows BMW Group to meet all US EV customer needs.

The most recent results from the Active E user experience survey show an encouraging take-rate for BMW GE products offerings. The largest customer of the Green Mountain Energy REC package is DriveNow, a 70 EV car sharing program in

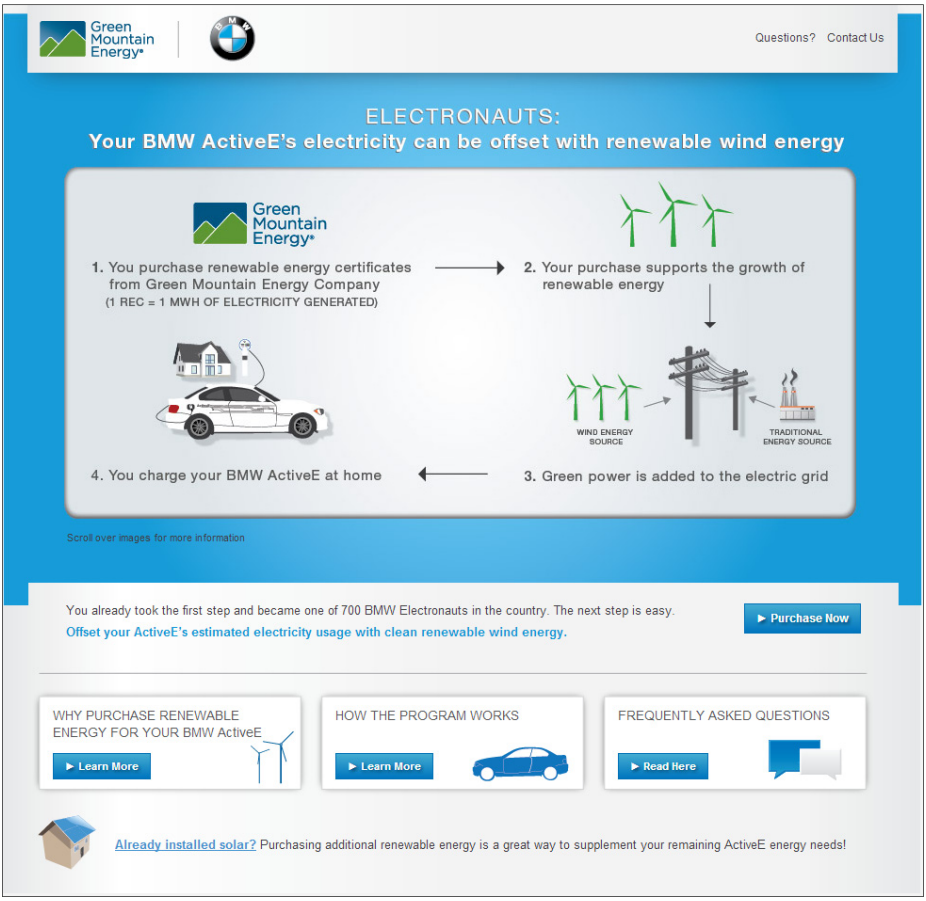

Fig. 3. Active E customers can purchase RECs through Green Mountain Energy

San Francisco. GE gives DriveNow a competitive advantage over other EV car sharing programs and is expected to attract environmentally minded consumers, which is why the GE program is front-and-center in marketing materials for the company. According to the preliminary results of the Active E user experience survey, 5% of respondents have purchased home solar through Real Goods and 3% of respondents have purchased wind energy through Green Mountain Energy.

6 Conclusions

In a multi-year project exploring the consumer demand for EVs and GE, BMW Group and numerous research partners completed a novel study, in three parts. The first, a literature review, aided the design of a unique multi-methodology study employing both focus group and survey research. The second, focus groups with MINI E drivers, conventional MINI drivers, and GE program participants in Los Angeles, New York

and New Jersey generated themes and language used in a larger nationwide online survey and design game. The third, a nationwide survey of new car buyers, which included subsets of hybrid buyers and recent EV lessees and owners, was used to justify the addition of two GE products for the BMW Active E.

EV customer preference for GE is very strong, with 29% of Active E customers reporting having home solar. One question remains: Is the BMW Group observing an early market phenomenon or a long term trend and opportunity? The vehicle and energy plan design game results illuminate the benefits to an auto OEM of a combined EV and GE product offering. Though conventional vehicle buyers are motivated by different reasons, fuel cost savings, combining EVs and GE increases the overall demand for EVs by 23% in that new car buyer segment.

EVs and GE are transformative and disruptive because the combination represents a disconnection from current liquid transportation fuel systems along with the decoupling of environmental impacts of vehicle mobility from on-board fuel consumption. GE for the home and EV has the potential to lower total household energy costs, which is appealing for new car buyers across all segments.

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