Impacts of Incorporating Electric Vehicle Charging into Zero Net Energy (ZNE) Buildings and Communities

Adam Rohloff, University of California Santa Barbara
Jon Roberts, CTG Energetics, Inc.
Noah Goldstein, Lawrence Livermore National Laboratory

ABSTRACT

The policy and infrastructure of building vs. transportation energy are traditionally considered separately. However, emerging policy from the building sector, transportation sector, and planning/entitlement community, coupled with improving technology are expected to shift transportation-related energy onto building energy meters through increasing penetration of plug-in hybrids (PHEVs) and electric vehicles. This is converging with a parallel movement towards zero net energy (ZNE) buildings (e.g., California's 2008 Long Term Energy Efficiency Strategic Plan calls for all new residential buildings to be ZNE by 2020). The implications of shifting transportation loads onto building meters in a ZNE context has not been adequately addressed. This analysis quantifies the potential range of increased building energy use from transportation (focusing on PHEV's) for a number of scenarios, and assesses its impact on ZNE achievability at the building and community level. Analysis shows that PHEV's will increase residential building energy loads by 13% and electricity use by 55% for a 2010 vintage home. Charging loads will become an increasing percentage of the total building energy loads over time as building energy codes tighten and market penetration rates of PHEV's increase. By 2030, PHEV charging will account for 20% of a typical home's total energy use and surpass building electricity use. While PHEV charging will impact the ability for buildings to achieve ZNE, it will not necessarily preclude them from it. Additional PV capacity, increased building efficiency measures, and/or reduced vehicle miles traveled should be able to offset PHEV charging loads.

1. Introduction

Growing concerns about climate change, energy security, energy costs, etc. are driving parallel but largely disconnected efforts to improve energy efficiency in buildings and transportation. Technological advances and market changes are driving development of a new generation of electric vehicles (EV's) and plug-in hybrid electric vehicles (PHEV's) that are expected to gain a significant market share in upcoming years. Southern California Edison expects 400,000 to 1.6 million electric vehicles in its service territory by 2020 (Schremp, Page and Weng-Gutierrez 2009). It is possible that we will witness a game-changing shift in transportation infrastructure from petroleum to electricity if vehicles such as the Chevy Volt (40 mile electricity-only range) and similar vehicles under development prove successful and battery technology continues to advance. The resulting vehicle charging will shift a significant portion of transportation-related energy use onto building electricity meters. This has profound implications on a parallel shift towards "zero net energy" (ZNE) buildings and communities. A ZNE building generates as much energy from renewable sources as it consumes on an annual basis. ZNE is gaining significant traction and is being incorporated in far-ranging building energy-policy.

This paper examines the impacts that merging transportation energy use onto the building energy meters will have on the ability of buildings to achieve ZNE, and explores a variety of policy options that will be affected by ZNE/Transportation Integration.

1.1. Policy Context and Drivers

The ZNE building concept is relatively new but gaining momentum quickly. ZNE buildings are motivated by three powerful and far-reaching policy domains: (1) utility energy efficiency programs, (2) greenhouse gas (GHG) emission reductions, and (3) building energy efficiency and sustainability. The concept is supported by organizations such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers, the US Green Building Council, and the American Institute of Architects. Passage of the U.S. Energy Independence and Security Act (EISA) of 2007 provided federal recognition. EISA authorized a ZNE Commercial Buildings Initiative within the U.S. Department of Energy and specified targets for 50% of U.S. commercial buildings to be ZNE by 2040, and for all U.S. commercial buildings to be ZNE by 2050 (Center for the Built Environment 2008). The American Clean Energy and Security Act of 2009 currently on the Senate floor builds upon these targets, calling for "the transformation of the building stock of the United States to zero net energy consumption"(H.R. 2454 2009).

ZNE buildings are also gaining support at the state level, notably in California. AB32, California's Global Warming Solutions Act of 2006, establishes significant GHG emission reduction goals for the state, including the building and transportation sector (Nunez 2006). The California Air Resources Board (CARB)'s Scoping Plan lays out specific actions needed to achieve the AB32 goals, with energy efficiency in both the transportation and building sectors playing a major role (California Air Resources Board 2008). Additionally, the California Public Utilities Commission (CPUC) established very aggressive goals for ZNE buildings and communities through its Long Term Energy Efficiency Strategic Plan (California Public Utilities Commission 2008). Residential sector goals are to have all new single and multi-family homes ZNE by 2020, with intermediate targets for 2011 (50% of new homes should surpass 2005 Title 24 standards by 35% and 10% surpass code by 55%) and 2015 (90% of new homes surpass 2005 Title 24 standards by 35%). Goals for existing homes are to reduce energy consumption 20% by 2015 and 40% by 2020. These goals are rapidly becoming embedded in a range of critical climate and energy related policies and regulations. For example, strategies for meeting the ZNE goals are being incorporated into updates to California's Title 24 Building Energy Code.

At the planning and entitlement level, consideration of GHG emissions related to buildings and transportation is required by California Senate Bill 97 (SB 97) and Senate Bill 375 (SB 375). SB 97 requires projects going through entitlement to consider climate change issues and GHG mitigation measures into their entitlement documents (Senate Rules Committee 2007). Consideration of GHG emissions throughout the project life-cycle is required, including construction, building energy use, water use, transportation, etc. SB 375 requires that Metropolitan Planning Organizations (MPO's) include Sustainable Communities Strategies within their regional transportation plans. These strategies are expected to reduce GHG emissions from transportation via changes in land use and transportation policies. The bill aligns transportation with housing and requires MPO's to collaborate with the California Air Resource Board to set regional GHG targets (Stivers 2008). Both SB 97 and SB 375 are driving cities, projects and others to more seriously consider ZNE and transportation efficiency strategies in general plans, specific plans, projects, and other entitlement activities.

1.2. Defining Zero Net Energy (ZNE)

While the concept of a ZNE building is simple (building energy use is zeroed out by renewable energy generation on an annual basis under a net-metering arrangement), precise definitions are more nuanced, and there are multiple definitions in use. ZNE definitions must specify what energy use is to be zeroed out (e.g., electricity only, total *site* energy, or *source* energy) and describe permissible renewable energy generation. For example, renewable generation may be limited to the building (e.g. roof mounted PV), the building's lot/site (e.g., a ground-mounted PV system), or even off-site and purchased renewable energy (Torcellini, et al. 2006). The CPUC has developed a unique ZNE definition pertaining to California's ZNE goals, which expands the ZNE "boundary" from a building to a "project":

> *"Zero Net Energy is herein defined as the implementation of a combination of building energy efficiency design features and on-site clean distributed generation that result in no net purchases from the electricity or gas grid, at the level of a single "project" seeking development entitlements and building code permits. Definition of zero net energy at this scale enables a wider range of technologies to be considered and deployed, including district heating and cooling systems and/or small-scale renewable energy projects that serve more than one home or business."*(California Public Utilities Commission 2007, 38).

A "project" can range from a single building to an entire development. This definition effectively sets the stage for ZNE "communities" and further deepens the nexus between building and transportation energy use.

None of the ZNE definitions in use explicitly address or exclude transportation-related loads such as vehicle charging from the building's electricity meter. As currently written (by the letter of the law), most ZNE *building* definitions would require these transportation loads to be zeroed out along with the rest of the building energy use unless they were separately metered. Separately metering transportation loads may be not always be practical, cost effective or desirable for a variety of reasons (e.g., consumer unwillingness to manage two electricity accounts, metering costs, higher electricity rates for multiple smaller meters, and the inability to net-meter two meters from a single renewable energy system under the current regulatory framework). Furthermore, separately metering transportation loads would be irrelevant for California *"projects"* using the CPUC ZNE definition. In most cases, the transportation meter would still be a part of the "project" and therefore have to be zeroed out.

Transferring transportation energy use to building/project energy meter(s) can significantly impact the potential for achieving ZNE. This is likely to become a contentious issue as ZNE gains popularity and becomes further embedded in policy and programs. In addition to understanding the energy implications of shifting transportation loads onto buildings, it is clear that policy and definitions need to explicitly address this issue.

2. Transportation Energy Use

EV's and PHEV's will likely be charged from a building's electricity supply. Likewise, natural gas vehicles may be charged from the building natural gas supply. PHEV's have the greatest potential for widespread market penetration and the literature indicates that most PHEV charging will likely occur at home during off-peak hours (Electric Power Research Institute 2007). This paper therefore focuses on PHEV's and residential ZNE buildings. Three California locations (Los Angeles, Fresno, and Alameda) providing a diversity of climates and transportation patterns were selected for analysis. Average per capita Vehicle Miles Traveled (VMT) and gasoline consumption projections from the 2009 Population and Vehicle Trends Almanac (California Air Resources Board 2009) are used. VMT and fuel use projections are available to 2020 only, at the county level. These projections factor in fleet efficiency changes and changes in driving patterns over time. This analysis assumes that annual per capita VMT and fuel efficiency remain constant thereafter. Data is shown in Table 1.

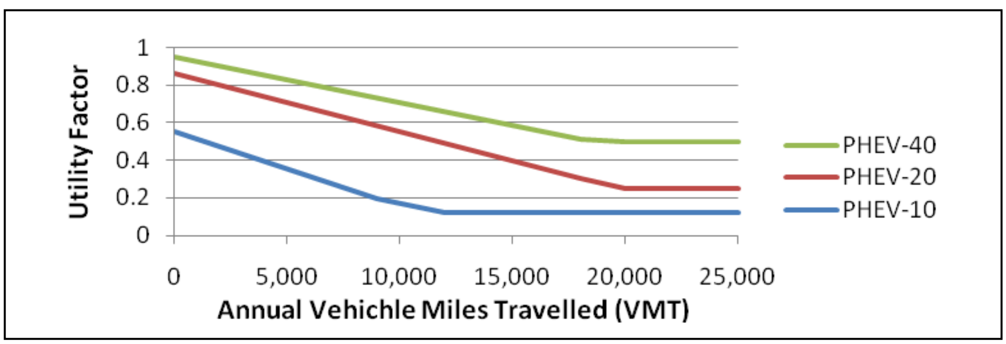
Table 1. Average per Vehicle VMT and Fuel Efficiency Projections Used in Analysis

Time (year)	Alameda County		Fresno County		Los Angeles County	
	VMT (miles)	Fuel Efficiency (mpg)	VMT (miles)	Fuel Efficiency (mpg)	VMT (miles)	Fuel Efficiency (mpg)
2010	11,579	22.3	13,305	23.3	12,269	21.1
2011	11,575	22.4	13,397	23.3	12,174	21.0
2012	11,569	22.5	13,461	23.4	12,099	21.1
2013	11,561	22.6	13,505	23.5	12,036	21.2
2014	11,554	22.7	13,536	23.6	11,964	21.2
2015	11,545	22.8	13,553	23.6	11,908	21.3
2016	11,528	22.5	13,559	23.7	11,840	21.2
2017	11,517	22.5	13,563	23.8	11,793	21.2
2018	11,507	22.6	13,559	23.8	11,762	21.3
2019	11,496	22.6	13,547	23.9	11,741	21.3
2020	11,485	22.7	13,529	24.0	11,729	21.4
2021-2030	11,485	22.7	13,529	24.0	11,729	21.4

Source: California Air Resources Board 2009

The impacts of three plug-in hybrid models that differ only in their all-electric driving range are analyzed: PHEV's with a 10, 20 and 40 mile all-electric range (PHEV-10, PHEV-20, and PHEV-40, respectively). The actual miles that a PHEV travels on electricity vs. gasoline depends on trip length, number of trips between recharging, driving speed, and other factors. The Electric Power Research Institute has studied this and correlated PHEV all-electric range and total annual VMT via a "utility factor" as shown in Figure 1.

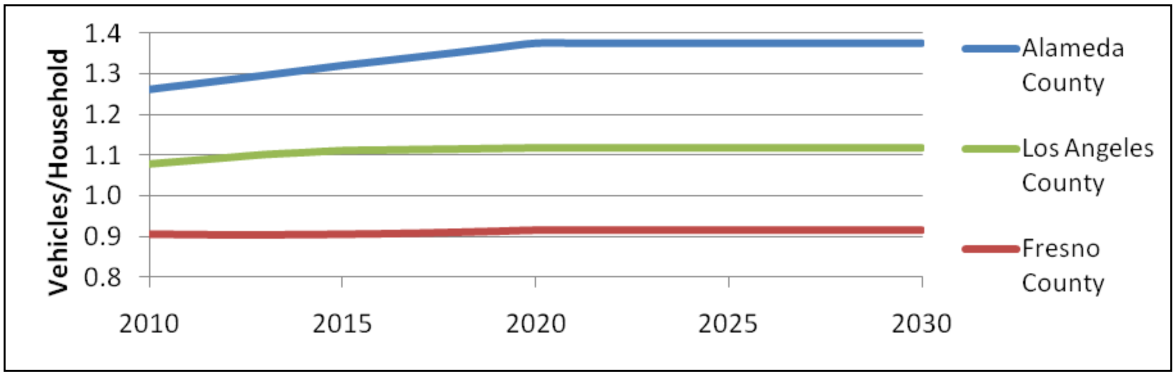
Figure 1. PHEV 'Utility Factor' as a Function of All-Electric Range and Annual VMT



Source: Electric Power Research Institute 2007, 4-6

The utility factor is used to estimate VMT driven in electric vs. gasoline mode for each of the three locations analyzed. Total VMT per vehicle remains relatively constant between 2010 and 2030; however, VMT per household increases. Since the utility factor is calculated on a per vehicle basis, the average number of passenger vehicles per household was calculated using CARB's Vehicle Trends Almanac (California Air Resources Board 2009) for number of passenger vehicles per county, and the 2008 American Community Survey database (US Census Bureau 2008) for number of households per county. This figure ranged from 0.90 to 1.38 depending on year and county, as shown in Figure 2.

Figure 2. Vehicles per Household for all Counties in Analysis



Charging electricity use for electric-mode VMT is calculated from an average electric vehicle efficiency rate based on the EPRI study (Electric Power Research Institute 2007). Efficiency starts at 0.298 kWh/mile in 2010 and increases linearly to 0.284 kWh/mile in 2030. Gasoline energy use for the remaining VMT is calculated using fleet average fuel efficiency rates shown in Table 1.

3. Building Energy Use

Single-family residential dwelling unit energy use is modeled using EnergyPro (EnergySoft 2010) for Fremont (Alameda County), Fresno (Fresno County), and Claremont (LA County) for a typical home that is compliant with the 2008 Title 24 code. The base-case model is a 2000 ft^2, 1.5-story home with a roof area of 1,333 ft^2. The average annual natural gas and electric energy intensity (kWh/ft^2) for the three locations is shown in Table 2.

Table 2. Modeled Annual Energy Intensity for a 2000 ft^2, 1.5 Story Home

County	**Electricity Demand** kWh/ft^2	**Natural Gas Demand** kWh/ft^2
Alameda	2.47	7.63
Fresno	3.68	7.30
Los Angeles	2.94	5.37

Energy use for future homes is assumed to decrease as Title 24 energy code becomes more stringent. Title 24 is on a triennial update cycle, with an assumed efficiency increase of 10% for each update cycle (this is consistent with the 2005-2008 cycle improvement and projections found in the Long Term Energy Efficiency Strategic Plan). ZNE homes typically include a range of energy efficiency measures and use less energy than code maximums. This analysis assumes 15% efficiency improvements over code requirements.

4. Photovoltaic (PV) Energy Production and Net Metering

This analysis assumes PV is the sole renewable supply option. PV energy generation (kWh/year generated per kW of installed PV rated capacity) is estimated by PV Watts (National Renewable Energy Laboratory 2001) for the three locations. PV space requirements are estimated at 75 ft^2/kW (typical of mono-crystalline panels). The PV array size (kW, area, and percent of available roof space) necessary to zero out the annual building energy use is then calculated. It is assumed that the building is net-metered (excess electricity generation from the PV is exported to the grid, unmet electricity loads are supplied from the grid, and the net electricity consumption is reconciled annually). This is consistent with the ZNE concept.

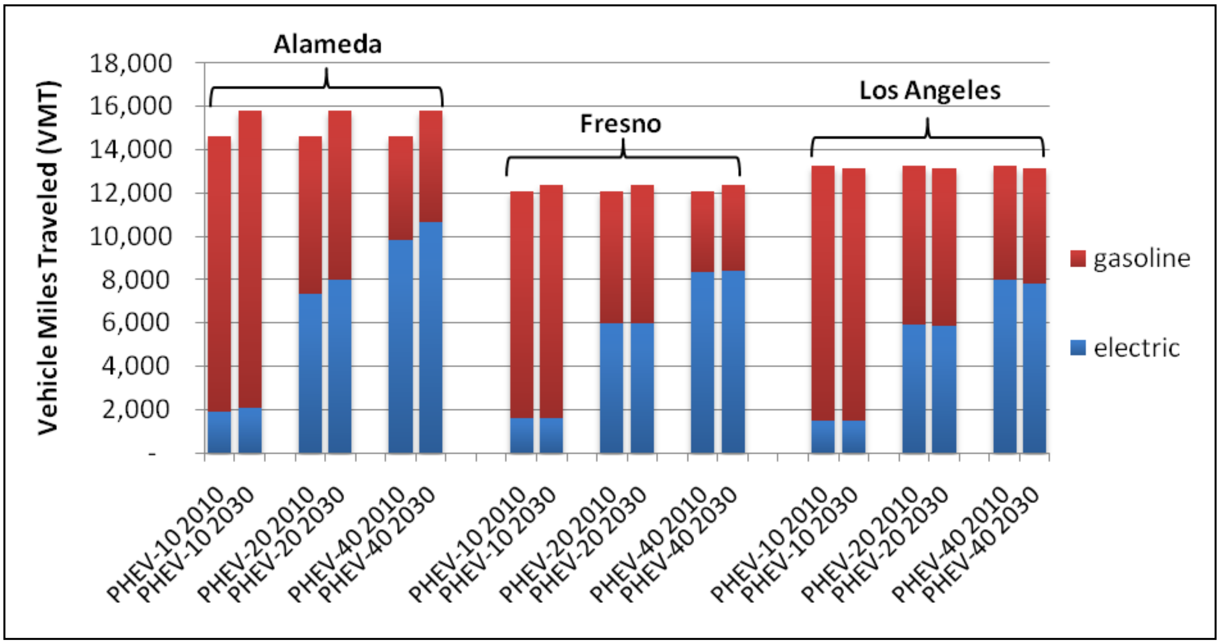
This paper does not examine time-of-use impacts on the electricity grid or emissions. As distributed generation and EV/PHEV charging continue to expand, new offset mechanisms such as distributed energy storage and time-of-use smart charging may be necessary, but are beyond the scope of this analysis.

5. Impacts of PHEV Charging Loads on New ZNE Homes (Single Home Analysis)

The impacts of adding PHEV electric charging loads onto newly built ZNE homes were analyzed for newly constructed homes from 2010-2030 for a variety of scenarios. This first analysis assumes that all household VMT is by PHEV.

FigureFigure 3 shows household VMT for electric vs. gas mode assuming household PHEV use. Alameda County has the greatest VMT per household and the largest charging loads.

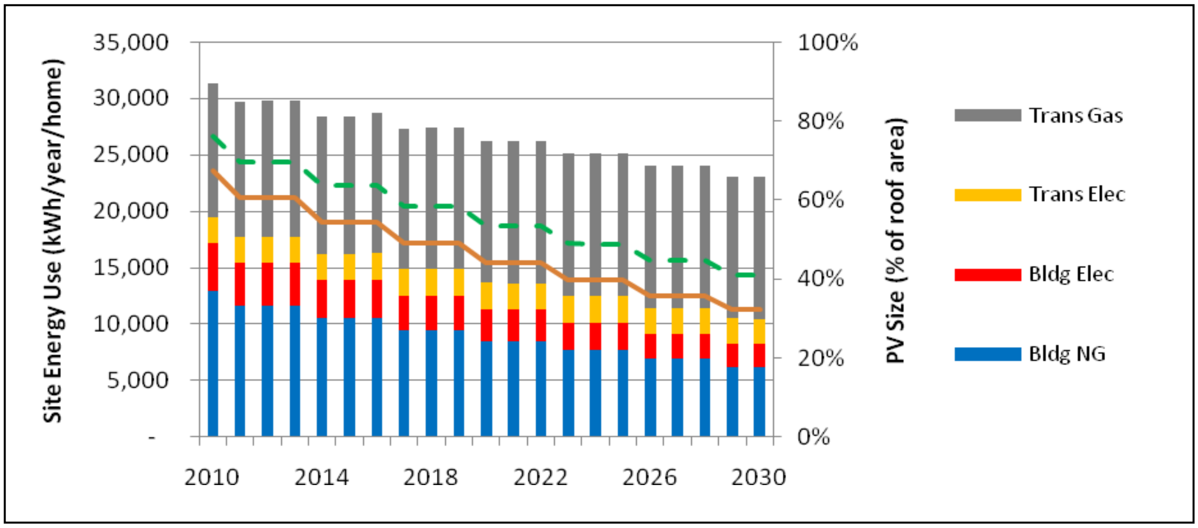
Figure 3. PHEV VMT by Fuel Source and Location for 2010 and 2030



The impacts of adding these PHEV charging loads to a ZNE home were examined. Variables affecting the analysis include: location (impacting VMT and household energy use), house square footage, numbers of stories (impacting roof area for PV), building efficiency (% above Title 24), and PHEV all-electric range (10, 20, and 40 miles). Several scenarios were examined.

Figure 4 presents the results of one such representative scenario for typical new homes located in Alameda County (Table 2) with building energy efficiency measures resulting in a 15% energy savings compared to Title 24 code, and a PHEV with a 20 mile all-electric range (PHEV-20). Household and transportation site energy use are shown on the left axis. All energy use is converted to kWh for easy comparison. Data is presented for 2010 through 2030; building energy use for each year is 15% better than current year Title 24 requirements, and PHEV data is based on annual statistics. The lines (right axis) represent the PV size (percent of the projected roof area covered in PV) required to achieve zero net energy. PV size data is presented for two scenarios: (1) the PV size required to net out building energy only (electricity and natural gas), and (2) the PV size required to net out the combined building energy use and additional PHEV electric charging loads. To net out building electricity and natural gas only, a 12 kW PV system would be required for 2010 vintage homes, and a 5.7 kW system for 2030 vintage homes. The decreased size is primarily due to the assumed triennial improvements in Title 24 building energy code. Note that household natural gas use is significantly larger than electricity use. Optimal paths to ZNE would therefore need to focus more heavily on natural gas reductions. To net out the building load *plus* the PHEV charging electricity, a 13.6 kW PV system would be required for 2010 vintage homes and a 7.3 kW system for 2030 vintage homes. PV roof requirements for 2010 vintage ZNE homes are ~ 70% of the total roof area, which presents significant constraints unless flat roofs are used (an unlikely scenario).

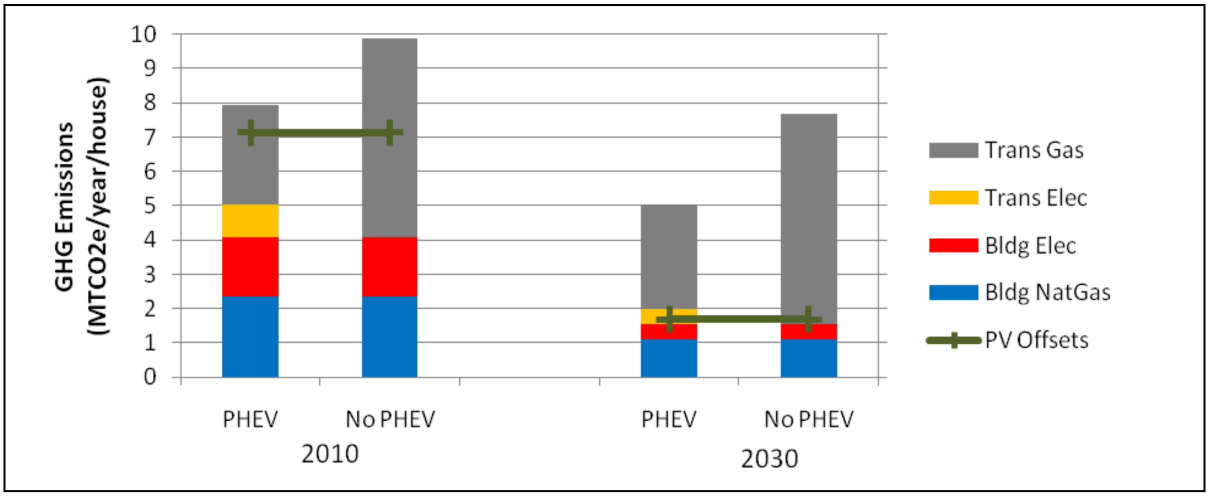
Figure 4. Impact of PHEV Electric Charging on New ZNE Homes in Alameda County



Transportation energy use remains relatively constant; small efficiency gains in electric vehicle technology and slightly positive trending VMT increases numerically cancel each other. In 2010, PHEV electricity use is 2,290 kWh, or 55% of the building electricity use (4,198 kWh). In 2030 PHEV charging drops only slightly (2,265 kWh), but building electricity use decreases over 50% (2,008 kWh). PHEV charging electricity use is then 110% of the building electricity load, primarily as a consequence of projected building energy code improvements. Vehicle charging is 13% of total building energy use (electricity and natural gas) in 2010, increasing to 20% in 2030. Adding PHEV charging onto the household electricity meter will require a 1.6 kW increase of PV capacity in 2010, and similarly in 2030, to maintain a zero net energy home. As buildings get more efficient over time while transportation loads remain relatively constant, the PV size required to achieve ZNE decreases, although the ratio of transportation charging electricity to building energy increases. Achieving ZNE will require a significant amount of roof area, but this can potentially fit onto the roof of the house depending on the roof characteristics. The biggest opportunities to reduce PV size requirements to achieve ZNE are to reduce natural gas consumption.

The GHG impacts of PHEV electric charging on a ZNE home are also examined. Figure 5 shows the GHG emissions in metric tonnes of CO_2-equivalents (MTCO2e) for each fuel (stacked bars). Electricity emissions are based on the statewide average emission factor of 0.96 lb CO2e/kWh and include mandated renewable portfolio standard impacts of 33% renewable energy by 2020. Natural gas and gasoline emission factors are 0.40 and 0.53 lb CO2e/kWh, respectively (California Air Resources Board et al. 2008). The horizontal line shows the GHG emission reductions by offsetting grid electricity with PV generation, with the PV sized to zero out building electricity and natural gas use only. In 2010, the energy used by the home and PHEV generate ~ 8 MTCO2e/year, while the PV system offsets ~ 7 MTCO2e from the grid. The GHG offsets from the PV are larger than the GHG emissions from the building energy use because the grid is more carbon intensive than onsite natural gas combustion. As RPS is phased in, the electricity generation offset by the PV system is less carbon intensive.

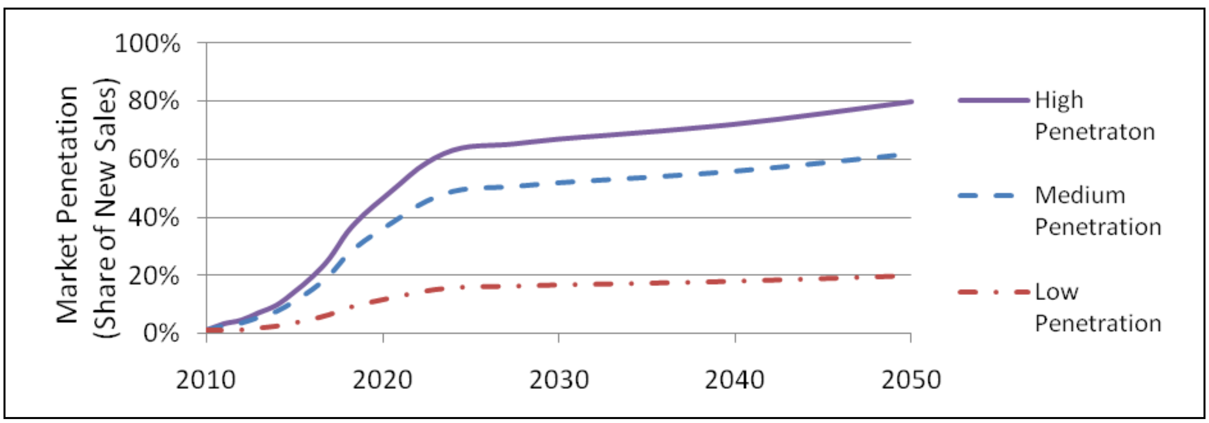
Figure 5. GHG Emissions Impact of PHEV Electric Charging on New ZNE Homes



6. Impacts of PHEV Electric Load on New ZNE Communities

The single home analysis illustrates the impacts of PHEV charging on a single home. In a multiple home project (e.g., per the CPUC ZNE definition) or community, market penetration may not be 100%. We examined the community-wide PHEV charging impacts. The EPRI study (Electric Power Research Institute 2007) projected PHEV market penetrations for low, medium and high penetration scenarios, shown in Figure 6. The low and medium market penetration scenarios compare to other recently published literature (Sullivan, Salmeen and Simon 2009).

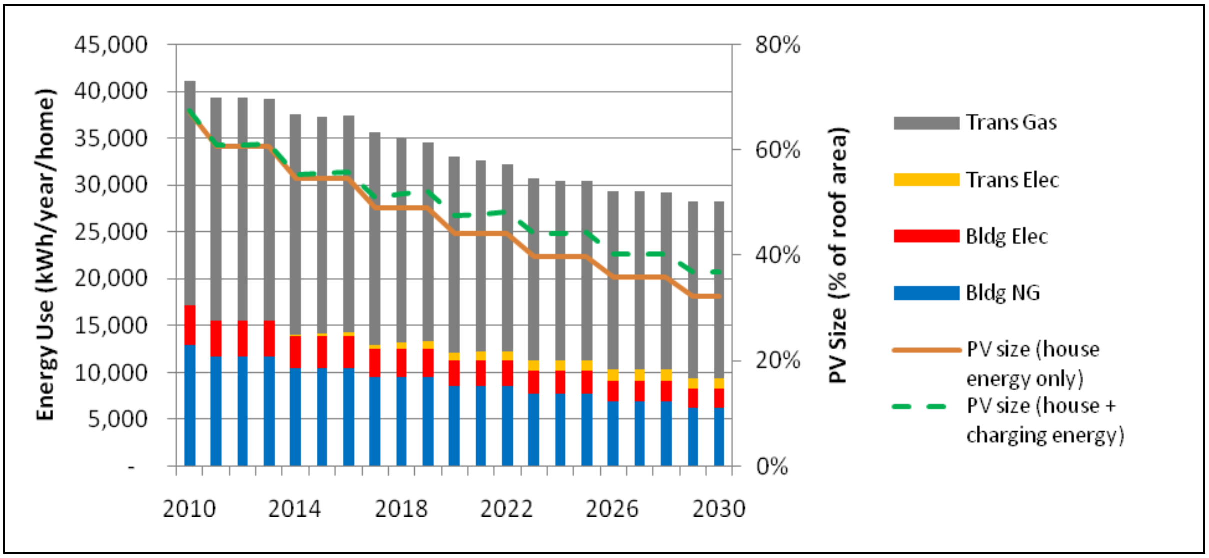
Figure 6. PHEV Market Share Projections



Source: Electric Power Research Institute 2007

An analysis analogous to that shown in Figure 4 (single home scenario) is presented in Figure 7, with the difference that PHEV's are assumed to slowly penetrate the market per the medium projection in Figure 6. In other words, only a small percentage of homes in a community will have PHEV's and therefore the community-wide PHEV charging loads will be less. The percent of homes with PHEV's increases over time placing greater charging loads on building electricity meters. However, building energy loads decrease at a faster rate due to building energy code improvements. Overall, PHEV charging will have less of an impact on a ZNE community than in the single home scenario.

Figure 7. Impact of PHEV Electric Charging on New ZNE Homes in Alameda County Factoring in a Medium PHEV Market Penetration[1]



Another way to look at the results is to consider what happens to an existing ZNE community as PHEV's are added over time. For example, a community of 200 homes built in 2020[2] would require 7.9 kW per home (1,580 kW total) of PV to net out natural gas and building electric load and 0.5 kW/home (100 kW total) of PV to net out the anticipated transportation electric load. By 2030 the community would need to install an additional 53 kW of PV capacity to remain ZNE due to a steadily increasing market penetration of PHEV's. Alternatively, if that same community reduced their annual VMT by 28% over this same time period, they would also be able to remain ZNE.

7. Conclusions

The single home analysis shows that PHEV electric charging loads are approximately 55% of the building electricity load in 2010, and 13% of the total building energy (electricity and natural gas) use. Although there are some minor variations throughout the three California locations studied, the results are similar. Over time, PHEV electric charging loads are expected to remain relatively constant, while building energy loads will likely decrease as California's Title 24 building energy code tightens. This then makes PHEV charging a larger percentage of a ZNE building's energy use; however, the total size of PV systems required to net out total energy use will decrease. It is projected that by 2030, PHEV charging will account for 20% of a typical home's total energy use and will surpass building electricity use.

The added PHEV charging electricity can affect the ability of a home to achieve ZNE. However, a realistically achievable increase in PV capacity or increased building efficiency can net-out any additional transportation charging loads. Residential natural gas loads are the largest

[1] Community-level impacts shown on an average per-home basis
[2] The goal of the CPUC Long Term Energy Efficiency Strategic Plan is for all new homes to be ZNE by 2020

component of the total building energy use and reducing building natural gas use (e.g. via heating efficiency, solar water heating, etc.) presents the largest savings opportunity.

At the project or community level, PHEV charging impacts will be significantly dampened due to the low PHEV penetration rates in early years. As PHEV penetration increases over time, community-wide charging electricity use will increase. However, since building efficiency decreases at a greater rate, PHEV charging therefore should not significantly impact project-level ZNE projects from attaining ZNE. Existing ZNE projects will likely be able to maintain ZNE over time as PHEV penetration rates increase by modest additional PV installations, increasing energy efficiency in existing buildings, and/or reducing community wide VMT. Regional variances in climate (renewable potential), local government policies/ incentives, and existing infrastructure will likely dictate the optimal mix of strategies that will most effectively achieve these goals.

None of the current ZNE definitions in use discuss the treatment of transportation loads that are likely to be added to building meters. As written, these transportation loads would have to be offset with renewables in a ZNE building or project, unless the transportation loads were separately metered and ZNE definitions were altered to explicitly exclude transportation energy. This analysis shows that while PHEV charging loads will impact ZNE buildings, they are relatively small compared to total building energy use and are not the primary factor affecting a building's ability to achieve ZNE. Nevertheless, this is likely to be a point of contention as ZNE finds its way into policy and the treatment of transportation loads appearing on building meters should be explicitly addressed in ZNE policy and definitions.

Adding transportation loads to building energy meters makes it difficult to compare ZNE buildings or communities. Some buildings may have connected transportation loads, and others may not. Even if transportation-related loads are included on a building meter, there is no precise measure of how much of the total transportation load has been shifted and the overall benefit.

Shifting transportation energy from gasoline to electricity (and/or natural gas) can help to reduce community-wide GHG emissions that are mandated by California's SB375. However there is a potential conflict between SB375 and California's ZNE goals. From the big-picture (SB 375) perspective, one would want to encourage projects to incorporate alternative fueled vehicle strategies such as PHEV/EV charging stations, natural gas vehicle refueling appliances, etc. However, projects may be discouraged from implementing these measures because they would increase the amount and expense of onsite renewable energy capacity required under California's current ZNE definition. ZNE policy makers will therefore want to ensure that projects are not discouraged from incorporating PHEV charging and related measures. It is recommended that the ZNE requirements be framed to explicitly exclude transportation loads from ZNE building requirements. Furthermore, it would be beneficial to have a corollary definition for a zero energy community (or perhaps climate neutral community) that includes total energy or GHG emissions from both building and transportation energy use.

8. References

North Carolina Solar Center, Interstate Renewable Energy Council. 2010. Database of State Incentives for Renewables & Efficiency. http://www.dsireusa.org/incentives. Raleigh, NC.: North Carolina State University.

California Air Resources Board. 2008. "**Climate Change Proposed Scoping Plan: A Framework for Change**." CA.: California Air Resources Board.

———. 2009. "**2009 Almanac - Population and Vehicle Trends Tool**." http://www.arb.ca.gov/app/emsinv/trends/ems_trends.php. CA.: California Air Resources Board.

California Air Resources Board, California Climate Action Registry, ICLEI and The Climate Registry. 2008, "**Local Government Operations Protocol for the Quantification and Reporting of Greenhouse Gas Emissions Inventories**." http://www.theclimateregistry.org/ . CA.: The Climate Registry.

California Public Utilities Commission. 2007."**Interim Opinion On Issues Relating To Future Savings Goals And Program Goals For 2009-2011 Energy Efficiency And Beyond**." http://docs.cpuc.ca.gov/word_pdf/FINAL_DECISION/74107.pdf. CA.: California Public Utilities Commission

———. 2008. "**California Long Term Energy Efficiency Strategic Energy Plan**." www.californiaenergyefficiency.com/docs/EEStrategicPlan.pdf. CA.: California Public Utilities Commission.

Center for the Built Environment. 2008. "**Getting to Zero Energy Buildings**." Berkley, CA.: University of California, Berkley

Department of Energy. 2009. Net Zero Commercial Building Initiative. http://www1.eere.energy.gov/buildings/commercial_initiative/zero_energy_definitions.html. Washington D.C.: U.S. Department of Energy.

Electric Power Research Institute. 2007. "**Environmental Assessment of Plug-In Hybrid Electric Vehicles Volume 1: Nationwide Greenhouse Gas Emissions**." Palo Alto, CA.: Electric Power Research Institute.

EnergySoft. 2010. **"EnergyPro v5.0.23.0**." Computer Software. Novato, CA.: EnergySoft LLC.

H.R. 2454, 111th Cong. 2009. "**American Clean Energy and Security Act of 2009**." Washington, D.C.: US Congress

H.R. 6, 110th Cong. 2007 "**U.S. Energy Indepedence and Security Act of 2007**." Washington, D.C.: US Congress

National Renewable Energy Laboratory. 2001. "**PV Watts: A Performance Calculator for Grid-Connected PV Systems v2**." Computer Software. Golden, CO.: NREL.

Nunez. 2006. "**AB32, California Global Warming Solutions Act of 2006**." Sacramento, CA.: California State Assembly.

Schremp, Gordon, Jim Page, and Malachi Weng-Gutierrez. 2009. "**Transportation Energy Forecasts and Analyses for the 2009 Integrated Energy Policy Report**." CA.: California Energy Commission.

Senate Rules Committee. 2007 "**SB97 Bill Analysis."** http://www.leginfo.ca.gov/pub/07-08/bill/sen/sb_0051-0100/sb_97_cfa_20070822_142622_sen_floor.html. CA.: California State Legislative Counsel.

Stivers, Mark. 2008. "**SB 375 Bill Analysis**." 2008. http://info.sen.ca.gov/pub/07-08/bill/sen/sb_0351-0400/sb_375_cfa_20080903_100317_sen_comm.html. California: California State Senate.

Sullivan, J.L., I. T. Salmeen, and C. P. Simon. 2009. "**PHEV Marketplace Penetration: An Agent Based Simulation**." MI.: Transportation Research Institute of the University of Michigan.

Torcellini, P., S. Pless, M. Deru, and D. Crawley. 2006. "**Zero Energy Buildings: A Critical Look at the Definition**" In *Proceedings of the* 2006 ACEEE Summer Study. Pacific Grove, California: American Council for an Energy-Efficient Economy.

US Census Bureau. 2008. "**American Community Survey 1-Year Estimates**." http://factfinder.census.gov. Washington, D.C.: US Census Bureau.