SCE DRET Findings
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DR13.05: Grid Integration of Zero Net Energy Communities

ZERO NET ENERGY COMMUNITIES

The State of California has set ambitious targets for greenhouse gas (GHG) reduction goals through landmark Assembly Bill (AB) 32. A key component to meet these targets is the Long-Term Energy Efficiency Strategic Plan, which set a goal that all new homes in California be Zero Net Energy (ZNE) by 2020.

This project focuses on a near-term high-penetration future in California, when the goal to attain ZNE in residential communities may lead to every home on particular distribution systems having significant amounts of PV.

This project has four primary objectives:

• Demonstrate cost-effective technology pathways for ZNE communities and leveraging this work to better understand load shapes and PV sizing in ZNE communities to create a roadmap for high PV penetration in new home communities.

• Model and measure how ZNE communities with high PV penetration and electrification can impact electrical distribution systems in an "as-is" scenario, addressing both distribution operation and planning.

• Evaluate, using field data, how emerging technologies with connected end loads and customer side storage can be used to balance high PV penetration and load peaks.

• Develop an end-to-end modeling approach that integrates building, modeling, and energy storage into distribution modeling and improves modeling with measured field data.

This project demonstrates the impacts of a near-ZNE home community on the local distribution systems, and mitigation of the impacts using multiple strategies centered on building energy management systems and energy storage. As ZNE communities become de rigueur, new home construction will become the largest source for distributed photovoltaic (PV) installations. This project evaluates various ZNE approaches to derive PV sizing and interconnection requirements that produce cost-effective and grid-integrated ZNE communities, as well as community solar. Meritage, the homebuilder partner, built 20 ZNE homes in Fontana, California for the field evaluation portion of the project.

INTRODUCTION

What is This Technology?

ZERO NET ENERGY HOMES AND RESIDENTIAL BATTERY STORAGE

In California, the Long-Term Energy Efficiency Strategic Plan set a goal that all new homes in California be Zero Net Energy (ZNE) by 2020. As defined by the 2013 California Integrated Energy Policy Report (IEPR), a ZNE home is one where the societal value of energy consumed by the home over the course of the year will be less than or equal to the societal value of the on-site renewable energy generated, measured using the California Energy Commission's Time Dependent Valuation (TDV) metric. These ZNE homes will potentially result in a high PV case combined with a low load case, accentuating the maximum back flow situation from these homes into the grid.

The typical ZNE home design is engineered to increase energy-efficiency of the envelope, space conditioning and water heating equipment, kitchen appliances, and lighting, and then add sufficient PV on the roof to attain zero TDV.

A potential key component to achieving a ZNE home is battery storage. Residential battery storage has been deployed globally for over 30 years. Energy storage systems (ESS) consist of three primary components: a power conversion system (PCS), a battery/battery management system (BMS), and an energy management system (EMS).

Figure 1: ZNE Design (left) and ZNE Community (right)

What We Did?

DESIGN A ZNE COMMUNITY AND COLLECT AND ANALYZE DATA

The first step of this study was to select a community in which to design and build ZNE homes. The community selected in Fontana, CA was representative of the larger population with loads representative of California. The site had to be chosen in the early stages of development. While originally an entire community was planned for the project, due to time and budget constraints it was decided that 20 ZNE homes be built within a larger community instead.

The planning of the community had three main tasks – end-use energy efficiency (EE) planning, solar planning, and electric grid planning. For grid balancing of high penetration PV and loads, connected devices and energy storage were used. Energy storage was implemented on the customer side for nine of the twenty homes in the study.

As a part of this study, there was substantial data collection and monitoring of the homes, which allowed for data analysis use cases which stretched across both the customer side and the utility side. Some of the use cases for the project include:

- Modeled vs. measured performance of ZNE homes
- Impact of individual EE measures
- Understand behavioral loads
- Demand management at single-home and community level
- Electric vehicles usage
- Grid optimization for cost and/or reliability
- Understanding capability of load shifting and load management from energy storage
- Plus many others

ZNE HOMES CAN BE COST-EFFECTIVE AND CASH FLOW POSITIVE This project demonstrated that ZNE homes can be cash flow positive to the homeowners. Up to $22,000 in additional costs (with incentives) can be offset with less than $100 in energy savings a month a typical 30-year mortgage. This also emphasizes the importance of managing trade-offs in energy efficiency to manage the additional cost for attaining Zero Net Energy.

ELECTRIFICATION OF HEATING LOADS For optimal customer economics, with a current NEM of 2.0, it's preferable to keep PV annual production at 85-90% of total annual electric use. However, average PV production is larger than the typical electric load of a gas heated residence. This can be solved by electrifying the heating loads, increasing the total annual electricity usage. The electrification of heating loads is also net first cost neutral, as eliminating gas lines and flue gas stacks, along with additional NOx fees, made it less expensive to install electric heating systems.

CUSTOMER SIDE ENERGY STORAGE IS NOT COST-EFFECTIVE FOR GRID BALANCING The total cost of the energy storage systems, excluding the cost of installation, was in the range of $20,000 per unit, borne as a cost share by EPRI's partners. While there is some value to customers in terms of backup power, it is not sufficient to offset the cost at scale. This means most of the value for energy storage lies in grid scale storage – either at transformers, specific feeder locations, or at substations.

COMMUNITY SOLAR AND STORAGE Community solar and storage on the utility side of the meter can play a key part in attaining ZNE communities. While there are business model challenges (who pays for it, where is it located, land availability), from a technical perspective, it can address the major issues with both over generation, and electrification of end-loads, and can also have a lower cost. The storage can also be sized smaller to take load diversity issues into account.

GRID INTEGRATION AND DISTRIBUTION PLANNING A distribution network has multiple points where planners must ensure reliability for extended lifetimes. The impacts on the various elements of the distribution network such as secondary wires, transformers, laterals, switches (load blocks), feeders, and substations can differ. The backfeed from PV mainly impacts protection mechanisms at the switches and substations as well as secondary wire size, while the load variability, system peaks and EV penetration will impact all elements of the distribution system.

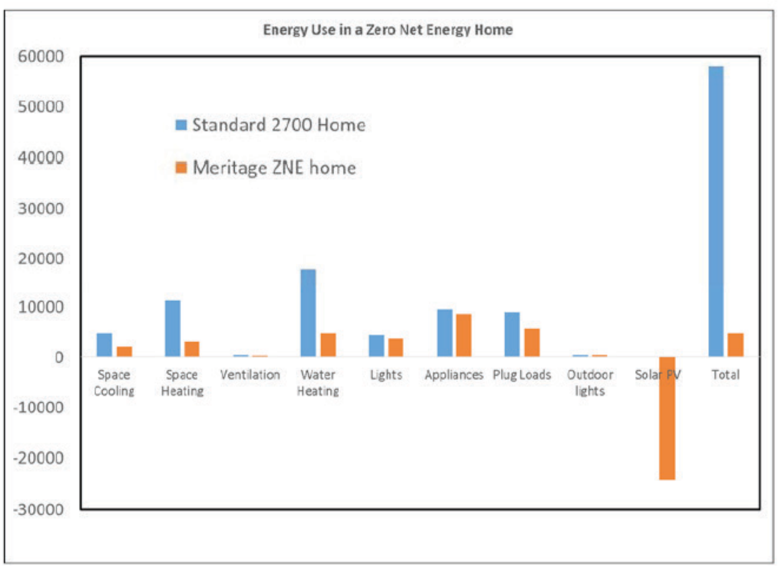

Figure 2: Energy Use in a Zero Net Energy Home

CONCLUSIONS

Lessons Learned

This study of 20 ZNE homes in a community, one of the first of its kind in California, provided many lessons learned throughout the project.

LESSONS LEARNED IN THE PLANNING PHASE

Planning a ZNE community requires tight coordination between the builder, the energy designer, the solar provider, the energy modeler, and the local utility. This is especially true as the utility grid planners are not yet familiar with the impacts of a ZNE community. A planning process chart for future ZNE communities needs to be developed and published to aid in developing future ZNE communities.

LESSONS LEARNED IN CONSTRUCTION PHASE

The advanced technologies present in a ZNE home require that researchers and designers take a more hands-on approach in overseeing the construction process, and in a more rigorous commissioning of the home. As well, the skill level of the electrical contractors will need to be elevated to deal with the new, advanced technologies.

LESSONS LEARNED IN GRID INTEGRATION

The load shape for ZNE communities is drastically different from the standard cooling peak-driven load shapes, as energy efficiency measures reduce the peak loads, and the presence of PV shifts the peak load to the evening hours. Electrification of heating loads combined with EE and future EV penetration can also significantly affect distribution planning, as it can increase the peak loads. Finally, energy storage, which can either benefit or harm the distribution grid based on the implemented controls scheme, needs support in the implementation process.

These Findings are based on the report “Grid Integration of Zero Net Energy Communities,” which is available from the ETCC program website, https://www.etcc-ca.com/reports.

Next Steps and Future Initiatives

This project revealed a high level of awareness of distribution impacts due to the combination of high PV penetration, EE, and electrification. The media coverage has raised the awareness in the R&D community and many of the results are being fed back in to the Title 24 code development of the ZNE code in 2019.

In California, the project team is leveraging these learnings in a new EPIC funded project to build community scale ZNE. This project will scale the first ZNE neighborhood into the first few communities, implementing ZNE communities in Orange County, Fresno, and the Bay Area with multiple builders. These initiatives will substantially help develop planning processes for ZNE communities and will help prepare for California’s future of high PV penetration with ZNE communities.

The next big step for meeting state policy goal is to move towards zero carbon construction. A clear pathway as the state ramps up renewable generation is electrification of new construction. A next effort should focus on how to attain all electric new homes cost-effectively both for the customer and the grid.