California Solar Initiative

RD&D: Research, Development, Demonstration and Deployment Program

GO solar CALIFORNIA

Final Project Report:

West Village Energy Initiative Target Area Two: APPENDIX A

Zero Net Energy Project: Single-family Homes Roadmap

Grantee:

University of California, Davis

Design & Construction Management

August, 2013

www.CalSolarResearch.ca.gov

PREPARED BY

University of California, Davis
Real Estate Services

255 Cousteau Place
University of California, Davis
Davis, CA 95618
530-754-1111

Principal Investigator:
Mary Goodell Hayakawa, Executive Director
Mghayakawa @ ucdavis.edu

Project Partners:
E3
DEG
General Electric

PREPARED FOR

California Public Utilities Commission
California Solar Initiative: Research, Development, Demonstration, and Deployment Program

CSI RD&D PROGRAM MANAGER

Program Manager:
Smita Gupta
Smita.Gupta@itron.com

Project Manager:
Smita Gupta
Smita.Gupta@itron.com

Additional information and links to project related documents can be found at

DISCLAIMER

"Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the CPUC, Itron, Inc. or the CSI RD&D Program."

http://www.calsolarresearch.ca.gov/Funded-Projects/

Preface

The goal of the California Solar Initiative (CSI) Research, Development, Demonstration, and Deployment (RD&D) Program is to foster a sustainable and self-supporting customer-sited solar market. To achieve this, the California Legislature authorized the California Public Utilities Commission (CPUC) to allocate **$50 million** of the CSI budget to an RD&D program. Strategically, the RD&D program seeks to leverage cost-sharing funds from other state, federal and private research entities, and targets activities across these four stages:

- Grid integration, storage, and metering: 50-65%
- Production technologies: 10-25%
- Business development and deployment: 10-20%
- Integration of energy efficiency, demand response, and storage with photovoltaics (PV)

There are seven key principles that guide the CSI RD&D Program:

1. **Improve the economics of solar technologies** by reducing technology costs and increasing system performance;
2. **Focus on issues that directly benefit California**, and that may not be funded by others;
3. **Fill knowledge gaps** to enable successful, wide-scale deployment of solar distributed generation technologies;
4. **Overcome significant barriers** to technology adoption;
5. **Take advantage of California's wealth of data** from past, current, and future installations to fulfill the above;
6. **Provide bridge funding** to help promising solar technologies transition from a pre-commercial state to full commercial viability; and
7. **Support efforts to address the integration of distributed solar power into the grid** in order to maximize its value to California ratepayers.

For more information about the CSI RD&D Program, please visit the program web site at www.calsolarresearch.ca.gov.

Acknowledgments

This report is the product of a research collaboration among multiple organizations. A number of people contributed to the research, including: Mary Hayakawa, Ardie Dehghani, Benjamin Finkelor, Gerald Braun, Kurt Wengler, Robert Segar, Sid England, and Steve Condrin at the University of California, Davis; Nolan Zail and Jon Paynter at WVCP; Adele Chang and Mark Rohling at Lim Chang Rohling & Associates; Bill Dakin, Alea German, Marc Hoeschele, and David Springer at Davis Energy Group; and Ben Norris and Tom Hoff at Clean Power Research.

Table of Contents

1 Report Summary 13

1.1 Introduction 13

1.2 Project Goals and Key Questions 14

1.3 Summary of Methods and Intermediate Results 15

1.3.1 Modeling Overview 15

1.3.2 Key Definitions 18

1.3.3 Baseline Home Development 19

1.3.4 Energy Efficiency Analysis 20

1.3.5 Energy Supply Analysis 23

1.3.6 EV, Fuel Cell, and Storage Analysis 27

1.3.7 Behavior 28

1.4 Roadmap Summary 29

1.4.1 Key Results 29

1.4.2 Further Research 31

2 Baseline Home Development 32

2.1 Development of Home Floor Plans 32

2.2 Incorporating Home Size Uncertainty 36

2.3 Studio Units 37

2.4 Description of Baseline EEM Packages 37

2.5 Potential Rate Schedule and Metering Configurations 43

3 Energy Efficiency Analysis 44

© 2013 Energy and Environmental Economics, Inc.

3.1 Modeling Tools and Assumptions 44
3.2 Design Charrette 47
3.3 EEM Incremental Costs and Screening Methods 50
3.4 Development of EEM Packages 55
3.5 Recommended EEM Package Details 58
3.5.1 Thermal Envelope 62
3.5.2 Mechanical Systems 66
3.5.3 Lighting & Appliances 70
3.5.4 Studio 72
3.6 Energy Use Data 72
3.7 Package Incremental Costs and Energy Efficiency Incentives . 78
3.7.1 California Advanced Home Partnership Energy Efficiency Incentives 79
3.7.2 Additional Energy Efficiency Incentives 82
3.8 Additional Energy Efficiency Measures Evaluated 83
3.9 Recommendations 89
4 PV System Analysis 92
4.1 PV Generation Modeling 92
4.2 PV System Cost 94
4.3 Solar PV Incentives 95
4.4 Sizing PV System under Uncertain Degradation and Consumption 96
4.5 Net Usage Bill Calculations 99
5 Biogas Analysis 100

5.1 The Case for Biogas 100
5.2 Biogas Energy Balance 102
5.3 Biogas Procurement Options 103
5.3.1 Biogas Contract 104
5.3.2 off-campus Biogas Project 104
6 Electric Vehicle Analysis 105
6.1 EV Penetration Rates and Use 105
6.2 Costs Assumptions for EVs and Conventional Gasoline Cars 107
6.3 Accommodating EV Penetration over Time 109
7 Identification of Potential Business and Regulatory Models 110
7.1 PV Business Models in the Current Regulatory Environment .. 110
7.1.1 Changes in PV System Costs over Time 111
7.1.2 Accommodating Future Usage and Generation Uncertainty 115
7.1.3 Regulatory Models 116
7.1.4 Electric Rate Selection 117
7.2 Results: Successful Business Model(s) under Current Regulations 118
7.3 Key Sensitivities 124
7.3.1 What PV Generation Strategy should be Employed? Should a Different PV Business Model other than Rooftop PV be Pursued? 125
7.3.2 What Level of EE should be Pursued? Should a Different EE PACKAGE be Pursued Depending upon Future PV Prices? 125

© 2013 Energy and Environmental Economics, Inc.

7.3.3 Do Results Change if EVs are Added? 126
7.3.4 What if Projected Retail Electricity Rates are Different than Assumed? 126
7.3.5 What if Studio Units are not Constructed? 127
7.3.6 What if Home Energy Use is Different than Assumed? 128
7.4 Business Models under Regulatory Change 129
7.4.1 Community Virtual Net Metering 129
7.4.2 Aggregated NHSP 130
7.4.3 Other Regulatory Issues 131
7.5 Utility Roles 132
7.5.1 Tax Equity Participation in Solar PV Ownership 133
7.5.2 Biogas Provider 133
7.5.3 Pilot Program for Submetering EVs 133
7.5.4 Billing Mechanisms 134
7.5.5 Participation in Visitor Center 134
7.5.6 Participation in Lab House 134
8 Fuel Cell and Storage Analysis 136
8.1 Fuel Cell Analysis 136
8.2 Storage Analysis 139
8.2.1 Storage Applications 139
9 Ways to Foster "Community" ZNE Experience at the West Village 144
9.1 Fostering Community 144

9.1.1 Lab House 144
9.1.2 Fostering Energy Efficiency Goals through Feedback 145
9.1.3 Car Share Program 146
10 Roadmap 147
10.1 Achieving Zero Net Energy at No Higher Cost is (Very Nearly) Possible 147
10.2 West Village Roadmap 148
10.2.1 Community resource option 150
11 Appendix 151

© 2013 Energy and Environmental Economics, Inc.

Acronyms Used in this Report

AC	alternating current
AFUE	annual fuel utilization efficiency
CAHP	California Advanced Homes Program
CARE	California Alternative Rates for Energy
CEC	California Energy Commission
CFA	conditioned floor area
CFL	compact fluorescent light
CHP	combined heat and power
CLTC	California Lighting Technology Center
CPR	Clean Power Research
CRRC	Cool Roof Rating Council
CSI	California Solar Initiative
DC	direct current
DEG	Davis Energy Group
E3	Energy and Environmental Economics, Inc.
EEM	energy efficiency measure
EER	energy efficiency ratio
EF	energy factor
EV	electric vehicle
FSEC	Florida Solar Energy Center
HERS	Home Energy Rating System

HPWH	heat pump water heater
HSPF	heating seasonal performance factor
HVAC	heating, ventilation and air conditioning
IOU	investor-owned utility
ITC	investment tax credit
kV	kilovolt
kW	kilowatt
kWh	kilowatt-hour
LCOE	levelized cost of energy
LCRA	Lim Chang Rohling & Associates
LED	light emitting diode
MEL	miscellaneous electric loads
MW	megawatt
NEM	net energy metering
NPV	net present value
NREL	National Renewable Energy Laboratory
NSHP	New Solar Homes Program
PG&E	Pacific Gas & Electric
PPA	power purchase agreement
PTHP	packaged terminal heat pump
PV	photovoltaic
QII	quality installed insulation
RASS	Residential Appliance Saturation Survey
RC	recessed can

© 2013 Energy and Environmental Economics, Inc.

REC	renewable energy credit
RECS	Residential Energy Consumption Survey
SEER	seasonal energy efficiency ratio
SIP	structurally insulated panels
SLA	specific leakage area
T-24	Title-24
TDV	time-dependent valuation
TOU	time of use
VNM	virtual net metering
WVCP	West Village Community Partnership, LLC
ZNE	zero net energy

1 Report Summary

1.1 Introduction

U.C. Davis West Village ("West Village"), a mixed-use development underway at the University of California, Davis, is the largest planned zero net energy (ZNE) community in the U.S. To meet its goals for environmental sustainability and affordable housing, UC Davis contracted with a consultant team to support the development of a ZNE roadmap, a collaborative stakeholder process that will enable the single-family homes in the West Village to serve their annual energy consumption with renewable resources at no higher cost to homeowners or the project developer. This report documents the development of the West Village single-family homes roadmap.

As a model ZNE community, the West Village is a laboratory for the development of ZNE communities elsewhere. California's Big Bold Energy Efficiency Strategy, for instance, sets a policy for all new residential construction to be ZNE by 2020. However, there is currently only a thin knowledge base on the mix of energy technologies, business models, regulations, and incentives that affect ZNE construction, and the changes in behavior that will be necessary to make ZNE buildings and lifestyles mainstream. In addition to providing a roadmap for the West Village, this report expands the ZNE knowledge base by providing a general methodology for assessing the benefits and costs of ZNE homes, considering and quantifying the implications of different business

© 2013 Energy and Environmental Economics, Inc.

models and regulatory changes on ZNE cost-effectiveness. The report also identifies a number of areas for future research.

1.2 Project Goals and Key Questions

The primary goal of this project was to create a roadmap for ZNE development of the single-family home portion of West Village at no higher cost to the developer or to homeowners, while using generation from multiple renewable resources. To the extent feasible and cost-effective, the roadmap seeks to incorporate community-scale resources, create integrated technology applications, locate generation onsite, provide roles for the utility, and design solutions that are replicable.

Energy and Environmental Economics, Inc. (E3), Clean Power Research (CPR) and Davis Energy Group (DEG) formed "the consultant team" and worked collaboratively with UC Davis, the project developer West Village Community Partnership, LLC ("WVCP"), the architect (Lim Chang Rohling & Associates), and the CSI grant administrator (Smita Gupta of ITRON) to develop the final roadmap.

The roadmap aims to describe potential ZNE pathways under multiple sources of uncertainty, providing a framework for accommodating change. A business model analysis identifies successful ZNE business models under a range of technological, regulatory, and economic scenarios. A regulatory analysis identifies a best plan under existing regulations, and identifies the changes to existing regulations that would have the most impact on project economics.

Key questions addressed in the Project include:

- What level of energy efficiency is cost-effective in West Village homes?
- What kind and level of onsite renewable generation strategy is most cost-effective for the West Village?
- How can "advanced" energy end-use and supply technologies be employed in the West Village?
- Can storage and fuel cells be deployed economically?
- How should future uncertainty be treated in the West Village project?
- What role does resident behavior play in achieving ZNE at the West Village?
- What are the most beneficial regulatory changes for the West Village project and which, if any, should be pursued?

1.3 Summary of Methods and Intermediate Results

The roadmap development relied on several component analyses. This section provides a brief overview of the methods used to develop the roadmap. More detail can be found in the individual sections of the report.

1.3.1 MODELING OVERVIEW

The roadmap analysis drew on three core components:

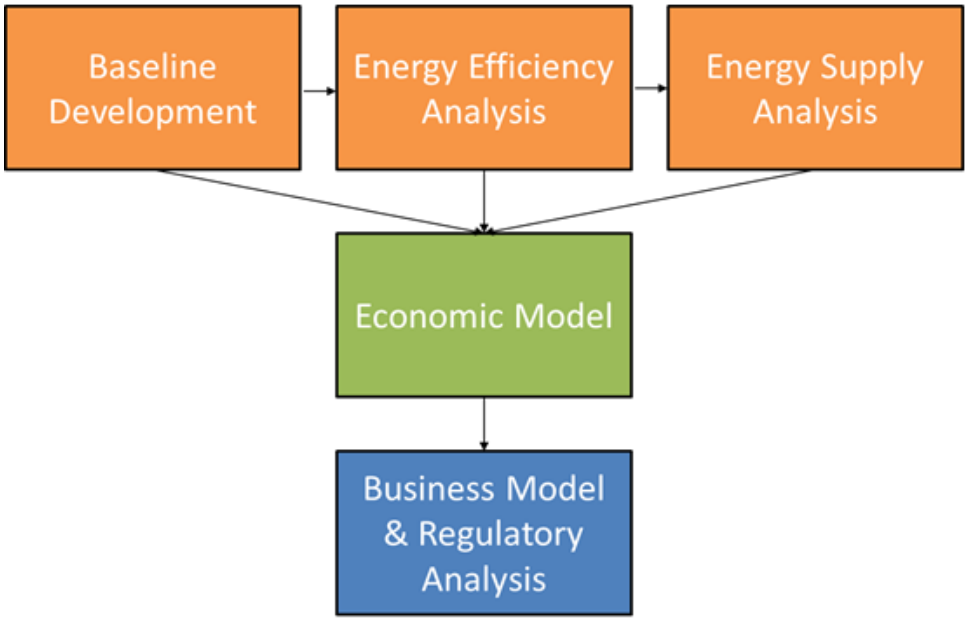
- *Baseline Home Development* created energy use and cost profiles for baseline homes, as the reference point for assessing the additional cost of West Village homes;

© 2013 Energy and Environmental Economics, Inc.

- *Energy Efficiency Analysis* assembled three energy efficiency measure (EEM) packages for the West Village homes;
- *Energy Supply Analysis* developed generation profiles and cost estimates for the energy technologies serving the West Village, focusing on solar PV and biogas.

These inputs formed the basis of an economic model that calculates the net costs of different technology options to developers and homeowners. The results from the economic model then fed into a business model and regulatory analysis (Figure 1). The consultant team examined a range of energy efficiency options and packages, solar PV generation options, construction timing, and regulatory models to form the core economic and regulatory analysis of the roadmap. The consultant team also examined electric vehicles (EVs) as a sensitivity to gauge how they would affect project economics. Finally, we examined the economics of an onsite fuel cell and onsite energy storage, though neither is included in the final roadmap because of their economics and the project's cost goals.

Figure 1. Modeling Framework



All of the analysis was conducted using a single, Excel-based model. This single-tool approach fosters continuity of context; aligns assumptions and business model scenarios; facilitates development of comprehensive solutions to the energy needs; and avoids duplication of modeling efforts, helping to deliver services cost-effectively. In addition, a single tool provides the systems perspective needed to capture interactions among technologies — for instance, the amount of energy efficiency in homes depends on the cost of photovoltaic (PV) systems, while the size and net use of the PV system depends on the amount of energy efficiency.

© 2013 Energy and Environmental Economics, Inc.

1.3.2 KEY DEFINITIONS

1.3.2.1 Zero Net Energy

Originally, U.C. Davis defined ZNE to mean producing enough renewable energy on-site to offset electricity use on an annual basis. When natural gas uses were included for the single-family homes, ZNE was re-defined to mean no net source energy from fossil fuel but did not strictly require all generation to be within the community. There are a number of ways to achieve ZNE homes under this definition. Since the project goal is to have multiple renewable resources within the community, for instance, the West Village roadmap aims to meet all expected electricity consumption from onsite renewable electric generation, but buy renewable energy credits (RECs) to make up any shortfalls from higher than expected consumption or PV degradation. Also, since biogas is not currently available onsite, we allow biogas offsets to offset natural gas rather than require all-electric homes. This definition strikes a balance between a rigorous interpretation of 'zero net energy' and cost-effective solutions.

1.3.2.2 No Additional Cost

We used two metrics to define 'no additional cost' which is a key goal for the project. For WVCP, capital costs in the developer scope, which include EEMs not otherwise required by Title 24 as adopted by the City of Davis (but not PV or EV costs), must be less than or equal to capital costs for the baseline home. A baseline home is of equal size, located in Davis, and achieves local energy efficiency requirements but is not ZNE. For the West Village homeowner, the lifecycle energy-related expenditures (including incremental capital costs and

operating costs and all energy bills) must be less than or equal to the lifecycle energy bills for the baseline home.

1.3.3 BASELINE HOME DEVELOPMENT

Energy use profiles for the single-family housing units were based on a 3 bedroom, 3 bathroom, two-story floor plan developed by the architect, Lim Chang Rohling & Associates (LCRA), with a total square footage of 1,756 ft^2 and a window area equal to twenty five percent (25%) of the conditioned floor area. Sixty percent (60%) of the homes were assumed to have studio units, which were assumed to be rented to lower income occupants, such as graduate students.

Some of the West Village homes are planned to be smaller or larger than this home. To accommodate homes of different sizes, the analysis included four home sizes: small (~1,400 ft^2); medium, or base (1,756 ft^2); large (~2,000 ft^2); and extra-large (~2,500 ft^2). Using these specifications, we created energy multipliers to scale simulated electricity and natural gas use for medium-size home to reflect the other home sizes. For the purposes of this analysis, we assumed that the 343 single-family homes planned for the West Village include 100 small, base, and large homes, and 43 extra-large homes.

Baseline homes were assumed to meet the energy efficiency standards required by local building codes. Since 2008, the City of Davis requires all new homes to be 15% more energy efficient than Title 24 specifications. Therefore, in addition to a Title 24 baseline home, we developed a baseline home based on 15% better than Title 24 ("Title 24 + 15%") for calculating the additional costs in the developer's scope that would otherwise have been required in Davis. Table 1,

© 2013 Energy and Environmental Economics, Inc.

below, shows the estimated annual energy use for these homes using building energy modeling software.

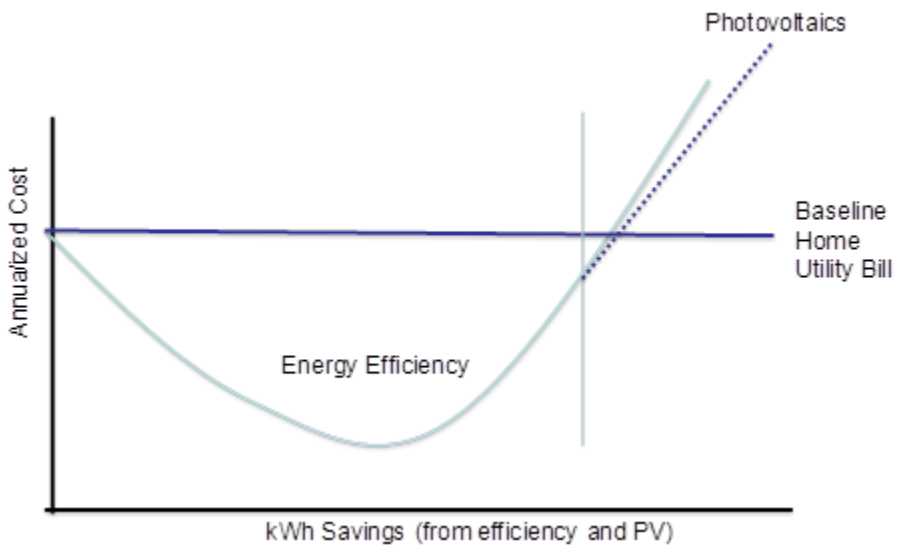
Table 1. Estimated Annual Energy Use in Baseline Homes

	Electricity (kWh)	Natural Gas (Therms)
Title 24	9,573	795
Title 24 + 15%	9,173	633

1.3.4 ENERGY EFFICIENCY ANALYSIS

Using a design charrette process, UC Davis, WVCP, LCRA, and the consultant team developed three EEM packages for the West Village homes: a basic performance package, an advanced package (Advanced A) that provides energy savings beyond the basic package, and a second advanced package (Advanced B) that provides savings beyond Advanced A. Within each package, individual measures were evaluated relative to solar PV and biogas costs to test their cost-effectiveness. Only EEMs with a lifecycle levelized cost per kWh savings that were lower than the levelized cost of energy (LCOE) for PV (electricity) or biogas (space heating and cooking) were included in the packages, as Figure 2 illustrates in the case of electricity and PV. The basic, Advanced A, and Advanced B packages were evaluated relative to average, low, and high cost PV estimates and biogas scenarios, respectively.

Figure 2. Selected Electricity Energy Efficiency Measures Cost Less than the LCOE of Solar PV



Based on the EEM packages, we conducted a detailed simulation of energy consumption by end use — heating, cooling, domestic hot water, lighting, appliances, and miscellaneous electric loads — in the homes and studios using the National Renewable Energy Laboratory's (NREL's) BEopt modeling software. We used EnergyPro to evaluate EEM performance relative to Title 24 code and to calculate EEM incentives. Total energy use by EEM package for medium-sized homes is shown in Table 2.

© 2013 Energy and Environmental Economics, Inc.

Table 2. Electricity and Natural Gas Use by EEM Package, Savings over Title 24 and Title 24 + 15%

	Electricity (kWh)	Natural Gas (Therms)
Title 24	9,573	795
Title 24 + 15%	9,173	633
Basic Performance	7,343	538
Advanced A	6,988	476
Advanced B	6,676	452

Package	Source Energy Savings Over Title-24		Source Energy Savings Over Title-24 + 15%	
	Main House	Studio	Main House	Studio
Basic Performance	28%	29%	18%	14%
Advanced A	34%	31%	26%	17%
Advanced B	38%	33%	30%	19%

Notes: Basic performance, Advanced A, and Advanced B packages are for the base case (medium-sized) home. Electricity use includes 60% of studio.

The incremental costs of the three EEM packages were estimated collaboratively with the developer and represent the additional capital cost of each package above the cost of a baseline home, net of energy efficiency incentives. The results in Tables 2 and 3 show that significant energy efficiency is possible in new construction at modest incremental cost.

Table 3. Incremental Cost and Net Incremental Cost of EEMs Versus a Title 24 + 15% Home

	Incremental Cost	Net Incremental Cost (after incentives)
Basic Performance	$4,993	$1,831
Advanced A	$6,372	$2,554
Advanced B	$11,924	$7,883

Note: 60% of homes are assumed to include studios. The cost, on a per-home basis, therefore includes 60% of studio.

1.3.5 ENERGY SUPPLY ANALYSIS

1.3.5.1 PV System

The main source of electricity generation in the West Village homes is planned to be onsite solar PV systems. Our analysis examined two possible configurations for these systems: (1) individual rooftop PV systems and (2) two community-scale PV systems, each sized to serve approximately half of the community's load. For both systems, we developed capital costs, a generation profile, and average capacity factors. Cost estimates were intended to be conservatively high for the purposes of evaluating the cost goals of West Village and were based on median values from the California Solar Initiative (CSI) database (Table 4).

© 2013 Energy and Environmental Economics, Inc.

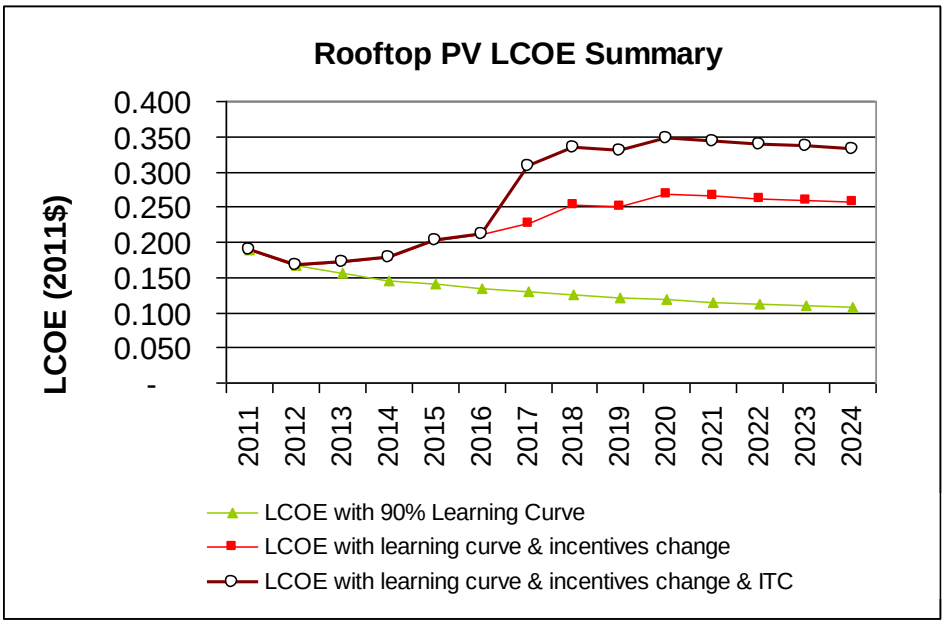
Table 4. Capital Costs, Levelized Costs, and Capacity Factors for PV Systems for 2011 Installation

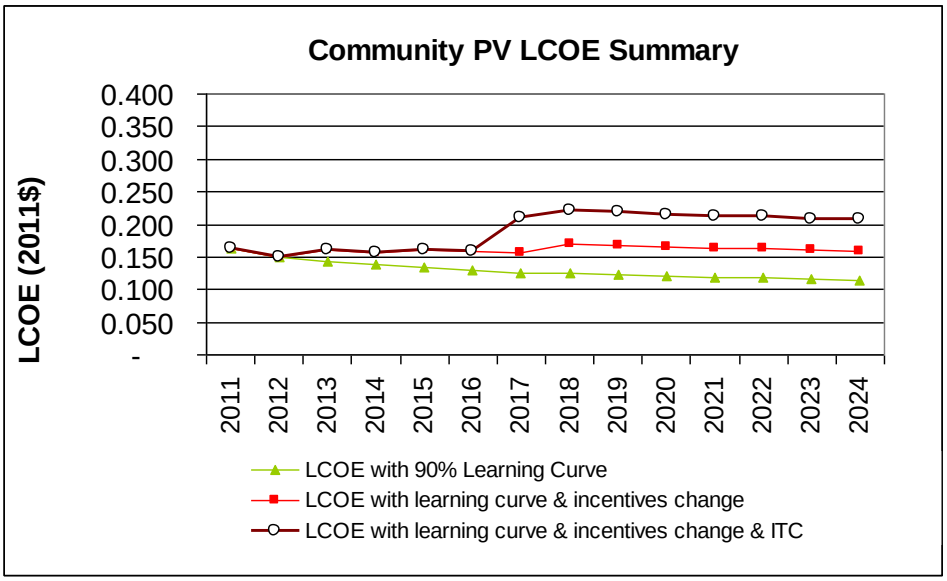
	Capital Cost (2011$/kW)	Levelized Cost (Real 2011$/kWh)	Capacity Factor
Community-scale	$5,138	$0.1626	21.5%
Rooftop	$7,418	$0.1884	18.4%

PV systems were sized to projections of annual electricity consumption for the homes and studio apartments. Systems were assumed to degrade at 0.7% per year, with any shortfalls in onsite PV generation made up through the purchase of RECs. We generated net usage bills for the West Village homes, based on 180 net usage scenarios and forecasted PG&E rates. The net usage scenarios span all combinations of home size, EEM package, studio energy use, metering approach for the studio, and, as a sensitivity, EV usage.

For both the community-scale and rooftop PV systems, we forecasted changes in installed PV costs over time using two scenarios; moderate reductions in the future (90% progress ratio) and fast reductions in the future (75% progress ratio). Solar incentive levels reductions are also modeled, as is the federal solar investment tax credit (ITC) reduction to 10% in 2016. The balance between these two forces for the moderate installed cost reduction scenario for rooftop and community PV systems is shown in Figure 3. While cost declines largely offset declining incentives, the federal ITC step down causes a significant increase in net costs, particularly for rooftop PV.

Figure 3. Levelized Cost of Energy for Rooftop and Community PV Systems with 90% Progress Ratio





© 2013 Energy and Environmental Economics, Inc.

1.3.5.2 Biogas

Displacing natural gas water heating and cooking is one of the more challenging aspects of ZNE home development, because it requires either an all-electric home, offsetting natural gas use with renewable energy credits or additional PV generation, or finding renewable sources of gas, such as biogas. In comparing all-electric and renewable gas-electric homes, we found that ZNE all-electric homes have higher operating costs and are less marketable than gas-electric homes.[1]

Without a means of delivering biogas directly to the homes, the roadmap develops an approach whereby UC Davis purchases a biogas "offset" on behalf of West Village residents rather than delivering biogas onsite. With this approach, UC Davis would purchase biogas from an in-state or out-of-state biogas provider, and the biogas would be mixed with conventional natural gas at the pipeline and sold as natural gas. The net loss on the sale would form the basis of the biogas 'offset.' The delivered cost of biogas purchased using this strategy (PG&E natural gas bill plus biogas offset) was conservatively assumed to be $2/therm.

Thus, the roadmap recommends supplying natural gas to West Village homes for cooking, water, and space heating, with a plan to procure biogas offsets, rather than build all-electric homes.

[1] In addition, given our loss assumptions for electricity and natural gas delivery, the amount of electricity exported / imported from the home, as well as appliance efficiencies, the combined biogas-electric homes also have marginally lower source energy consumption.

Originally envisioned as part of the West Village community, an anaerobic biodigester has been constructed approximately 2 miles to the southwest at the former UC Davis landfill. The biodigester is owned and operated by CleanWorld using technologies licensed from UC Davis. Approximately 50 tons per day of organic matter from the campus and the region will be supplied to the biodigester at full capacity. The facility is located on the site of the former campus landfill where it also is able to take advantage of the available landfill gas. The biogas produced by the facility and the landfill gas power a microturbine and a Rankine-cycle engine-generator using waste heat from the microturbines. The facility is expected to produce approximately 5.6 million kWh per year for the UC Davis campus grid. Biogas from this facility is not expected to be available for West Village use.

1.3.6 EV, FUEL CELL, AND STORAGE ANALYSIS

1.3.6.1 EVs

EVs are not mandatory in the West Village and were included as a sensitivity in the analysis — no EVs were assumed in the core results. EV cost and performance assumptions included: a cost of $12,200 more than a conventional car, with decreasing costs over time; $10,000 in federal and state incentives; and a range of vehicle ownership, driving, and charging scenarios. EVs were assumed to be submetered on PG&E's E-9 rate, with an additional charger cost of $1,500 and additional metering costs of $450. Over their lifecycle, EVs reduce costs and carbon at the West Village.

© 2013 Energy and Environmental Economics, Inc.

1.3.6.2 Fuel Cells and Storage

As part of the analysis, we also examined the cost-effectiveness of biogas fuel cells and storage. A biogas fuel cell would provide a baseload renewable generation resource at West Village. The fuel cell was assumed to have a system cost of $8.59/W and, based on system performance assumptions, a levelized cost of $0.2095/kWh, before changes in current incentive levels or learning curve improvements. Storage allows homeowners to charge during off-peak periods and discharge during on-peak periods, saving the difference in retail time-of-use (TOU) electric rates, and may also provide backup for the onsite PV system in limited situations where the grid does not. However, at current cost estimates, neither fuel cells nor storage were found to be cost-effective.

1.3.7 BEHAVIOR

Maintaining ZNE goals will require ongoing engagement with the West Village community. West Village residents need feedback on their energy use, particularly as households purchase new appliances or add new family members. Feedback could be provided, for instance, through in-house displays that show real-time energy use. Community engagement could also be done through seminars and workshops that help residents manage their energy use, or fees that discourage excessive use.

1.4 Roadmap Summary

1.4.1 KEY RESULTS

Overall, the analysis showed that it is possible to meet the project goal of ZNE homes at no added cost to homeowners and only a small added cost to the developer that can likely be passed on to homeowners. The roadmap provides an action plan for UC Davis to achieve these goals.

The lifecycle benefits and costs of West Village homes depend primarily on the construction rate for new homes, changes in PV costs over time, and the choice of PV business model (Table 5). The lifecycle net benefits are calculated using net present value (NPV), which is defined as the difference between the costs of the baseline homes and the West Village homes, with a positive figure indicating that the West Village homes are more cost-effective. The pace of home construction is important because solar incentives decline over time. With a faster pace of construction (e.g., 100 homes per year) rooftop PV has a positive NPV regardless of changes in PV costs. At a slower construction pace, the choice of business model — whether and when to build rooftop versus community-scale PV — becomes more important. In all scenarios, it is most cost-effective to begin with rooftop PV, and then consider a "delayed" community-scale PV system in a later year.

© 2013 Energy and Environmental Economics, Inc.

Table 5. NPV of PV Systems for Different Home Deployment Rates, Progress Ratios, and Business Models

Home Construction Rate	PV Cost Scenario (Progress Ratio)	Business Model	NPV (M$)
30 homes / year	Fast decline (75%)	Rooftop	0.9
		Rooftop, then delayed Community-scale	1.3
	Moderate decline (90%)	Rooftop, then delayed Community-scale	-0.3
60 homes / year	Fast decline (75%)	Rooftop	1.8
	Moderate decline (90%)	Rooftop, then delayed Community-scale	-0.1
100 homes / year	Fast decline (75%)	Rooftop	2.5
	Moderate decline (90%)	Rooftop	0.6

Based on the analysis, we recommend that UC Davis pursue the following key elements in the West Village Roadmap.

Summary of the West Village Roadmap

- Pursue EEM package Advanced A measures with developer;
- Pursue rooftop PV through 2014, then evaluate whether to proceed with a community PV system;
- Establish a biogas offset program for offsetting natural gas usage;
- Purchase or sell RECs to adjust for differences between onsite energy systems and energy demand;
- Research mechanisms to allow West Village residents to monitor and adjust their energy use habits; and

- Development of an adaptive learning process to assess the roadmap with adjustments over time, as needed.

1.4.2 FURTHER RESEARCH

The roadmap identifies three priority areas that require further research: (1) regulatory changes that allow and encourage community-scale PV systems, (2) electric vehicle metering and rate design, and (3) residential financing for energy efficiency. California's current PV policies do not promote the lowest societal cost outcome because they encourage the development of more expensive rooftop systems that serve individual homes rather than larger systems that can serve a community or development. Community-scale PV systems, which are less expensive than rooftop systems, face significant regulatory barriers.

EVs also face rate and regulatory uncertainty. For instance, the ability to sub-meter and provide appropriate incentives for EVs is critical for their deployment, but neither has yet been resolved. Financing for residential energy efficiency projects, both in new homes and home retrofits, is critical for lowering cost hurdles. However, the financial, policy, and regulatory communities are still searching for workable models for residential energy efficiency financing.

© 2013 Energy and Environmental Economics, Inc.

2 Baseline Home Development

The additional cost of the West Village single-family homes is measured against a baseline home — the home that a West Village homeowner might have bought had the West Village home not been available. This section describes the methods used in developing floor plans and energy use for the baseline homes.

2.1 Development of Home Floor Plans

The project developer, WVCP, provided five potential floor plans designed for the West Village Project. These were reviewed to select a representative floor plan for the analysis. We determined that floor layout and room configuration were fairly similar among the plans. Total glazing area and orientation, along with the presence of shading, often has the most pronounced effect on building energy use, all else remaining constant. Window area as a percentage of conditioned floor area (CFA) for each floor plan, based on the plans provided, is presented in Table 6. Because a complete set of elevations had not yet been developed, window heights were estimated based on the front elevation, in coordination with WVCP.

Table 6. Floor Plan Specifications

Floor Plan	CFA (square feet)	Window Area (% of CFA)
Plan 1	1,404	26%
Plan 2	1,587	25%
Plan 3	1,756	25%
Plan 4	1,874	23%
Plan 5	2,001	23%

Given that the window areas are relatively similar across all plans, we selected Plan 3 as the base case home for the analysis, as it represents average values for both floor area and window area with a CFA of 1,756 ft^2 and a window area of 25% of CFA. Figure 4 and Figure 5 show the floor plan and elevations, respectively for Plan 3.

© 2013 Energy and Environmental Economics, Inc.

Figure 4. Floor Plan 3

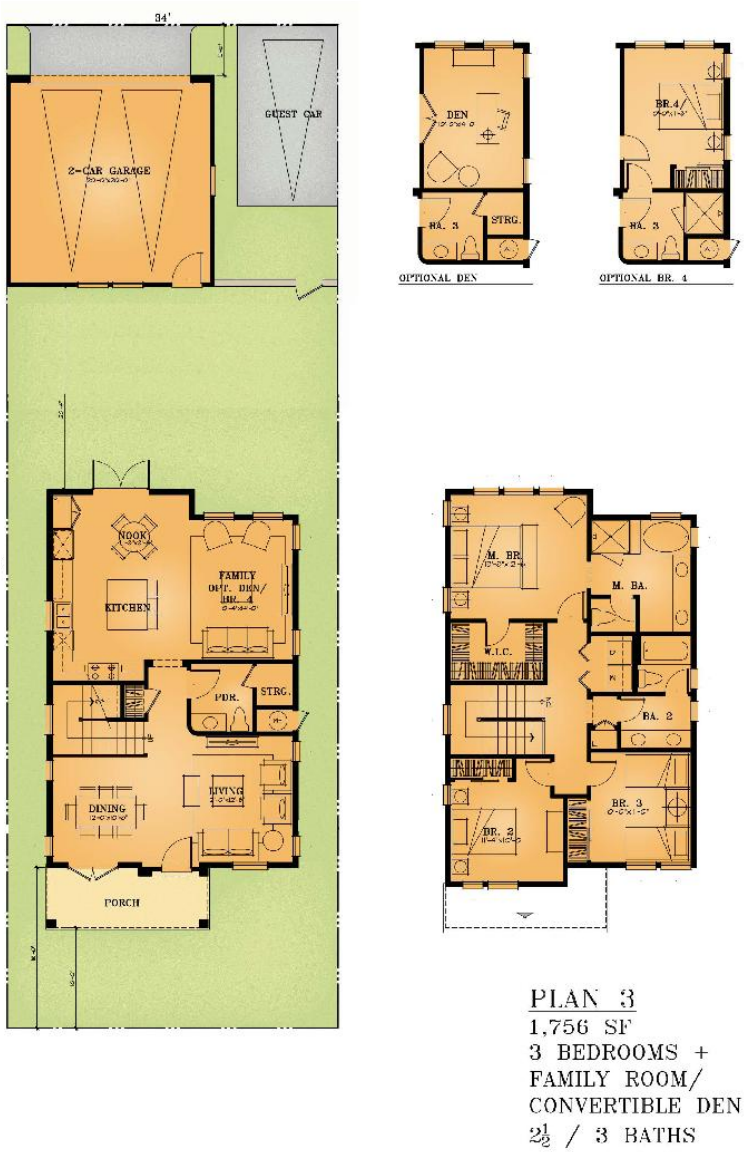
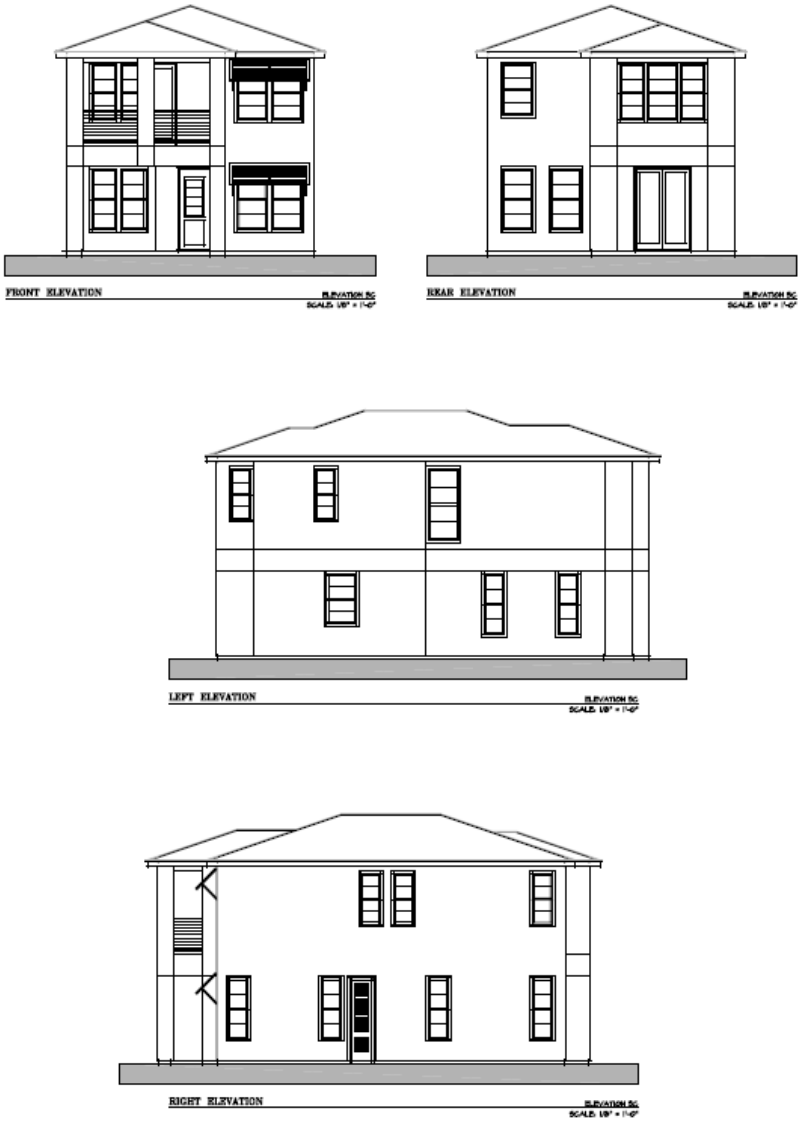


Figure 5. Plan 3 Elevations



© 2013 Energy and Environmental Economics, Inc.

2.2 Incorporating Home Size Uncertainty

The 1,756 ft^2 Plan 3 was selected as the base case West Village home for which detailed modeling was undertaken. However, actual home models can be smaller or larger than this base case. Due to project budget and schedule objectives, multiple floor plans were accommodated as follows. To incorporate uncertainty in home sizes, the project model provides for four home sizes: small (approximately 1,400 ft^2), medium (approximately 1,756 ft^2), large (approximately 2,000 ft^2), and extra-large (approximately 2,500 ft^2). We created usage multipliers to scale base case natural gas and electric consumption to appropriately reflect home size. These are given in Table 7 below. Project results assume 100 each of small, base, and large homes, and 43 extra-large homes.

Table 7. Natural Gas and Electricity Use Multipliers

Usage Scenario	Usage Multipliers
Natural Gas – small home	0.850
Natural Gas – medium home	1.000
Natural Gas – large home	1.090
Natural gas – extra-large home	1.230
Electricity – small home	0.843
Electricity – medium home	1.000
Electricity – large home	1.057
Electricity – extra-large home	1.169

2.3 Studio Units

Studio units are an option at West Village. Homeowners may desire a studio unit as a rental unit or as additional family living space. An estimated 60% of homes were assumed to purchase the optional studio unit. Of these, 100% were assumed to be rental units.

2.4 Description of Baseline EEM Packages

This evaluation considers two base cases for both energy savings and incremental cost comparisons. The City of Davis has adopted a local ordinance under the 2008 Title-24 specifications that requires all new construction within the city limits to be 15% more efficient than Title-24 performance specifications ("Title 24 + 15%"). While this does not impact new construction on UC Davis property (as it exceeds Title 24 + 15%), it does represent the effective base case for a consumer who would be making a comparison to a similar new home in Davis. A Title-24 code compliant house represents the base case for homes in California, as well as Davis homes that were constructed prior to 2008. Energy savings and incremental costs presented in this report are thus compared to both Title 24 and Title 24 + 15% base cases.

Table 9 lists the base case measure details for the main house for the Title-24 as well as the Title-24 + 15% base case. The values listed in the Title-24 + 15% base case column are for measures that differ from the 2008 Title-24 case. If no value is listed, then the specification does not change. The base case specifications for the studio are similar, with the main difference being that a packaged terminal heat pump (PTHP) was assumed for the studio as opposed to

© 2013 Energy and Environmental Economics, Inc.

a central ducted split system furnace and air conditioner. Complete measures details for the studio base cases are provided in Table 10.

With these measures, we simulated total annual energy use in the baseline homes, using the building energy modeling software described in Section 3. The results of this simulation, for electricity and natural gas, are shown below.

Table 8. Estimated Annual Energy Use in Baseline Homes

	Electricity (kWh)	Natural Gas (Therms)
Title 24	9,573	795
Title 24 + 15%	9,173	633

Table 9. Base Case Measure Details for the Main House

Measure Category	Base Case 2008 Title-24	Base Case Title-24 + 15%
Envelope		
Window Area - % of Conditioned Floor Area	26%	
Exterior Wall Construction	2x6 16"oc	
Exterior Wall Insulation	R-19	R-21
Foundation Type & Insulation	Slab on Grade - Uninsulated	
Floor Over Garage/Open	R-19 Batt	
Roofing Material & Color	Comp. Shingles, Medium	
Ceiling Insulation	R-38 Blown Cellulose	R-49 Blown Cellulose
Radiant Barrier	Yes	
Interior Thermal Mass	None	
House Infiltration - Blower Door Test (HERS)	No	
Thermal Bypass Inspection - QII (HERS)	No	Yes
Windows & Patio Doors	Dual Non-Metal 0.32 / 0.32	
HVAC Equipment		
Heating Type & Efficiency	Gas Furnace / AFUE 78%	Gas Furnace / AFUE 80%
AC Type & Efficiency	AC / SEER 13	
Duct Location & Insulation	Attic, R-6	
Duct Leakage Verification (HERS)	Yes, <6% of system airflow	
Verify Refrigerant Charge Credit (HERS)	Yes	
Verify High EER (HERS)	No	
Verify Cooling Coil Air Flow (HERS)	Yes	No
Verify Fan Watt Draw (HERS)	Yes	No
Verify Cooling Right Sizing (HERS)	No	
Mechanical Ventilation	Standard exhaust meeting ASHRAE 62.2	
Ventilation Cooling	None	

© 2013 Energy and Environmental Economics, Inc.

Measure Category	Base Case 2008 Title-24	Base Case Title-24 + 15%
Water Heating Equipment		
Water Heater Type & Efficiency	Gas Storage, EF 0.575	Gas Tankless, EF 0.82
Tank Capacity/Gallons	50	0
HW Distribution	Standard, Kitchen Pipes Insulated	
Solar Water Heater Type & Solar Fraction	None	
Appliances, Lighting & MELs		
Appliances	Standard	ENERGY STAR Dishwasher
Dryer Fuel	Gas	
Oven / Range Fuel	Gas	
Fluorescent Lighting Package	20%	20%
MEL Controls	N/A	

Note that the values listed in the Title-24 + 15% base case columns are for measures that differ from the 2008 Title-24 case. If no value is listed, then the specification does not change.

Table 10. Base Case Measure Details for the Studio

Measure Category	Base Case 2008 Title-24	Base Case Title-24 + 15%
Envelope		
Window Area - % of Conditioned Floor Area	13%	
Exterior Wall Construction	2x6 16"oc	
Exterior Wall Insulation	R-19	R-21
Foundation Type & Insulation	Slab on Grade - Uninsulated	
Floor Over Garage/Open	R-19 Batt	
Roofing Material & Color	Comp. Shingles, Medium	
Ceiling Insulation	R-38 Blown Cellulose	R-49 Blown Cellulose
Radiant Barrier	Yes	
Interior Thermal Mass	None	
House Infiltration - Blower Door Test (HERS)	No	
Thermal Bypass Inspection - QII (HERS)	No	Yes
Windows & Patio Doors	Dual Non-Metal 0.32 / 0.32	
HVAC Equipment		
Heating Type & Efficiency	PTHP / HSPF 7.7	
AC Type & Efficiency	PTHP / SEER 13, EER 10	
Duct Location & Insulation	N/A	
Duct Leakage Verification (HERS)	N/A	
Verify Refrigerant Charge Credit (HERS)	No	
Verify High EER (HERS)	No	
Verify Cooling Coil Air Flow (HERS)	No	
Verify Fan Watt Draw (HERS)	No	
Verify Cooling Right Sizing (HERS)	No	
Mechanical Ventilation	Standard exhaust meeting ASHRAE 62.2	
Ventilation Cooling	None	

© 2013 Energy and Environmental Economics, Inc.

Measure Category	Base Case 2008 Title-24	Base Case Title-24 + 15%
Water Heating Equipment		
Water Heater Type & Efficiency	Gas Storage, EF 0.575	Gas Tankless, EF 0.82
Tank Capacity/Gallons	50	0
HW Distribution	Standard, Kitchen Pipes Insulated	
Solar Water Heater Type & Solar Fraction	None	
Appliances, Lighting & MELs		
Appliances	Compact dishwasher, 10sqft fridge, stacked washer/dryer	
Dryer Fuel	Gas	
Oven / Range Fuel	Gas	
Fluorescent Lighting Package	20%	
MEL Controls	N/A	

Note that the values listed in the Title-24 + 15% base case columns are for measures that differ from the 2008 Title-24 case. If no value is listed, then the specification does not change.

2.5 Potential Rate Schedule and Metering Configurations

A number of rate schedule and metering configurations are possible for baseline and West Village homes. For rooftop scenarios with one meter on the property, PG&E's default tiered residential electricity rate (E-1) or its tiered time-of-use (TOU) rate (E-6) apply. The studio apartment, if separately metered and depending on the occupant's income, may qualify for CARE (EL-1 or EL-6) rates. Each resident would make this application with PG&E when new service is initially requested. Sub-metered electric vehicle usage was assumed to be billed on schedule E-9. For community solar configurations, PG&E schedule A-6 or E-19 (both TOU schedules) apply.

For metering, we considered scenarios in which the studio in the baseline home is and is not separately metered. If the studio is separately metered, the real levelized electric rate for the baseline home would be about $0.164/kWh. If the studio is not separately metered, the rate would climb to $0.261/kWh for E-1 and $0.278/kWh for E-6, as the studio would no longer qualify for CARE rates and its electricity use pushes the home into a higher priced rate tier. The results in this report are based on the more conservative assumption that the baseline studio is separately metered and the occupant qualifies for CARE. The West Village home was also assumed to have a separately metered studio.

Retail natural gas rates for the Standard and West Village homes were assumed to be the PG&E's default gas rate (G-1) for the main home and CARE rate (GL-1) for the studio.

© 2013 Energy and Environmental Economics, Inc.

3 Energy Efficiency Analysis

The West Village's energy strategy takes an "energy efficiency first" perspective, incorporating all cost-effective energy efficiency into building design before sizing and deploying renewable energy. This section describes the methods used in developing and evaluating EEMs for the West Village's single-family homes.

3.1 Modeling Tools and Assumptions

Two modeling software programs were used to evaluate single-family home energy use. NREL's BEopt software was used to estimate and compare energy use for end uses, including heating, cooling, domestic hot water, lighting, appliances, and miscellaneous electric loads (MELs). BEopt employs both DOE-2 and TRNSYS simulation engines and is the principal modeling tool used by the Department of Energy's Building America program. Field and laboratory research has contributed to the development of occupant schedules and load profiles in BEopt. These provide for better estimation of actual energy use than California code compliance software, which favors time-dependent valuation (TDV) of energy to achieve peak load reduction goals. EnergyPro, a Title-24 compliance tool, was used to evaluate performance relative to Title 24 code and to calculate estimated incentives available through participation in utility energy efficiency incentive programs.

Generally, most modeling assumptions were taken from the Building America House Simulation Protocols,[2] which are embedded in the BEopt software. The assumed heating and cooling set points were a constant temperature of 71°F in the winter and 76°F in the summer. However, assumptions for household miscellaneous electric loads (MEL) usage were based on California new construction data provided in the Residential Energy Consumption Survey (RECS). The RECS new construction data is 23% lower than BEopt estimations. Studio MEL usage was further decreased to reflect multi-family MEL electricity usage per the 2009 Residential Appliance Saturation Study (RASS).[3] Appliance energy usage for the studio was altered to reflect compact appliances based on data from the ENERGY STAR website. Occupancy for each plan was defined per the Building America assumptions as equal to (0.59 * # bedrooms) + 0.87 (for example, a 3 bedroom home was assumed to have 3.23 occupants). General performance assumptions of evaluated measures are described below.

Floor plan 3 was evaluated in all four cardinal orientations in BEopt. Total household energy use varies little among orientations, with North/South orientations using 2% less energy than the East/West orientations. For the purpose of evaluating individual EEMs, the West facing orientation, which resulted in the greatest total source energy use, was selected. For development of hourly annual (8760) data in the evaluation of total community level energy use, the South facing orientation was used. This orientation was selected because the site layout shows the majority of homes (2/3) oriented on East/West streets with the front of the homes facing either North or South (see

[2] Hendron, R.; Engebrecht, C. (2010). *Building America House Simulation Protocols*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-550-49246.

[3] Palmgren, C; Stevens, N; Goldberg, M; Barnes, R; Rothkin, K. (2010). *2009 California Residential Appliance Saturation Study*. KEMA, Inc. Prepared for the California Energy Commission. CEC-200-2010-004-ES.

© 2013 Energy and Environmental Economics, Inc.

Figure 6 for the site layout). Total household energy use of North and South facing homes is similar; therefore, the hourly data and annual energy use of the South facing orientation was used for the community level evaluation. Table 11 shows the effect of orientation on total source energy for the Title-24 base case.

Figure 6. Single-family Home Site Plan

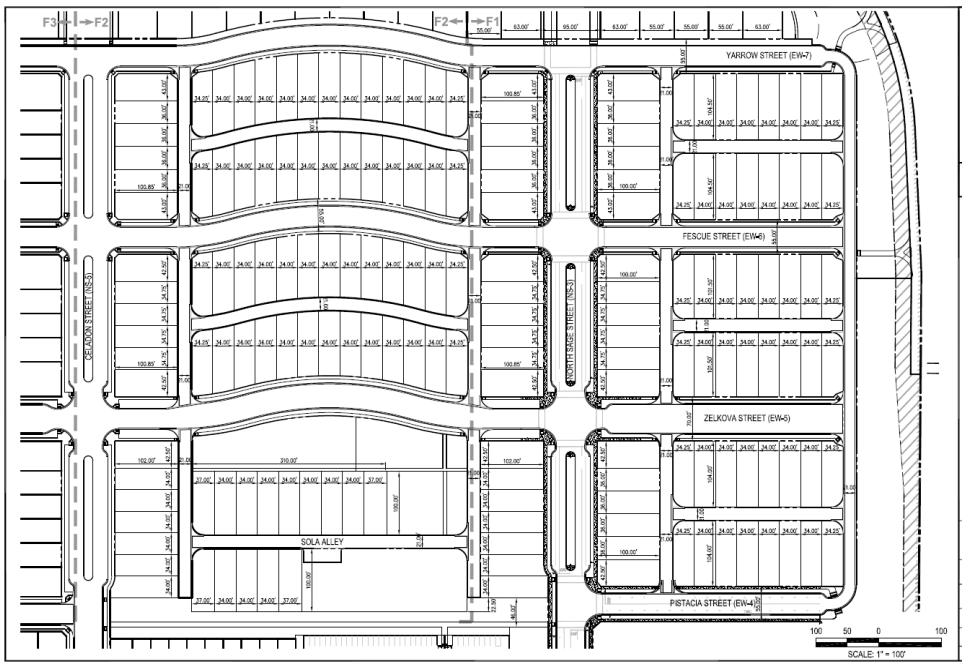


Table 11. Effect of Orientation on Total Source Energy Use

Plan Orientation	Annual Title 24 Source Energy Use (MBtu)
North	135
East	138
South	135
West	138

3.2 Design Charrette

The consultant team coordinated an all-day design charrette on June 22, 2011 with UC Davis, the developer (WVCP), and the architect (LCRA). The purpose of the charrette was to summarize the initial modeling assumptions and results, to define the proposed design measures to be evaluated, and to discuss additional measures to evaluate. The intent was to engage project stakeholders in the proposed design and efficiency measures and to develop a common understanding of the project goals and needs. The focus was on the technical feasibility of the proposed measures from a design and construction standpoint, and on identifying any potential measures that could be eliminated from evaluation based on design or constructability issues. Cost-effectiveness of the measures was not the focus of the charrette, as this would be evaluated later.

For the purpose of the charrette, floor plan 3 was used as the basis of evaluation and discussion. The starting point for defining a performance package was to use the original package of EEMs selected in the initial West Village Community Energy Efficiency Study and reported on in May 2010. Performance of the basic performance package was compared to both the Title 24 and Title-24 + 15% base cases. In that study, the package of measures included electric fuel options only. For the charrette, both all electric and gas/electric basic performance packages were evaluated.

The charrette process allowed us to gather input from WVCP and LCRA on design and constructability issues associated with the various proposed efficiency measures. The charrette covered HVAC gaps and barriers, including HVAC system sizing, duct location, distribution system losses, system airflow,

© 2013 Energy and Environmental Economics, Inc.

HVAC zoning, and airflow balancing. Several strategies to bring ducts and HVAC equipment into conditioned space were presented, including integrated design, plenum integrated trusses, and conditioned non-vented attics. Other recommended design strategies to optimize building energy performance were also covered, including:

- Building siting and orientation;
- Glazing areas;
- Ventilation cooling;
- Water heating distribution and water efficient fixtures; and
- Space conditioning and water heating design strategies for the detached studios.

The charrette concluded with a discussion of additional EEMs to be considered for inclusion in advanced packages. These measures and technologies may have been new or unfamiliar to the developer and design team and the focus was to identify potential issues or concerns that would need to be addressed or would result in eliminating the measure from further consideration. Table 12 summarizes the key items discussed and the feedback and/or results that arose from the charrette.

Table 12. Design Charrette Discussion Summary

Item / Measure	Description	Comments / Responses
Siting / Home Orientation	28% and 11% variance in cooling and HVAC energy use, respectively, due to orientation. Options for optimizing home performance Site specific designs Reducing effects of orientation through reduced glazing areas or exterior shading	Site specific designs were not well received by WVCP WVCP and LCRA were open to exterior shading strategies
Siting for Rooftop PV	Avoid complicated roof designs	Limitations with tight lot widths and available roof area discussed
Reduced Window Areas	Current designs ≈ 25% of conditioned floor area State average for new construction = 14% Reducing window area saves energy and reduces construction costs	LCRA & WVCP will look into possible window reductions but are sensitive to marketability issues with reducing window area
Ducts in Conditioned Space	Ducts typically located in unconditioned attic. Results in high distribution system losses Moving into conditioned space eliminates attic heat gains through ductwork and duct losses to outdoors Ability to downsize HVAC equipment	Developer open to the idea but need to find a strategy that works with home designs. No closet space available for equipment. LCRA suggested a hybrid concept of revised truss design with dropped ceilings to get equipment & ducts in conditioned space.
Advanced Framing	Benefits include reduced costs and improved building performance due to reduction of wood used in framing walls	WVCP unfamiliar with practice and constructability. Builder had concerns with single top plate and two stud corners. LCRA concerned with limitations on window locations.
Exterior Foam Sheathing	1" exterior foam provides R-4 continuous insulation and reduces thermal bridging at framing members	Standard practice with stucco but builder has installation concerns over siding due to nailing through siding and durability
Heat pump water heaters	Efficient electric water heating option	Outdoor water heater closet not compatible with HPWH. Not enough ventilation space

© 2013 Energy and Environmental Economics, Inc.

Item / Measure	Description	Comments / Responses
Ground loop heat pump water heaters	HPWH using ground loop in existing trenching for heat absorption loop	Builder rejected. Not comfortable with ground loop required and lack of products
Solar Water Heating	Both active and passive strategies discussed. Can contribute 30-60% of annual hot water load	Concerns with room on roof for collectors and for storage tank in closet.
Advanced Lighting Design	LED, indirect lighting	Interest in getting design assistance from CLTC

At the end of the design charrette, it was decided to move forward and evaluate the cost-effectiveness of the measures not rejected. Additionally, we agreed to work with the design team to further investigate some of the issues and concerns brought up during the charrette.

3.3 EEM Incremental Costs and Screening Methods

Based on previous evaluations, feedback from the design charrette, and our experience, we compiled a list of EEMs to be evaluated. EEMs evaluated include those in the original performance package (as defined for the design charrette), as well as other advanced measures. The original performance package included measures that were selected and approved for the zero net energy

evaluations in the initial West Village Community Energy Efficiency Study and reported on in May 2010. Through communications with the developer and their subcontractors and leveraging cost information from DEG's recent projects, we developed costs for each of the identified measures incremental to both the Title-24 and Title-24 + 15% base cases.

Table 13 lists all the EEMs evaluated and their costs incremental to both the Title-24 and the Title-24 + 15% base cases. Incremental costs for the main house and the studio are also shown. Instances where a given measure is not applicable to both the main house and studio are denoted in the notes column of the table. Figures are hard costs and only take into account incremental labor and material costs. Soft costs are excluded from these figures, but are added later at the package level.

© 2013 Energy and Environmental Economics, Inc.

Table 13. Incremental Costs for Evaluated EEMs over Title-24 and Title-24 + 15% Base Cases

Evaluated Measures	Incremental Cost over Title-24		Incremental Cost over Title-24 + 15%		Notes
	Main House	Studio	Main House	Studio	
Envelope					
R-21 Batt Insulation in Walls	$253	$93	$0	$0	
1/2" Exterior Foam Sheathing	$1,445	$529	$1,445	$529	
1" Exterior Foam Sheathing	$2,077	$760	$2,077	$760	
Advanced Framing	-$948	-$205	-$948	-$205	Savings associated with both labor and material.
R-49 Ceiling Insulation	$232	$95	$0	$0	
Cool Roof	$0	$0	$0	$0	Based on product used in student housing.
5/8" Interior Drywall	$1,095	$0	$1,095	$0	Only considered in main house in conjunction with whole house fan.
R-10 Slab Edge Insulation	$1,526	$336	$1,526	$336	Cost for studio is 50% of total: Assume only 1/2 of studios are on-grade, 1/2 above garage.
Low-E Windows: U-value 0.32, SHGC 0.23	$0	$0	$0	$0	Negligible incremental cost for Low-E windows.
Window Reduction from 26% to 22% of CFA	-$500	$0	-$500	$0	Window reduction for main house only.
Reduced Infiltration, SLA ≤ 1.8	$247	$89	$247	$89	Cost for extra caulking and sealing only, blower door cost under HERS tests.

Evaluated Measures	Incremental Cost over Title-24		Incremental Cost over Title-24 + 15%		Notes
	Main House	Studio	Main House	Studio	
HVAC Equipment					
High Efficiency Furnace + AC	$600	$0	$600	$0	Only considered for main house.
High Efficiency Furnace + Evaporative Condenser	$1,972	$0	$1,972	$0	Only considered for main house.
High Efficiency Heat Pump	$1,750	$300	$1,750	$300	Split system for main house, PTHP style for studio.
Mini-Split Heat Pump	$10,301	$2,600	$10,301	$2,600	Main house: 2 outdoor units serving 5 zones total. Studio: A single indoor & outdoor unit.
Combined Hydronic Heating	$600	$0	$600	$0	No additional cost compared to high efficiency equipment. Only considered for main house.
Ducts in Conditioned Space	$1,075	$0	$1,075	$0	Ductless unit in studio.
Adequate Return Air Path for Bedrooms	$450	$0	$450	$0	Ductless unit in studio.
Whole House Fan	$1,200	$0	$1,200	$0	Only considered for main house.
NightBreeze	$2,040	$0	$2,040	$0	Only considered for main house.
Water Heating Equipment					
Tankless Gas Water Heater	$250	$250	$0	$250	
Condensing Tankless	$650	$650	$400	$650	
Condensing Storage	$250	$250	$0	$250	
Active Solar Water Heating System	$3,048	$0	$3,048	$0	Costs include technology specific incentives. Only considered for main house.
Passive Solar Water Heating System	$2,545	$0	$2,545	$0	Costs include technology specific incentives. Only considered for main house.
PEX Piping; Engineered Design	$0	$0	$0	$0	Negligible cost if incorporated in design.

© 2013 Energy and Environmental Economics, Inc.

Evaluated Measures	Incremental Cost over Title-24		Incremental Cost over Title-24 + 15%		Notes
	Main House	Studio	Main House	Studio	
3rd Party Testing / Verification (HERS)					
Quality Insulation Inspection / Verification	$300	$0	$0	$0	
Tight Envelope (Blower Door Test)	$150	$0	$150	$0	
Refrigerant Charge / EER Verification	$50	$0	$50	$0	HERS testing only on main house.
System Airflow / Fan Watt Draw	$0	$0	$100	$0	HERS testing only on main house.
Lighting / Appliances					
100% Fluorescent Fixtures. Improved Lighting Design w/ Controls & Ceiling Fans	$1,635	$166	$1,635	$166	Outdoor & garage lighting is included in the main house cost.
Advanced Lighting Design: LED in RCs	$924	$264	$924	$264	
Advanced Lighting Design: LED in RC & throughout kitchen	$1,566	$442	$1,566	$442	
Advanced Lighting Design: Soffit fluorescent lighting	$1,399	$0	$1,399	$0	Only considered for main house.
Advanced Lighting Design: Soffit LED lighting	$5,241	$0	$5,241	$0	Only considered for main house.
Energy Star Dishwasher	$0	$0	$0	$0	Negligible incremental costs for standard features.
Energy Star Refrigerator & Clothes Washer (replacement incentive)	$200	$0	$200	$0	Only considered for main house. Assumes negligible incremental cost for refrigerator & $200 for washer.
GreenWave	$533	$0	$533	$0	Only considered for main house.

3.4 Development of EEM Packages

To develop EEM packages, levelized EEM incremental costs were compared against levelized electricity or biogas costs, by measure. Because the West Village Project is designed to achieve ZNE goals, individual EEM costs were benchmarked against the projected cost of renewable energy serving the project. Savings in electricity use (kWh) offset onsite PV capacity, and savings in natural gas use (therms) offset the need for biogas. Thus, EEMs in the final measure packages are more cost-effective than the projected cost of renewables assumed for the given package. When the cost-effectiveness of an efficiency measure exceeded the assumed price of renewable energy, the measure was not included in the proposed measure package. In that instance, it is more economic to utilize additional renewable energy.

Levelized incremental costs for the EEMs were developed using the incremental costs provided in Table 13 and assumptions for financing, the useful life of each measure, and replacement costs. Energy usage information was obtained through a parametric analysis of the various EEMs in BEopt. EEM costs were assumed to be financed through the homeowner's mortgage at a 5.5% nominal interest rate for a term of 25 years. Assumptions for measure lifetimes are shown in Table 14. At the end of equipment useful life, equipment was assumed to be replaced with that of similar performance. Replacement cost was assumed to be the same as the initial incremental cost.

© 2013 Energy and Environmental Economics, Inc.

Table 14. Assumed Lifetimes of EEMs

Measures	Lifetime
Envelope	50 years
HVAC	20 years
Domestic hot water	13 years
Appliances	10 years
Lighting	Incandescent lamps: 2 years CFL: 14 years LED: 20 years

The LCOEs for PV and biogas, against which EEMs were evaluated, are displayed in Table 15. These LCOEs reflect the cost ranges that were expected for PV and biogas at the time the EEMs were evaluated. Development of these costs is discussed further in Sections 4 and 5.

Table 15. Levelized Cost of Renewable Energy Scenarios Used for EEM Analysis

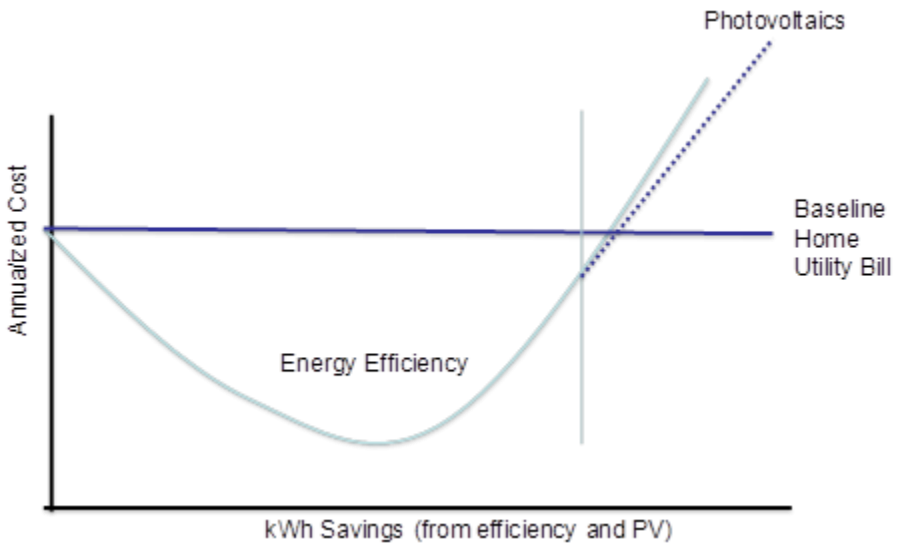
EEM Package	LCOE Scenario	PV ($/kWh)	Biogas ($/Therm)
Basic Performance	Average LCOE	$0.21	$2.20
Advanced A	Low LCOE	$0.14	$2.00
Advanced B	High LCOE	$0.30	$2.40

EEM packages were developed based on the cost-effectiveness of each individual measure versus the LCOEs shown in Table 15. The EEMs in the basic performance package are cost-effective compared with the Average LCOE scenario for PV and Biogas. Measures included in the original performance

package were evaluated individually. Measures in the original package that did not meet the cost effectiveness criteria established by the Average LCOE were removed from the basic package. Two advanced packages were developed that looked at additional measures not in the original package. The Advanced A Package incorporates measures that are cost-effective when compared to the Low LCOE scenario. The Advanced B Package includes all measures in the Advanced A package, along with additional measures that may not have been cost-effective under the Basic or Advanced A packages but are cost-effective under a high renewable LCOE scenario. Figure 7 illustrates this approach for electric EEMs and PV.

© 2013 Energy and Environmental Economics, Inc.

Figure 7. Illustration of Cost-Effectiveness Comparison between Electric EEMs and PV



3.5 Recommended EEM Package Details

Table 16 details measure specifications for the three final packages for the main house. Table 17 describes measure specifications for the three final packages for the studio unit. Measures listed under the Advanced A and B columns are for measures that differ from the Basic Performance Package only. Studio specifications are similar, with changes only where building size or cost concerns required alternative strategies.

Table 16. Package Measure Details for the Main House

Measure Category	Basic Performance	Advanced A	Advanced B
Envelope			
Window Area - % of Conditioned Floor Area	26%	22%	22%
Exterior Wall Construction	2x6 16"oc	2x6 24"oc Advanced Framing	2x6 24"oc Advanced Framing
Exterior Wall Insulation	R-21		R-21 Batt w/ 1" R-4 sheathing
Foundation Type & Insulation	Slab on Grade - Uninsulated		
Floor Over Garage/Open	R-19 Batt		
Roofing Material & Color	CRRC Certified Roof (0.28 Reflectance, 0.91 Emittance)		
Ceiling Insulation	R-49 Blown Cellulose		
Radiant Barrier	Yes		
Interior Thermal Mass	None		5/8" Drywall Throughout
House Infiltration - Blower Door Test (HERS)	SLA 1.8		
Thermal Bypass Inspection - QII (HERS)	Yes		
Windows & Patio Doors	Dual Non-Metal 0.32 / 0.23		
HVAC Equipment			
Heating Type & Efficiency	Gas Furnace / AFUE 92%	Combined Hydronic	Combined Hydronic
AC Type & Efficiency	AC / SEER 15, EER 12.5		
Duct Location & Insulation	Conditioned Space, R-6		
Duct Leakage Verification (HERS)	Yes, <6% of system airflow		
Verify Refrigerant Charge Credit (HERS)	Yes		
Verify High EER (HERS)	Yes, 12.5		
Verify Cooling Coil Air Flow (HERS)	No	Yes	Yes
Verify Fan Watt Draw (HERS)	No	Yes	Yes
Verify Cooling Right Sizing (HERS)	No		
Mechanical Ventilation	ENERGY STAR exhaust meeting ASHRAE 62.2		
Ventilation Cooling	None		Whole House Fan

© 2013 Energy and Environmental Economics, Inc.

Measure Category	Basic Performance	Advanced A	Advanced B
Water Heating Equipment			
Water Heater Type & Efficiency	Gas Tankless, EF 0.82	Condensing Tankless, EF 0.96	Condensing Tankless, EF 0.96
Tank Capacity/Gallons	0		
HW Distribution	PEX Piping, Engineered Design, Kitchen Pipes Insulated		
Solar Water Heater Type & Solar Fraction	None		
Appliances, Lighting & MELs			
Appliances	ENERGY STAR Dishwasher	ENERGY STAR Dishwasher, Fridge & Clothes Washer	ENERGY STAR Dishwasher, Fridge & Clothes Washer
Dryer Fuel	Gas		
Oven / Range Fuel	Gas		
Fluorescent Lighting Package	100% w/ Controls & Ceiling Fans		
MEL Controls	None		

Note: Measures listed under the Advanced A and B columns are for measures that differ from the Basic Performance Package only.

Table 17. Package Measures Unique to the Studios

Measure Category	Basic Performance	Advanced A	Advanced B
Envelope			
Window Area - % of Conditioned Floor Area	13%	2x6 24"oc Advanced Framing	2x6 24"oc Advanced Framing R-21 Batt w/ 1" R-4 sheathing
Exterior Wall Construction	2x6 16"oc		
Exterior Wall Insulation	R-21		
Foundation Type & Insulation	Slab on Grade - Uninsulated		
Floor Over Garage/Open	R-30 Batt		
Roofing Material & Color	CRRC Certified Roof (0.28 Reflectance, 0.91 Emittance)		
Ceiling Insulation	R-49 Blown Cellulose		
Radiant Barrier	Yes		
Interior Thermal Mass	None		
House Infiltration - Blower Door Test (HERS)	SLA 1.8		
Thermal Bypass Inspection - QII (HERS)	Yes		
Windows & Patio Doors	Dual Non-Metal 0.32 / 0.23		
HVAC Equipment			
Heating Type & Efficiency	PTHP / HSPF 8.5	Mini Split / HSPF 11.0	Mini Split / HSPF 11.0
AC Type & Efficiency	PTHP / SEER 15, EER 12.5	Mini Split / SEER 21, EER 12.5	Mini Split / SEER 21, EER 12.5
Duct Location & Insulation	N/A		
Duct Leakage Verification (HERS)	N/A		
Verify Refrigerant Charge Credit (HERS)	No		
Verify High EER (HERS)	No		
Verify Cooling Coil Air Flow (HERS)	No		
Verify Fan Watt Draw (HERS)	No		
Verify Cooling Right Sizing (HERS)	No		
Mechanical Ventilation	ENERGY STAR exhaust meeting ASHRAE 62.2		
Ventilation Cooling	None		

© 2013 Energy and Environmental Economics, Inc.

Measure Category	Basic Performance	Advanced A	Advanced B
Water Heating Equipment			
Water Heater Type & Efficiency	Gas Tankless, EF 0.82	Condensing Tankless, EF 0.94	Condensing Tankless, EF 0.94
Tank Capacity/Gallons	0		
HW Distribution	PEX Piping, Engineered Design, Kitchen Pipes Insulated		
Solar Water Heater Type & Solar Fraction	None		
Appliances, Lighting & MELs			
Appliances	Compact dishwasher, 10sqft fridge, stacked washer/dryer		
Dryer Fuel	Gas		
Oven / Range Fuel	Gas		
Fluorescent Lighting Package	100% w/ Controls		
MEL Controls	None		

Note: Measures listed under the Advanced A and B columns are for measures that differ from the Basic Performance Package only.

The remainder of this section describes selected measures and recommendations, by building category, in greater detail.

3.5.1 THERMAL ENVELOPE

3.5.1.1 Walls

In the basic performance package, the exterior wall construction is 2x6 framing, 16” on center (o.c.) with R-21 cavity batt insulation. Originally, one-half inch of rigid insulation sheathing was also proposed to be installed on the exterior side of the wall to reduce the thermal bridging effects due to framing. However, the high incremental cost, largely associated with additional labor, and the relative marginal energy benefits of the ½” R-2 sheathing, resulted in elimination of this

measure. Since the incremental cost of 1" versus ½" of sheathing is much smaller than going from no sheathing to ½", and roughly doubles the energy savings, 1" of R-4 EPS foam sheathing was determined to be cost-effective and included in the Advanced Package B. To reduce the effects of thermal bridging, 1" exterior foam will become a requirement of ENERGY STAR version 3 beginning October 2012. Additionally, 2x6 walls with minimum R-4 exterior foam are slated to be included in the 2013 Title 24 specifications in Climate Zone 12.

Advanced framing using 2x6 framing, 24" o.c. is included in both of the advanced packages. Aside from wider stud spacing, advanced framing techniques also include:

- 2-stud corners;
- Single headers;
- Eliminate headers in non-load-bearing walls & size headers for loads;
- Framing members aligned with roof trusses;
- Window and doors aligned within existing stud openings
- No jack studs or cripples;
- Raised heel trusses to accommodate full depth of ceiling insulation out to eaves; and
- Single top plates (may not be feasible in high seismic zones).

It is recommended that, whenever possible, these strategies be employed in the framing design for the single-family homes. Engineered framing design allows for cost and labor savings and increased thermal performance of the wall

© 2013 Energy and Environmental Economics, Inc.

without compromising structural integrity. This is a very cost-effective measure as it saves both energy and money.

The insulation contractor must ensure the single-family homes comply with Title 24 quality insulation installation (QII) criteria to minimize thermal bypass and achieve full credit for the installed insulation. An air barrier must be installed and all gaps and penetrations caulked or otherwise sealed to prevent air movement between conditioned and unconditioned spaces. All insulation must be inspected by a third party HERS rater; wall insulation shall be inspected before drywall is installed.

3.5.1.2 Ceiling & Roof

The attic space must be insulated at the ceiling level with either R-49 blown insulation or batt fiberglass, as appropriate. The insulation contractor must ensure the homes comply with Title 24 quality insulation installation (QII) criteria to minimize thermal bypass and achieve full credit for the installed insulation.

A continuous radiant barrier must be installed at the top chords of the roof truss/rafters underneath the roof deck, as well as on all vertical surfaces such as gable end walls. The material and installation procedures must conform to appropriate ASTM specifications. To qualify for this credit under Title 24, attics must provide a minimum free ventilation area of not less than one square foot for each 150 ft^2 of attic floor area, with no less than 30 percent of the vent area as upper vents. The installed roofing product must be rated and labeled by the Cool Roof Rating Council (CRRC). The product specifications (0.28 Reflectance,

0.91 emittance) are the same as that installed on the student housing buildings in West Village.

Traditional heel trusses result in the inability to install ceiling insulation to its full depth at the eaves where the roof slope meets the bottom chord of the truss. Under the advanced framing measure listed above, the trusses are designed with raised heels so that the full depth of insulation can be installed out to the eaves.

3.5.1.3 Windows

Original plans showed window areas approximately equal to 25% of CFA, much higher than the California average for new homes of 15% and the Title 24 prescriptive maximum of 20%. DEG recommended window area reductions without negatively impacting daylighting benefits, but WVCP was concerned that significantly reducing window areas would reduce the marketability of the homes. Upon further review with the design team, window plans were re-designed and window area was reduced to 22%. This window area reduction is included as a measure in both advanced package A & B. Window specifications are non-metal frame, with spectrally-selective Low-E glass with a U-value ≤ 0.32 and SHGC ≤ 0.23.

3.5.1.4 Infiltration

The units must be built with careful consideration for tight construction and sealing of all penetrations in exterior walls and between the attic and home to minimize unintentional infiltration and exfiltration. Penetrations and gaps will be caulked or otherwise sealed to prevent air movement between conditioned

© 2013 Energy and Environmental Economics, Inc.

and unconditioned space. The measured leakage rate of the buildings must result in a specific leakage area (SLA) of 1.8 or lower to meet the criteria. To quantify the leakage rate, a blower door test must be performed by a HERS rater at 50 Pa in compliance with ASTM E779 specifications.

3.5.2 MECHANICAL SYSTEMS

3.5.2.1 Space Heating and Cooling

In the basic performance package, a high efficiency condensing gas furnace is specified with a minimum annual fuel utilization efficiency (AFUE) of 94%. Several high efficiency HVAC alternatives were evaluated for the advanced packages, including high efficiency heat pumps, mini-split heat pumps and combined hydronic systems using a condensing water heater for both domestic hot water and space heating. The most cost-effective of these alternatives was the national gas combined hydronic option, using a condensing gas tankless water heater. This allows for the installation of a single gas appliance for all the building's heating needs. This system also provides efficiency benefits due to reduced cycling and improved part-load efficiencies. Gas furnaces are not available in capacities low enough to match the low heating load of these homes, which will result in poor heating performance and occupant comfort due to short cycling. The tankless water heater is able to throttle across a wide range to match the necessary load, and the hydronic air handler can be better matched to the homes' heating load. The air handler will have a hot water coil and several manufacturers offer air handlers matched with tankless water heaters and an integral circulation pump. Heating is delivered through the air

duct distribution system similar to a gas furnace. See water heater section for appliance specifications.

Cooling is provided by a high efficiency air conditioner rated at 15 seasonal energy efficiency ratio (SEER) and 12.5 energy efficiency ratio (EER). The mechanical contractor must hold an EPA refrigerant handler certification and be familiar with proper residential HVAC commissioning procedures. Nameplate EER (minimum of 12.5), and refrigerant charge must be verified by a home energy rating system (HERS) rater. In addition, in both the advanced packages cooling coil airflow, and air handler fan watt draw will be verified by a HERS rater. These HERS measures ensure proper commissioning of the air conditioner. Field studies have shown that operating air conditioner efficiencies are much lower than rated, partially due to improper refrigerant charge and reduced airflow and high fan power consumption.

Cooling and heating loads and equipment size calculations must be performed in accordance with ACCA Manual J Residential Load Calculations and Manual S Residential Equipment Selection, respectively.

3.5.2.2 Ductwork

All heating and cooling ductwork shall be sized in accordance with ACCA Manual D Residential Duct Systems to ensure proper air flow and distribution. Ducts must be sized based on room-by-room load calculations developed under the Manual J methodology. All ducts must be insulated to a minimum of R-6 insulation, and duct leakage must be tested by a HERS rater and verified to be less than 6% of nominal system airflow (based on 400cfm per rated ton). All ductwork and equipment shall be located within conditioned space. No more

© 2013 Energy and Environmental Economics, Inc.

than 12 linear feet of ductwork (including the air handler) may be installed in unconditioned space. This requires visual verification by a HERS rater. The current design utilizes a combination of modified roof trusses and dropped ceilings to provide space for the air handler and ductwork. An air barrier is required between the soffitted spaces and the unconditioned attic in order to isolate the ductwork from the unconditioned attic.

3.5.2.3 Nighttime Ventilation

These measures are included in Advanced Package B. Originally, the NightBreeze central fan nighttime ventilation system was included in the basic performance package. Limited availability of space for the damper in the conditioned attic space and high incremental costs resulted in elimination of this system from the package. However, there are significant energy, peak demand, and comfort advantages associated with ventilation cooling and we wanted to retain this option, hence a whole house fan is included in advanced package B. The fan should have an insulated damper to minimize unintentional heat loss or gain between the attic and conditioned space. This type of system is manual and requires the occupant to be cognizant of outdoor conditions and initiate the ventilation cooling by opening windows and turning on the fan. Given the goals and culture of West Village, it seems an apt location for whole house fan installation. If implemented, success of ventilation cooling would benefit with educating occupants on how proper household operation can provide improved comfort and reduced air conditioner operation.

5/8” interior drywall was included along with nighttime ventilation. These two measures are mutually supportive since nighttime ventilation cooling works best

in houses with high thermal mass that has the capacity to store heat during the day and subsequently delay increases in interior temperatures. Since none of the current modeling tools are capable of modeling ventilation cooling systems, whole house fan savings were estimated using a beta version of MICROPAS that is being developed for 2013 Title-24 code compliance. MICROPAS was used to model typical savings for a whole house fan in a high performance Davis home and the interactive effects of coupling the whole house fan with the 5/8" drywall were not modeled. Other advantages that are not taken into account in the MICROPAS model are the peak demand savings potential and cost savings associated with a time-of-use rate. Additionally, it is proposed in the 2013 Title 24 code that whole house fans be included in the prescriptive package for Climate Zone 12.

3.5.2.4 Water Heating

A gas tankless water heater with a minimum energy factor of 0.82 is specified in the basic performance package. This is the same system specified in the Title 24 + 15% base case. Several high performance water heating technologies were evaluated, including condensing tankless, condensing storage, and heat pump water heaters, as well as solar water heating. The high efficiency condensing tankless option with a minimum energy factor of 0.94 was selected for both advanced packages, in a combined hydronic configuration with the water heater providing hot water for space heating as well (see space heating and cooling description above). This option was the only additional water heating measure that met the cost criteria.

© 2013 Energy and Environmental Economics, Inc.

3.5.3 LIGHTING & APPLIANCES

3.5.3.1 Lighting Design

All packages specify high efficacy hardwired lighting in all fixtures. All lighting is compact fluorescent (CFL), except linear fluorescents in the under cabinet fixtures in the kitchen. Infrared manual on / auto off vacancy sensors will be installed in the bedrooms, bathrooms, laundry room, closets, living room, family room, dining room, and exterior porches. The kitchen under-cabinet lighting will be controlled by a dimmer. Hardwired lighting is specified in all bedrooms, living room and family room consisting of ceiling fans with integrated CFL lighting. Additional lighting technologies, including LED lighting, are evaluated and are discussed later.

3.5.3.2 Appliance Selection

An ENERGY STAR dishwasher is included in all three packages. Both advanced packages assume ENERGY STAR refrigerators and clothes washers, in addition to the dishwasher. The ENERGY STAR designation is not currently available for clothes dryers. To encourage the use of ENERGY STAR appliances, the builder can provide an incentive to the homeowner for replacing their current appliances with Energy Star models, which for modeling purposes were assumed to be installed in all of the homes for the advanced packages. Another option would be for the builder to supply ENERGY STAR refrigerators and clothes washers as a standard part of the home package.

If the homeowner replacement incentive is offered as an option rather than a requirement, some homeowners will choose to keep their existing appliances. If

replacement is a requirement, buyers who already own energy efficient appliances will be forced to purchase new ones. Following are guidelines provided by ENERGY STAR that may be used to identify an appropriate methodology for any replacement program that may be implemented.

- Replace refrigerators that are manufactured prior to 1990: refrigerators manufactured in the 1980s use roughly 4 times as much electricity as current similar ENERGY STAR models and those made before 1980 use over 5 times as much electricity.[4]

- Replace clothes washers that were manufactured prior to 1999 as they use approximately 4 times as much electricity as current Energy Star models.[5]

Secondary refrigerators or freezers can represent a significant electrical load, especially since they are often older models and are installed in the garage or other unconditioned spaces. The use of these appliances should be discouraged. Additional incentives are available to homeowners through PG&E, which offers $35 to customers for recycling refrigerators or freezers that are over 10 years old.

3.5.3.3 Miscellaneous Electric Loads

MEL controls were evaluated using pricing based on GreenWave display and in-home controls, but due to lack of information on the GreenWave's abilities and

[4] http://www.energystar.gov/index.cfm?fuseaction=refrig.calculator
[5] http://www.energystar.gov/index.cfm?fuseaction=find_a_product.showProductGroup&pgw_code=CW

© 2013 Energy and Environmental Economics, Inc.

the actual savings that could be achieved by homeowners change in behavior, no MEL controls are included in the proposed packages.

3.5.4 STUDIO

The studio specifications are mostly the same as the main house specifications. The main difference for the studio is the use of high efficiency PTHPs in the basic performance package and mini-splits in the advanced packages. The small living area of the studio does not warrant a central ducted split system; a single point of supply is sufficient. The efficiency specifications for the PTHP are a minimum 8.5 heating seasonal performance factor (HSPF) for heating and 15 SEER and 12.5 EER for cooling. Mini-split heat pumps can achieve better operating efficiencies with 11.0 HSPF for heating and 22 SEER and 12.5 EER for cooling. The tankless water heater is specified with the same efficiency levels as in the main house. However, the unit will be much smaller as the hot water load for the studio is relatively low.

The HVAC-related HERS measures that are recommended in the main house packages are not included in the studio. The air conditioner HERS verifications are not applicable to manufacturer packaged systems such as PTHPs and mini-splits. The HERS measures for QII and blower door testing to a level equivalent to a specific leakage area (SLA) of 1.8 should still be required.

3.6 Energy Use Data

Table 18 shows total annual electricity and gas usage for the base cases and the proposed packages. Energy use is provided for the main house and the studio.

Table 18. Total Annual Energy Use for Each Energy Efficiency Scenario

Package	Annual kWh		Annual therms	
	Main House	Studio	Main House	Studio
Title-24	7,135	4,064	717	131
Title-24 + 15%	6,907	3,777	588	75
Basic Performance	5,436	3,177	495	72
Advanced Package A	5,118	3,116	438	64
Advanced Package B	4,873	3,005	414	64

Tables 19 and 20 show the energy breakdown for electricity and gas, respectively, by end-use, for the main house. Results are provided for the Title-24 base case and the three performance packages.

Table 19. Electricity End-use Breakdown for the Main House

Electric End-Use	Title-24 (kWh)	Basic Performance Package (kWh)	Advanced A (kWh)	Advanced B (kWh)
Misc.	2,594	2,541	2.540	2,538
Vent Fan	171	143	143	143
Lg. Appl.	817	795	658	658
Lights	1,759	989	989	989
HVAC Fan/Pump	547	550	379	338
Cooling	1,247	418	409	207
Total	7,135	5,436	5,118	4,873

© 2013 Energy and Environmental Economics, Inc.

Table 20. Natural Gas End-use Breakdown for the Main House

Gas End-Use	Title-24 (therms)	Basic Performance Package (therms)	Advanced A	Advanced B
Heating	439	283	262	238
Hot Water	194	129	102	102
Lg. Appl.	76	76	66	66
Misc.	8	8	8	8
Total	717	495	438	414

Table 21 shows source energy savings for both the main house and the studio compared to the two base cases.

Table 21. Source Energy Savings Compared to the Title-24 and Title-24 + 15% Base Cases

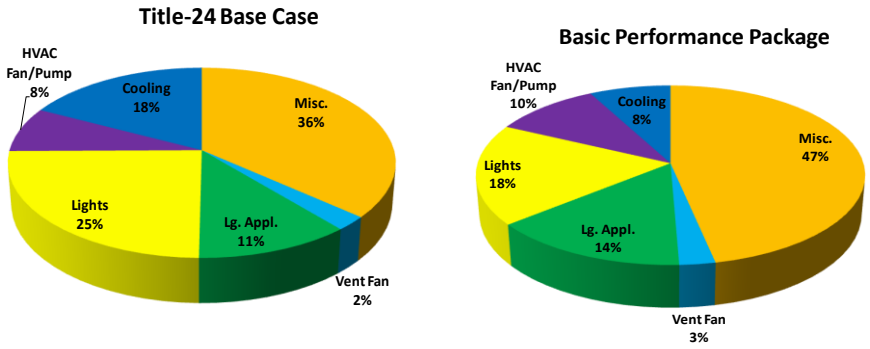
Package	Source Energy Savings Over Title-24		Source Energy Savings Over Title-24 + 15%	
	Main House	Studio	Main House	Studio
Basic Performance	28%	29%	18%	14%
Advanced A	34%	31%	26%	17%
Advanced B	38%	33%	30%	19%

Figures 8 and 9 compare the relative contribution of each end use to total electricity and natural gas consumption for the Title-24 base case and the basic performance package. Load reduction and cooling measures significantly reduce the air conditioning component from 18% in the Title 24 base case to 8% of total

electricity in the basic performance package. Lighting measures reduce lighting use from 25% to 18%. In both cases, the largest component is MEL. While MEL annual kWh usage is the same across all packages, due to the absence of any load reduction measures in the basic performance package, they represent a larger portion of total electricity in the basic performance package at almost 50%. MELs are the most difficult end use with which to confidently achieve savings since these are almost completely contributed by the occupant and are not builder supplied. However, this figure shows the importance of addressing the miscellaneous end uses when looking at zero energy buildings.

The natural gas comparison is much more similar across the two cases than for electricity. The two primarily gas end-uses, space heating and water heating, are both substantially reduced in similar proportions in the basic performance package through the use of high efficiency equipment and better building envelope.

Figure 8. Comparison of Electricity End-use Energy Use for the Main House



© 2013 Energy and Environmental Economics, Inc.

Figure 9. Comparison of Natural Gas End-use Energy Use for the Main House

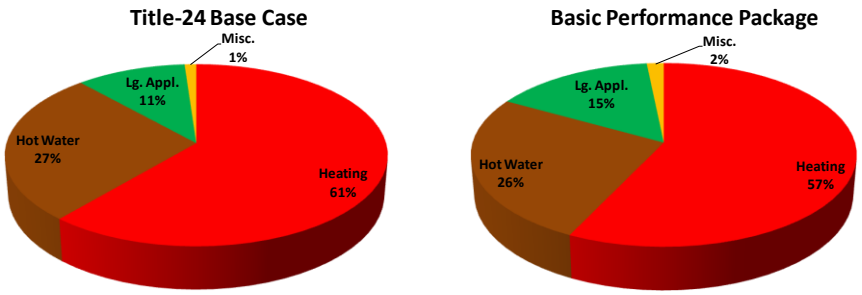
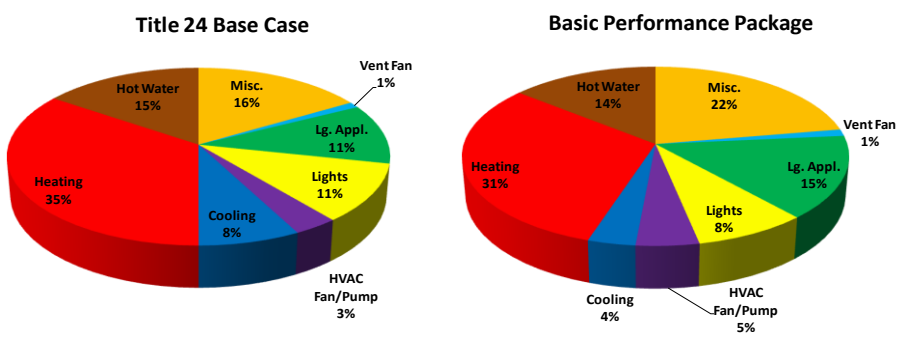


Table 22 and Figure 10 show a breakdown of source energy use for the main house (without netting onsite energy production). From a total source energy perspective, the largest changes from the Title 24 package to the basic performance package scenarios are: (1) a large reduction in the amount and share of energy for heating; (2) a reduction in the amount of energy for hot water; and (3) and increase in the share of energy for MELs and large appliances.

Table 22. Source Energy End-use Breakdown for the Main House

End-Use	Title-24 (MMBtu)	Basic Performance Package (MMBtu)	Advanced A (MMBtu)	Advanced B (MMBtu)
Misc.	23	22	22	22
Vent Fan	1	1	1	1
Lg. Appl.	15	15	13	13
Lights	15	8	8	8
HVAC Fan/Pump	5	5	3	3
Cooling	10	4	3	2
Heating	48	31	29	26
Hot Water	21	14	11	11
Total	138	100	91	86

Figure 10. Comparison of End-use Source Energy Use for the Main House



© 2013 Energy and Environmental Economics, Inc.

3.7 Package Incremental Costs and Energy Efficiency Incentives

Incremental costs for the proposed packages were calculated both before and after taking into account utility incentives. These costs are presented in Tables 23 and 24 Incremental costs are measured against the Title 24 and Title 24 + 15% base cases. These costs include a 15% soft costs adder reflecting developer carrying costs such as overhead, financing, and insurance.

Table 23. Total Package Costs Excluding Incentives versus the Title-24 and Title-24 + 15% Base Cases

Package	Incremental Cost versus Title-24		Incremental Cost versus Title-24 + 15%	
	Main House	Studio	Main House	Studio
Basic Performance	$5,395	$1,338	$4,320	$1,123
Advanced A	$5,052	$4,207	$3,977	$3,992
Advanced B	$10,080	$5,082	$9,004	$4,866

Table 24 presents net EEM package costs, comprising incremental costs for the main house, less incentives, and 60% of the incremental costs for the studio, based on the assumption that roughly 60% of homes will be built with the detached studio. At the time of this study, utility incentives are not available for the studio and therefore none are included.

Table 24. Net Package Costs Including Incentives versus the Title 24 and Title 24 + 15% Base Cases

Package	Net Incremental Cost versus Title-24	Net Incremental Cost versus Title-24 + 15%
Basic Performance	$2,667	$1,831
Advanced A	$3,390	$2,554
Advanced B	$8,719	$7,883

Note: 60% of homes are assumed to have studio units. Therefore, net package costs on a per-home basis include 60% of the studio cost.

3.7.1 CALIFORNIA ADVANCED HOME PARTNERSHIP ENERGY EFFICIENCY INCENTIVES

The California Advanced Home Partnership (CAHP) incentives included in this analysis are listed in Table 25. These incentive levels are assumed to be valid throughout the Project construction period.

© 2013 Energy and Environmental Economics, Inc.

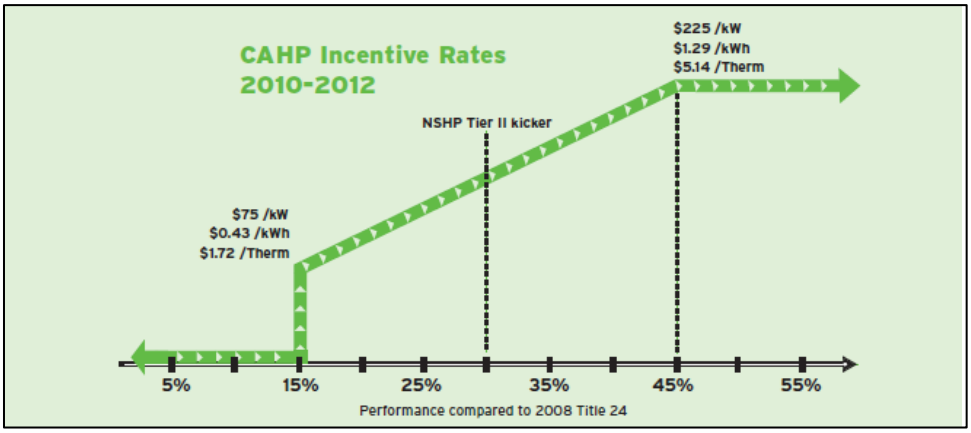
Table 25. CAHP Incentives

Incentive	Basic Performance Package	Advanced Package A	Advanced Package B
CAHP Electricity Incentive	$ 1,010	$ 1,244	$ 1,310
CAHP Demand Incentive	$ 428	$ 495	$ 518
CAHP Natural Gas Incentive	$ 1,177	$ 1,363	$ 1,438
Compact Home credit	$ 392	$ 465	$ 490
ENERGY STAR	$ 262	$ 310	$ 327
Green Home Program	$ 262	$ 310	$ 327
Total PG&E Incentives	$ 3,531	$ 4,187	$ 4,410

3.7.1.1 Electricity, Natural Gas, and Demand Reduction Incentives

Energy efficiency incentives for electricity, natural gas, and demand reductions are available through PG&E and the CAHP. Incentive amounts are calculated based on performance relative to Title-24 and are available for projects that achieve a minimum of 15% savings. Figure 11 shows that incentive rates increase from this 15% threshold until 45% savings are achieved.

Figure 11. CAHP Incentive Scale[6]



All three proposed EE packages perform at least 45% better than Title-24 on a TDV basis, as seen in Table 26. Therefore, the incentive calculations utilize the highest available incentives. Incentives are only available for the main house and are not available for the studio unit due to rules of the CAHP program.

Table 26. Title 24 Compliance Savings for the Main House

Package	Title-24 Compliance Savings - Main House Only
Basic Performance	47%
Advanced A	55%
Advanced B	58%

[6] California Advanced Homes 2010-2012 Participant Handbook and Program Agreement for Single-Family and Multi-Family New Construction Projects.

© 2013 Energy and Environmental Economics, Inc.

3.7.1.2 ENERGY STAR Program Energy Efficiency Incentives

The ENERGY STAR program incentive requires that the project participate in the national EPA program and receive the ENERGY STAR label.

3.7.1.3 Green Home Program Incentives

Green Home certification requires participation in a recognized green building program that involves third-party verification of green building elements. Such programs include LEED for Homes and GreenPoint Rated. Some of the green requirements that must be met are now mandatory under the California Green Building Standards.

3.7.1.4 Compact Home Credit

The threshold for compact home compliance is 1,710 ft^2 for a 3-bedroom home, 2,340 ft^2 for a 4-bedroom, and 2,565 ft2 for a 5-bedroom. This analysis assumed that this incentive could be collected for Plan 3 and Plan 4 if the den were converted into a bedroom. The remaining three plans all comply.

3.7.2 ADDITIONAL ENERGY EFFICIENCY INCENTIVES

Two additional incentives are available through the CAHP:

- NSHP Tier II incentive of $1000 per home for reaching Title-24 + 30% savings and 30% cooling energy savings for the relevant CEC climate zone.
- CAHP zero peak homes $/kW incentive. This incentive amount varies depending upon the home's peak kW reduction due to onsite solar PV

systems, from $75/kW if the home achieves Title 24 + 15% and up to $225/kW if the home achieves Title 24 + 45%.

These incentives are only included in the project economics for applicable business model scenarios (i.e., community-scale installations are not eligible). Hence, they were not included in, and are in addition to, the EEM incentive figures described above.

The CAHP as currently designed will be active through 2012; after 2012, incentives may change. Funding is assumed available through 2015. Modeling results assume no change in these CAHP incentive levels through 2015.

3.8 Additional Energy Efficiency Measures Evaluated

Several technologies were considered and eliminated from evaluation at the design charrette. They were eliminated either because they were deemed too difficult to implement or would not work at West Village due to space constraints or other concerns. These measures are described below.

- Structurally insulated panels (SIPs) were discussed but rejected in favor of advanced framing due to builder unfamiliarity, and higher installed costs in the region resulting from a lack of local SIP manufacturing facilities.
- Ground-coupled heat pumps are an efficient means of providing heating and cooling to the community, but because of the efficient home design and the relatively mild climate, it is difficult to justify the additional costs required for these systems, even with federal tax credits reducing installation costs by up to 30%.

© 2013 Energy and Environmental Economics, Inc.

- Combined heat and power (CHP) was evaluated on another project of a similar scale in the City of Davis, and after a lengthy study and evaluation, the technology could not be made cost-effective because there were not enough uses for the waste heat.
- The option of tying into the university central plant was also considered but was rejected because the community is located too far from the central campus and because the central plant does not currently have the capacity to handle the additional load.

In addition to the above technologies, there were a number of measures that were evaluated after the charrette and identified as not cost-effective under the current evaluation methodology employed for this study. For these measures, the incremental cost was not justified by the energy savings when compared to the cost of renewable energy described in Table 15. In some cases additional evaluation is recommended.

Exterior Foam Sheathing: Originally, one-half inch of rigid insulation sheathing was proposed for the basic performance package, but the high incremental cost largely associated with additional labor and the relative marginal energy benefits of the ½" R-2 sheathing resulted in elimination of this measure. However, 1" of R-4 EPS exterior foam sheathing was determined to be cost-effective in advanced package B.

Slab Edge Insulation: Slab edge insulation is most effective in cold climates where heat loss through the slab to the ground can be significant during the winter. However, in a cooling-dominated climate such as Davis, slab edge insulation is not as valuable. In the summer months, coupling the building slab to the ground underneath provides cooling benefits by providing a heat sink for

warm indoor air. Slab edge insulation resulted in heating savings but no cooling performance benefits. The net savings were not large enough to justify the additional cost to install the Formsulate product evaluated.

Evaporative Condenser: The evaporative condensers currently on the market are sold at very low volumes. Hence incremental costs are relatively high. Additionally, the benefits of evaporative condensers are most pronounced when compared to standard efficiency air conditioning equipment. In this case, it was compared to a high efficiency air-cooled condenser, resulting in marginal energy savings.

High Efficiency Central Heat Pump: High efficiency central heat pumps were evaluated alongside high efficiency gas furnace/AC and combined hydronic/AC options. A high efficiency heat pump does provide source energy savings, but with a $500 incremental cost over the high efficiency gas heating option, the high efficiency gas heating options were found to be more cost-effective.

Mini-split Heat Pump: Mini-split heat pumps were evaluated because of high efficiency performance and the ability to eliminate ductwork and associated efficiency losses. They are well-suited for low load buildings with their variable compressor technology and smaller capacity options. Due to the layout of the single-family homes, a minimum of two mini-split condensers was required, each serving two to three indoor units, hence this option was prohibitively expensive. Mini-split heat pumps were found to be cost-effective and included in the recommendations for the one room studios.

NightBreeze: NightBreeze central fan night ventilation system was originally included as part of the basic performance package. In order to accommodate

© 2013 Energy and Environmental Economics, Inc.

ductwork in conditioned space, the attic design was augmented to convert a portion of the attic into conditioned space so the air handler or furnace could be located inside the thermal envelope. This design results in limited space within the conditioned attic area. The largest component of the NightBreeze system is the damper box that attaches to the return plenum and measures 34”x22”x30”. Concerns over availability of space for the damper in the conditioned attic and high incremental costs resulted in elimination of NightBreeze from the package. A whole house fan was included in the advanced package B.

Heat Pump Water Heating: This technology was considered early in the evaluation process as an efficient electric source of hot water for the single family homes, but due to space constraints was eliminated early on. Heat pump water heaters (HPWH's) require a minimum of 700-1,000 cubic feet of space surrounding the evaporator in which to pull air from and operate. The small water heater closets in the preliminary designs did not provide enough ventilation air for proper heat pump operation, even with louvered vents in the closet doors. There are currently no home models that allow for outdoor installations, and the garage is detached. While HPWH's are an excellent alternative to electric resistance water heating, they were not found to be feasible in this application.

Condensing Storage Water Heater: Field testing of residential water heaters has shown that condensing storage water heaters perform worse than both standard and condensing tankless models under typical California recovery load

scenarios[7]. This is due to standby losses associated with storage tank water heaters. Project modeling also found this result. For this reason, and due to space constraints, storage units were not included in the final packages.

Solar Water Heating: Both active and passive solar water heating systems were evaluated. Estimates of annual solar fraction were correlated to a research study conducted by the Florida Solar Energy Center (FSEC) in California.[8] Solar fractions of 60% and 44% were used for the active and passive systems, respectively. Incremental costs incorporated incentives offered through California AB1470 as well as the 30% federal tax credit, yet the levelized cost of solar water heating was higher than that for biogas so was not included in the final packages.

Advanced Lighting Design: LCRA developed two lighting designs for Plan 3, a 100% fluorescent design with controls and an advanced design which incorporated LED lighting and architectural soffits for indirect lighting. These lighting plans were reviewed with the California Lighting Technology Center (CLTC) who provided comments and recommendations. Based on these two designs, WVCP worked with its lighting supplier to select and price fixtures for the lighting options. The Title-24 base case was developed through identifying the least expensive strategy complying with the Title-24 lighting code (fluorescent or incandescent with controls). WVCP also worked with its framers to identify costs associated with framing of the additional soffits. From this

[7] Based on results from a California Energy Commission PIER funded project on field testing of advanced water heaters in California. (Hoeschele, M., E. Weitzel, "Monitored Performance of Advanced Gas Water Heaters In California Homes", ASHRAE Transactions 2013, Volume 119, Part 1)

[8] Parker, D; Gil, C. "Performance of Solar Water Heating Systems in the United States." Florida Solar Energy Center. ACEEE Hot Water Forum. June, 2009, Asilomar, CA.

© 2013 Energy and Environmental Economics, Inc.

information, five options were identified and evaluated. The first was that included in the basic performance package and discussed previously. The other four advanced options are described in Table 27. Incremental costs for the main house over the basic performance package are also provided.

Table 27. Advanced Lighting Options and Incremental Costs Relative to the Basic Performance Package for the Main House

Option	Description	Incremental Cost
A	Advanced Lighting Design: LED in RCs	$924
B	Advanced Lighting Design: LED in RC & throughout kitchen	$1,565
C	Advanced Lighting Design: Soffit fluorescent lighting	$1,399
D	Advanced Lighting Design: Soffit LED lighting	$5,241

The incremental cost for LED lighting in recessed cans (RCs) (compared to CFLs) is based on a cost of $66 per fixture. While these fixtures are typically the least expensive LED fixtures available, they are not cost-effective. The linear LED lighting in the under-cabinet fixtures is particularly expensive.

The soffit lighting costs include $1,000 for framing of the soffit areas. This strategy provides better light distribution throughout the room and allows for dimming. Soffit lighting is most cost-effectively applied above cabinets or in areas where architectural soffits have already been incorporated into the design. While soffit lighting for the entire house was determined not to be cost-effective in this study due to the cost of building the soffits, it should still be considered as a potential strategy in the kitchen alone, where linear

fluorescents can be installed over the kitchen cabinets at little additional cost. Further, the lighting savings estimated from the dimming controls was not enough to justify the incremental cost.

MEL Controls: As shown in Figure 8, MELs comprise nearly 50% of the electric use. Strategies to control and reduce MELs are critical to the continuing success of zero energy homes. For this evaluation, the GreenWave system, which is currently being installed in the student housing buildings, was evaluated. GreenWave provided a system quote that included the Gateway, in-home displays, 4 power-strips, a meter reader, and a controllable thermostat. The price per home also included a cost for developing the consumer platform but did not include any web hosting, which was required for the student housing. Details of the capabilities and potential energy savings of this system are largely unknown. Estimates of 5% MEL savings were assumed to be reasonable. No heating or cooling savings were assumed since the functionality of the controllable thermostat was nebulous. Based on costs and the estimated savings, the GreenWave was not economic and was not included in the packages. If a load control strategy or technology were implemented at a lower cost or if the GreenWave strategy could achieve 10% MEL savings, it would be economic to incorporate in the packages. Further evaluation is required.

3.9 Recommendations

Cost Changes Over Time. As the project moves forward in design and construction, it would be valuable to continue to look for additional opportunities that could assist in the performance and cost-effectiveness of the project. Some of the measures that were not included in the recommended

© 2013 Energy and Environmental Economics, Inc.

packages may, based upon new pricing, additional information or incentives, be economic for inclusion in future energy efficiency packages. Such measures include:

- Advanced lighting design / LED lighting
- MEL load control strategies and technologies
- Solar thermal water heating

Future LED Incentives. Previous utility new construction programs offered incentives for CFL lighting upgrades as well as the installation of ENERGY STAR appliances. Currently, the CAHP does not offer any prescriptive incentives. LED fixtures provide high quality lighting with long lifetimes, but the market share has not expanded enough to significantly bring down costs. Future incentives provided through utility new home performance or prescriptive incentive programs would allow for early adoption of this technology and result in market uptake.

Future Incentives for Carriage Units. Living quarter structures detached from the primary residence are not currently eligible for rebates through the CAHP. However, these units must meet all CAHP criteria, including achieving 15% savings compared to Title 24. This results in a cost burden on the developer that is not adequately supported through the incentive structure. Regulatory change enabling non-primary residence living quarters to receive energy efficiency incentives would enable additional levels of cost-effective energy efficiency in these units.

Community Education Outreach. The community's success in reaching its net zero energy goals depends on occupant behavior and associated energy use reductions. Education would support these behaviors. This education may be in the form of one-time or ongoing neighborhood workshops, informative plaques within the homes, home owners' manuals, brochures, or other mechanisms. Specifically, MEL reduction should be a focus area, including proper selection and operation of electronics and computer equipment, and using power strips. Another specific topic should be whole house fans, which require occupant initiation of the ventilation cooling equipment and with which many homeowners may be unfamiliar. Education on proper household operation may enable occupants to better manage this appliance providing improved comfort and reduced air conditioner operation. Other topics may include tankless water heater behavior, thermostat setbacks, and lighting.

Equipment Maintenance. It may be worthwhile to consider implementation of a university-based routine maintenance program. The hard water issues in Davis demand that tankless water heaters undergo an annual maintenance regime of flushing out the heat exchanger. This is a relatively simple process that can be undertaken either by UC Davis maintenance, contracted out to a plumber, or performed by the homeowners themselves. Since the tankless units will be located in an exterior closet, creating easy access. An alternative to this would be installation of a water softener up-flow from the water heater. Air conditioner maintenance is also important for continued high efficiency performance of systems and includes regular replacement of air filters and periodic inspections of refrigerant charge, ductwork, and coil fouling.

© 2013 Energy and Environmental Economics, Inc.

4 PV System Analysis

Solar PV will be the main source of electricity supply at the West Village. There are a number of complexities when planning PV installations for ZNE communities, ranging from uncertainty over future consumption and incentive levels to accounting for PV system degradation in the future. This section describes the methods used in developing solar PV generation profiles and costs, and in addressing PV uncertainties, for the West Village.

4.1 PV Generation Modeling

A residential and a community solar PV system configuration were analyzed for the Project's location west of the UC Davis campus. The results were then used in different combinations when developing the business models.

- Residential system:
  - West facing system
  - Roof with 4:12 pitch and no shading
  - Non-tracking
  - kW rating such that average annual PV energy produced over a 5-year weather period (2006-2010) equals annual consumption.
- Community system:

- South-38 orientation
- Non-tracking
- No shading
- kW rating such that average annual PV energy produced over a 5-year weather period (2006-2010) equals annual electricity consumption by a West Village homeowner.

To evaluate the system sizes, a Xantrex XW6048 commercial inverter and Sunpower PL-ASE-100 PV module were selected for PV generation modeling. The number of PV modules was varied iteratively such that the total PV output over a five-year weather period equaled the total consumption of a generic home, including any studio unit. The final PV requirements were scaled to match West Village home consumption in each of the energy efficiency package and home size scenarios. Electric loads were assumed to be the same for each year and electricity consumption behavior was assumed not to change over time. To put this assumption in context, overall PG&E residential consumption has increased less than 0.15% per year over the last 30 years. The size of the inverter was confirmed by ensuring that it could accommodate maximum modeled output.

Using the equipment defined by the sizing study, we created a data set showing hourly output for five years. Output for each hourly period was averaged for use in the economic model. This led to an average 18.4% capacity factor for a rooftop PV system and a 21.5% capacity factor for a community-scale system. With an average annual home usage of about 6,800 kWh (including 60% of studio use), the total required PV capacity under a rooftop configuration is about 1.5 MW if all homes are floor plan 3 with Advanced A energy efficiency

© 2013 Energy and Environmental Economics, Inc.

packages. The total required capacity under a community-scale system is about 1.3 MW. These figures exclude electric vehicle requirements.

4.2 PV System Cost

Costs for the two configurations were estimated using actual PV system costs in the PowerClerk database under the California Solar Initiative (CSI) incentive programs through 7/6/11. These costs included data for each of the three IOUs in California.

For determining the community system capital costs, assuming two loops, the target system size was assumed to be about 1 MW for each loop. Note that the high amount of energy efficiency in the Advanced A package reduces the target system size to 1.3 MW, or about 0.65 MW in each loop, from the initially estimated 1 MW for each loop. The system cost was estimated as the median cost of all systems with the following filters: commercial sector, installed, sized between 800 kW and 1200 kW CEC-PTC (i.e., within 20% of the 1 MW target), where the "First Incentive Claim Request Review Date" occurred in 2011. There were 10 candidate systems and the median value was $5,200 per kW.

For determining the rooftop system capital costs, the target system size was assumed to be 6.392 kW AC (7.8 kW DC). The approach was the same as for the community PV system, but the filters were: residential sector, installed, sized between 6.24 kW and 9.36 kW CEC-PTC (i.e., within 20% of 7.8 kW target), "First Incentive Claim Request Review Date" occurred in 2011. There were 1,674 candidate systems, and the median value was $7,400 per kW. Note that the

high amount of energy efficiency in the Advanced A package reduces per home PV requirements from the initially estimated 6.4 kW, to about 4.4 kW.

4.3 Solar PV Incentives

A variety of solar energy incentives are available to both rooftop and community-scale PV systems. Incentive amounts through the New Solar Homes Partnership (NHSP) were $2.35/W at the time of this analysis. Once NSHP incentives have been paid, PV system expansion (for example, to serve an electric vehicle) is no longer eligible for NSHP, but is eligible for CSI incentives. A separately metered EV is not eligible to receive NSHP, but would be eligible for CSI. The maximum NSHP incentive capacity is 7.5 kW AC. For CSI, system size is limited to 5 MW, however the maximum incentive capacity is 1 MW. NSHP incentives expire in 2019 and must be filed for by the end of 2016; CSI incentives must be filed for by the end of 2016 and expire 18 months from filing. Operation of the PV system must be achieved prior to expiry.

Rooftop and community-scale systems were assumed to be financed with a power purchase agreement (PPA). This method of financing ensures PV capital costs are not included in the developer's scope, and yields 5-year MACRS tax depreciation benefits. UC Davis financing for the community-scale system was also analyzed, and in this scenario a 20% labor premium for triggering prevailing wage rates. Estimated 25-year real (versus nominal) levelized costs after incentives were $0.1884/kWh for the rooftop PV system and $0.1626/kWh for the community-scale PV system. The levelized cost for community PV excludes trench and security costs but does include an annual land cost of about $15,000.

© 2013 Energy and Environmental Economics, Inc.

An overview of PV modeling results is provided in Table 28.

Table 28. Overview of PV Modeling Results

	Rooftop	Community
Inverter	Xantrex 6 kW (Model XW6048-120/240)	Xantrex 6 kW (Model XW6048-120/240)
PV Array	Sunpower 100 W (Model PL-ASE-100)	Sunpower 100 W (Model PL-ASE-100)
Orientation	West, 4:12 roof pitch (18^0)	South, 38^0
NZE Ratings (per generic home)	7.8 kW DC, 6.392 kW CEC-AC	6.7 kW DC, 5.491 kW CEC-AC
5-year Energy Production (per generic home)	51,427 kWh	51,597 kWh
Cost ($/kW, CEC-AC)	$7,418	$5,138
LCOE (2011$/kWh)	$0.1884	$0.1626
Current incentive levels	NSHP: $2.35/W (2012)	CSI: $0.09/kWh (2012)

Note: The community rating of 5.491 kW CEC-AC offsets the load for a generic home, so the actual aggregate rating of the system must be multiplied by the number of houses, scaled down for the energy efficiency package assumption, and adjusted for studio unit penetration and assumed EV penetration.

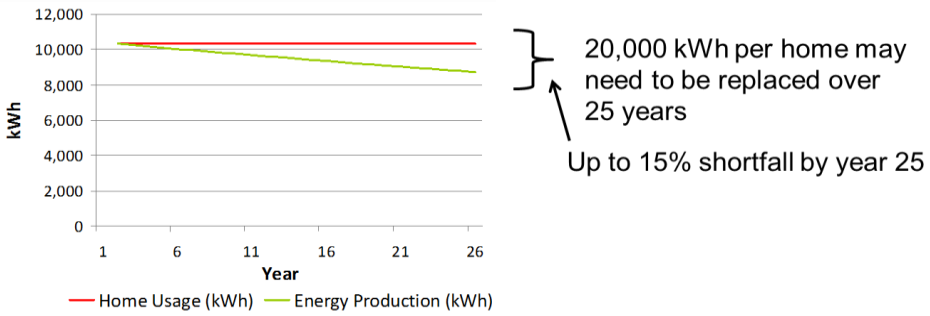
4.4 Sizing PV System under Uncertain Degradation and Consumption

There is uncertainty in both the amount of PV generation and the amount of household energy consumption, which will affect whether the West Village can achieve its ZNE goals in any given year or over time. For the purposes of planning, we assumed a fixed PV degradation rate, constant energy consumption over time, and used renewable energy credits (RECs) to either sell

surplus renewable attributes or purchase additional renewable attributes to make up for shortfalls. These uncertainties are discussed further in the section on behavior and in the overall roadmap.

The PV system will degrade over time, reducing its output, though it is uncertain by how much. In this analysis, we assumed PV degradation of 0.7% per year, which would lead to a shortfall of 20,000 kWh (15%) in year 25 assuming that household electricity use is constant (Figure 12). The PV system degradation rate reflects the combination of reduced PV module output, and increased downtime for other system components such as inverter and is based on the 2010 CSI Load Impact evaluation conducted by ITRON.[9] Similar to cost, this is a conservative estimate since a routine cleaning and maintenance program may reduce the degradation levels below 0.7%.

Figure 12. Generation Shortfall Caused by 0.7%/yr PV Degradation, if PV Sized to First-Year Consumption

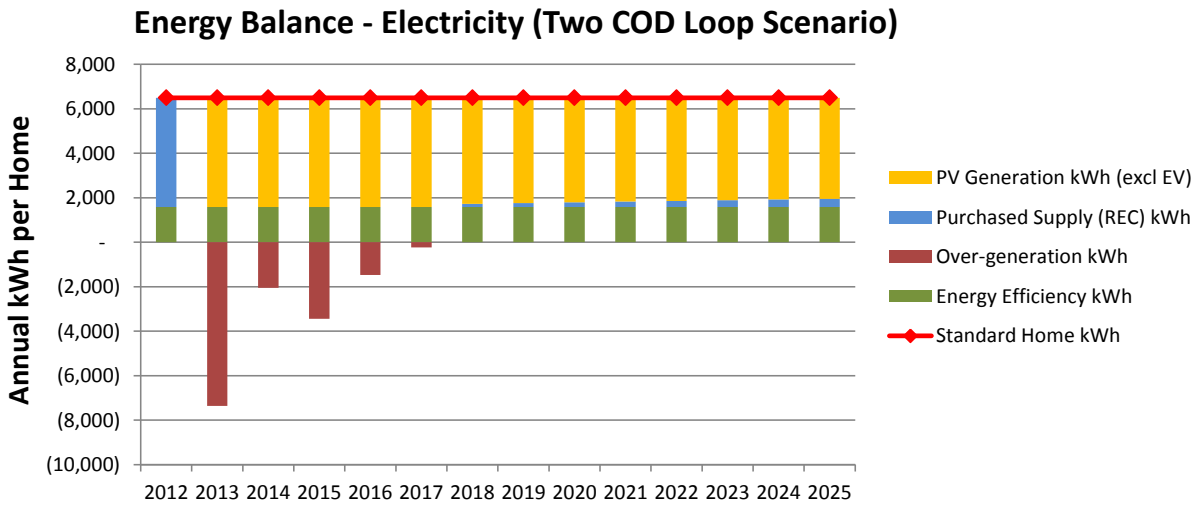


[9] See http://www.cpuc.ca.gov/NR/rdonlyres/E2E189A8-5494-45A1-ACF2-5F48D36A9CA7/0/CSI_2010_Impact_Eval_RevisedFinal.pdf.

© 2013 Energy and Environmental Economics, Inc.

Unlike the rooftop PV approach, the community-scale PV system output will not always closely match the home consumption during the development period since the number of expansions of community-scale arrays is limited. Therefore, the community-scale approach would require selling generation in years where generation is in excess and procuring additional clean energy, for example through purchasing RECs, when generation is insufficient. For instance, when one community PV "loop" is built in 2013 and one in 2015, the project will need to purchase RECs or procure another clean energy source in 2012, will over-generate until 2017, and will then need to purchase RECs or other clean energy again beginning in 2018 and indefinitely after (Figure 13).

Figure 13. Energy Balance for a Two Loop Community PV System Online in 2013 and 2015



Note: The above example assumes 60 homes per year construction, and Loops constructed in 2013 and 2015.

4.5 Net Usage Bill Calculations

Annual utility bills were calculated using CPR's PowerBill software. PowerBill calculations were based on PG&E rate schedules in place in July 2011. Net usage scenarios were developed based on the hourly PV generation simulation and hourly home consumption simulation. A total of 180 annual baseline home usage and West Village home net usage scenarios were calculated to reflect combinations of rooftop or community configuration, home size, EEM package, studio energy use, metering scenario, and, as a sensitivity, EV usage. We generated annual utility bill cost estimates for each of the 180 usage scenarios.

Net usage bills for rooftop PV were calculated using PG&E's tiered (E-1 and EL-1), tiered time-of-use (E-6 and EL-6), and EV (E-9) rates. Net usage bills for community-scale PV were calculated using PG&E's small and medium general time-of-use rates (A-6 and E-19, respectively).

The net usage bill amounts used in this analysis can be found in the project model, available at: **http://calsolarresearch.ca.gov/funded-projects/75-west-village-energy-initiative-csi-rd-d-project**.

© 2013 Energy and Environmental Economics, Inc.

5 Biogas Analysis

Early in the project's design phase, the consultant team, in close collaboration with UC Davis and the developer, made a decision to use both electricity and natural gas in the West Village homes. Our analysis found that the most cost-effective way to achieve ZNE goals would be to purchase natural gas and a biogas offset. In addition, the developer supported the marketability of a gas-electric home versus an all-electric home. This section describes the methods used in developing biogas use and cost estimates for the West Village.

5.1 The Case for Biogas

In much of California, natural gas is used for water heating, space heating, and cooking. To achieve ZNE goals, renewable substitutes for natural gas are needed, either through renewable electricity (an all-electric home) or renewable gas (a gas-electric home). Pros and cons of the gas-electric home are enumerated below.

Table 29. Pros and Cons of the Gas-Electric Home

Pros of gas-electric	Cons of gas-electric
• Significantly lower lifecycle cost of ownership than all-electric scenario • Less difficult to demonstrate 'multiple renewables' in the community • Overall source efficiency is higher • Natural gas stoves make homes more attractive from a marketing standpoint	• Cannot eliminate gas lines (however, utility service extensions reduce the cost) • Cannot eliminate combustion appliances in the home • May be more difficult to market a home as "ZNE" since a "biogas offset" is required to offset the natural gas use

From an energy, economic, and marketability standpoint, the gas-electric home has a number of advantages over the all-electric home. For instance, in the Basic Performance package, we estimated that the all-electric home would require 6% more source energy (end use energy plus conversion losses) than the gas electric home.[10] Although the all-electric home avoids gas costs, it requires a larger and more costly PV system and is, on balance, more expensive than the gas-electric home.[11]

For a gas-electric ZNE home, there are three options for "netting" natural gas use:

[10] This estimate uses the Basic Performance package energy consumption results, assumes an electricity conversion loss factor of 2.4639 and a natural gas distribution loss factor of 1.092, and assumes that electric appliances that replace gas appliances require 14.5 kWh for each therm replaced, based on modeled energy use estimates.

[11] Cost differences depend on assumptions. For a PV system with a levelized cost of $0.186/kWh, $2/therm biogas, an average retail electric rate of $0.188/kWh, natural gas prices of $1.20/kW, 3%/yr retail electricity price escalation, 2%/yr gas price escalation, and the assumptions from the previous footnote, the all-electric home is roughly $2,000 more expensive than the gas-electric home.

© 2013 Energy and Environmental Economics, Inc.

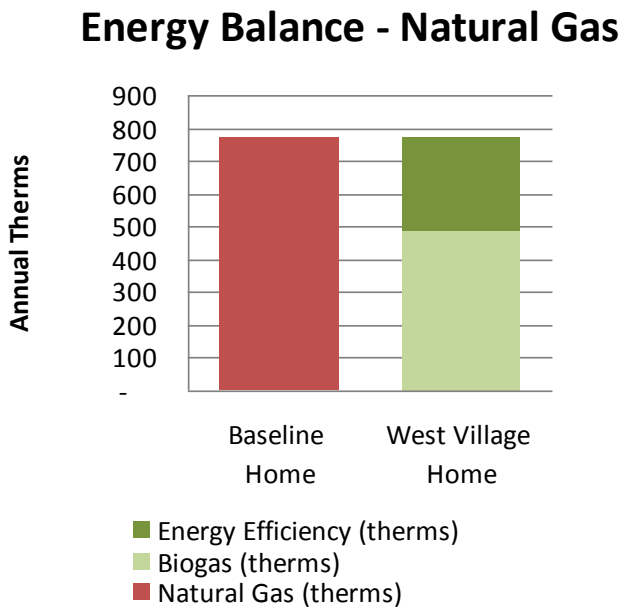
- Produce and/or purchase biofuel
- Generate additional electricity to sell to the grid
- Generate additional electricity for electric vehicles to displace gasoline or diesel use.

Of these, the simplest and most cost-effective option would be to purchase biogas offsets, with the biogas injected into the natural gas pipeline system. Generating additional electricity is not cost-effective because excess generation is compensated at a very low market value (~$0.04/kWh) under California's current net energy metering (NEM) policy.

5.2 Biogas Energy Balance

The biogas program would work by purchasing biogas and then selling it into the natural gas pipeline system at the source of the biogas. Therefore, biogas would not be directly combusted in homes, and West Village retains the biogas "offset". West Village homes would continue to be served via PG&E retail natural gas service per applicable residential rates. The incremental cost of biogas above its sales price is the cost of the biogas offset. Residents would be billed for the biogas offset costs via monthly homeowner dues. A conservative estimate of $2 per therm total cost for biogas was utilized in the project model. Figure 14 shows the energy balance for a baseline home with natural gas and a more energy efficient West Village home with biogas.

Figure 14. Energy Balance of Natural Gas and Biogas + EE



5.3 Biogas Procurement Options

We evaluated the feasibility and current costs of purchasing biogas offsets for the West Village and found that, while for small quantities (e.g., individual homes) biogas offsets are not viable because of minimum procurement obligations and transaction costs, for the development as a whole the procurement of biogas is feasible. Incremental biogas costs can be collected periodically via home owner community service fees.

There are two main ways to procure biogas: (1) purchase or develop a biogas project; and (2) purchase biogas contracts. Each procurement mechanism has

© 2013 Energy and Environmental Economics, Inc.

its pros and cons, and each should be evaluated against project goals before a final procurement determination is made.

5.3.1 BIOGAS CONTRACT

A contract is a convenient mechanism for (1) purchasing small quantities; (2) phasing in quantities as demand grows; or (3) short-term procurement until a campus facility may be operational.

Biogas contracting could occur via a supplier such as Shell Energy North America. Including transportation costs, out-of-state biogas contracts can currently be obtained for roughly $1.65/therm. In-state contracts, including transportation costs, are approximately $1.3/therm.

5.3.2 OFF-CAMPUS BIOGAS PROJECT

Association with a physical project may be desirable to provide a tangible example of ZNE goals. Such a project could be located near West Village, within California, or out of state. For example, with a biogas project approach, marketing materials for the West Village homes could include photographs of a tangible biogas asset to explain the biogas offset to potential home buyers.

Using this approach, an entire biogas project could be purchased, or a substantial portion of the output of a biogas project could be contracted. Because the entire biogas project would need to be constructed upfront, such an arrangement would likely require selling of excess biogas to another party during construction phase-in.

6 Electric Vehicle Analysis

Automobiles were not part of the ZNE scope defined for West Village community, but electric vehicles (EVs) were considered as part of the roadmap to understand how they affect West Village energy supply, demand, and economics. This section describes the methods used in developing EV penetration, use, and cost estimates for the West Village relative to a baseline of gasoline-powered cars.

6.1 EV Penetration Rates and Use

Forecasts of EV penetration in California vary widely. The EV penetration assumption used to create project economics is from a "medium" penetration scenario in an EPRI study (Table 30). With this penetration rate, by 2030 residents would own approximately 85 EVs (based on 2 vehicles per home, 343 homes, and 12.4% penetration). The balance of cars in the West Village was assumed to be gasoline-powered, and the economic impact of these vehicles was assumed to be the same as those owned by residents of baseline homes. The analysis did not assume behavior differences with respect to cycling or walking among West Village and general Davis households.

© 2013 Energy and Environmental Economics, Inc.

Table 30. Estimated Penetration Rate for EVs in California[12]

	2010	2015	2020	2025	2030	2035
Medium	0.04%	1.00%	3.30%	7.30%	12.40%	21.13%

To estimate EV driving, we assumed that each household has two vehicles. For the EV, we assumed that driving patterns, on average, reflect a mix of an "errand runner" that takes more frequent trips, and a "commuter" that works away from the West Village five days a week and has higher total mileage. Based on data from the Federal Highway Administration's 2009 National Household Travel Survey (NHTS), we estimated daily vehicle miles for the errand runner (~30 miles/day weekday, ~39 miles/day weekend/holiday) and commuter (40 miles/day weekday and weekend/holiday).[13] We assumed that any daily driving outside of the EV's electric driving range (35 miles) was done in gasoline-powered mode.[14]

Using the above VMT estimates and middle of the road assumptions about vehicle efficiency (0.34 kWh/mi, 35 mpg), we estimated that, for an EV, the two kinds of drivers would have annual electricity and gasoline consumption of:

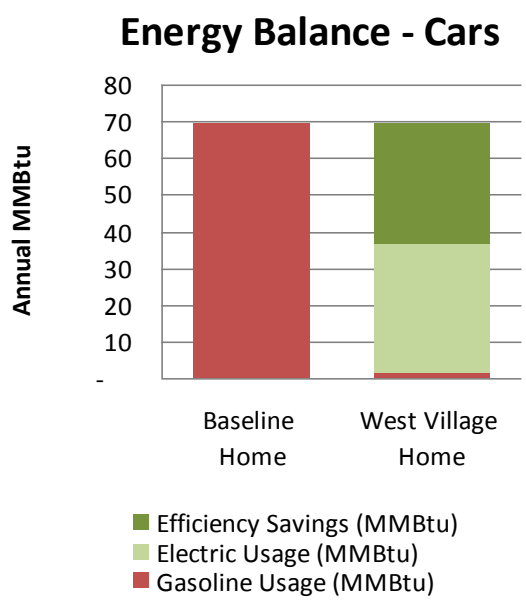
- "Errand runner" – 4,702 kWh per year + 12 gallons of gasoline

[12] EPRI, Transportation Electrification: A Technology Overview, July 2011. Table 4-1 and Figure 4-3. Available at: http://my.epri.com/portal/server.pt?space=CommunityPage&cached=true&parentname=ObjMgr&parentid=2&control=SetCommunity&CommunityID=404&RaiseDocID=000000000001021334&RaiseDocType=Abstract_id.
[13] Online at: http://nhts.ornl.gov.
[14] The errand runner was assumed to charge twice per day during the weekday, and once per day during the weekend. The commuter was assumed to charge once per day. Driving range was based on a Chevy Volt, from www.chevy.com.

+ "Commuter" – 3,910 kWh per year + 32 gallons of gasoline

In the analysis we assumed 65% of EVs are owned by commuters and 35% by errand runners. Figure 15 shows the energy balances of a baseline home gasoline-powered vehicle and a West Village home EV.

Figure 15. Energy Balance of Standard Gasoline-Powered Cars and West Village EVs



6.2 Costs Assumptions for EVs and Conventional Gasoline Cars

The net cost of EVs relative to conventional gasoline-powered cars is a trade-off between higher vehicle costs and fuel savings, as EVs are more energy efficient than gasoline-powered cars. The initial EV cost was assumed to be $12,200

© 2013 Energy and Environmental Economics, Inc.

higher than the average cost of a gasoline-powered vehicle, with future projected cost declines of 3% per year. These higher incremental costs were offset by the following incentives:

- Federal tax credit of $7,500, available until approximately 2020 (expires when 200,000 EVs from each manufacturer have been produced); and
- California $2,500 incentive, available until approximately 2015.

The incremental costs of the EV sub-meter and 220 kV charger were assumed to be $450 and $1,500, respectively. These amounts are assumed to be paid directly by homeowners so are outside of the developer's scope. We examined controlled and uncontrolled charging scenarios, but used controlled in analyzing project economics. In scenarios with EVs, the PV system is sized to accommodate EV usage.

Baseline home residents were assumed to own only conventional gasoline-powered cars, with driving patterns equivalent to those described above for West Village residents:

- Errand runner mileage of 11,851 per year with 18 miles per gallon fuel efficiency; and
- Commuter mileage of 14,600 miles per year with 25 miles per gallon fuel efficiency.

6.3 Accommodating EV Penetration over Time

Because the studio does not have its own garage, studio units are not assumed to own EVs. Charging for studio occupants could be accommodated through streetlight or car port charging stations.

In order to receive NSHP incentives, incremental rooftop PV to serve EVs must be installed within six months of home ownership. CSI incentives are available (until program expiry) if the homeowner is no longer eligible for NSHP funds.

© 2013 Energy and Environmental Economics, Inc.

7 Identification of Potential Business and Regulatory Models

There are a number ZNE business models available for the West Village, from different strategies for financing PV systems to different construction rates for the homes. Which among these alternatives is most attractive depends significantly on regulatory opportunities and constraints. This section identifies potential business models for the West Village under current regulations, and examines regulatory changes that could significantly affect project economics.

7.1 PV Business Models in the Current Regulatory Environment

In the current regulatory environment, UC Davis will need to choose among PV system configurations, system sizes, regulatory strategies, financing options, and home construction rates amidst changing demand conditions for housing, PV incentive levels and uncertainty in PV costs and generation requirements over time. A robust business model analysis must account for all of these factors.

7.1.1 CHANGES IN PV SYSTEM COSTS OVER TIME

Rooftop PV for new construction is currently eligible for the New Solar Homes Partnership (NSHP) incentive; rooftop PV for existing homes or rooftop system expansion is eligible for California Solar Initiative (CSI) incentives. Community-scale PV is only eligible for CSI incentives. Home owners installing PV systems are eligible for the federal investment tax credit (ITC). PV systems owned by taxable third parties are eligible for the ITC and 5-year MACRS tax depreciation. Both the NSHP and CSI incentives are expected to decline over time, and the ITC is expected to decline from 30% to 10% starting in 2017. Table 31 shows the incentive levels used to produce the results described in this report and the impact on PV LCOE relative to the initial LCOE results over time.

Table 31. CSI and NSHP Incentive Levels

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Timing Impacts on CSI										
CSI Incentive Level	0.090	$ 0.09	$ 0.05	$ 0.05	$ 0.03	$ 0.03	$ 0.03	$ -	$ -	$ -
Impact on LCOE	-	-	0.019	0.019	0.028	0.028	0.028	0.042	0.042	0.042
Timing Impacts on NSHP										
NSHP Incentive Level	2.350	$ 2.35	$ 2.10	$ 1.85	$ 1.35	$ 1.10	$ 0.85	$ 0.35	$ 0.35	$ -
Impact on LCOE	-	-	0.016	0.031	0.063	0.078	0.094	0.125	0.125	0.147

PV cost reductions will offset some of the declines in incentives, but because PV cost declines and future incentives are uncertain, the PV cost trajectory is unclear. Learning curves, which quantify the relationship between cumulative production volume and cost, provide a tool for systematically incorporating PV cost uncertainty into the analysis. In this analysis, we used two learning curves, with a fast reduction in PV costs scenario that assumes a progress ratio of 75%

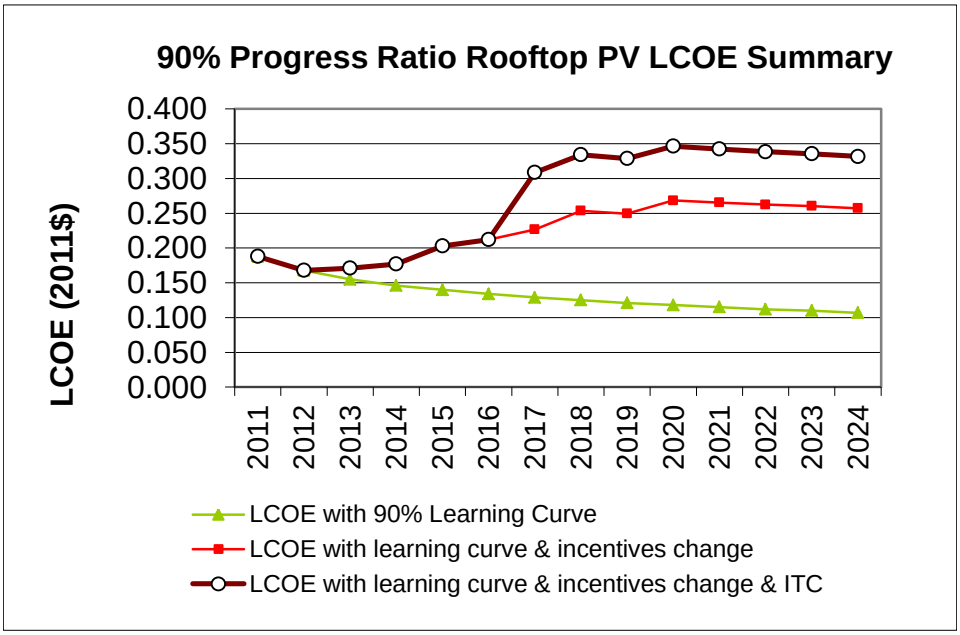
© 2013 Energy and Environmental Economics, Inc.

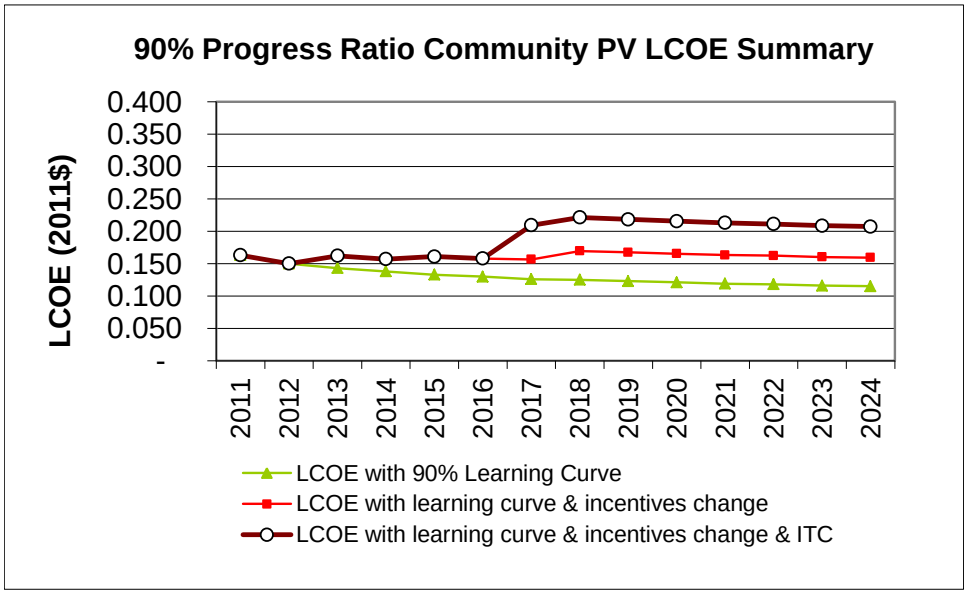
and a moderate PV cost reduction scenario that assumes a progress ratio of 90%,[15] to capture PV cost uncertainty over time.

Figure 16 shows the balance between PV cost reductions and incentive declines over time for both the rooftop PV and community-scale PV systems. Brown lines show the final LCOE trajectory after taking into consideration cost reductions, changes in incentive levels, and the ITC step down. In the rooftop scenario, cost reductions largely offset the reduction in NSHP incentive over time, but are not significant enough to make up for the reduction in the ITC in 2016. In the community scenario, cost reductions are greater than CSI incentive declines, and eventually also nearly offset the ITC step down. The figures show that rooftop PV is impacted to a greater degree as incentives roll off.

[15] A progress ratio is the ratio between costs in an initial period and costs with a doubling of cumulative production volume. A 90% progress ratio, for instance, would imply that a doubling of base year PV capacity would reduce costs by 10%.

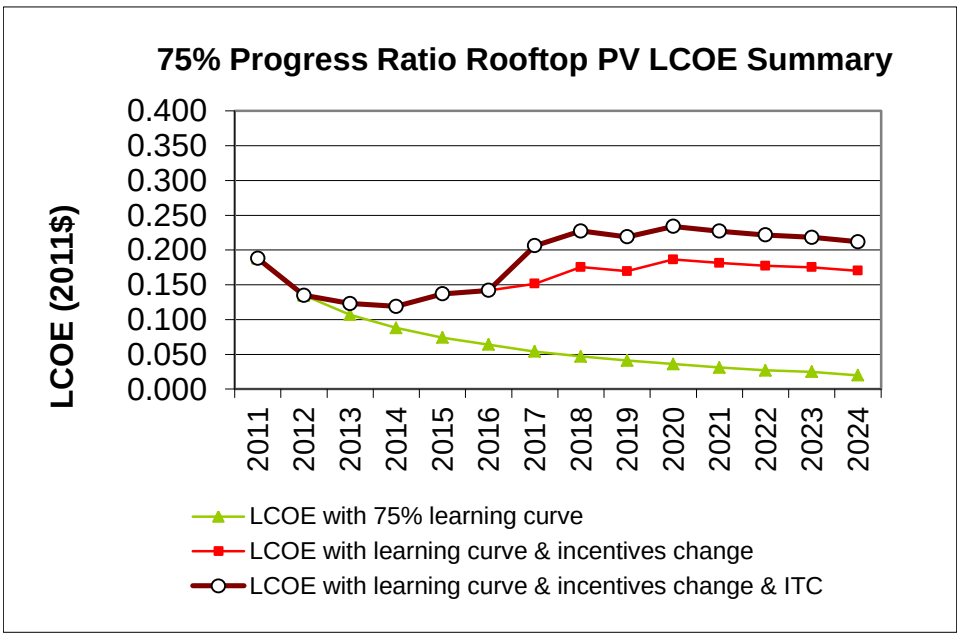
Figure 16. Rooftop and Community PV Costs with a 90% Progress Ratio, Incentive Changes, and ITC Step Down

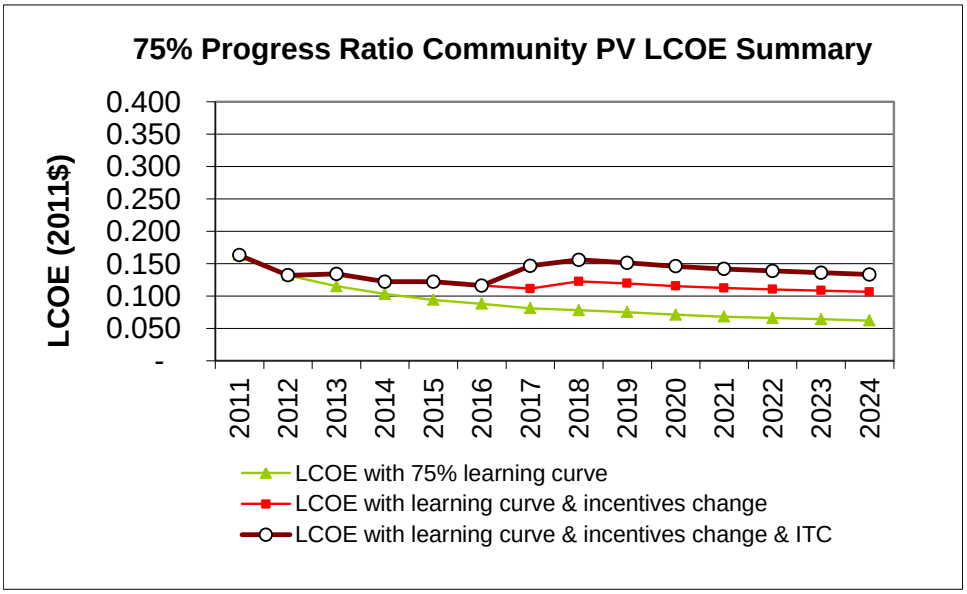




© 2013 Energy and Environmental Economics, Inc.

Figure 17. Rooftop and Community PV Costs with a 75% Progress Ratio, Incentive Changes, and ITC Step Down





7.1.2 ACCOMMODATING FUTURE USAGE AND GENERATION UNCERTAINTY

Future electricity generation requirements are uncertain because homeowner electricity use may increase (decrease) over time (e.g., homeowners may purchase or eliminate appliances or EVs), which would lead to a generation shortfall (surplus) if the PV system were sized to current use. Occupancy rates are also uncertain – for example, occupancy for a 3-bedroom home could range from 1 to 4 persons, and perhaps more. Additionally, a generation shortfall could occur because the PV system will degrade over time (see Section 4). To deal with potential shortfalls in generation, the PV system could be initially oversized to meet projected lifetime use, additional PV modules could be installed in the future, a fuel cell could be added onsite to generate electricity, or renewable energy credits (RECs) could be purchased to cover the shortfall.

If the PV system is initially oversized, surplus electricity could be sold. However, for rooftop PV, the current surplus generation rate is approximately $0.04/kWh[16]. A community system could potentially negotiate a short-term small renewable generator power purchase agreement (PPA) with PG&E under Schedule E-SRG, at a rate of approximately $0.12/kWh (market price referent multiplied by a 1.2 time-of-delivery factor). Surplus power could also be sold under a negotiated PPA with UC Davis. The levels of compensation associated with these strategies are not, however, cost-effective. The most cost-effective way to deal with uncertainty in generation requirements is to right-size or under-size the PV system and purchase RECs to cover the shortfall. At a REC

[16] For the monthly scenario of net surplus rates at PG&E see: http://www.pge.com/includes/docs/pdfs/shared/solar/AB920_RateTable.pdf.

© 2013 Energy and Environmental Economics, Inc.

cost of $0.05/kWh, the total cost to homeowners of purchasing electricity from PG&E under the rooftop scenario would be about $0.19/kWh (= $0.05/kWh REC cost + $0.14 levelized residential electric rate).

7.1.3 REGULATORY MODELS

For rooftop PV, only one regulatory model is currently available — net energy metering (NEM). For community-scale PV, UC Davis can choose between NEM and PG&E's bill credit transfer (RES-BCT) program. The ability for the UC Davis campus to have multiple houses behind a single meter is unique and likely not available to other developers since all of the land will be owned by UC Davis and leased to homeowners. In addition, even as part of campus load, submetering and billing individual homes would not be allowed under PG&E Rule 18. An analysis of PG&E schedule RES-BCT, which would allow UC Davis to transfer PV generation bill credits to eligible UC Davis accounts, proved uneconomic because it credits only the generation portion of the rate, and because CSI incentives are available for net usage only.

A combination of rooftop and community-scale PV would also be possible where either (1) the West Village begins with rooftop PV and subsequently builds a "delayed" community-scale PV system; (2) the West Village begins with a community-scale PV system and subsequently builds rooftop PV for any additional generation requirements; or (3) the West Village installs rooftop PV for homeowner electricity use, and subsequently builds a community-scale PV system to charge EVs (Figure 18). Carport EVs in the third option could be for residents with more than one EV, for studio renters who have an EV, or for a car share program. The first and third options may be cost-effective. The delayed

rooftop option, however, is not cost-effective because it delays rooftop PV until incentives have expired and the costs of rooftop PV have increased significantly (Figure 18). Hence, we removed this option from consideration.

Figure 18. Hybrid Business Models for PV

Potential PV Business Model	Regulatory Model	Incentive	PG&E Rate	Status
Delayed community PV - Initial development with rooftop PV - Community PV sized for remaining development later	NEM	NSHP initially, but none later (CSI likely expired)	Initial homes residential Small commercial TOU for later homes	Evaluated
Delayed rooftop PV - Initial development with community PV - Rooftop PV for remaining development later	NEM	CSI initially, but small or none later (NSHP largely expired)	Small commercial TOU for initial homes Later homes residential	Removed
Rooftop and Community PV Combination - Rooftop PV for home, studio, and homeowner EV - Community PV for community EV carport	NEM	CSI (unless/until expired)	Residential for homes and studio PG&E TOU rate for EVs	Evaluated

7.1.4 ELECTRIC RATE SELECTION

For rooftop PV, the most economic PG&E electric rate is E-1 for the main home, EL-1 for the studio, and E-9 for the electric vehicle. For community-scale PV, the optimal system configuration is dictated by PG&E rates. PG&E rate schedule A-6 is valid for customers from 200 kW to 499 kW, and schedule E-19 is valid for customers from 500 kW to 1 MW. NEM rate credits for the latter are

© 2013 Energy and Environmental Economics, Inc.

significantly less economic than the former, hence it makes more economic sense to build two 499-kW systems than one 1-MW system to meet West Village peak demand. The base case community PV scenario thus assumes NEM billed at the A-6 rate.

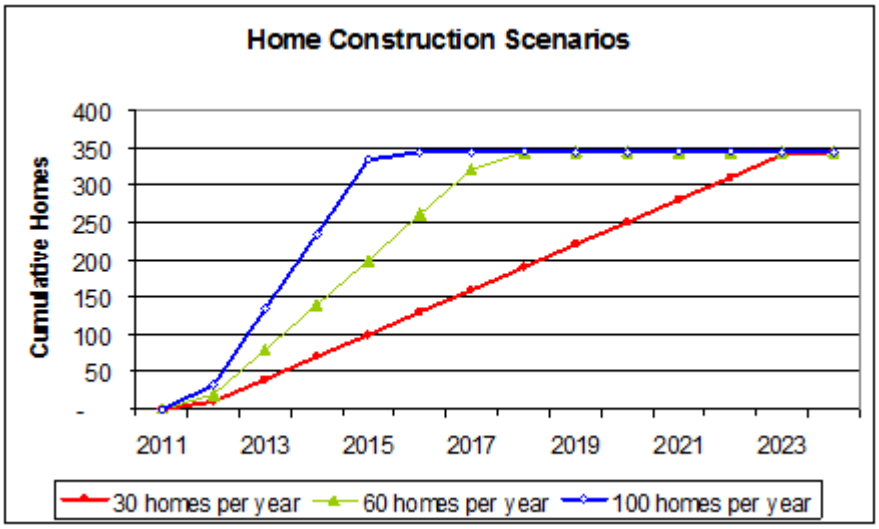
7.2 Results: Successful Business Model(s) under Current Regulations

The choice of business model is highly sensitive to home construction rates and PV cost reductions. In the seven business models analyzed, we use three construction rate and two PV cost trajectory sensitivities (Table 32). The construction rate scenarios assumed that 30, 60, and 100 homes are built per year, depending on market demand. If the rate is 60 per year, construction would be complete in 2018. At 30 per year, about 50% of homes would be completed by the end of 2017 (Figure 19).

Table 32. Business Models and Sensitivities

Business Models	Sensitivities
➢ Rooftop, PPA	**Home Construction Rate**
➢ Two Loops, 2013 COD, PPA	➢ 30 homes/year
➢ Two Loops, 2013 COD, UCD + Tax Equity Financing	➢ 60 homes/year
➢ Two Loops, 2013 & 2015 or 2018 COD, PPA	➢ 100 homes/year
➢ Two Loops, 2013 & 2015 or 2018 COD, UCD + Tax Equity Financing	
	Learning Curve Progress Ratio
➢ Rooftop then Delayed 2017 Loop, PPA	➢ 75%
➢ Rooftop then Delayed 2017 Loop, UCD + Tax Equity Financing	➢ 90%

Figure 19. Home Construction Scenarios, 30, 60, and 100 Home per Year Construction Rates



We identify business models that are 'successful' in the roadmap as those that meet project cost goals: (1) at no higher cost to the developer vis-à-vis a baseline home and (2) at no higher cost to homeowners over the 25-year life of the PV system than a baseline home. For the purposes of the first cost goal, EEMs and the trench for the community-scale PV "loop" are in the scope of developer costs, but the solar PV system, incremental biogas costs, EVs, and any fuel cell or storage system are not. These costs are included, however, in the lifecycle homeowner costs and are compared with baseline home electricity, natural gas, and in EV scenarios, gasoline costs.

© 2013 Energy and Environmental Economics, Inc.

The results of our analysis are measured as net present value (NPV) of the total cost difference between West Village homes and baseline homes from 2012 to 2024. All costs are reported in $2011. The West Village homes may be more/(less) economic than baseline homes; a positive NPV indicates that the West Village home is more economic. The NPV discount rate is the estimated homeowner real cost of capital based on a nominal home mortgage rate of 5.5%.[17] The results are shown after trench costs of $1 million per loop, which includes estimated trench, security and administrative costs associated with the community PV system. In the two scenarios where UC Davis is involved in the financing, a 20% prevailing wage factor has been added to labor costs.

Table 33 shows results for 30, 60, and 100 home per year construction rates with moderate PV cost declines (90% progress ratio). In this scenario, only the rooftop with Advanced A EEM package (100 homes per year) is economic. In the 60 home per year scenario, no strategy produces an economic business model, and the best strategy is the rooftop + delayed loop with Advanced A EEM package, which produces a $0.2 million NPV shortfall. However, significant risks are associated with pursuing a loop strategy, hence it is likely advisable to pursue the rooftop configuration in this scenario, even though its projected NPV is lower by $0.3 million. Similarly, in the 30 home per year scenario, no strategy produces an economic business model, and the best strategy is rooftop + delayed loop with an Advanced A EEM package, which produces a $0.3 million NPV shortfall. In this case, the $1.4 million difference in cost between this scenario and the rooftop PV scenario may justify pursuit of the delayed loop in 2017.

[17] Assumed here to be 3.4%, using an inflation rate of 2% (= ((1+5.5% nominal)/1.02)-1).

Table 33. NPV of Incremental Costs for the Seven Business Models, 30, 60, and 100 Homes per Year, 90% Progress Ratio (M$)

Home Constr Rate	EEM Package	Learning Curve	Two Loops 2013 COD PPA	Two Loops COD 2013 & 2015 (60) or 2018 (30) PPA	Two Loops 2013 COD UCD + Tax Equity	Two Loops COD 2013 & 2015 (60) or 2018 (30) UCD + Tax Equity	Rooftop PPA	Rooftop + Delayed 2017 Loop PPA
30	Proposed	90%	(2.5)	(2.6)	(1.7)	(1.4)	(2.5)	(1.0)
30	Adv A	90%	(1.7)	(1.8)	(1.0)	(0.7)	(1.7)	(0.3)
30	Adv B	90%	(2.6)	(2.7)	(1.9)	(1.6)	(2.5)	(1.1)
60	Proposed	90%	(2.0)	(1.8)	(1.2)	(1.0)	(1.3)	(1.0)
60	Adv A	90%	(1.2)	(1.1)	(0.5)	(0.3)	(0.5)	(0.2)
60	Adv B	90%	(2.2)	(2.0)	(1.5)	(1.3)	(1.4)	(1.0)
100	Proposed	90%	(1.7)	n/a	(0.9)	n/a	(0.2)	(0.8)
100	Adv A	90%	(1.0)	n/a	(0.2)	n/a	0.6	(0.2)
100	Adv B	90%	(2.0)	n/a	(1.6)	n/a	(0.4)	(1.3)

Table 34 shows results for 30, 60, and 100 home per year construction rates with faster PV cost declines (75% progress ratio). In this scenario, all business models that begin with rooftop PV are economic, and the most economic case is the rooftop PPA with Advanced A package. The two loop models are only cost-effective with UC Davis + tax equity financing and Advanced A packages.

© 2013 Energy and Environmental Economics, Inc.

Table 34. NPV of Incremental Costs for the Seven Business Models, 30, 60, and 100 Homes per Year, 75% Progress Ratio (M$)

Home Constr Rate	EEM Package	Learning Curve	Two Loops 2013 COD PPA	Two Loops COD 2013 & 2015 (60) or 2018 (30) PPA	Two Loops 2013 COD UCD + Tax Equity	Two Loops COD 2013 & 2015 (60) or 2018 (30) UCD + Tax Equity	Rooftop PPA	Rooftop + Delayed 2017 Loop PPA
30	Proposed	75%	(1.8)	(1.3)	(1.1)	(0.4)	0.2	0.6
30	Adv A	75%	(1.1)	(0.7)	(0.5)	0.2	0.9	1.3
30	Adv B	75%	(2.0)	(1.6)	(1.3)	(0.7)	-	0.3
60	Proposed	75%	(1.3)	(0.2)	(0.6)	(0.3)	1.0	0.9
60	Adv A	75%	(0.6)	(0.2)	0.1	0.4	1.8	1.5
60	Adv B	75%	(1.6)	(1.2)	(1.0)	(0.7)	0.8	0.9
100	Proposed	75%	(1.1)	n/a	(0.4)	n/a	1.8	1.0
100	Adv A	75%	(0.4)	n/a	0.2	n/a	2.5	1.7
100	Adv B	75%	(1.4)	n/a	(0.8)	n/a	1.4	0.6

Across scenarios, four trends emerge: (1) a faster construction schedule is more economic because more houses are built before incentives decline; (2) under slow PV cost declines (90% progress ratio scenario) the economics are difficult; (3) two loops are less economic than either rooftop or rooftop + delayed loop, which are both economic in all construction rates under lower PV cost scenarios; and (4) the Advanced A package is always most economic. Table 35 summarizes the most cost-effective business model for each construction rate and progress ratio combination. Again, with our assumptions about trench costs, the most cost-effective business models at least begin with rooftop PV.

Table 35. Optimal Business Models and their NPV (M$) under Different Home Construction Rates and PV Learning Curve Progress Ratios

Home Construction Rate	PV Cost Scenario (Progress Ratio)	Business Model	NPV (M$)
30 homes / year	Fast decline (75%)	Rooftop	0.9
		Rooftop, then delayed Community-scale	1.3
	Moderate decline (90%)	Rooftop, then delayed Community-scale	-0.3
60 homes / year	Fast decline (75%)	Rooftop	1.8
	Moderate decline (90%)	Rooftop, then delayed Community-scale	-0.1
100 homes / year	Fast decline (75%)	Rooftop	2.5
	Moderate decline (90%)	Rooftop	0.6

In addition to better economics given the available incentives, the rooftop PV approach also has the least regulatory risk and far fewer challenges with metering and billing given the prohibition of submetering customers in PG&E's Rule 18. The rooftop scenario, however, is more dependent on construction rates and the timing of incentives since the NSHP incentive rates are larger than those available through CSI. Table 36 summarizes the pros and cost of the two different approaches.

© 2013 Energy and Environmental Economics, Inc.

Table 36. Pros and Cons of Rooftop versus Community PV

Rooftop PV	Community PV
Pros Most economic business model Straightforward to implement	**Pros** Supports community solar goals May better achieve ZNE (reduce over-production versus rooftop solar)
Cons Does not directly promote community solar goal Rooftop space on homes may be limited	**Cons** Rule 18 billing issues Cost of trench Maintenance of trench Security at PV location Land requirements

An additional issue that should be considered for the rooftop + delayed loop scenario is the optics among residents of having only a portion of houses with rooftop PV, and the related cost and billing discrepancies that would be associated with serving only a portion of residents on the community loop.

7.3 Key Sensitivities

To create a robust roadmap, we tested the sensitivity of the results to changes in key variables, described below.

7.3.1 WHAT PV GENERATION STRATEGY SHOULD BE EMPLOYED? SHOULD A DIFFERENT PV BUSINESS MODEL OTHER THAN ROOFTOP PV BE PURSUED?

Our results show that, with given assumptions, the most cost-effective strategy is to begin with rooftop PV, but optimal strategies depend on both construction rates and reductions in PV costs. The above evidence suggests:

If the construction rate is…	Then
30 homes per year	pursue rooftop PV first, then, depending on trench costs, pursue a delayed loop.
60 homes per year	with slow PV cost declines, pursue rooftop PV only, but with faster PV cost declines, pursue rooftop PV first, then, depending on trench costs, pursue a delayed loop.
100 homes per year	pursue rooftop PV only.

Note: NSHP declines are the main driver of these results.

7.3.2 WHAT LEVEL OF EE SHOULD BE PURSUED? SHOULD A DIFFERENT EE PACKAGE BE PURSUED DEPENDING UPON FUTURE PV PRICES?

As the above tables show, Advanced A is the most economic package across all PV price scenarios, but this conclusion should be re-evaluated if EEM costs or incentive levels change significantly. Future PV prices do not appear to have a substantial impact on EE package selection.

© 2013 Energy and Environmental Economics, Inc.

7.3.3 DO RESULTS CHANGE IF EVS ARE ADDED?

There are a number of potential EV scenarios. The results presented in Table 37 below assume 65% commuter, 35% "errand runner" usage and controlled charging. In the scenarios considered in this study, EVs are cost-effective relative to gasoline-powered vehicles. Adding EVs increases the NPV of benefits to West Village homeowners, but does not affect the choice of business model.

Table 37. Change in Results with EVs (Change in NPV, M$)

Home Construction Rate	EEM Package	Learning Curve Progress Ratio	Rooftop PPA	Rooftop + Delayed 2017 Loop PPA
30	Advanced A	75%	1.2	1.7
30	Advanced A	90%	0.5	1.3
60	Advanced A	75%	1.6	2.1
60	Advanced A	90%	1.1	1.5
100	Advanced A	75%	1.7	2
100	Advanced A	90%	1.2	1.2

7.3.4 WHAT IF PROJECTED RETAIL ELECTRICITY RATES ARE DIFFERENT THAN ASSUMED?

Changes in retail electricity rates impact homeowner costs for both residents in the West Village and baseline homes. PG&E retail electric rates were assumed to escalate at 2.3% real (versus nominal) through 2020.[18] Post-2020 retail electric rate escalation was assumed to be 1.5% in the base case. Increases in projected retail electric rates increase the NPV of benefits to West Village

[18] E3 CPUC GHG Calculator, http://www.ethree.com/public_projects/cpuc2.php.

homeowners, but again do not affect the choice of business model. There is approximately a $1 million difference between low (2.3% through 2020, 0.5% post-2020) and high rate escalation (2.3% in all years) rate increase scenarios.

Table 38. Change in Results with Low Rate Escalation (0.5% after 2020) and High Rate Escalation (2.2% after 2020) (Change in NPV, M$)

Home Construc-tion Rate	EEM Package	Learning Curve Progress Ratio	Low Rate Escalation		High Rate Escalation	
			Rooftop PPA	Rooftop + Delayed 2017 Loop PPA	Rooftop PPA	Rooftop + Delayed 2017 Loop PPA
30	Advanced A	75%	-0.5	-0.5	0.4	0.4
30	Advanced A	90%	-0.5	-0.4	0.4	0.4
60	Advanced A	75%	-0.4	-0.4	0.3	0.5
60	Advanced A	90%	-0.4	-0.4	0.4	0.3
100	Advanced A	75%	-0.3	-0.4	0.3	0.3
100	Advanced A	90%	-0.3	-0.8	0.3	-0.1

7.3.5 WHAT IF STUDIO UNITS ARE NOT CONSTRUCTED?

Because they are not eligible for energy efficiency incentives, and because CARE rates lead to lower electric bill differentials between West Village and baseline homes, studio apartments in the West Village have higher overall costs than baseline homes. Hence, not building studios increases the NPV of energy benefits to West Village homeowners, but does not affect the choice of business model (Table 39). The results in Table 39 assume no electric vehicles. Of course, attractiveness of studio apartments to West Village homeowners will not be driven by energy cost considerations alone.

© 2013 Energy and Environmental Economics, Inc.

Table 39. Change in Results without Studio Apartments (M$)

Home Construction Rate	EEM Package	Learning Curve Progress Ratio	Rooftop PPA	Rooftop + Delayed 2017 Loop PPA
30	Advanced A	75%	1.2	0.8
30	Advanced A	90%	1.9	1.3
60	Advanced A	75%	1.1	1
60	Advanced A	90%	1.7	1.4
100	Advanced A	75%	1	1
100	Advanced A	90%	1.5	1.1

7.3.6 WHAT IF HOME ENERGY USE IS DIFFERENT THAN ASSUMED?

If home energy use is different than assumed it raises two issues: (1) how to maintain ZNE at the West Village, and (2) whether the West Village remains economic relative to the Standard home. As discussed previously, the most economic strategy for maintaining ZNE is through minimizing PV system over-generation and purchasing RECs. Depending on future technology costs, shortfalls in onsite energy supply may also be addressed with additional renewable generation such as an onsite biogas fuel cell. If West Village energy use decreases over time, surplus PV generation may be sold. Increases in energy use due to new technology adoption would likely increase baseline home energy use commensurately.

7.4 Business Models under Regulatory Change

Two changes in regulatory policy could have particularly important implications for the West Village, improving project economics: (1) virtual net metering (VNM); and (2) aggregated NSHP (Table 40). These two changes could significantly improve economics for other developments planning to achieve zero-net energy use on a community scale as well. In addition, there are regulatory issues around energy efficiency and biogas that could affect project economics.

Table 40. Business Models under Regulatory Change

Potential PV Business Model	Regulatory Model	Incentive	PG&E Rate	Status
Community PV - Generation facility not necessarily at West Village – no trench costs	Community Virtual Net Metering	CSI	Residential (tiered or tiered TOU)	√
Community PV	NEM	NSHP	PG&E small commercial TOU rate	√

7.4.1 COMMUNITY VIRTUAL NET METERING

Under a community virtual net metering (VNM) model, the West Village would construct an appropriately sized community-scale PV system on the West Village site and directly connect to the PG&E distribution system. The community VNM approach considered would look similar to the VNM allowed for multi-family buildings, but relaxes the single 'Service Delivery Point' (SDP)

© 2013 Energy and Environmental Economics, Inc.

requirement to the various delivery points in the West Village community[19]. The system would receive CSI incentives (or NSHP incentives if the program were changed as discussed below), residents of the community would subscribe to a portion of the community project and would receive a bill based on standard PG&E rates per their consumption, less the generation of their portion of the community project. If made available, the community VNM model would improve the West Village project economics by approximately $1.8 million (NPV). However, current regulations do not support community VNM. UC Davis could consider pursuing a regulatory change to implement community VNM for the zero net energy single-family homes at West Village.

7.4.2 AGGREGATED NHSP

Under an "aggregated NSHP" model, the New Solar Home Partnership (NSHP) incentives would be made available for community-scale rather than single rooftop installations. With a rule change for NSHP that allowed this approach, West Village would construct a community-scale PV system billed under schedule A-6 with NEM bill credits and would receive NSHP incentives that aggregate over installed system kW. However, NSHP is not available for community-scale PV systems even if planned and built in conjunction with a new residential development. This encourages rooftop solar PV systems, even though a community system would be more cost-effective and allow more PV to be built per incentive dollar from the program. If the California Energy Commission were to allow aggregated NSHP, the effect would be at least a $3 million (NPV) improvement in the West Village project economics. An

[19] See http://www.cpuc.ca.gov/PUC/energy/DistGen/vnm.htm for a description of the existing California VNM rules

aggregated NSHP change would significantly help West Village because of the unique situation of faculty / staff housing on UC Davis land, however, it would likely not help other ZNE community developments without the simultaneous adoption of community VNM. The two rule changes together would make a significant impact on ZNE developments in the State.

7.4.3 OTHER REGULATORY ISSUES

Aside from regulatory issues already mentioned, such as incentive decline or expiry, a number of other regulatory changes could affect West Village energy choices and project economics.

- Increasing compensation for excess PV generation sold to the grid through net energy metering (NEM) could strengthen the case for oversizing PV systems to account for future degradation and uncertainty in energy consumption. Currently, net surplus compensation provides less than $0.04/kWh while feed in tariff is nearly $0.12/kWh.
- Changes in energy efficiency incentives or individual measure costs (e.g., for LED lighting or natural gas incentives) could increase the "supply" of energy that West Village homes obtain from energy efficiency and reduce PV and biogas needs. Measure costs should be periodically re-evaluated and the Advanced A package adjusted accordingly.
- Allowing more than one building per property to be eligible for utility energy efficiency incentives would make the studio apartments more cost-effective and promote greater energy efficiency investment in the new studio apartments. This rule change aligns with building greater residential density, and encouraging 'in-fill' of existing residential areas which has other benefits like increase effectiveness of public transportation and better land use.

© 2013 Energy and Environmental Economics, Inc.

- Developments in regulatory issues around biogas in pipelines could reduce the costs of biogas, or make this strategy more difficult to achieve. More restrictive rules on out-of-state biogas may limit out-of-state options. Less restrictive rules on in-state biogas may make working with PG&E for biogas easier and less expensive.
- Retail rate levels, metering abilities and/or rate designs may change in the future, in ways that could materially impact Project economics.
- Allowing and facilitating submetering for EVs would significantly improve EV economics, particularly by removing EV electricity use from the baseline allowances in the tiered residential rate structures.

7.5 Utility Roles

The project analysis considered potential roles for PG&E in the zero-net energy single-family home business models. These potential roles could allow PG&E to participate in nearly every aspect of the project and would support the research and business and regulatory change necessary to meet the State's 2020 residential zero-net energy metering goal. Table 41 summarizes the potential roles; they are described in more detail below.

Table 41. Potential Utility Roles

Area	Role
Solar PV	Tax equity participation in solar PV ownership
Biogas	Biogas offset provider
EV	Pilot program for submetering of EVs
Administrative	Billing mechanisms, such as on-bill energy efficiency financing
Other	Participation in West Village visitor center or lab house

7.5.1 TAX EQUITY PARTICIPATION IN SOLAR PV OWNERSHIP

Under such an arrangement, PG&E Corporation would provide capital to the solar PV equipment provider in exchange for payments, including federal ITC and 5-year MACRS tax depreciation. PG&E has established such an arrangement with SolarCity Corp. and SunRun, Inc.

7.5.2 BIOGAS PROVIDER

Under such an arrangement, PG&E would sell biogas offsets from its biogas supplies to the West Village. West Village residents would continue to take PG&E retail natural gas supply, with a premium to offset costs of biogas. This option might appeal to other PG&E natural gas customers that want to achieve a higher mix of renewable generation as well and the size and purchase power of PG&E would likely make biogas, using the existing pipeline system, a more feasible option.

7.5.3 PILOT PROGRAM FOR SUBMETERING EVS

Allowing and facilitating submetering for EVs would significantly improve EV economics, particularly by removing EV electricity use from the baseline allowances in the tiered rate structures. A PG&E pilot program at West Village would test EV submetering on a pilot basis before it is implemented for all PG&E ratepayers.

© 2013 Energy and Environmental Economics, Inc.

7.5.4 BILLING MECHANISMS

PG&E offers zero interest on-bill financing for many EEMs to its business and government agency customers; residential customers are not eligible for this program. While West Village residents can be billed for incremental energy costs via monthly community service invoices, a PG&E billing mechanism may instead be utilized to bill residents for certain costs, such as those related to PG&E-procured biogas offsets or the costs of a community PV system. This on-bill program may help keep utility costs on one bill, versus the ground-lease billing mechanism.

7.5.5 PARTICIPATION IN VISITOR CENTER

There are several ways in which PG&E could participate in a West Village visitor center including: Sponsorship of exhibits, programs, information, or data to support visitor center activities and supplying full- or part-time staff.

7.5.6 PARTICIPATION IN LAB HOUSE

There are several ways in which PG&E could participate in a West Village lab house, including:

- With resident approval, provision of PG&E data such as residents' rate schedule and usage could be provided for student research;
- Sponsorship of or participation in pilot programs such as electric vehicle submetering, or demonstrations of emerging technologies such as lighting or energy efficiency;
- Supply of lab house equipment;

- Supply of full- or part-time staff;
- Supply of information or data to support lab house activities.

© 2013 Energy and Environmental Economics, Inc.

8 Fuel Cell and Storage Analysis

We examined an onsite fuel cell and storage device to determine whether either of these technologies would be cost-effective for the West Village. This section describes the fuel cell and storage analysis.

8.1 Fuel Cell Analysis

If added in conjunction with the solar PV system, fuel cells fueled by biogas would contribute to West Village goals because they demonstrate multiple renewable resources. Therefore, we evaluated the expected costs of biogas fuel cells to determine if it could be implemented and still meet the project cost goals. The economics of fuel cell implementation at the West Village hinge on fuel cell capital costs and the availability of biogas on site. Current fuel cell costs were established based on current capital and operating costs and current incentive levels. Future fuel cell costs were projected based on learning curves and declines in future incentive levels.

Fuel cell capital costs were assumed to be $8.50/W.[20] Fuel cells utilizing biogas were assumed to be eligible for a California's self-generation incentive program (SGIP) incentive of $4.50/W[21] and a 30% federal ITC. The fuel cell useful life was assumed to be 10 years.[22] Additionally, current PG&E tariff regulations specify a $0.015/kWh departing load charge. To calculate a fuel cell LCOE, we developed an Excel-based pro forma model incorporating the impacts of capital and operating costs, incentives, taxes, and cost of capital to estimate a total net cost of fuel cells to the West Village project. Given the assumptions described above, a 90% capacity factor, and assuming biogas costs of $2/therm, the real LCOE would be approximately $0.21/kWh.

Future fuel cell costs were projected using the following assumptions: A learning curve with a progress ratio of 82%; expiration of the SGIP incentive ($4.50/W) at the end of 2015; and a decline of the ITC to 10% in 2017. The resulting fuel cell LCOE is shown below.

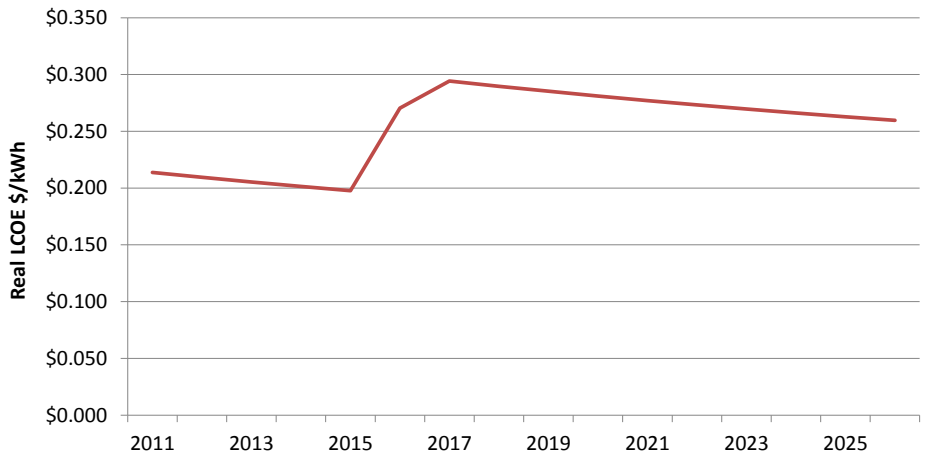
[20] Based on Itron, "CPUC Self-Generation Incentive Program: Cost-Effectiveness of Distributed Generation Technologies Final Report," February 9, 2011, Page A-20. Available at: http://www.cpuc.ca.gov/NR/rdonlyres/2EB97E1C-348C-4CC4-A3A5-D417B4DDD58F/0/SGIP_CE_Report_Final.pdf

[21] See http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA23F&re=1&ee=1. This incentive is based on a $2.50/W fuel cell incentive and a $2.00/W biofuel incentive.

[22] Based on the performance guarantee of 10 years for fuel cells cited in: http://docs.cpuc.ca.gov/efile/CM/141128.pdf.

© 2013 Energy and Environmental Economics, Inc.

Figure 20. Fuel Cell Levelized Cost of Energy by Install Year



Depending on cost reductions in solar PV, future fuel cells may be cost-effective. For example, in 2017 levelized costs for rooftop PV under slower cost reductions (90% progress ratio) are $0.35/kWh, while fuel cell costs are $0.30/kWh. However, with faster learning curve improvements, solar PV will remain more economic than a fuel cell. Even with faster than anticipated reductions in fuel cell costs, the most significant challenge to onsite biogas-fueled fuel cells is likely to be obtaining a steady source of biogas. In addition, a larger fuel cell with these economics is only feasible in the loop configuration since the size is large compared to any single homes energy use. It follows that the same submetering challenges, and trenching costs for West Village that are problematic for community solar PV apply to the fuel cell as well. Therefore, because of relatively poor economics, challenges with the loop model, and availability of local biogas, the fuel cell is not a recommended component of the West Village roadmap at this time.

8.2 Storage Analysis

Onsite electricity storage is another possibility in West Village and could potentially provide a range of applications at the West Village, including: load following to smooth the West Village consumption profile, firming intermittent output of onsite solar PV generation, improving reliability in the event of a utility outage, and reducing retail bills through shifting energy consumption from low-cost to high-cost periods. These potential applications, and their costs and benefits, are described below.

8.2.1 STORAGE APPLICATIONS

8.2.1.1 Load Following

A load following storage application charges when loads are low and discharges when loads are high, thereby flattening and smoothing the net load shape of the community consumption profile. Storage does not displace the amount of solar PV generation required for ZNE; it simply changes the timing of when energy is supplied from the grid such that more is drawn during periods when loads are low and storage is charged, and less is drawn during periods when loads are high and storage is discharged. While an improved load profile may benefit the PG&E grid, this application was not evaluated for West Village because there is no monetary benefit to West Village of a smoother consumption profile.

© 2013 Energy and Environmental Economics, Inc.

8.2.1.2 Firming Intermittent PV Generation

A firming storage application is similar to a load following application, but would charge when there is excess PV generation and discharge when there is a shortfall. The affect would be less imports / exports to the PG&E grid and an improved 'net load' profile of the West Village project. However, this storage application was not evaluated for West Village because there is no monetary benefit to West Village of a smoother consumption profile.

8.2.1.3 Retail Rate Arbitrage

This storage application was analyzed by looking at the potential to shift energy consumption to lower cost periods in the retail rates. For example, a TOU rate charges less at night and more on-peak so a retail rate arbitrage application would charge at night and discharge during the day. Like the other storage applications, storage does not displace the amount of solar PV generation required for ZNE, but instead changes the timing of energy supplied from the grid such that more is drawn during off-peak periods to charge storage when energy is inexpensive and less is drawn during on-peak periods when energy is expensive and storage is discharged. Since PG&E offers retail rates that vary by TOU period, there is a way for customers to be paid for shifting consumption off-peak with an energy storage device.

Storage was modeled for the duration of a typical year and relevant electric rate schedules using E3's Energy Storage Valuation Tool (ESVT), which was developed for the Electric Power Research Institute (EPRI) and uses the Analytica software program. The household load shape was based on annual

home usage net of PV generation. For the community scenario, retail rates assumed the A-6 tariff, which is a TOU tariff with no demand charges. For the rooftop PV scenario, rates assume E-6, which is a tiered TOU rate with no demand charges.

Results of the retail rate arbitrage scenario are shown in Table 42, below. Several technology types were evaluated; industrial lead-acid, sodium-sulfur, and lithium-ion batteries of both large- and small-scale were evaluated given their respective cost, performance, and degradation characteristics based on number of charge / discharge cycles. Table 42 shows that, given current storage costs and electric rates, storage is not economic. With community PV, the 1 kW / 6 kWh industrial lead-acid battery is close to being economic, requiring a 4% decline in capital costs to break even. In the rooftop PV scenario, capital cost declines of over 60% are necessary to break even. The inclusion of electric vehicles does not impact these results because electric vehicles do not impact the arbitrage cost and benefit streams.

© 2013 Energy and Environmental Economics, Inc.

Table 42. Storage Results for Community and Rooftop PV Systems

Community PV with A-6 tariff

Usable Energy Storage	NPV of Benefits	System Cost	System Life (Years)	Net NPV
1000 kW Industrial Lead-Acid				
4000 kWh	$1,576,698	$1,700,000	10	($140,405)
6000 kWh	$2,475,678	$2,550,000	10	($99,977)
1000 kW Nas				
4000 kWh	$1,095,752	$1,776,000	20	($547,871)
6000 kWh	$1,744,494	$2,664,000	20	($720,941)

Rooftop PV Systems with E-6 Tariff

Usable Energy Storage	NPV of Benefits	System Cost	System Life (Years)	Net NPV
1 kW Li-Ion				
4 kWh	$738	$3,852	10	($2,986)
6 kWh	$1,085	$5,778	10	($4,502)
1 kW Lead-Acid				
4 kWh	$609	$1,700	10	($1,034)
6 kWh	$956	$2,550	10	($1,510)
8 kWh	$1,157	$3,400	10	($2,131)
10 kWh	$1,225	$4,250	10	($2,884)

8.2.1.4 Improving Grid Reliability

This storage application was analyzed by comparing annual outage costs for West Village home owners and the annual costs to purchase and operate an onsite storage system as a backup source of electricity. The avoided cost of outages was derived from System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) figures for PG&E assuming that West Village would receive average reliability. SAIDI tracks the duration of outages, while SAIFI tracks their frequency. Storage can eliminate or reduce the duration and frequency of these outages, thereby avoiding outage costs.

In the improving grid reliability application, the benefits of avoiding outages through installation of storage are not remotely close to economic and provide

on the order of 3% of benefits from rate arbitrage. PG&E reliability levels are very high, and improving them further through battery storage is not cost-effective, particularly for the residential customers in the West Village.

© 2013 Energy and Environmental Economics, Inc.

9 Ways to Foster "Community" ZNE Experience at the West Village

The focus of the West Village roadmap is in developing a community capable of achieving ZNE goals. Building and maintaining a "community" experience at the West Village — creating a "ZNE lifestyle" — is as important as technology for maintaining and meeting longer-term ZNE goals. This section describes possible approaches to developing such a community experience.

9.1 Fostering Community

In absence of a community-scale PV system, finding methods of fostering community among West Village single-family home owners may take on a greater importance. Periodic community social gatherings can generate strong community cohesion. Additional opportunities include seminars or workshops on community energy issues.

9.1.1 LAB HOUSE

Creation of a lab house at West Village can bring the West Village, City of Davis, UC Davis staff and students, and energy communities together.

- With resident approval, household data such as demographics, house plan type, house size, and usage could be provided for student research. PV system degradation could also be studied.
- The lab house could provide a test bed for emerging technologies to be integrated in subsequent project phases. Industry could be engaged to help reduce costs. The California Lighting Technology Center (CLTC) and Western Cooling Efficiency Center (WCEC), in particular, could undertake technology research.
- The lab house could provide a showcase for the community and the general public highlighting technologies and/or student research. For example, it could employ very high levels of energy efficiency as a demonstration.
- The lab house could provide a central gathering place in the West Village for the UC Davis energy community.

9.1.2 FOSTERING ENERGY EFFICIENCY GOALS THROUGH FEEDBACK

Promoting and re-enforcing energy efficient behavior through providing feedback on energy use will be important in maintaining ZNE in the future. On-going feedback can be provided to residents in many ways, including via:

- In-home displays
- Tools to control "leaking" energy use
- Education
- Usage Tracking Energy usage comparisons to neighbors or other communities
- Contests promoting continuous incentives to conserve
- Publicity of consumption data, such as posting at community mailboxes

© 2013 Energy and Environmental Economics, Inc.

9.1.3 CAR SHARE PROGRAM

An electric vehicle car share program could be implemented at the West Village. This could increase EV usage among residents and contribute to improving the quality of life at the West Village. The southeast corner of the Los Rios parking lot has been identified as a potential location for such a program, however this location may be too distant from residents.

10 Roadmap

10.1 Achieving Zero Net Energy at No Higher Cost is (Very Nearly) Possible

This report finds that the goal of achieving ZNE at no higher cost to the developer is nearly within reach. The developer costs for constructing the ZNE homes are on the order of $2,500 per home relative to a comparable home in the City of Davis after incentives, assuming 60% penetration of studio units. These cost estimates are based on detailed architectural and engineering estimates, and include soft costs for incorporating energy efficiency. If these costs were passed on to the home buyer, or covered in a UC Davis financing arrangement, the developer could actually achieve no higher cost.

From the homeowner perspective, the lifecycle cost of buying and owning the home ranges from higher to lower than a conventional home. If PV cost reductions and home construction rates are slower, lifecycle costs of the West Village ZNE homes are higher than conventional homes. If construction rates are faster, or with more rapid PV cost declines, the ZNE homes cost less than conventional homes. In the scenario with the highest net benefits, we estimate that the lifecycle savings may be as large as $2.5 million, or more than $7,000 per home.

© 2013 Energy and Environmental Economics, Inc.

10.2 West Village Roadmap

Based on the analysis described in this report, we recommend that UC Davis pursue the following roadmap.

UC Davis West Village Roadmap

- Pursue mid-level EEM package Advanced A.
- Because of regulatory obstacles to community-based solar, use rooftop solar strategy for electricity generation through 2014, then re-evaluate.
- Use tradable RECs and offsets for demand/supply balancing of PV and biogas, given the challenge of forecasting future electricity and natural gas demand and solar PV degradation.
- Pursue natural gas homes with biogas offsets to reduce costs, improve system efficiency, and improve marketability of homes.
- Foster electric vehicle adoption; car share and/or in-home charging can improve economics and reduce overall carbon footprint of the community.
- Explore feedback mechanisms to manage energy consumption post-construction.
- Explore a smaller, community-based system coupled with downsizing of rooftop PV to improve customer economics and optics.

The rationale for this roadmap is described in Table 43, below.

Table 43. Rationale for Roadmap Measures

Roadmap Measure	Rationale
Pursue mid-level EEM package Advanced A.	This package delivers the most economic set of energy efficiency measures, providing source energy savings versus a Title 24 + 15% home of 26% for the main house and 17% for the studio, at an incremental cost of $2,554.
Use rooftop solar strategy for electricity generation through 2014, then re-evaluate.	Due to current virtual net metering regulations, community-scale PV is not economic. The West Village team should potentially pursue a community-scale PV system in the future should virtual net metering regulations change and the economics of a community PV system improve.
Use tradable RECs and offsets for demand/supply balancing of PV and biogas, given the challenge of forecasting future electricity and natural gas demand and solar PV degradation.	The strategy of using RECs and biogas offsets to balance renewable energy supplies provides great flexibility to the West Village ZNE development. For electricity, any future usage growth or shortfalls in PV panel generation due to degradation can be easily supplied using PG&E retail electricity and made renewable via RECs. Similarly, biogas offsets can be procured in amounts to match construction period phase-in, as well as future usage fluctuations.
Pursue natural gas in homes with biogas offset (rather than all-electric homes)	The use of natural gas in homes, with a biogas offset, rather than developing all-electric homes, reduces costs, improves system efficiency, and improves marketability of homes.
Foster electric vehicle adoption	In-home charging and/or car share programs can improve West Village economics and reduce the overall carbon footprint of the community.
Explore feedback mechanisms to manage energy consumption post-construction.	The economic success of the West Village hinges on reinforcing energy efficient behaviors among residents throughout the life of the development. Exploring feedback mechanisms and integrating education and behavior reinforcement will be keys to ensuring zero net energy is achieved at the West Village at no higher cost.

© 2013 Energy and Environmental Economics, Inc.

10.2.1 COMMUNITY RESOURCE OPTION

As West Village nears construction using a rooftop approach, there may be some economic opportunity to introduce some 'community' solar PV resources. In particular, one option was suggested by the West Village team for future evaluation. It would entail a smaller, community-based system coupled with downsizing of rooftop PV to improve customer economics and optics. Under this scenario, the rooftop PV systems would be downsized, for example, to 80% of projected household usage. This would ensure that systems would not yield excess generation annually. The community-based PV system would be sized for remaining output (i.e., the remaining 20% of projected usage for all households in the West Village).

The presence of a community system would help reinforce the community nature of the West Village. With no virtual net metering, there is no direct mechanism to credit output of the community system to customers. Hence, the community-based generation would be sold via a power purchase agreement (PPA), likely including renewable attributes. PPA revenues would be credited to residents, largely but not entirely offsetting the cost of the community system. Usage above rooftop PV generation would be served with PG&E retail electricity service with purchased RECs. If renewable attributes were not sold with the PPA, purchased RECs would not be required. Although we were not able to include analysis of this business model in this report, it will be included in future West Village analysis.

11 Appendix

Table 44 below matches sections of the report to the grant tasks to which they correspond.

Table 44. Rationale for Roadmap Measures

Section	Name	Grant Tasks Involved
2	Baseline Home Development	CSI RDD Grant Task 1 (Complete Financial Modeling of Business Models) CSI RDD Grant Task 4 (Develop Offering Materials including Financial Pro Forma and Draft Term Sheet)
3	Energy Efficiency Analysis	CSI RDD Grant Task 1 (Complete Financial Modeling of Business Models) CSI RDD Grant Task 4 (Develop Offering Materials including Financial Pro Forma and Draft Term Sheet)
4	PV System Analysis	CSI RDD Grant Task 1 (Complete Financial Modeling of Business Models) CSI RDD Grant Task 4 (Develop Offering Materials including Financial Pro Forma and Draft Term Sheet)
5	Biogas Analysis	CSI RDD Grant Task 1 (Complete Financial Modeling of Business Models) CSI RDD Grant Task 4 (Develop Offering Materials including Financial Pro Forma and Draft Term Sheet)

© 2013 Energy and Environmental Economics, Inc.

Section	Name	Grant Tasks Involved
6	Electric Vehicle Analysis	CSI RDD Grant Task 1 (Complete Financial Modeling of Business Models)
7	Identification of Potential Business and Regulatory Models	CSI RDD Grant Task 3 (Identify Regulatory Barriers to Adopting Business Model) CSI RDD Grant Task 4 (Develop Offering Materials including Financial Pro Forma and Draft Term Sheet)
8	Fuel Cell and Storage Analysis	CSI RDD Grant Task 1 (Complete Financial Modeling of Business Models)
9	Ways to Foster "Community" ZNE Experience at the West Village	CSI RDD Grant Task 3 (Identify Regulatory Barriers to Adopting Business Model)