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FINAL REPORT

UC DAVIS WEST VILLAGE RESCO TECHNICAL INTEGRATION PROJECT

Prepared for: California Energy Commission
Prepared by: University of California, Davis
Environmental Stewardship and Sustainability

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The Zero Net Energy (ZNE) goal for West Village grew out of a collaborative effort between UC Davis and West Village Community Partnership, LLC; after the neighborhood was already well along in the design phase. Preliminary evaluation of affordable energy efficiency measures done in collaboration with the UC Davis Energy Efficiency Center revealed that the ZNE goal might be within reach. The California Energy Commission Renewable-based Energy Secure Community (RESCO) grant program funding became available at a critical stage to support the evaluation and feasibility analyses necessary to develop the technical, financial, policy and legal understanding necessary to decide how to pursue the goal. The Energy Commission RESCO grant was foundational to the ZNE effort at West Village.

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This final report summarizes the results of a broad team that researched and analyzed the many aspects of the effort. Follow are some of the key leaders in this effort. We are deeply indebted to all:

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PREFACE

The California Energy Commission Energy Research and Development Division supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The Energy Research and Development Division conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

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- Renewable Energy Technologies
- Transportation

UC Davis West Village RESCO Technical Integration Project is the final report for the UC Davis West Village RESCO Technical Integration project (Grant Award Number PIR-08-035) conducted by the University of California, Davis. The information from this project contributes to Energy Research and Development Division's Renewable Energy Technologies Program.

For more information about the Energy Research and Development Division, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-327-1551.

ABSTRACT

The University of California, Davis, is striving to develop a Zero Net Energy (ZNE) community at West Village, an on-campus neighborhood for university students, faculty and staff. ZNE is defined as zero net energy from the grid measured on an annual basis. Including deep energy efficiency measures in all facilities is fundamental to meet demand with on-site renewables. Several alternative approaches to meeting the remaining demand with renewable energy were also evaluated. West Village Community Partnership, LLC, the private developer for West Village, ultimately chose to supply renewable energy using photovoltaic panels developed through the California Solar Initiative's New Solar Home Partnership program. Financial, regulatory, technical and policy evaluation of various approaches to ZNE solutions was conducted and recommendations were made to facilitate achieving ZNE goals at other communities in the future. The feasibility of developing a biodigester to produce electricity from biogas also was evaluated. This generation source was not included in the West Village development for financial and technical reasons; however, it was constructed elsewhere on the campus. During the course of planning for West Village, the potential for Plug-in Electric and Plug-in Hybrid Electric Vehicles to significantly increased grid-based energy was characterized and strategies developed for providing local renewable energy.

Keywords: Anaerobic Digester, Biodigester, Energy Conservation, Energy Efficiency, Onsite Generation, Plug-in Electric Vehicle, Plug-in Hybrid Vehicle, Renewable Energy, RESCO, Technology Transfer, UC Davis, West Village, Zero Net Energy

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EXECUTIVE SUMMARY

Introduction

In 2003, the University of California adopted a plan to create a new neighborhood for students, faculty and staff. Today, this community is known as UC Davis West Village (West Village). When completed, it will cover approximately 205 acres and will be the home for approximately 3,000 students and 475 staff and faculty families with a total population of approximately 5,000. The community also will host the first community college on a University of California campus and will have approximately 42,500 square feet of retail/office space.

Through a collaborative design process with West Village Community Partnership, LLC, and UC Davis expanded its core principle to make UC Davis West Village environmentally responsive and launched the West Village Energy Initiative. Working together, UC Davis and West Village Community Partnership first looked for ways to make West Village as energy efficient as possible. In 2007, the UC Davis Energy Efficiency Center and the Davis Energy Group identified deep energy efficiency measures that could be included in the design of the student housing and single family residences. The results demonstrated that by adopting extensive energy efficiency measures, West Village Community Partnership could reduce energy consumption in West Village by nearly 50 percent beyond the California Energy Efficiency Building Code.

With this result, West Village Community Partnership and UC Davis realized that a larger goal was within reach – the goal of making West Village a Zero Net Energy (ZNE) community. In 2008, West Village Community Partnership engaged Chevron Energy Solutions to evaluate the conceptual financial feasibility of achieving a ZNE or "zero net electricity from the grid measured on an annual basis" goal.

In 2009, West Village Community Partnership and UC Davis decided to strive for this goal. Because West Village had to be accessible for UC Davis faculty, students and staff, the ZNE goal had to be balanced against affordability. The West Village Energy Initiative was created and the following principles adopted:

- West Village would strive to use ZNE from the grid measured on an annual basis.
- ZNE must be achieved at no additional cost to the developer.
- ZNE must be achieved at no additional cost to the consumer.
- West Village would adopt deep energy efficiency measures to reduce energy demand.
- ZNE would be achieved through multiple renewable resources developed on-site at a community scale.
- West Village would be used as a living laboratory for further energy-related topics.

Project Purpose

UC Davis was awarded a California Energy Commission Renewable-Based Energy Secure Community (RESCO) grant in February 2010 and work on the ZNE project began immediately.

The overall goal of the UC Davis RESCO grant agreement was to resolve the remaining barriers to make the West Village one of the world's leading sustainable communities.

The Energy Commission RESCO grant was foundational to develop strategies for the ZNE goal. It provided a significant portion of the funds required to pursue the ZNE concept that was in the implementation stages, not in preliminary design. The topics evaluated with Energy Commission RESCO funding include:

- Evaluate deep energy conservation measures;
- Determine the energy requirements of the community;
- Understand the likely increasing demand for plug-in vehicles;
- Evaluate renewable energy options;
- Evaluate multiple physical design models;
- Select the current approach to ZNE;
- Understand the financial and regulatory incentives and barriers to the ZNE goal; and
- Recommend methods for advancing ZNE to other communities.

Project Results

Evolution of the ZNE Concept

The overall approach to ZNE at West Village included evaluating several design concepts and all were predicated on adopting deep energy conservation measures:

- An "islanded" community with on-site renewable energy through community solar arrays and a community energy park that included a biodigester linked to a fuel cell and advanced storage battery system.
- A "three-loop model" distributing solar and fuel cell renewable energy in three one-megawatt distribution loops to the multifamily and mixed use portion of West Village and a solar power purchase agreement for single family homes.
- An "all photovoltaic" renewable energy model for the multifamily housing under the California Solar Initiatives New Solar Home Partnership.

The "all photovoltaic" concept was chosen and implemented for multifamily housing at West Village. Further analyses concluded that the "three-loop" and "all photovoltaic" models were not feasible for various combinations of these reasons:

- Regulatory issues for an "islanded" community;
- Cost of the fuel cell and battery;
- Low tariffs available for biogas electricity;
- Lack of incentives for non-solar renewable energy;

- Higher costs to construct three 1-megawatt loops to take advantage of California Solar Initiative incentives;
- Lack of reimbursement by the Investor-Owned Utility for behind the meter infrastructure;
- Regulatory issues for community-scale solar; and
- Financial issues associated with the timing of housing construction and phasing of renewable energy resources.

Feasibility analysis and preliminary planning for the biodigester resulted in a shifted focus for that element of the ZNE concept. Building on a previous Energy Commission RESCO grant analyses, UC Davis was awarded a U.S. Department of Energy Community Renewable Energy Grant and an Energy Commission American Recovery and Reinvestment Act matching grant for design and construction of a biodigester. As a result, a 50-ton per day facility was built in collaboration with CleanWorld and opened April 2014. The site for the biodigester is the existing campus landfill located approximately 1.5 miles southwest of West Village. The electricity from the facility will be connected to the campus electrical grid. While this source of electricity will not directly feed West Village, which is tied to the Pacific Gas & Electric grid, a portion of the renewable energy could be credited to West Village to meet the ZNE goal.

Designing and Integrating PEVs into ZNE Communities

The potential for Plug-in Hybrid and Electric Vehicles to significantly increase electricity demand has grown substantially in recent years. Under the RESCO project the team was able to expand their evaluation to include integrating smart grid electric vehicle charging stations and also provide a case study on planning and installing Electric Vehicle Supply Equipment (EVSE) and mitigating electric vehicle charging loads with solar PV. The project resulted in these results and recommendations:

- Similar to traffic impact analysis for new real estate developments, developers and planners should also consider evaluating travel to understand the potential energy impacts to the community from future electric vehicle charging loads. Such an analysis would inform electrical infrastructure investment, including appropriate sizing of renewable energy generation systems in ZNE communities.
- ZNE communities should embrace and engage electric vehicle infrastructure in early planning and construction stages. These communities cannot be viewed as sustainable without addressing electric vehicle infrastructure. Installing conduit dedicated to vehicle charging in parking areas during construction is a strong recommendation. Given the current and project growth of the electric vehicle market, developers and planners should plan aggressively for electric vehicle charging infrastructure.
- For the modeled energy consumption from electric vehicle use at the single family homes in West Village, the project team found great variability ranging from 3.0 kWh to 27.5 kWh's per day. Given this variability, it is not reasonable to expect that the onsite solar PV at West Village can accommodate 100 percent of these loads. Rather, West

Village and other real estate development projects should consider providing a minimum amount of extra PV resources or build the homes PV system to be easily expandable, making the home Solar Plug-in Electric Vehicle Ready.

- Smart controls are readily available for many electric vehicle charging stations. These controls can be valuable, particularly to the efficiency of the grid. Those installing or considering installing Level II or higher power electric vehicle chargers in public and workplace applications should strongly consider choosing a charger that has control capabilities. This will allow these charging stations to participate in controlled electric vehicle charging programs such as Demand Response in the future.

Lessons Learned for Future ZNE Communities

West Village provided several key lessons that will be useful to policy-makers and developers interested in pursuing similar projects. These are discussed in greater detail in section 4.2 and are summarized here:

- Creating a ZNE community is feasible under market-rate conditions;
- Given the myriad of challenges any project of this type is sure to encounter, early team alignment on goals is critical for success;
- A rigorous and active approach to energy and financial modeling is critical to be responsive to changing conditions;
- Engage local utility early and often on issues related to project design and operation;
- Building user behavior can have significant and unpredictable impacts on energy use; and
- Opportunities exist to improve the regulatory landscape for future ZNE developers including providing greater certainty on incentive programs and providing flexibility for project owner/operators to provide signals to residents to encourage efficiency.

The uniqueness of West Village has resulted in international media coverage of the project and the project becoming an invaluable case study for achieving market-rate ZNE performance on large construction projects. West Village's distinctiveness comes, in part, from how the design integrates cost-effective energy efficiency and renewable generation measures rather than relying on using a single technology or approach to construction. The lessons learned at West Village can be applied to a wide range of future projects.

Recommend methods for advancing ZNE to other communities

UC Davis led the ZNE Technology Transfer Plan (ZNETTP) efforts. The ZNETTP is designed as a platform for sharing best practices and on-going key learning, not just from West Village, but also other signature large-scale ZNE projects. The plan describes the target audiences, the outreach leadership team, the list of outreach activities, the estimated costs for those activities, and the fundraising strategy for funding the plan.

UC Davis partnered with the Exploratorium to develop specifications for education and outreach tools that can be used to reach general audiences. The tools are specific to West Village, through an Energy Collaboration Laboratory and outdoor energy exhibits, but can be extended through media and partner institutions (including the Exploratorium).

UC Davis also worked with Davis Energy Group to create an on-line ZNE Community Assessment Feasibility Tool to provide a starting point for public and private sector stakeholders as they consider ZNE feasibility for community-scale projects they are working to develop.

Project Benefits

The Energy Commission RESCO grant allowed the UC Davis team to evaluate policy, regulatory, and technological issues associated with ZNE construction in a large real-world project. These evaluation results are consolidated and available to disseminate to, and use by, parties interested in ZNE construction. Prior to the West Village project, an information source of this type did not exist for teams considering ZNE construction.

As the largest planned ZNE community in North America, the benefits associated with disseminating the lessons learned on West Village are unique to the project and could not have been realized any other way than by the team responsible for the project's implementation. These benefits include the ability for interested parties to gain real-world information about:

- Designing and developing a large-scale, market-rate, mixed-use project built to meet California's goals for ZNE residential construction;
- Creating a living laboratory where the effectiveness of various cost-effective ZNE large scale implementation strategies can be evaluated on an ongoing basis;
- Creating and implementing a design methodology that evaluates optimal tradeoff points between completing energy efficiency measures and renewable generation technologies;
- Regulatory issues that may act as barriers to increasing ZNE buildings in California, and suggestions for how regulations may be improved.
- Specific design and construction strategies that may be used across building types to aid building energy efficiency;
- Energy efficiency or renewable generation strategies not supported by current policy, regulation, or technological development.

Availability of this information will aid policy-makers, developers, and building designers by providing a distillation of the lessons learned during the 13-year timeframe of the West Village project. This will assist the building design and construction community in reducing the costs of ZNE construction, and will assist the state in developing future policies that encourage widespread ZNE deployment.

In addition to providing a case study on integrating electric vehicle charging into West Village, the project team's report is intended to assist real estate developers and community planners in preparing for electric vehicles in future zero-net-energy communities. The project team anticipates these findings will help future communities plan for and mitigate electric vehicle charging loads with local renewable energy resources. The findings on energy consumption, mitigation, planning and controlling vehicle charging also benefit California rate payers. By providing best practices for integrating electric vehicles into zero-net-energy communities and understanding the benefits of electric vehicle charging controls, communities can optimize integrating zero-emissions electric vehicles and renewable energy resource into future California zero-net-energy communities.

As California strives to achieve its strategic goals around ZNE, the ZNETTP that UC Davis and the Exploratorium created presents a blueprint for how the state might invest in building a ZNE outreach initiative. Such an initiative would increase the market facilitation ofZNE by positively influencing the targeted specific audiences of policymakers considering regulatory and legislative changes that impact ZNE and key public sector and private sector stakeholders involved in community scale development projects that can incorporate ZNE. The initiative would also influence the public, increasing the market demand for ZNE (retrofit and new home construction applications). Even if the state does not completely fund implementing the plan, having the ZNETTP in place allows potential funding by other entities and its ultimate implementation, which will benefit California going forward.

While the on-line ZNE Community Assessment Feasibility Tool will provide direct initial benefit to users who are considering ZNE (and technological approaches and best practices) for their community projects, it is also an investment. The tool, with additional funding support by the state and/or other entities, can continue to be refined over time to benefit its variety of stakeholders.

CHAPTER 1:
UC Davis West Village and the Zero Net Energy Goals

1.1 UC Davis West Village

In 2003, the University of California, Davis (UC Davis) Long Range Development Plan and the accompanying master plan to create a new neighborhood for students, faculty and staff were adopted by The Regents of the University of California. Today, this community is known as UC Davis West Village (West Village) and is located on the UC Davis campus between Russell Boulevard and Hutchison Drive, just west of State Route 113 (Figure 1). When completed, West Village will cover approximately 205 acres and will be the home for approximately 3,000 students and 475 staff and faculty families with a total population of approximately 5,000 (Table 1). The community also will host the first community college on a University of California campus and at build out will have approximately 42,500 square feet of retail/office space.

West Village is being developed in two phases (Table 1). The site plan for Phase 1 (Figure 2) has a village square at the center surrounded by mixed-use buildings with retail/office space on the ground floor and apartments above. The Sacramento City College Davis Center is located on the southwest corner of the square. Student apartments are located along across the southern half of the site with single family homes along the northern half. In addition, the site includes generous open space as part of the overall design.

Phase 1 of the community is being developed through a public-private partnership between UC Davis and West Village Community Partnership, LLC, (WVCP) a joint venture of Carmel Partners from San Francisco and Urban Villages from Denver.

Figure 1: Location of UC Davis West Village

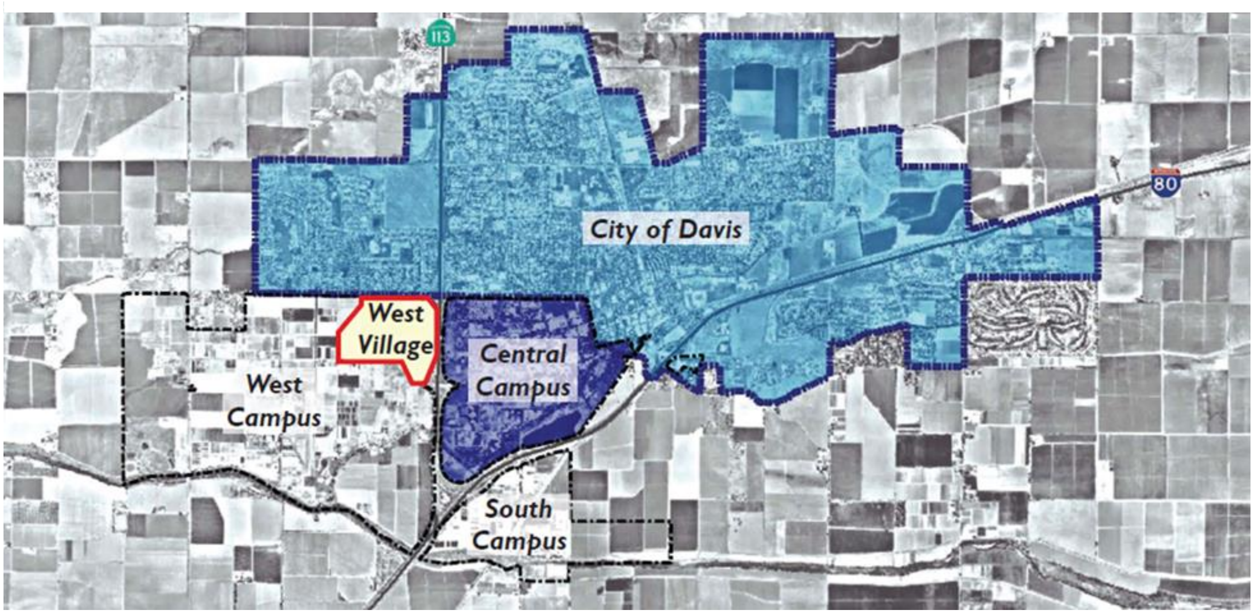


Table 1: West Village Program Goals

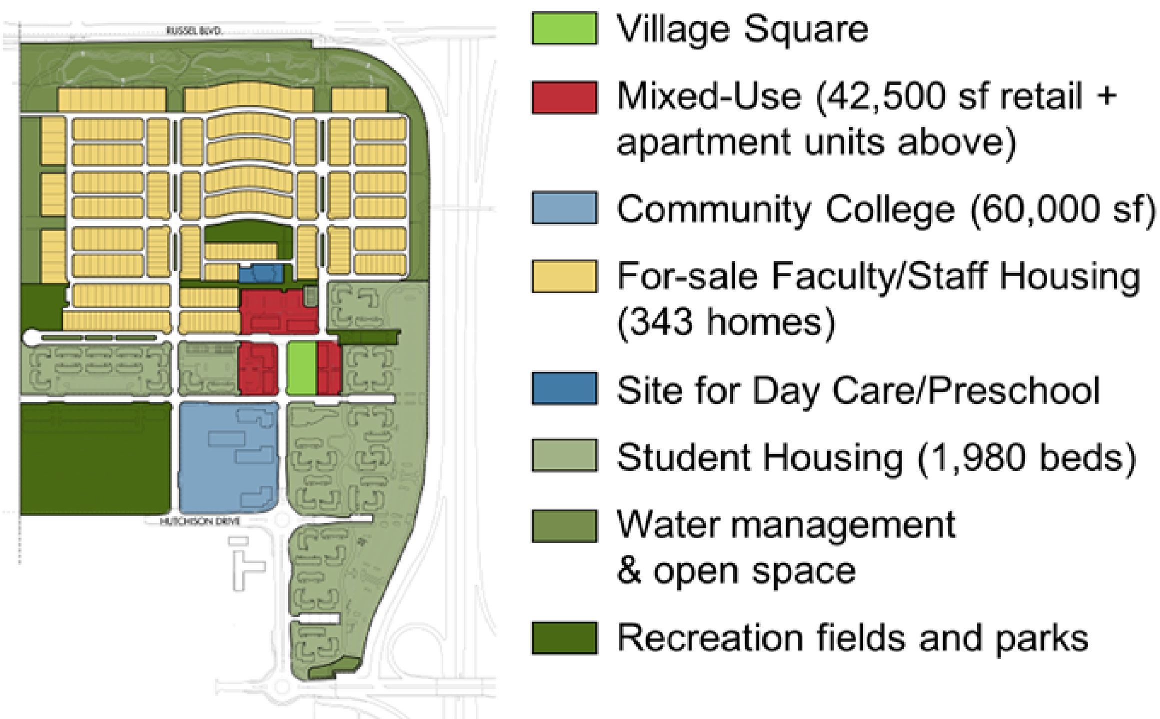
Program	Phase 1	Phase 2	Total
Size	130 acres	75 acres	205 acres
Faculty/Staff Housing	343 units	132 units	475 units
Student Housing Beds	1,980 beds	1,158 beds	3,000 beds
Retail/Office Space	≤ 42,500 sf	--	≤ 42,500 sf
Community College	60,000 sf	--	60,000 sf

1.1.1 West Village Goals

The West Village creates a neighborhood that will ensure that many students, faculty and staff who wish to live in the community where they study and work will be able to do so. The neighborhood will help maintain a "college town" atmosphere for the community and will be a vibrant addition to the university and Davis communities. The goals for the design and implementation of the community are:

- *Quality of Place* – to create a great community and desirable place to live that will help UC Davis recruit the best and brightest students, faculty and staff, to let them live within walking or cycling distance of the campus, and to participate fully in campus life.
- *Affordability* – to enable faculty and staff to purchase new homes locally at below market prices and to expand the choices for students to live near campus.
- *Environmental Responsiveness* – to develop the site and buildings according to sound environmental principles so as to reduce reliance on cars, limit energy consumption, enable renewable energy production, and contribute to a healthy environment.

Figure 2: Site Plan for UC Davis West Village Phase 1



1.1.2 Development and Construction Status

Construction of the first West Village apartments began in 2010. The Phase I Ramble Apartments (192 units with 654 student beds) were occupied in September 2011. The mixed-use buildings around the Village Square, including the Viridian Apartments (123 units with 192 beds) on the second through fourth floors, were occupied in September 2012. The first building of the Sacramento City College West Village Center opened in January 2012. The Phase II Ramble Apartments (192 units with 630 student beds) opened in September 2012. The final phase of student housing built by WVCP, the Solstice Apartments (156 units with 504 beds) opened in September 2013 (Figure 3). Construction of single family model homes is expected to start in 2014.

Figure 3: Aerial photograph of UC Davis West Village, September 2013

State Route 113 is in the foreground, and north is to the right side of the image. Roadways on the lower right are the location of future development of single family homes.

1.2 The UC Davis West Village Energy Initiative

1.2.1 Goals and Objectives

Through a collaborative design process with WVCP, UC Davis expanded upon its core principle of making UC Davis West Village environmentally responsive and launched the West Village Energy Initiative (WVEI). Together, the UC Davis and WVCP team first considered how to make West Village as energy efficient as possible. In 2007, UC Davis commissioned a study with its own UC Davis Energy Efficiency Center and local consulting firm, the Davis Energy Group, to help identify deep energy efficiency measures that could be included in the design of the student housing and single family residences to be built as part of West Village. The results of this study demonstrated that by adopting deep energy efficiency measures, WVCP could reduce consumption in West Village by nearly 50 percent compared to the California Energy Efficiency Building Code.

With this result, WVCP and UC Davis realized that a much larger goal was within reach – the goal of making West Village a Zero Net Energy (ZNE) community. In 2008, WVCP engaged Chevron Energy Solutions to evaluate the financial feasibility of achieving a ZNE goal defined as "zero net electricity from the grid measured on an annual basis."

In 2009, WVCP and UC Davis decided to strive for this goal. Because West Village had to be accessible for UC Davis faculty, students and staff, the ZNE goal had to be balanced against the goal of affordability. In response to these competing principles, WVEI was created and the following principles were adopted by the team:

- West Village would strive to use ZNE from the grid measured on an annual basis.
- ZNE must be achieved at no additional cost to the developer.
- ZNE must be achieved at no additional cost to the consumer.
- West Village would adopt deep energy efficiency measures to reduce energy demand.
- ZNE would be achieved through multiple renewable resources developed on-site at a community scale.
- West Village would be used as a living laboratory for further energy-related topics.

1.2.2 The California Energy Commission Renewable-Based Energy Secure Community Program

UC Davis was awarded a California Energy Commission Renewable-Based Energy Secure Community (RESCO) grant in February 2010 and work on the ZNE project began immediately. The goal of the UC Davis RESCO grant agreement was:

- To resolve the final remaining barriers to make the West Village one of the world's leading sustainable communities.

The objectives of the grant agreement were:

- To ensure that the West Village community will be Zero Net Energy;
- To provide energy to residents, among others, that is at or below the cost of what they would have paid in a "business as usual" case, while maintaining or improving the quality of life for the residents; and
- To seek to be a source of information and inspiration for additional communities in California, and further California's key environmental goals, including Assembly Bill 32, the California Global Warming Solutions Act, and the new California Renewables Portfolio Standard (RPS) aimed at reducing the state's greenhouse gas emissions by 33 percent by 2020.

The target for the WVEI was to be a ZNE community through integrating a diverse array of renewable energy resources. While the community was proposed to use a commercially available and state-of-the-art technology, the integrating those activities in a large scale development posed a new set of challenges:

- How the renewable energy project can be effectively coordinated with the West Village project.

- How to integrate and optimize multiple distributed energy resources with a smart grid at a community scale including connecting each Demand Energy Response (DER) into the smart grid, interconnection to a static disconnect switch, and the integrating plug-in hybrid electric vehicle fueling stations.

- How to optimize each specific distributed energy resource, especially the biogas digester, so that they run as efficiency and cleanly as possible and produce the maximum benefit to West Village.

- How to integrate performance monitoring into the smart grid system. How to build additional functionality into the smart grid so that it contains advanced tools for consumers and is able to adapt to new technologies and changes at the West Village in the future.

The Energy Commission RESCO grant was foundational to develop strategies for the ZNE goal. It provided a significant portion of the funds required to pursue the ZNE concept for a community that was in the implementation stages, not in preliminary design. The topics evaluated with Energy Commission RESCO funding include:

- Evaluate deep energy conservation measures (Chapter 2);
- Determine the energy requirements of the community (Chapter2);
- Understand the likely increasing demand for plug-in vehicles (Chapter 2);
- Evaluate renewable energy options (Chapters 2 and 3);
- Evaluate multiple physical design models (Chapter 2);
- Select the current approach to ZNE (Chapters 2 and 4);
- Understand the financial and regulatory incentives and barriers to the ZNE goal (Chapter 4); and
- Recommend methods for advancing ZNE to other communities (Chapter 4).

1.2.3 Evolution of the WVEI

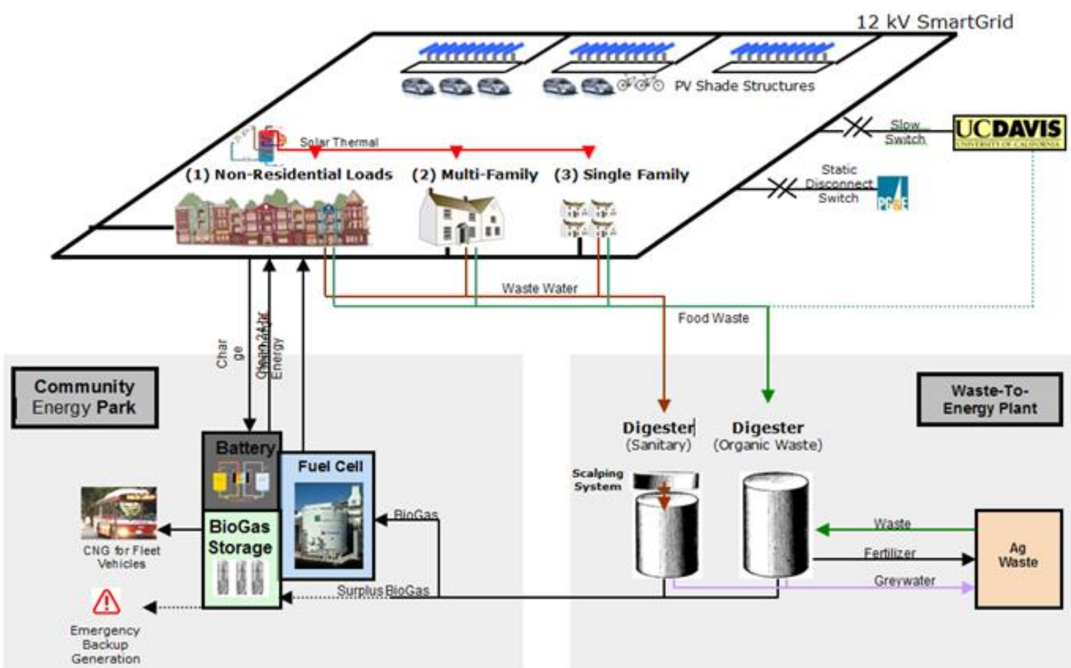
A fundamental challenge for the WVEI was that West Village was an active project being designed, constructed, and occupied while the initiative was underway. As the design and implementation of West Village proceeded, the approach to the ZNE goal evolved.

The initial ZNE design concept relied on deep energy conservation measures to reduce demand and to produce renewable energy through community solar arrays and a community energy park that included a biodigester linked to a fuel cell and advanced storage battery system (Figure 4). This concept would have allowed the community to be self-sufficient for electrical energy needs and would have been connected to the regional power grid for backup. Analyses conducted under the Energy Commission RESCO grant revealed that this approach was not feasible due to:

- Regulatory issues for an “islanded” community;

- Regulatory issues for community-scale solar;
- Cost of the fuel cell and battery;
- Lack of incentives for non-solar renewable energy; and
- Financial issues associated with the timing of housing construction and phasing of renewable energy resources.

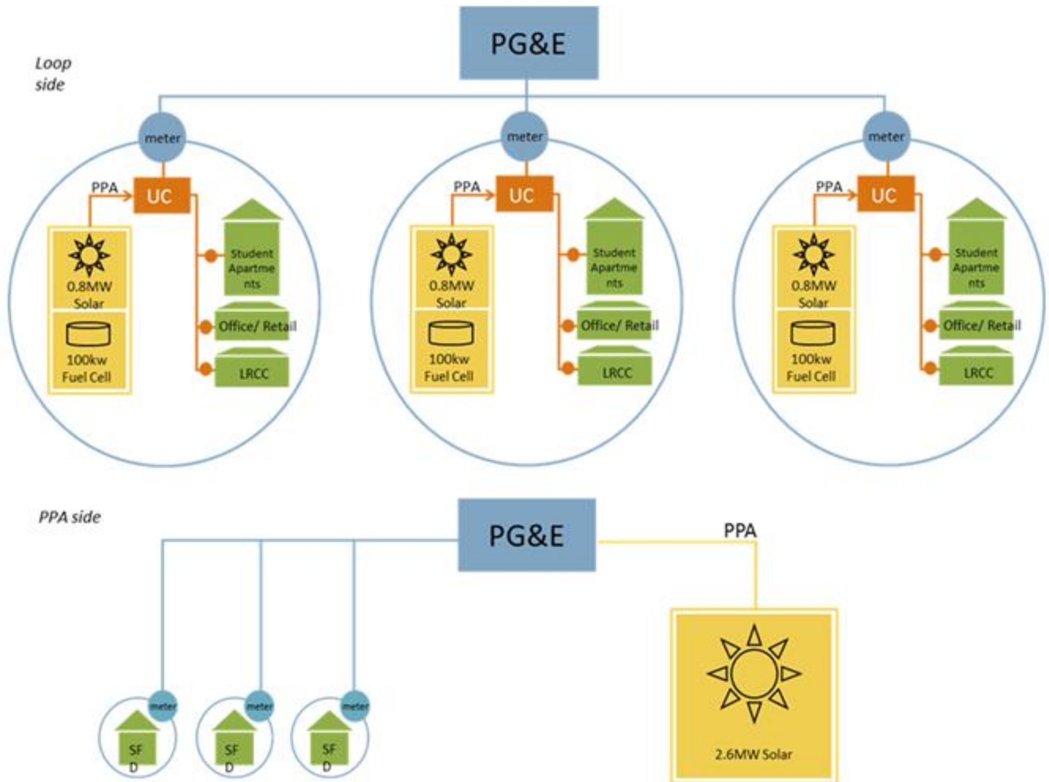
Figure 4: "Islanded" Zero Net Energy Concept for UC Davis West Village



Later analyses considered a three-loop distribution model to distribute renewable energy in three one-megawatt distribution loops to the multifamily and mixed use portion of West Village (Figure 5). Analyses conducted under the Energy Commission RESCO grant revealed that this approach was not feasible due to:

- Regulatory issues for a smaller but still "islanded" community;
- Cost of the fuel cell and battery;
- Low tariffs available for biogas electricity;
- Lack of incentives for non-solar renewable energy;
- Higher costs to construct three 1-megawatt loops to take advantage of California Solar Initiative incentives; and
- Lack of reimbursement by the Investor-Owned Utility for behind the meter infrastructure.

Figure 5: "3-Loop" Zero Net Energy Concept for UC Davis West Village



Based on the results of these analyses, WVCP made the decision to implement the photovoltaic renewable energy for the multifamily housing under the California Solar Initiative's New Solar Home Partnership.

See Chapter 2 of this report for technical information related to the evaluation of alternative concepts and to Chapter 4 for a summary of regulatory issues and recommendations.

The initial ZNE concepts for West Village included a biodigester to convert organic waste to electricity. Feasibility analysis and preliminary planning for the biodigester progressed under Energy Commission RESCO grant and through a grant from a U.S. Department of Energy Community Renewable Energy Deployment program (DOE CRED). The Energy Commission RESCO included funding for certain elements of the feasibility analysis and materials testing at the campus pilot plant (See Chapter 3). The DOE CRED grant included funding to help with design and construction. Although, a biodigester is not being constructed as part of a Community Energy Park at West Village, a result of this background work is that a 50-ton per day biodigester facility was completed in December 2013. The site for the biodigester is the existing campus landfill located approximately 1.5 miles southwest of West Village. The electricity from the facility will be connected to the campus electrical grid. While this source of electricity will not directly feed West Village, which is tied to the Pacific Gas & Electric (PG&E) grid, a portion of the renewable energy could be credited to West Village to meet the ZNE goal.

CHAPTER 2: SmartGrid Integration Final Engineering and Design

2.1: Goals of the Task

This task tested scenarios to achieve the ZNE goal by identifying appropriate energy efficiency measures, forecasting demand and matching with renewable energy resources. Task 2 addressed load reduction and optimization, integration with the community design (energy systems, and sub-systems), and energy efficiency throughout the community served by the West Village grid, as well as aspects of the grid itself including electrical distribution and interconnection; design, integration and interaction with renewable energy assets; and integration of Plug-in Hybrid Electric Vehicle (PHEV) charging stations. As discussed in chapter 1.2.3, the results of these analyses led to an evolving design and method that shifted from an "islanded" community energy park to a three-loop model for the multi-family housing and eventually to a PG&E grid-connected model using solely PV panels for the multi-family buildings. As a result, the nature of the analysis also evolved.

The analysis provided primarily by Chevron Energy Solutions (CES February 2014) and Davis Energy Group (DEG May 2010) can be broken down into three primary efforts.

- **Consumption:** An analysis and selection of different energy efficient designs for the buildings in the community. It covers the utility and financial analysis performed to determine the energy and cost budget. Finally, it provides information on the phase-in assumptions made for the community.
- **On-Site Generation and Distribution:** Design of the on-site renewable generation and its distribution. Various scenarios are examined for this project including the community energy park, multi-family housing options and single family options.
- **Interconnection to Load Serving Entity:** Analysis and designs considered for interconnection the West Village project to the load serving entity. These results are presented in detail in the CES final report (CES February 2014) and are not summarized below.

2.2: Consumption

2.2.1 Load Estimation

In late 2008, Davis Energy Group (DEG) was retained by Chevron Energy Solutions to provide a refined analysis that would precisely quantify the cost-effectiveness of energy efficiency packages as well as provide detailed hourly energy usage profiles for each of the key building construction types in the project. Developing the 8,760 hourly profiles is critical for Chevron Energy Solutions in quantifying the complicated energy transfers that must occur with PG&E to balance generation and consumption over the course of a year. These hourly profiles are included in the DEG report (DEG May 2010). Table 2 presents the building types planned in 2008-10 to demonstrate the relative contribution to the overall project energy budget.

Table 2: West Village Project Building Types

Building Type	Floor Area (ft^2)	# of Units
Student Housing - Ramble A	432,300	324
Student Housing - Ramble B	241,200	204
Student Townhomes	33,400	20
Student Housing - Subtotal	706,900	548
Single Family (60% with detached flats)	637,600	343
Mixed Use Commercial	42,300	TBD
Mixed Use Residential	116,700	120
Leasing Building	13,300	1
Community College	56,000	3 buildings

2.2.2 Energy Efficiency

The overriding goal was to develop a cost-effective package of energy efficiency measures that provided favorable life cycle economics and insured that the required level of energy efficiency was integrated to meet the community ZNE goals. A community energy consumption target of 9.2 MWH/year was determined based upon the maximum expected contribution of onsite renewable energy generation.

Additional project energy efficiency goals included:

1. Minimize natural gas use to facilitate meeting a 9.2 MWH/year goal and maximize the contribution of on-site generation to on-site energy loads[1].
2. Evaluating project-wide full-year hourly energy use profiles, by developing hourly electrical and natural gas energy projections for each product type.
3. Estimating expected energy bill savings from adopting the proposed energy efficiency packages for the different product types using standard PG&E tiered electric and gas rates. Using standard PG&E rates develop the expected costs of the energy bill for the West Village tenants and then develop simple payback and life cycle cost economic evaluations to document package performance. Life cycle cost evaluation incorporated maintenance and replacement costs and time intervals.

[1] Since community energy use comprises both electricity and gas consumption, the ZNE calculation requires a conversion of gas energy to electrical energy. This conversion can either be made at a “site” efficiency level (29.3 kWh/Therm) or power plant “source” efficiency (9.8 kWh/Therm at an assumed 33.3% plant efficiency). For this study, the 29.3 kWh/Therm was assumed.

4. Supporting the community developer and their design team in finalizing the package of energy efficiency measures.

The assumed base case requirements for the single and multi-family building types are summarized in Table 3. The requirements are based on the 2008 prescriptive requirements, but modified based on what local builders/developers are currently using to demonstrate compliance[2]. Base case mechanical system for multi-family was assumed to be individual storage gas water heaters providing both domestic hot water and space heating (via fan coil). Base case systems for single family homes assumed gas storage water heaters for water heating only and ducted gas furnace with ducts and furnace located in the attic. Cooling was assumed to be provided by a split system air conditioner for both products.

Table 3: Base Case Assumptions for Single and Multi-Family Building Types (2008 Title 24)

	Single Family	Multi-Family
BUILDING ENVELOPE:		
Walls (Exterior)	2x6 16" o.c. R-19 batt.	2x6 16" o.c. R-19 batt.
Roof (Attic)	R-38 blown insulation; Radiant barrier roof sheathing	R-38 blown insulation; Radiant barrier roof sheathing
Roofing Products (roof slope > 2:12)	Aged solar reflectance ≥ 0.2; thermal emittance ≥ 0.75 (Cool Roofing products)	Aged solar reflectance ≥ 0.2; thermal emittance ≥ 0.75 (Cool Roofing products)
Glazing U-Factor/ SHGC	Average U ≤ 0.33 / SHGC ≤ 0.21	Average U ≤ 0.35 / SHGC ≤ 0.35
HVAC:		
Cooling	13 SEER / 10.5 EER AC split system	13 SEER / 10.5 EER AC split system
Heating	80% AFUE Gas Furnace	Hydronic heating off of water heater
Ducts	R-6.0 ducts in attic	R-6.0 Ducts (attic on third floor, else in between floors)
Fresh Air Mechanical Ventilation	Per ASHRAE 62.2, mandatory Jan. 2010	Per ASHRAE 62.2, mandatory Jan. 2010
WATER HEATING:		
Type	Individual 50 gal. gas storage water heaters; 0.60 Energy Factor	Individual 50 gal. gas storage water heaters; 0.62 Energy Factor
3RD PARTY TESTING / VERIFICATION:		
Duct Tightness / Duct Location	Tight Attic Ducts; Tested at < 6% Leakage	Tight Attic Ducts; Tested at < 6% Leakage
Envelope Integrity / Tightness	None	None
Cooling System	None	None
LIGHTING / APPLIANCES:		
High Efficacy Lighting	Kitchens: 1/2 of installed Wattage must be fluorescent. Other Rooms/ Outdoors: High efficacy or motion sensor/dimmer	Kitchens: 1/2 of installed Wattage must be fluorescent. Other Rooms/ Outdoors: High efficacy or motion sensor/dimmer
Energy Star Appliances	Builder Standard Appliances	Builder Standard Appliances

[2] Builders typically do not exactly follow the prescriptive requirements, often substituting other measures to obtain performance tradeoffs.

Cooktop / Oven	Standard Electric	Standard Electric
Miscellaneous Load Control	None	None

Building Energy Optimization software (BEopt) developed by the National Renewable Energy Laboratory was used to evaluate water heating energy use for both single and multifamily building types. Solar thermal systems were evaluated based on information provided by the bids and specifications received from the various solar contractors that Carmel Partners was working with WVCP. The target performance for active solar systems was 60 percent annual solar fraction. Lower solar fractions were assumed for the batch or integrated collector storage (ICS) systems, since these systems are lower efficiency (35-45 percent solar fractions).

Multifamily Results: Table 4 summarizes proposed measures for the student apartments for a 3-story student apartment building which includes six three bedroom and six four bedroom units. Measures that are italicized indicate no change from the base case specification. Table 5 presents the energy use projects for the twelve student apartments included in the model building with and without the recommended energy efficiency measures.

Table 4: Multifamily Building Description - Summary of Final Package

	DESCRIPTION
BUILDING ENVELOPE:	
Walls (Exterior)	2x6 16" o.c. R-21 batt w/ ½" exterior foam. Quality Insulation Inspection.
Roof (Attic)	R-49 blown insulation; *Radiant barrier roof sheathing*
Roofing Products (roof slope > 2:12)	*Aged solar reflectance ≥ 0.2; thermal emittance ≥ 0.75 (Cool Roofing products)*
Glazing U-Factor/ SHGC	*Average U ≤ 0.33 / SHGC ≤ 0.21*
Distributed Thermal Mass	Additional 1/2" gypcrete on Floors 2 and 3
HVAC:	
Cooling	15 SEER / 12.5 EER Heat Pump
Heating	8.5 HSPF Heat Pump
Ducts	R-6.0 ducts in conditioned space
Fresh Air Mechanical Ventilation	*Per ASHRAE 62.2, mandatory Jan. 2010*
WATER HEATING:	
Type	Central HPWH in each bldg. (3.3 COP ETech unit); Active solar water heating option
3RD PARTY TESTING / VERIFICATION:	
Duct Tightness / Duct Location	Ducts in Conditioned Space; *Tested < 6% Leakage*
Envelope Integrity / Tightness	Blower Door Testing @ CFM50: ≤ 3.0 SLA; 3rd Party Quality Insulation Inspection
Cooling System	ACCA Manual J & D; Fan Power and EER Verification; Cooling Coil Air Flow
LIGHTING / APPLIANCES:	
High Efficacy Lighting	All hard-wired lighting fluorescent or LED. Assume 80% hardwired lighting. Lighting controls / Vacancy sensors.
Energy Star Appliances	Dishwasher, Refrigerator, Washer
Cooktop / Oven	*Standard Electric*
Miscellaneous Load Control	One switch wiring, energy usage displays

Table 5: Projected Multi-Family Annual Building Energy Use (no solar thermal)

	Title 24 Base Case		Final ECM Package	
End Use	**therms**	**kWh**	**therms**	**kWh**
Cooling	0	18,356	0	8,230
Heating	2,093	0	0	12,728
Water Heating	2,357	0	0	17,885
Lighting	0	16,076	0	6,547
Pumps and Fans	0	5,193	0	4,731
Miscellaneous (& appliances)	0	47,283	0	40,727
Total	**4,449**	**86,909**	**0**	**90,848**

Single Family Results: A total of 343 single family detached homes are proposed for West Village, ranging in size from 1,300 to 4,000 square feet in size. There are four product types, based on lot width, with three different plans within each product type. All single family plans are two-story. Table 6 summarizes the proposed measures for the detached single family homes. Measures that are italicized indicate no change from the base case specification. For more details on the analysis of the proposed measures as well as the analysis for the other building types, please refer to DEG (May 2010).

Table 6: Single Family Building Description - Summary of Final Package

	DESCRIPTION
BUILDING ENVELOPE:	
Walls (Exterior)	2x6 16” o.c. R-21 batt w/ ½” – 1” exterior foam. Quality Insulation Inspection.
Roof (Attic)	R-49 blown insulation; *Radiant barrier roof sheathing*
Roofing Products (roof slope > 2:12)	*Aged solar reflectance ≥ 0.2; thermal emittance ≥ 0.75 (Cool Roofing products)*
Glazing U-Factor/ SHGC	*Average U ≤ 0.33 / SHGC ≤ 0.21*
Distributed Thermal Mass	5/8” drywall throughout
HVAC:	
Cooling	15 SEER / 12.5 EER Heat Pump
Heating	8.5 HSPF Heat Pump
Ducts	R-6.0 ducts in conditioned space
Fresh Air Mechanical Ventilation	NightBreeze for summer night ventilation cooling & fresh air mechanical ventilation
WATER HEATING:	
Type	Heat Pump Water Heater in garage or exterior closet. Adequate ventilation required.
Mfg. / Efficiency	Energy Factor ≥ 2.0
Solar Water Heating	Active solar water heating system (0.60 solar fraction). 1 4x8 collector per home.
3RD PARTY TESTING / VERIFICATION:	
Duct Tightness / Duct Location	Ducts Conditioned Space; *Tested < 6% Leakage*
Envelope Integrity / Tightness	Blower Door Testing @ CFM50: ≤ 1.5 SLA; 3rd Party Quality Insulation Inspection
Cooling System	ACCA Manual J & D; Fan Power and EER Verification; Cooling Coil Air Flow
LIGHTING / APPLIANCES:	
High Efficacy Lighting	All hard-wired lighting fluorescent or LED. Assume 80% hardwired lighting. Lighting controls / Vacancy sensors.

Energy Star Appliances	Dishwasher; Homeowner incentives to encourage purchase of other EnergyStar appliances
Cooktop / Oven	Induction cooktop as buyer option
Miscellaneous Load Control	One switch wiring, energy usage displays

2.2.3 Energy Budget

A tariff simulation model for the community was used to estimate the utility costs of different mixes under different scenarios (CES February 2014). Table 7 identifies the different PG&E rates that were reviewed.

Table 7: PG&E Electric Rates applicable to West Village

Rate	Type	Time-Of-Use	Demand Charges	Max KW allowed
E1, E7	Single Family Residential	No	No	Tier structured
E6	Single Family Residential	Yes	No	Tier structured
ES,EM	Multifamily	No	No	Tier structured
A1	Small General	No	No	<200
A6	Small General	Yes	No	<200
A10	Medium General	Yes	Yes	<500
E19	High General	Yes	Yes	<2000

Table 8 and Table 9 summarize the results of the tariff simulations undertaken to establish the baseline energy budget for the community and the impact of energy conservation measures on energy use and utilities bills. Further information and analysis is included in the Microsoft Excel spreadsheet model in Appendix 1.2 to the CES report (CES February 2014).

Table 8: BAU West Village Annual Energy Consumption and Budget

	Energy Summary			Utility Bills Summary				
Unit Type	**Electricity (KWh)**	**Gas (Therms)**	**Total Energy (KWh)**	**Elec. Rate**	**BAU Elec Bill**	**BAU Gas Bill**	**Metering Bill**	**Total Annual Bill**
Single Family	2,169,982	266,540	9,899,646	E-1	$277,569	$258,428	$31,582	$567,579
Multi Family	3,962,889	198,587	9,721,898	E-6	$640,412	$198,587	$50,605	$889,604
MU Residential	628,499	29,776	1,492,002	E-6	$87,699	$29,776	$11,358	$128,833
MU Commercial	532,494	5,733	698,763	A-10S	$87,063	$5,733	$10,950	$103,746
Los Rios	537,592	2,970	623,708	E-19S	$101,312	$2,970	$1,825	$106,107
Common Areas	299,999	0	299,999	LS-3	$38,844	$0	$73	$38,917
TOTAL	**8,131,455**	**503,606**	**22,736,017**		**$1,232,899**	**$495,493**	**$106,393**	**$1,834,786**

Table 9: Proposed ECM Annual Energy Consumption and Budget

Unit Type	Energy Summary			Utility Bills Summary				
	Electricity (KWh)	Gas (Therms)	Total Energy (KWh)	Elec. Rate	PKG-B Elec Bill	PKG-B Gas Bill	Metering Bill	Total Annual Bill
Single Family	3,444,270	0	3,444,270	E-1 All elec	$430,238	$0	$31,582	$461,820
Multi Family	4,067,892	0	4,067,892	E-1 All elec	$483,544	$0	$0	$483,544
MU Residential	703,635	0	703,635	E-1 All elec	$83,517	$0	$0	$83,517
MU Commercial	491,831	5,733	658,100	A-10S	$81,478	$5,733	$10,950	$98,161
Los Rios	537,592	2,970	623,708	E-19S	$101,312	$2,970	$1,825	$106,107
Common Areas	150,015	0	150,015	LS-3	$19,424	$0	$73	$19,497
TOTAL	**9,395,234**	**8,703**	**9,647,620**		**$1,199,513**	**$8,703**	**$44,430**	**$1,252,646**

2.3: Onsite Generation and Distribution

The goal of this RESCO task was to develop the best method to integrate Renewable Energy Sources (RES) into West Village Community Electrical Distribution System. The focus of the work was to coordinate with the developer on placing central inverters throughout the community and integrating them into the ZNE community design. This section provides the details of the multiple community designs considered for the project. For each scenario, examination of the technical, regulatory, and financial requirements of the community was undertaken. A full joint trench design for was developed for the infrastructure as in available in Appendix 2.1 to the CES Report (CES February 2014).

Scenarios examined for the West Village Community include:

- **Community Energy Park:** looking at the entire development, examining its energy needs, available energy resources, and how to meet the project goals from a holistic approach.
- **Single Family and Multi-Family/Mixed-Use Hybrids:** Within each scenario there were two different designs analyzed: community-scale (at different levels) and building-by-building.

2.3.1 Community Energy Park

The West Village ZNE Community Energy Park Concept was designed and conceived, maximizing an organized and integrated approach. Figure 4 illustrates the initial ZNE Community Energy Park concept. With this approach, West Village would satisfy its annual electricity and gas demand by integrating solutions that reduce energy consumption with a diverse array of indigenous renewable energy resources in an economic and technically optimal manner. Planned technologies included: Energy efficiency (passive & active)

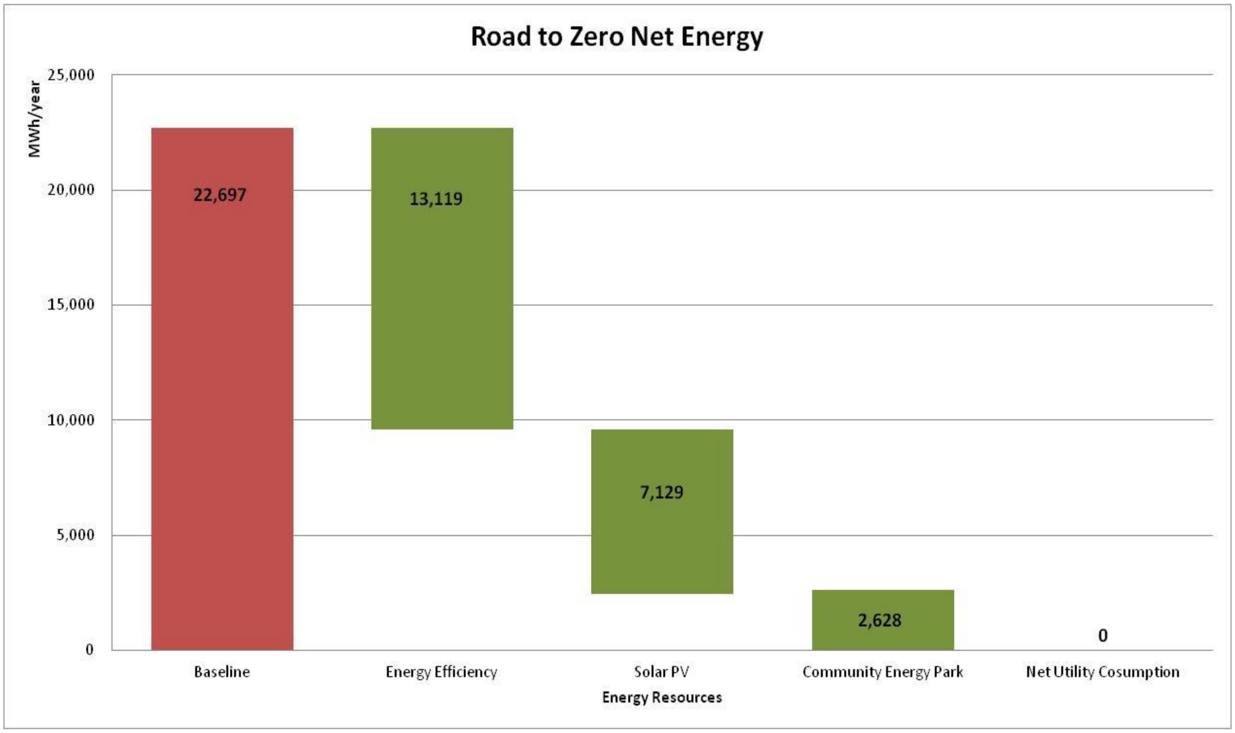
- Distributed Solar Photovoltaic
- Distributed Solar Thermal
- Biogas digester
- Fuel Cell(s)
- Advanced energy storage
- SmartGrid technology
- Bio-methane upgrade system

This scenario envisioned a single point of interconnection with PG&E. The entire development would have been considered a single customer from the utility perspective. The WVEI team studied PG&E and California Public Utility Commission (CPUC) tariff books and codes to determine how such a system will work. Given the energy demands of the development, PG&E's electrical tariff E-19 would have been the most applicable tariff which applied to medium and large commercial customers. This tariff provided the system with two critical success factors:

- Time-of-Use Tariff: this is necessary to reflect the true cost of energy as it is being consumed during the day.
- Net Metering: the development energy profile – shown below – represented a "negative peak" profile, where Solar generated during the day can be exported to the utility at a higher value than power consumed at night.

The baseline building energy usage at full build-out (assuming 2008 Title 24 standards) for West Village implied an annual energy load of approximately 23,000 MWh. Of this, 11,100 MWh was gas demand and 12,000 MWh was electric demand. This demand had to be completely offset to achieve the goal of ZNE. Figure 6 demonstrates this path to ZNE.

Figure 6: West Village – Energy Resources Mix for Zero Net Energy



Matching load with generation during the ramp-up period of the development was considered a critical challenge to overcome, as it added uncertainty to the business model and ownership structure that were hindering its development, especially as it related to the single family units.

Conversely, multi-family residences and mixed use commercial areas appeared able to take advantage of the non-residential/high-rise exceptions in Rule 18 for master-metering of the smart grid at the point of connection with PG&E. Unfortunately, due to Net-Metering limitations, the single electrical distribution loop for approximately 3MW demand load would have to be split into three radial distribution systems of less than 1 MW demand threshold for net-metering and CSI incentives. This resulted in financial complications for interconnecting all of the components of the ZNE smart grid due to load matching and redundant distribution costs. The smart grid estimated costs increased in the following ways:

- The three distribution system cost of $1.5 million was 3 times the original one loop distribution cost estimates
- The increased cost for gas line deletion was estimated at approximately $100k in added costs for the increased number of transformers due to the electrical load increased by an all electrical community.

After the analysis of this scenario, and the work done by the different stakeholders including the Utility, the University and the developer, it was concluded that this scenario would not be applicable under the current conditions and further scenarios were examined. The recommendation was to explore different scenarios for the Single-Family portion of the development than for the Multi-Family and Mixed-Use tenets. All of these scenarios were analyzed with respect to solar system construction feasibility, utility interconnection issues, available incentive programs and regulatory requirements.

2.3.2 Single Family – Community PV Array with PPA Provider

This scenario explored a rather unique and innovative strategy to meet the energy demands of the Single Family portion of the West Village Development. The system design was ground-mounted, located at the West Village sports field area and an adjacent area planned for a future phase of the West Village development. It would have been connected directly to the PG&E utility grid. The amount of energy generated by the system would have been equal to that of the energy demands estimated of the Single Family units. Each unit would be connected separately to the utility and buy their energy directly from the utility. The ground-mount design lowered the cost of the system and allowed for more energy generation taking advantage of higher tilts.

This scenario was considered the least challenging from a regulatory and utility interconnection perspective. It would have utilized existing tariffs and rulings without the need for any changes. The system's only challenge would have been to finance the system and sell power at the wholesale generation cost for the Utility.

2.3.3 Single Family – Rooftop PV Array with Smaller Community PV Array

Realizing the limitations of the previous scenario, a different virtual ZNE scenario was analyzed where each dwelling unit would include installation of the most economically feasible PV system on its roof and the remaining energy would be offset by a Virtual ZNE ground mount system. Given the available roof space, a roof-top system of 5 KW DC was considered. The rooftop systems in aggregate were estimated to offset close to two-thirds of the energy needs of the Single-Family development at total of 1,700 KW and energy production of 2,380 MWh. The remaining third of the energy demand would have been met by the ground-mount system which could have been developed in a similar structure of the previous scenario. The system size is estimated at 700 KW DC.

With this approach, maximized captured incentive must be weighed carefully against the increased complexity of the system design, construction costs and uncertainty of ownership model. With Solar PV part of each unit, questions over who owns the system and who has responsibility to maintain and guarantee the upkeep of the equipment becomes more challenging. This analysis also revealed that the financial feasibility of such a small ground-mount system is difficult to attain, given that it will need to compete with much larger systems where economies of scale savings are captured.

2.3.4 Multi-Family/Mixed-Use – One Loop

This design approached the Mixed-Use portion of the development with similar philosophy of the initial design scenario: an integrated approach with the entire mixed use and multifamily portion of West Village considered a single user with an electrical distribution loop that has one interconnection with the utility. Following completion of the previous scenarios, the initial

Solar PV opportunities were understood, and the development layout was finalized. The resulting system consists of:

- Parking-Shade Structures, and
- Public area shade structures

The total system size is 2,400 KW DC with estimated production of 4,000 MWh. The drawing below shows the location of the Solar PV in the development. The system design incorporates more PV in the recreation fields' area. This provides dual benefits in shading to the residents and spectators of the sports area. Initial design of bike and pond are shade structures were eliminated.

This scenario envisioned one joint trench that would serve the mixed-use portion of the development. Renewable energy sources were to be connected at multiple points around the development. This system would have provided the benefits of economy-of-scale, minimized interconnection points to the electrical distribution, and provided another advantage in that it allowed for the construction of the Solar PV system independently from the construction of the buildings and the beginning of the use. This was critical to the project given the different time drivers of the project: while the construction schedule and full build-out of this portion of the development was over three years, the Solar PV was on a shorter time scale driven by the financial needs of the project, incentives and cost of PV variability. The list below summarizes the benefits for this scenario:

- Economy of Scale with minimal system components and necessary supporting infrastructure, leading to a more economically feasible installation
- System sizing to meet 100 percent of load: the aggregation of the units and end-users minimized the variability and uncertainty of usage, thus allowing the system sizing to be close to 100 percent
- Construction Schedule can be independent from the absorption rate of the development, minimizing the need to match load and generation
- Minimal impact on the joint trench design and the electrical distribution network

This scenario, paired with either of the Single-Family scenarios, would have achieved the goals and objectives of the WVEI from the regulatory and technical perspectives. It integrated seamlessly with the business as usual electrical distribution network. The drawbacks of this scenario were the low incentive level captured and the challenge of matching load with generation during the ramp-up periods of the development.

2.3.5 Multi-Family/Mixed-Use – Multiple Loop

Following from the previous scenario, a design approach was examined where the mixed-use family portion is broken down to multiple loops. This approach minimized the downfalls of the previous scenario by:

- Maximizing incentives by splitting the system into multiple loops with each loop considered a separate system eligible for maximum incentive size, essentially making the entire system eligible for the incentives
- Minimizing the gap between load and generation, the multiple loops would be built at different times and for each loop, the associated PV System can be built with it.

The total system size remained 2,800 KW DC with estimated production of 4,000 MWh. This analysis maximized the California Solar Incentive and provided a better integration of the Solar PV schedule with the community construction schedule. However, this was achieved at a large added cost to the joint trench and electrical distribution costs.

2.4: Designing and Integrating PEVs into ZNE communities

Integrating “Smart” electric vehicle infrastructure is not just about installing reliable controls technology. Equally important is thorough planning and assessment of electric vehicle adoption, expected travel distances and vehicle energy use to determine the impacts attributed to electric vehicle charging. At West Village, this has become even more of a challenge, as the project must accommodate a growing number of electric vehicles into the ZNE goal. This section of the report documents effort to address the following issues. Details are presented in Barr (March 2014):

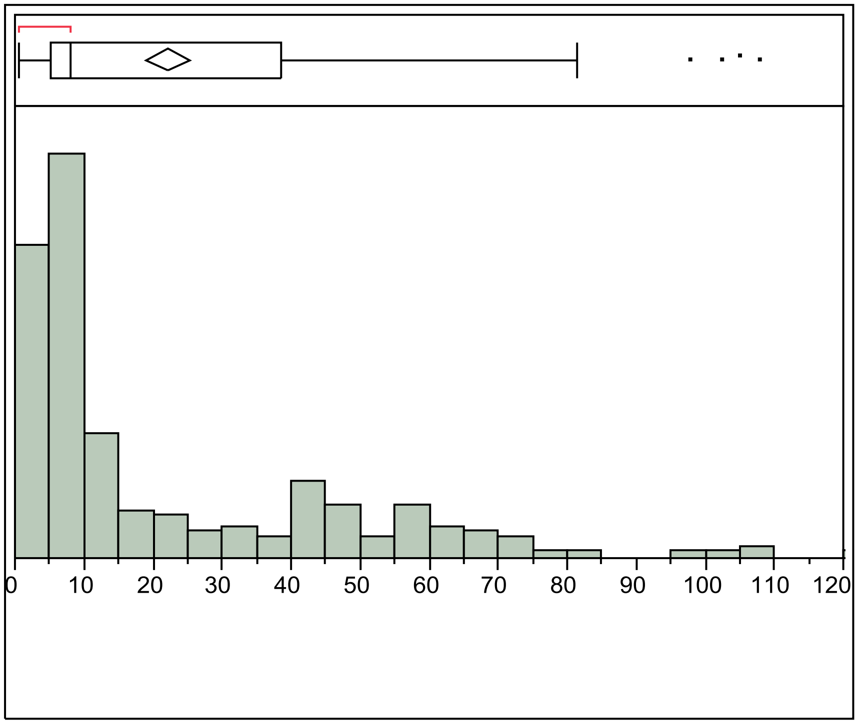
- Integrating the smart grid enabled electric vehicle charging stations at West Village
- Making recommendations for future communities and real estate developments
- Developing a process to perform assessments of estimated adoption and energy use from plug-in electric vehicles
- Estimating demand and recommending how to accommodate electric vehicle charging loads with solar at the single family homes to be built at West Village
- Providing market perspectives for electric vehicles and solar based on activities in 2014

2.4.1 Estimating Vehicle Charging Loads by Evaluating Travel Distances

To determine estimated impact from future electric vehicle charging at the single family homes at West Village, it was necessary to understand travel distances and vehicle type. To understand the unique travel of West Village, regional data from local authorities was used and filtered according to those who were identified as employs of UC Davis.

After the simulation was executed, and the potential households that would buy PEV were estimated, the following results were found. There are 259 households that currently live in West Davis that have at least one household member who works in UC Davis. It was assumed that 20 percent of households would have PEV. After each household’s probability to purchase PEV calculated from the number of drivers in the household, the researchers randomly selected 48 households that are most likely to purchase PEV. Those households that are estimate to purchase a PEV demonstrate vehicle miles traveled (VMT) distributions shown in Figure 7.

Figure 7: Commuter Car Total Daily Miles



The total home energy consumption of a PEV is based on a combination of the daily VMT and the electric range of the vehicle. Two scenarios were calculated. The lower scenario is based on the assumption that each PEV owner will charge the car at home to 100 percent of battery capacity once a day and also will use public charging or workplace charging whenever available. The second scenario is based on up to two charging events per day at home and using a public charging or workplace charging only if additional miles are needed. The average consumption used is 333 watt hours per mile for all vehicles or about 3 miles per kWh. If most of the VMT will be urban the energy consumption may be lower, up to about 4 miles per kWh.

The total energy consumption per car is capped by the battery size (capacity), amount of time elapsed during charging events (energy absorbed during refueling), and is also dictated by the energy consumed by operating the vehicle, which is based on the miles traveled per day. Table 10 illustrates energy consumption of each vehicle type based on our two scenarios and takes into account that weekend trips are more likely to use 100 percent of the PHEV battery and up to 80 percent of the BEV range, thus consuming more energy.

Table 10: Estimated home charging energy consumption per vehicle per week day

Vehicle type	lower demand: one home charging per day plus workplace charging	Maximum demand: Two home charging per day Minimum workplace charging
PHEV 10	3.0 kWh	6.1 kWh
PHEV 20	6.1 kWh	9.4 kWh
PHEV 40	9.1 kWh	13.0 kWh
BEV 70	6.1 kWh	15.2 kWh
BEV 100	7.6 kWh	18.8 kWh
BEV 150+	10.6 kWh	27.3 kWh

2.4.2 Mitigating Vehicle Charging Loads with Solar

To highlight the impact of siting solar PV generation the estimated yearly solar PV energy production from two examples of West Village Solar PV orientations was compared to ideal conditions. Table 11 summarizes the range ideal orientation for optimal efficiency given the constraints of the Solar PV system designs for the single family homes development.

Table 11: Summary of ideal solar PV orientation and for West Village Single Family Homes

Array Description	Tilt angle (degrees)	Azimuth angle (degrees)
Ideal orientation	30	180
South facing home with LR* config.	22.6	180
East facing home with L config.**	22.6	90

***LR refers to a configuration where an equal number of solar panels are split between the left and right sides of the roof.**
****L refers to a configuration where all of the solar panels are located on the left side of the roof**

Using PVWatts[3], the yearly energy production values for each of these solar PV orientations is estimated for system with a nameplate rating of 1kW DC. Researchers compared the estimated production value for the 1 kW array across all scenarios for solar PV orientation. The difference between the ideal and the planned orientations for West Village homes gives insight on the degree to which the best and worst solar PV orientations in the development will affect the overall efficiency of the system. Because the single family homes at West Village were designed prior to considering integrating PV or achieving ZNE, the roof elevations are not optimal for PV. Using standard derate factors, it was estimated that depending on orientation, West Village homes will require between 0.86 and 18.84 percent more nameplate panel capacity to meet the ZNE requirements for PEVs than from a solar PV system which is sited according to an "ideal" configuration. These results are show in Table 12.

Table 12: Impact of Solar PV orientation at West Village on total production

	Ideal (kWh)	South facing home with LR config.	East facing home with L config.
Yearly energy production (kWh)	1,468	1,458	1,237
Difference from ideal (%)	NA	-0.68 %	- 15.7%
Additional nameplate capacity needed w/ derate factor of 20%		**0.86%**	**18.84%**

2.4.3 How Much Extra PV Solar should be Installed to Achieve ZNE for a Community?

Using the energy requirements from PEV shown in Table 10, in Table 13 researchers estimated the additional array size required to provide ZNE over the course of a year for some of the PEVs currently available for consumer purchase. Since there will be a combination of vehicles on the market it was important to illustrate how to weight PV sizing to account for the correct mix of vehicles on the road, which is a factor of what kinds of PEVs are purchased and what percent of the market they make up. It is important to note that the market mix and penetration will change depending on the market area and could change over time. The results of the scenario illustrated here show that depending on the vehicle technology, mix of vehicles, orientation of the solar PV panel, and the amount of charging which happens at home, the average panel sizing (in nameplate kW) to achieve ZNE will be between 0.6 to 3.2 additional kW per home, or 0.45 to .8 kW on every home in a ZNE community where 35 percent of all of the cars are PEVs.

Table 13: Estimates for Solar PV system size to meet ZNE under a variety of scenarios

[3] The PVWatts® Calculator is a web application developed by the National Renewable Energy Laboratory (NREL) to estimate the electricity production of a grid-connected roof- or ground-mounted photovoltaic (PV) system based on a few simple inputs that allow homeowners, installers, manufacturers, and researchers to easily gauge the performance of hypothetical PV systems that use crystalline modules.

Amount of charging at home		Ideal (kW)	South facing home with LR config. (kW)	East facing home with L config. (kW)
All charging done at home	Plug-in Prius	0.8	0.8	0.1
	CMAX energy	1.4	1.5	1.7
	Volt	2.2	2.3	2.7
	Leaf	2.8	2.9	3.3
	Market mix & penetration	**0.6**	**0.6**	**0.8**
33% of charging done away from home	Plug-in Prius	0.6	0.6	0.8
	CMAX energy	1	1.1	1.3
	Volt	1.6	1.7	2
	Leaf	2	2.2	2.6
	Market mix & penetration	**.45**	**0.5**	**0.6**

2.4.4 Dealing with Uncertainty: Making Solar PV Systems Easily Expandable

The implications of the results in Table 13 vary considerably depending on the assumptions used, system design, market area and goals laid out of a developer. Considerable professional resources can be required to address complex questions such as the specific vehicle mix or market penetration, amount of away from home charging, and future technological progress of vehicles. Therefore, the uncertainty in the process described above is enormous. The variation observed in Table 13 is not likely to go away and will make it difficult to predict how much "extra" solar PV a specific home will need to offset the energy use of a PEV. Even if one could predict how much extra was needed for the first buyer there is no guarantee that the second buyer will also have a PEV or if an occupants travel or vehicle energy demand might change and so on. On the aggregated community level it is considerably less variable, but there is still some uncertainty and risk associated with not installing enough capacity and with increasing home costs for consumers who may not necessarily benefit because they do not own a PEV or PEV owners who might prefer reducing electricity consumption around the home before adding new capacity.

In general, combining Solar PV and time of use rates with a PEV is financially compelling. The timing of when consumers plug in at home coincides with low cost, off-peak or super off peak electricity rates. At the same time the solar PV will generate excess electricity during peak rate periods. In general, these credits for on-peak electricity generation outweigh the cost of off-peak electricity to charge their PEV. As such, it might be expected that most buyers who already have solar PV on their homes might be interested in expanding the system. With this in mind it could be auspicious to consider making homes "Solar PEV Charging Ready Home", by designing easy solar PV system expansion into the home, so in the future consumers can add capacity at minimum cost, rather than equipping every home with potentially arbitrary additional solar capacity. The concept is similar to that of the Renewable Energy Ready Home (RERH) guidelines. The following actions, which are of minimal cost to a developer, should enable future residents to make easy and straightforward modifications to expand Solar PV systems when they purchase the home, or if and when they purchase a PEV. Appropriate steps home builders and developers could take to accommodate the "Solar PEV Charging Ready Home" could be:

Provide homeowners with a site assessment

- Propose a location for additional solar PV. In the case of limited roof space they may identify options for solar canopies on the property.
- Identify the orientation of proposed panels.
- Identify the inclination of proposed panels.
- Conduct a solar shading study
- Document the solar resource potential at the designated array location

Complete structural and safety considerations

- Document the maximum dead and live load on the proposed panel location
- Install a permanent roof anchor fall safety system on sloped roofs

Infrastructure for expanding solar PV

- Assess strategies to make solar PV easily expandable, these may include using micro-inverters, oversizing a line inverter, etc.
- Dedicate enough space for additional inverters or a larger inverter
- Install a conduit for the DC wire run
- Dedicate extra panel space and capacity to accommodate additional solar PV
- Provide architectural drawings and diagrams of additional PV system components

Infrastructure for a home Electric Vehicle Supply Equipment (EVSE)

- Install a dedicated breaker to support a 240V and 40 amp appliance
- Dedicate a space for an EVSE
- Provide conduit, pathway, or standard from panel to EVSE location, or install a 14-40 plug.

Homeowner education

- Provide home buyers with marketing information and relevant information in a dedicated pamphlet
- Discuss the features of the system

2.4.5 Integration of SmartGrid Vehicle Charging Systems

The RESCO project allowed West Village to explore the integration of a smart grid controlled electric vehicle charging station. The project accomplished this through a smart energy gateway, which communicates wirelessly with a group of vehicle charging stations installed at West Village.

During the period of development for West Village, there was a push to develop a smart grid. Loosely defined the Smart Grid is generally accepted as technology systems and applications on the distribution network and customer's side of meter which enables real-time controls, energy management and data monitoring to optimize the electrical grid. If electrical vehicle chargers and other electrical appliances behind the customer's meter have the capability to provide real-time data and controls, theoretically energy demand could be optimized. The original vision at West Village included a smart grid distribution network, dynamic renewable energy generation, and controls and automation in the buildings. However, the project was not able to pursue smart grid integration past the early planning stages. The project abandoned pursuing the smart grid due to excessive costs associated with owning and maintaining electricity distribution infrastructure. Also, there are many rules and regulations governing interconnection to the utility and the incentive eligibility for technologies such as solar PV are significantly curtailed when a customer or end use is not directly served by the utility. Thus the project didn't have the financial resources or the appetite for risk to endure these challenges. As such the project decided to pursue a zero-net energy, grid-tied PV structure, which typically has little communication and no grid interactive automation capabilities.

2.4.6 Benefits of Controlled Vehicle Charging

Currently, because electric vehicles have only recently become available for purchase and penetration in the total vehicle fleet is still ramping up, grid impacts from charging electric vehicles are not considered to be an issue. It's generally accepted that until there are more than one million vehicles on the road in California the additional demand on the grid can be easily met with current generation resources[4]. While this is mostly correct, there are many activities and behaviors recently observed that might change the general perceptions of when and how electrical vehicle owners charge their vehicles. For example, prior to the availability of electric vehicles it was widely accepted that the majority of EV drivers would charge at home, during the night or early morning. While this assumption was reasonable, other developments in the market place, such as free workplace and public charging, are causing many electric vehicle drivers to charge during daytime during on-peak hours. While the promise of free public and workplace charging has helped to ramp-up electric vehicle sales, it could cause concern for the grid earlier than previously thought, particularly on grid system peak demand days. Also, while the grid system in California as a whole has adequate capacity, extra on-peak loads could cause problems on some of the distribution networks with limited capacity, causing that particular distribution circuit to require updating sooner than anticipated. Finally, additional on-peak grid loads cause concern in the wholesale bulk power market place and can also lead to unnecessary power plant emissions. This is because on high demand days, the cost of energy to meet the demand from on-peak charging could cause the overall power cost to rise rapidly as supply dwindles and transmission becomes constrained. Often, in order to meet the peak demand grid operators often have to ramp up "peaker plants", which typically don't run optimally and may have more emissions than other sources. In fact, grid operators might be

[4] California Plug-in Electric Vehicle Collaborative, *Taking Charge* (2010).

required to import coal energy from other states during these high demand events or risk blackouts and brownouts.

With these concerns and benefits in mind, applying controls to vehicle charging could elevate much or all strains on the grid. Mechanisms such as demand response, which currently exist in the energy market, could be applied to electric vehicle charging. Other potentially beneficial applications, such as vehicle-to-grid energy storage and dispatch, are currently being evaluated and demonstrated. The combination of controlled charging, vehicle-to-grid and demand response could be instrumental in managing loads and variable renewable generation on the grid. While the benefits of distributed load controls and energy storage applications are not fully understood, they are generally view optimistically by researchers, automakers, ISO and many utilities.

2.4.7 SmartGrid Electric Vehicle Charging Conclusions

Through the process of designing, installing and commissioning this system, the project has made the following conclusions:

- Controlled charging can offer benefits to the grid stability and financial benefits to those users who participate in demand response events.
- When selecting vehicle charging stations it is important to consider equipment with communications capabilities, as this equipment can easily be integrated into smart grid systems. This is particularly important with workplace, public and mixed use charging installations as these applications can expect to observed charging station use during on-peak utility tariff hours, when the grid could be potentially strained for generation resources.
- Given the current direction and pace of California's Title 24 requirements for new construction, it's reasonable to assume that similar to the 2013 commercial lighting requirements, demand response capability may be required in the future for electric vehicle charging stations.

2.4.7 Lessons Learned: Project Benefits and Conclusions

The purpose of this project was not only to help prepare West Village for growing PEV adaption, but also to tell the story of Electric Vehicle Service Equipment (EVSE) integration at West Village for the betterment of future ZNE communities. The documentation of this process, including a description of the methods and techniques used to determine potential near term impacts, is intended to provide guidance to city and county planners and real estate developers interested in similar ZNE projects. It is a record of lessons learned from the first ZNE community built in the United States as well as research and recommendations on the integration of electric vehicles into new communities. As PEV adoption grows it is imperative that decision makers adequately plan for the impacts of a transportation system that is slowly shifting from being powered by fossil fuels to electricity provided by the grid. The implications are important as more ZNE communities are promoted, planned and built. PEVs contribute significantly to community sustainability goals and should not be addressed as an afterthought.

Lessons Learned from EVSE Integration at West Village

Given the experience of integrating electric vehicle charging infrastructure at West Village this report provides the following considerations for new communities and zero-net-energy community:

- Providing conduit at multiple parking locations, regardless of current need of the community is important to streamline vehicle charger installation at a later date.
- While West Village did place extra conduit aggressively, there are concerns that there will not be adequate capacity to support the amount of electric vehicles expected in the near to midterm at West Village, thus more infrastructure is beneficial.
- Providing a separate, isolated electrical panel and meter for electric vehicle charging add significant value as it enables electric vehicles to be metered separately, take advantage of future electricity rates for electric vehicle charging, doesn't interfere with building load panel size calculations and enables solar PV to be dedicated specifically to electric vehicles.
- While Level 2 charging is valuable and should be made available, more low power Level 1 charging should be installed. At West Village, this was particularly true for workplace and residential applications, where electric vehicles are parked for eight hours or more.

EVSE SmartGrid Integration at West Village

The RESCO project allowed West Village to explore the integration of a smart grid controlled electric vehicle charging station. The project accomplished this through a smart energy gateway, which communicates wirelessly to a group of vehicle charging stations installed at West Village. Through the process of designing, installing and commissioning this system, the project has made the following conclusions:

- Controlled charging can offer benefits to the grid stability and financial benefits to those users who participate in demand response events.
- When selecting vehicle charging stations it is important to consider equipment with communications capabilities, as this equipment can easily be integrated into smart grid systems. This is particularly important with workplace, public and mixed use charging installations as these applications can expect to observed charging station use during on-peak utility tariff hours, when the grid could be potentially strained for generation resources.
- Given the current direction and pace of California's Title 24 requirements for new construction, it's reasonable to assume that similar the 2013 commercial lighting requirements, demand response capability may be required in the future for electric vehicle charging stations.

Estimating Travel and Energy Impacts of PEVs at West Village

To determine estimated impact from future electric vehicle charging at the single family homes at West Village, it was necessary to understand travel distances and vehicle type. To understand the unique travel of West Village, regional data from local authorities was used and filtered to select those identified as employees of UC Davis.

- To understand travel and electric vehicles, tools have been created to help developers, planners and others. When considering accommodating electric vehicle charging loads with renewable resources, its important practitioners should become familiar with these resources in order to accurately estimate the impacts from electric vehicles.
- The range of travel and vehicle choice at West Village was found to be widespread and ranged from 3kWh to 27.3 kWh per day of energy use between two scenarios.
- Given the range of energy use, accommodating 100 percent of electric vehicle charging energy with on-site renewables at West Village probably is not practical.

Mitigating Estimated PEV Charging Impacts to Achieve ZNE Goals

Using regional and local travel data collected for the project, models were created to evaluate mitigating these expected vehicle charging loads in a new or existing community with solar. The project found:

- Due to the diversity of vehicles and travel distances, those who strive to accommodate electric vehicle charging loads with renewables should consider careful analysis as to optimize their renewable energy systems size and costs.
- Regardless of the wide range and often unpredictable nature of electric vehicle charging energy use, with careful analysis, it is achievable and reasonable to mitigate a significant portion of a community's electric vehicle energy consumption with solar arrays ranging from 0.8 to 4 kW in size.
- Estimating future vehicle charging demand can be complex and also warrants careful consideration. One effective approach for single family homes is to, at a minimum, install adaptable PV infrastructure that can be readily and easily expanded to meet increasing PEV charging needs of future residents. This design philosophy is called solar PEV charging ready.
- Including the appropriate PV size or the capability to easily expand the home's PV system to accommodate electric vehicle charging loads could be important marketing tool for builders and developers to attract home buyers.

CHAPTER 3:
Site Specific Technology Optimization – Renewable Energy Anaerobic Digester Feasibility

3.1. Goals of the Task

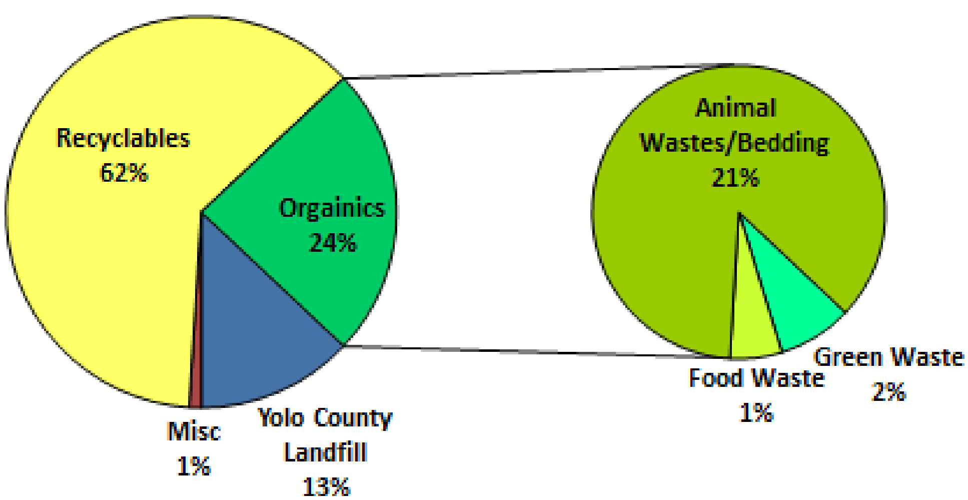
The goals of this task were to finalize engineering design, site architectural plans and cost estimates for a UC Davis Renewable Energy Anaerobic Digester (READ) facility that would convert organic residuals on the campus of UC Davis and West Village into biogas energy, compost and fertilizer products and provide biogas energy to West Village. The following findings are extracted from reports prepared by HDR (2011) and Zhang and Zhang (2014).

3.2. Quantification and Characterization of Organic Wastes at UC Davis

3.2.1. Inventory of Organic Residuals

In 2012, the UC Davis main campus produced 123 tons/day of waste. The waste was characterized by waste type and fate: recycled 76 tons/day, organics 30 tons/day, and landfilled 16 tons/day with a remaining "miscellaneous" fraction. Three main organic waste sources were identified at UC Davis – food waste, green waste, and animal wastes. More than 85 percent of the organic waste produced at UC Davis was animal-based, primarily as animal waste and bedding (e.g., straw or rice hulls) (Figure 8).

Figure 8: Waste Characterization for UC Davis 2012



A departmental survey and review of waste disposal records were conducted to develop a feedstock inventory of the campus organic waste stream. Site visits were made to individual locations on the campus in Davis and to the health sciences campus in Sacramento. The purposes of this approach were to:

- Assess the quality and quantity of the materials for assessment of their suitability as feedstock for anaerobic digesters;
- Gain insights as to the unique issues associated with the generation and consolidation at each potential source; and
- Determine the logistics of feedstock availability in terms of collection frequency, method, and responsibility.

The sources and quantities of organic wastes were determined and those potentially suitable for an anaerobic digester are summarized in Table 14.

Table 14: UC Davis organic waste considered potentially suitable feedstock for READ facility

Department	Facility	Waste Stream	TS to Digesters (tpy)	TS (wet tpd)	Dry Solids (tpd)	TS (wet lb/d)	% Solids	Methane Production (scfd)
Sodexho (Food Waste)	Segundo	Compactor - Other	170	0.47	0.08	932	18%	1,539
		Compactor - Food Pulper	80	0.22	0.04	438	18%	724
		Waste Oil	3.12	0.01	0.00	17	18%	28
	Trecero and Cuarto/Oxford	Compactor	170	0.47	0.08	932	18%	1,539
		Waste Oil	2.26	0.01	0.00	12	18%	38
Olive Center	Olive Press	Olive Pomace	10	0.03	0.01	55	29%	81
Animal Science	Dairy	Manure	2600	7.12	3.42	14,247	48%	32,483
	Feed Lot	Manure + Straw Bedding	1440	3.95	0.63	3,945	16%	6,014
	Sheep	Manure + Straw Bedding	300	0.82	0.13	1,644	16%	1,253
	Beef	Manure + Straw Bedding	100	0.27	0.04	548	16%	414
	Horse (Cole Facility)	Manure + Straw Bedding	460	1.26	0.20	2,521	16%	2,356
	Goat	Manure + Straw Bedding	150	0.41	0.08	822	19%	811
Center for Equine Health	Center for Equine Health	Straw Bedding	371	1.02	0.33	2,033	32%	2,370
		Dry Lots	35	0.10	0.03	192	32%	213
Campus Recreation	Equistrian Center	Barn	1530	4.19	0.80	8,384	19%	6,209
		Pasture	510	1.40	0.60	2,795	43%	1,403
ASUCD	Coffee House/MU	Pre-Consumer Food Waste	50	0.14	0.05	274	38%	635
Med Center	New Facility	Canola Shortening	11	0.03	0.01	60	18%	100
Institute for Wine	Winery	Pomace	5	0.01	0.00	27	29%	40
Food Service	Cafeterias	Grease Trap Waste	104	0.28	0.04	571	15%	1,465

3.2.2. Sampling and Analysis of Organic Waste

An extensive characterization study was carried out to investigate the potential biogas yield of organic waste with a high potential for inclusion in the READ facility. Samples were taken from various sources and analyzed in the laboratory for physical and chemical characteristics relevant to anaerobic digestion. Their biogas and methane generation potential were determined using laboratory batch digestion tests. Two rounds of batch tests were carried out over a two-month period. The main objective of batch digestion tests was to determine the digestibility of these waste streams under thermophilic conditions in terms of biogas yield and methane yield. The results would be useful for determining the operating conditions (e.g., temperature, hydraulic retention time, and loading rate) of a continuous digester fed with a mixture of the different types of waste.

The waste streams sampled and tested (Table 15) included: food waste from the Segundo Dining Commons, one of three Sodexo-operated food restaurants on campus; coffee grounds from the ASUCD Coffee House, a student-run restaurant serving 7000 meals per day; olive pomace from the Olive mill; paper towels from the custodial department which services restrooms all over campus; animal bedding and manure from the Campus Dairy and Feedlot; animal bedding and manure from the Center for Equine Health and the Equestrian Center; and clean straw bedding and cow manure. Additionally, various cardboards from an outside vendor were tested in conjunction with campus wastes.

Table 15: Organic waste streams tested and their sources

Substrate	Source
Round 1:	
Thin cardboard	Outside Vendor
Thick cardboard	Outside Vendor
White cardboard	Outside Vendor
White paper towel	Restrooms/Custodial
Brown paper towel	Restrooms/Custodial
Olive pomace	Olive to Bottle Olive mill
Food waste	Segundo Dining Commons dish room
Inoculum, 1 week old	East Bay Municipal Utility District
Round 2:	
Coffee grounds	ASUCD Coffee House
Horse Manure from barns	Equestrian Center
Horse Bedding - Wood Shavings	Center for Equine Health
Cow Bedding - Rice Hulls	Dairy
Horse Manure from pasture	Equestrian Center
Straw bedding, clean	Vet Med Large Animal Clinic
Cow Bedding – Straw	Feedlot
Cow Manure - from cow on antibiotics	Vet Med
Inoculum, 4 weeks old	East Bay Municipal Utility District

Note: all beddings contain animal manure/urine unless described as "clean."

3.2.3. Biogas Yield and Production Rate

Laboratory-based biogas yields for the thermophilic digesters are provided in Table 16 and Table 17. The total digestion times for Round 1 and Round 2 were 18 days and 37 days, respectively, at which time the biogas production had leveled off for most of the digesters. Biogas yield varied from 96 (wood shavings) to 858 ml/gVS (food waste) and methane content of biogas varied from 58 to 70 percent. The biogas yield of dairy cow manure and horse manure is 338 and 374, respectively. Food waste had the highest biogas yield, 858 mL/gVS. Olive pomace has a lower biogas yield, 509 mL/gVS. The biogas yields of cardboard and paper towel samples ranged from 465 to 606 mL/gVS.

Table 16: Biogas and methane yields and final characteristics of the organic wastes tested in round 1 after 18 days of thermophilic digestion at F/M of 1.0

Parameter	Thin cardboard	Thick cardboard	White cardboard	White paper towel	Brown paper towel	Olive pomace	Food waste
Biogas Yield (mL/gVS)	529	606	465	505	547	509	858
Methane Yield (mL/gVS)	306	356	262	329	324	350	608
Final CH4 Content of biogas (%)	59.2%	59.7%	58.0%	65.1%	60.3%	67.9%	70.0%
Initial pH[a]	8.23	8.22	8.21	8.20	8.17	8.15	8.20
Final pH[a]	7.17	7.14	7.13	7.25	7.19	7.17	7.21

[a] The measured pH value includes substrate and sludge together.

Table 17: Biogas and methane yields and final characteristics of the organic wastes tested in round 2 after 35 days of digestion.

Parameter	Coffee grounds	Horse Manure from barns	Horse Bedding - Wood Shavings	Cow Bedding - Rice Hulls	Horse Manure from pasture	Straw bedding, clean	Cow Bedding – Straw	Cow Manure - from cow on antibiotics
Biogas Yield (mL/gVS)	533	374	96	222	318	577	477	338
Methane Yield (mL/gVS)	387	263	83	154	220	367	334	234
Final CH4 Content of biogas (%)	67.6%	64.6%	64.4%	61.8%	63.3%	61.0%	65.2%	63.5%
Initial pH[a]	8.55	8.62	8.64	8.60	8.54	8.53	8.50	8.45
Final pH[a]	7.84	7.75	8.09	7.76	7.75	7.59	7.73	7.72

3.3. Anaerobic Digester Design and Operation Optimization

3.3.1. Pilot Testing

The existing pilot biogas energy facility at UC Davis (Figure 9) was used to test the High Solids Digestion (HSD) system for co-digestion of dairy manure and food waste (Figure 10). The pilot biogas energy facility was developed previously with funding support from the Energy Commission research and development program. The details for the engineering design and construction of this pilot facility is available in the report by Zhang et al. (2012). To perform the pilot digestion test for this project, improvements were made to the mechanical components and computer software.

Daily production of biogas was measured and recorded (Figure 11). The chemical composition of the biogas was measured periodically by taking gas samples from ports installed in the hydrolysis and biogasification reactor biogas collection lines and analyzing them with a gas chromatograph (GC). Additionally, a gas flow meter was used to continually monitor the gas production and record the values at a central supervisory control and data acquisition (SCADA) computer.

Figure 9: UC Davis pilot biogas energy facility.

Figure 10: Quantities of dairy manure and food waste fed into the pilot digester.

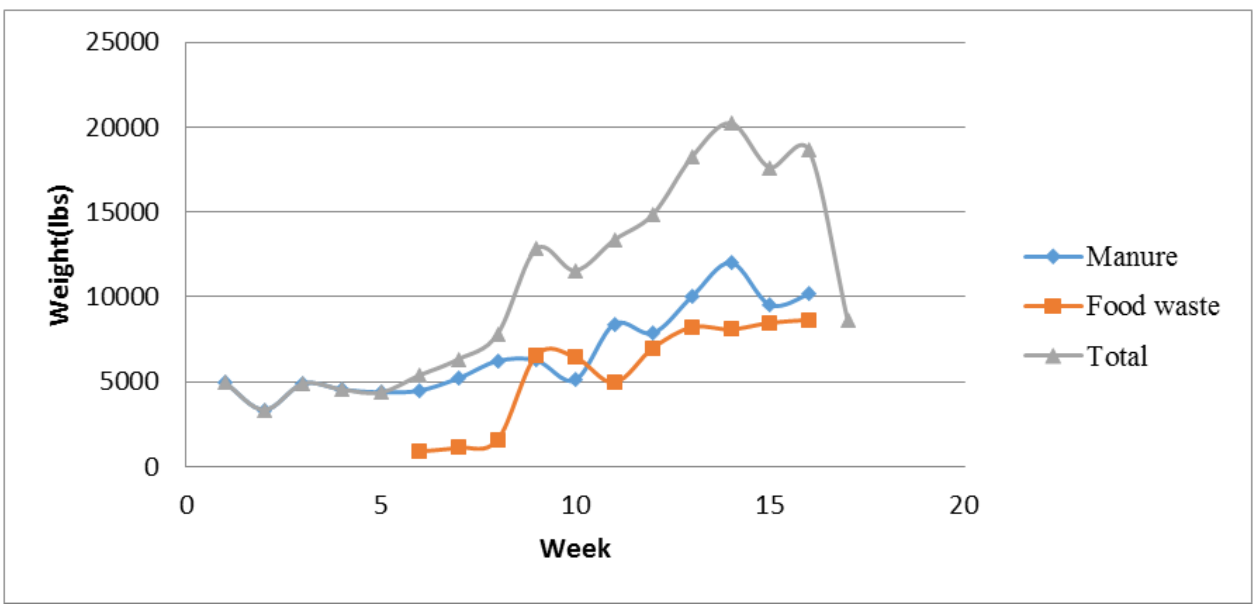
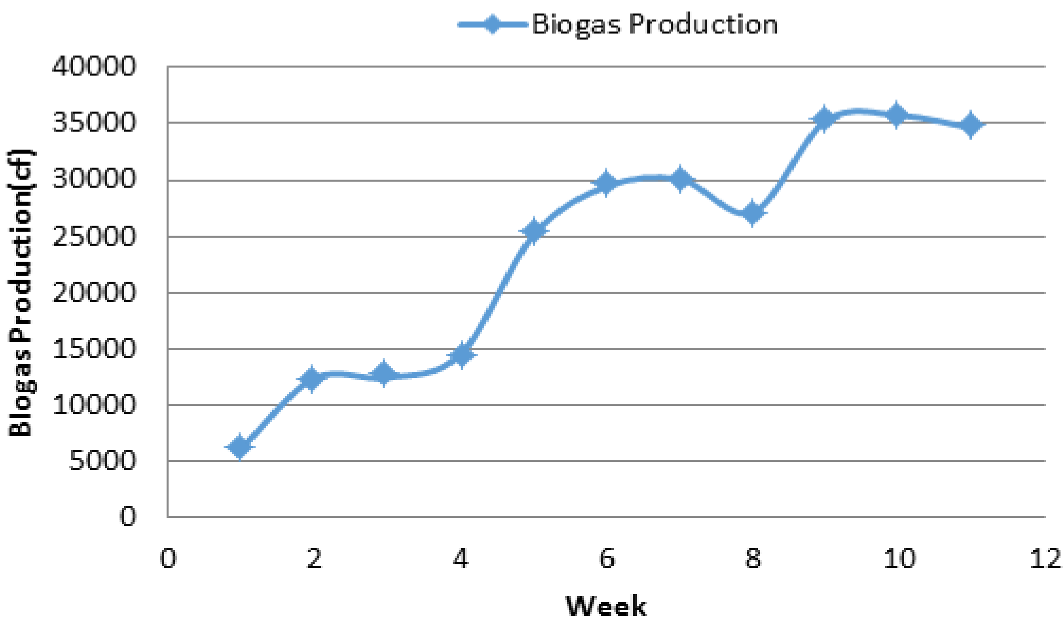


Figure 11: Biogas production from pilot digester fed with dairy manure and food waste



The pilot biogas energy facility used a comprehensive computer control and monitoring system for the operation and data collection. The computerized control system was used to monitor all mechanical components and various processes. Lighted and animated control panels provided the indication of the operational status of all mechanical, operational and process components. The operator(s) was able to control and oversee the various processes from the computer station and make required adjustments and changes as needed.

Once the feedstock (dairy manure or food waste) arrived at the pilot plant, it was weighted and sampled. The samples were quickly transported to the Bioenvironmental Engineering Research Laboratory for solids and moisture analysis. Samples were also taken regularly from hydrolysis and biogasification reactors to measure solids and ammonia contents and pH. The biogas samples were taken from the biogas collection line to measure the contents of methane, carbon dioxide and hydrogen.

Food waste was stored in collection bins and delivered to pilot digester once a week. Dairy manure was scraped from UC Davis Dairy Farm and transferred to pilot digester by truck once a week. Initial operation started with feeding dairy manure from April 2012 for a month with about 5000 lbs. per week. Co-digestion operation started from May 2012 with feeding about 1000 lbs. food waste per week and then increased to 6000 lbs. per week.

From 5/15/2012 to 7/20/2012, 65 tons including 39 tons of dairy manure and 26 tons of food waste were fed into the pilot digesters. The VS loading rate of dairy manure and food waste was approximately 1:1. Dairy manure had total solids content range in 17 to 45 percent with average of 32 percent and volatile solids content ranged in 11 to 21 percent with average of 16 percent. VS/TS data of dairy manure were relatively low compared with previous batch digestion dairy manure sample. Scrape process on the farm collected much more sands and dirt contributing to high fixed solids content. Food waste had total solids content range in 12 percent to 31 percent with average of 25 percent. VS/TS data of food waste were relatively high with average of 94 percent. The average biogas yield was 613 ml/g-VS (9.83 cf/lb-VS) with average methane content of 62 percent.

3.3.2. Effluent Treatment

After one month start-up operation, the effluent samples of pilot digesters were collected once a week and analyzed for pH, solids and nutrient contents. Total Solids content of digester effluent ranged from 3.3 to 4.7 percent and Volatile Solids from 2.5 to 3.6 percent. As shown in Figure 12, the pH of the digester effluent has increased gradually throughout the operation period and became stable at 7.4-7.6 toward the later period of operation. As shown in Figure 13, ammonia concentrations increased over time with the increasing loading and were stabilized at around 2000 mg/L toward the end of operation.

Figure 12: pH of pilot digester effluent

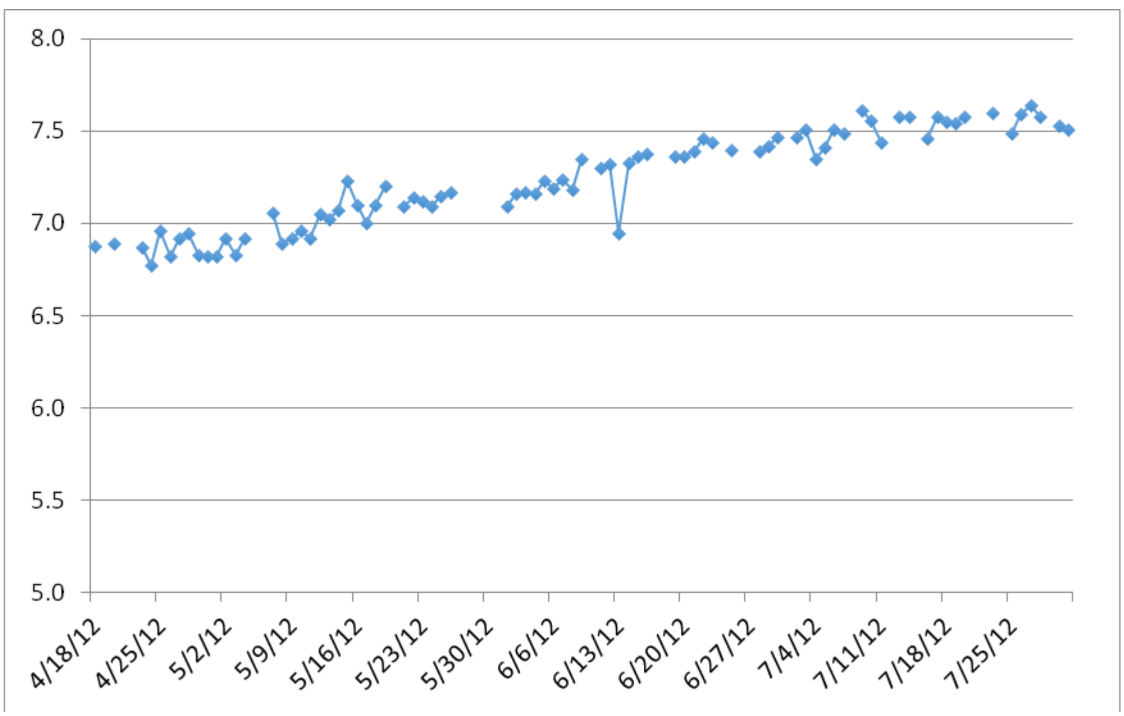
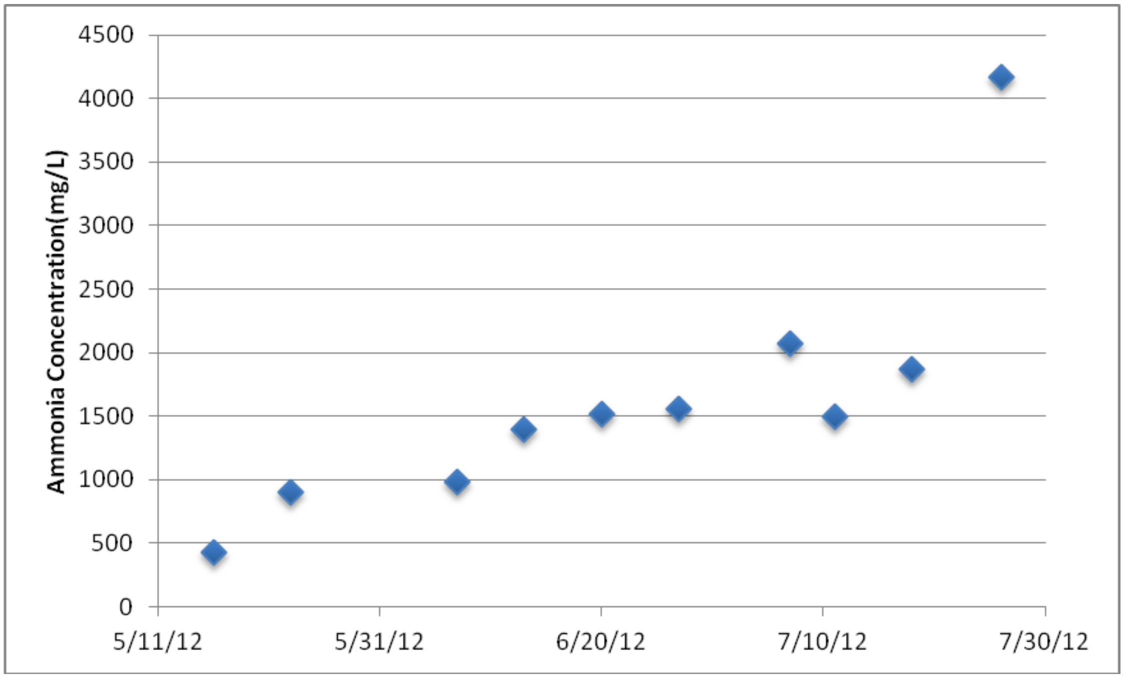


Figure 13: Ammonia concentration of pilot digester effluent



One week after loading ceased, samples were analyzed for nutrient content after processing through a microfiltration unit. The nutrient contents of these samples are presented in Table 18.

In order to reduce the odors and chemical oxygen demand of the digester effluent and also partially convert ammonia into nitrate to result a concentrated liquid fertilizer product that contains mixed ammonia and nitrate, an integrated treatment system was designed as shown in Figure 14 for recovery of nutrients and water.

The digester effluent was processed through a bench-scale microfiltration unit. The filtration performance was assessed by comparing the permeate with raw digester effluent. The total suspended solids (TSS) was reduced from 6845 mg/L to less than 1 mg/L, representing close to 100 percent removal. The chemical oxygen demand (COD) was reduced from 14500 mg/L to below 2000 mg/L, representing approximately an 88 percent removal.

The evaluation of the aerobic (aeration) treatment used a bench-scale sequencing batch reactor that was designed as a nitrification system. The operating conditions of the SBR were controlled such that the nitrification was allowed to occur while ammonia loss through volatilization was minimized so that as much as nitrogen was kept in the effluent for future utilization. About 80 percent COD removal was achieved, and over 88 percent ammonia removal and 70 percent nitrogen conversion were also accomplished (Table 19). However, there was about 19 percent nitrogen loss due to volatilization. About 80 percent of converted nitrogen was nitrite nitrogen instead of nitrate nitrogen. Nitrate nitrogen was more desired than nitrite nitrogen. Longer retention time might be needed in the second SBR in order to achieve more complete nitrification.

Table 18: Nutrient Analysis for Permeate and Retentate Samples (Wet basis)

Element	Unit	Permeate	Retentate
Total C	mg/L	1390	24110
Total N	mg/L	1170	2710
NH4-N	mg/L	1120	13
NO3-N	mg/L	<0.1	39
P	mg/L	3.34	1321
S	mg/L	29.9	841
K	mg/L	668	835
Ca	mg/L	20.9	1451
Mg	mg/L	29.8	305
Na	mg/L	396	467
Cl	mg/L	461	424
Fe	mg/L	1.95	3091
Zn	mg/L	0.04	148
Mn	mg/L	<0.02	21
Cu	mg/L	0.05	13
B	mg/L	0.88	2
Cd	mg/L	<0.01	<0.01
Cr	mg/L	<0.01	1
Pb	mg/L	<0.05	1
Ni	mg/L	0.03	1
Mo	mg/L	0.02	0.2
Al	mg/L	<0.5	693

Figure 14: Integrated treatment system for recovery of nutrients and water from digester effluent

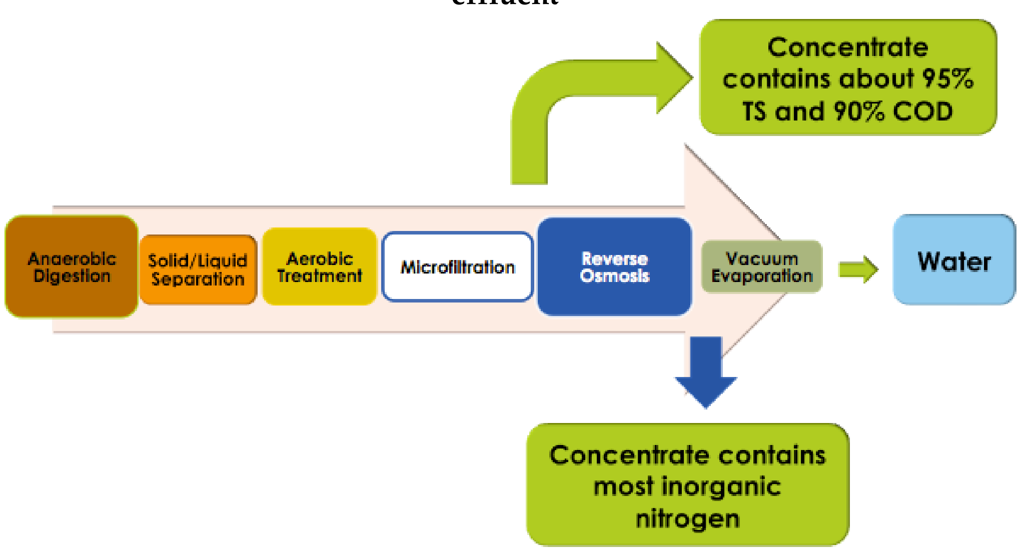


Table 19: Aeration treatment results for anaerobic digester effluent

	Volume (L)	pH	NH3-N (mg/L)	NO3-N (mg/L)	NO2-N (mg/L)
Anaerobic Digester Effluent	6	7.72	1610	35	0.4
Aeration Effluent	6	7.29	200	245	886

A series of reverse osmosis tests were conducted in order to select reverse osmosis (RO) membranes based on the criteria for effective separation of ammonium and nitrate/nitrite ions. In the first RO membrane test, five types of RO membranes were tested. The membrane specifications are presented in Table 20 and the performance characteristics are presented in Table 21 and Table 22.

Table 20: Specifications of RO membranes

Designation	Manufacturer	Polymer	Pore Size	Rej-Size (NaCl)	25C pH Range	Typical Flux/psi GFD@ PSI
SE	GE Osmonics	Thin Film	0 MWCO	98.9	2.0-11.0	22/425
SG	GE Osmonics	Thin Film	0 MWCO	98.2	2.0-11.0	22/225
TFC-HR	Koch Membrane	Thin Film composite polyamide	0 MWCO	99.5	4.0-11.0	not measured
ACM1	TriSep	Polyamide	0 MWCO	99.5	2.0-11.0	25/225
ACM2	TriSep	Polyamide	0 MWCO	99.5	2.0-11.0	30/225

Table 21: Performance of RO membranes for separation of ammonium and nitrate

Membrane Type	NO3-N			NH4-N		
	Permeate (mg/L)	Concentrate (mg/L)	Wash water (mg/L)	Permeate (mg/L)	Concentrate mg/L)	Wash water (mg/L)
ACM2	146	172		233	245	
SE	190	228		75	92.6	
TFC-HR	29	620	37	17.5	695	105
SG	23	310	72	16.8	290	30
ACM1	37	320	66	16.4	137	44

Table 22: Recovery of nutrients after RO treatment

Membrane Type	NO3-N rejection factor (%)	NO3-N Yield_1 (%)	NH4-N rejection factor (%)	NH4-N Yield_1 (%)
ACM2	27	74	7	10
SE	5	34	70	11
TFC-HR	86	73	93	67
SG	89	81	93	62
ACM1	82	91	93	58

3.4. Project Planning and Engineering

The detailed analysis for a biodigester project at UC Davis was included in the feasibility study prepared HDR (2011). This feasibility study was is a joint result of the Energy Commission RESCO grant and a Department of Energy Community Renewable Energy Deployment Grant to UC Davis. RESCO-funded results reported above were used in the feasibility analysis.

3.4.1. Site Evaluation

Three sites were evaluated for the location for the READ facility on the UC Davis campus: (1) the existing UC Davis landfill on the west side of County Road 95; (2) Hopkins Road near the University Airport; and (3) the UC Davis wastewater treatment plant south of Interstate 80. The primary differences between the sites related to costs of relocating existing uses and compatibility of neighboring uses. Detailed analysis is presented in HDR (2011). After considering all factors, the decision was made to locate the READ facility and the campus landfill site.

3.4.2. Engineering and Economic Design Considerations

Using the results from the testing of campus feedstocks described above, the following digester technologies were considered:

technologies were considered:

- High-Solids Anaerobic Digestion
  - Single-state Systems
  - Multi-stage Systems
  - Anaerobic Phased Systems
- Low-Solids Anaerobic Digestion
  - Not applicable
- Dry Fermentation
  - Bunker Type
  - Flexible Membrane Type

The high solids phased anaerobic system was selected as the best technology at UC Davis because: (1) it was well suited for highly biodegradable solids waste streams and mixed solid/liquid such as food waste, animal manure and bedding, and paper waste; (2) it was capable of handling variable deliveries of diverse feedstocks; (3) conversion efficiencies were high; (4) the footprint requirements were small; and (5) environmental issues were minimal.

Based on the cost estimates prepared and economic feasibility analysis performed by HDR, the anaerobic digestion project was deemed not economically feasible. Subsequently, UC Davis decided to partner with CleanWorld, a start-up company in Sacramento, which was formed to commercialize the high solids digestion technology developed at UC Davis. At the time when this partnership was formed, CleanWorld had designed and built two anaerobic digestion facilities in Sacramento, converting food and other municipal organic waste into biogas energy.

3.5. Analysis of Biomethane and Biofuels Production

Biogas generated during anaerobic treatment can be recovered in a variety of ways at the READ facility to generate electricity or to provide an additional heat source at the UC Davis campus. One of the important variables considered in alternative applications is the condition of the biogas.

Biogas generated from the AD facility may contain approximately 60 to 70 percent methane, 30 to 40 percent carbon dioxide, hydrogen sulfide, and other trace gases. The biogas from the AD reactors will also be saturated with moisture. As the biogas cools during handling, water will condense in biogas piping and therefore provisions for condensate removal must be considered. Depending on how biogas is recovered and utilized, extraneous biogas constituents including water, sulfur, carbon dioxide, and siloxanes, may need to be removed from the gas before it is utilized. Furthermore, air emission restrictions may require additional biogas treatment upstream of utilization beyond what may be required by the biogas utilization equipment. Therefore careful consideration of biogas quality is important to properly account for biogas treatment requirements needed for a particular facility.

A review and analysis of alternative technologies that could be applicable to READ facility considered the following applications:

- Electricity
  - Internal Combustion Engines
  - Microturbines
  - Fuel Cell
- Boiler Fuel Source
- Compressed Natural Gas Transportation Fuel

Several uses of the methane are potentially available, including supplementation of existing natural gas use in boilers at UC Davis facilities (such as the Primate Center), electricity generation using fuel cells, internal combustion engines or microturbines, cleaning of the biogas for injection into the natural gas pipeline or use in vehicles that use compressed natural gas (Table 23). Of these alternatives, utilizing the biogas in existing boilers is typically the most cost effective and efficient means for utilizing the methane unless the cost to convey the gas to the boiler facility is too high or there is a large demand for waste heat generated with the use of fuel cells, internal combustion engines or microturbines. A portion of this waste heat from electrical power generating devices could be used for digester heating yet excess heat would still be available. The Primate Center management is considering modifications to its existing boiler system that could include continued use of the existing landfill gas and use of biogas from the READ facility.

Alternatively, the biogas could be cleaned to pipeline quality or converted to electricity using an IC Engine, microturbine or fuel cells. Any one of these means for using biogas for energy generation could be employed for each digester technology presented earlier. That is, the biogas quantity or quality from each digester technology will be similar and does not dictate which biogas recovery option should be used for the READ facility. Any biogas recovery and utilization alternative could be used for any one of the digester technologies presented above. A summary of the biogas alternatives including advantages and disadvantages is provided in Table 23.

Some of the biogas recovery alternatives require unique feed gas composition or qualities and therefore the extent of gas cleaning varies between biogas recovery alternatives. Table 23 summarizes equipment and costs for biogas treatment technologies associated with each alternative. The cleaning requirements are the most robust for bio-methane production since CO_2 removal is required for this alternative. Among the remaining options, gas cleaning for fuel cells is the next most extensive. The requirements for cleaning biogas for recovery as a supplemental fuel in existing boilers or use in an IC Engine or microturbine are similar and reflect the lowest cost option. Preliminary cost estimates indicated that the fuel cells would be approximately two to three times the capital cost of the other alternatives.

Table 23: Summary of Biogas Recovery Alternatives

Biogas Recovery Alternative	Technology Approach to Biogas Cleaning	Advantages	Disadvantages
Recovery in Existing Boilers	Chiller system (moisture removal) Single stage iron sponge (sulfur removal)	Moderately low cost Would expand upon the current practice of using landfill gas as a supplement to the natural gas boilers at the Primate Center	Adds complexity to boiler operation Would be limited to use for sites within close proximity to the Primate Center
IC Engine	Chiller system (moisture removal) Single stage iron sponge (sulfur removal)	Well established technology Moderately low cost	Potentially higher NOx could result in higher permitting costs
Microturbine	Chiller system (moisture removal) Two-stage iron sponge (sulfur removal) Media filter (particulate removal)	Available in small sizes compatible to UC Davis biogas generation Less NOx is generated so potentially less permitting	Low efficiency (~25-30% overall efficiency) Moderately high cost Less established use
Compressed Natural Gas	Water scrubber (CO2 and H2S removal) Biofilter (air stripper off-gas)	Available pipelines nearby candidate READ facility sites Efficient use of gas	Significant biogas cleaning needed Moderately high cost
Fuel Cell	Chiller system for (moisture removal) Two-stage iron sponge (sulfur removal) Activated Carbon Filter (organic sulfur removal) Media filter (particulate removal)	Highest efficiency (~47% electrical efficiency) Less NOx is generated, so potentially less permitting	Highest cost Significant biogas cleaning needed

Table 24: Capital and Operating Costs for UC Davis Biodigester

	22 tpd	50 tpd
Capital Cost	$14,400,000	$23,570,000
O&M Cost	$730,000	$1,100,000
Revenue	$760,000	$1,740,000
Net Present Value	$13,900,000	$14,800,000
ROI (yrs)	480	37

Ultimately, the decision was made to use microturbines for biogas to energy conversion. The anaerobic digesters are expected to produce 120 cubic feet per minute of biogas containing 55-65 percent CH4, 35-45 percent CO_2. Currently the landfill from the UC Davis landfill generates 130 cubic feet per minute (cfpm) of landfill gas (primarily 40-45 percent CH4, 55-60 percent CO_2). It was decided to combine the biogas and landfill gas for co-generation of electricity and heat using four Capstone C200 Microturbines (CARB approved 31 percent +/- 2 percent efficiency, each rated @ 200 kW) and a Rankine-cycle engine for energy recovery from waste heat (rated @ 125 kW, dependent on heat available). An integrated biogas to energy conversion system was designed and built at UC Davis READ facility as shown in Figure 15. The biogas and landfill gas are cleaned using a series of filters (water vapor via chiller, H2S via iron sponge, siloxanes and volatile organic carbons via carbon filter).

Figure 15: UC Davis READ digesters, biogas cleaning, and energy generation equipment

CHAPTER 4: Technology Transfer and Wide Scale Implementation Plan

4.1 Technology Transfer and Wide Scale Implementation Plan

4.1.1 The Current Landscape of ZNE and Understanding the Obstacles to Wide Scale Implementation

ZNE as a goal for new development has gained considerable interest as a strategy to save energy and cut greenhouse gas emissions. A ZNE building or community as defined for this project is one that uses a combination of improved efficiency and distributed renewable generation to cover at least 100 percent of its net annual energy use. California agencies have set ambitious goals for ZNE in new homes by 2020 and in commercial buildings by 2030 and are pursuing various policies and strategies to achieve those goals[5]. Furthermore, in 2012, California Governor Jerry Brown signed Executive Order B-18-12 that sets a ZNE target for 50 percent of the square footage of existing state-owned buildings by 2025 and ZNE for all new or renovated state buildings beginning design after 2025.

The intent of this analysis (White et al. March 2014a and March 2014b) is to augment the existing body of literature with the lessons learned from a project team actively seeking to create a large-scale ZNE project. Existing literature commonly recommends sharing the lessons learned in specific projects.[6] The fact that relatively few ZNE projects have been constructed to meet the strict financial demands of the private investment market makes the West Village case study especially relevant to current policy discussion and future deployment of ZNE buildings by the private sector.

As a result of California's goals for transforming the building industry by encouraging ZNE outcomes for all new residential construction by 2020 and all new commercial construction by 2030, ZNE buildings and communities are the subject of a growing body of literature and research. Such literature includes "The Road to ZNE: Mapping Pathways to ZNE Buildings in California" by the Heschong Mahone Group, Inc. (2012), and "The Technical Feasibility of Zero Net Energy Buildings In California" (December 2012) by Arup[7] This research explores, at a

[5] California Public Utilities Commission Energy Efficiency Strategic Plan, various documents, http://www.cpuc.ca.gov/PUC/energy/Energy+Efficiency/eesp/

[6] Heschong Mahone Group, Inc., "The Road to ZNE: Mapping Pathways to ZNE Buildings in California," November 20, 2012, http://www.calmac.org/publications/The_Road_to_ZNE_Report_CALMAC_PGE0327.01.pdf.

[7] Arup North America Ltd., *The Technical Feasibility of Zero Net Energy Buildings in California*, December 31, 2012, http://www.energydataweb.com/cpucFiles/pdaDocs/904/ California_ZNE_Technical_Feasibility_Report_Final.pdf.

high-level, the broad range of issues that must be addressed to enable wide-scale implementation of ZNE in California. Existing research includes analysis of California's building and energy codes, electrical grid infrastructure impacts, utility planning efforts, and existing and proposed regulatory and policy issues that may contribute to or detract from the state's overall ZNE goals.

4.1.2 Challenges for Developers and Builders

Identifying and aligning contractual, reputational, and financial incentives of all team members from the earliest stages of a project is a necessary step to ensuring attainment of challenging goals such as ZNE construction. Several key items that were important to the success of West Village included:

Use of Energy and Financial Models

Energy and financial models were intensively used during all phases of the West Village project and had significant bearing on the outcome of the project. The use of these models exceeded that of conventional projects.

Recommendations:

Developers pursing ZNE status should allow time and resources for this process when preparing project budgets, schedules, and assembling project teams.

Enforcing High Construction Standards

Regardless of the level of analysis and technology that is used in building design, building performance is significantly dependent on the quality of construction. Basic elements such as tightly sealed building envelopes, properly installed insulation, and properly installed and calibrated equipment are often overlooked in the midst of construction. These elements affect energy consumption of a building and are not easily remedied once a building is complete. Additionally, inspections by a qualified Home Energy Rating System (HERS) inspector are given credit by the California Building Code for energy modeling and permitting purposes, as well by utility incentive programs. For that reason it is important that attention is paid to these items during the construction process; for West Village DEG recommended inspection by a qualified third party for the building envelope and mechanical systems. As the owner and builder of the project, WVCP was incentivized to provide such inspection, as the cost of this service can be recovered many times over throughout a building's lifetime as a result of increased energy savings.

Recommendations:

- Conduct inspections during the construction process using an independent third party

Optimizing Airflow

Optimizing airflow in buildings can be addressed to a large degree by good construction practices as noted above, as well as by passive measures implemented during the design of a building. The prototypical student housing building, The Ramble, features single-loaded corridors (corridors with apartments on only one side) open to the exterior that allow all apartment units to receive natural cross-ventilation. Additional passive or near-passive design features, such as the use of operable windows and ceiling fans, provides occupants with the option for natural ventilation and air circulation with low or no-energy systems. Davis's large temperature swing from day to evening is ideal for nighttime natural ventilation during summer months and daytime natural ventilation during winter months. The impact on building energy use as a result of these systems is dependent on the behavior of building users, can vary widely from occupant to occupant, and is therefore difficult to predict accurately.

Airflow as a result of mechanical systems is more directly controllable by design. Typical inefficiencies involve incorrectly sized or inefficiently routed ductwork, leaky ducts, and inefficiently sized mechanical equipment. At DEG's recommendation a third party review of these issues was implemented at West Village, including detailed HVAC calculations for equipment and duct sizing by the project's mechanical designers, and for tightly sealed ducts located in the conditioned spaces of buildings. Title 24 provides credit for these measures, as do utility incentive programs, both of which benefited West Village.

While approaches like these would ideally be standard practice in the building industry, historically they have been the exception. This situation is changing due to the increasing stringency of energy efficiency regulations and the proliferation of green building rating systems such as LEED, which provides credit for these measures.

Recommendations:

- Design buildings for maximum passive natural ventilation.
- Engineer mechanical ventilation (airflow and duct sizes) specifically for the needs of each space; do not rely on standards.
- Specify tightly sealed ductwork, verified through third party inspection.

Hot Water Heating

Heating water for domestic use constitutes the largest use of energy in the typical base-case scenario. Reducing the energy use of this function can result in substantial net energy savings. While solar hot water heating was not used on the project, the next most efficient method of heating water, a heat pump water heater system, was chosen instead.

Compared to conventional gas or electric water heaters, air-to-water heat pump systems are relatively complex and are typically not used in market-rate developments. However, the U.S. Department of Energy finds that such systems can reduce the energy required for water heating by 33 – 66 percent over conventional electric storage water heaters.[8] Their use at West Village was important in achieving the project's energy saving goals. Heat pump systems, which work

[8] "Heat Pump Water Heaters | Department of Energy," *Heat Pump Water Heaters | Department of Energy*, accessed August 13, 2013, http://energy.gov/energysaver/articles/heat-pump-water-heaters.

best in a climate that averages between 40 F and 90 F year-round,[9] are well suited for Davis. The developer and design team alike consider the heat pump water heater system to be the project's most unique approach to energy savings. Despite some early challenges keeping these systems operating correctly, the issues are now thought to be resolved, and the heat pump water heating system should continue to provide energy savings for the lifetime of the project.

Water-heating system sizes were minimized to the greatest extent possible by incorporating water-saving appliances such as high-efficiency horizontal axis washing machines, high-efficiency dishwashers, and low-flow plumbing fixtures. In addition to high-efficiency water heaters, the design of the plumbing network itself can degrade or enhance energy efficiency. Long distances between a water heater and the end use result in lost heat and lost energy. To reduce this loss, the design of the plumbing infrastructure is optimized to use the shortest runs of water piping possible. Additionally, all piping providing hot water to the buildings and back to the water heaters is insulated and installed inside conditioned spaces, where feasible, to further minimize heat loss.

Recommendations:

- Maximize efficiency of hot water systems by reducing pipe runs and fully insulating supply and return hot water pipes.
- Evaluate feasibility of expanding existing incentive programs, or creating new programs, to increase the market penetration of efficient water heating technologies such as air-to-water heat pumps.

Space Heating

Space heating accounts for 28 percent of base-case energy use, and DEG was able to reduce this amount by 50 percent in the energy models they provided. Passive measures improved the thermal performance of the buildings considerably and accounted for a large percentage of space heating energy savings. DEG's recommendation for active systems was a high-efficiency (15 Seasonal Energy Efficiency Ratio [SEER] / 12.5 Energy Efficiency Ratio [EER]) air heat pump, which was incorporated into the project. Further energy savings were achieved by installing ducts inside of conditioned space, where feasible, and by fully sealing and insulating all ducts, regardless of location. These design and construction measures decrease heat loss and increase the operating efficiency of HVAC equipment.

Recommendations:

- Reduce space heating loads to maximum extent possible through efficient building envelope design.
- Investigate the use of heat-pump systems for remaining space heating.

Lighting and Appliances

[9] Ibid.

Interior lighting and appliances combined account for 29 percent of the base-case building energy use. Gross energy use for these functions was reduced through the design of lighting systems and specification of appliances, but as energy use was reduced in other areas, lighting, appliances, and miscellaneous loads combined continue to represent the largest percentage of building energy use.

Measures to address lighting energy use include vacancy sensors integrated into light fixtures to automatically turn lights off when occupants are not present. DEG recommended, and the builder implemented, hard-wired high-efficacy lighting in the bedrooms of the multi-family buildings. This measure is not typically incorporated into projects, as it is not required by building codes and adds cost to construction. The benefit is that permanently installing these fixtures reduces the number of (potentially inefficient) occupant-owned lamps that are needed and ties this light source to vacancy sensors. High efficacy lighting was also installed in kitchens and bathrooms of each unit, per building code standards.

Researchers at UC Davis are conducting leading-edge research and development of LED light sources. LED technology offers tremendous potential for energy savings, as it can provide illumination using a fraction of the energy that high-efficiency fluorescent fixtures use today. Because of their relatively new status in the marketplace at the time, LEDs had not yet seen wide market uptake for general area lighting needs and had a high relative first cost compared to other light types, although due to energy savings and long bulb life these costs can be recovered several times over. During the product review and selection process the design and development team analyzed these LED fixtures closely, and ultimately determined that lack of market standardization and uptake would make them inappropriate selections for the West Village project.

The decision to use florescent lighting in the multi-family portion of West Village was made in 2009. Since that time the price, market uptake, and standardization of LED fixtures has improved considerably. Future teams working on high-efficiency projects would be wise to perform a benefit-cost analysis of these fixtures for their project.

The energy use for many residential appliances is regulated by the federal government, and these regulations cannot generally be made more stringent by an individual state, which presents challenges in adopting statewide goals for ZNE construction. However, individual building owners are free to select appliances that meet their cost and efficiency needs. Because WVCP will remain the owner of the multi-family and mixed-use buildings on site, they were able to closely control appliance selection. DEG's recommendations for appliances included Energy Star-rated dishwashers, refrigerators, washers and dryers.

Recommendations:

- Market penetration of LED technology is advancing rapidly. Conduct benefit-cost analysis for including LED lighting in a proposed project. Such analysis should incorporate lifetime costs such as increased bulb life and reduced electrical consumption.

- Consider providing incentives, such as low-cost energy-efficient appliance packages, to entice homebuyers to purchase efficient appliances for their new homes.
- Furnish rental housing with energy-efficient appliances.

Control of Miscellaneous Electrical Loads

Miscellaneous electrical loads (MEL), sometimes called 'plug loads,' from devices owned and operated by building occupants constitute the majority of energy use in buildings that have been designed to high standards of operational efficiency. These loads also represent energy use that is largely out of the control of building designers and owners of multi-tenant buildings, and this energy use is increasing due to the proliferation of electronic devices. Central to efforts to curb the increase of MEL is the creation of feedback mechanisms that inform building occupants about the amount of energy being consumed and providing them with appropriate incentives to conserve and the ability to control it easily. The market for controls is rapidly growing and ranges from devices that are built-in to a building's infrastructure (the electrical system, automated building management system, or both) to loose devices easily installed and operated by building occupants. In an effort to reduce building electrical consumption, WVCP contracted with a manufacturer of a loose device but was faced with serious implementation challenges that ultimately led to the device's removal from the project.

The chosen loose devices resembled traditional surge-protector power strips typically used for computer and stereo equipment. What made the devices used at West Village unique was the fact that each was equipped with data recording capability and WiFi functionality that allows it to transmit historical and real-time data to a user-interface, which can be accessed on the user's computer or smart phone. The interface provides users with the ability to turn individual devices on or off in real time or to program schedules for the operation of particular devices. In addition to reducing the energy use of devices that are constantly on, this type of controllability also reduces so-called phantom energy loads associated with electronic devices that are turned off but still draw power. The graphical, user-friendly interface allows users to view current and past energy use snapshots in a simple and readily comprehensible way.

Conceptually, these devices addressed the dual needs of providing feedback to users about their energy use and a simple and direct way to control it. At the time of implementation in 2011, the concept of remote management of MEL was still relatively new, and unforeseen problems quickly emerged. The WiFi signals generated by the devices operated on the same frequency as building-integrated WiFi Internet service, and may have caused or contributed to a widespread outage of student Internet service at critical periods. Additionally, the device's WiFi signal caused a disruption of the PV system's automated wireless data gathering and reporting, resulting in approximately 45 days of lost information regarding energy generation of the PV system. Unable to provide a remedy in the field for these problems, the manufacturer of the devices and the project developer removed them from the project after the source of the issue had been identified. In the meantime, the developer was tasked with resolving student's complaints about Internet access being lost in the midst of midterm exams, many of which are administered online. To date, a replacement for the devices has not been selected and MEL remain unmanaged on the West Village project, although the manufacturer of the devices, and the industry as a whole, have since worked to eliminate such conflicts with their hardware.

Recommendations:

- Provide intuitive, non-obtrusive but powerful method of user control and feedback for MEL.
- Test compatibility of new systems with other building infrastructure prior to widespread deployment.

Proposals to control the amount of energy consumed by MEL also emerged in CES's 2009 ZNE proposal. The use of a master switch to control all lighting and miscellaneous loads in a unit would provide occupants with the ability to easily limit energy use while away from home. CES took this concept further and recommended that this switch be integrated with student ID cards, allowing for tracking of occupant energy-use behavior. The developer chose not to incorporate this feature into the project due to concerns over cost as well as lifestyle effect on occupants. Wiring apartment units in this manner would add small incremental cost per unit, but when multiplied by 663 units would result in notably increased project cost. Additionally, coordinating the use of a master switch among four independent apartment occupants could be difficult. As a result, MEL remains unmanaged at West Village and represents a large remaining area of energy savings for the project.

NEM vs. VNM costs for PV inverters

The West Village development team chose to take advantage of NSHP incentives for PV arrays in 2010, well after construction had begun on West Village. NHSP incentives could not be applied to solar installations serving more than one residential unit in 2010, but have since been modified to allow for virtual net metering in multifamily buildings. As a result of this limitation, WVCP LLC, who had assumed that virtual net metering would be used in the multifamily buildings at West Village, had to undertake design changes to the project in the midst of construction. The total amount that was added to the construction cost of West Village due to these revisions was not disclosed by WVCP, but included the cost of 671 inverters and significant amounts of electrical infrastructure such as added conduit, conductors, and underground connectors. In addition to the added cost of construction (which for a typical building is a small percentage of total cost of ownership over a building's lifetime), the addition of multiple small electrical inverters will create ongoing maintenance and replacement costs over the lifetime of the buildings. With an industry-standard lifespan of 10-12 years, each inverter will need to be replaced five to seven times on average during the 65-year ground lease period. Using a current cost average of $1,454 per inverter, this amounts to a lifetime ownership cost of between $4,878,458 and $6,829,841 for the project's owners. Had a VNM arrangement been available, fewer inverters would have been used, and those would have been larger and potentially more durable. Although the design of the system under that scenario would have determined the actual costs, rough estimates indicate a $477,512 difference in costs for inverters only and between $2,387,558 and $3,342,581 difference in total lifetime ownership costs for those inverters. These amounts represent added costs that WVCP (or any developer of market-rate multi-family homes) realized as the result of NEM rules in place at the time.

California's NEM rules were revised in late 2011 and now allow VNM on market-rate, multi-family housing projects. WVCP has taken advantage of this rule change and has modified the design of the PV system for the apartment buildings built after that date. For the West Village project, 156 apartment units are affected by this change and will be supplied with energy from PV systems in a VNM configuration. Examining costs for inverters only reveals that under the VNM arrangement 156 apartment units are provided with 65 inverters at a total cost of $170,430, for an average of $1,109 per apartment for inverters only. This compares with an average cost per apartment of $1,875 for inverters under the previous arrangement. Under the VNM arrangement, lifetime ownership costs are projected to be 17 percent of the costs incurred under the NEM configuration.

The various incentive programs that were used to finance the installation of PV were sufficient to allow WVCP to include the system in the project with limited to no effect on ROI and no net financial effect on the occupants of West Village. Reductions in the cost of the PV system would have allowed the same incentives to purchase larger amounts of PV generating capacity, or would have allowed the developer to install the same amount of PV while using less funding from incentive programs. Given that available pools of incentive funding are limited statewide, this approach would have allowed the incentives to support additional renewables on other projects.

Recommendations:

- Allow for VNM arrangements for multi-family and single-family homes.
- Arrange incentive programs to recognize community-scale renewable generation.
- CEC and CPUC should continue to examine size limits and other implementation effects of NEM regulations to ensure that they do not result in an inefficient use of state resources intended to promote the use of renewable energy generation.

4.1.3 Challenges for Residents

The performance of any construction project typically fluctuates widely during the early stages of occupancy as building systems are calibrated, construction errors or omissions are corrected, and building users gain experience with the operation of the new structure. Critical issues are discovered during the period of initial building occupancy, and properly identifying and correcting these issues affects the building's performance over its lifetime. Having a thorough and detailed action plan to address this process is a fundamental aspect of high-performance buildings and has been incorporated into green building rating systems such as the USGBC's LEED program. In commercial construction, this process begins with building commissioning by neutral third parties meeting strict requirements for competency and extends through post-occupancy surveys that shed light on building functions and user behavior. For complex commercial buildings, it is not uncommon for the process of measurement, verification, and adjustments to last one to two years after initial occupancy, or longer. For some new buildings, the implementation of continuous commissioning over the building's lifetime is becoming more common. In residential construction, similar needs are addressed by on-site inspections performed by neutral third-party inspection firms to ensure building functionality. Because residential construction is typically less complex than commercial construction, the scope and cost of this process is usually less than for commercial structures, however, the potential for improvements in building performance are measureable in both cases.

Although it is primarily a residential project, the scale of West Village and the combination of multiple energy efficiency measures with large amounts of renewable energy generation make the initial break-in period more complex and lengthy than for typical residential projects. Multiple systems need to function properly both independently and in concert with one another. The energy use behavior of building occupants creates an additional variable that is difficult to model (See section below titled, *Building Occupant Behavior*). As systems are optimized and user behavior interventions are made, the energy consumption of the buildings will begin to stabilize and approach the estimates included in early building energy models.

Building Occupant Behavior

The way occupants use a building is not limited to a single end use of energy. Rather, it spans every assumption made during the energy modeling process, affects all building systems, and impacts overall energy use. Some systems at West Village have been designed to override certain occupant behaviors, such as vacancy sensors on built-in light fixtures to prevent lights from being left on in unoccupied rooms. Other types of energy-consumptive behavior, such as having low thermostat set points for air conditioning or multiple electronic devices drawing power, are more difficult to address with design measures and are hard to quantify specifically without detailed submetering. Submetering could provide the opportunity for separate billing for individual users and establish financial incentives to conserve energy.

Education of building users holds additional potential for energy savings, although the nature of tenancy at West Village presents challenges in this regard. The rental cycle at West Village is currently arranged to roughly correspond to the UC Davis academic calendar. Leases for every apartment begin September 1 and are 12 months in duration. Tenants are allowed to renew leases and remain in an apartment over multiple years. Under this leasing cycle, as is common with most student housing projects, West Village receives an influx of new tenants every year, and the process of educating these users about energy use begins anew. The project has not yet been occupied for sufficient time for data to be collected on energy use of new versus existing tenants. Gathering and analysis of this data may offer insight into the effectiveness of tenant education and incentive programs in the future.

Critical to the concept of promoting energy-conscious user behavior is the ability for building users to receive real-time feedback about how their use of the building impacts energy consumption. Many companies within the building industry have responded to this need, and a wide range of devices are available that measure energy use against a pre-established baseline and inform users about their energy use in real-time as well as over extended periods. The most common of these devices are digital dashboards that graphically present the information in an easy-to-understand format. Use of these devices requires either the submetering of the monitored systems or that meters be installed post-construction. One approach for post-construction installation of metering and control equipment is by the use of loose devices that are plugged in-line with user-owned equipment (See section above titled, Control of Miscellaneous Electrical Loads). An approach of this type may be used at West Village in the future if the benefit can be shown to outweigh the cost for the project owner.

4.2 Recommendations for Advancing Successful Adoption of ZNE Communities

California's regulatory and incentive system is complex and outside the range of expertise of most participants in a development project. Development teams will benefit from a team member with specialized policy expertise in these areas. Conversely, a clear regulatory pathway to attaining ZNE in an economical way is needed to facilitate achieving the state's goals for ZNE deployment.

Engagement of the local utility provider early in a project will aid success

ZNE projects are faced with regulatory hurdles unique to energy use and generation. Early and frequent consultation with local utility providers will minimize confusion and expedite the decision-making process.

Building users have significant, and unexpected, effects on energy use

As buildings become more energy efficient, the remaining energy demand becomes even more dependent on those that occupy the building. Addressing this component of energy demand is critical to achieving ZNE results.

Incentives for renewables need to be acted on quickly

The landscape of incentive programs evolves rapidly relative to the timescales of large development projects, which tend to require years of planning, approvals, and financial analysis. Consequently, where possible, participants in large development projects should act early to lock in incentives.

4.2.1 Lessons Learned

Lesson #1: Creating a ZNE Community is Feasible under Market-Rate Conditions

Above all else, West Village is a real estate development project undertaken by a private developer in pursuit of profit. Although the developer was contractually obligated to make the project environmentally responsive, they were not under contract to pursue ZNE status and only agreed to do so to the degree that WVCP's ROI could be sustained while providing market-rate costs to tenants and owners. Developers such as WVCP have institutional investors that expect returns comparable to any other real estate investment, whether it is sustainable design or not. WVCP has a fiduciary responsibility to their investors and therefore all measures of efficiency and renewable generation had to work within their financial framework. Incentives for renewable generation aided the project and allowed ZNE to be pursued. Similar incentives are available to other developers, although state and federal programs are constantly in flux and must be considered based on their likely contribution at the time of construction.

The design and construction of West Village is not exotic and is replicable in other private developments. Site plans for multi-family and single-family homes do take environmental considerations into account while exceeding real estate industry norms for density and design—in fact, the density of West Village greatly exceeds typical suburban development indicating that high-density designs are compatible with the pursuit of ZNE at least on sites with adequate space for renewable generation. The project does not rely on cutting-edge technology to attain high levels of energy efficiency. With the exception of the air-to-water heat exchange hot water heaters, all components of the project are off-the-shelf and readily available to other project teams. WVCP and their consultants actively sought to avoid including custom or unproven technologies in the project. Buildings are Type-2 and Type-5 construction, which is typical for residential buildings in California. The major steps taken to ensure efficient buildings include careful attention to detail in the design of buildings, heavy reliance and responsiveness to energy modeling, and on-site quality inspection of construction details by an independent third party. These techniques are available to any design and construction team in California and are essential to achieving highly efficient buildings.

Lesson #2: Team Alignment is Critical for Success

Designing an environmentally responsive community was a key goal of UC Davis from the earliest conceptualization of the project, and a development partner was chosen who was committed to this objective. As the goals of the project evolved to include the attainment of ZNE status, all team members, including the developer, UC Davis, and their supporting entities committed themselves to achieving this goal despite the fact that no one was contractually obligated to do so. The reality of West Village is that a handful of key decision makers representing WVCP and UC Davis were committed to attaining ZNE. Without them, it would not have happened.

The pursuit of ZNE involved effort and risks that a typical project would not experience. Interviews conducted with key high-level participants of the project revealed a consistent belief that 30 - 40 percent more effort was required at a management level due to ZNE goals than for a typical project. Extra effort was needed to address financial, regulatory, and technical challenges. Most of the key team members shouldered this workload in addition to their regular jobs and did not receive additional compensation for their effort. Commitment to the challenge and to "doing the right thing" prevailed to motivate the team, as did reputational benefits. Risks for the team included financial risks for the developer if anticipated energy efficiency measures did not perform as anticipated, or if highly efficient buildings proved undesirable to lease. To date neither concern has borne out.

The alignment of entities at West Village was a unique occurrence that is uncommon in the construction industry. Seldom do owners, developers, designers and contractors march in unison towards the same goal, as each typically has different incentives for financial and legal performance. Frequently the incentives of one entity are in competition with the incentives of another. Although the pursuit of ZNE was not a contractual requirement, three factors contributed to the alignment of the team's goals and were critical for the project's success:

- **Flexibility of Approach** - Carmel Partners, the major equity partner of WVCP LLC., has a long track record of developing highly successful conventional real estate projects. WVCP's representative on the West Village project took the lead in proving to Carmel Partner's senior management team that ZNE could be achieved without sacrificing ROI. Carmel Partners agreed to the proposed approach. Without this approval, ZNE status would not have been pursued.

- **Owner-Builder** - Carmel Partner's subsidiary, Construction West, acted as the General Contractor for the West Village project. The fact that the owner of the project was also the builder eliminated the misalignment of financial incentives that typically exists between owners and contractors, and ensured close pre-construction coordination between the development, design, and construction teams. This coordination was important to the benefit-cost analysis that was performed on various efficiency measures and greatly expedited construction time, thus reducing costs.

- **Reputational Involvement** - As noted previously, West Village has extensive media attention. This coverage began while the project was still in the planning stages and continues today. One result of this coverage was to publically commit the project's major stakeholders to the goal of ZNE, whether they had committed to it privately or not. Backing away from ZNE goals could have created strong negative public perception of the responsible party, a perceived risk that none of the participants were willing to take.

Future projects pursuing ZNE status should seek to create alignment of incentives during the earliest stages of their project. Incorporating the goals of ZNE into contract language and providing incentives for attainment will help create this alignment. Such performance-based contracts can be problematic for the insurance companies and attorneys that represent design professionals, as the actual performance of a building is ultimately out of the designer's control. This is an industry-wide issue that needs to be addressed within the construction industry in the near future, as performance-based contracts are becoming more widespread in the building industry as high-performance buildings become more commonplace.

Lesson #3: A Rigorous, Active Approach to Energy and Financial Modeling is Critical

West Village was heavily influence by the use of energy and financial modeling before detailed design began. The fortuitous inclusion of DEG in the project brought many years of experience in modeling residential energy use to bear on the project, and analysis of the energy performance and financial impacts of energy-related decisions continued at every stage of the project. As opposed to sticking with one approach for the project, the design team was responsive to the energy modeling effort and adapted the design of the project based on input from the models. This differs somewhat from more traditional methods of energy modeling, whereby a model is developed at the schematic design phase and not updated again until the design is complete and ready for permitting. At West Village the models were a living component of the project and provided continual feedback to the owners and design team. This added effort comes at a price, and DEG was supported by a $500,000 grant from the U.S. Department of Energy through the Build America program. A takeaway lesson for future owner and design teams that do not have access to grant funds is to structure consultant fees in a way that supports a level of involvement of energy modeling by a design team that is experienced with the technology and is contractually committed to an iterative process of design and energy modeling.

Financial modeling was used in conjunction with basic energy modeling and was performed by DEG as well as the owner-builder, WVCP and Construction WEST, respectively. Using a benefit-cost analysis on individual efficiency measures guided the team in selecting the final suite of measures that were incorporated into the project. Results of such an analysis will vary for each project and each site, and are recommended as a means of attaining maximum energy efficiency per unit of economic investment.

Lesson #4: Engage Local Utility Early and Often

At the start of the project, the West Village team admittedly was inexperienced concerning the extent of challenges that would be involved with pursuing a ZNE project. UC Davis, WVCP, and their consultants spent considerable time pursing design options that were ultimately not incorporated into the project. Such schemes included a community that was fully independent of the electrical grid except for emergencies, and the Three Loop concept that incorporated multiple forms of renewable generation into the project. All of these schemes failed to address the regulations and technical barriers of the utility provider, and were not structured to conform to the typical financial relationship between the utility provider and the customer. Early and frequent consultation with a knowledgeable representative of PG&E may have helped the team to avoid some of this effort, and certainly could have helped the team to navigate the relatively intricate web of regulations that govern the generation and sale of electricity in California. It is strongly recommended that design teams establish a close working relationship with their local utility provider and utilize them as a resource throughout the pre-design and design process. Additionally, to further ZNE penetration in California, it is recommended that utility companies have knowledgeable staff with meaningful decision-making authority available for this purpose at no charge to project teams. State incentives could encourage utilities to create these positions and increase support for ZNE construction.

Lesson #5: Building Users Have Significant Impacts on Energy Use

As noted multiple times in the case study, energy use by building users remains a large variable at West Village, and real-time user feedback about energy use is not available for the project. Preliminary energy modeling for West Village assumed that the apartments would be used similarly to a space shared by a nuclear family; that is, with amenities such as televisions, gaming systems, and stereo equipment shared among users. College students tend to own these devices individually and not share with their roommates, thus increasing energy use from miscellaneous electrical loads.

Exacerbating this problem is that the project has no mechanism to provide real-time feedback on energy use to building occupants. Rather, due to the time lag of the utility billing cycle and management processing time, building occupants do not receive feedback until up to 45 days after the energy has been used, mitigating the chances for effective behavioral interventions. While this time lag is typical for utility customers, building industry research has revealed that real-time, automated feedback is the most effective method of encouraging energy efficient behavior. Future project teams would benefit from including feedback systems in a benefit-cost analysis that examines estimated savings over the lifetime of a project. Such an analysis will help teams to determine the proper level of feedback to include in their project.

At the West Village project, the CPUC's Rule 18 also acted to limit the feedback available to users regarding energy use. By prohibiting building owners from charging tenants proportionally for electricity, Rule 18 creates barriers to owners of multi-family buildings seeking to recover investments in renewable generation systems. WVCP responded to this barrier by electing to pay the properties' electric bills directly. While regulatory requirements are satisfied under this arrangement, building occupants no longer receive a signal connecting their energy use with financial consequences. Thus, a crucial tool for motivating behavior change has been removed from the project.

In addition to user feedback, continual engagement by building management with building users about energy efficiency can help building users to constantly improve their energy performance. The management of West Village targets the top 5 percent of energy users each month for energy audits and energy education programs, and is considering implementing a reward system of pizza parties, tickets to sports events, or other similar gestures for the apartments that reduce their energy use by the largest amount each month. Such incentive programs can promote healthy competition among building users and result in energy savings and improved finances for building owners.

Lesson #6: Expertise in State Policies, Regulations, and Incentives is Needed on Project Teams; Clarity is needed from the State

The state's current framework of regulations, policies, and incentives for energy efficiency and renewable generation is complex and creates multiple hurdles for project teams seeking to create ZNE or deeply energy efficient projects. Multiple entities within the state have put forward goals for increased penetration of local renewable energy and ZNE buildings, yet few of these aspirational goals are fully coordinated across state policies and even fewer are codified into law. Existing utility company regulations have not been updated to encourage large-scale ZNE projects and certain rules inhibit innovation at the level of individual projects. Incentive programs are frequently evolving or expiring, while new incentive programs seem to be introduced on an annual basis. The result is a complex landscape that is confusing at best and that creates uncertainty and a reluctance to pursue ZNE at worst.

A sentiment that was repeated several times in interviews with stakeholders of the West Village project was that a clear pathway that would allow the team to meet the legal requirements of the state, capitalize on available incentive programs, and construct the project in an economical way did not initially appear to exist. Multiple members of the West Village team noted that they felt they were inventing the process as they proceeded, resulting in significant additional work for all involved. The team credits the fact that they underestimated the effort required as the reason they were willing to commit to the process early on, but that future project teams will strongly benefit from including a team member with relevant experience to assist in navigating these issues. Utility companies are in a position to act in this capacity if they have incentive to do so, as they tend to have broad understanding of state energy policy, regulations, and available incentives.

Lesson #7: Lock-in incentives when possible

The constantly evolving landscape of incentive programs means that decisions to pursue particular programs need to be locked in quickly. Incentive programs such as the California Solar Initiative (CSI) offer tiered benefits depending on when an application is filed to participate in the program, or based on achievement of a project milestone such as the purchase of renewable generation equipment. Rebates offered through the CSI program (and others) decline over time.[10] Due to the length of time that has elapsed between the decision to utilize the CSI program and the construction of West Village's single-family homes, some financial benefit may be lost due to declining incentive amounts. Project teams are encouraged to identify and lock in available incentives to maximize available benefits.

4.2.2 Key barriers to Success and Policy Recommendations

CPUC Rule 18 and Building User Feedback of Energy Usage

Apartments at West Village are individually metered but do not pay an electrical bill; rather, the cost of utilities is included as a flat fee into their monthly rent. This rent remains fixed over the term of a 12-month lease. Thus, the cost of electricity is indistinguishable from the cost of rent, and energy conservation does not result in financial savings to the tenant. Under this arrangement, the tenant has no strong incentive to conserve electricity. The owner, however, pays the utility bills and is therefore incentivized to induce the tenants to use less energy. This lack of financial incentive for tenants makes it more difficult to achieve ZNE status at West Village.

The CPUC's Electric Rule 18 governs the resale of electricity by building owners to occupants and is part of the utilities tariff structure enforced by the CPUC.[11] A component of Rule 18 is that residential building owners that have a master meter on a building or dwelling unit are prohibited from selling electricity passing through that meter to building tenants. Because of this rule, WVCP is unable to charge tenants directly for electricity delivered from the project's PV array.

By absorbing a typical energy bill into the cost of the lease for each unit and by assuming responsibility for payment of all utility bills, WVCP can realize financial benefit. WVCP is able

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[10] "California Solar Initiative (CSI) - Rebate Levels," *California Solar Initiative Rebates*, accessed October 9, 2013, http://www.gosolarcalifornia.ca.gov/csi/rebates.php.

[11] Gordon R. Smith, "Electric Rule No. 18: Supply to Separate Premises and Submetering of Electric Energy" (PG&E, February 4, 1997), http://www.pge.com/tariffs/tm2/pdf/ELEC_RULES_18.pdf.

to recover its costs for the purchase of the PV array, offer tenants an apartment that is financially competitive with other apartment units in Davis, and realize a long-term financial benefit after the cost of the PV system has been recovered. But by removing the fundamental signal that building occupants respond to with regard to energy use—the price signal—WVCP has also encountered a situation whereby its tenants' incentives regarding energy use are not aligned with its own. The result is an ongoing effort of tenant education and persuasion by WVCP to encourage tenants to reduce their energy consumption.

WVCP receives monthly bills from PG&E for the entire project's electricity use. Through analysis of these bills, WVCP is able to determine the high, medium, and low energy users every month. WVCP currently identifies the highest energy users and targets these occupants for education and incentive programs. Education programs consist of trained staff inspecting units for obvious signs of excessive energy use such as mini-refrigerators in tenant bedrooms or thermostats not adjusted for maximum efficiency. Letters containing suggestions for energy conservation are sent to these users informing them that they are in the top 5 percent of energy users and steps need to be taken to reduce consumption. Incentive programs include owner-provided pizza parties, tickets to athletic events, or other rewards for those units that reduce energy consumption by the largest amount each month. WVCP is currently considering additional steps that can be taken, including financial penalties of various forms for exceeding monthly energy thresholds. WVCP acknowledges that care must be taken with any such action as to avoid running afoul of Rule 18, and is studying the issue closely.

Any effort at behavior modification is most effective when the feedback mechanism is temporally linked to the targeted behavior. By using utility bills to determine intervention, WVCP is providing feedback to building users a considerable time after the behavior has occurred. Utility bills are backward-looking and by the time WVCP has received the bills, analyzed them, and determined which users require intervention, it is not unusual for 30-45 days to have elapsed since the energy was consumed. The result is a suboptimal arrangement for behavior modification and increased costs for WVCP as they are continually trying to chase past behavior to change future results. Added to this situation is the fact that the typical inhabitant of West Village exhibits vastly different energy use tendencies than a typical, non-student apartment dweller.

A typical apartment dweller's energy use would tend to follow the overall patterns of electricity use in the state, with peak use occurring in the late afternoon and early evenings. In this scenario, the largest sources of energy use would typically be space heating and cooling, water heating, and MEL. Student-occupied apartments do not exhibit a consistent time-of-use profile, but overall trends show electricity use peaking much later in the day and evening compared with non-student occupied buildings. Night-owl students cooking, doing laundry, and running electronic equipment mean that the dominant forms of energy use are MEL, lighting, and space conditioning (primarily space heating in winter), thus shifting even greater importance on providing real-time feedback to building occupants combined with the ability to control MEL energy consumption.

Recommendations:

- Provide funding for research to determine the effectiveness of non-monetary incentives and programs to encourage efficiency that are consistent with existing utility rules
- Consider changes to the utility rules (incl. Rule 18) that would allow for the owner-operators of ZNE projects to provide a proportional and meaningful price signal to residents to encourage efficiency.

Design Related Issues

The lack of submetering of individual electrical circuits within each building prevents a detailed analysis of energy use patterns. Each residential unit is served by a master electrical meter, and there is no direct way to disaggregate energy use into different end uses within each unit. It is therefore difficult to determine which energy load—such as lighting, MEL, space heating, cooling, or hot water generation—is responsible for the largest portion of energy consumption. While it is widely assumed that MEL from user-owned equipment is the dominant energy use, this cannot be measured quantitatively against predicted use patterns. The inclusion of submeters onto each electrical circuit would provide the opportunity for such measurement and would allow the building owners to effectively target areas of underperformance and quantitatively assess the results of these interventions. The cost of submetering would be incurred during the construction phase of the project, but potential savings from effective interventions would accrue to the owners throughout the lifetime of the building. Further research is required to determine the benefit-cost effects of providing these meters compared with other potential investments in energy measurement and control.

Recommendations:

- Provide funding for research to determine behavior associated with different occupant types, and the costs and benefits associated with submetering in multi-family buildings.

Pacific Gas & Electric (PG&E), through a subcontractor and in conjunction with WVCP, is conducting a study that has provided submeters on individual end-use circuits for 144 apartment units in West Village. The goal of this study is to disaggregate energy use within a sampling of units and by doing so, extrapolate the findings to the project as a whole. Results of this study are not available at the time of this writing.

Building Energy Modeling

Preliminary energy modeling of the West Village buildings relied on a number of well-founded assumptions to predict total building energy use. Subsequent evaluation of actual energy use versus predicted values revealed that some of the initial assumptions included in the energy model were not borne out on the completed project. Primary among these assumptions was that each four-bedroom apartment unit in West Village was modeled as if it were occupied by a traditional family and not four individual students. A traditional family would use the apartment units in a fundamentally different way than students—common amenities such as a television, computer, stereo, gaming system, and refrigerator would typically be shared by a family but are often not shared by students. In a student-occupied scenario each occupant may each have these devices independently, thus increasing MEL energy usage by as much as a factor of four. These higher MEL are likely one of the reasons for the shortfall in ZNE performance. In addition to addressing user behavior through awareness and education (as noted below), the developer is considering adding increased PV cells to the project to compensate for these loads. This expansion of the PV array is the subject of business negotiations between UC Davis and WVCP, and additional study is required to determine the precise amount of additional PV that is required to reach ZNE status.

Recommendations:

- Provide funding for research to determine if energy use in student housing is affected by the process by which roommates are assigned—for example, whether or not randomly assigned roommates behave differently from students who live together by choice.

4.3 Importance of Modeling Tools and Resources for Stakeholders

Extensive use of and reliance on energy models has been a hallmark of West Village from the earliest stages of the project to present. Davis Energy Group (DEG) has performed the majority of the modeling work for West Village. Founded in 1981, DEG has a record of participation in the U.S. Department of Energy's Build America Program, which aims to improve building energy efficiency through research and innovation. DEG was a participant in the Build America Program in 2004, an effort that included energy modeling for prototypical housing units similar to those that were being planned for the West Village project. This work informed early efficiency goals for the project. DEG's work was updated in 2007 while working as a consultant for the EEC, and was the technical basis for the EEC's Energy Efficiency report that same year. As noted previously, this report contained analysis for varying levels of efficiency and renewable generation and provided an economic framework for each. A high-level outcome of this work was the realization that the project could be readily designed to outperform the then-pending Title 24 energy guidelines by approximately 50 percent, and that this performance could be achieved in an economical manner. Current literature on the design of ZNE buildings suggests that attaining performance 50 percent below current Title 24 energy standards is a minimum efficiency threshold for ZNE buildings.[12] The efficiency scenarios developed by DEG and the EEC provided a roadmap of attaining this level of efficiency and became the basis for attainment of ZNE status.

One product of the West Village RESCO project was a web modeling tool that would assist builders, developers and planners in the early stages of development to evaluate ZNE potential and provide an early barometer relating to the ZNE feasibility of the project.

[12] Heschong Mahone Group, Inc., *The Road to ZNE: Mapping Pathways to ZNE Buildings in California.*

Summary and Purpose of ZNE Modeling Tool

The intent of this tool is to provide a high level feasibility planning model for developers, institutions, planners, and others to assess the potential for achieving community-wide ZNE performance in California. This tool is not intended as a replacement for designing of ZNE communities or for sizing of community scale renewable energy systems. The model evaluates new developments comprising single and multi-family buildings, and common area end uses such as community centers, street and parking lot lighting, and swimming pools. Based on user inputs and assumptions built into the model, community energy consumption is estimated along with photovoltaic system size and associated land use required to achieve ZNE.

Assumptions built into the model were developed from modeling exercises, 2013 Title-24 code requirements, and current standard construction practices in California. Energy use intensities (EUI) in kBtu/ft2 by building type (single family, low-rise multifamily & high-rise multifamily) are based on results from the study, *The Technical Feasibility of Zero Net Energy Buildings in California*[13] funded by the Investor Owned Utilities. This work identified the characteristics of base case and exemplar prototypes for various building types. The base case prototypes are 2013 Title-24 code compliant buildings while the exemplar cases represent ZNE ready construction in 2020. Performance was evaluated using the Department of Energy's EnergyPlus simulation software. Proposed measures that were determined to be not technically feasible in 2014 were removed for the purposes of this tool. User inputs that drive the energy calculations include the following:

- Location by California climate zone: 7 climate zones are currently included (3, 7, 10, 12, 13, 15, 16)
- Building characteristics including occupancy type, floor area, # of stories, # units, # of like buildings
- 2013 Title-24 target compliance margin (as a function of percent better than code)
- Fuel choice (electricity or natural gas) for space heating, water heating, and appliances
- Total installed lighting wattage of street & site lighting OR characteristics areas & lengths
- Size of swimming pools & spas

The tool assumes energy consumption is offset by on-site, grid-connected photovoltaic (PV) systems to meet ZNE goals, installed on building rooftops and/or located off-roof within the community. PV energy generation by climate, tilt, and azimuth was estimated using the

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[13] ARUP, 2012. The Technical Feasibility of Zero Net Energy Buildings in California. Prepared for Pacific Gas & Electric Company. December, 2012.
http://www.energydataweb.com/cpucFiles/pdaDocs/904/California_ZNE_Technical_Feasibility_Report_Final.pdf

EnergyPlus tool. In most cases results are provided for South, West, and East facing arrays. User inputs that affect the PV production calculations include the following:

- Roof pitch
- PV module efficiency (4 tiers based on NREL PV Watts14)
- Available area for off-roof PV including parking structures, and ground mounted systems

Community scale ZNE performance is evaluated relative to both site energy (in kWh and therms), and "Time Dependent Valuation" (TDV) energy. TDV is a core metric for California's Building Energy Efficiency Standards and is the proposed starting place for the State's eventual ZNE definition15. TDV energy use is based on the 2013 Title-24 hourly multipliers by climate zone applied to both hourly energy consumption and hourly renewable generation. For projects with natural gas, site energy evaluation assumes only electricity use is offset by PV, while TDV energy evaluation accounts for both electricity and gas use. Outputs from the tool include the following:

- Annual energy use (kWh, therms, TDV kBtu)
- PV size (kW) and associated area (ft2) to reach net zero electricity and net zero TDV.
- Annual energy use reduction relative to code minimum construction
- Annual carbon offsets relative to code minimum construction

Results are provided to the user for each building type, for each common area group (i.e. street lighting) and for the community as a whole.

<u>Additional Scope of the Modeling Tool</u>

Development of this tool has been limited in scope and various expansions have been identified that would add value to the model.

- Expand the 7 California climate zones that are currently covered to all 16.
- Incorporate other renewable options such as biomass generation.
- Incorporate other building types such as mixed use buildings.
- Integrate with a visual tool such as BEopt that could easily allow the user to input # of building types, building orientation, and roof lines. NREL currently has plans to develop a community version of BEopt which would align well with this tool.

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14 http://pvwatts.nrel.gov/

15 The Energy Commission's 2011 Integrated Energy Policy Report references "time-dependent valuation" as a recommended ZNE metric. http://www.energy.ca.gov/2011_energypolicy/

- Integrate the tool with a PV design tool that already has the ability to accurately account for offsets and shading.
- Include electric vehicle charging and energy storage strategies.
- Evaluation of demand impacts and incorporation of demand response strategies.

4.3.1 Technology Transfer Plan

Technology Transfer plans are typically required by publicly-funded agencies that sponsor technology research. The agencies, and therefore the researchers that are funded by them, are expected to provide public benefit, and this positive societal impact, especially when it involves investment in advancing emerging technologies, is expected to manifest ultimately in market transactions and behaviors. The goal is to have both private sector firms and citizens alike adopting these new technologies.

Typical Transfer Plans emphasize the importance of the protection of intellectual property and then strategic licensing of those assets to private sector firms that are active and influential in the market. This approach both enables and maximizes economic and societal benefit. Securing intellectual property empowers private sector firms to attract the necessary upfront financial capital to fully develop a technology and achieve its optimal market penetration. This strategy is common when the innovation associated with the research being funded can indeed be protected as intellectual property.

The innovation associated with this research project does not fit, however, the criteria of traditional technology development. The research funded under this agreement supported integrated design and modeling of energy components for West Village. While the research did ultimately lead to market adoption of an integrated set of technologies, it did not produce any intellectual property that could be patented and/or licensed. While it does not make sense to use the traditional technology transfer model for the research outcomes from this project, it is clear that the outcomes, which involve regulatory lessons learned and technology best practices, do have valuable societal benefit if they can be effectively shared with the right audiences.

4.4 Education and Technology Transfer Strategies for West Village

The Technology Transfer Plan described in the Scope of Work for our proposal was originally envisioned to share best practices from the research outcomes of just the RESCO solicitation. The project has leveraged the California Energy Commission's initial investment through this project and empowered a number of related West Village ZNE R&D projects. They are all part of the WVEI. The Technology Transfer Plan being established is a platform for sharing lessons learned from all ZNE related R&D projects within the WVEI. In order to broaden the market impact, the plan is defined as the Zero Net Energy Technology Transfer Plan (ZNETTP) with the framework designed to share best practices not only from West Village, but also from similarly market leading large-scale ZNE projects throughout California and the world.

West Village is a discreet project, but if California is to achieve its Big/Bold strategic goals of ZNE for residential new construction by 2020 and commercial new construction by 2030, West Village will need to be the first of many more community-scale projects to come. West Village can be a catalyst, inspiration and source of best practices for other such projects, especially if the Technology Transfer plan is implemented successfully.

4.4.1 Key Strategies

Given the unique and market-leading nature of the West Village Community development and its energy infrastructure, the lessons learned from the West Village Energy Initiative are of critical importance to a number of different audiences. The Technology Transfer approach intend to be used will make information accessible to regulatory and legislative public officials, communities and developers considering ZNE implementation, members of the construction industry, residents of West Village, and the general public.

For public-sector community-planners as well as private-sector master planners and developers, as well as those in the construction industry, the researchers are developing an on-line feasibility tool that will help delineate the considerations to keep in mind in the pursuit of ZNE. It is anticipated there will be value in updating and refining this tool over time and also value in collaborating with trade organizations to facilitate discussions about obstacles and overcoming those obstacles to achieving successful ZNE implementation.

Public agencies are increasingly interested in market facilitation (the Demonstration and Deployment portion of RDD&D) and are dedicating resources towards overcoming key barriers to market adoption and commercialization of advanced technologies. The ZNETTP provides a unique market facilitation tool for advancing ZNE. The plan identifies and addresses key regulatory and legislative barriers and potential solutions for ZNE adoption. The plan also addresses the need for broad ZNE education for both the general public and specific practitioners as well.

In the coming years, public sector agencies will be releasing solicitations, which will hopefully be inclusive of opportunities to conduct many or all of the elements included in the ZNETTP.

Below is a list of public agencies that may announce applicable funding opportunities:

- CA Air Resources Board
- CA Energy Commission: EPIC Market Facilitation
- CA Public Utilities Commission
- US Department of Energy
- US Department of Education
- National Science Foundation
- Pacific Gas & Electric: ZNE Pilot Program

Corporate, Foundation and Individual Fund-Raising Strategy

UC Davis has a strong track record of engaging the private sector, both large and small entities, in meaningful collaboration on RDD&D. Corporations will be motivated to sponsor the

ZNETTP for a diverse set of reasons. Many companies and organizations will only be interested in a select set of activities, while others will be interested in supporting a broader, more comprehensive effort. Ultimately, the outreach and education (Table 25) team will need to be responsive to needs and interests of its private sector partners.

Table 25: Identified West Village Outreach Leadership Team

UC Davis	
Energy Efficiency Center	Ben Finkelor, Executive Director Sumiko Hong, Director of Development and External Relations Alan Meier, Visiting Scientist and Researcher Ernie Hoftyzer, Management Services Officer
Department of Design	Susan Verba, Associate Professor
Center of Excellence for Visualization	Kwan-Liu Ma, Director and Professor
Facilities Management	Josh Morejohn, Manager, jdmorejohn@ucdavis.edu Kiernan Salmon, Project Manager (Campus Energy Feedback Systems)
Plug-in Hybrid & Electric Vehicle Research Center	Dahlia Garas, Program Director Tobias Barr, Assistant Project Manager
California Lighting Technology Center	Kelly Cunningham, Outreach Coordinator
Western Cooling Efficiency Center	Paul Fortunato, Outreach Coordinator
Office of Research	Paul Dodd, Associate Vice Chancellor for Research Darenne Hackler, Executive Director
Campus Planning and Community Resources	Bob Segar, Assistant Vice Chancellor
Real Estate Services	Mary Goodell Hayakawa

Corporate, foundation and individual prospects will be solicited to fund key elements within the ZNETTP. Initially, corporations that were involved in the implementation of the WVEI, such as Carmel Partners, Chevron Energy Solutions, PG&E, SunPower, Honda, and Wells Fargo will be primary prospects.

We will develop additional corporate prospects that have shown involvement in other ZNE developments such as sponsors of US Department of Energy Solar Decathlon (For example, Bosch, Cisco, Edison International and Schneider Electric, or sponsors of individual Solar Decathlon teams, such as United Brotherhood of Carpenters, International Brotherhood of Electrical Workers, Sheet metal Worker International Association, DIRECTV, General Electric, Intel Corporation, Applied Materials, Design Within Reach, SMA Solar Technology and Itron.)

We will also develop foundation and individual prospects that have grant or giving priorities in energy efficiency, and renewable energy, smart grid, ZNE, policy development, carbon reduction, improving energy literacy in school aged children and general audiences and science and engineering education. Initial Foundation prospects include, Energy Foundation, Hewlett Foundation, Packard Foundation, Kresge Foundation and Doris Duke Charitable Foundation. Tours and conduct outreach activities will continue to be provided as well as opportunities to develop support from individual donors.

4.4.2 Education and Outreach Tools

UC Davis has established a partnership with the Exploratorium of San Francisco, an international leader in hands-on informal science education, to collaborate on education and outreach programs that advance scientific understanding for the general public. Staff at the Exploratorium took the lead on developing this chapter and white paper specifying the education and outreach tools that would be specifically useful for engaging general audiences, including tours, experiential education exhibits and infrastructure, and interactive websites.

The underlying objective behind these education and outreach tools is to create learning experiences around renewable energy, energy efficiency, smart grid, sustainability science and technology, and ZNE goals using the West Village Project and the Exploratorium's sustainable building as case studies and dissemination platforms.

Audiences Targeted include: Residents, Students, Campus visitors (parents, policy-makers, visiting delegations), K-12 students and educators, and the general public.

There are 5 key components listed and described in this white paper. Additional education and outreach components to consider included are listed at the end.

West Village Energy Collaboration Laboratory & Visitor Center

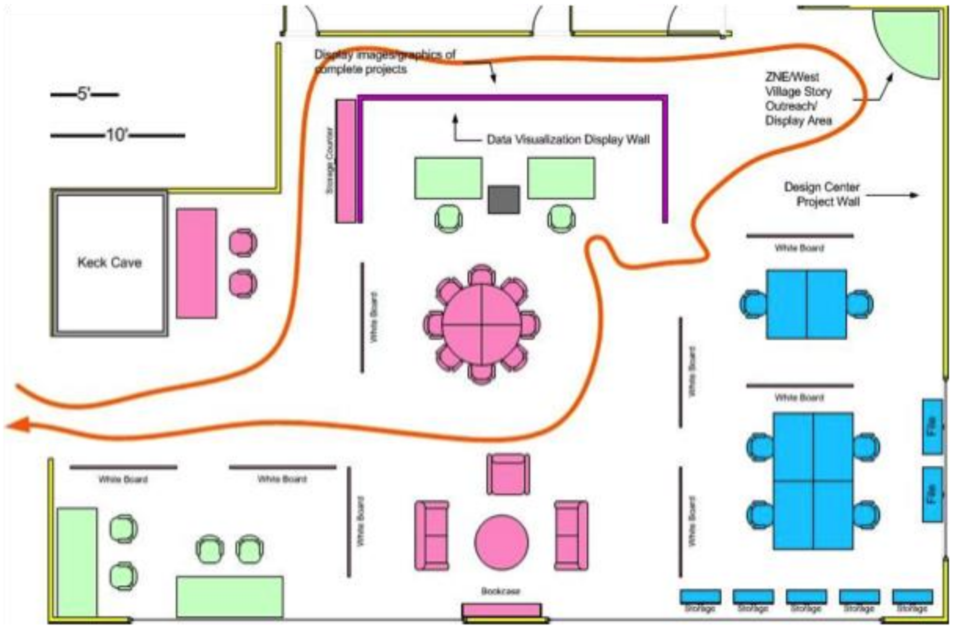
Located within the West Village Community, the Energy Collaboration Laboratory (ECL) is a mixed-use center that combines:

1. Work space for interdisciplinary design and research teams to collaborate and do design testing; and,

2. Exhibition and meeting space where residents, students, faculty, visiting delegations and the public can come to learn more about ZNE and sustainable living.

It's important that the design of this space is open, inviting and active and not just an exhibition space that is only populated when a tour comes through or a meeting takes place. The room design should also be flexible so it can be reconfigured for different uses (furniture and exhibits on wheels). A model for a combination learning lab, workshop and public space is the Exploratorium's Observatory Gallery, a glass building that takes advantage of views of the natural and built environment of the San Francisco waterfront. The gallery was designed for multiple activities: an interactive exhibit gallery focusing on the local landscape, a workspace for scientists, designers and educators, a teaching and presentation space for public and professional invited audiences, and a private event and reception space.

Figure 16: Overview of Observatory Gallery



4.4.3 Elements of the Energy Collaboration Laboratory

- Video Wall Touch Screen, where visitors can:

1. Watch an introductory video with interviews recounting the story of the West Village Project from multiple perspectives (developer, planner, architect, engineer, public agency, utility company, residents);
2. Learn about the economic and technological feasibility of ZNE in West Village, and lessons learned in the process of building and occupying West Village;
3. Explore current weather data and data visualizations about current energy use and production in West Village;
4. Learn about UC Davis research on transportation, renewable energy, energy efficiency (including lighting, HVAC, water efficiency), electric charging infrastructure, behavior and user interface, and international energy technologies;,
5. Watch time-lapse video studies of weather, solar motion and community life.

6. Gain access to similar outreach material that features the Exploratorium building and other ZNE case study projects.

Figure 17: Exploratorium interactive Wall

- Flexible "hotel" work space that can accommodate interdisciplinary teams of students and researchers across the fields of design, programming, engineering and social sciences collaborate on projects related to energy efficiency, renewable energy, transportation, data visualization and user interface design.
- Lounge area where small groups can meet, work or relax.
- Presentation, events and meeting space for workshops, talks, receptions, and openings.

Figure 18: Reception in Exploratorium Observatory

- Display and storage cabinets for computer and monitor equipment, supplies, tools, teaching props, chairs, and prototypes. Graphics and a white board can be mounted on the cabinets, providing background text, images and event announcements about West Village and the ECL.
- Interactive exhibits, space allowing. These could initially be Exploratorium-built exhibits that demonstrate the science behind energy technologies. Current examples include Heat Pump, which shows how heat exchangers work, Invisible Light, which shows how much infrared radiation is given off by various light sources from incandescent to LED, and Sky Theater, a walk-in mini planetarium showing how solar motion changes seasonally which affects solar power generation. In the future, new exhibits could be developed in collaboration with designers and scientists from UC Davis, demonstrating technologies developed on campus such as the operation of advanced sensors in lighting systems, "swamp cooler" technology for low-energy cooling, and new energy efficient technologies. Such exhibits could be deployed as they become available.

Figure 19: Invisible Light interactive Exploratorium exhibit

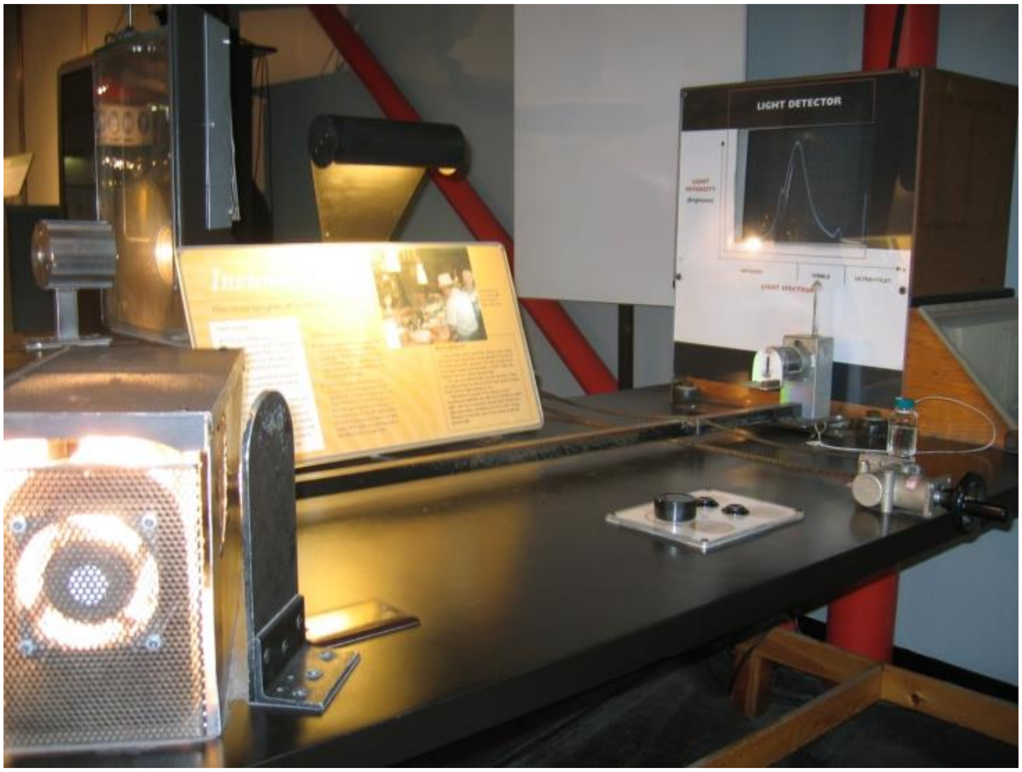
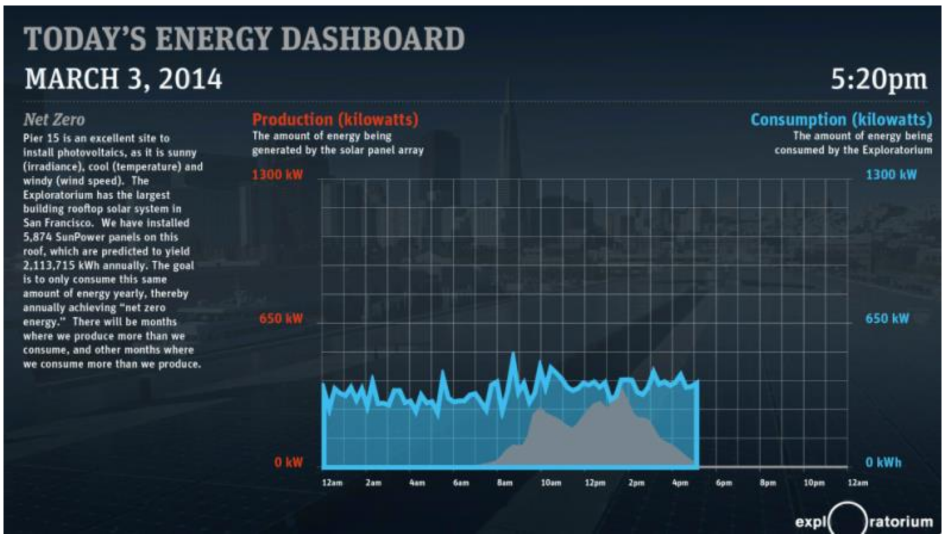


Figure 20: Heat Camera interactive Exploratorium exhibit

4.4.4 Zero Net Energy Data Visualizations

Taking advantage of programming and visualization capabilities at UC Davis combined with education design and prototyping expertise at the Exploratorium, the two institutions could collaborate on creating data visualizations to both educate about energy production and usage for ZNE goals and provide feedback for residents and building users at West Village and the Exploratorium. Data visualizations would incorporate current and time series data from building and energy production systems--along with energy usage and environmental (weather) conditions—to create data visualization and user interface designs that will provide continuously updated context for global building systems at both West Village and the Exploratorium. The displays could be deployed at multiple locations, beyond the ECL, including the lobby of the West Village Lease & Recreation Center, the lobby of the local Community College, the Hub coffee shop, and on mobile apps.

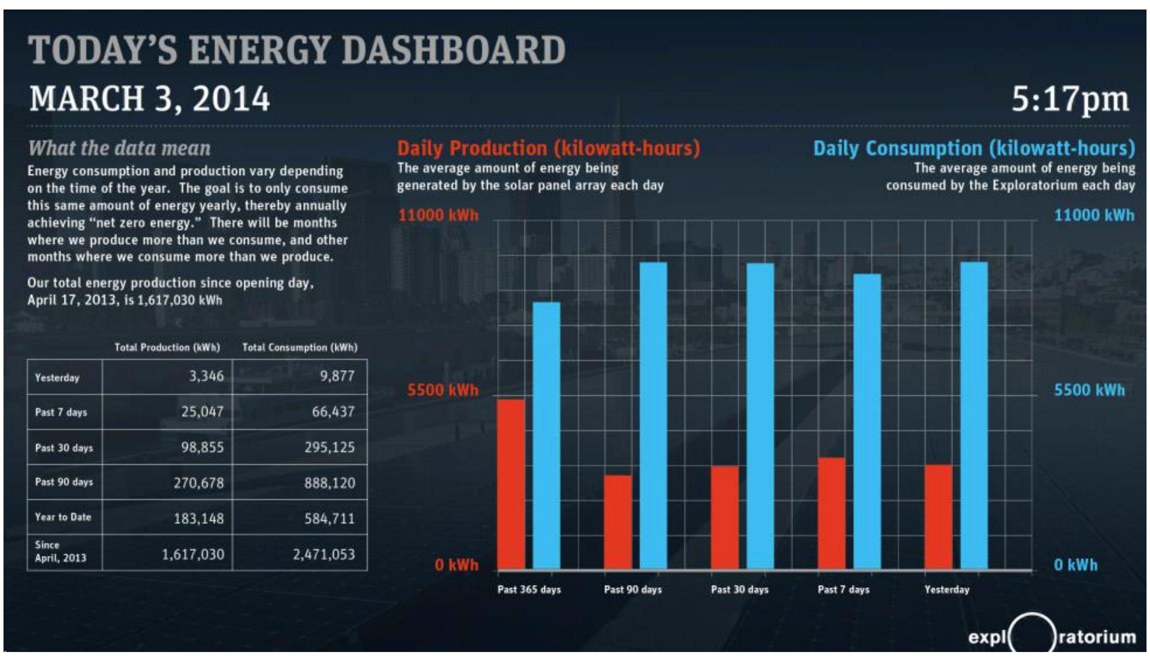
Figure 21: Energy dashboard display: PVC production and consumption



At the Exploratorium, the building usage and PV production would be displayed on a monitor in the un-ticketed bulkhead space as well as the Wired Pier data wall in the Observatory Gallery at the opposite end of the building. It would be incorporated with real-time atmospheric, oceanic and weather data being collected by instruments placed on the roof and in the water of Pier 15. Other information includes background on NZE goals, energy-efficient building design, bay-water heating and cooling system, water conservation and other sustainability practices. The ways in which the building and its occupants respond to environmental data will create learning opportunities to explore interactions between built and natural environments in San Francisco. This display would also incorporate long-term climate data and content to demonstrate how building systems provide solutions to climate challenges without compromising comfort, economics or usability.

Figure 22: PVC Solar array at Exploratorium

Figure 23: Time series energy production vs consumption ZNE goals



To generate both interest and engagement, data visualizations for West Village will be made available in the Exploratorium displays and conversely, data visualizations for the Exploratorium building will be made available on displays in West Village. As more access to the data visualization for additional projects is made available, they can also be offered on respective displays.

The data visualizations would also be available on the Web, providing learning opportunities for distant public audiences, educators and students. By combining the visualizations with information about local weather and climate patterns, Web visitors can compare their locations to explore what energy solutions might work best for their climate and energy needs.

Figure 24: Residential Energy Usage Application

Currently, real-time data on energy use is largely unavailable for residential users even though smart-meter technology makes such data delivery possible. In the absence of information, residents have little understanding of how much energy their appliances are using and whether there are ways to reduce their consumption. To address this information gap, the team would design simple energy-usage apps and display that would incorporate granular data from individual apartments within West Village to provide current and time series energy usage and production information for residents. This data could be deployed on multiple platforms, including resident smartphones or dedicated energy displays inside the apartments. The design of the user interface could be provided by existing vendors or could be designed, tested and optimized by a team of UC Davis researchers as part of a dedicated research project. The data can also be displayed in a central location in the common area. The energy app would provide feedback for residents to both monitor their own energy usage and compare it to average usage in the other buildings in West Village.

Such an app would be useful to engage and educate West Village residents and provide feedback that could lead to behavior change (for instance alert residents upon leaving their apartment if they've left their lights on or computers running). It can also be used as a platform to test different intervention techniques (such as gamification) to study energy conservation behavior and motivation. Long-term use of these apps would allow for tracking attitudes and social norms over time.

We anticipate such an interface would also form the basis of a more general citizen science project where participants provide access to energy usage data through their smart meters (available by request of their energy providers). In exchange, the participants would receive instruments that measure usage of various appliances in their household and training on how to audit their energy usage. Through the energy app, information would be provided to the Citizen Scientists about ways to make energy efficiency or retrofitting improvements in their households and cost-savings they could realize through incentives and reduced energy usage.

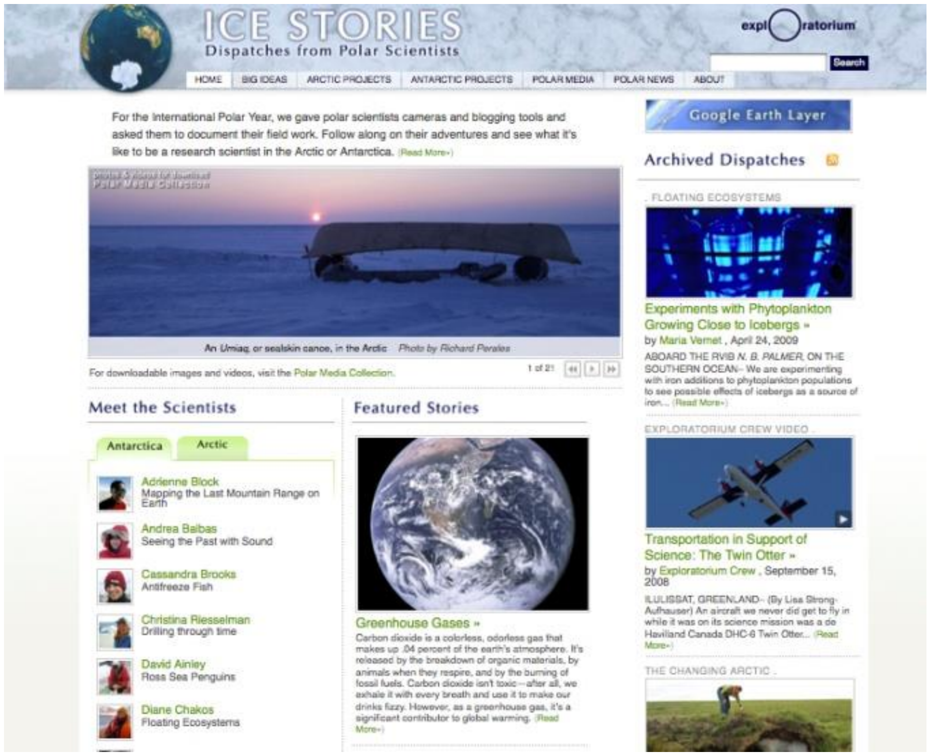
The energy app would track whether participants change their energy usage over time as a result of participating in the project. For a set of dedicated volunteers, the Exploratorium and UC Davis would leverage the West Village experience and organize a set of workshops to introduce concepts and energy audit tools, develop an energy-savings plan, and track users over time with periodic social and educational events with awards for meeting targets. This could tie into incentive programs that state programs (Energy Upgrade California), Utility programs (PG&E), and third-party programs might offer to incentivize retrofitting buildings and/or modifying behavior for optimal energy consumption and sustainability.

Media and Content Development for the Web

Developing content for the Web would be a major priority early in the project and additional content could be repurposed from other elements of the project including the data visualization displays, energy pathway tours, introductory video, and energy efficiency and usage information developed for the Citizen Science project. Additionally, materials developed for this project could be distributed on multiple platforms including the Exploratorium and UC Davis websites, the California Energy Commission and other ZNE websites.

Elements of the website would include navigation that could direct specific audiences, including policy makers, teachers, student, private sector businesses, and general public, to content tailored for their interests.

Figure 2: Exploratorium "Ice Stories" Website design example



Website content areas include:

- Virtual fields trips to ZNE Projects at West Village and the Exploratorium's Pier 15 providing overview information about the development of both sites. These pages could be expanded in the future to include other ZNE through California, the US and internationally including the David Packard Foundation headquarters. Through text, video, and photography these field trips will provide inspiring examples of how to achieve sustainable practices in thriving communities. Data visualizations would show how the systems are working in real time.

- Video interviews (10-12 initially) of project participants, experts, and stakeholders from both West Village and Exploratorium (planners, developers, engineers, energy providers, policy makers, climate scientists, and residents/users), to create narratives that reflect different roles and viewpoints, including lessons learned (identified in Chapter X) and the "aha" moments that led to the development of West Village. Narrative story-telling is an effective way to frame and communicate complex information in a way that people can absorb and evokes positive imagery and social normative messaging that makes behavior change more likely. The individual videos could be distributed on multiple platforms, for instance the Exploratorium's "Science in the City" series, the West Village Website and Visitor Center, the California Energy

Commission and other ZNE websites. It can also be used on social media platforms, such as YouTube and Facebook and shared widely through media networks.

- For city planners and developers, a section on Title 24 and other policies to achieve energy sustainability, efficiency and independence
- For general public, media and educators, tips on conserving energy, retrofitting for efficiency, advanced technologies, and renewable energy systems. Links to the Citizen Science online project from this section. Links to UC Davis research in Sustainable Transportation, Energy Efficiency Center, Plug-in Hybrid and Electrical Vehicle Center, Western Cooling Efficiency Center and other relevant sites from this section.
- General background on environmental sustainability and climate change
- The Website will also include a web-based tool for planners as an initial scope to test for feasibility of ZNE in their project

Other Outreach Material

- West Village Energy Initiative Annual Report: The first issue of this report was published for 2012-2013. Subsequent editions will cover the annual leasing cycle (September through August), with energy consumption and production during the 12 month period being reported in Winter of the following year.
- Additional Print Pieces: Book about West Village, to be sold or given away (modeled after Exploratorium books). PDF (mobile and printed) describing site selection and sustainability factors from access to transportation and biking, to water conservation, energy generation, and indoor environmental quality.
- One-page Flyer and more detailed white paper for specialized audiences that frame NZE according to interests: economics for planners, climate for environmentalists, energy independence for conservatives. Discuss context for California policy changes (Title 24) with the NZE goals for residential building by 2020 and commercial buildings by 2030. Specific outreach piece for new development projects such as Hunter's Point. Media outreach and article in journals from museum and informal science education to "green architecture" magazines.
- Teacher Professional Development Workshops: In collaboration with Exploratorium Teacher Institute, develop a week-long summer institute on energy and sustainability suitable for NGSS. Tie into climate change education community for informal audiences.
- Engage maker community with Maker's Faire booth and Burning Man camp to encourage and demonstrate ZNE technologies.
- Research study on attitudes of West Village residents and Exploratorium visitors on ZNE science background, environmental objectives and goals of WV project and Exploratorium "net zero carbon" building system. What are the different frameworks employed in communicating impacts and goals of ZNE policy (economic, societal,

environmental, and moral). Extend study to policy makers, real estate developers, contractors, city planners, energy providers, key influentials, and other specialized audiences.

- Public Programs, lecture series on sustainability with focus on local environment as part of Observatory "Lab and Lunch" series for professional audiences. Work with Science of Sharing workshop series to explore social science issues related to climate change and behavior change. Include session on policy changes for construction codes to implement ZNE outcomes for all residential construction (by 2020) and commercial (by 2030)
- Conferences/Workshops— Exploratorium and UC Davis jointly organize a symposium at AAAS annual conference 12/29/14on energy, sustainability and science education for 2015 in San Jose CA.
- Work with other sustainable buildings and communities to create a Web-based virtual network of NZE projects, creating virtual field trips, social media connections, and case studies. Show how principals of ZNE can be employed even in regions, such as colder northern climates, where solar energy isn't adequate to cover all power needs for a community.
- Develop training program for Exploratorium Explainers and student docents at West Village using pathways and demonstrations to exhibitive the building systems and the communities' sustainable practices.
- Develop set of outdoor exhibits, displays and points of interest related to energy and sustainability, relating to observing natural phenomena such as solar irradiation, black body, wind, tides/waves. This would involve a site study and research to develop a relevant set of outdoor experiences (similar to development model for Ft. Mason exhibit set.
- Energy & Climate Education Summit: Assemble group of Bay Area science advisors for two-day workshop on developing education and programming to move the conversation about climate solutions beyond atmospheric CO_2 and changing light bulbs.
- Develop a set of exhibit prototypes and demonstrations as an inquiry (NSF Pathways) phase of a traveling exhibition on energy, technology and the environment for Exploratorium and other ISE venues that also include human behavior exhibits developed through the NSF-funded Science of Sharing project at the Exploratorium.

GLOSSARY

Term	Definition
CEC	California Energy Commission
CES	Chevron Energy Solutions
CPUC	California Public Utilities Commission
CSI	California Solar Initiative
DOE CRED	U.S. Department of Energy Community Renewable Energy Deployment
EVSE	Electric Vehicle Service Equipment
DEG	Davis Energy Group
DER	Distributed Energy Resources
PEV	Plug-in Electric Vehicle
PG&E	Pacific Gas and Electric
PHEV	Plug-in Hybrid Electric Vehicle
PV	Photovoltaic
READ	Renewable Anaerobic Digester
RESCO	Renewable-based Energy Secure Community
UC Davis	University of California, Davis
WVCP	West Village Community Partnership, LLC
WVEI	West Village Energy Initiative
ZNE	Zero Net Energy

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