# CSI RD&D Program- UC Davis West Village Energy Initiative

Ann Peterson– Itron CSI RD&D Program Manager

Smita Gupta-Itron CSI RD&D Grant Manager

# Agenda:

I. Project Overview– Sid England CSI RD&D Project Principal Investigator

II. West Village Battery Buffered PEV Charging Station, Hengbing Zhao– Presenter, Dr. Andy Burke– Demonstration PI

III. Single Family Home 2nd Life Battery Energy Storage System, Antonio Tong- Presenter, Dr. Jae Wan Park– Demonstration PI

   I. Questions

IV. Solar Hybrid (PVT) Demonstrations– Jun Li Presenter, Dr. Pieter Stroeve– Demonstration PI

   I. Questions

V. West Village Smart Grid and AMI Implementation Study– Matt Lecar, Principal– GE Smart Grid Center of Excellence

   I. Questions

VI. Conclusions and Discussion

# Project Overview

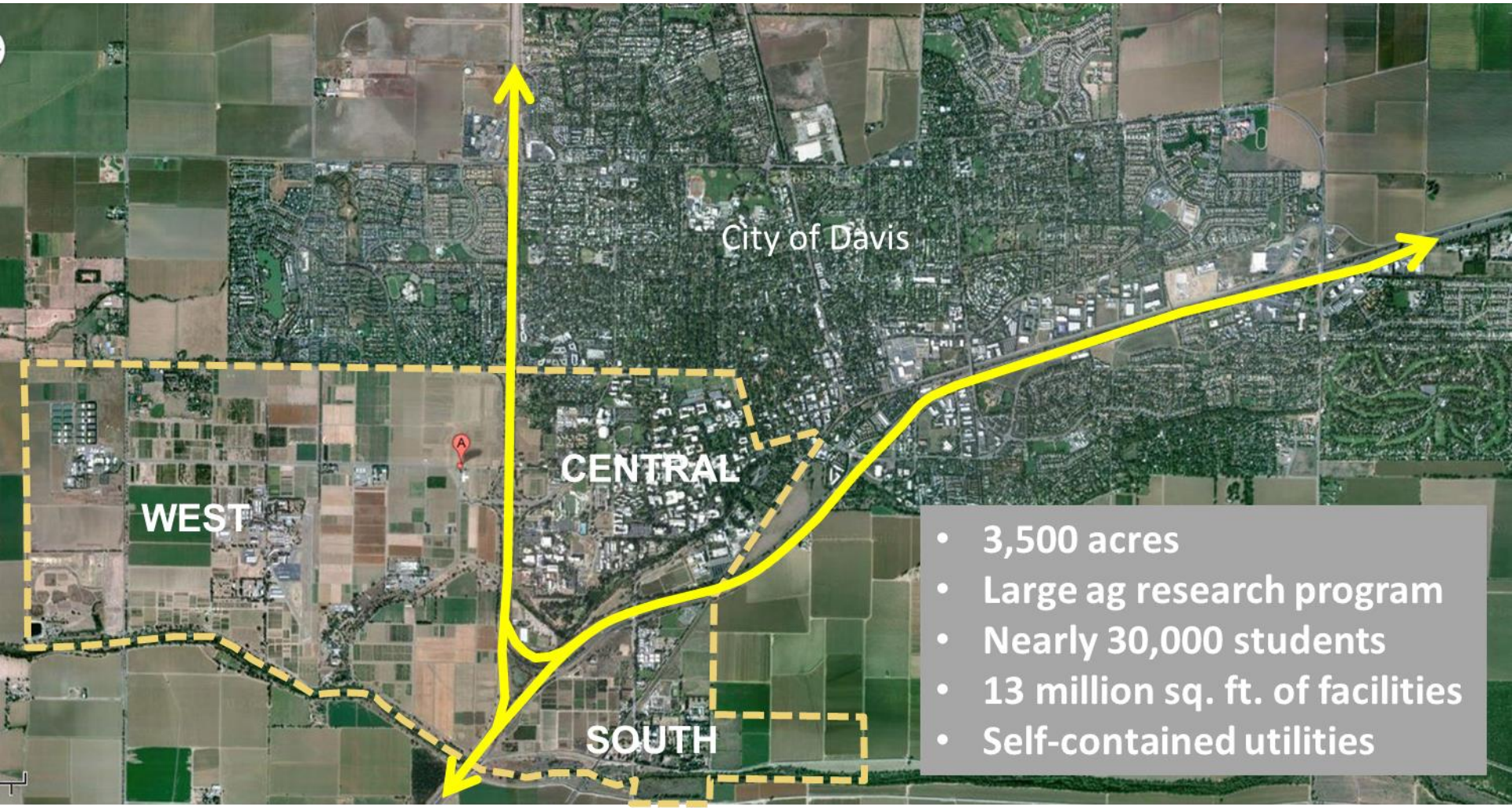
Sid England Ph.D.

Assistant Vice Chancellor

Environmental Stewardship and Sustainability

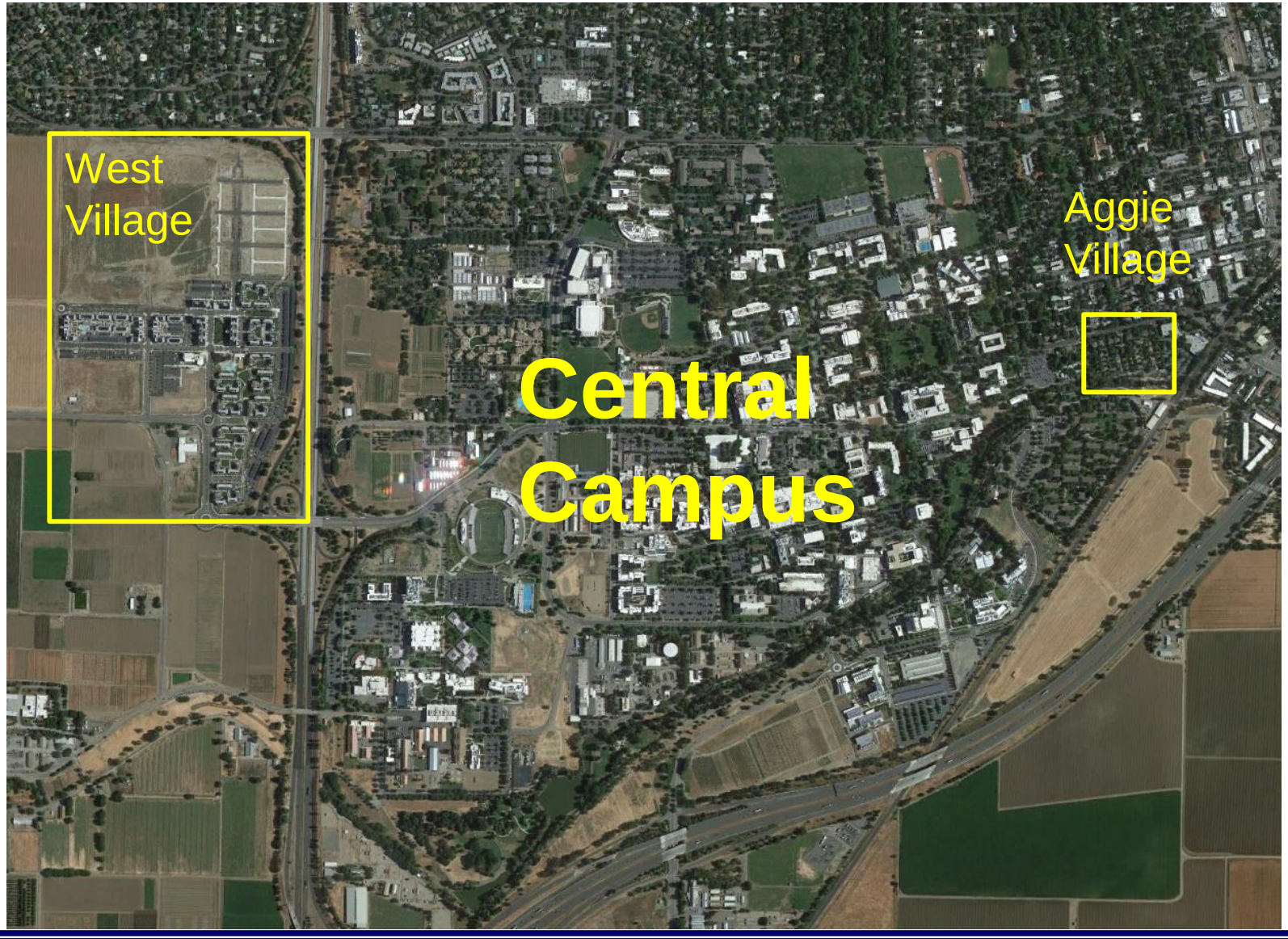
UC Davis

# Campus Overview

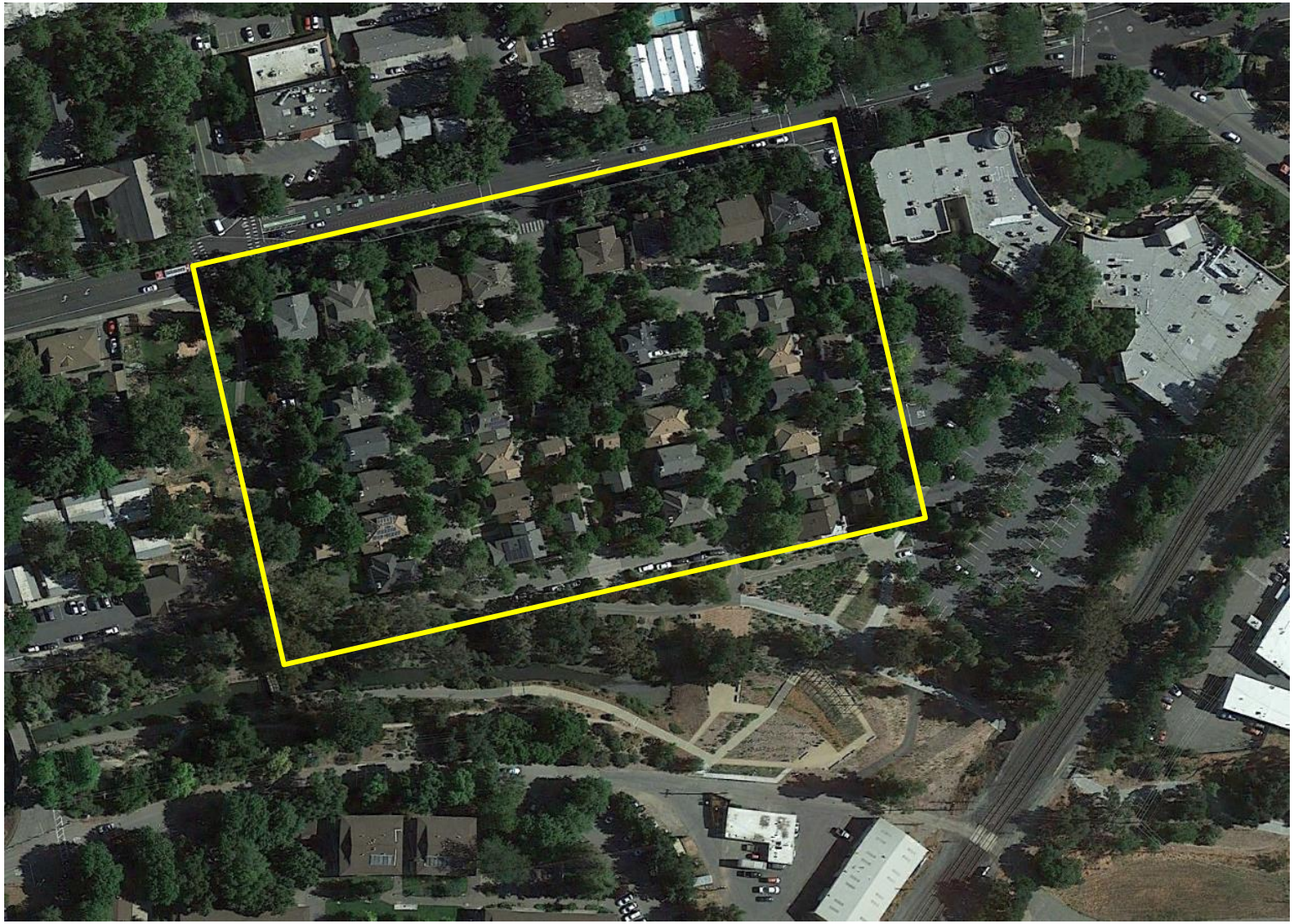



- 3,500 acres
- Large ag research program
- Nearly 30,000 students
- 13 million sq. ft. of facilities
- Self-contained utilities

# Campus Overview



# Aggie Village



# West Village

# West Village Energy Initiative

- Strive for zero net energy from the grid on an annual basis
- Adopt deep energy efficiency measures to reduce demand
- Develop renewable energy resources on-site at a community scale
- Serve as a living laboratory for further energy-related topics

# West Village Battery Buffered Electric Vehicle Charging Station

Hengbing Zhao– Research Scientist UC Davis Institute of Transportation Studies

Dr. Andy Burke– UC Davis Institute of Transportation Studies

# Outlines

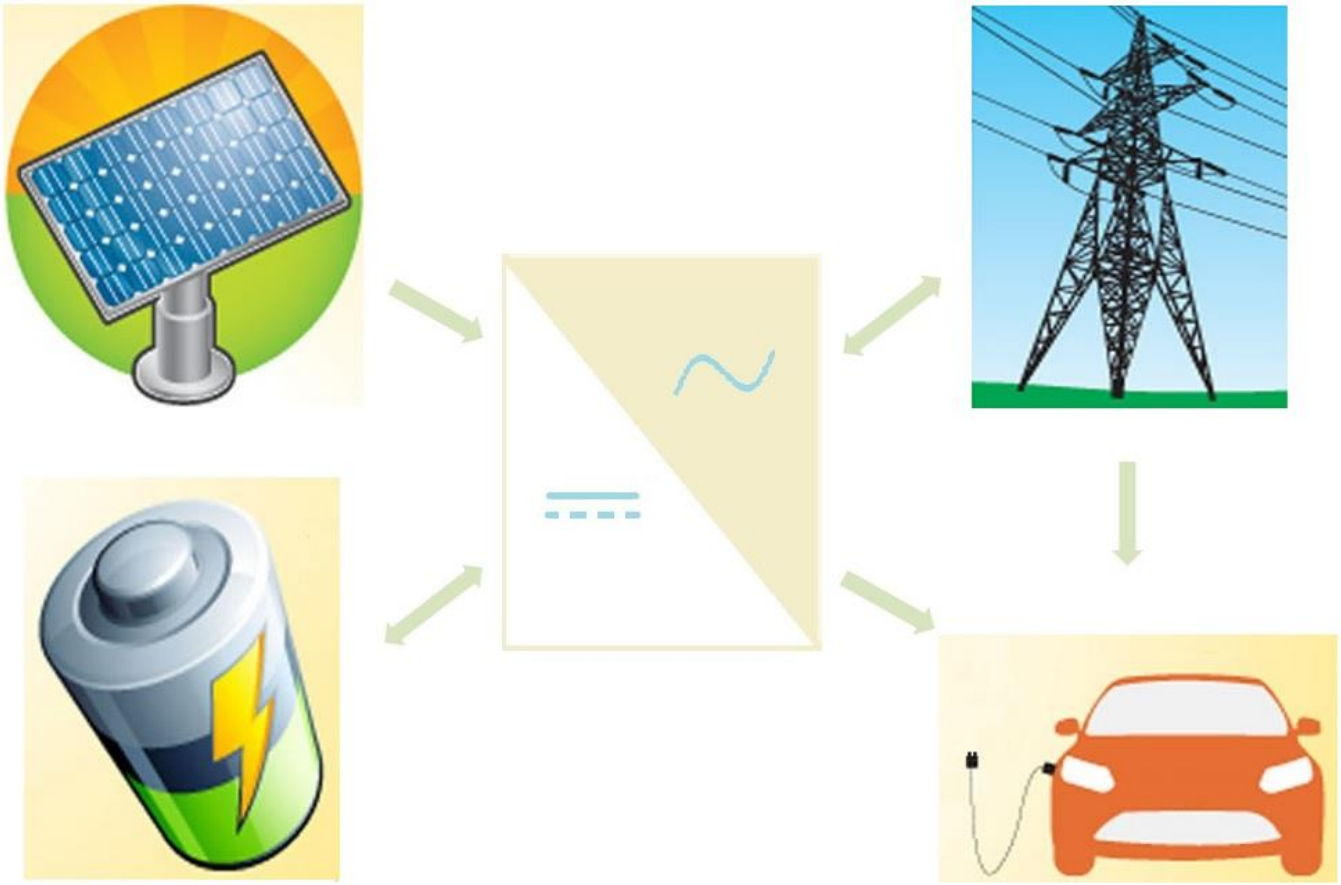
- ❑Project Objectives
- ❑Project Planning
- ❑System Design
- ❑Construction and Installation
- ❑Data Collection and Analysis
- ❑Summary and Conclusions

# Project Objectives

- Design, install, checkout and demonstrate a solar PV powered battery buffered electric vehicle charging station in West Village.

- Reduce impact of PV power generation and EV  charging on the utility grid.

# System Planning



# Project Planning

- Assess battery technologies and select a battery for use in project
- Determine where energy storage and electronics would be placed and a source of PV energy
- Determine the specifications for the bi-directional inverter and identify a source for purchase of the unit
- Layout the complete system and plan for its installation
- Develop a control strategy for the system and plan for the preparation of the required software
- Schedule the purchase of the equipment and the tasks required to assemble, checkout, and test the system

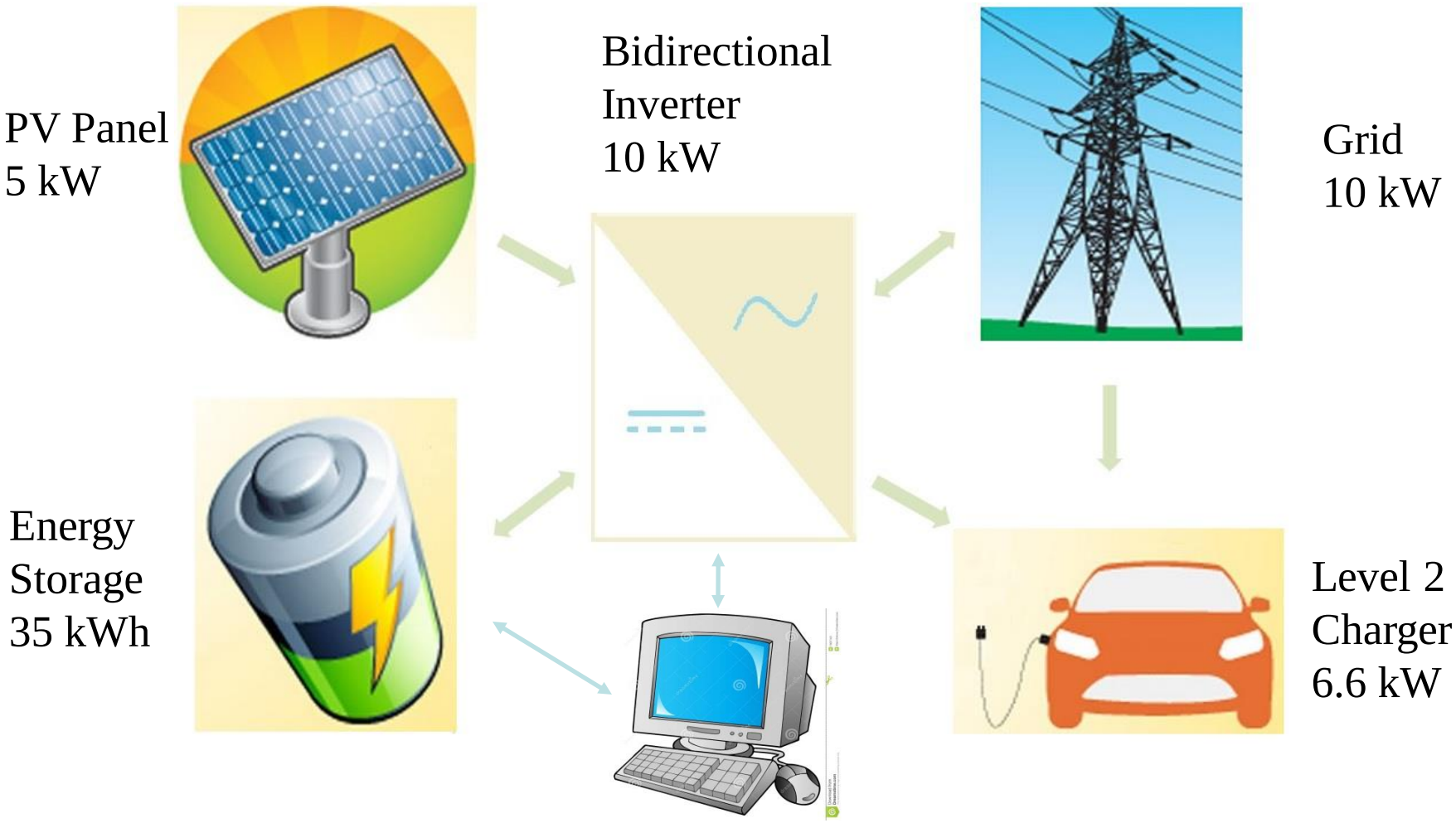
# Project Planning

**Major Challenges in Implementation**

- Dealing with the third parties are time-consuming.
- The energy storage system is a customized product, needs new product certification.
- The bidirectional inverter is just coming into use for this kind of system.
- Different components use different communication protocols.
- The control room storing the batteries is just off the main work area from the students in an office/resident building. The fire marshal was very careful to assess all safety issues.

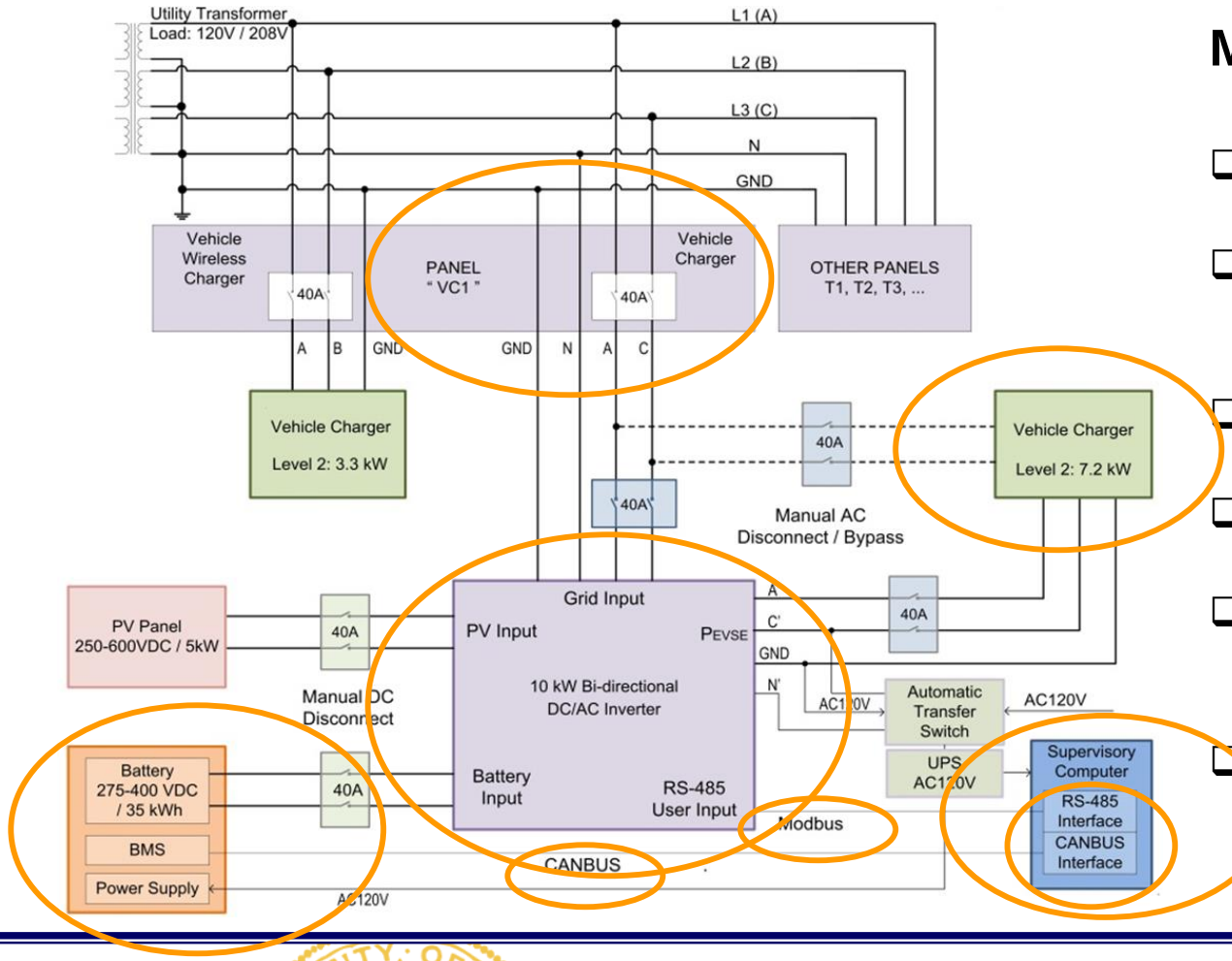
**The system became operative in July 2014, and has been used routinely by 2-3 EVs on a daily basis.**

# System Design



# System Design — Hardware

## Block Diagram of the Charging Station System

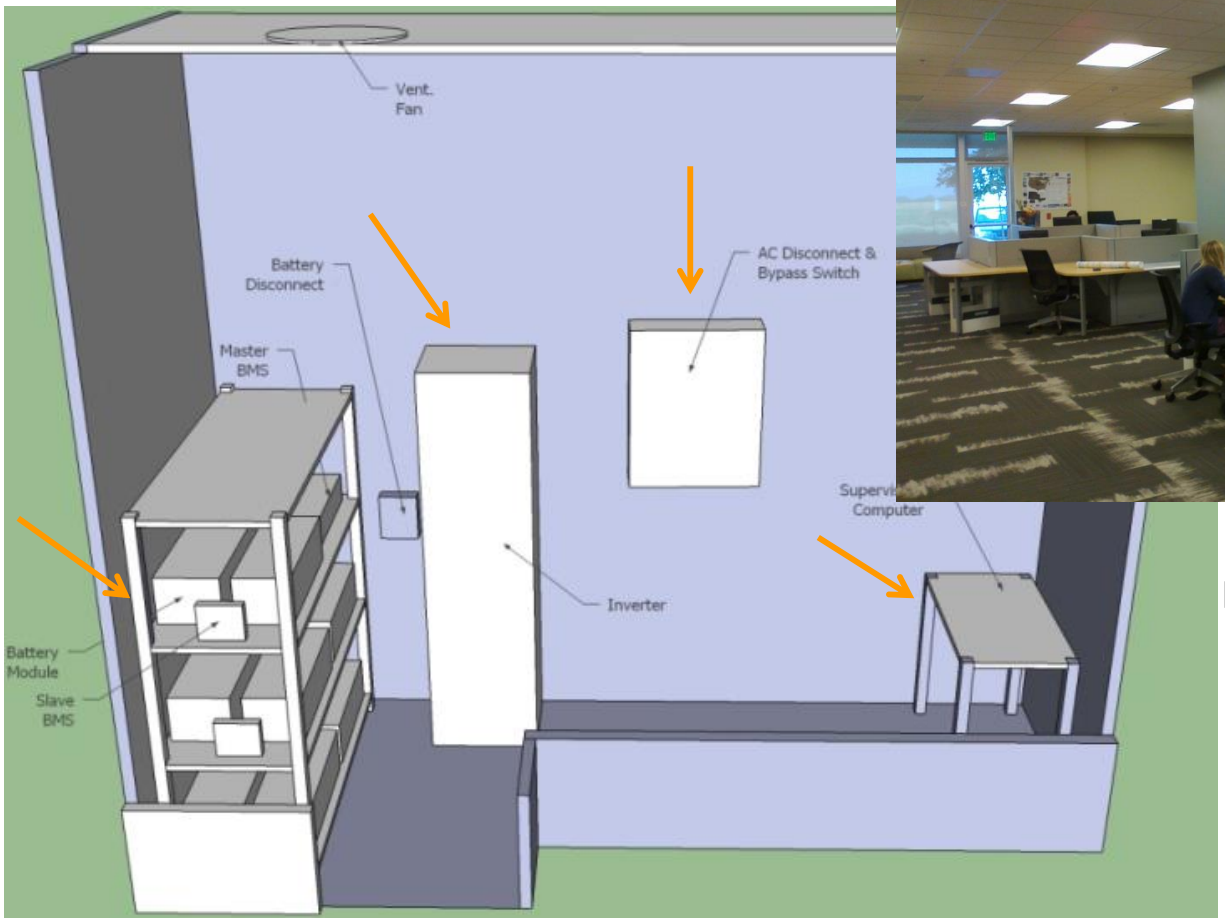


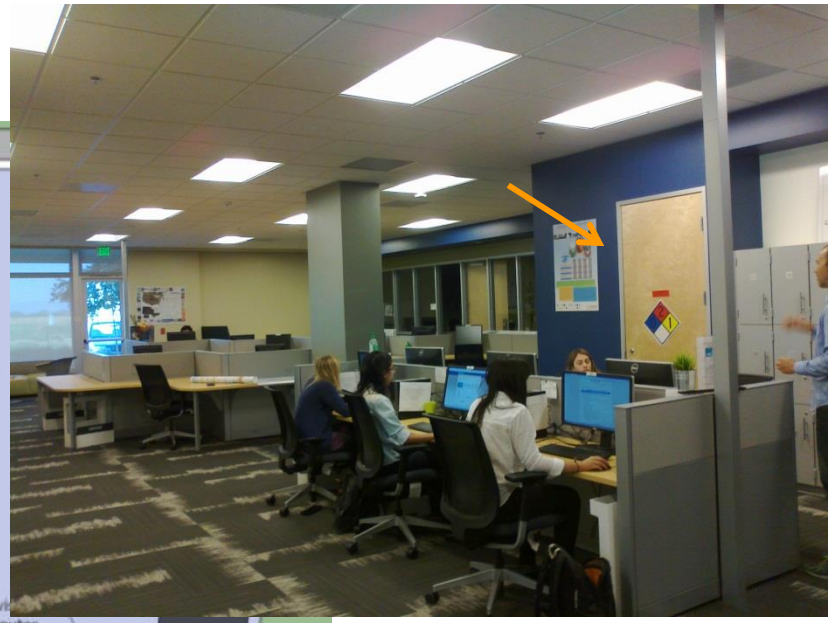

## Major Tasks

- ❑ Install an EV charging panel and a meter
- ❑ Design, assembly, and install battery storage system
- ❑ Select and install bidirectional inverter
- ❑ Select and install EV charging stations
- ❑ Design the control strategy and program supervisory control & monitoring system
- ❑ Communicate with different units via different communication protocols.

# System Design — Hardware

## Layout of the Control Room



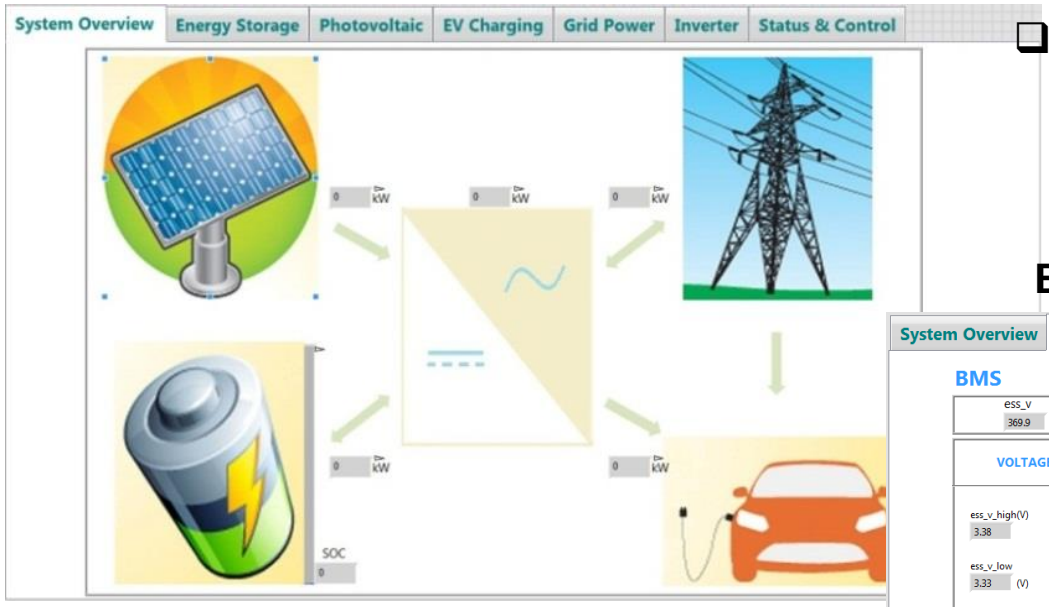



- Battery storage, bidirectional inverter, bypass panel, and supervisory control system are located in a closet at West Village.

# System Design — Software

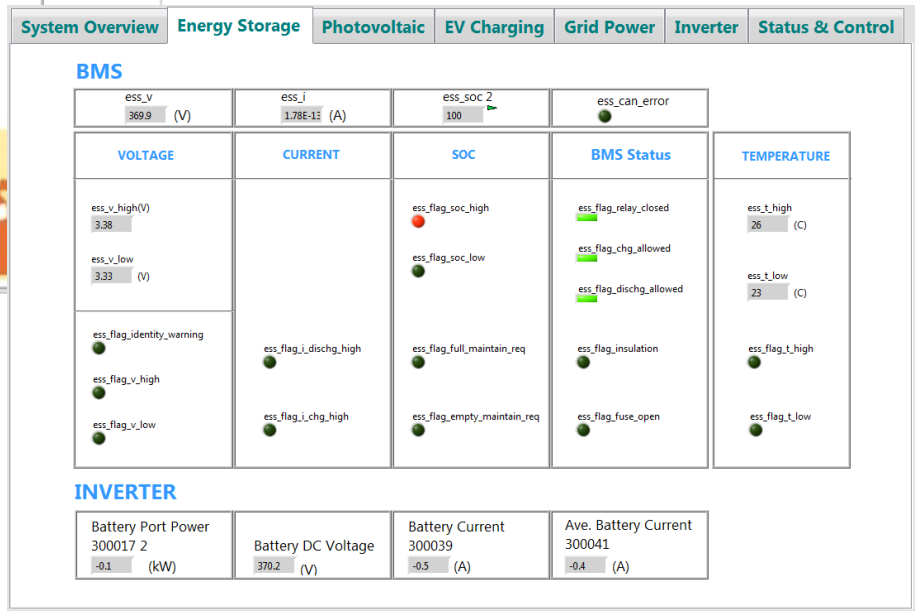
The control, monitoring, and data logging were developed with Labview.

**Main System Monitoring Interface**




- Monitor power flow between different units.

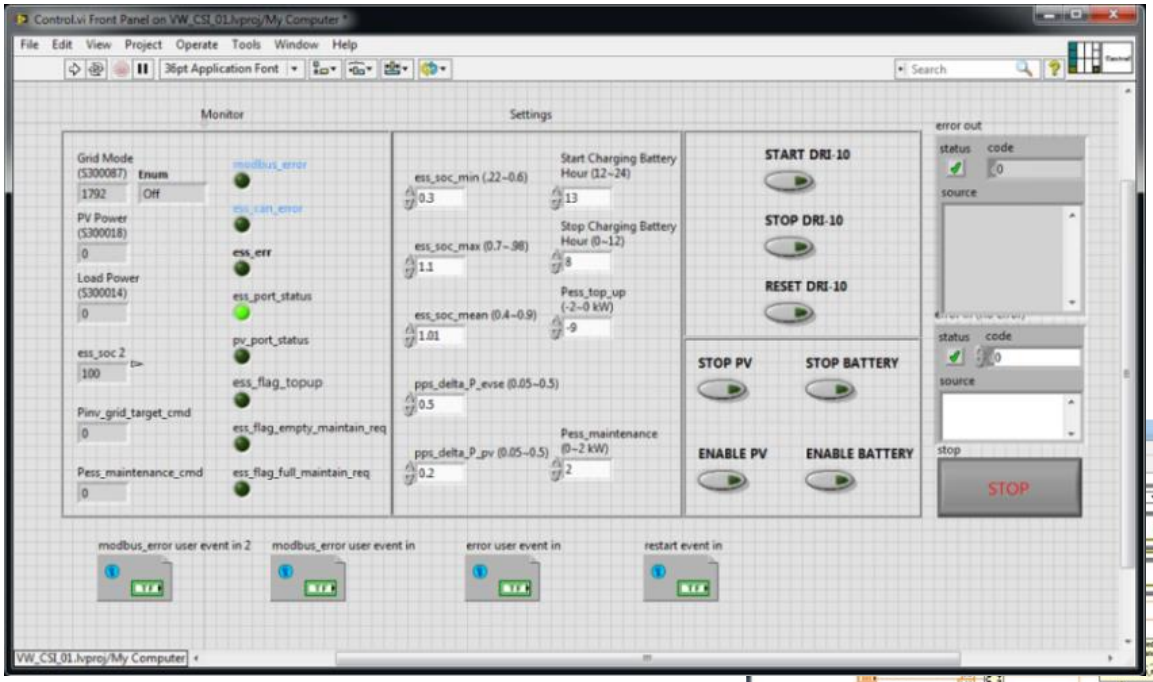
**Battery Monitoring & Protection**

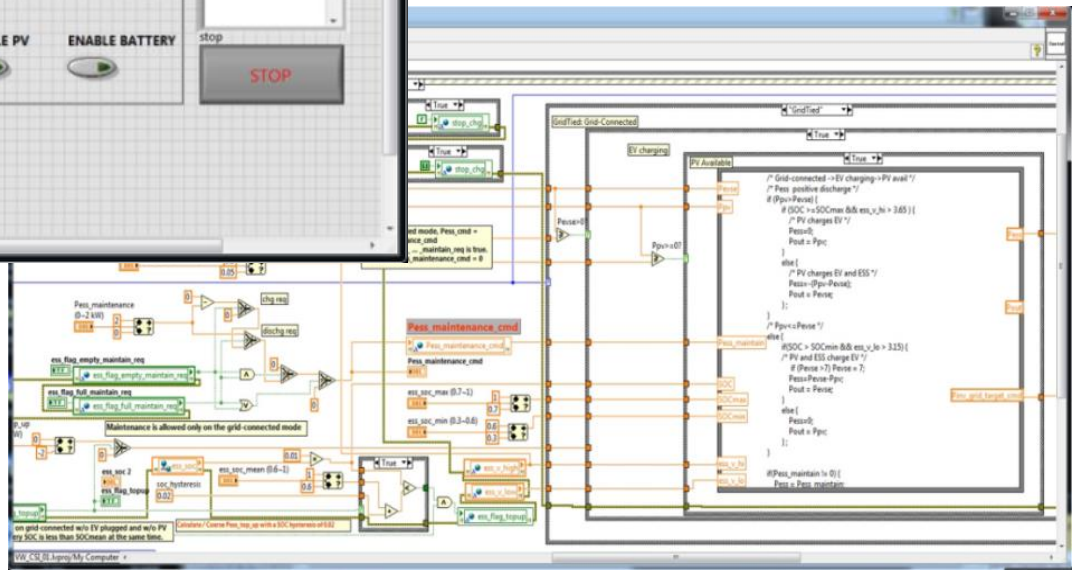



- Monitor cell voltage, cell imbalance, current, temperature, battery SOC, system and its communication status.

# System Design — Software

## Control Interface and Control Block Diagram




- Monitor operation modes and status
- Set control parameters
- Change system operation modes

# System Design — Control

## Control Strategy

- ❑ Maximize PV energy for EV charging, minimize energy exchange with grid;
- ❑ Reduce power spikes of Solar PV Power and EV charging on utility grids.

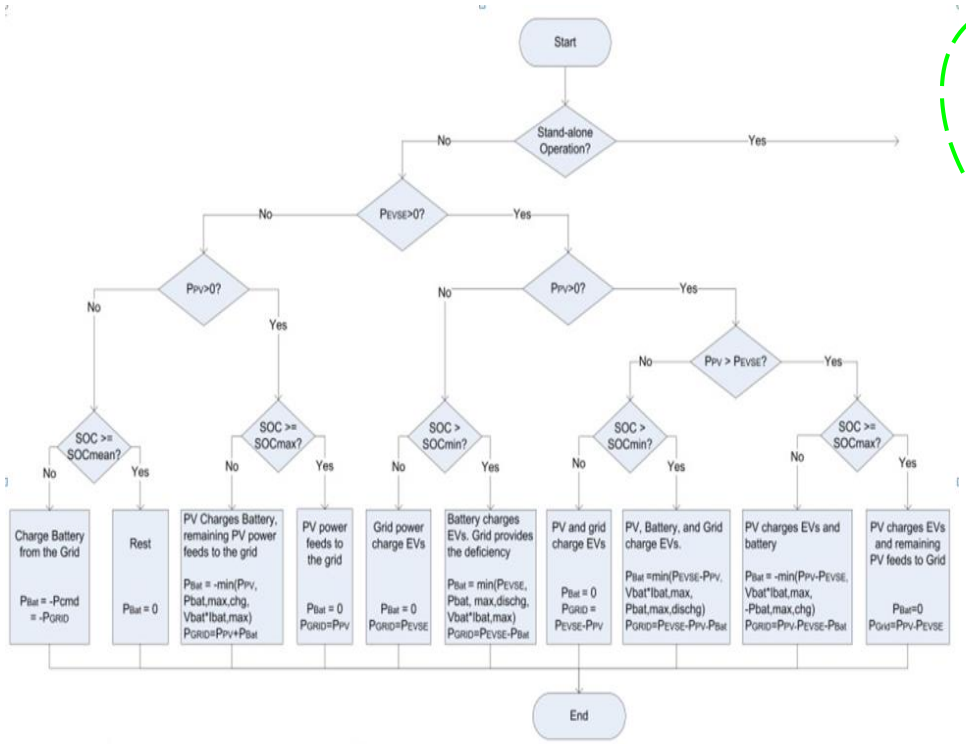
## Operation Modes

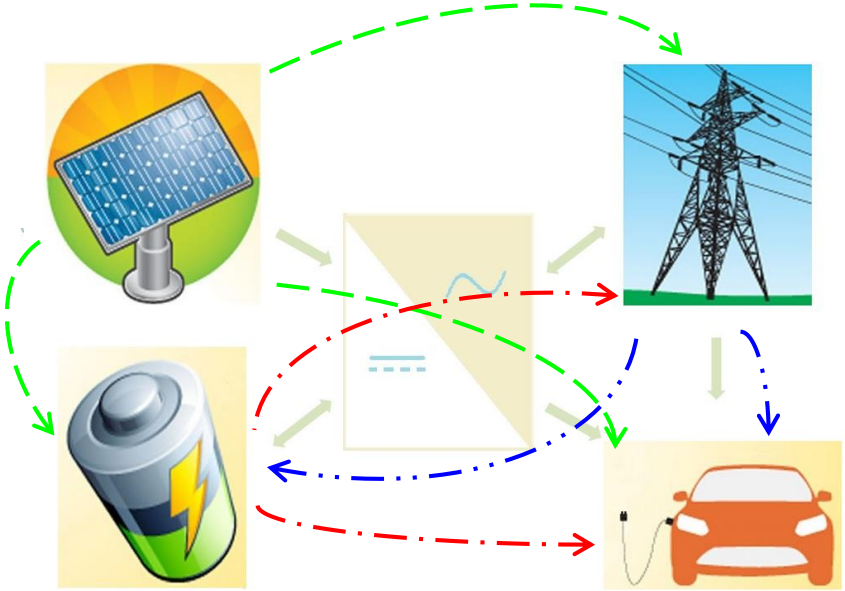
- ❑ Grid-tied mode: the EV can be charged from PV, the battery, and/or the grid.
- ❑ Standalone mode: the EV is charged from PV and the battery.

The system can switch between the two operation modes automatically depending on the grid conditions.

# System Design — Control

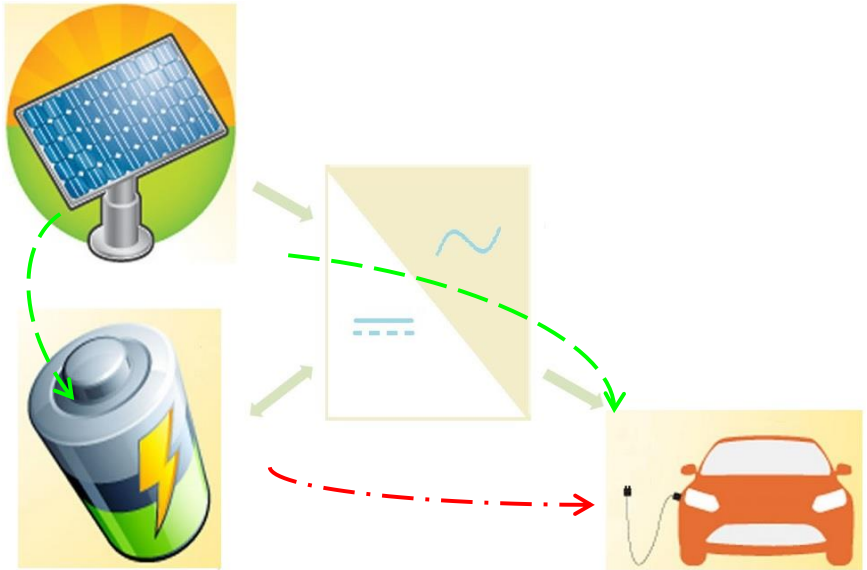
## Grid-tied Operation Mode

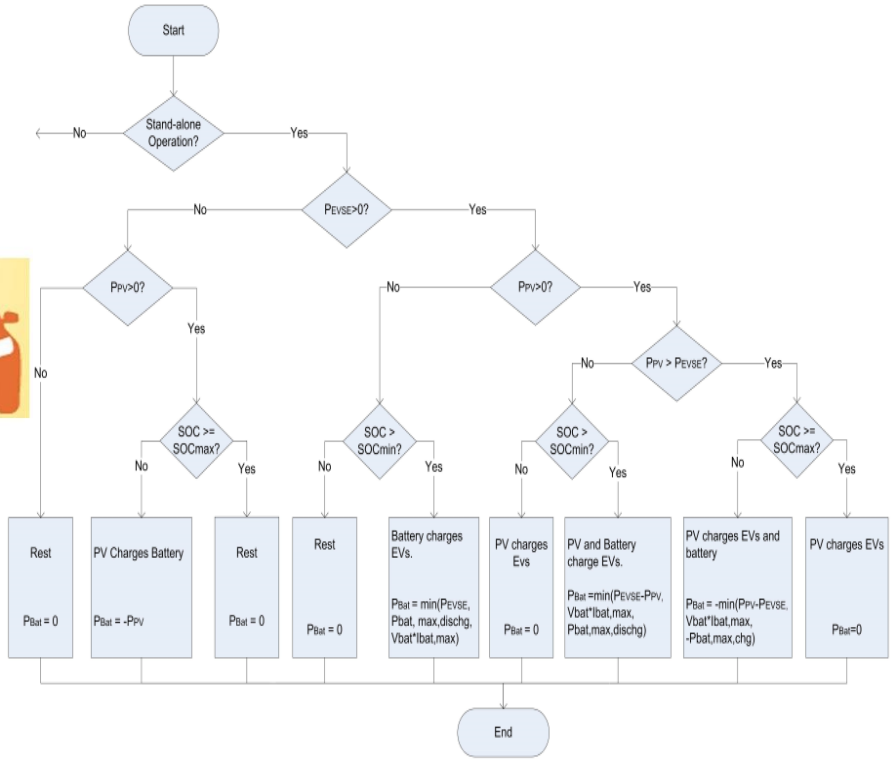


# System Design — Control

## Stand-alone Operation Mode

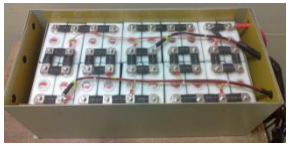




# Construction and Installation

# Construction and Installation

Battery module assembly and installation



Supervisory & control computer with dual power supply

Bidirectional inverter installation

PV disconnect installation

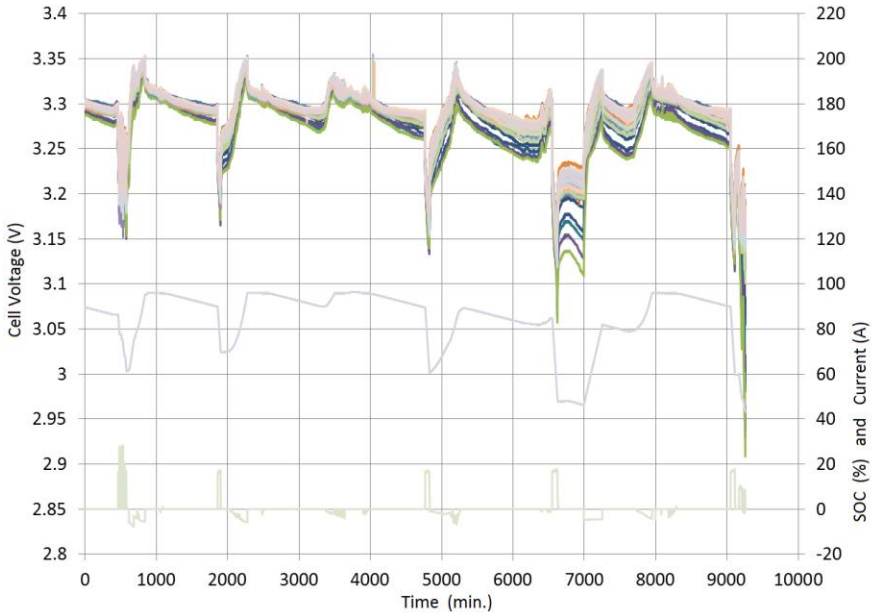
PV charger panel and EV charger installation

Battery storage and control system room

# Battery Management

## Battery cell diagnosing and balancing

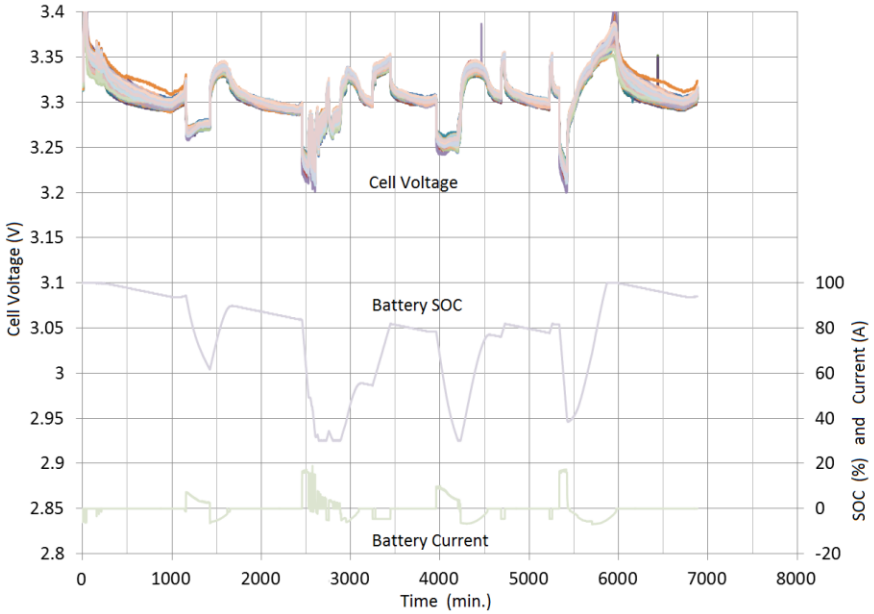
### Cell Voltage Before Balancing




Battery cell imbalance happened due to cell capacity dissimilarity and self-discharging after being stored unused for a long period of time.

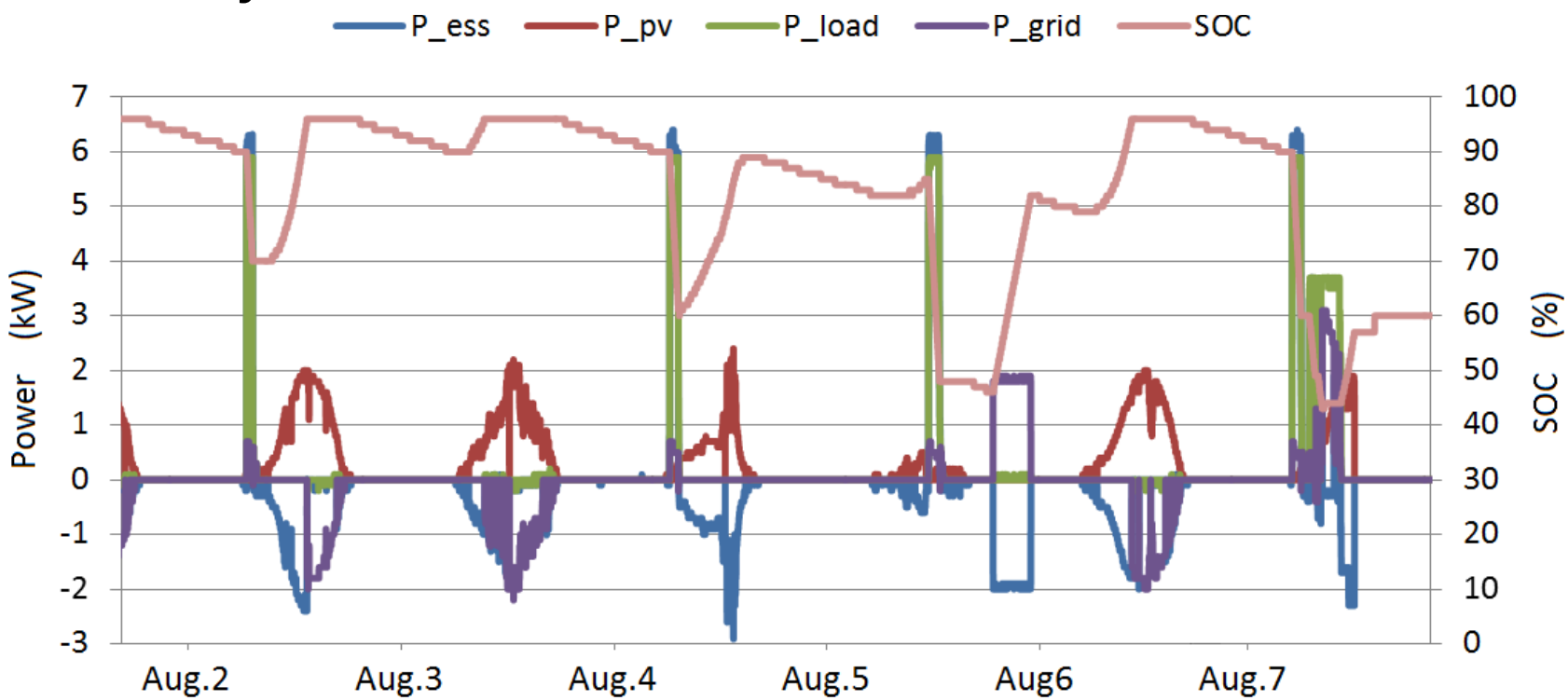
After replacing the cells with low capacity and balancing cells with low voltage, the 220 cells perform identically.

### Cell Voltage After Balancing



# Data Collection and Analysis

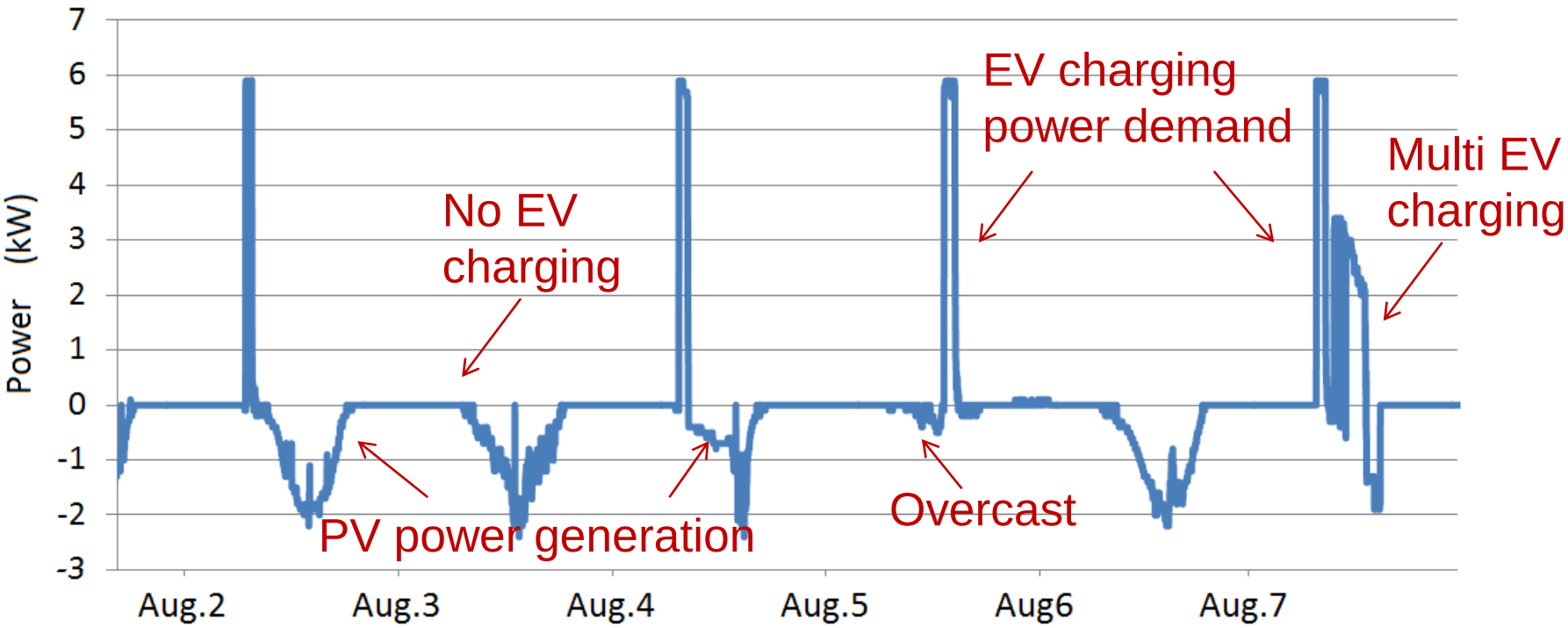
**Profiles of battery power, PV power, EV charging load, grid power, and battery SOC**




The battery power and SOC, PV power, EV charging load, and the grid power, are collected from the battery management system via CAN bus and the bidirectional inverter via MODBUS, and logged in the supervisory and control PC every minute.

# Data Collection and Analysis

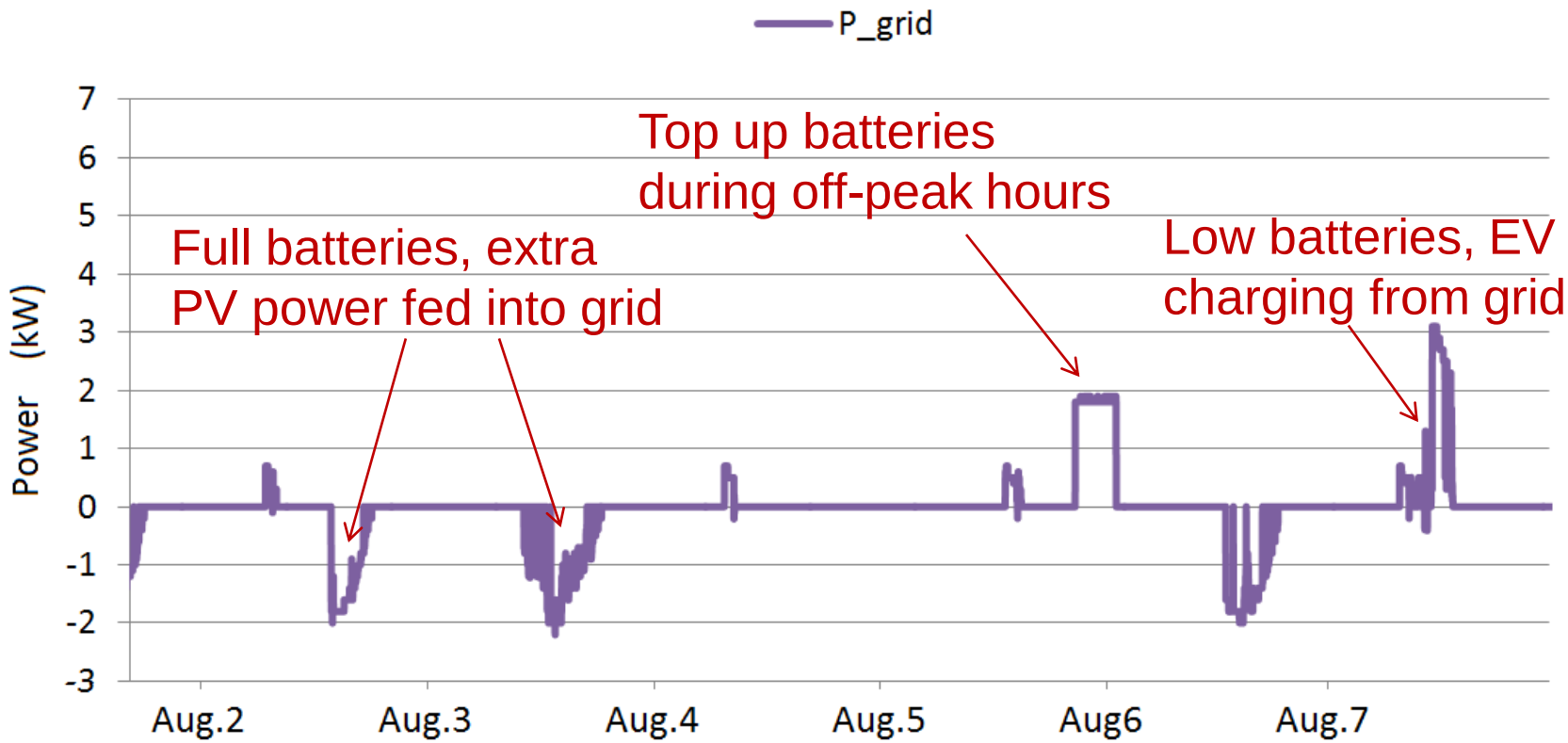
## Profiles of PV power and EV charging load




- Most of EV charging happens in the early morning for a work place EV charger.
- PV power can not be used directly for EV charging in the early EV adoption stage.
- This is the power imposed on the grid for a PV powered EV charging station without energy storage.

# Data Collection and Analysis

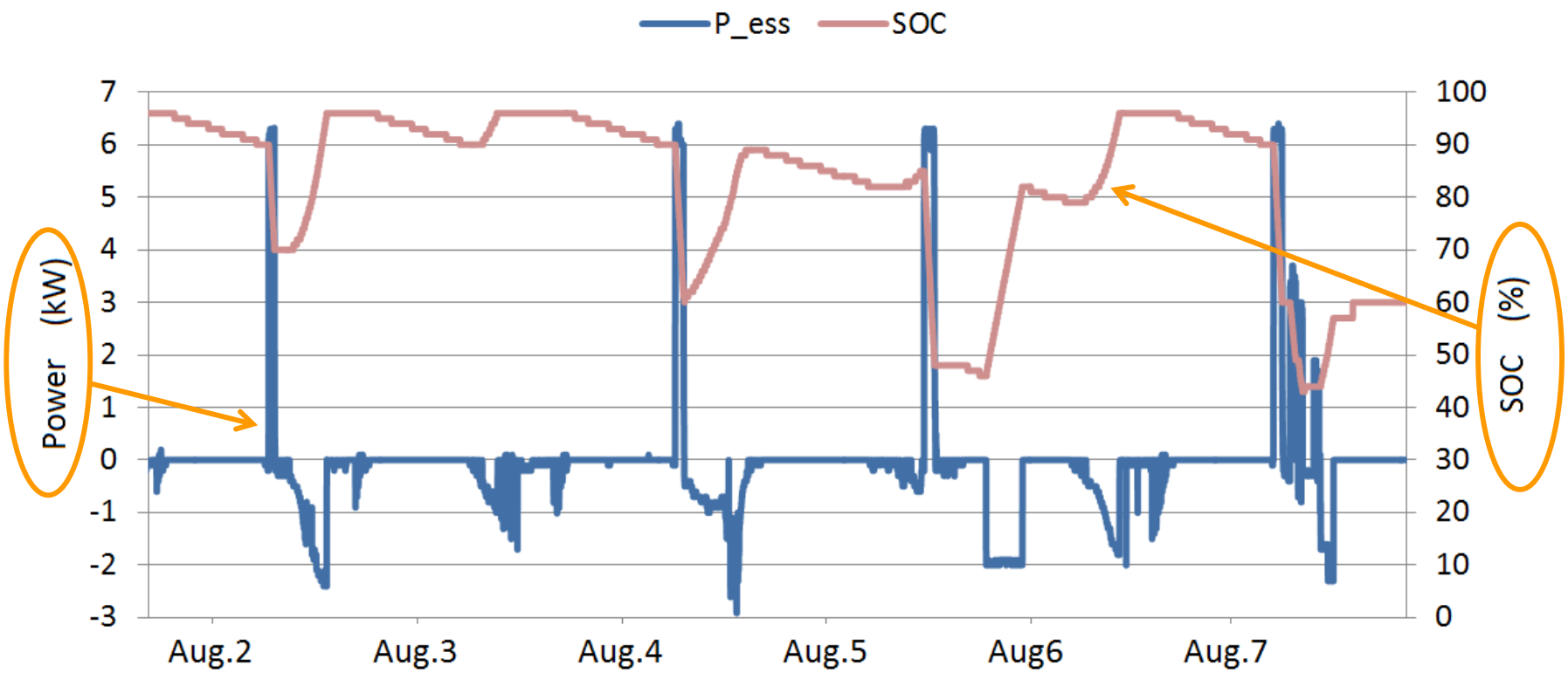
## Actual Grid Power Demand With Buffer Battery




- Compared to the power demand of the PV powered EV charging station without buffer battery, the grid power spikes were reduced by a factor of 2.

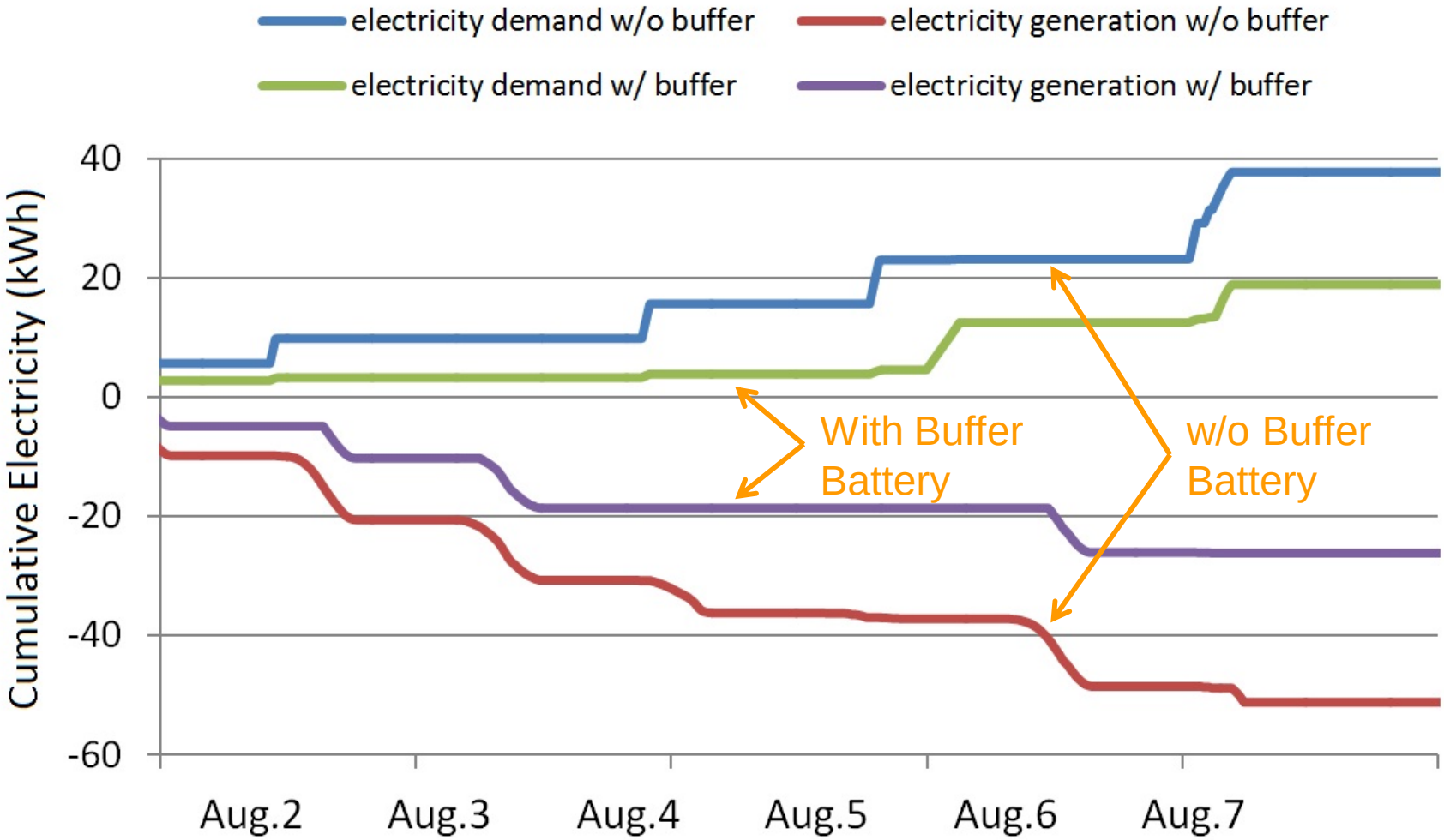
# Data Collection and Analysis

**Profiles of battery power and SOC**




- The power spikes from the EV charging and the PV electricity were transferred into the buffer battery.

# Data Collection and Analysis




- The energy exchange between the charging station and the grid were decreased by half.

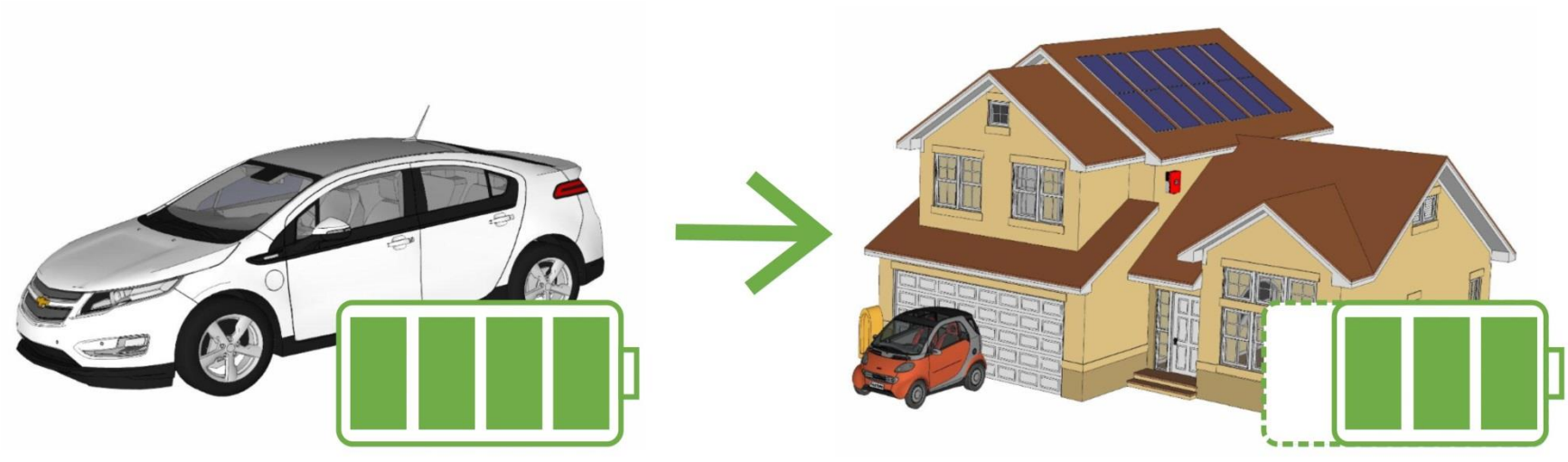
# Summary and Conclusions

- The battery buffered charging station is operational and used routinely to charge several EVs .
- The impact of vehicle charging on the grid is minimized consistent with the limited PV energy available to the charging station. The benefits of battery buffered charging will become increasingly important as the number of electric vehicles in California continues to increase and the need for storage by the utilities becomes greater as the contribution of PV power generation becomes larger.
- As experience is gained with the use of the vehicle charging station in West Village, we will be in a position to recommend to other groups in California how they can best utilize PV energy for EV charging and the value of battery buffering as part of their systems.
- Further research will optimize the energy storage according to weather forecasts (solar intensity) and projections of the daily vehicle use patterns of the station.

# Single Family Home 2nd Life Li-ion Battery Energy Storage

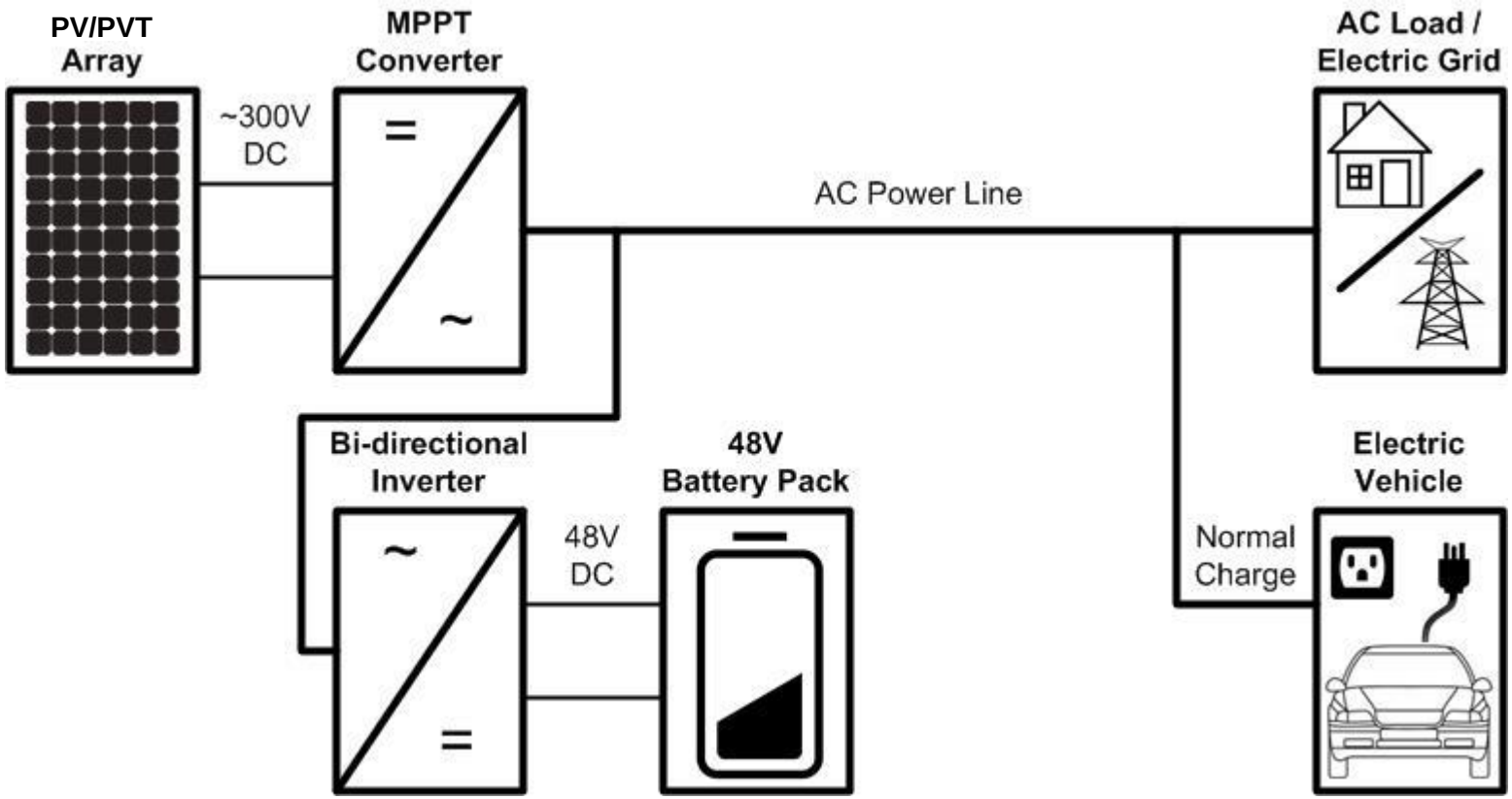
Antonio Tong– Ph.D. UC Davis Mechanical and Aerospace Engineering

Dr. Jae Wan Park– Professor UC Davis Mechanical and Aerospace Engineering

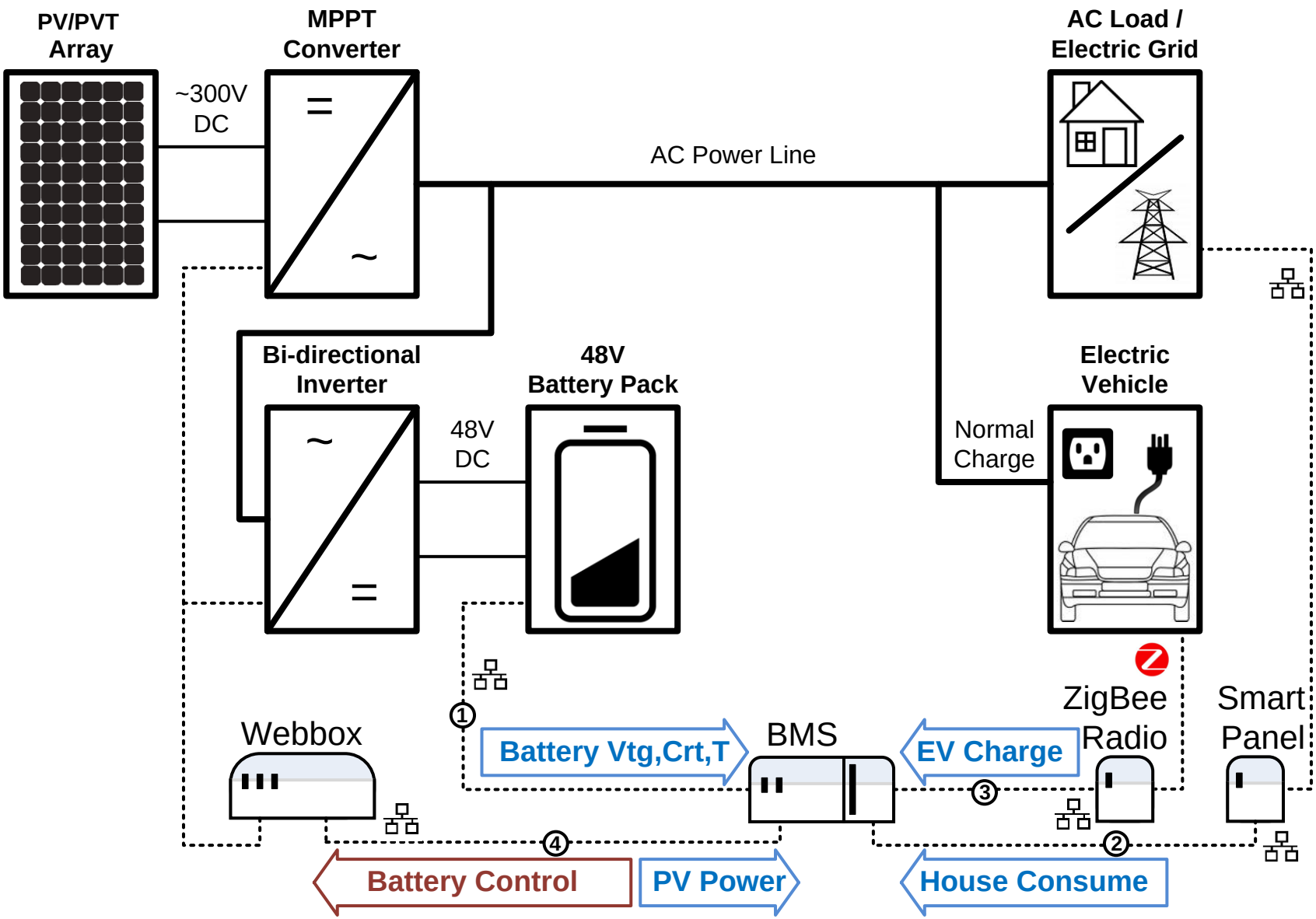


1st Life: Vehicle Traction Battery  2nd Life: Smart Home Energy Storage

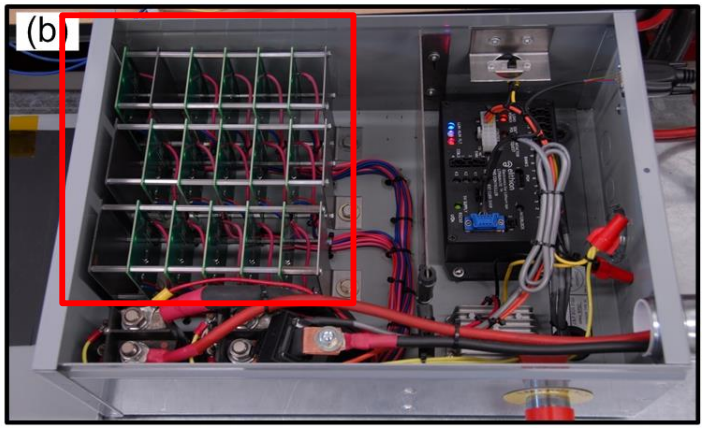
# System Planning

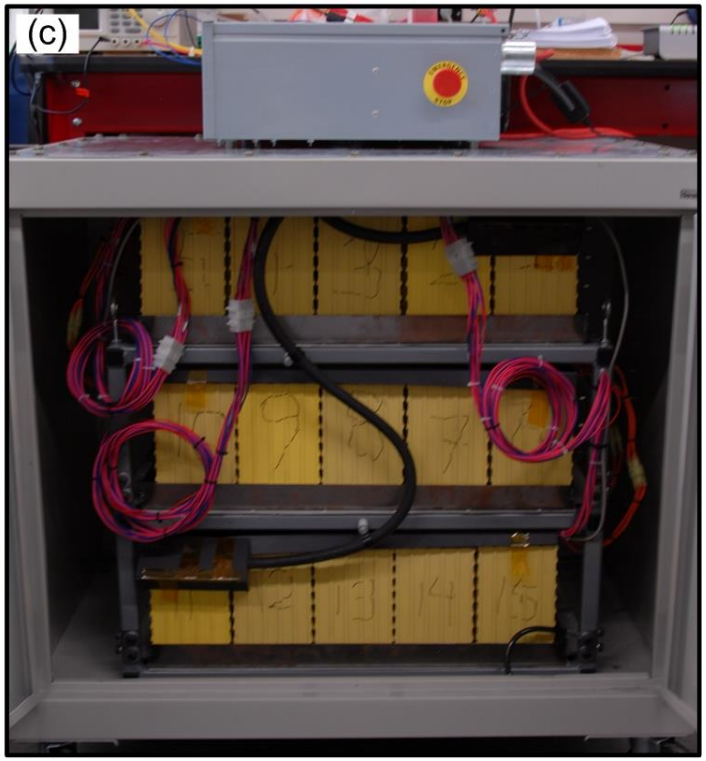


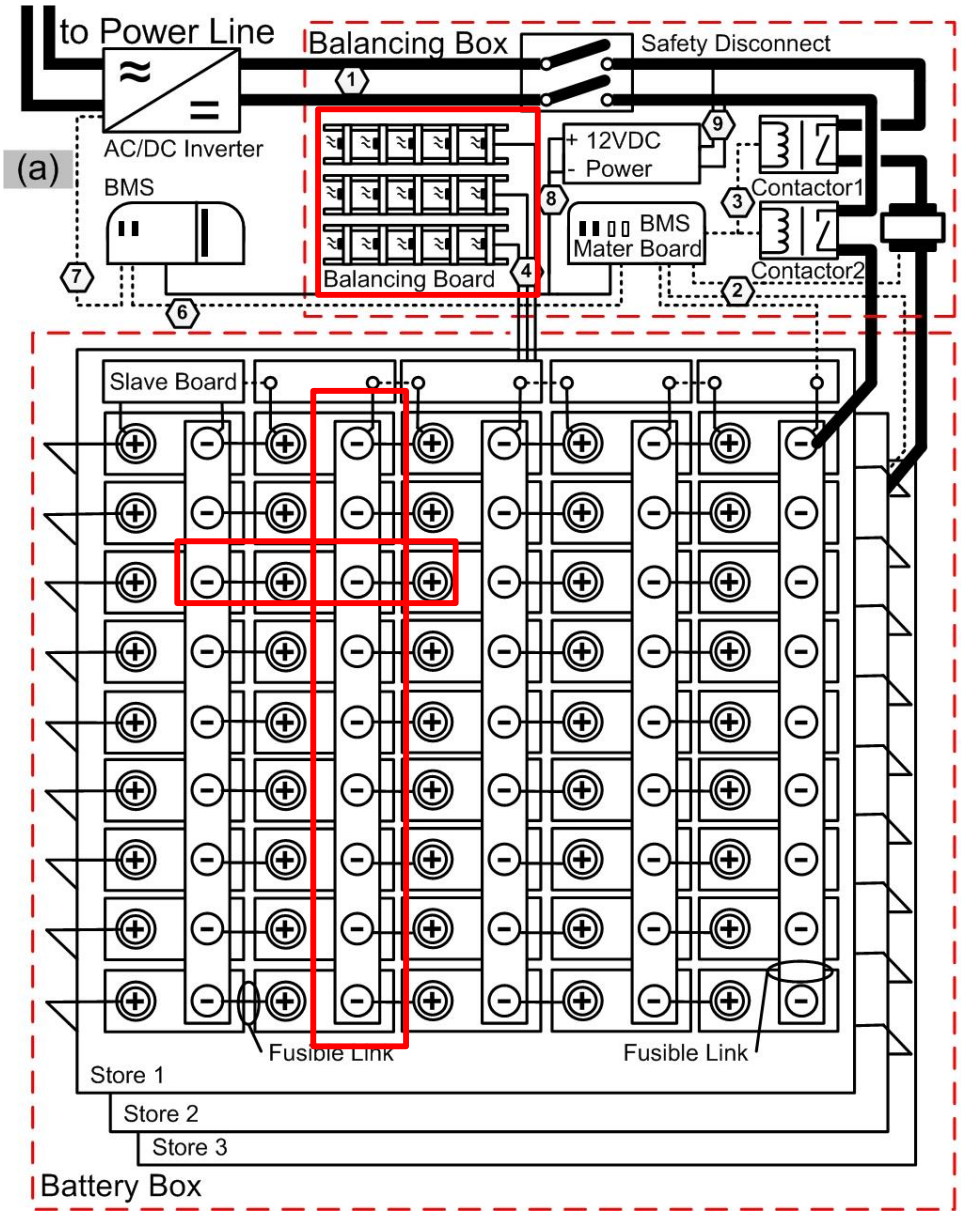
# System Planning



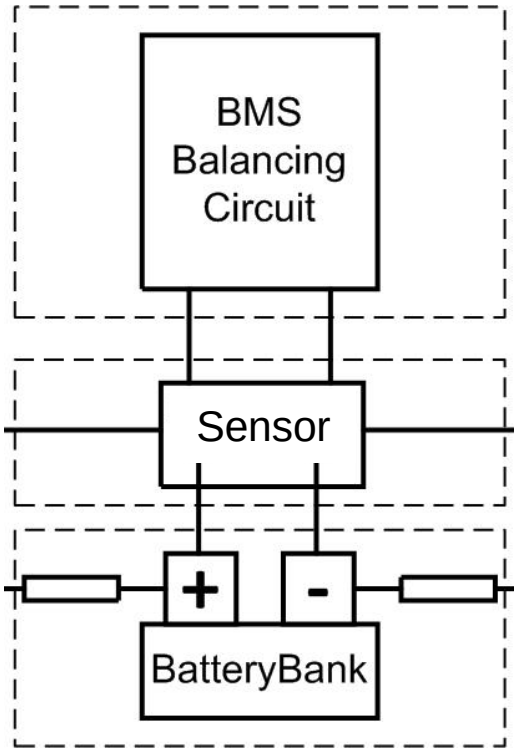
# Battery Assembling



# Battery Protection




**2 A Balance** Condition:

Cell Voltage > 3.4

**SLAVE Board** Function:

V, C, T monitoring

**Fusible Link** Function:

10 AWG Short Circuit Protection

**DC-AC Inverter** Condition:

Pack Voltage = 30~54 V

Max Current = 200 A

Manual Break

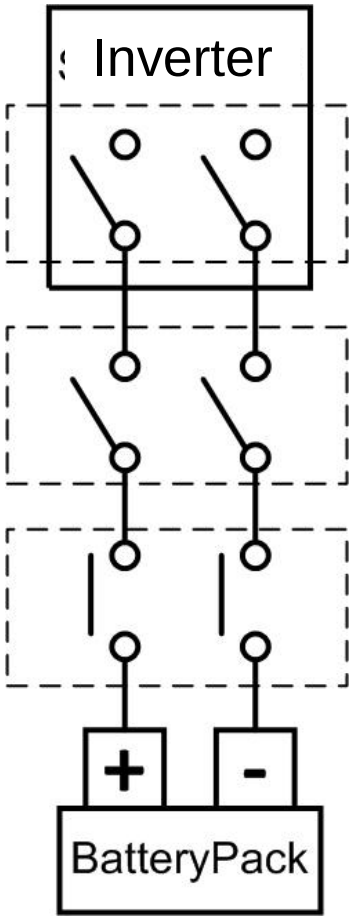
**DC Breaker** Condition:

Manual Break

**Two Contactors** Condition:

Cell Voltage: 2.8~3.65 V

Max Current = 250 A



# Energy Management

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | F | T | T | F | N | T | F | N | T | T | N | F | N | F | N | T | F | N |
| 2 | T | F | T | T | T | F | T | T | F | T | T | F | F | F | F | T | F | F |
| 3 | T | T | F | F | F | F | N | N | N | T | T | T | T | F | F | N | N | N |
| B | C | D | C | C | C | D | C | C | D | - | - | - | - | - | - | - | - | - |
| G | - | - | - | - | - | - | - | - | - | F | F | S | S | S | S | F | S | S |

Input

1:UtilityPrice T :Peak Price, N: Partial Peak, F: Off Peak

2:PVvs.Load T :PV product > demand, F: PV product < demand

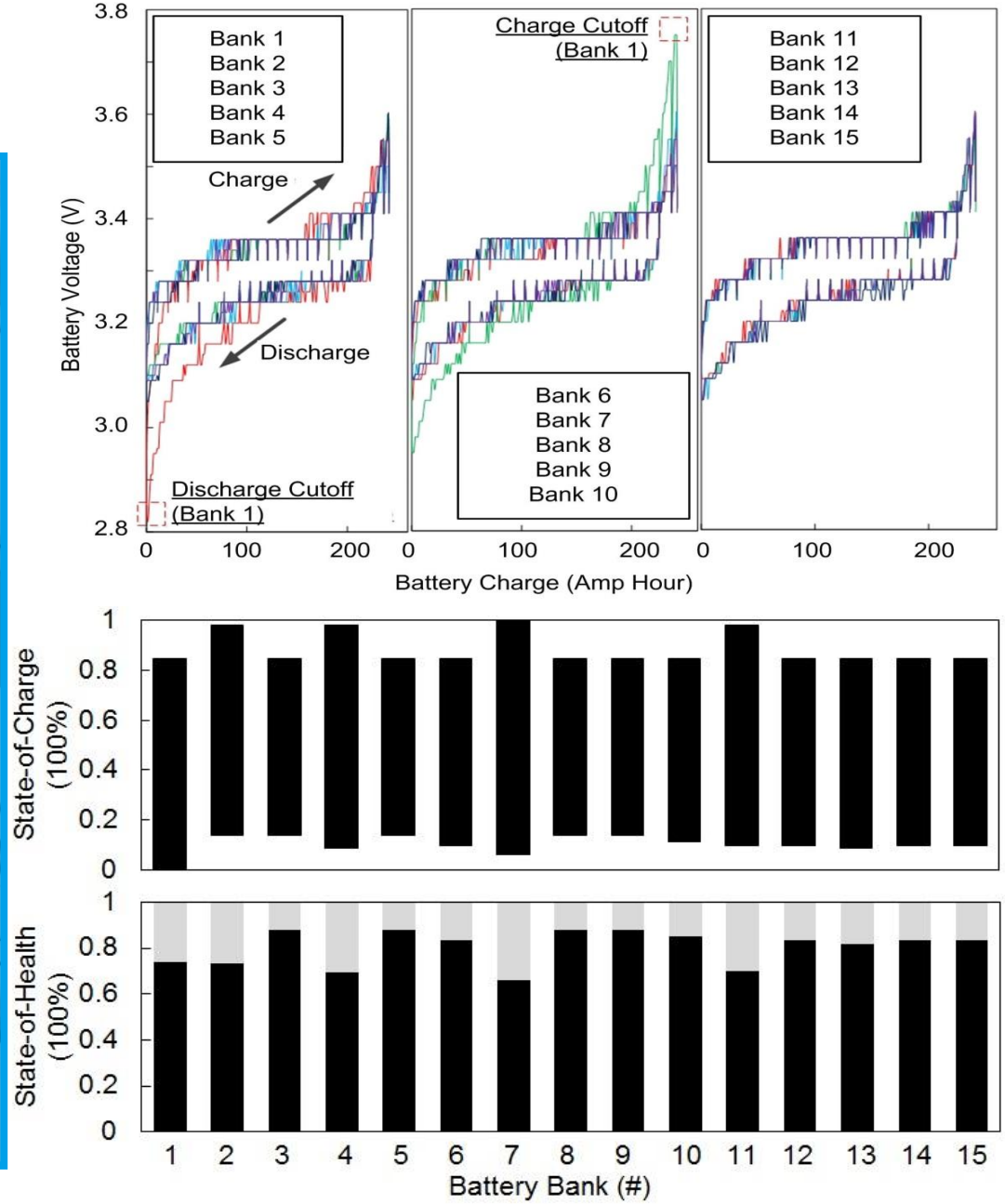
3:BattSoC T : 80%~100%, N: TargetSoC~80%, F: 0%~TargetSoC

Action B: Battery G: Utility Grid

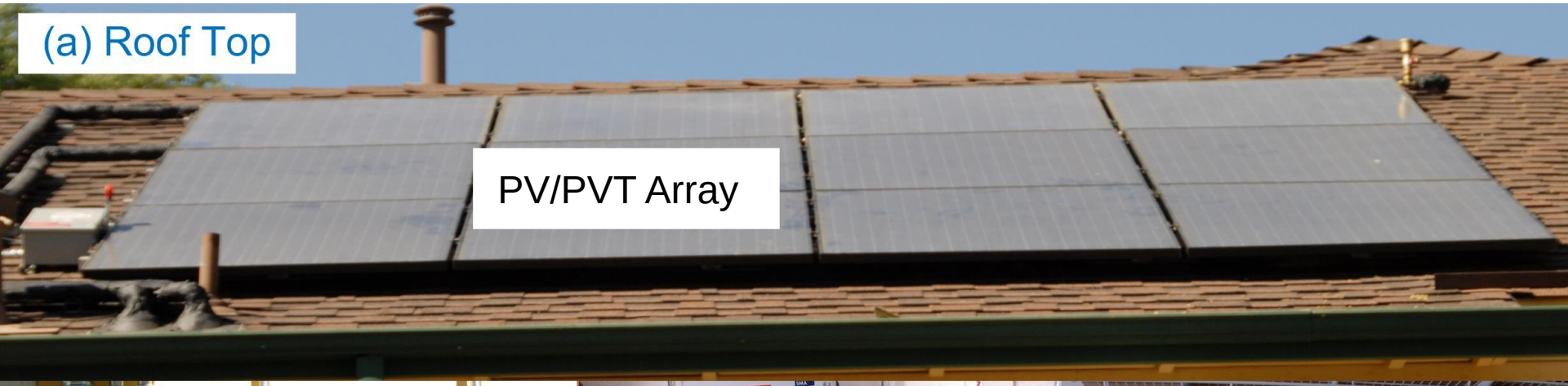
F: Grid Back Feed. S: Grid Supply.

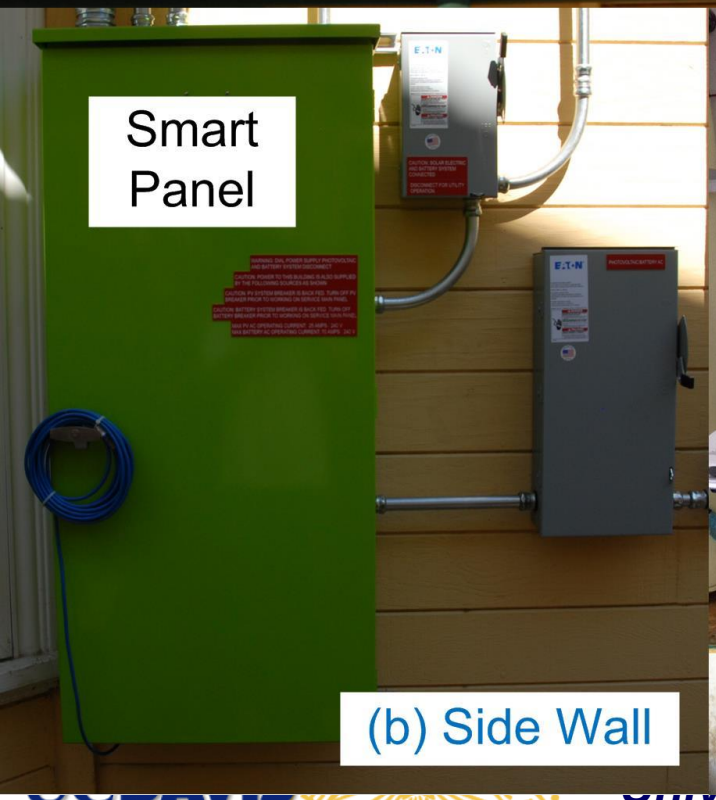
C: Battery Charge. D: Battery Discharge.

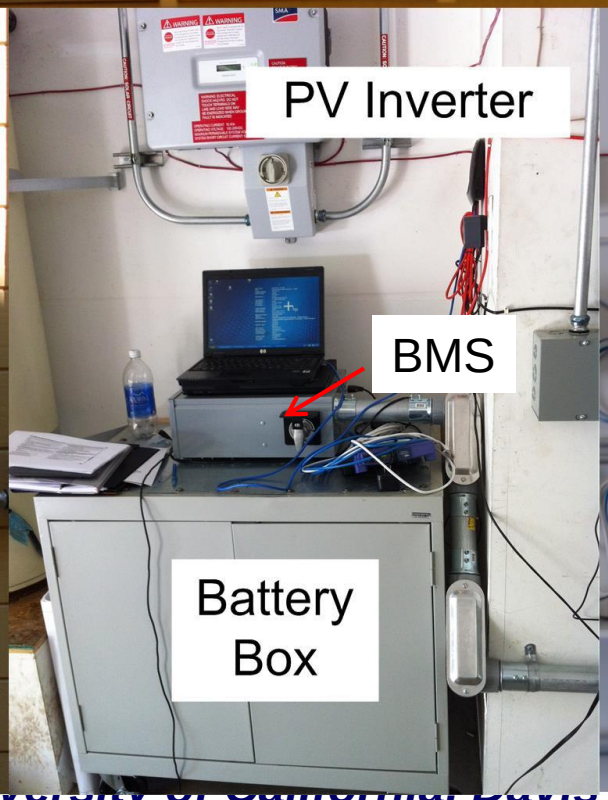
# Battery Pack Installation

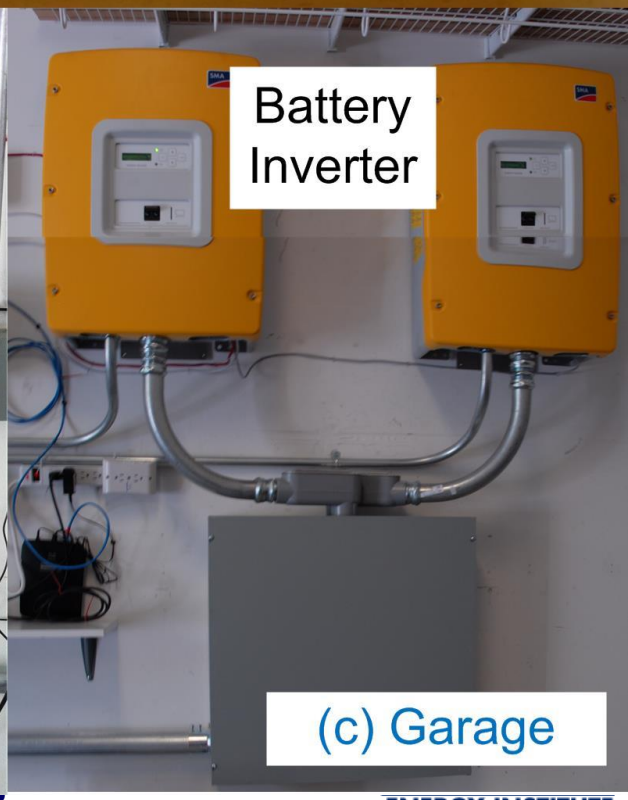


# System Installation

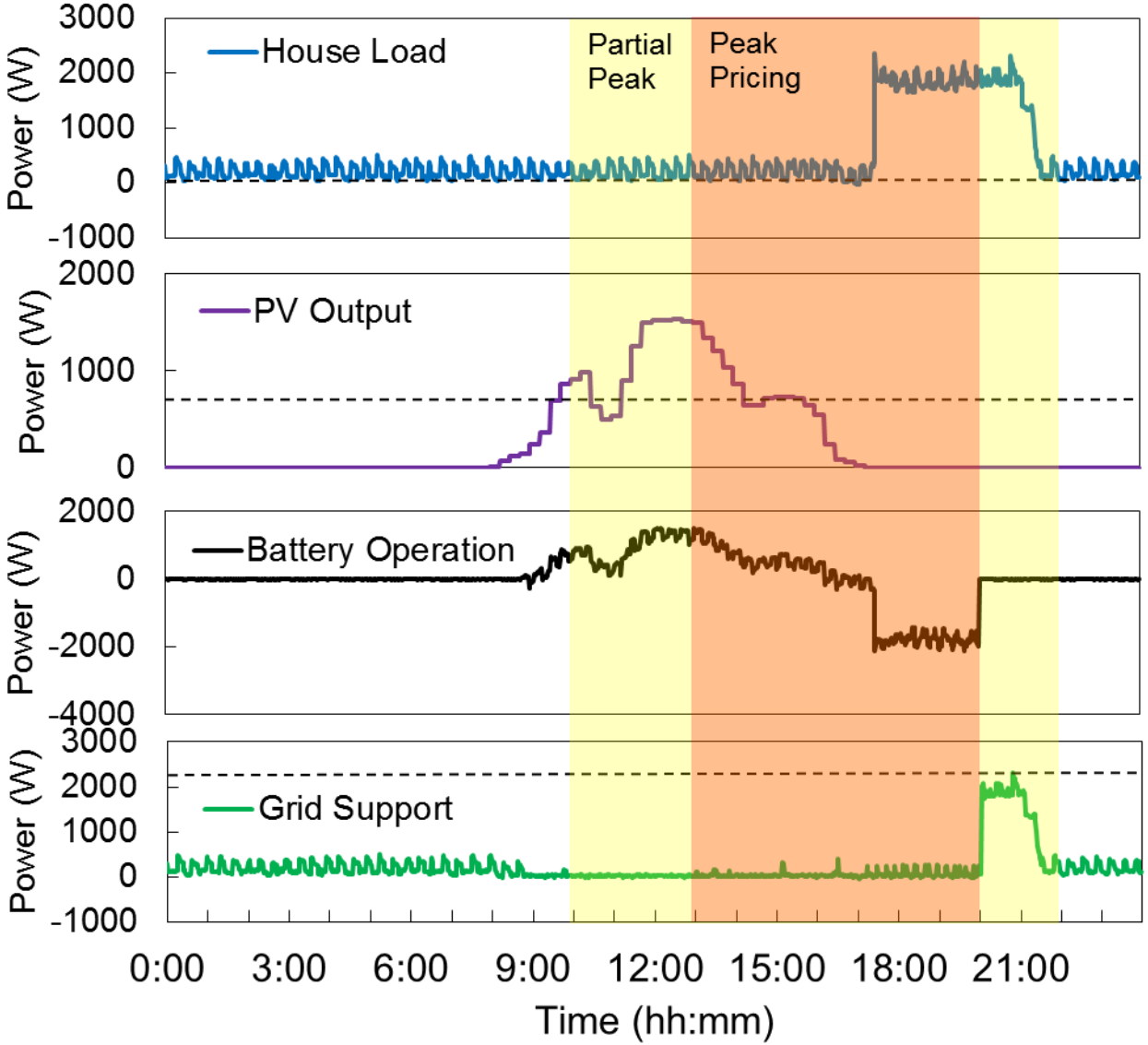


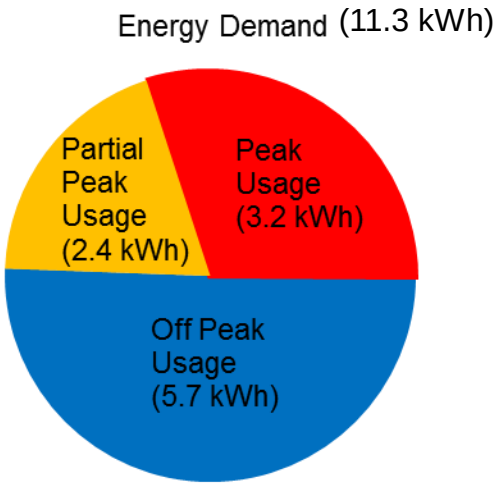



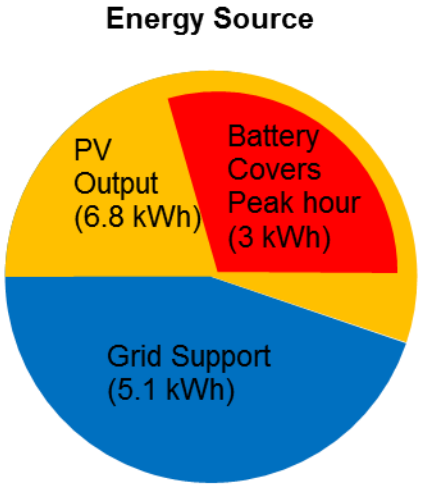



# System Operation Result



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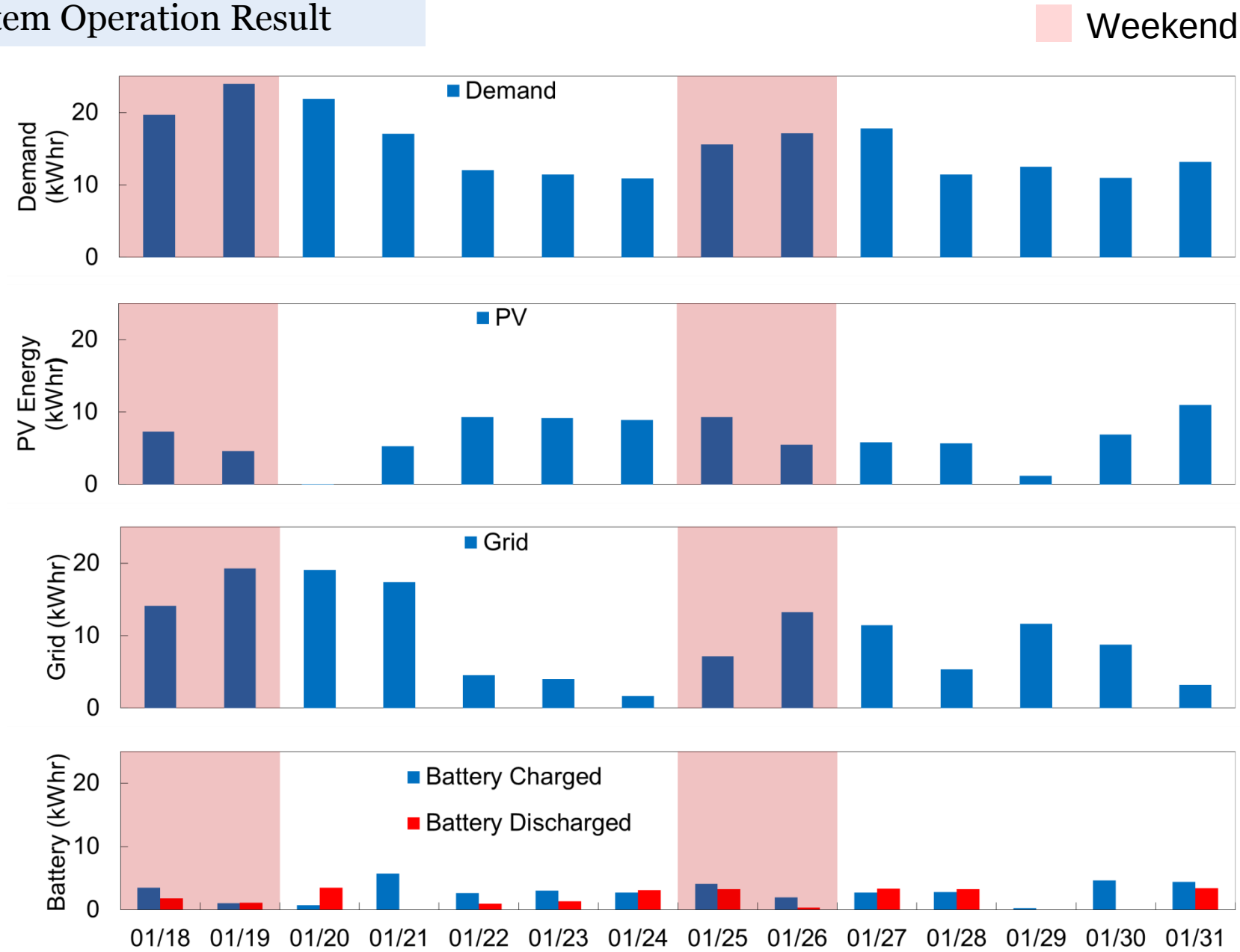
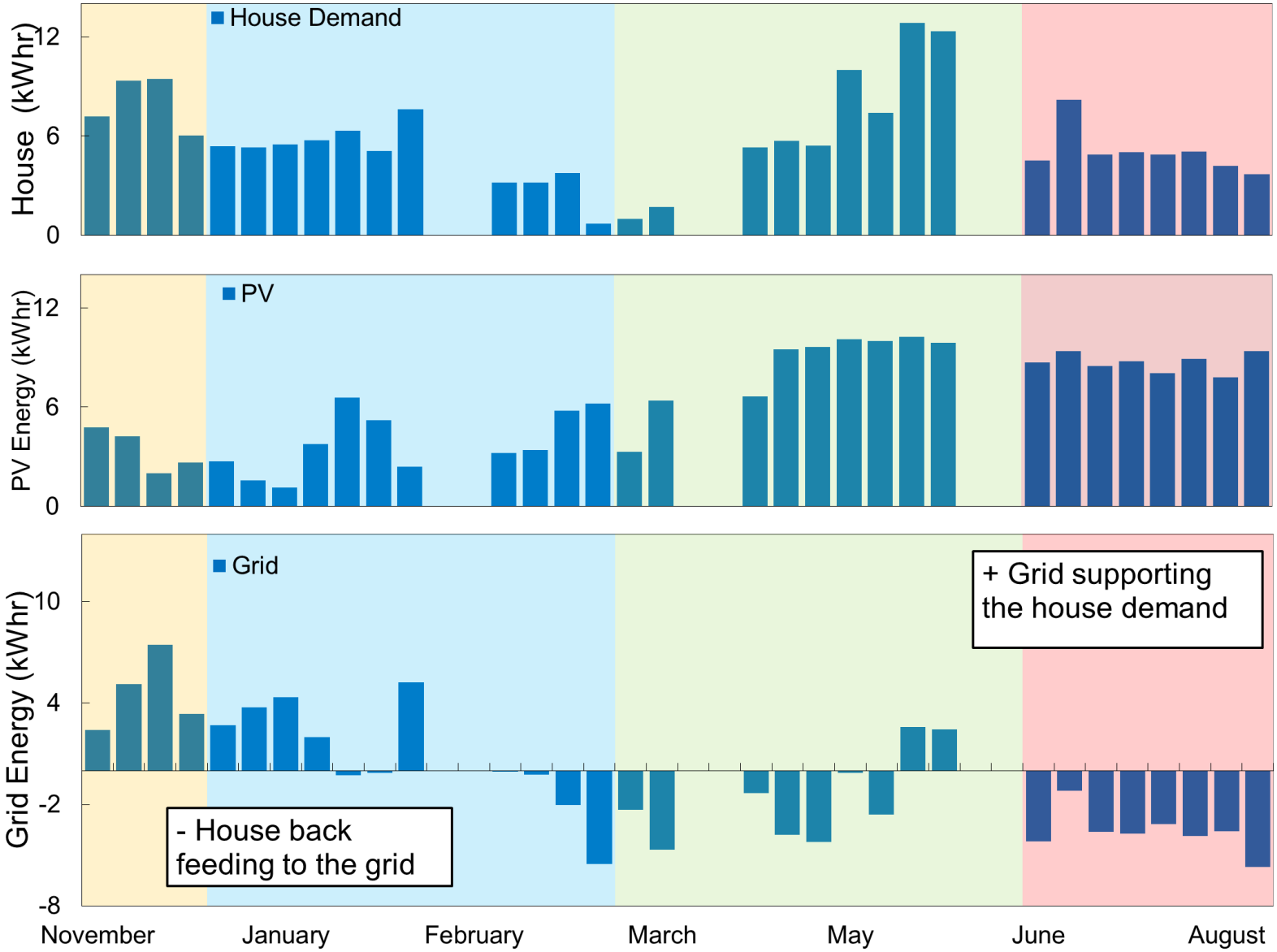


# System Operation Result



# Conclusion

**Improves grid stability and reduces grid dependency.**

- The 2kWPV with 10kWh battery System achieved >95% of peak shifting.
- >80% of the days, the system achieved >8kWh delivery.

→ **More Solar Penetration**

**Reduces energy cost and environmental impact.**

- It reduces consumption of natural gas generated power at peak hours.
- More utilization of solar energy during peak hours will result in cost saving for rate payers. And cut solar payback time.

→ **Sustainable Low Cost Energy**

**Lithium battery recycle**

- A 2nd life battery pack costs about 1/5~1/2 of a equivalent new pack, with >5 year service life.
- It reduces PEV cost, promotes li-ion cell recycling and PEV commercialization.

→ **PEV Technology**

# Thank you!

Green Transportation Laboratory PI:
Dr. Jae Wan Park
Researcher:
Dr. Shijie (Antonio) Tong
Tsz Fung
Matthew Klein
David Weisbach

## Special thanks to Sponsors and Collaborators:

# Questions?

# Solar Hybrid (PVT) Technology Demonstrations in Single and Multifamily Buildings

Jun Li– Ph.D. candidate, Chemical Engineering and Material Science

Dr. Pieter Stroeve– Chemical Engineering and Material Science

# Purpose of Task

- *The purpose of task 3 is to evaluate existing and innovative hybrid photovoltaic/thermal (PVT) technologies and strategies for solar hot water production that can be capable of working with other smaller scale solar systems in community-wide installations with multiple users.*

- *The results of Task 3 will provide practical insight for hot water systems at the West Village as well as a broader body of knowledge of solar thermal applications for net-zero energy buildings.*

# Subtasks

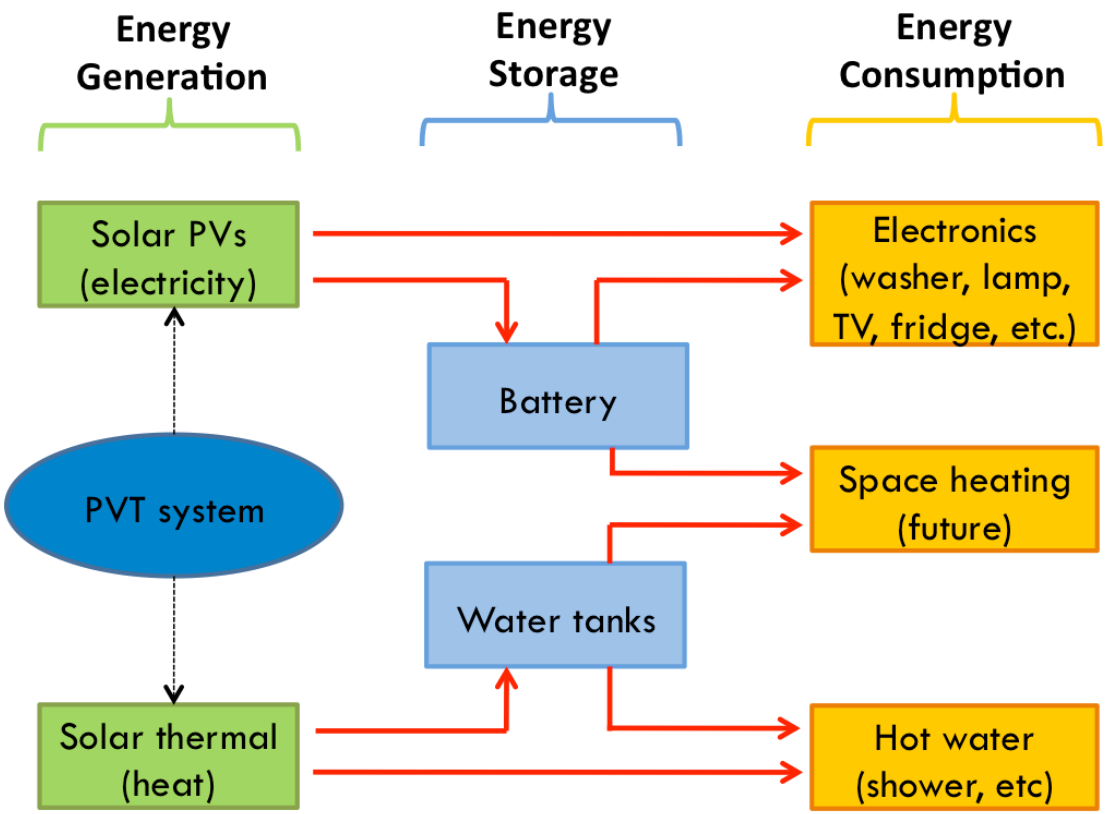
- *Demo 1: Demonstrate hybrid photovoltaic/solar thermal system optimized for the new Solstice apartment building.*

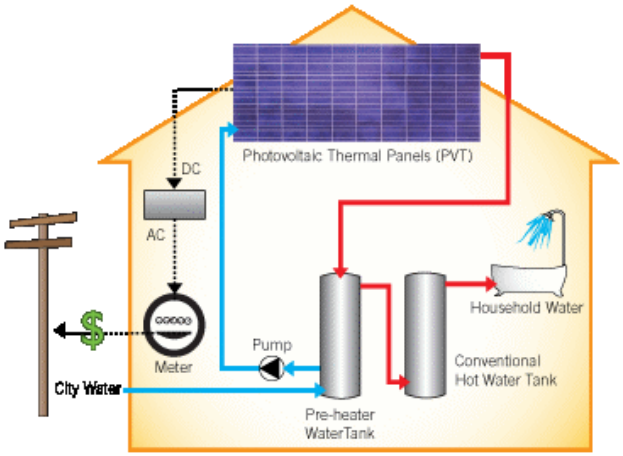
- *Demo 2: Demonstrate hybrid photovoltaic/solar thermal system optimized for Aggie Village single family home.*

# TASK 3 DEMO 2

## HYBRID SOLAR PHOTOVOLTAIC/THERMAL SYSTEM FOR SINGLE FAMILY HOME

# Project Planning




*Source: www.bosssolar.com*

- Energy Distribution System

# Project Planning

## Table: summary of PVT manufacturers

| No. | Company | Location | Medium | PV eff. | ST eff. | Total eff. | Roof | Remarks |
|---|---|---|---|---|---|---|---|---|
| Flat plate, air PVT | | | | | | | | |
| 1 | Conserval | Canada | Air | 15 | 40 | 55% | Y | Flat |
| 2 | Grammer | Germany | Air | | | 70% | Y | Flat |
| Flat plate, liquid PVT | | | | | | | | |
| 3 | Millenium | Israel | Air/$H_2O$ | 15 | 70 | 85% | Y | Flat |
| 4 | Solarzentrum | Germany | Glycol | 15 | | | Y | Flat |
| 5 | Solimpeks | Turkey | $H_2O$ | 15 | 55 | 70% | Y | Flat |
| 6 | EchoFirst | USA | Air | | | 50% | Y | Flat |
| 7 | Dawn | USA | $H_2O$/glycol | | | | Y | Flat |
| 8 | Helios | China | $H_2O$/glycol | | | | Y | Flat |
| 19 | ecoTec | USA | | | | 35% | Y | Flat |
| 10 | Erjin | China | $H_2O$ | 15 | | | Y | Flat |
| Solar concentrator, liquid PVT | | | | | | | | |
| 11 | Cogenera | USA | $H_2O$ | 15 | 60 | 75% | N | Conc. |
| 12 | Absolicon | Sweden | $H_2O$ | | | 45% | Y | Conc. |
| 13 | ZenithSolar | Israle | $H_2O$ | | | 75% | N | Conc. |
| 14 | Solergy | Italy | | 30 | 45 | 75% | N | Conc. |

*Source: refer to company websites for more information*

# Project Planning

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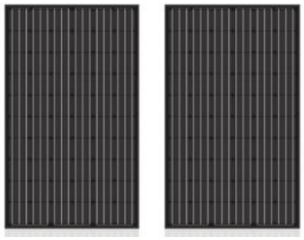
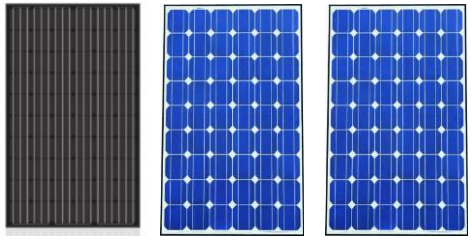
*Source: refer to company websites for more information*

# Project Planning

- **System design**



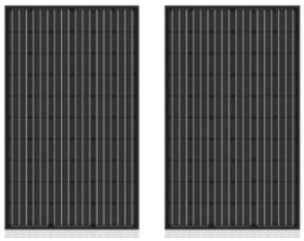
***PVT only***



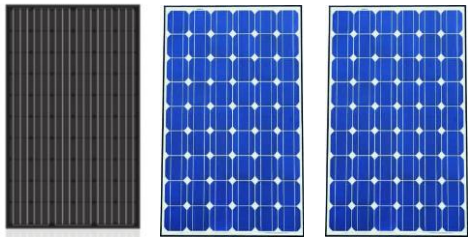
***PVT + PV***

# Project Planning

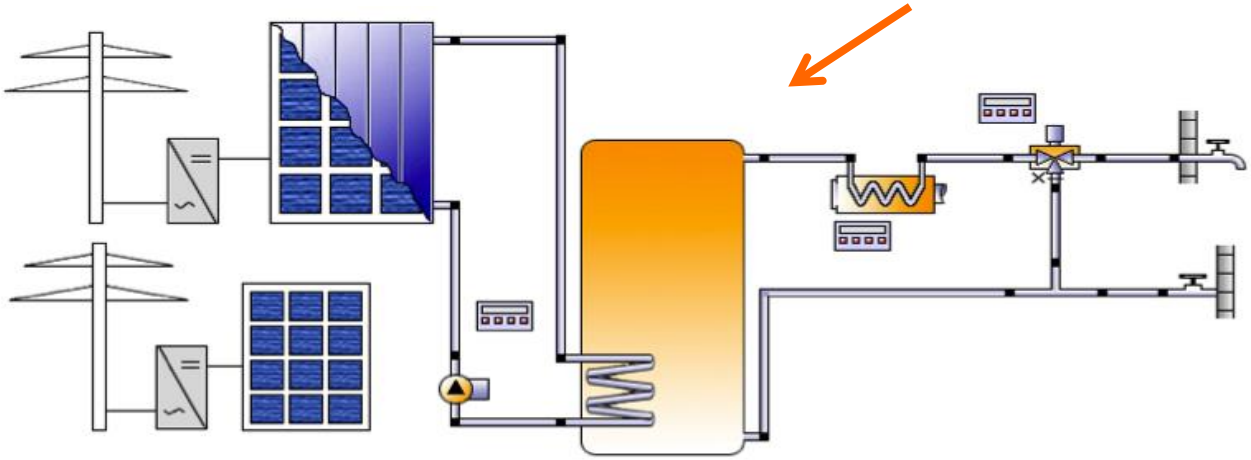
- **System design**



***PVT only***



***PVT + PV***

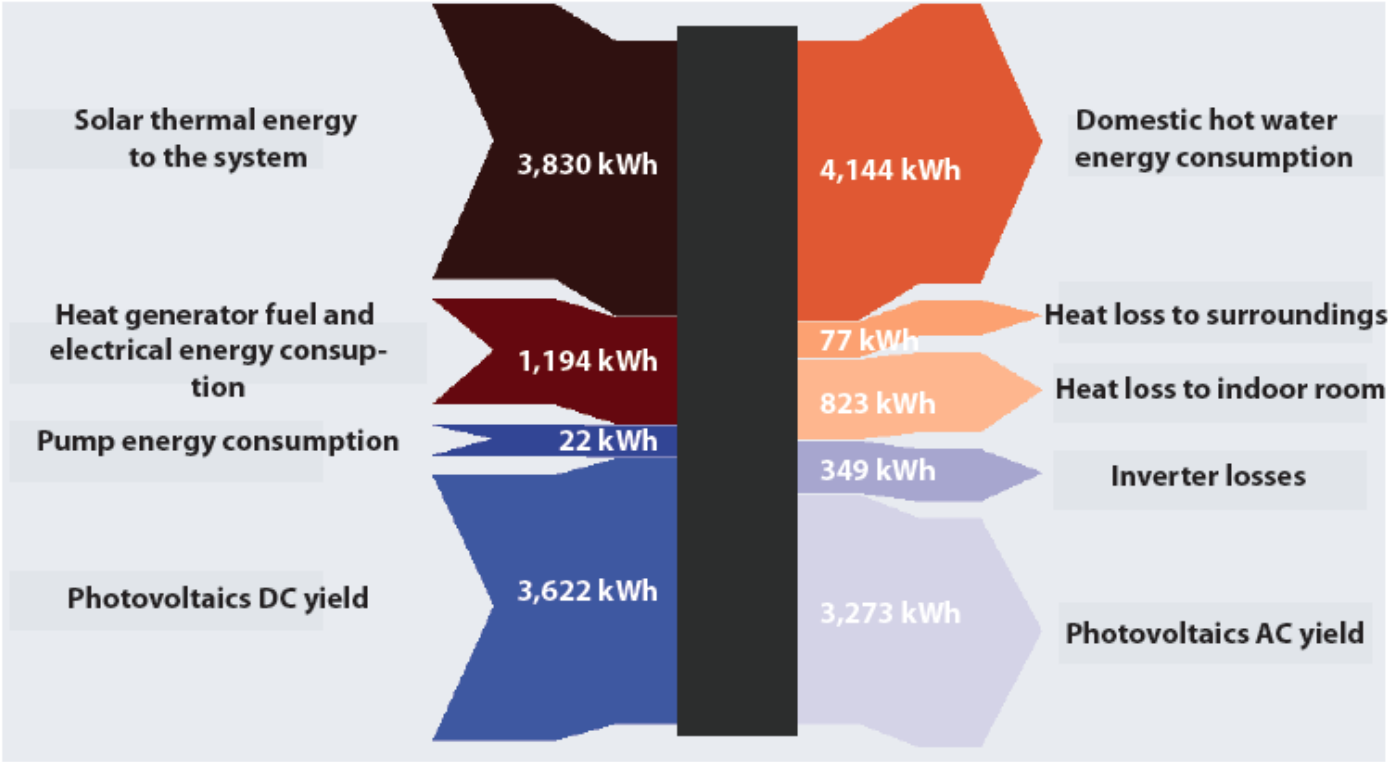


**Combined PVT + PV model for Aggie Village House**

** Simulations are preformed using Polysun software*

# Project Planning

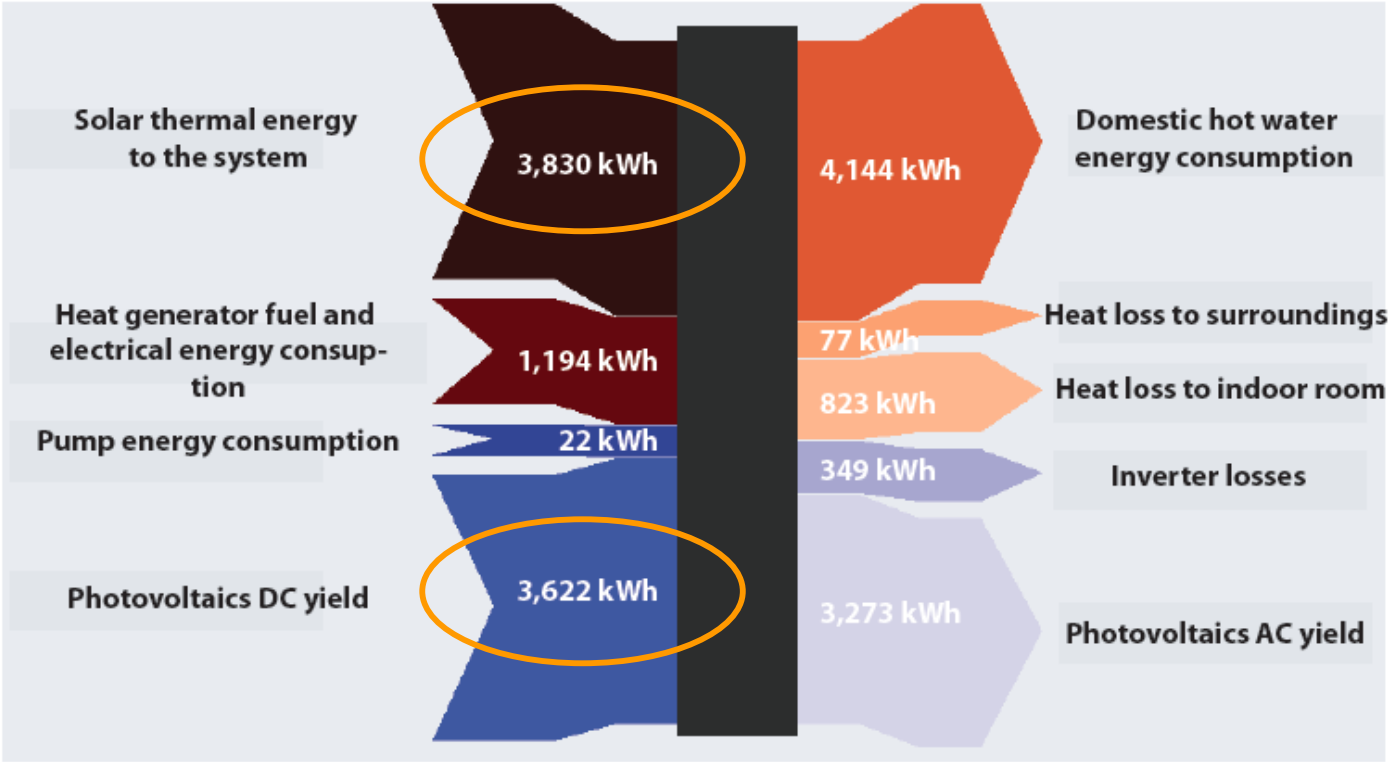
- **System performance prediction**




- The simulation shows that the estimate electrical generation and thermal generation will be able to cover about **46% electricity consumption** and **92% domestic hot water consumption**.

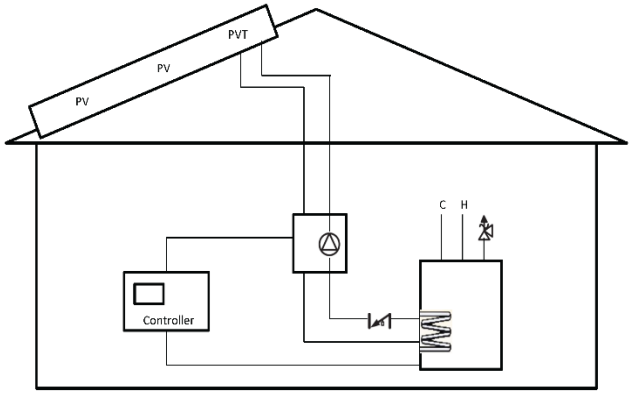
# Project Planning

- **System performance prediction**




- The simulation shows that the estimate electrical generation and thermal generation will be able to cover about **46% electricity consumption** and **92% domestic hot water consumption**.

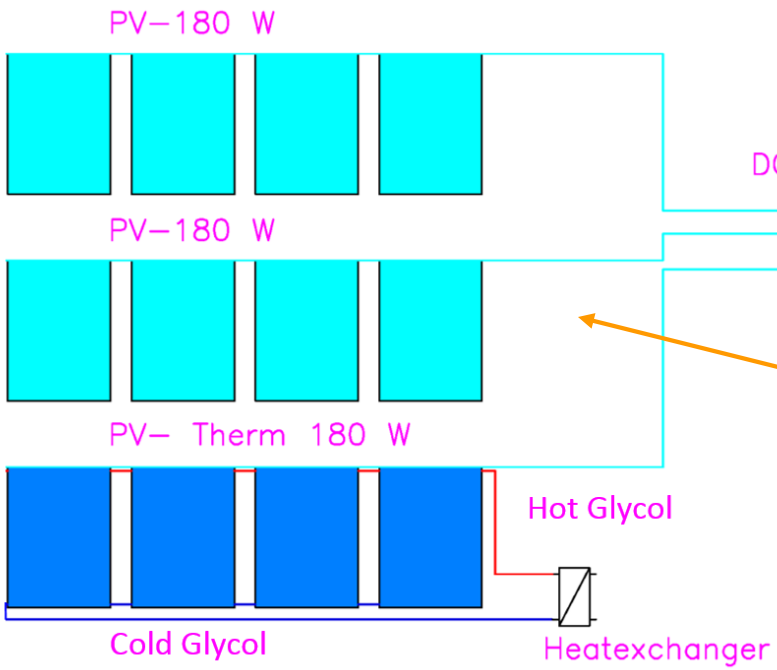
# System Engineering

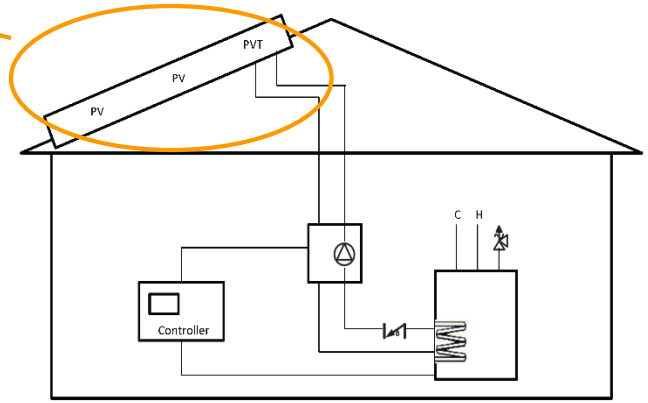



**Simplified PVT system diagram**

# System Engineering

**PVT/PV panels layout**

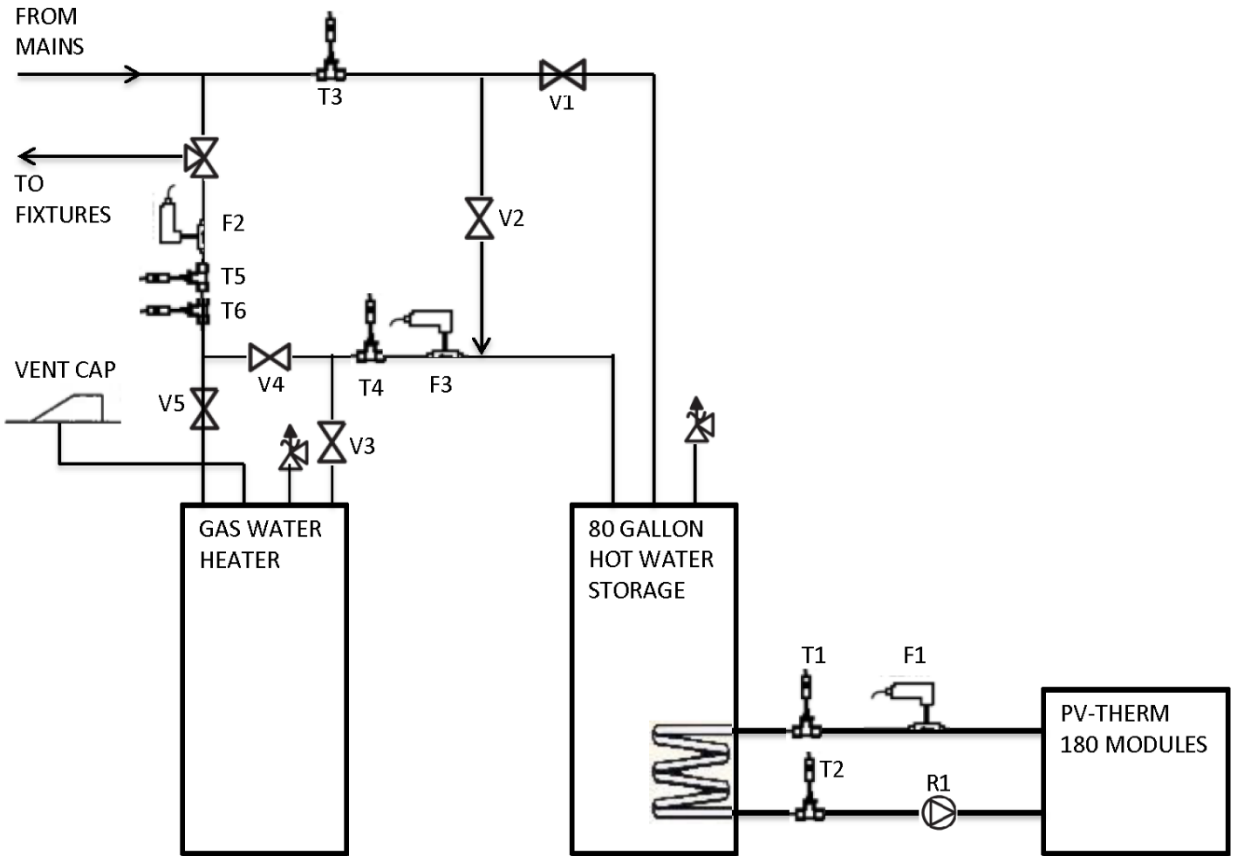



**Total Electrical Power: 2.2 kW**

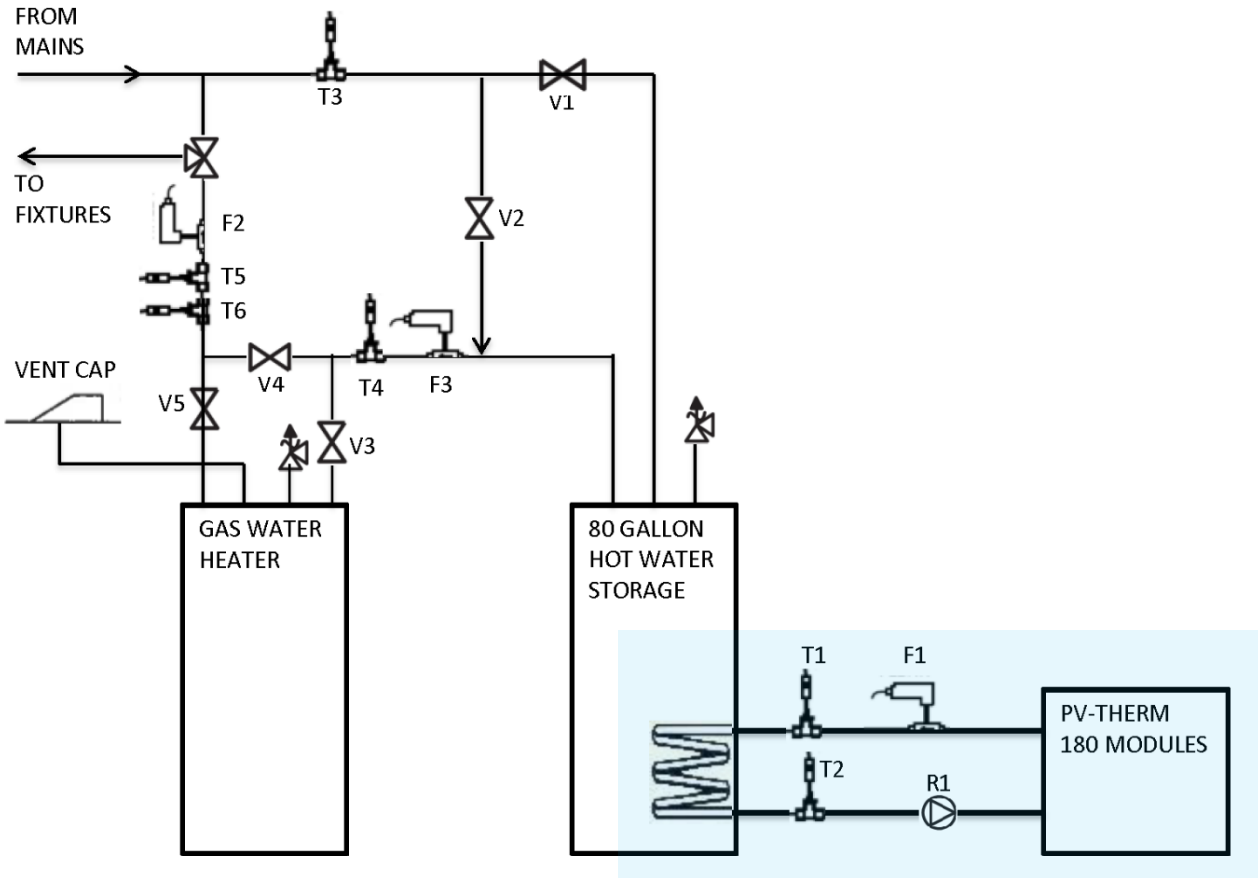
**Simplified PVT system diagram**

# System Engineering



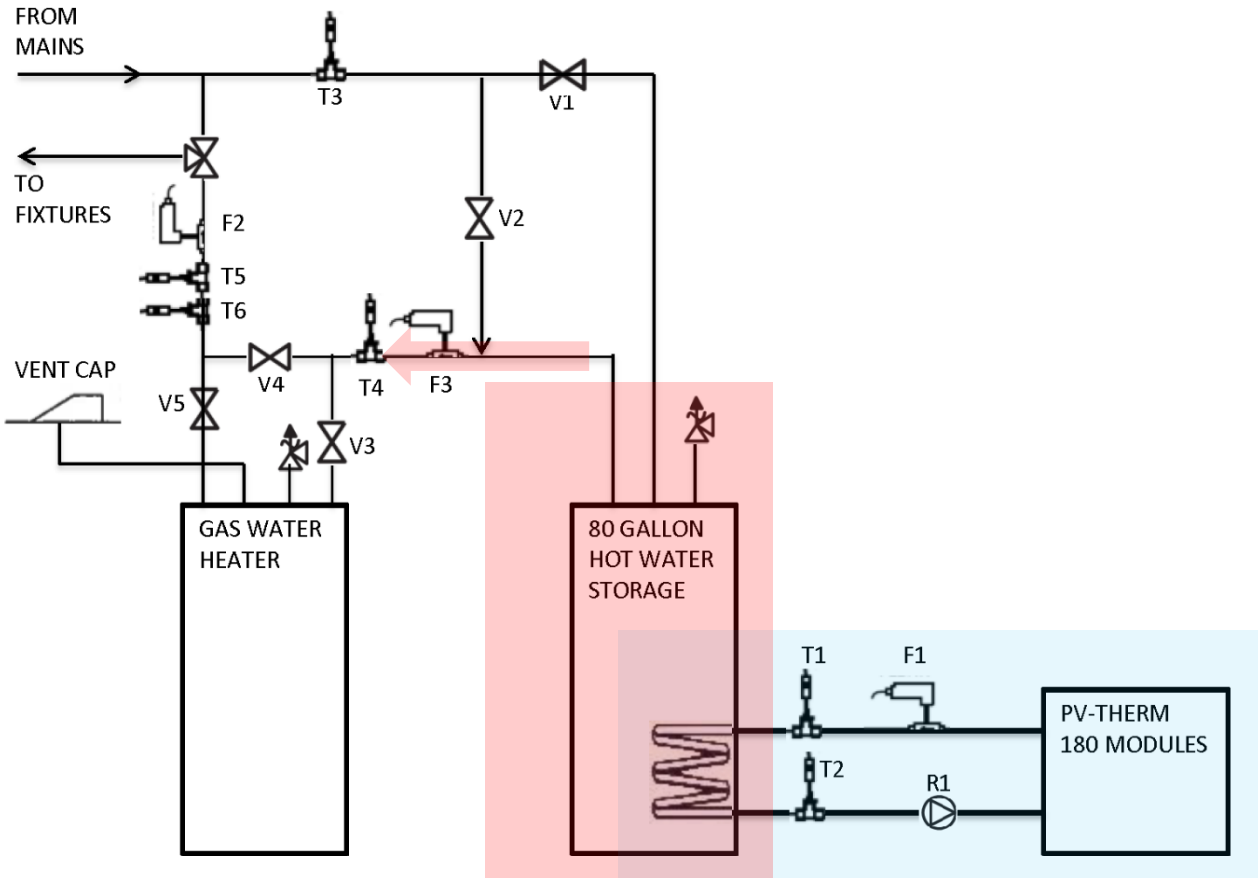

**Aggie Village House Solar Thermal Instrumentation Diagram**

# System Engineering



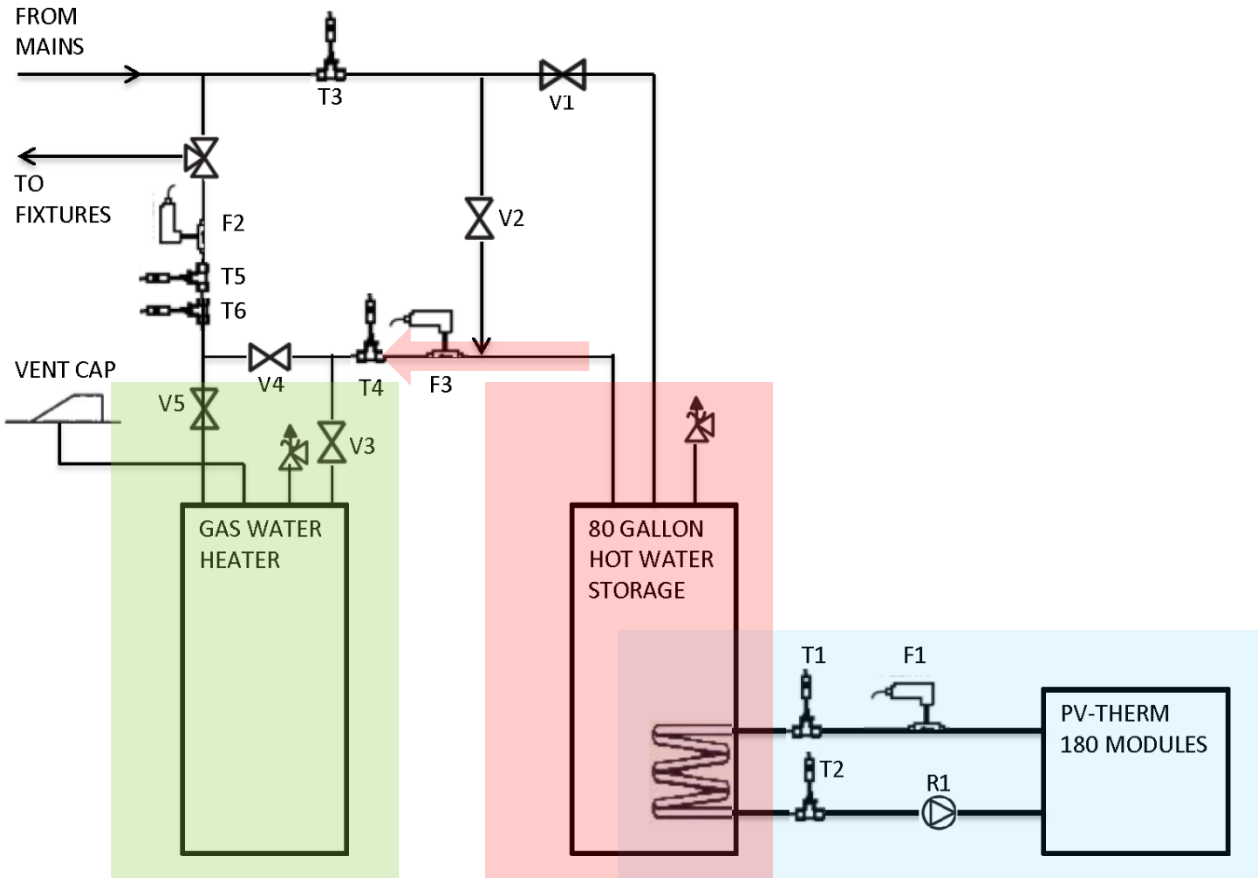

**Aggie Village House Solar Thermal Instrumentation Diagram**

# System Engineering



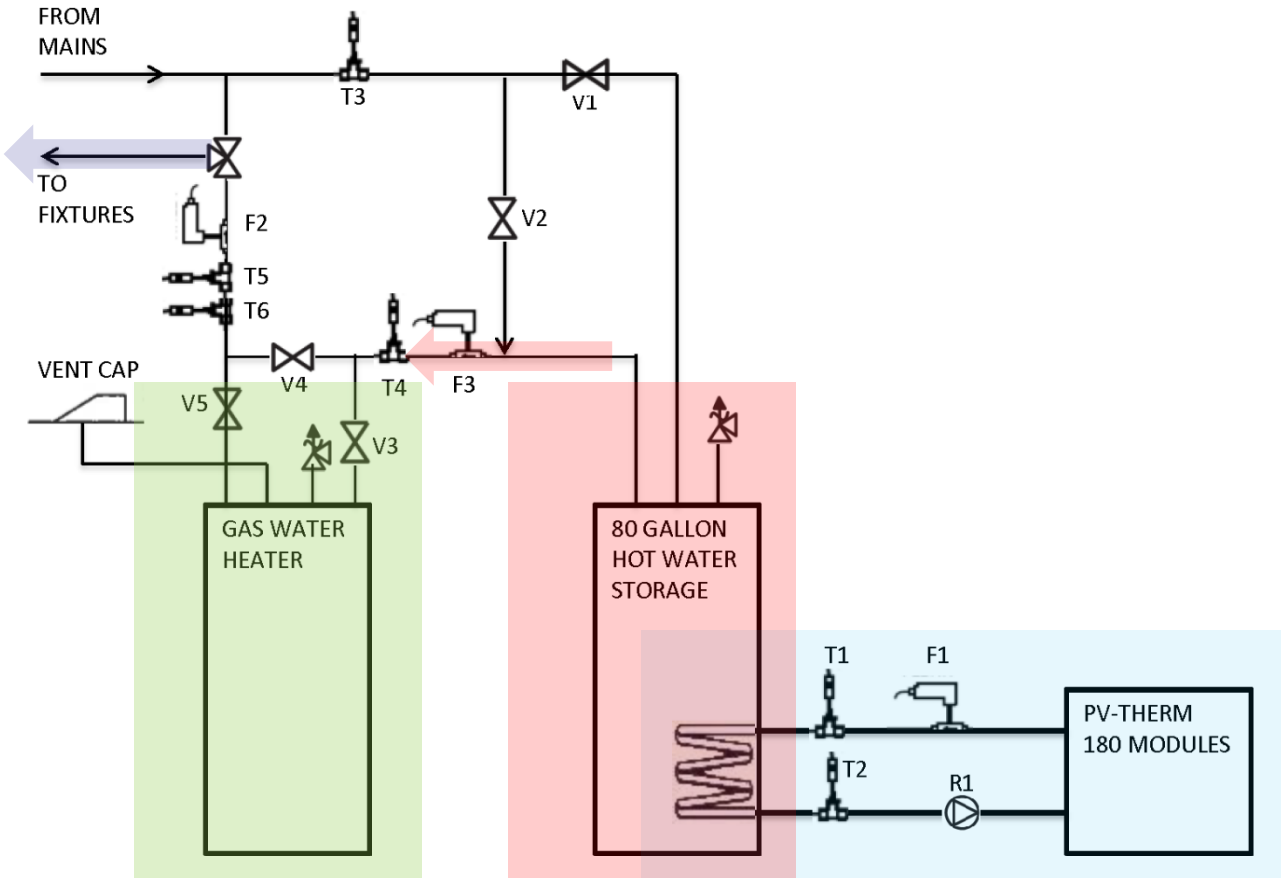

**Aggie Village House Solar Thermal Instrumentation Diagram**

# System Engineering




**Aggie Village House Solar Thermal Instrumentation Diagram**

# System Engineering




**Aggie Village House Solar Thermal Instrumentation Diagram**

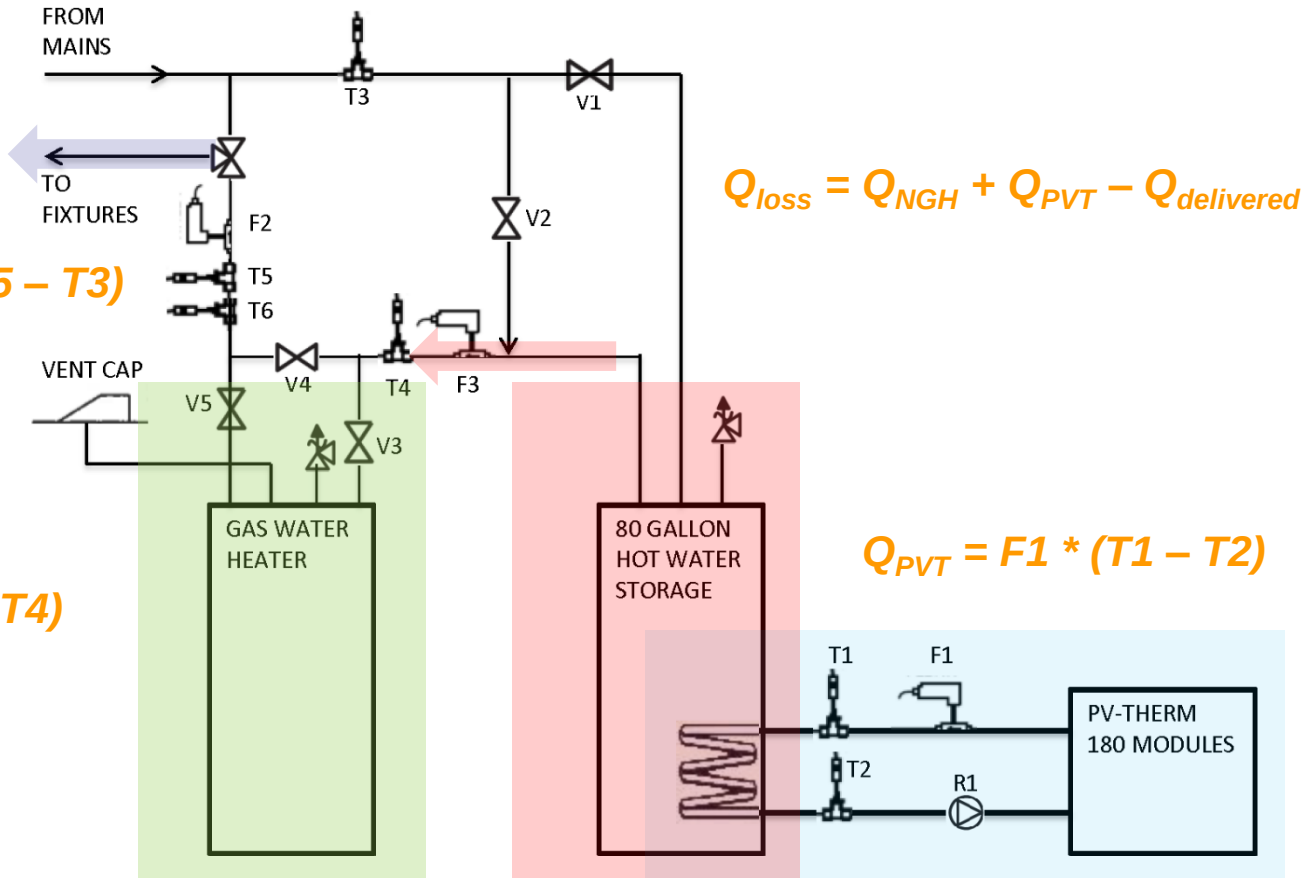
# System Engineering

$Q_{loss} = Q_{NGH} + Q_{PVT} - Q_{delivered}$

$Q_{delivered} = F2 * (T5 - T3)$

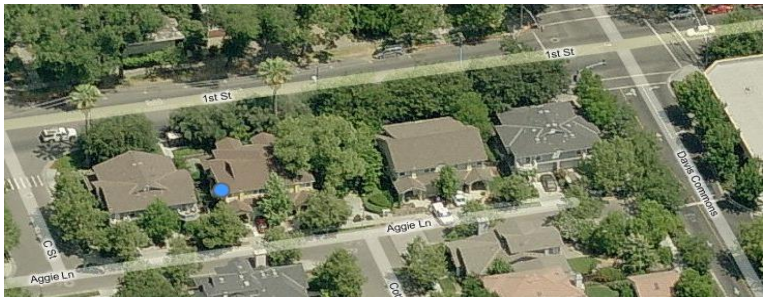
$Q_{NGH} = F2 * (T6 - T4)$

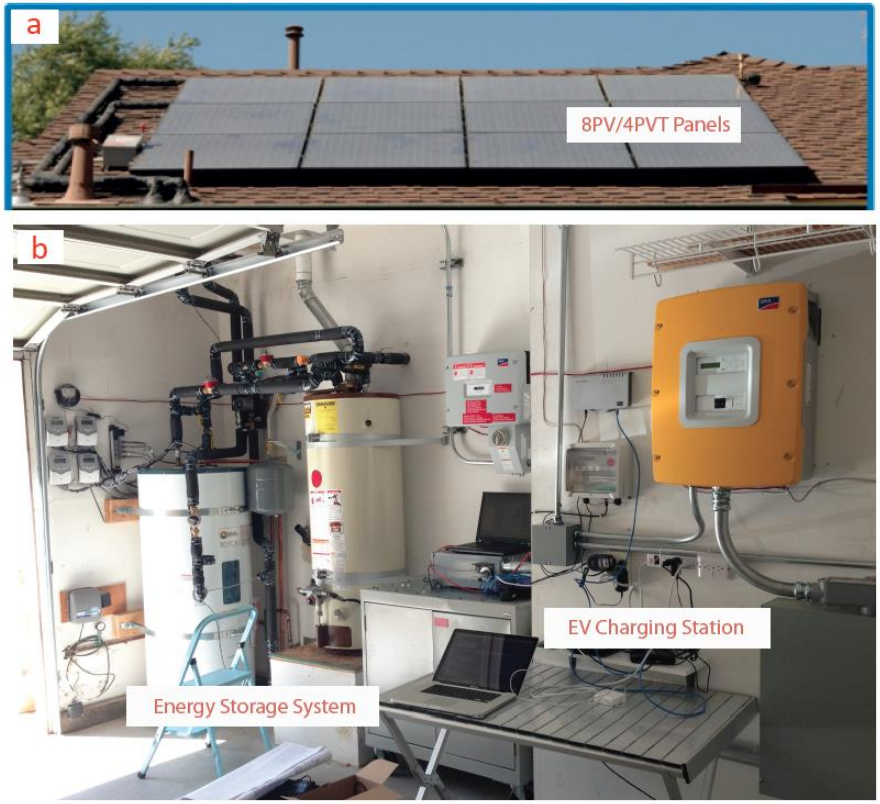
$Q_{PVT} = F1 * (T1 - T2)$



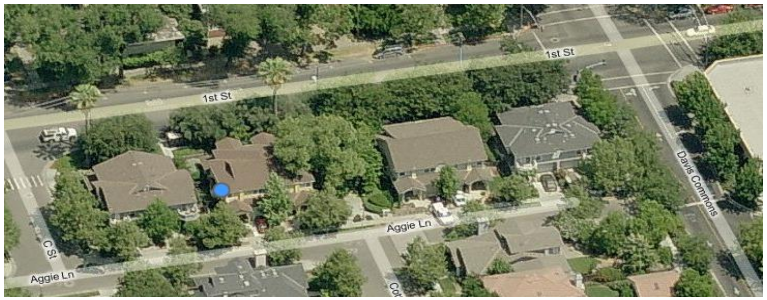

**Aggie Village House Solar Thermal Instrumentation Diagram**

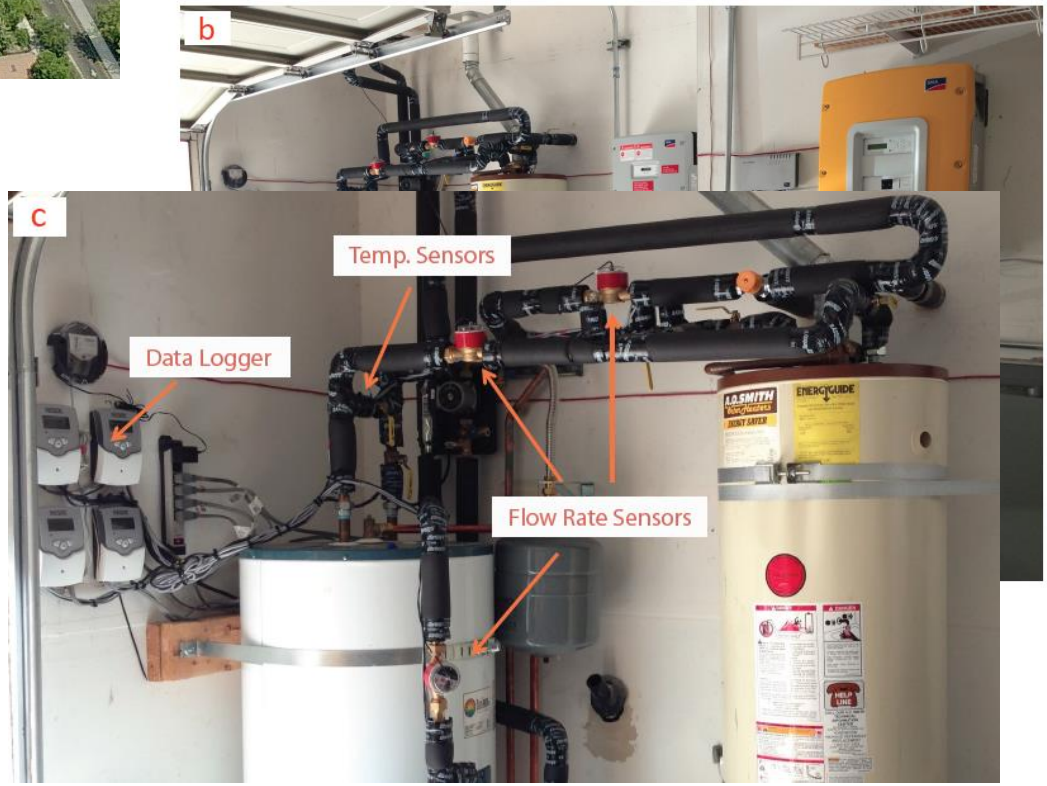
# Installation





# Installation

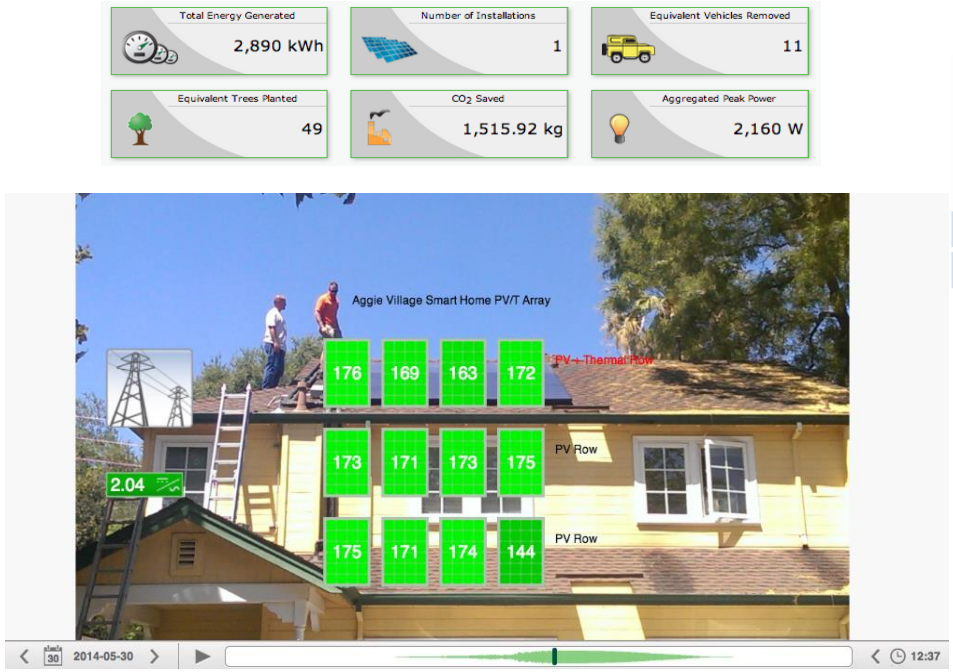




# Performance/Data

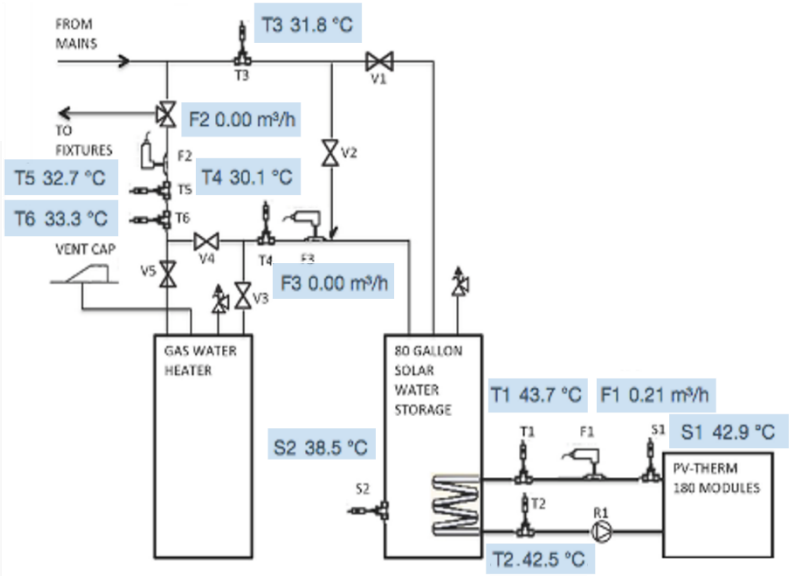
- **Data Visualization**

***PV***




http://www.tigoenergy.com/site.php?aggievillagepvt

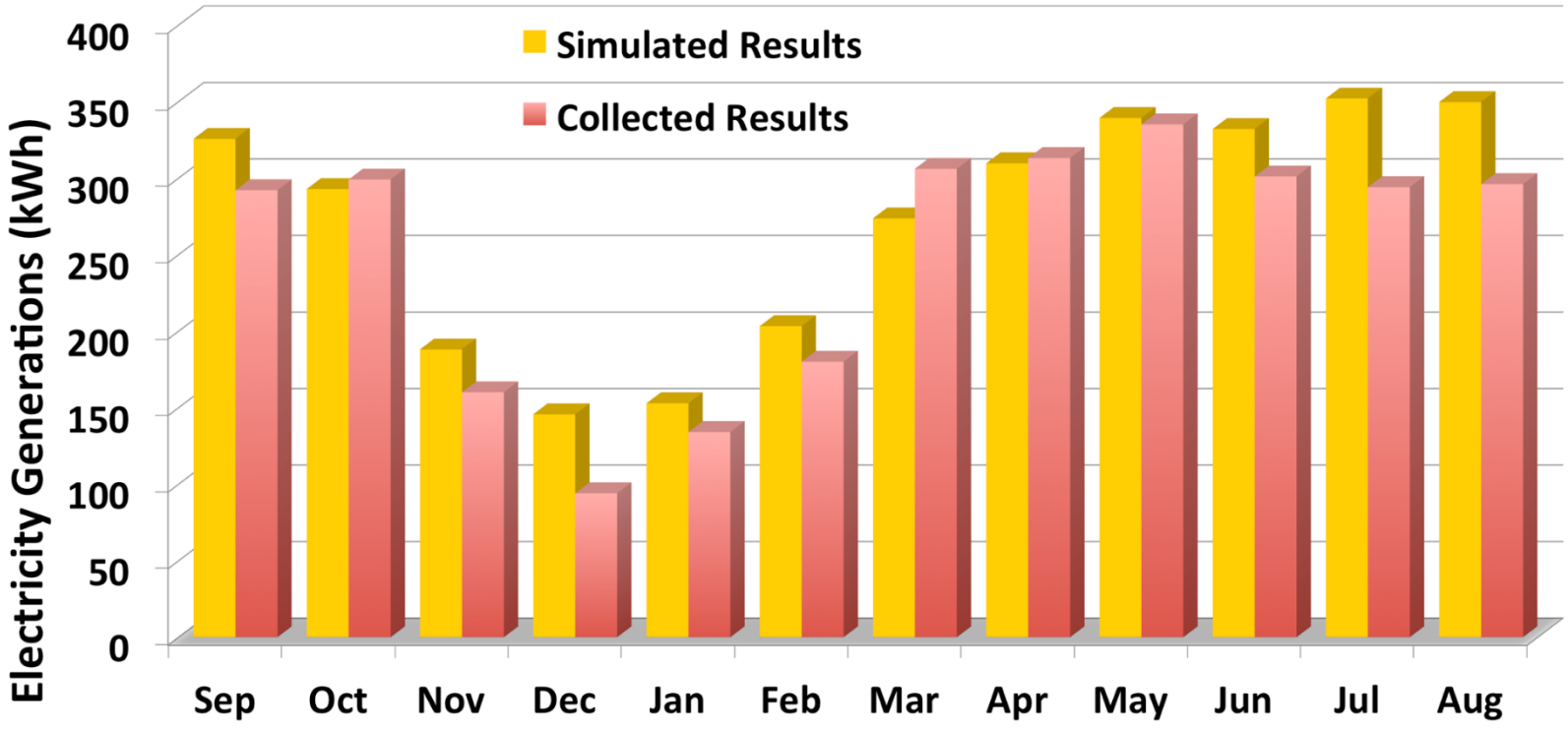
***Solar Thermal***




http://www.vbus.net/vbus/scheme/id/792

# Performance/Data

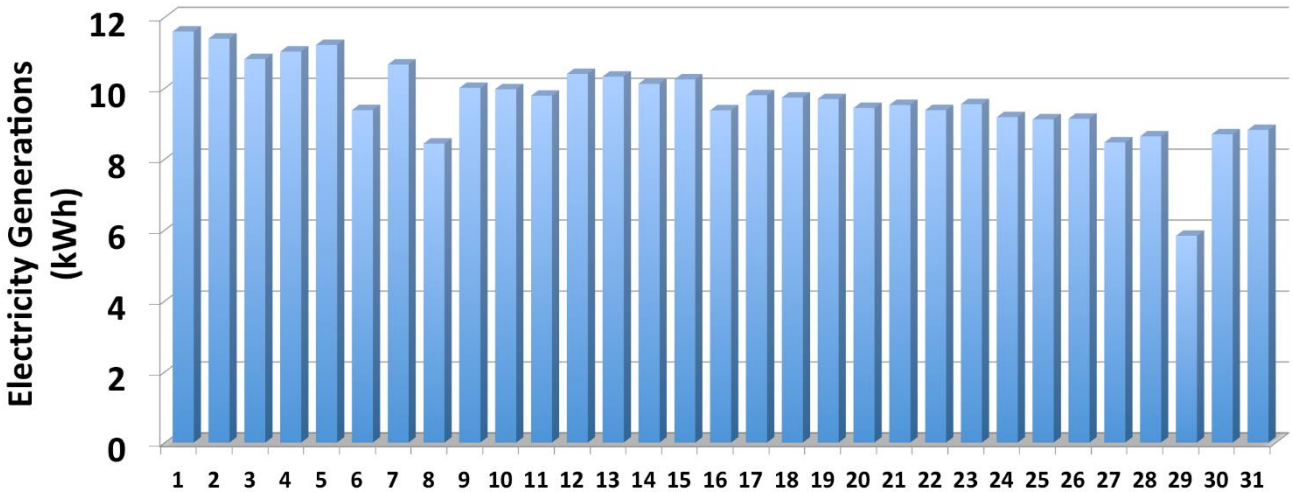
## PV side



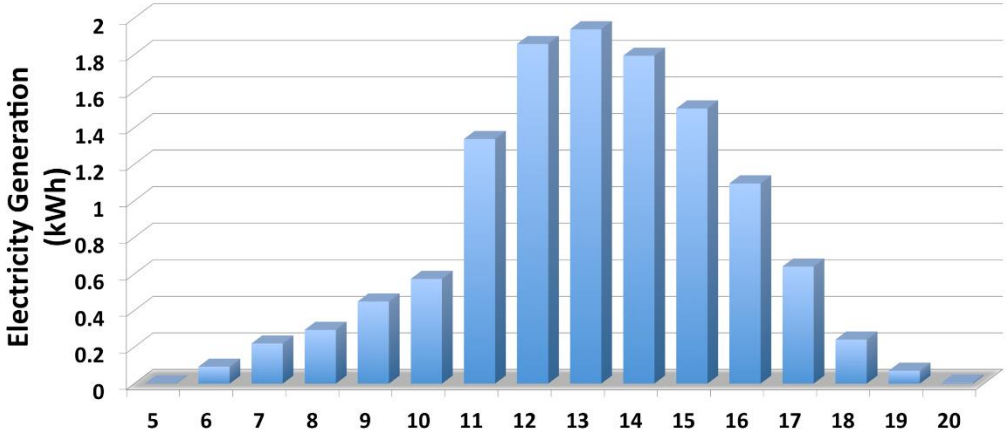

Monthly Electricity Generations between Sep. 2013 and Aug. 2014

# Performance/Data

## PV side



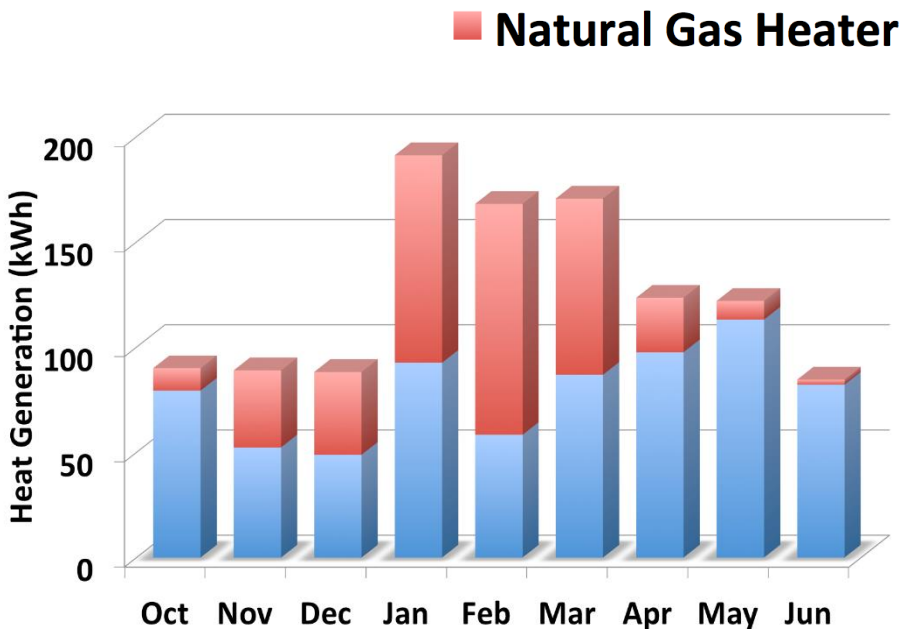

**Electricity Generations of PVT System during Oct. 2013**



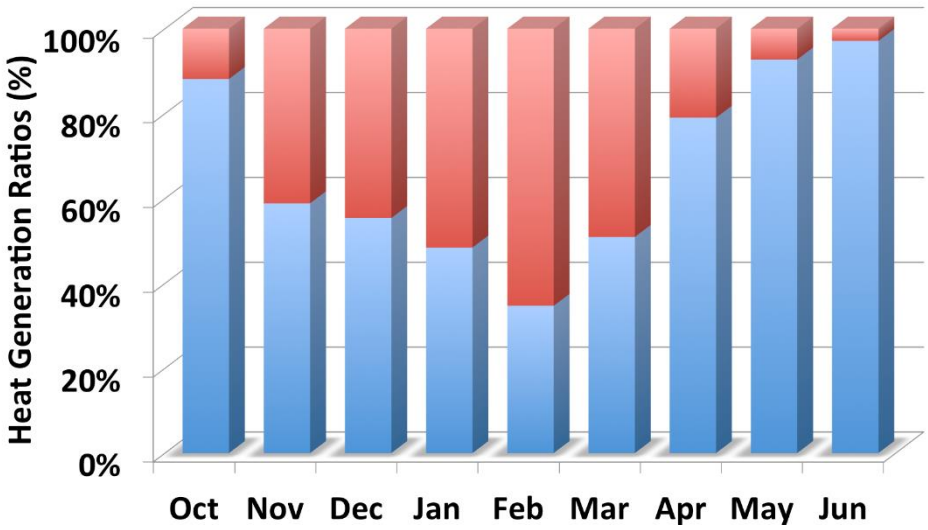

**Hourly Electricity Generations in a Typical Sunny Day (May 30th, 2014)**

# Performance/Data

## Thermal side



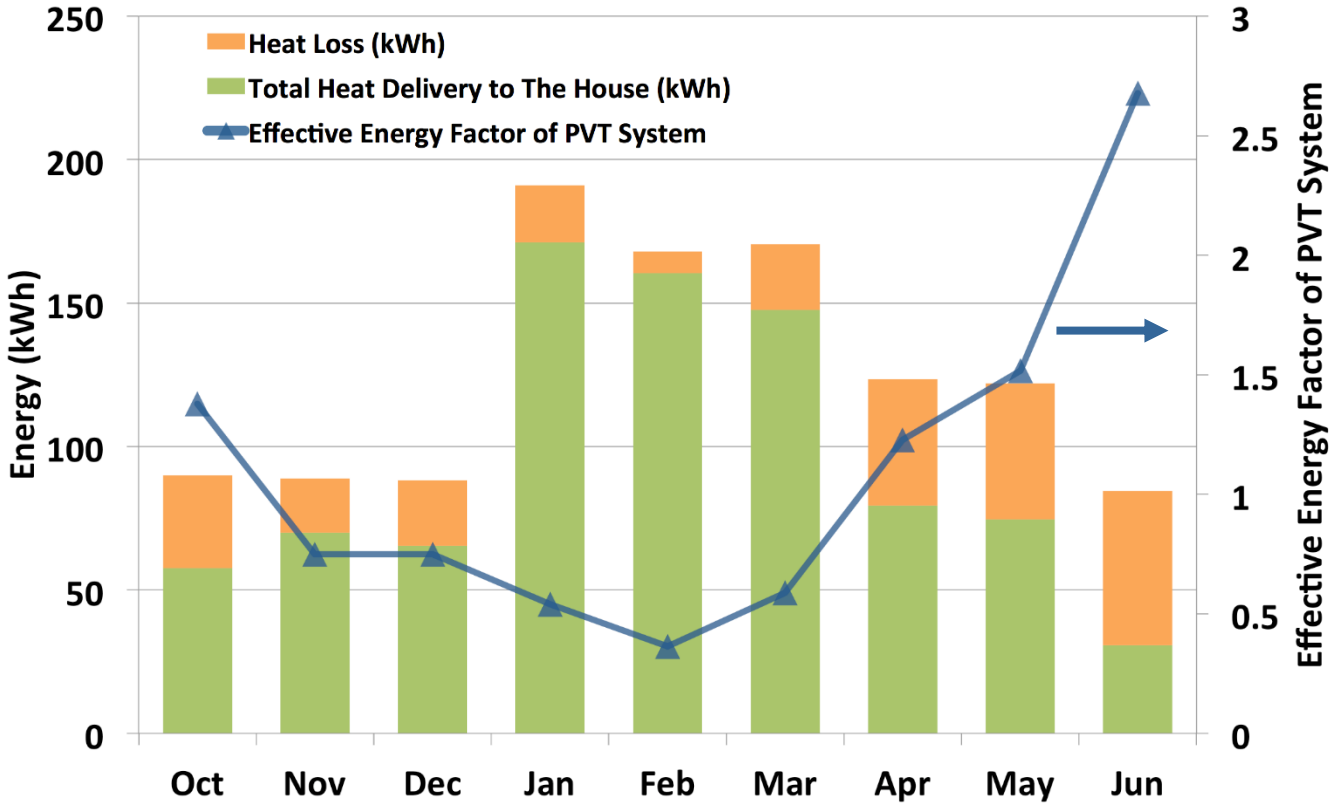

Monthly Heat Generations in our PVT System




Monthly Heat Generations Ratios Diagram

# Performance/Data

## Thermal side

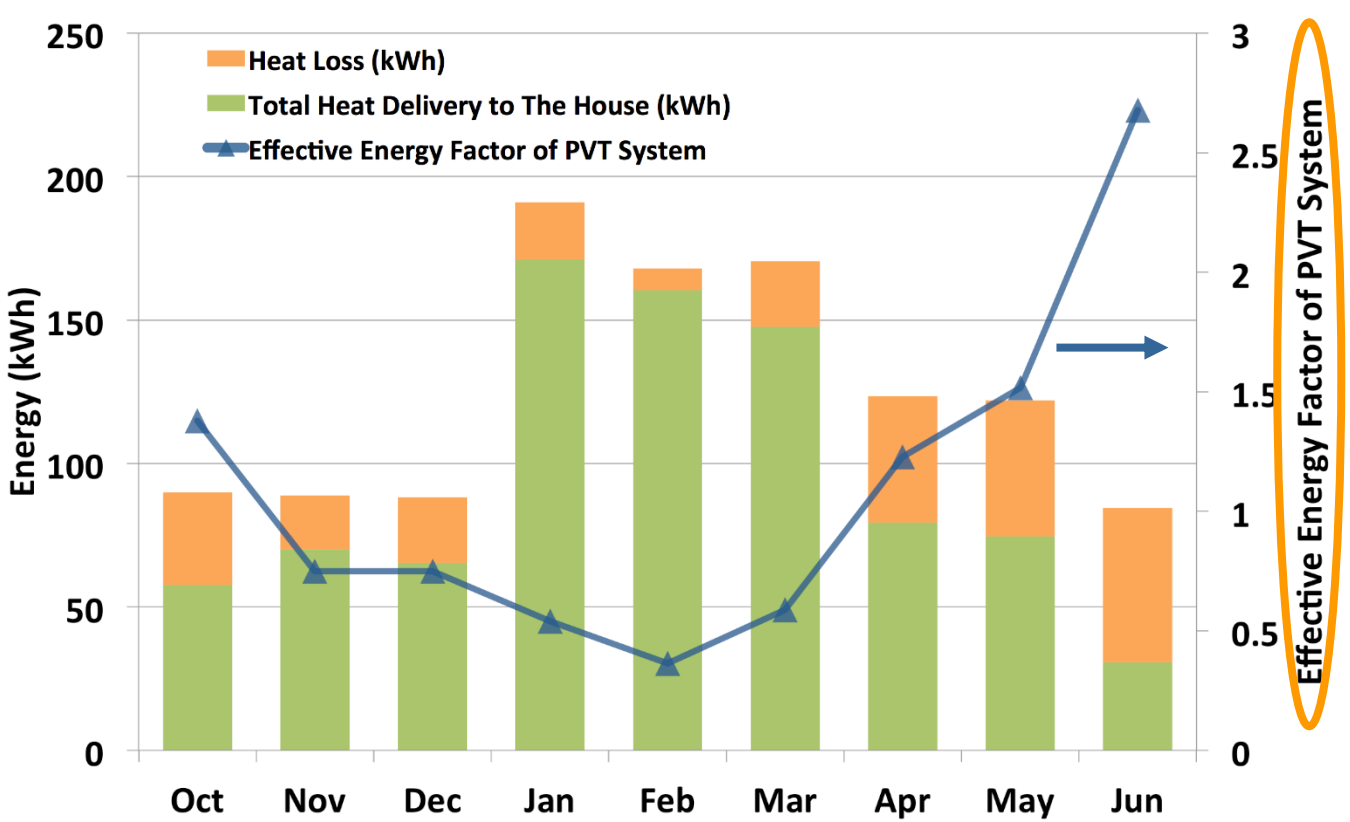



Monthly Heat Delivery, Heat Loss and Effective Energy Factor of PVT System

# Performance/Data

## Thermal side

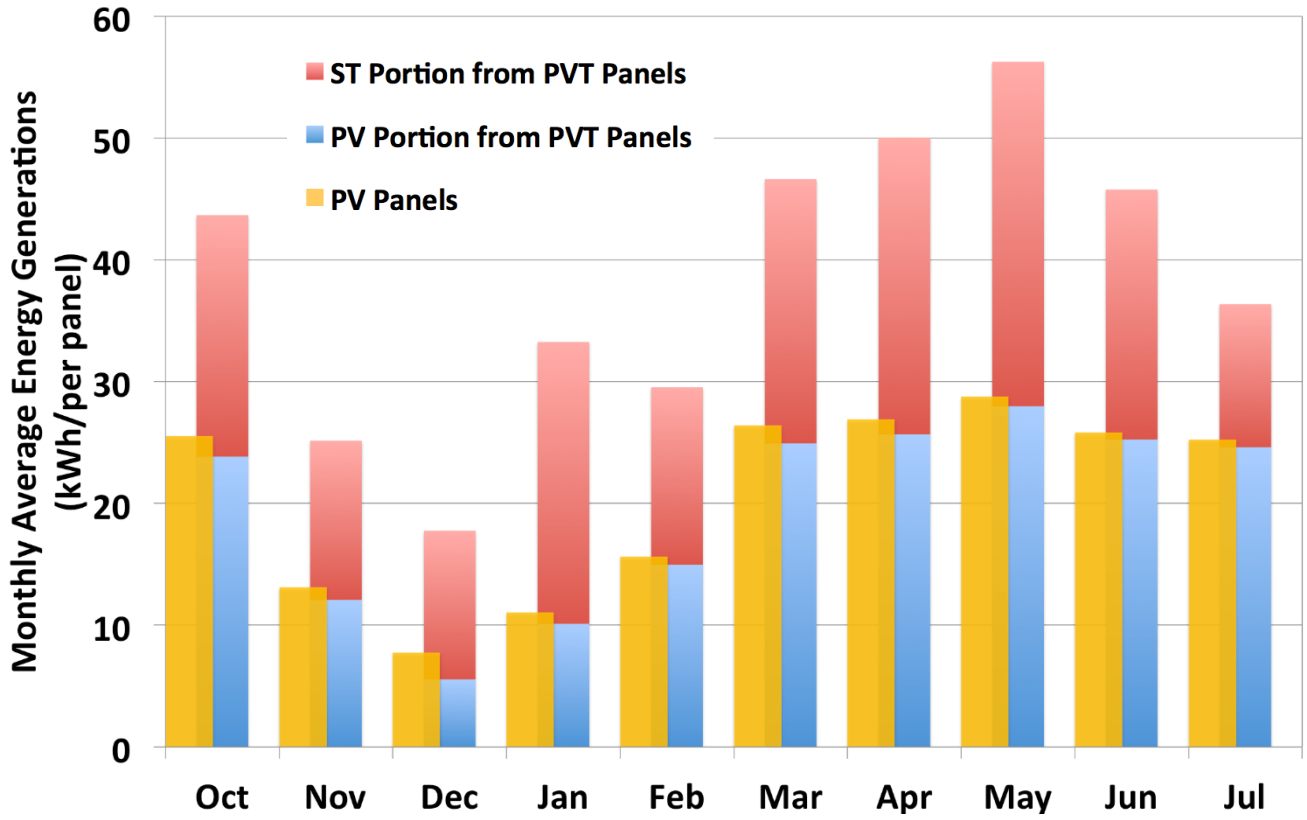
*Effective energy factor of PVT system = $Q_{pvt}$ / $Q_{demand}$*




Monthly Heat Delivery, Heat Loss and Effective Energy Factor of PVT System

# Performance/Data

## PVT vs. PV




Total Panel Performances Comparison

# Findings for Aggie Village

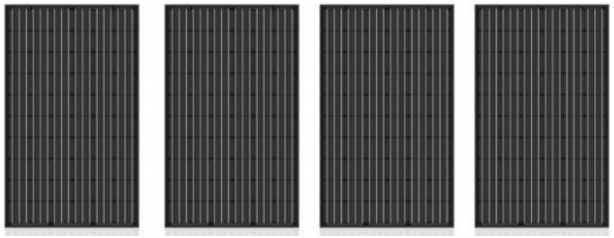
- From both technical and economic point of view, combined PV + ST seem to be the best choice according to the model results for our project.
- Data have been successfully collected and analysis is performed. By end of July 2014, the PVT system has generated a total of 2,890 kWh of electricity. The peak power of system is 2.16 kW.
- During our monitoring months, the PVT panels produce at least 70% more energy (PV+ST) that conventional PV panel. In May, it almost provides two times energy than PV panels, which reaches 56 kWh for each PVT panel.

# TASK 3 DEMO 1

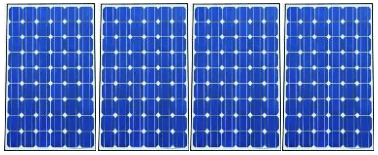
## HYBRID SOLAR PHOTOVOLTAIC/THERMAL SYSTEM FOR WEST VILLAGE APARTMENT BUILDING

# Project Planning

- **System design**

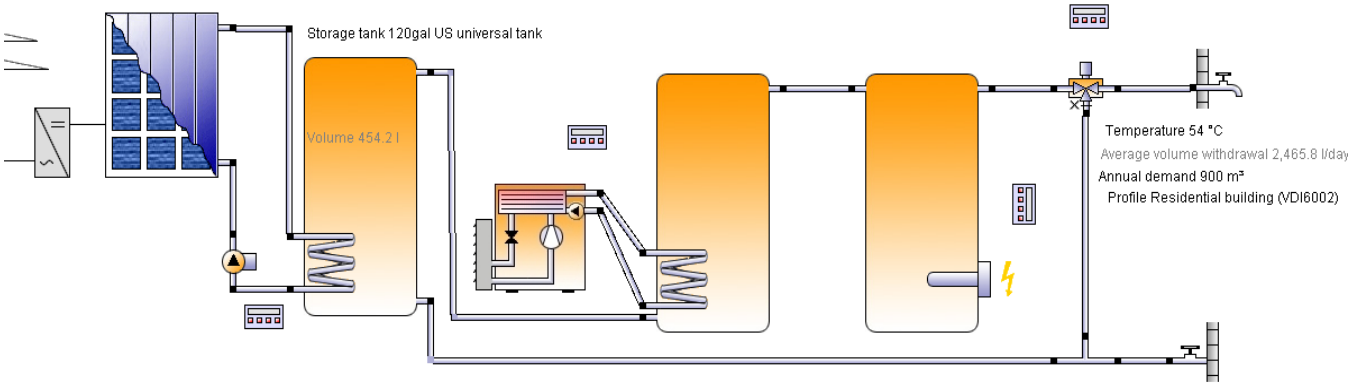


***PVT only***



***Existing PV***

**Fig. PVT only model for WV apartment**

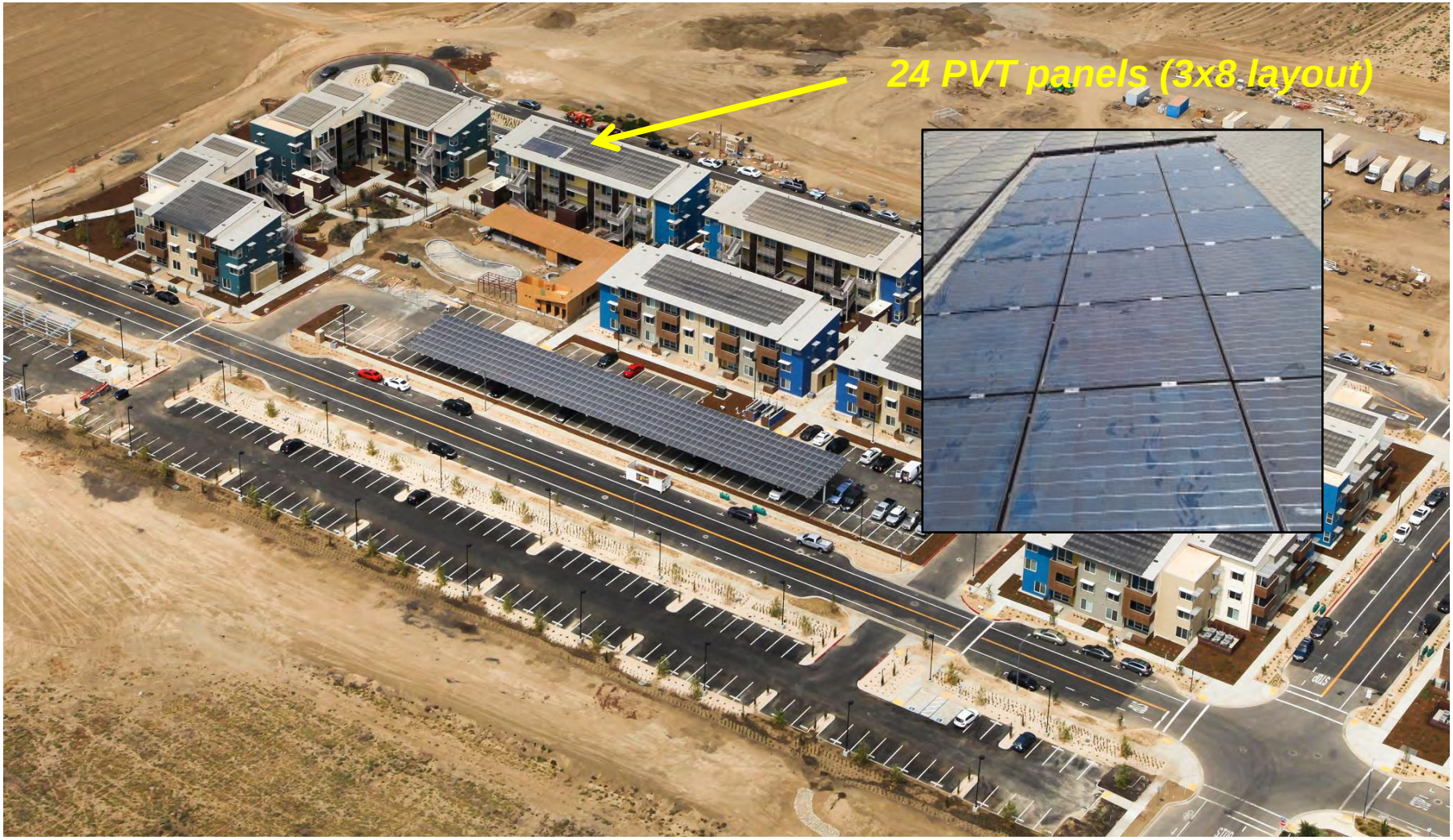



- The simulation shows that the estimate electrical generation and thermal generation from **24 PVT** will be able to cover about **50% electricity consumption** and **81% domestic hot water consumption** for two apartment units.

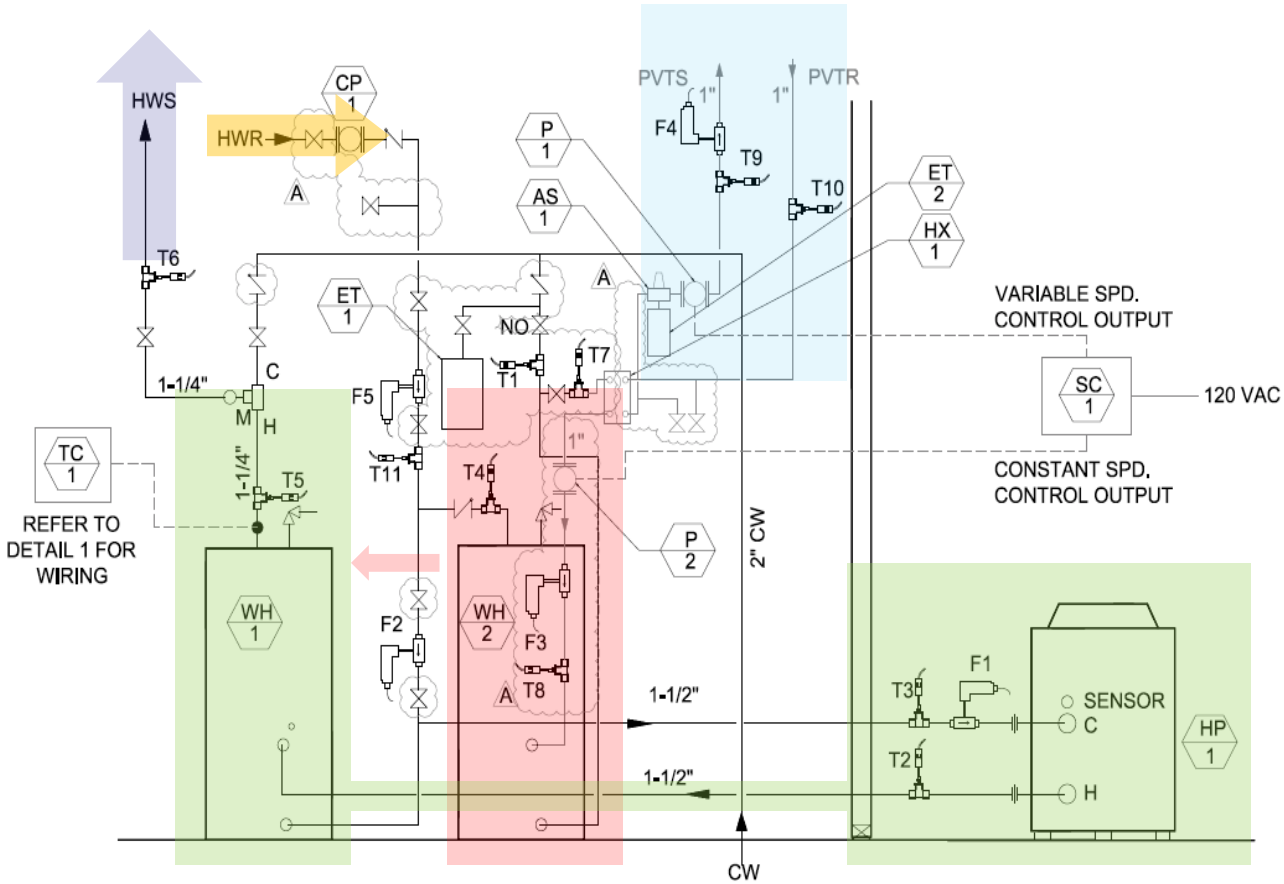
** Simulations are preformed using Polysun software*

# System Engineering

# System Engineering



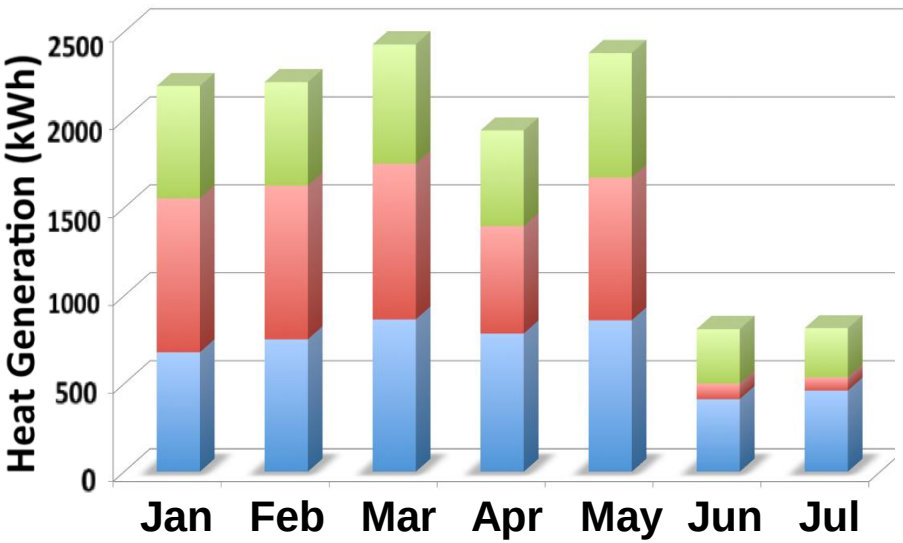
# System Engineering



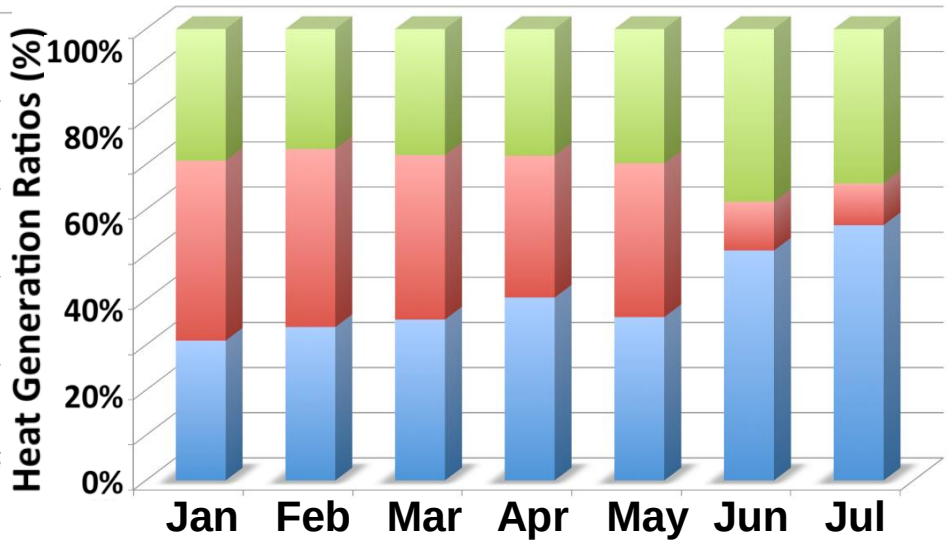
**WV Apartment Solar Thermal Instrumentation Diagram**

# Performance/Data

## Heat Generation




Monthly Heat Generations in PVT System

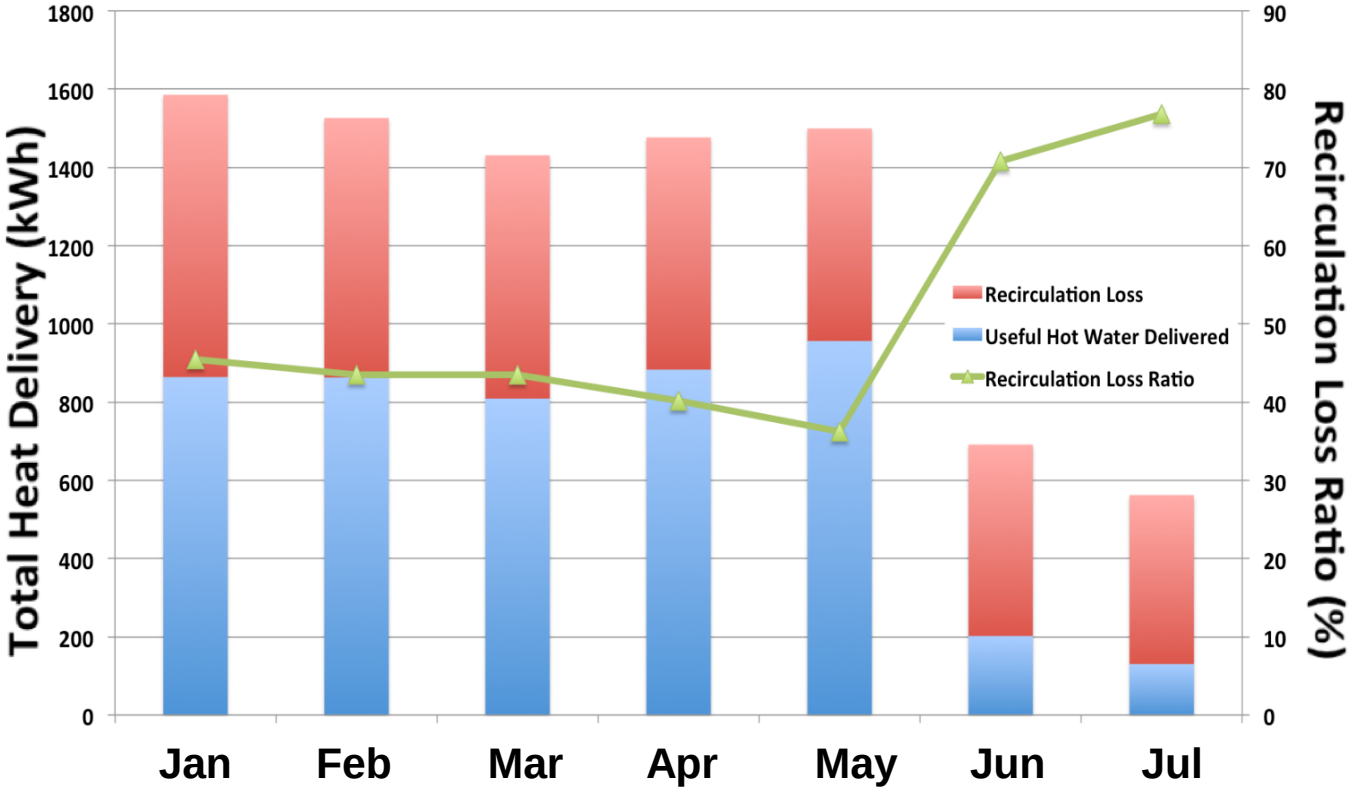



Monthly Heat Generation Ratios Diagram

PVT Heat Pump Water Heaters

# Performance/Data

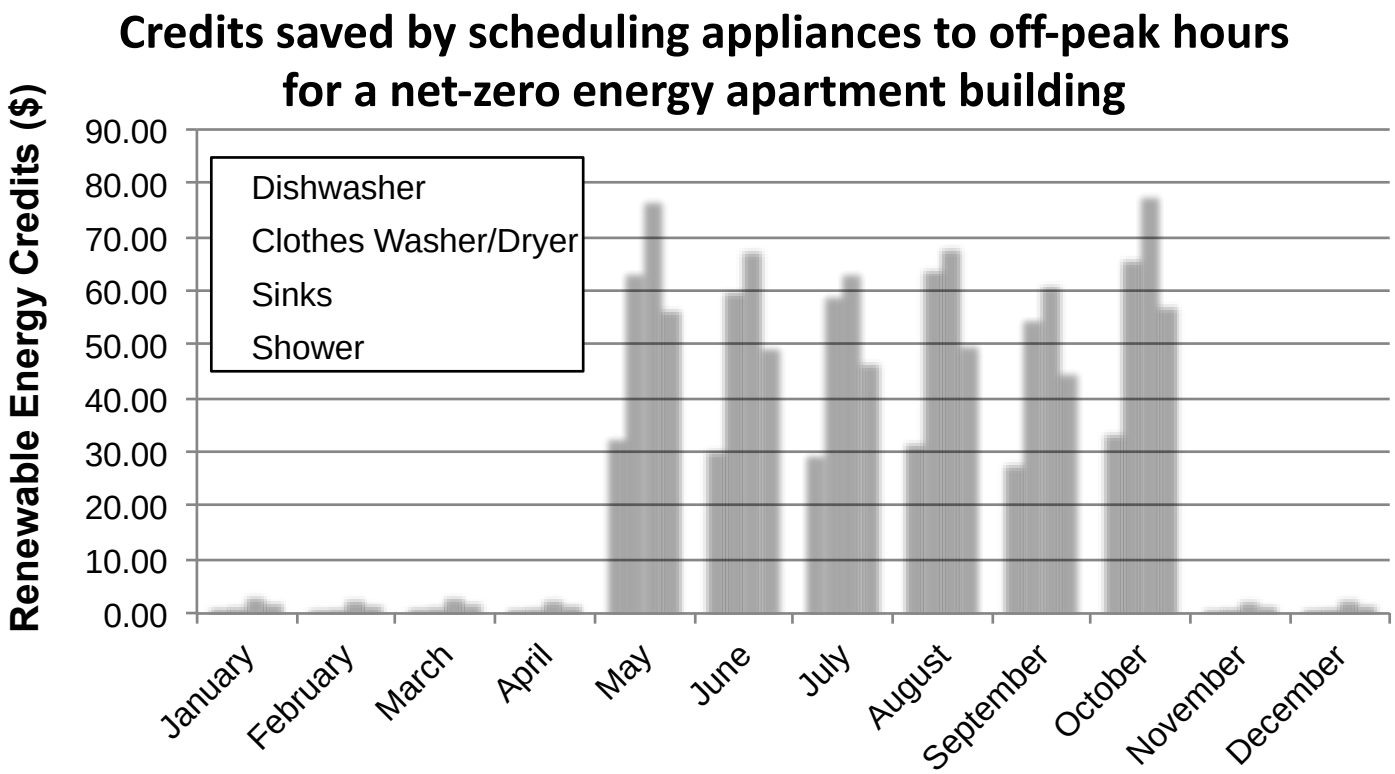
## Heat Consumptions and loss




Monthly Recirculation Loss and Useful Hot Water Delivered in Multifamily Apartment

# Performance/Data

- **The impact of scheduling appliances and rate structure on bill savings for net-zero communities**




*Kyle Gaiser and Pieter Stroeve, The Impact of Scheduling Appliances and Rate Structures on Bill Savings for Net-Zero Energy Communities: Application to West Village,* ***Applied Energy****, 113, 1586-1595, 2014.*

# Findings for WV

- We reviewed and evaluated near term market PVT technologies from technical and economic points– systems available but not a mature market.
- Hybrid PVT and monitoring systems design were developed and installed. The prediction shows 24 PVT modules system will provide 50% of the annual electricity and 81% of the thermal demand for two West Village units.
- *Between January 1st and end of July 2014, our PVT multifamily demo has generated 4,817 kWh energy on thermal side. The total heat energy, which includes energy produced by PVT panel, water heater and heat pump, is 12,780 kWh.*
- *Large recirculation losses were discovered in the system. Average 40% heat is lost due to recirculation in a typical month in this demo.*

# Questions?

# West Village Smart Grid: Integration of AMI with PV

Matt Lecar– Principal, GE Smart Grid Center of Excellence

# West Village CSI RD&D (Task 2)
## *Integration of AMI with PV*

imagination at work

GE Energy Consulting

# UC Davis West Village: An Evolving Zero Net Energy (ZNE) Community

imagination at work

# GE Task Scope and Timeline

- Subtask 1: Develop a baseline model of current energy performance at UC Davis West Village, including both solar PV and energy consumption
  - *How is performance tracking relative to the ZNE goal?*
- Subtask 2: Recommend a functional architecture for on-going monitoring and control
  - *What levers are there to adjust performance moving forward?*
- Costs and Benefits of additional control hardware
- Other program considerations (regulatory, user acceptance, etc.)

- Project began August 1, 2012
- First Interim Review (Subtask 1) on December 12, 2012
- Second Interim Review (Subtask 2) on January 16, 2013
- Final Review March 7, 2013

# Subtask 1: Baseline Energy Model

# Data Gathering

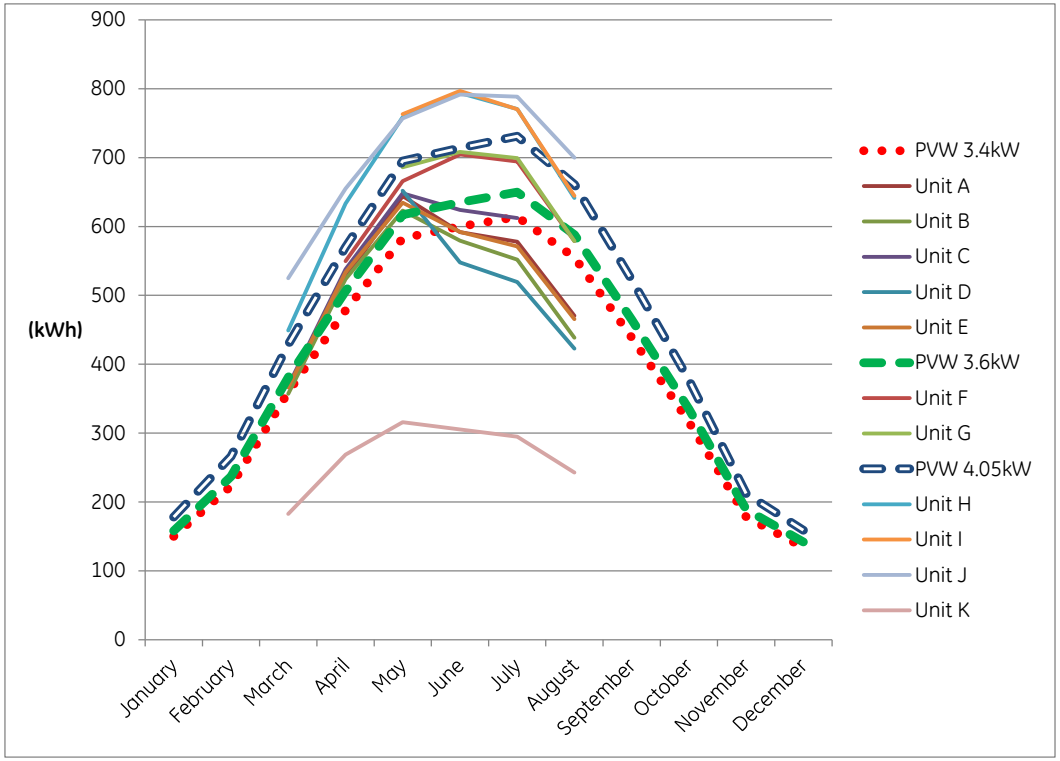
The major data collected and analyzed included:

- WV Community Plan and Related Files
  - 100% CD West Village Student Housing Phase 1.pdf
  - MU1-MU6 University Approved (Complete).pdf
  - West Village Student Housing Phase 1.pdf
  - Mixed Use Commercial Space_Energy Budget_Analysis_07112012.pdf
- Solar PV Inventory
  - SunPower UCD checklist Master List.xlsx
- PG&E Billing
  - Davis electrical tracking 2012 trueup v25 ~9-17 w' daily use.xls
- Hourly Sun Power Data
  - Interval Production and Consumption Data (via manual download)
- Other Tools Used
  - PVWatts (NREL), HVACOPCOST

# Challenges Encountered

- Mix of existing buildings with partial historical data (Ramble Phase I, Veridian, Rec Center, MU) and to-be-built (Solstice, Ramble Phase II, Faculty Staff Housing)
- Unknown occupancy patterns, future tenancy/commercial use
- Student load shapes are highly unusual
- Incomplete end-use breakdown
- PG&E monthly bill history (Net Energy Metering), SunPower hourly production and consumption needed to be reconciled
- Limited access to hourly interval data (only one week of history downloadable at a time)
- SunPower consumption data anomalous; software error later confirmed

# Comparison of NREL PVW data with Sun Power Data




We determined that NREL PWV data for Sacramento was good and accurate proxy for solar power generation at WV.

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# Modeling Approach

- "Synthetic year": In order to compare units with varying amounts of history, including both existing and to-be-built structures, we modeled each unit as if it were in steady state for a full year, with normalized weather and occupancy patterns
- Bottoms Up Load Estimation:
  - The Model builds up consumption based on known square footage and tenancy (number of bedrooms) and engineering formulas to create estimates for appliance, heating, cooling, and lighting usage
- Normalized solar PV production
  - Based on each unit's rated kW PV capacity and PVWatt monthly energy projections
- The Model allows changes in assumptions on a unit by unit basis, as new and better data become available
- The Model could be further developed in the future with more complex "agent-based" or stochastic/probabilistic features to better represent the variability of individual units

# Summary Model Results

- Annual Solar PV Electricity Production: 9,271 MWh
- Annual Electricity Consumption: 12,042MWh
- Consumption to Production Ratio: 125%
- Disclaimer: Given data limitations, the Model is intentionally conservative - results below should be regarded as directional rather than definitive

| Aggregate Unit Type Category | Area (SF) | Production (kWh) | Consumption (kWh) | C/P | P/A (kWh/SF) | C/A (kWh/SF) |
|---|---|---|---|---|---|---|
| Phase-1-Ramble | 243,047 | 1,460,047 | 1,922,542 | 132% | 6.01 | 7.91 |
| Phase-1-Viridian | 120,357 | 789,210 | 897,906 | 114% | 6.56 | 7.46 |
| Phase-2-Ramble | 237,823 | 1,469,063 | 1,869,308 | 127% | 6.18 | 7.86 |
| Phase-3-Solstice | 195,452 | 1,111,052 | 1,420,166 | 128% | 5.68 | 7.27 |
| Faculty Staff Housing | 674,631 | 4,167,286 | 4,873,509 | 117% | 6.18 | 7.22 |
| Recreation | 0 | 210,070 | 483,285 | 230% | 0.00 | 0.00 |
| Mixed-Use | 0 | 401,427 | 563,870 | 140% | 0.00 | 0.00 |
| EV Fleet | 0 | 0 | 11,280 | 0% | 0.00 | 0.00 |
| **Total** | **1,471,310** | **9,608,156** | **12,041,867** | **125%** | **6.53** | **8.18** |

*Note: Zero values indicate information not available or not applicable.*

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# Summary Conclusions Subtask 1

- The model points to performance somewhat above ZNE for the multi-tenant units.
  - Viridian performing better than Ramble or Solstice
- The Rec and Lease center and the MU spaces appear to be farther from achieving the ZNE objective.
- The Faculty Staff Housing appears to be well designed to achieve ZNE performance, with small variations by floor plan and solar system size.
  - Studio units may be too small to accommodate sufficient solar
- Uncertainty in the evolution of future loads, such as EV charging and energy-intensive operations associated with the Western Cooling Efficiency Center

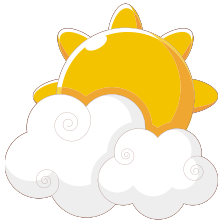
# Subtask 2: Functional Specification for Demand Controls

# Proposed Master Energy Manager (MEM)

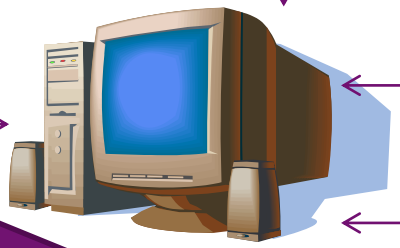
- The vision of a Master Energy Manager is a "living" version of the Baseline Model that can be used to drive operational control actions
- Automate routine collection of data for continuous updating of baseline energy model
  - Script for daily download of SunPower data
  - GreenButton for PG&E SmartMeter data
  - Other: PG&E SmartDay notifications, weather forecasts, EV charging
- Create a messaging platform to residents and smart devices
  - Broadcast event messages to WV residents
  - Standards-based DR messaging protocol (SEP 2.x or Open ADR) for smart devices within the community
- Periodically update estimates for new/under construction buildings to provide a community-level view of energy performance against ZNE goal

# Proposed Master Energy Manager (MEM)

EV Charging Data



DR event and Weather Forecast Data



PV Production Data

Messaging to Residents

PG&E Smart Meter Data

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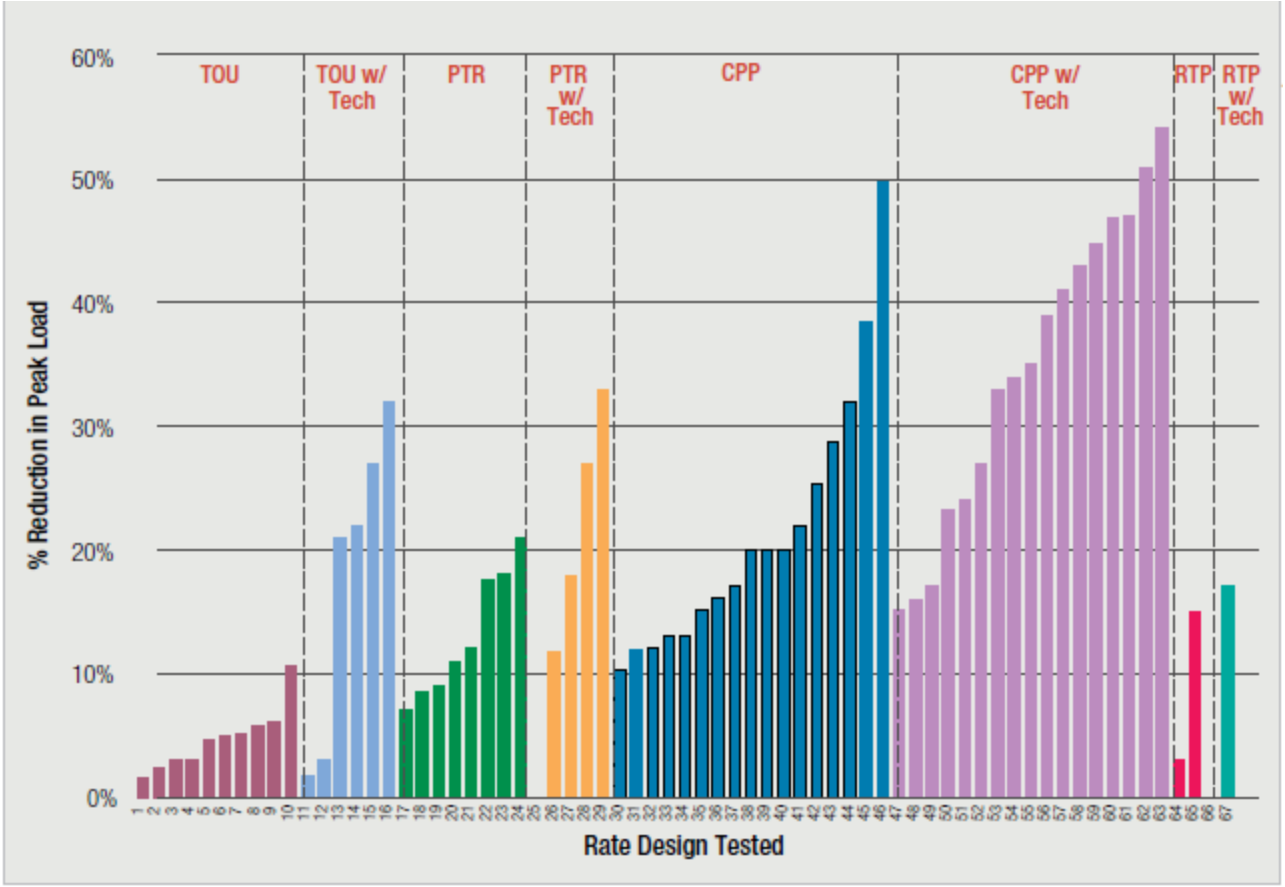
# DR Performance Estimates Sorted By Rate Design And Technology




Source: "Rethinking Prices - The changing architecture of demand response in America", By Ahmad Faruqui, Ryan Hledik, and Sanem Sergici, Public Utilities Fortnightly, January 2010.
(Permission for inclusion in the report/presentation has been granted by the principal author.)

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# Technology Options for Residential Demand Control

- Range of savings in utility pilots correlates highly with investment in "enabling technology"
- 5-10% energy/peak savings typical in TOU with information only
- 10-30% peak savings with CPP and/or IP-addressable PCT "enabling technology"

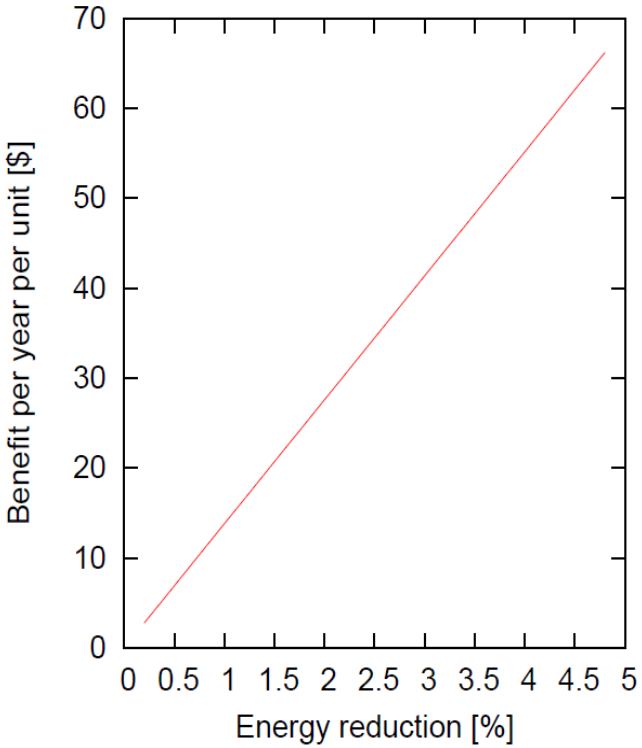
- Sample costs of IP addressable control equipment
  - Plug monitoring ($20) *Kill-A-Watt, etc.*
  - Basic PCT/HEM ($100) *EnergyBuddy, EnviR, Battic*
  - Advanced Control ($250) *NEST, EverSense, EcoBee, EnergyHub*
  - Other *Ecofactor (subscription based service)*

# Cost-Benefit Examples: Methodology

- Used Ramble Phase I loads (most history available)
- Used representative costs for three scenarios of enabling technology: Customer Information Delivery, TOU w/PCT, CPP w/PCT
- Savings percentages based on typical utility DR program experience
- Based pricing on PG&E E-6 (TOU) and SmartRate (CPP) schedules
- Assignment of energy to TOU blocs based on average of 12 years PG&E dynamic load profile history for residential general service (E-1)

# Scenario 1: Customer Information Delivery

- Enable daily delivery of energy usage information, no automated control
- Requires manual intervention by residents to achieve savings
- Typical utility program savings 2-6%
- Cost to implement low (~$20/customer)
- Benefit: $27.57
- Simple Payback: <1 year
- Response fatigue likely a long term issue

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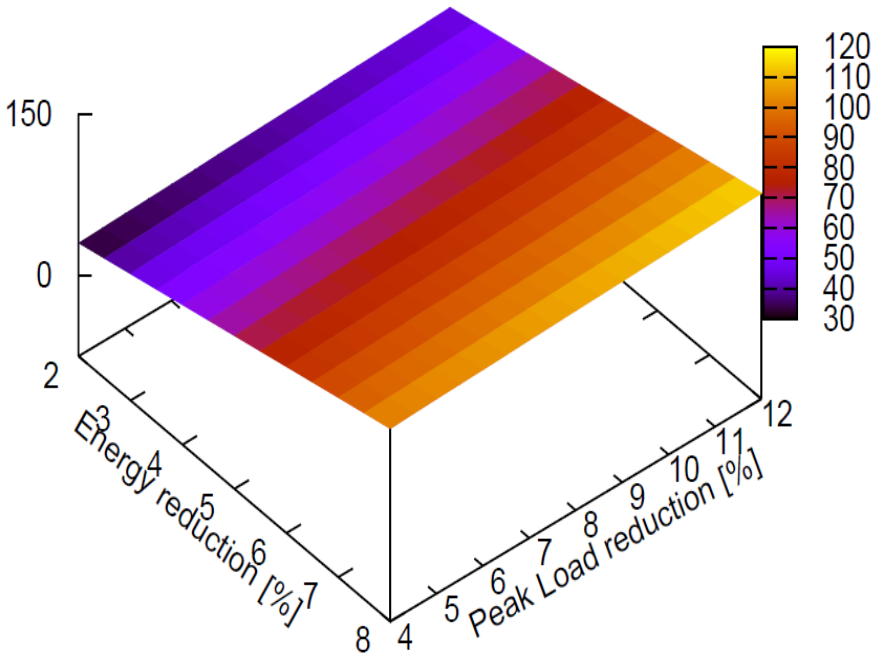
# Scenario 2: TOU w/PCT

- Time of Use (TOU) pricing with a Programmable Communicating Thermostat
- Cost for simple PCT (~$100)
- Typical utility program savings of 5% energy, 10% peak
- Benefit: $76.54 per year
- Simple payback in 1.3 years

## Dollar Value of TOU

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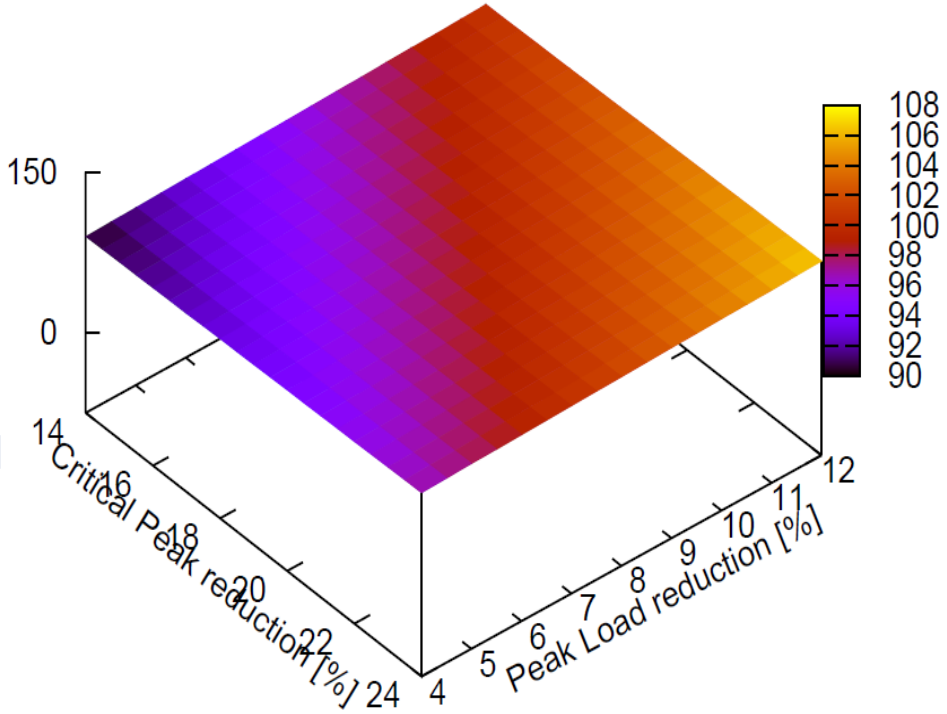
# Scenario 3: CPP w/PCT

- Critical Peak Pricing (CPP) with PCT
- Requires dynamic messaging and control
- Higher cost for IP-addressable smart thermostat or HEM kit (~$250)
- Savings targeted only to peak periods
- Typical utility program experience is 10% peak savings, 20% during critical peak events
- Benefit: $101.70 per year
- Simple payback: 2.5 years

## Dollar Value of CPP

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# Other Programmatic Considerations

- PG&E Tariff Rule 18 interpretation unclear
  - Intended to prevent gouging by landlords, not TOU/CPP participation
  - If unable to get a different interpretation, consider:
    - Non-price incentives to residents
    - Centralized control of PCTs (with local override)
- Good program design should also consider unique student characteristics
  - Frequent occupant turnover, including summer subletting
  - Unusual lifestyle patterns and daily schedules
  - Use of major appliances (less laundry and cooking; more computers and gaming consoles)
  - Low disposable income
  - High acceptance of new technology (mobile messaging)

# Summary Conclusions

# Summary Conclusions

- The Baseline Energy Model developed in Subtask 1 provides a directional understanding of current energy performance, but specific numbers should be taken with a grain of salt
- Overall, the Model indicates that West Village is performing 25% above ZNE under conservative assumptions
  - The Viridian buildings are performing better than Ramble and Solstice
  - The MU and Rec Center are farther above "zero" and may require additional performance improvement (or more generation)
  - The Faculty Staff Housing appears well designed to achieve ZNE
  - Future loads from EV charging and the energy-intensive equipment at WCEC will require further attention
- The Baseline Energy Model can and should be updated as new and better data become available to provide on-going tracking of ZNE performance

# Summary Conclusions (continued)

- Subtask 2 developed the idea of a desktop Master Energy Manager (MEM) that would automate data gathering and populate a “living” version of the Baseline Energy Model
- The MEM could be enhanced to support broadcast event messaging to residents and IP addressable devices such as smart appliances and Programmable Communicating Thermostats (PCTs) within the West Village community
- Assuming the Rule 18 issue can be overcome, the cost-benefit case for investment in additional demand controls, such as PCTs that accept dynamic response appears quite compelling, with simple paybacks less than 3 years under a wide range of options
- Additional program features should be tailored to the unique lifestyle characteristics of students, such as their unusual schedules, high degree of turnover and occupancy changes, and comfort with mobile technology and messaging

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# Questions?

# Project Conclusions:

## Energy Storage

- The benefits of distributed energy storage are clear, however management strategies and dispatch of storage is complex. Optimization for multiple scenarios is possible and standards for dispatch of distributed storage should be developed by utility, industry and consumer stakeholders.
- While 2nd life lithium-ion battery cells are expected to be available at very low costs, the BMS required for these batteries can be complicated. If California wants to embrace this technology, automobile and battery manufactures must develop standards and business models which will streamline repurposing and stationary application installation.
- Sizing batteries for residential applications remains challenging.
- Given the harmony of workplace charging and PV, more data is needed to justify and understand the benefits of introducing a battery buffer to the system.

# Project Conclusions Cont.

## Solar Hybrid PVT:

- PVT panels demonstrated achievable efficiency increases for solar technology.
- PVT technology tested enables achievable ZNE in high density residential building types and reduces variable electric loads from water heating.
- PV generation improvement due to cooling is inconclusive and probably unachievable in most single family home applications.
- Solar installers will require some additional training for PVT systems, but not a significant constraint.
- To our knowledge, no incentives exist specifically for PVT technology– incentives are needed to build the market for PVT

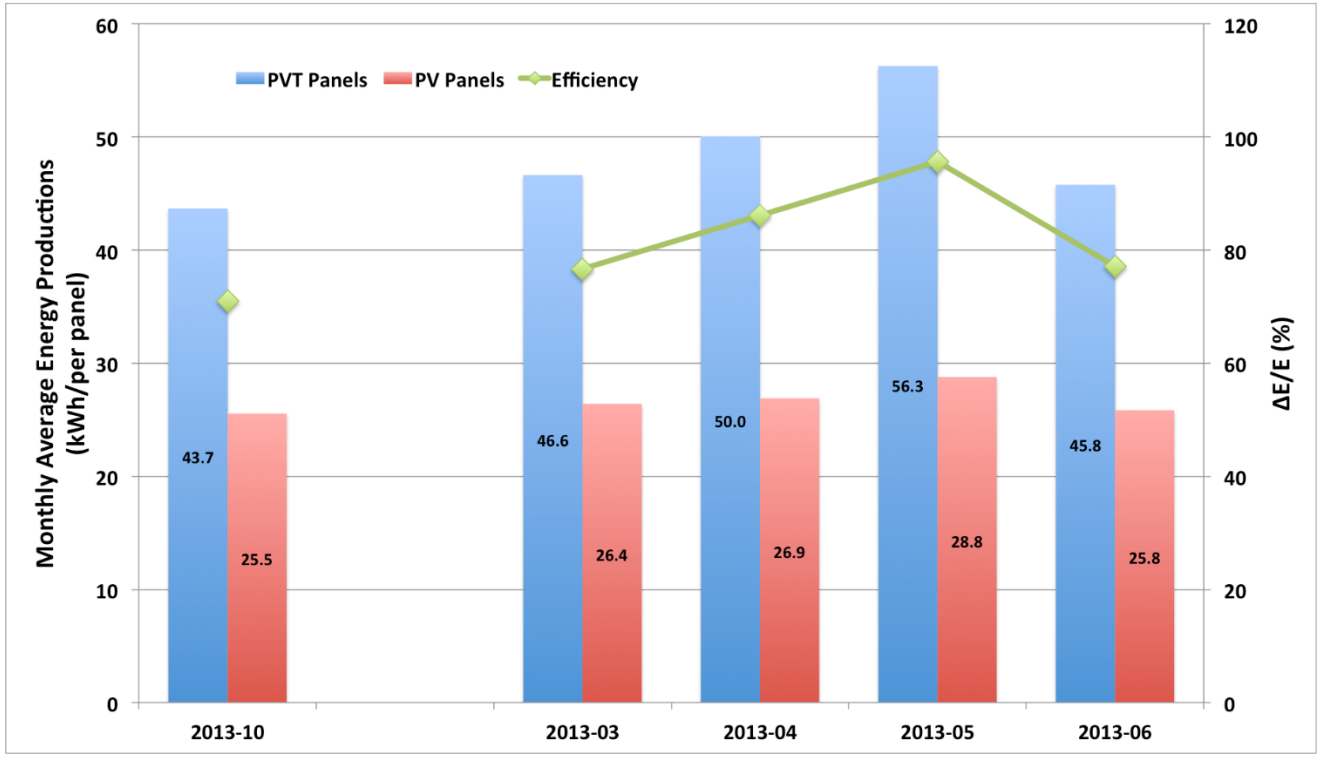
# Thank You

- California Public Utilities Commission
- Itron, Inc.
- West Village Community Partnership, LLC
- Davis Energy Group
- KM Engineering
- SMA America
- Wireless Glue Networks
- Construction Partners:
  - Aztec Solar, SonRay Construction, SunPower, and CP Construction West
- UC Davis
  - Energy Institute
  - Institute of Transportation Studies
  - Department of Mechanical and Aerospace Engineering
  - Department of Chemical Engineering and Materials Science
  - Design and Construction Management
  - Real Estate Services
  - Materials Management and Business Contracts

# Backup slides

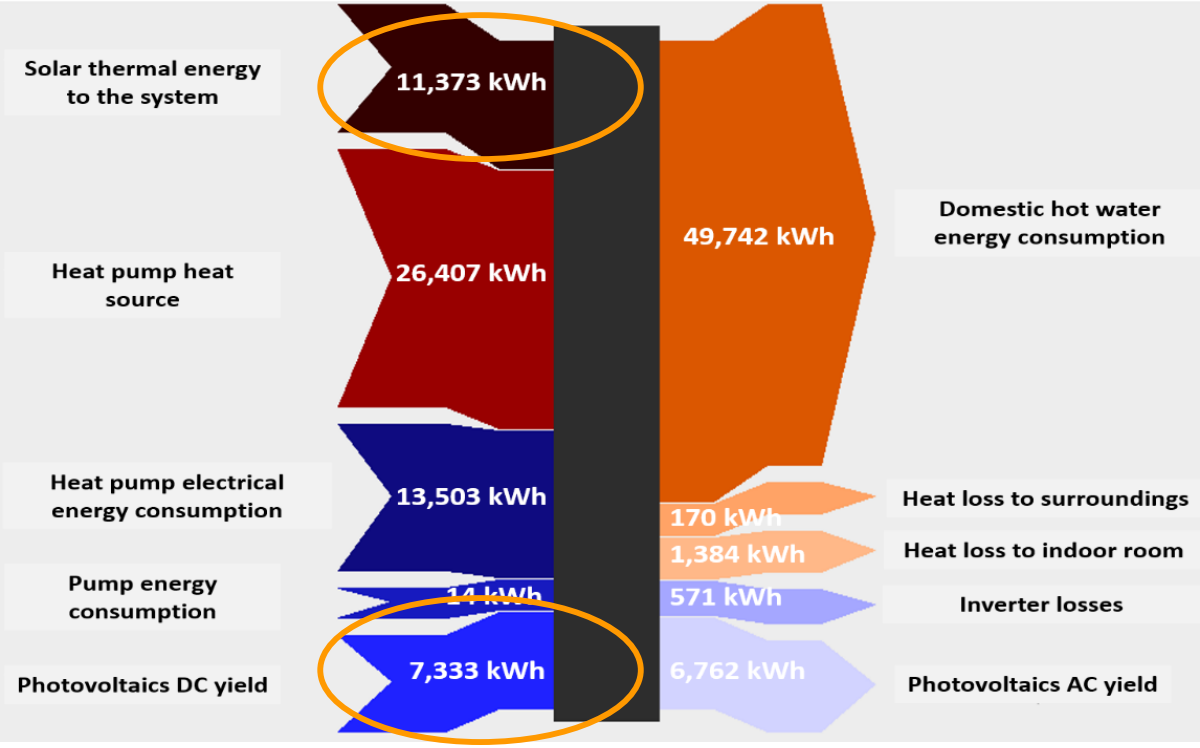
# Performance/Data_Aggie Villa

*PVT vs. PV*



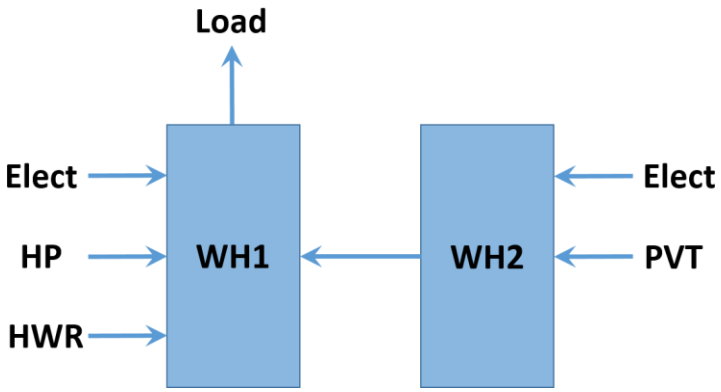
# Project Planning_WV

- **System performance prediction**




- The simulation shows that the estimate electrical production and thermal production will be able to cover about **50% electricity consumption** and **81% domestic hot water consumption** for two apartment units.

# System Engineering_WV




*Simplified energy flows in PVT system*

- *The energy balance equation can be written as:*

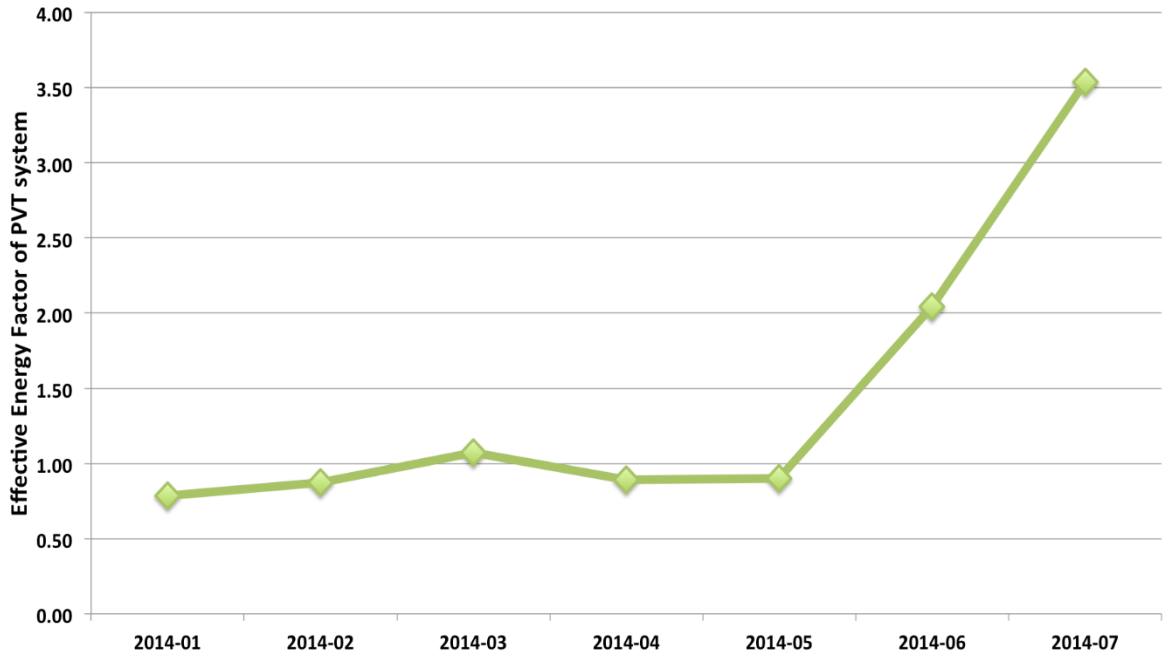
*PVT + Heat Pump Energy + Resistance Heat = Hot Water Use + Recirculation Loss + Tank & Pipe Loss*

*Heat Generations* — *Heat Consumptions & Loss*

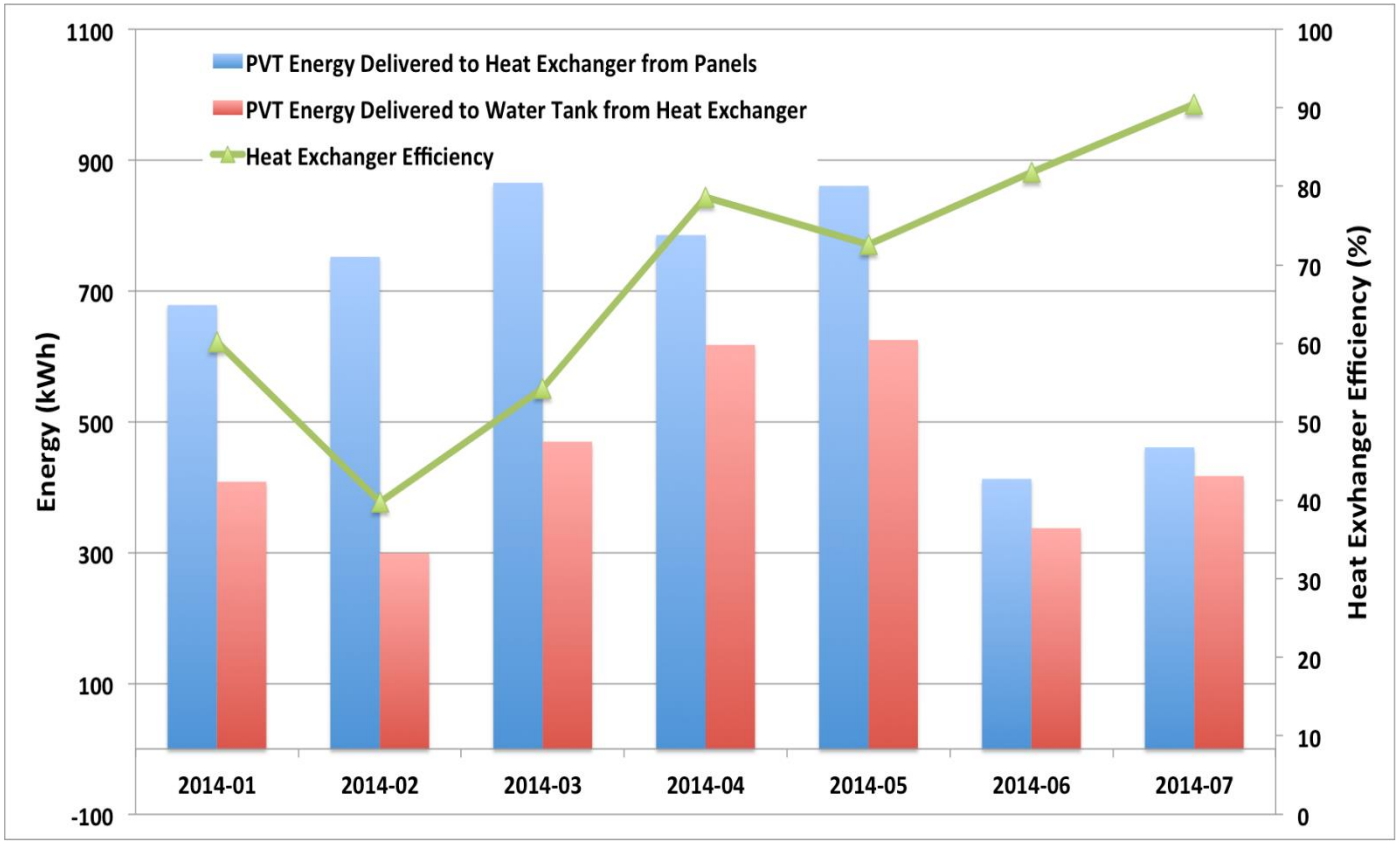
# Performance/Data_WV

## *Heat Generation*

***Effective energy factor of PVT system = $Q_{pvt}$ / $Q_{delivered}$***




**Monthly effective energy factor diagram**

# Performance/Data_WV

***Heat exchanger efficiency***