Solara: A Case Study in Zero Net Energy Design for Affordable Housing

Design, Construction, and Operational Lessons Learned from a

California Energy Commission Zero Energy New Homes Project

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Solara Intro

- 56 unit, 2-story affordable apartments
- Poway, CA (1883 HDD, 1022 CDD)
- Developed by Community HousingWorks in conjunction with Global Green USA




Solara ZENH Project Goals

1. Exceed 2005 Title 24 energy code by at least 25%
2. Reduce electricity cost by at least 70%
3. Have a coincident peak demand of less than 1kW
4. Increase the first cost per unit by less than $5,000

Design and Modeling

- Designed to be 33-37% better than 2001 Title 24 energy code
  - 12-15% above 2005 Title 24
  - High performance windows, overhangs, high efficiency HVAC, centralized hydronic DHW and heating, radiant barrier
- Modeled using EnergyPro (CEC approved compliance software)
  - Does not calculate lighting, plug, or appliance loads
  - Observed to significantly underestimate cooling demand

From Design to Construction: Lessons Learned

- HVAC oversized
- Leaky ducts
- Hydronic heating controls – good in modeling but not in practice
- Tradeoff between PV and solar thermal – competition for roof space




Performance Monitoring and Verification

- 50% of Solara units monitored for power consumption
  - Dent ElitePro power meters
  - 15 minute data
- 100% of PV systems monitored at Solara
  - Fronius IG Access add-on
  - 15 minute data
- 4 “baseline” units monitored nearby
  - Same developer and builder

Monitoring period: Aug ‘07 – Aug ‘08

M&V: Lessons Learned

- Off the shelf monitoring equipment not suited for long term data collection
  - Robust hardware
  - Poor software for communications and data collection
- Packaged PV monitoring solution from inverter manufacturer – extremely unreliable

More R&D needed for commercialized, highly reliable M&V equipment

Comparison of Solara and Baseline Units

- Utility bills: included in rent at Solara, paid by tenant at Hillside
- Cooking appliances: electric at Solara, gas at Hillside
- Heating: Centralized hydronic at Solara, furnaces at Hillside
- DHW: Centralized tankless at Solara, individual tankless at Hillside

Performance Results: ZENH Goals

	ZENH Goal	Solara Performance	
		Modeled	Monitored Performance
1. Title 24 Energy Performance Above Code	25%	12-15%	NA
2a. Electricity Cost Reduction (*Per Unit*)	70%	85%	68%
2b. Electricity Cost Reduction (*Normalized per SF*)			62%
3. Average per Unit CA ISO Coincident Peak Demand (kW)	1kW	NA	0.58 kW
4. Average per Unit SDG&E Coincident Peak Demand (kW)	1kW	NA	0.51kW

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Performance Results: Electricity Consumption

	Solara (kWh)		Hillside (Baseline) (kWh)	Reduction from Baseline	
	Net (With PV)	Gross (Without PV)		Net (With PV)	Gross (Without PV)
Average Consumption - *per Unit*	480.7	3709.6	3693.7	87%	0%
Average EUI - *per 1000 SF*	477.7	4097.1	3655.4	87%	-12%
Average EUI - *per BR*	228.1	1760.5	1458.0	84%	-21%

Conclusions:

- Energy efficiency measures observed to have little or no impact on gross consumption
- Utility billing structure and electric appliances have a significant impact

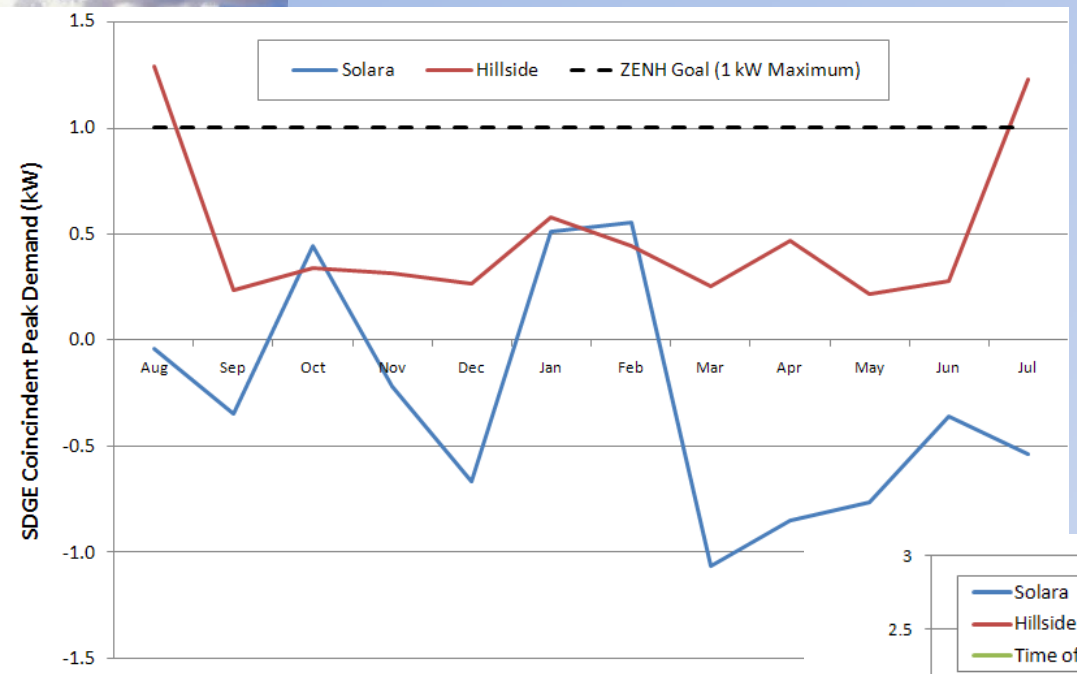
Performance Results: Electricity Cost

	Solara		Hillside (Baseline)	Reduction from Baseline	
	Net (With PV)	Gross (Without PV)		Net (With PV)	Gross (Without PV)
Average Utility Cost – *per Unit*	$ 125.55	$ 546.56	$390.70	68%	-40%
Average ECI – *per 1000 SF*	$ 145.03	$ 631.39	$383.77	62%	-65%
Average ECI – *per BR*	$ 59.58	$ 259.38	$151.94	61%	-71%

Conclusions:

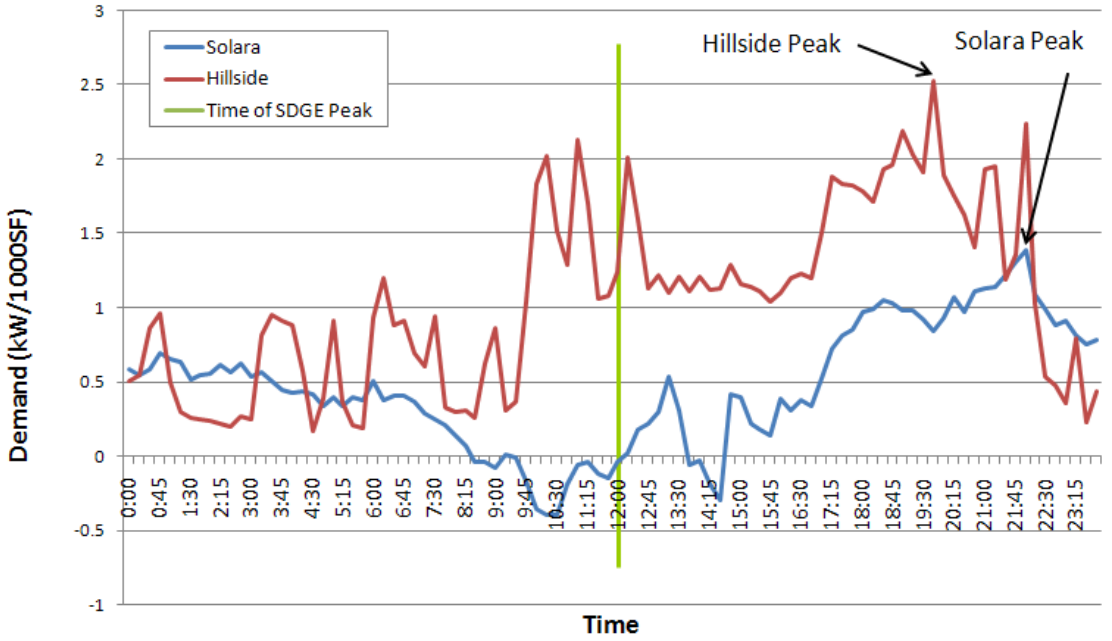
- Minimum daily charge has a significant impact on total utility cost at Solara
- Billing arrangements important: Solara not eligible for low-income rates because bills included in rent

Performance Results: Peak Demand

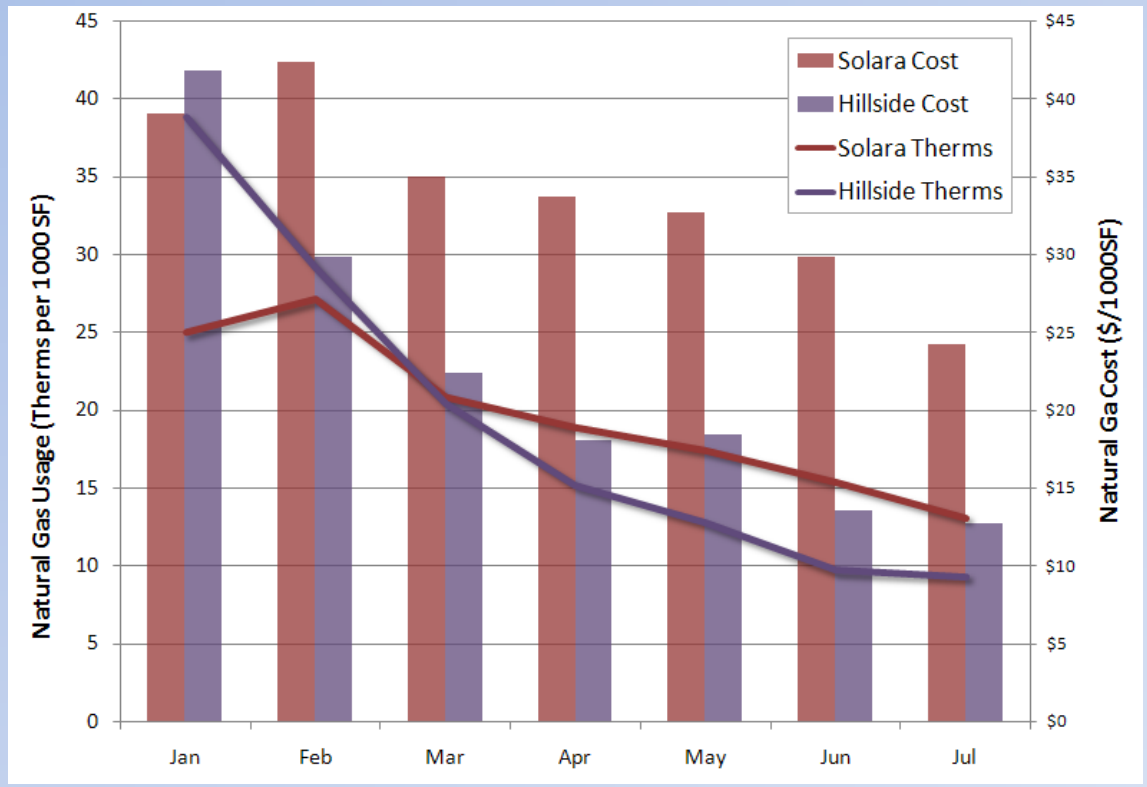


Conclusions:

- Solara net exporter 9 out of 12 months, including all summer months
- Solara peak shifted compared to baseline



Performance Results: Natural Gas



Conclusions:

- Solara heating system design: efficient during heating season and inefficient during cooling season
- Solara cost very high due to lack on low income rates and incorrect rate structure

Performance Results: Site Energy

Month	Total EUI (kBtu per 1000 SF)					Total Average ECI ($ per 1000 SF)		
	Solara Net	Solara Gross	Hillside	Net Reduction	Gross Reduction	Solara Net	Hillside	Reduction
Jan	2843.3	3477.9	4956.7	43%	30%	$53.3	$75.4	29%
Feb	2839.6	3761.4	3795.0	25%	1%	$55.2	$56.6	3%
Mar	1934.3	3148.5	2772.4	30%	-14%	$43.9	$45.0	2%
Apr	1713.1	2987.8	2348.1	27%	-27%	$42.6	$43.7	3%
May	1520.8	2922.8	2159.4	30%	-35%	$41.1	$45.3	9%
Jun	1639.6	3136.2	1899.5	14%	-65%	$44.3	$52.9	16%
Jul	1498.4	2905.2	2335.4	36%	-24%	$42.1	$57.8	27%
Total	13989.2	22339.7	20266.6	31%	-10%	$322.4	$376.9	14%

Conclusions:

- Net energy use performance much lower than electricity performance due to gas usage
- Gas use and rate structure differences have a significant impact on overall cost performance




Performance Results: Comparison with Modeled Projections

Category	Modeled	Observed	Observed Performance vs. Modeled
Gross Electricity Consumption (kWh)	3612.4	3709.6	3%
PV Production (per kWDC installed) (kWh)	1351.0	1477.3	9%
Net Electricity Consumption (kWh)	675.9	480.7	-29%
Electricity Cost ($/apartment)	$132.20	$125.55	-5%
Natural Gas Consumption (therms/apt)	80.0	211.9	165%

Conclusions:

- Post processing resulted in very accurate projections
- PV production higher than PV Watts (NREL) estimate
- Gas consumption significantly underestimated

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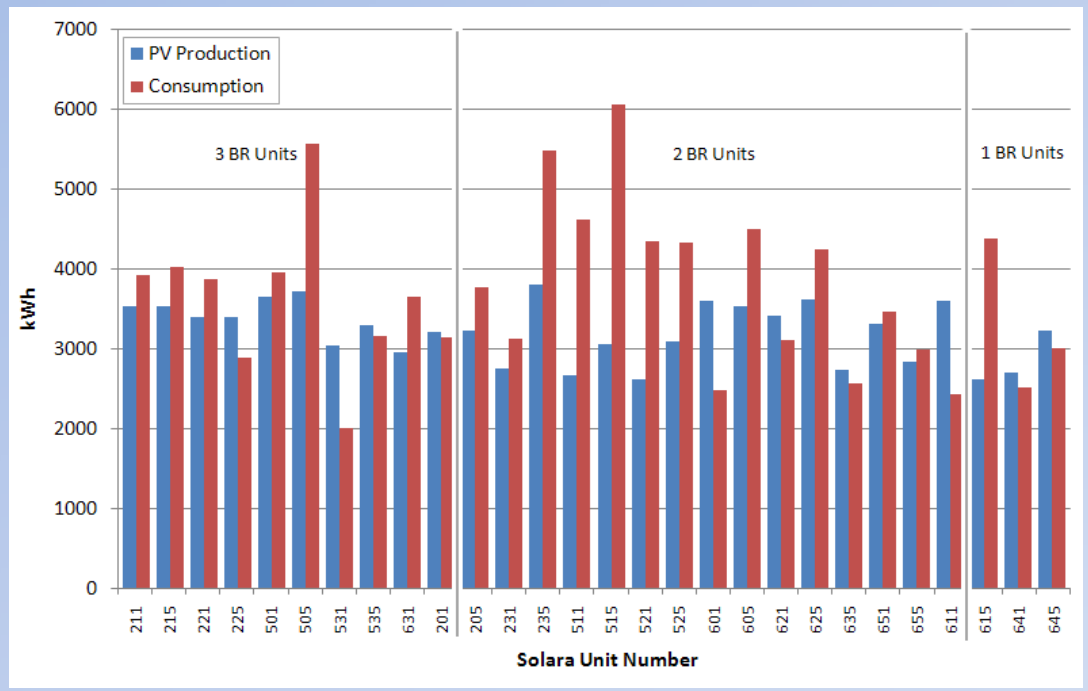
Modeling – lessons learned

- Significant post processing needed to go from model outputs to accurate projections
  - 50% increase in cooling energy
  - Addition of lighting, appliance, and plug loads based on Building America Benchmark
- Modeling software significantly underestimates heating hot water use – lack of controls detail

Lesson Learned: Occupant Behavior



Average electricity use per bedroom – 1862 kWh

Low range – 669 kWh

High range – 4557 kWh

Std Dev – 839 kWh

Conclusions:

- Occupant behavior varies wildly
- Feedback mechanisms may be necessary to cost-effectively achieve zero net energy
- More research needed

Conclusions

- EE + PV reduced electricity consumption by 87%
- Net exporter during Utility peak period during critical summer months
- Energy modeling tools need post-processing for zero energy design
- Focus on electricity may shift demand to other fuels – total site energy reduced by 31%
- Occupant behavior is critical to achieving zero net

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