NATIONAL RENEWABLE ENERGY LABORATORY

Community Energy:

Analysis of Integrated Distributed Energy Systems for Power and Transportation (Draft)

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November 15, 2012

Objective

The HTAC committee is charged with evaluating the benefits of hydrogen as an enabler of renewables. The potential benefits of integration of renewable electricity generation with transportation fueling is one aspect of this mandate and the focus of this presentation.

An analysis of hydrogen for community-scale electricity storage was completed previously

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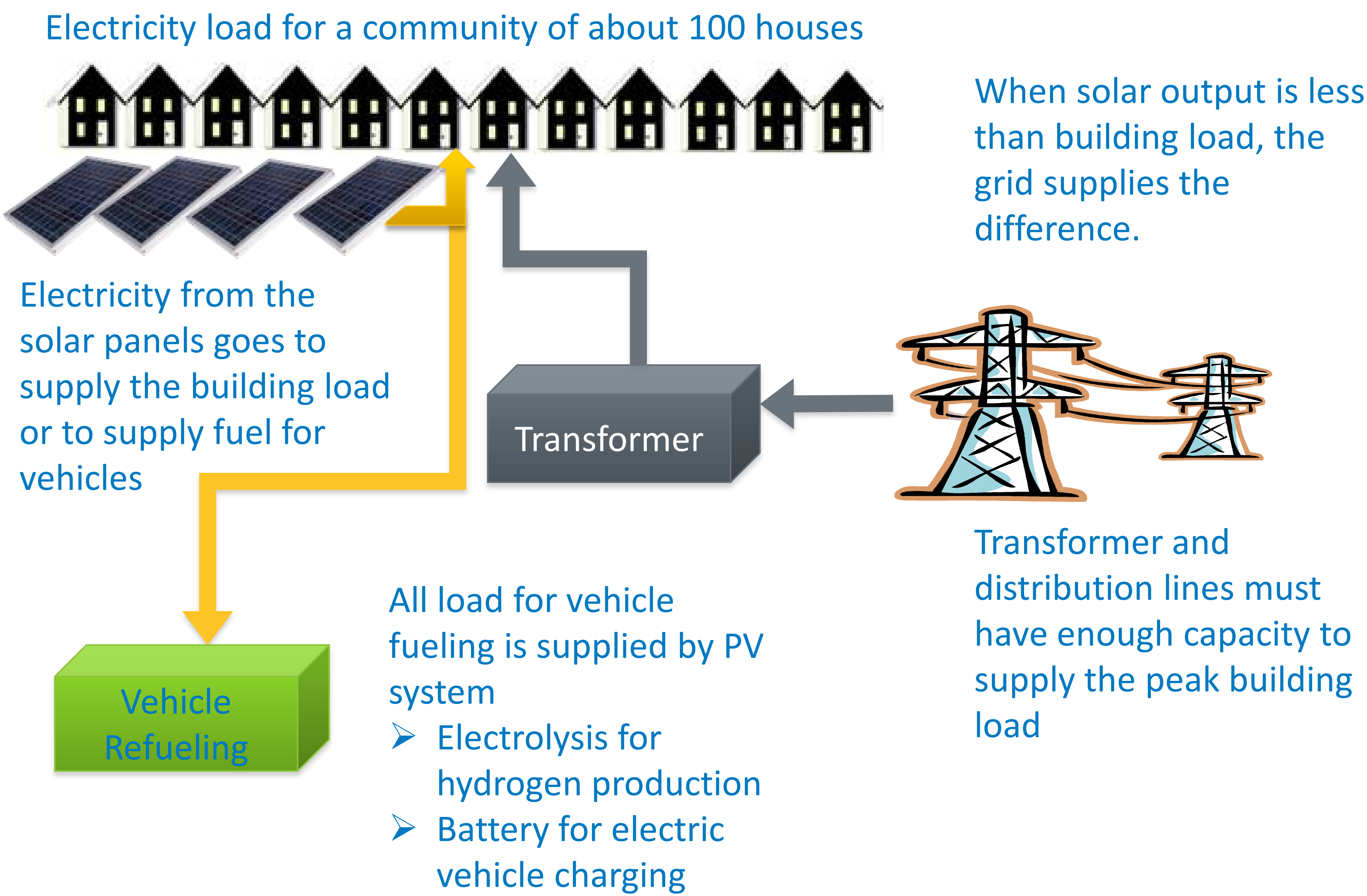
Grid-Independent Renewable Energy Vehicle Fueling System Schematic



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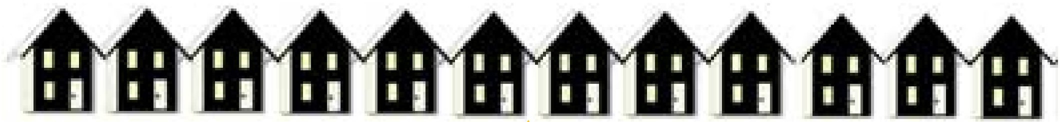
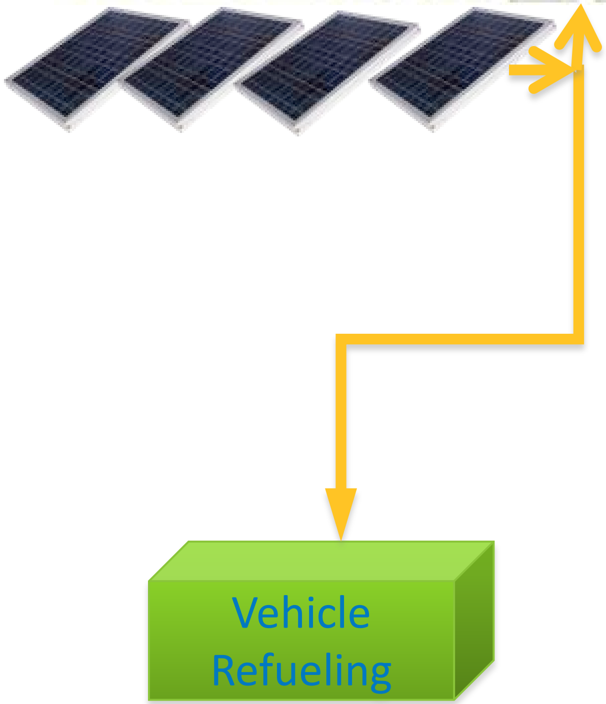
Grid-Independent Renewable Energy Vehicle Fueling System Schematic

Building demand: Maximum = 125 kW, ~573,000 kWh/year

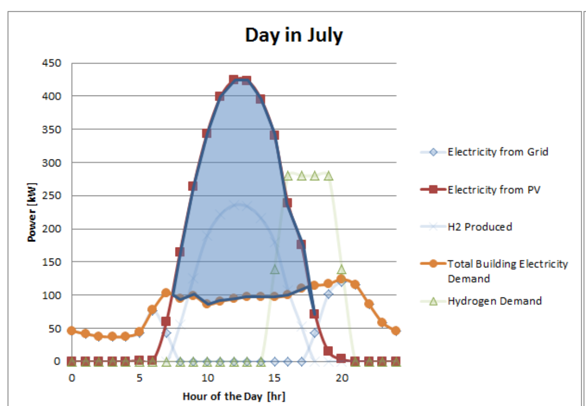




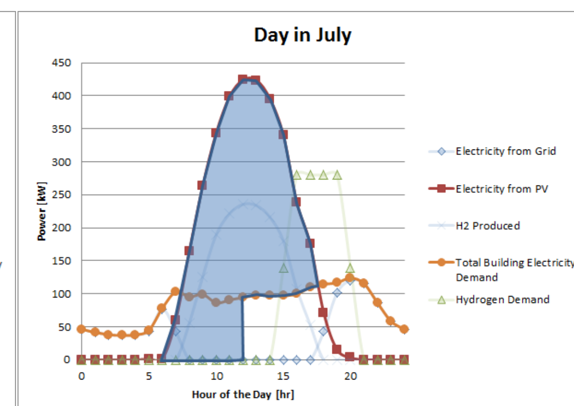
Three example PV system sizes cover a range from about ½ the yearly building load to approximately 2X the building load:

- 1,200 m2 (146 kW peak output); 287,000 kWh/y
- 4,000 m2 (490 kW peak output); 760,000 kWh/y
- 7,000 m2 (850 kW peak output); 1.3M kWh/y

Case 1 – PV output in excess of building load to vehicle refueling



Case 2 – PV output before noon and output in excess of building load to vehicle refueling



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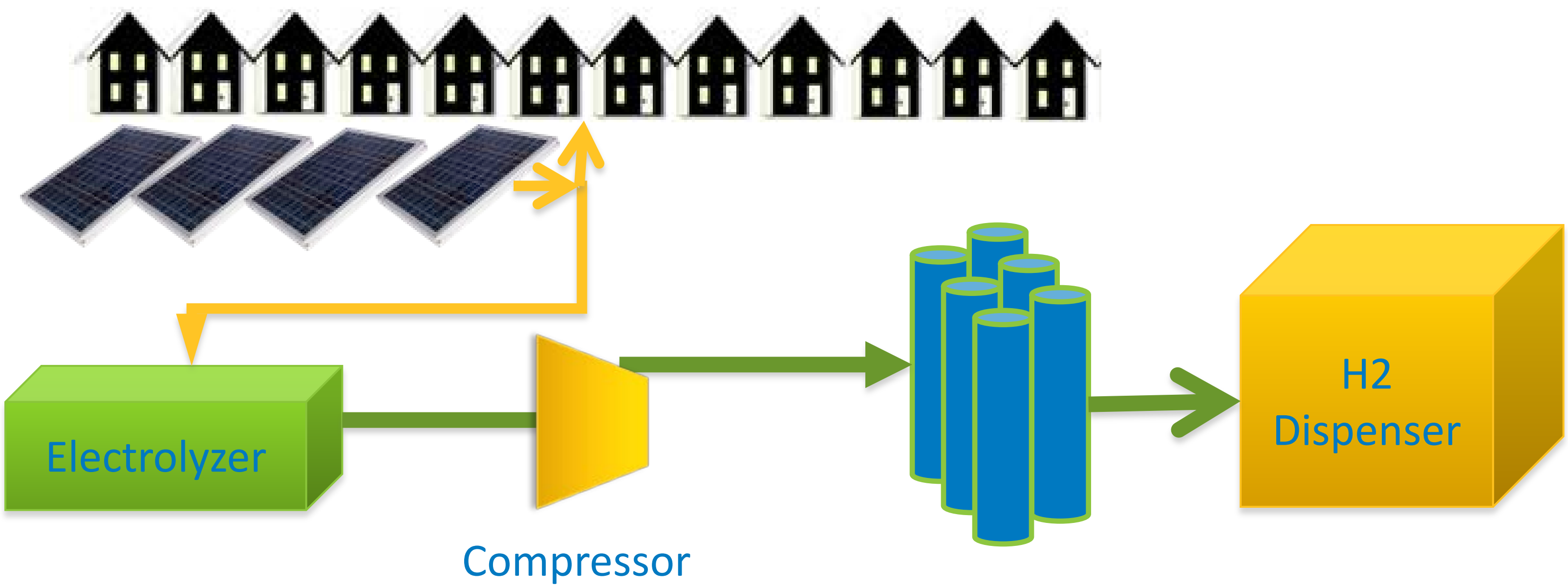
Renewable Energy Hydrogen Vehicle Fueling System Schematic



Electrolyzer	Electrolyzer sized to maximum difference between PV output and building load
Compressor	Sized to peak hourly hydrogen flowrate
Hydrogen Storage	Assumed daily full cycling of storage system (no multi-day storage)
H2 Dispenser	One assumed in all cases. 350 bar dispensing.

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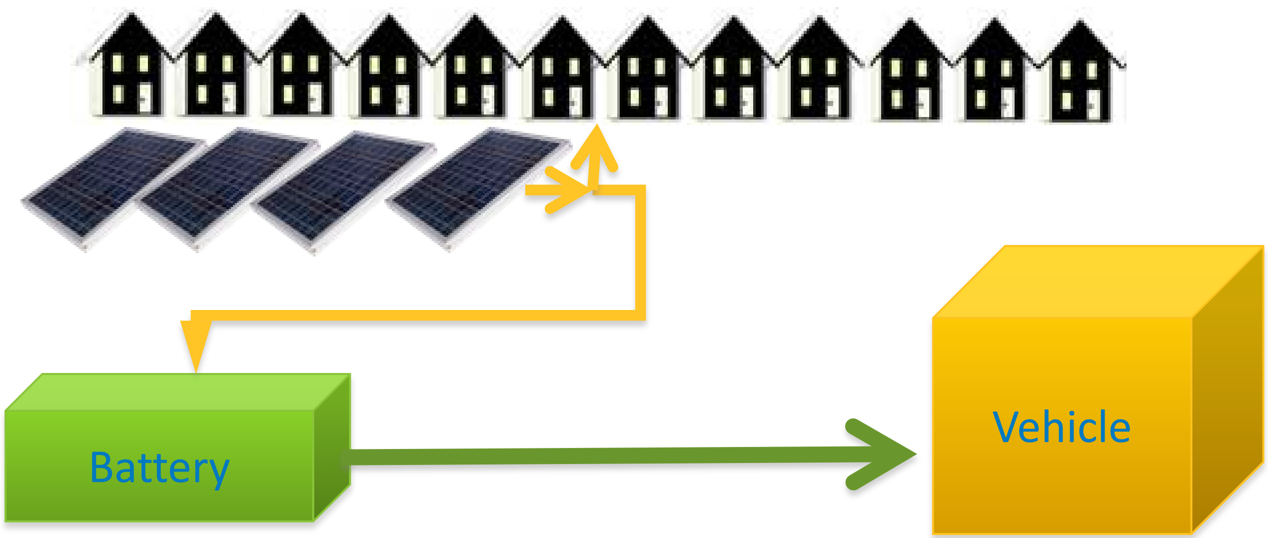
Renewable Energy Electric Vehicle Fueling System Schematic



Zinc Air Battery	Battery sized to maximum kWh in storage + 50% assuming full discharge of the battery daily (i.e., no multi-day storage)
Level I charging	Assume home vehicle charging (comparable to 350 bar hydrogen system).

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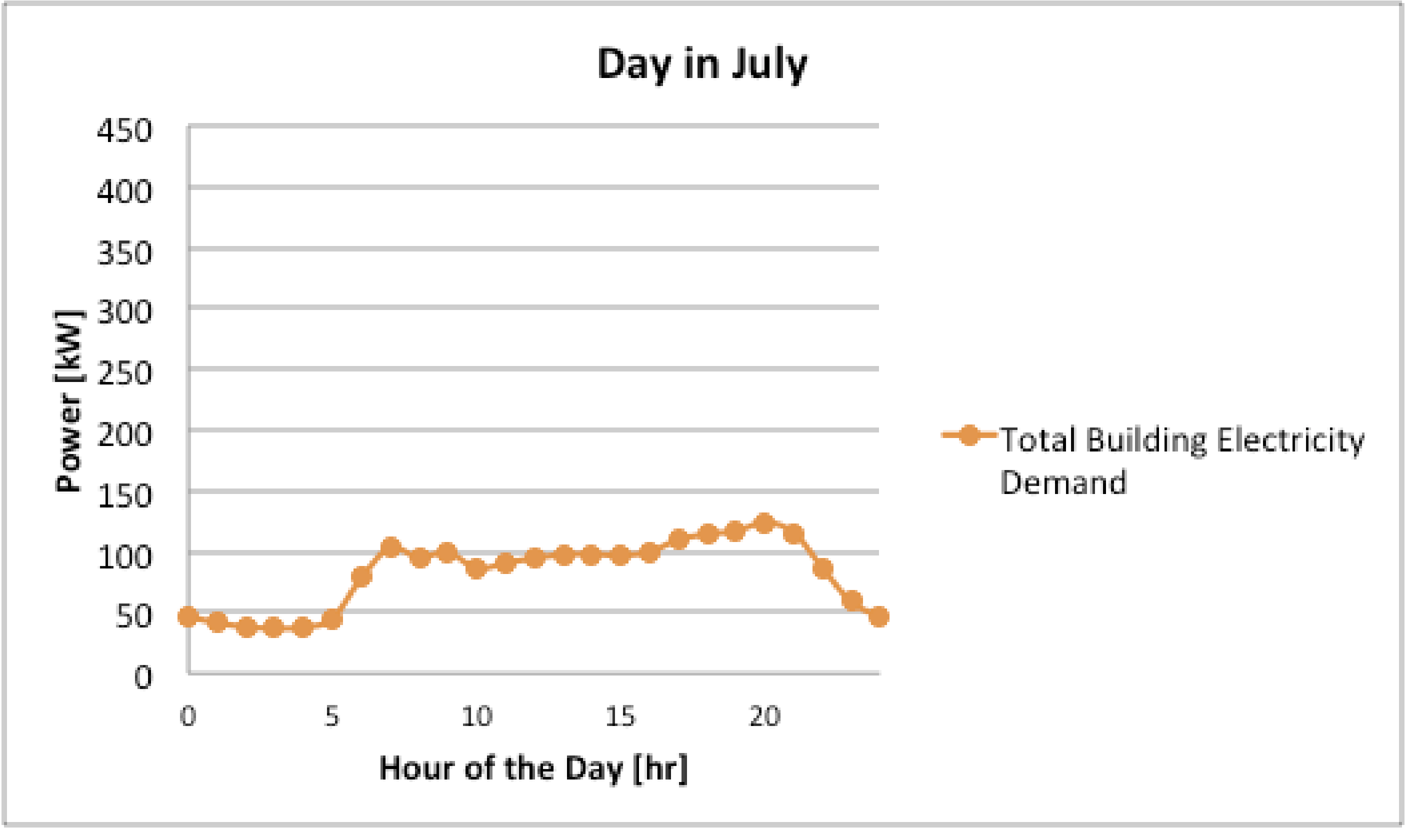
Example building, PV and vehicle load – 4,000 m2 PV system

Building load is based on a small hotel, which has a similar load profile to residential housing.

Peak load = ~125 kW, 573,000 kWh/year



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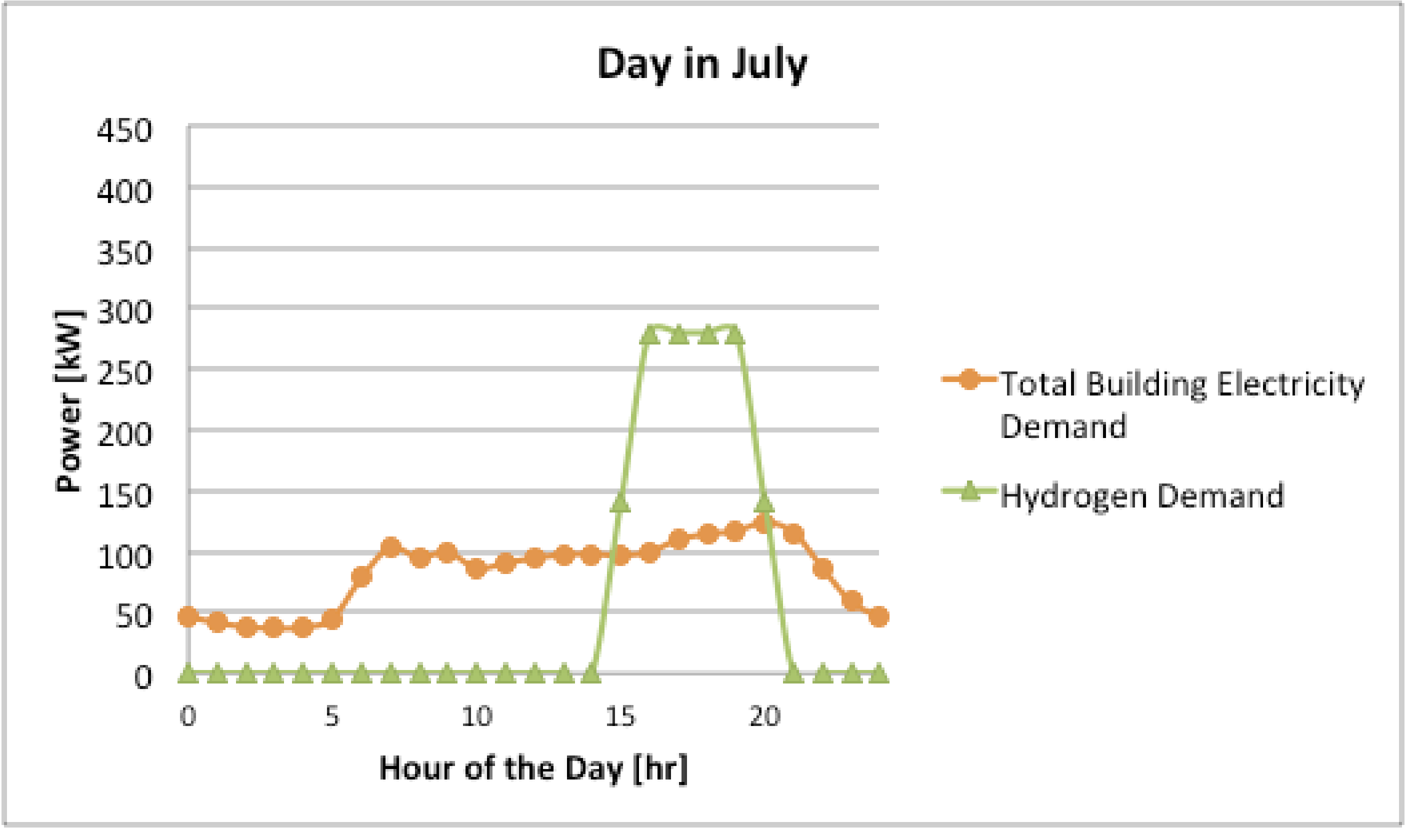
Example building, PV and vehicle load

Hydrogen and electric vehicles would have similar charging profiles.

Daily profiles are identical, but total daily demand is matched to available PV electricity



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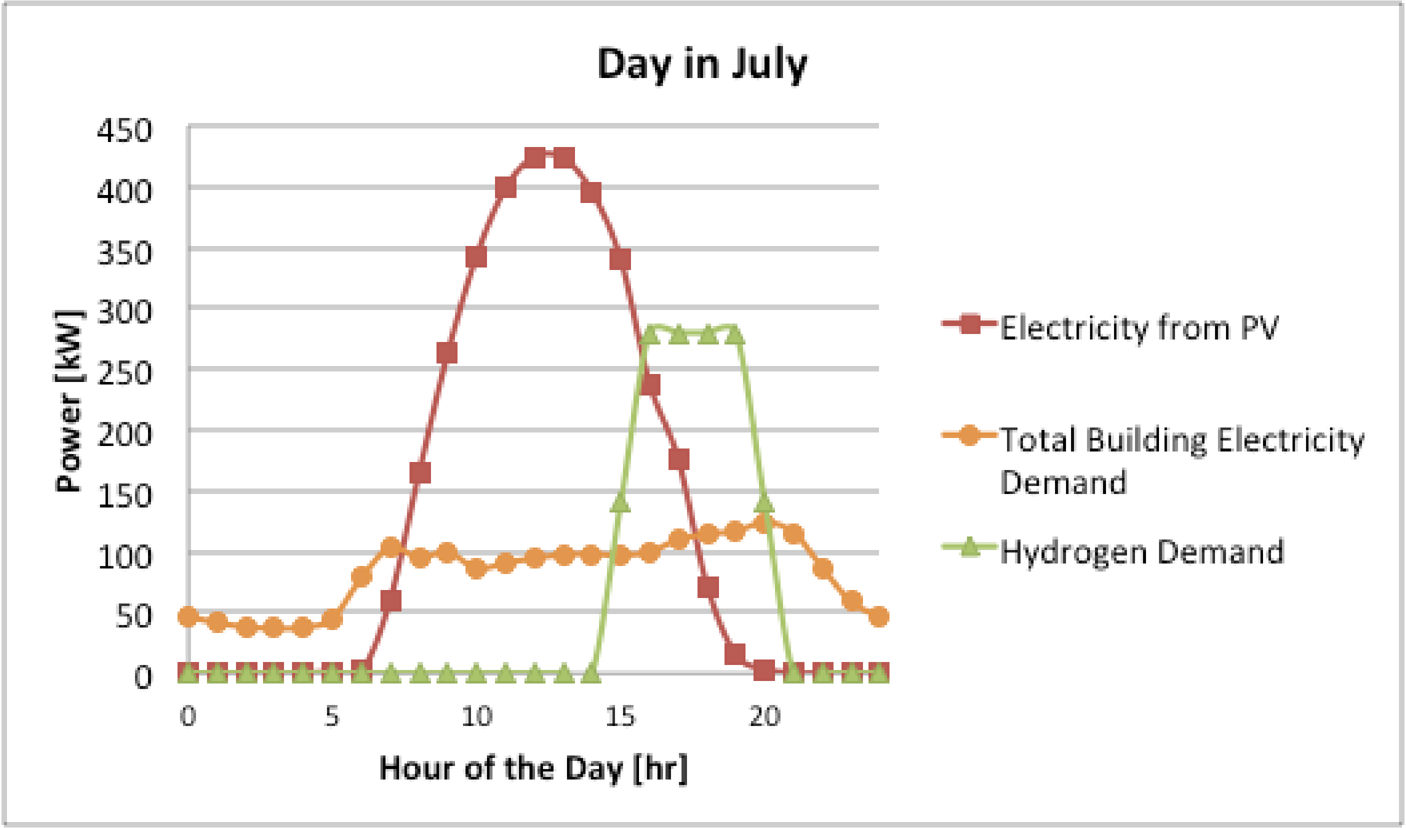
PV output is based on hourly data from Boulder, Colorado and realistic current PV technology.



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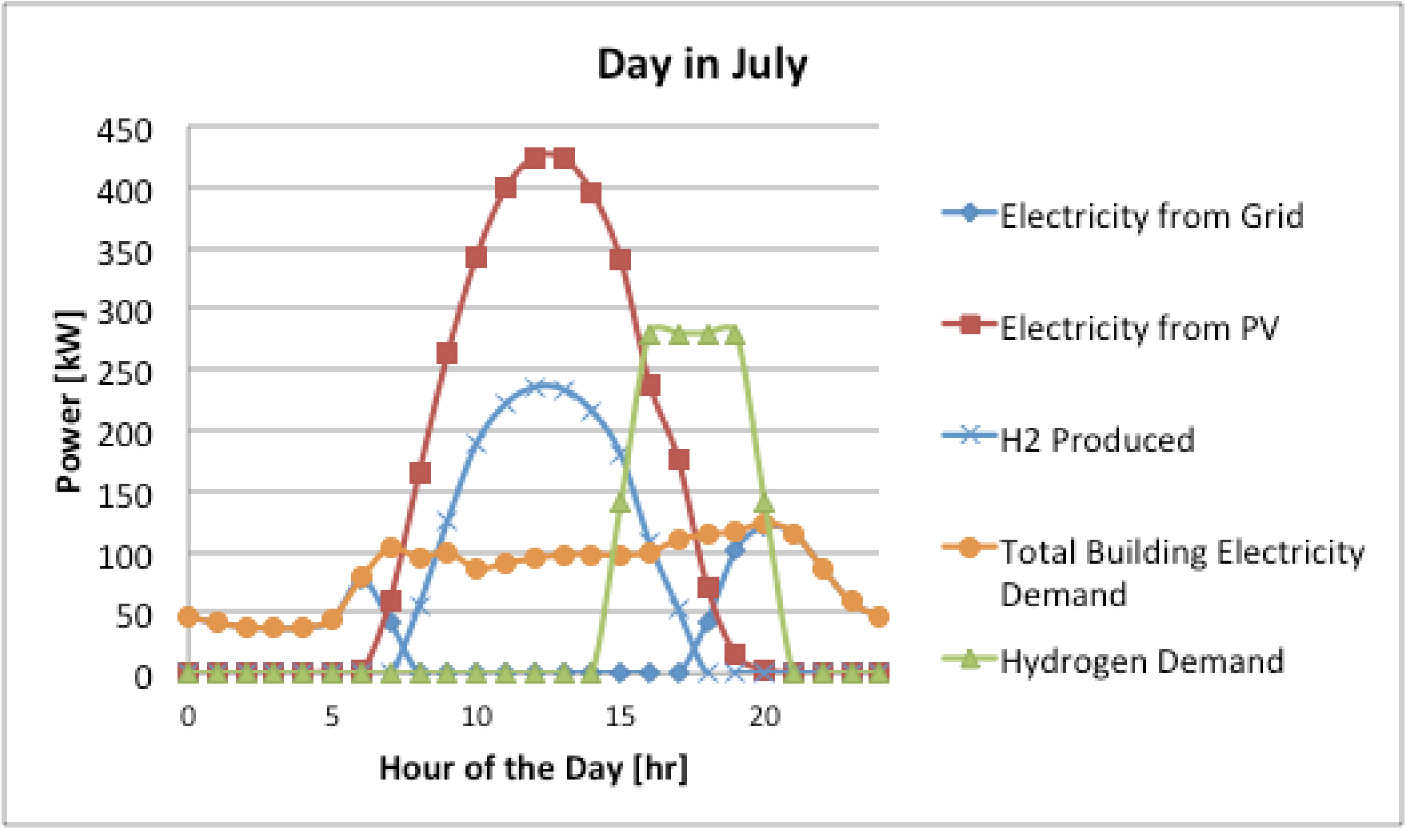
Example building, PV and vehicle load

Hydrogen (or electricity to battery) produced when PV system output exceeds the building load.



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Overview of Results

The hydrogen system including an electrolyzer, compressor, storage and hydrogen dispensing is about 2X the cost of a battery system.

For both hydrogen and electric vehicles, diverting more electricity from the PV system improves the economics, but the effect is more pronounced for the hydrogen system

Best case hydrogen cost is for the 7,000 m2 PV system Case 2.
•About 90% of the PV output goes to hydrogen production or battery storage for EV charging
•28% of the building load is supplied by the PV system
•The electrolysis system produces about 32,000 kg/year (~90 kg/day) or supply for 160 vehicles
•**Hydrogen cost is about $11/kg or ¢19/mile**

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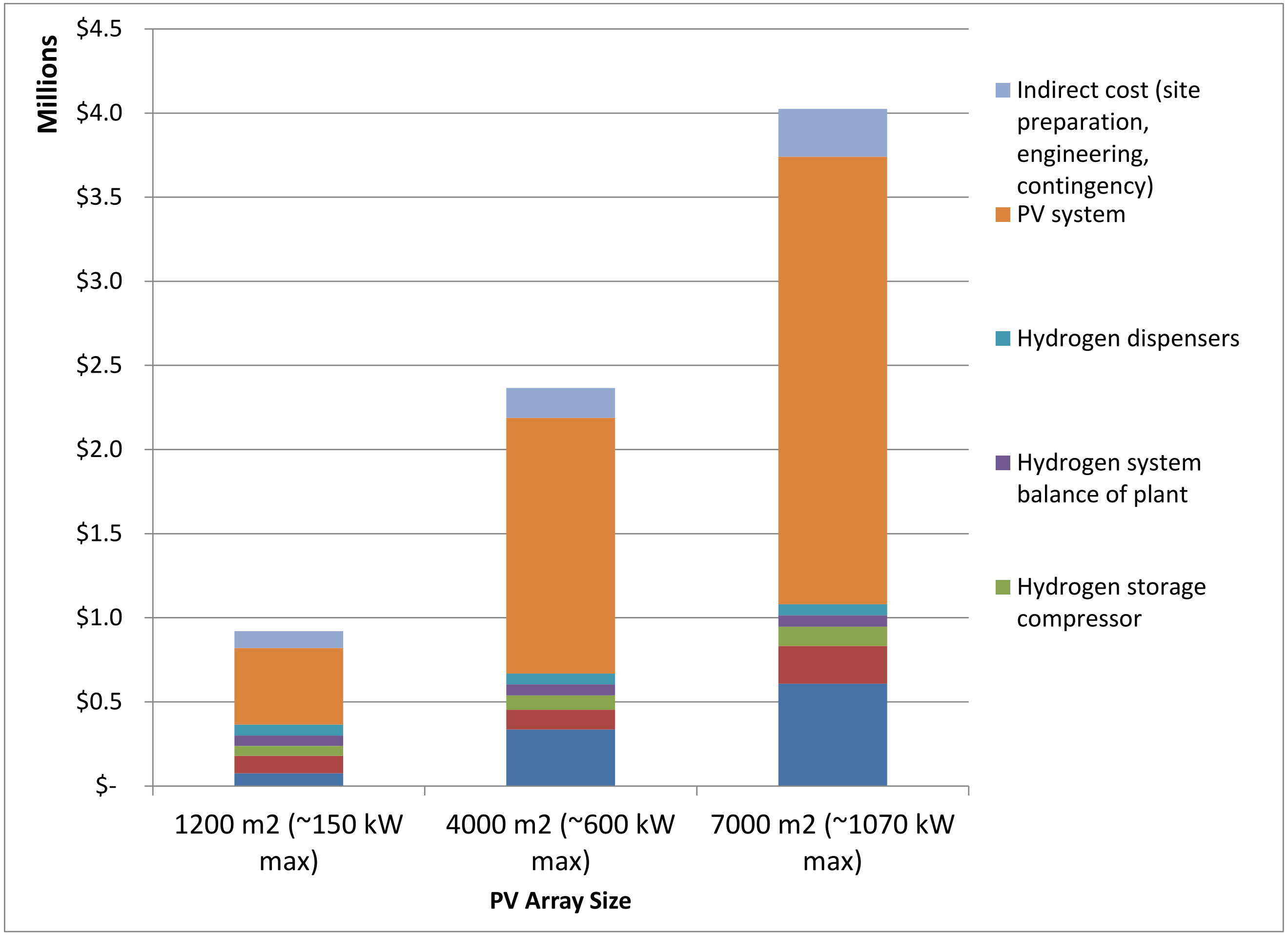
Full System Costs are Dominated by the PV Panels

Hydrogen System – PV System is the largest cost item, followed by the hydrogen storage system.



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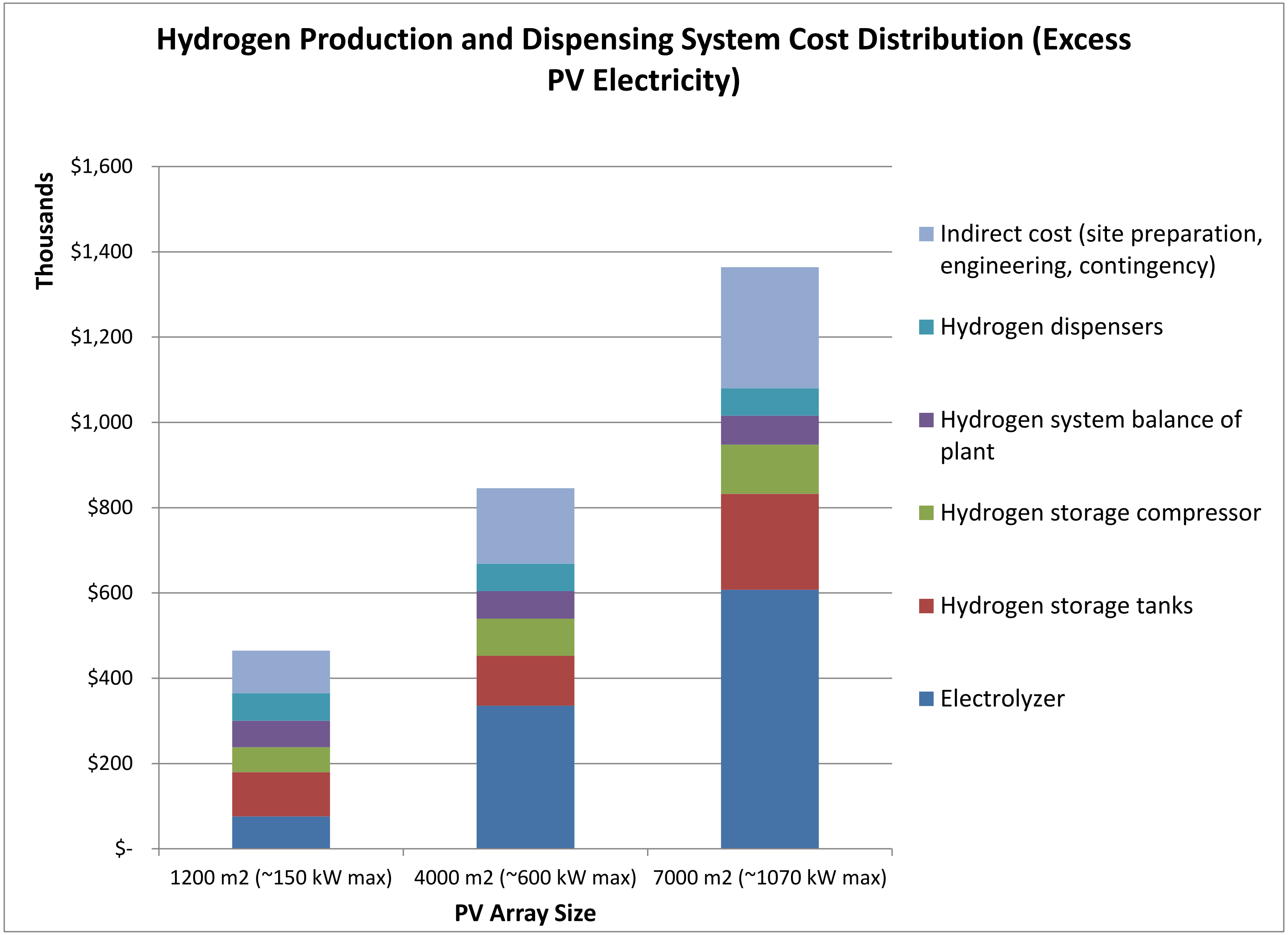
Hydrogen System Costs for Case 1 are Dominated by the Electrolyzer Costs

Hydrogen System – Case 1



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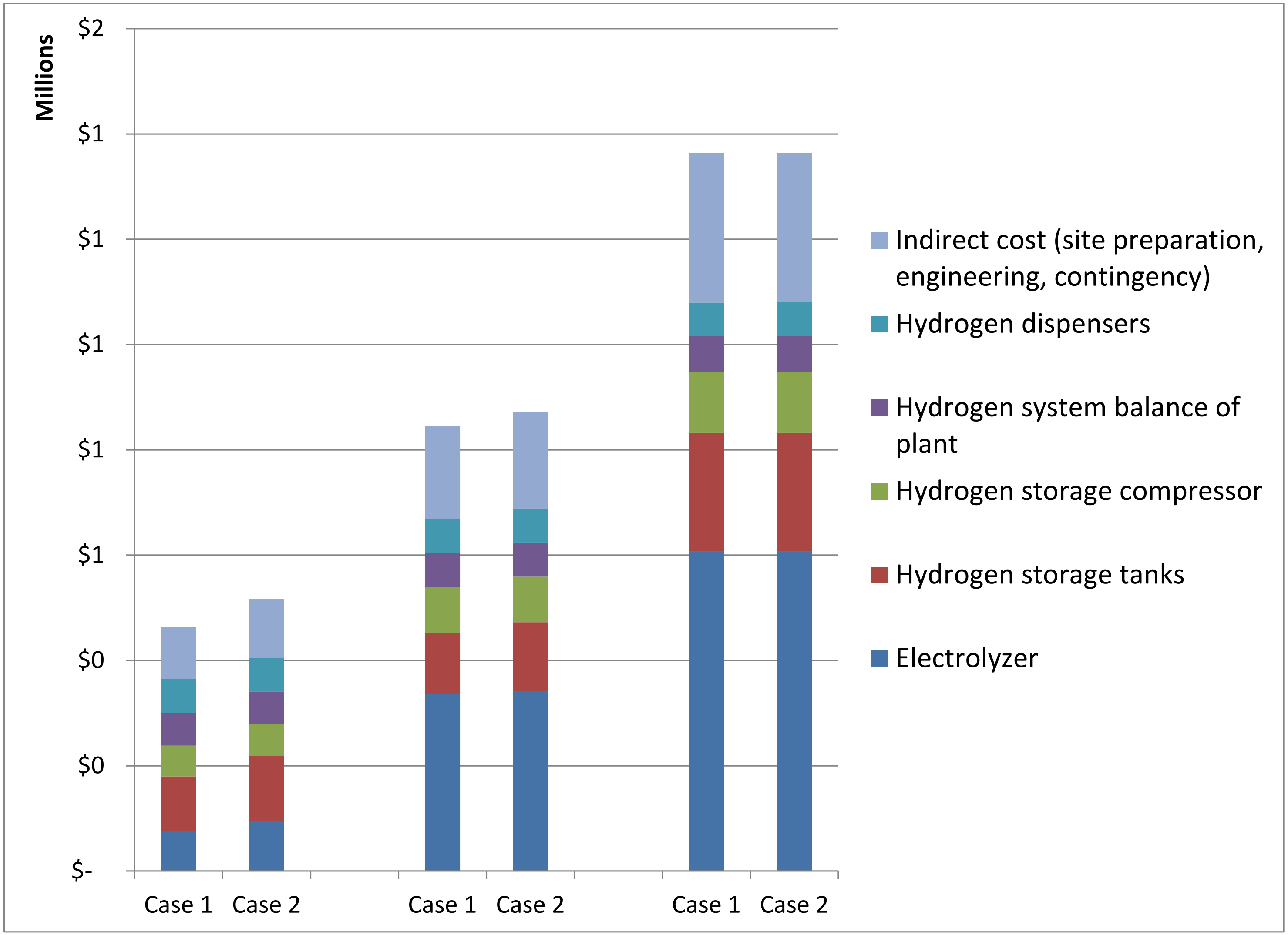
Comparison of Case 1 and Case 2 for Hydrogen

Hydrogen System – Case 2 storage systems are slightly larger



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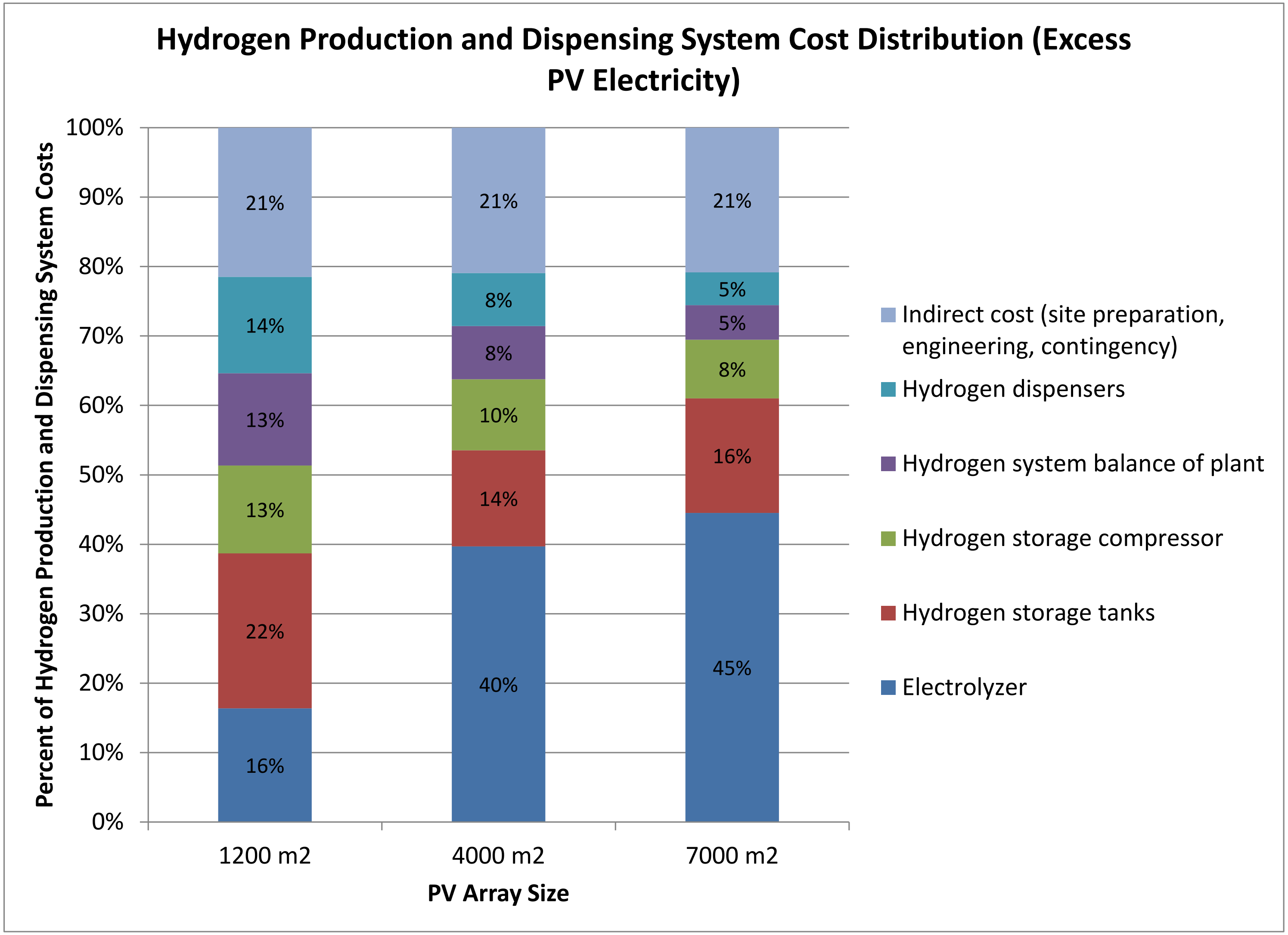
Hydrogen System Costs as a Percentage of the Total



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Overview of Results

Hydrogen								
PV System Size (% of total building load)	Case 1 - Excess Electricity (kg H2/year)	Number of vehicles	$/kg	¢/mile	Case 2 - Morning Output + Excess Electricity (kg H2/year)	Number of vehicles	$/kg	¢/mile
1200 m2 (~50)	1,804	8	34	63	3,541	17	24	41
4000 m2 (~170)	14,564	71	13	22	16,985	83	12	21
7000 m2 (~300)	29,274	143	12	20	31,898	156	11	19
Full Electric Vehicle (EV)								
PV System Size	Case 1 - Excess Electricity (kWh/year)	Number of vehicles	$/kWh	¢/mile	Case 2 - Morning Output + Excess Electricity (kWh/year)	Number of vehicles	$/kWh	¢/mile
1200 m2	61,726	15	$1.04	35	121,936	30	0.45	15
4000 m2	500,755	123	$0.41	14	585,475	145	0.40	13
7000 m2	1,008,212	249	$0.39	13	1,100,877	272	0.39	13

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Conclusions

This analysis does not present a very compelling for community-scale hydrogen fueling.

However;

- **The system allows us to have a fully renewable fueling scenario**
- **The system allows us to have higher PV penetration without reverse power flow and voltage fluctuations.**
- **The analysis shows that the number of vehicles supported are comparable to the number expected for the number of residences represented by the building load.**
- **The storage system for hydrogen is more flexible than the battery – e.g., an additional kWh of H2 is cheaper than additional kWh of battery storage**
- **100 mile range for electric vehicle may not fully support the needs of every resident.**

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Recommendations for Further Work

Perform sensitivity analysis to determine what hydrogen system component costs would have to be to be competitive with the battery system.

Explore more realistic scenarios for dealing with seasonal variation in PV output.

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Thank You

Supplementary Slides

Hydrogen Refueling

Hydrogen compression, storage and dispensing costs adapted from the H2A forecourt models

System	Design Calculations	Values
Primary Compressor – One compressor assumed for both low pressure storage and cascade storage	Compressor design calculations taken from H2A forecourt model	~ 2.4 kW compressor power/(kg/h) H2 flowrate ~$6,000 /kW (for comparison, at 1500 kg/day the cost is ~1,800/kW, $3,900/kg/h)
Dispenser	Source: H2A forecourt models	~$64,000 installed
Cascade storage – One cascade system assumed	Total volume 65 kg H2 (in 3-tank system)	~$1,700 per kg
Low pressure storage	Volume varies by application	~$1,040 per kg

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Battery and Electric Vehicle information

System	Design Calculations	Values
Zinc Air Battery	Design based on maximum kWh in "storage" at any time during the year	$315/kWh installed
Electrical Upgrades and Charging Stations	5% of installed batter cost	
All Electric Vehicle based on the Nisson Leaf	100 mile all electric range	12,000 miles per year
PHEV	20 mile all electric range 40% of yearly miles traveled are all electric	12,000 miles per year

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Building Load Statistics

Building Load Statistics	
Demand maximum (kW)	125.3
Demand minimum (kW)	28.4
Demand average (kW)	65.4
Demand Stdev (kW)	22.8
Demand total (kWh/year)	572,518

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