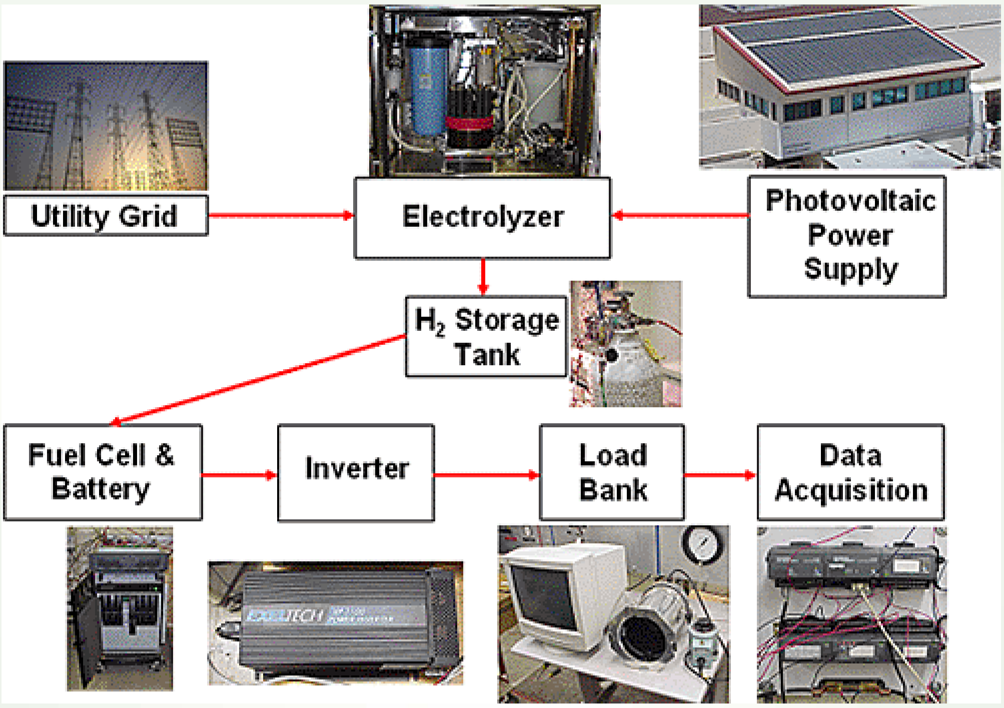
DYNAMIC MODELING
RESIDENTIAL DATA AND APPLICATION

The introduction of the reversible or regenerative fuel cell (RFC) provides a new component that is analogous to rechargeable batteries and may serve well as a replacement for rechargeable lead acid batteries when integrated with solar photovoltaic (PV) systems used in residential applications. A RFC can operate in both fuel cell (FC) mode to generate electricity and in electrolyzer (EZ) mode to produce hydrogen and oxygen from water. The hydrogen generated can then be stored to meet electrical demand at the appropriate time or used as a multi-purpose fuel in other applications such as cooking, heating, and transportation. One of the inherent advantages of the RFC over batteries is that energy storage can be decoupled from the energy conversion device. This comes from the ability to store hydrogen energy in a tank, separately from the FC. This should result in longer term energy storage capability compared to batteries. To better understand the RFC’s response to the dynamics of residential applications, experiments were run on both an EZ coupled to a PV array and a FC connected to an AC load. The goal of the study is to assess the response of the EZ and the FC to dynamic power input and power demand, respectively.

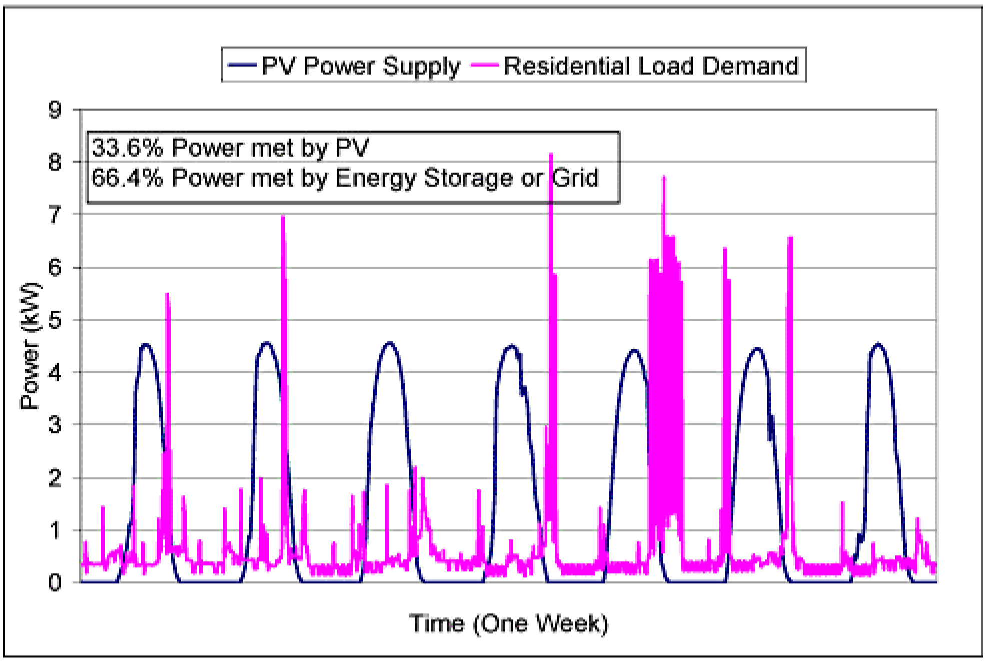
Results show that the EZ was able to produce hydrogen from the PV array provided 750 W was available upon start-up and 250 W was available upon shut-down. When PV availability dipped below 250 W for over 10 minutes the EZ was unable to maintain its system pressure and would shut down. The FC system studied functioned in parallel with a battery bank, as such it is an hybrid energy storage device. The FC operated as a base-load device and battery charger, while the battery operated to meet highly dynamic load demand. As such, the FC system was able to ramp at very fast power rates up to 842 W/s. Energy density of the FC system was limited to both stored hydrogen capacity and by a minimum FC system operational voltage of 41.5 V.

Experimental Schematic and Components



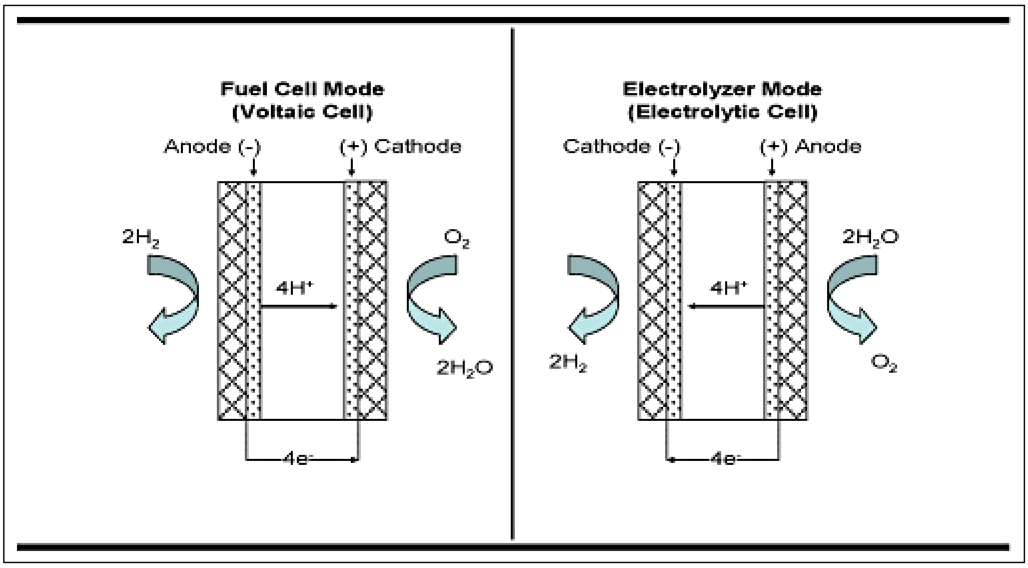
BACKGROUND

Energy storage is needed to supply the majority of power demand in residential stand-alone photovoltaic systems

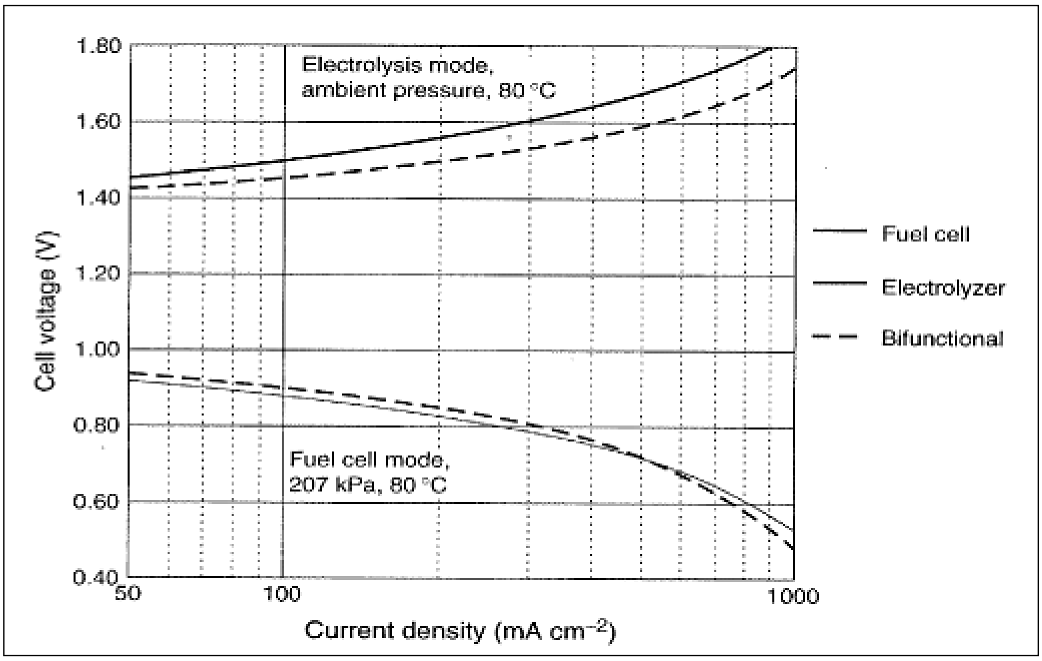


Photovoltaic power supply (5kW Unisolar a-Si array) and residential power demand (Irvine, Ca family residence). August 2003

Reversible fuel cell function is analogous to that of a rechargeable battery

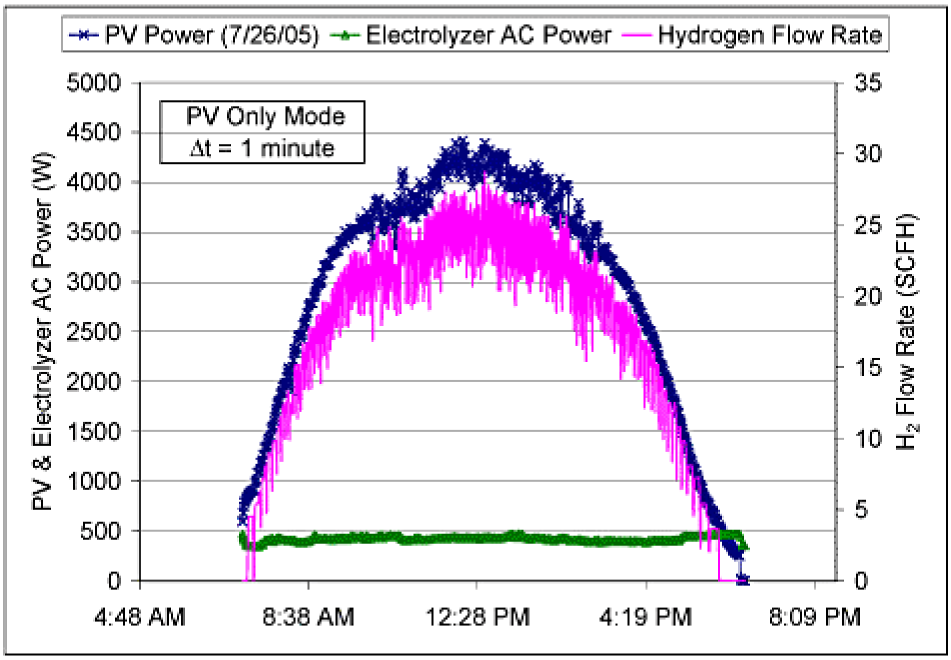


The advantage of a reversible fuel cell over a rechargeable battery is potentially greater energy storage capacity



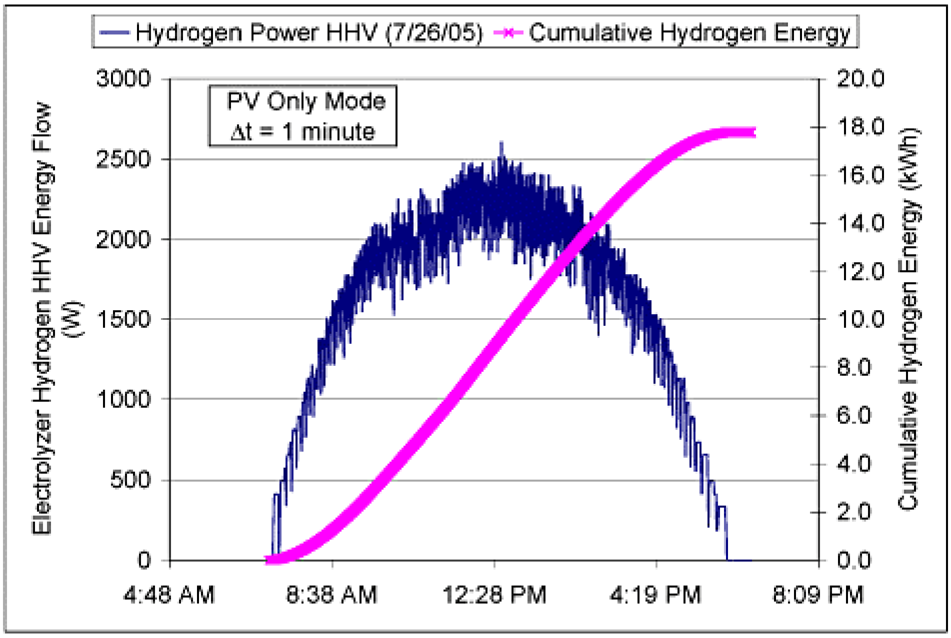
General reversible fuel cell V-I performance curves. (Giner Electrochemical Systems)

The 10 kW electrolyzer can generate H2 as long as the PV array provided 750 W upon start-up and 250 W upon shut-down



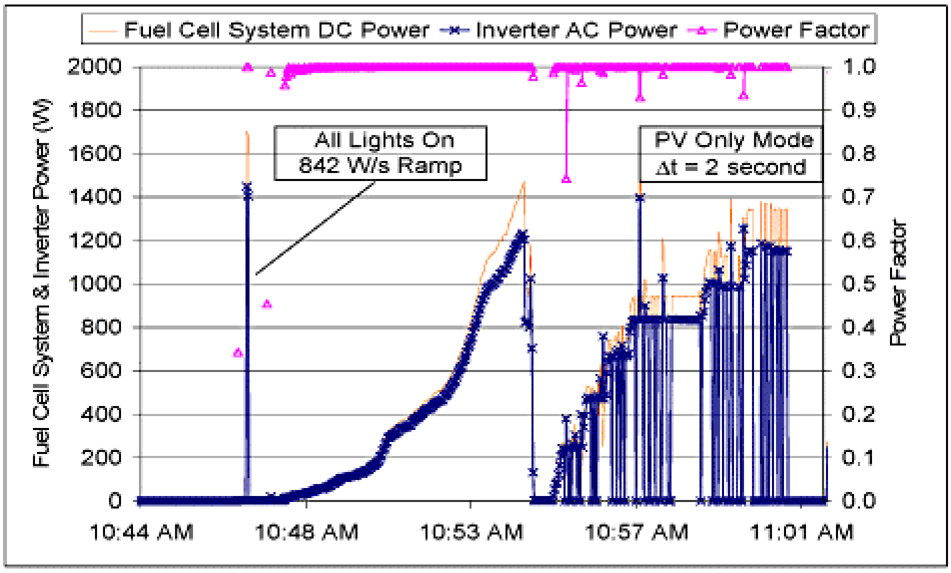
H_2 flow rate follows the solar availability. The electrolyzer consumes ~470 W of AC power from the grid regardless of operational mode

18 kWh of H2 energy was produced by the electrolyzer on a typical summer day



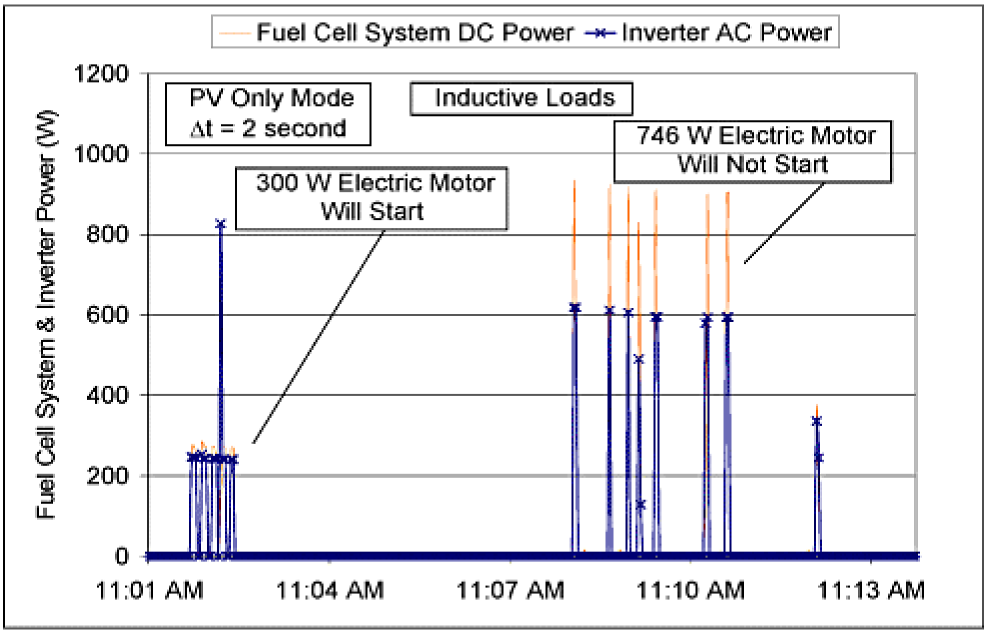
$H_2$is generated at 200 psig

The 1 kW fuel cell system can meet dynamic load demand. Power rates of 842 W/s were met, indicating that meeting the max rate of 857 W/s seen in the residence is feasible



RESULTS

The fuel cell system can meet inductive and capacitive loads



A 1 HP motor start proved impossible for the fuel cell system due to high in-rush current

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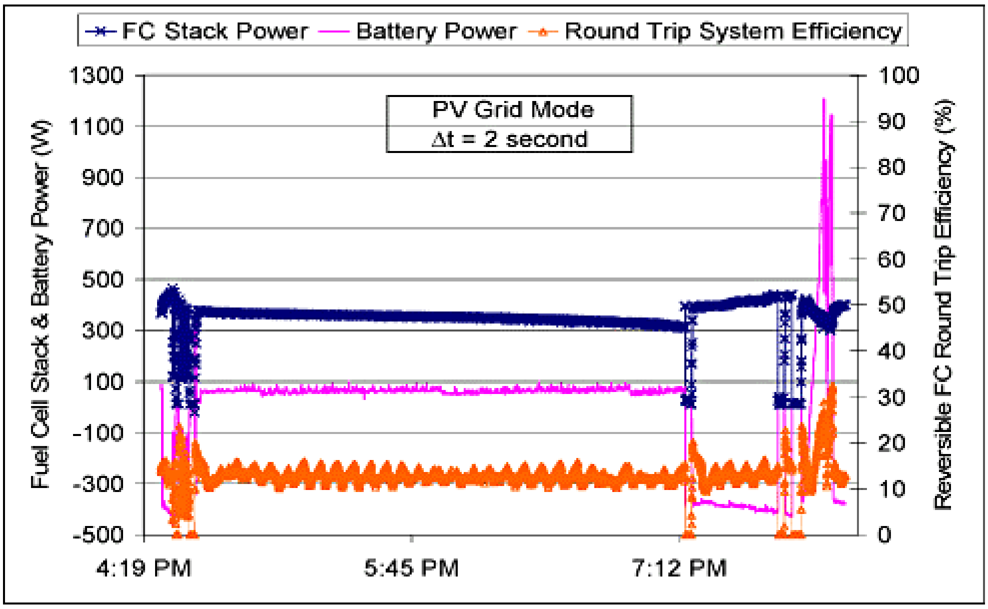
The fuel cell stack operates as a base-load device and battery charger. The battery operates to meet peak demand



Round trip system efficiency was 13% under a 370 W load but increased to 33% with battery use

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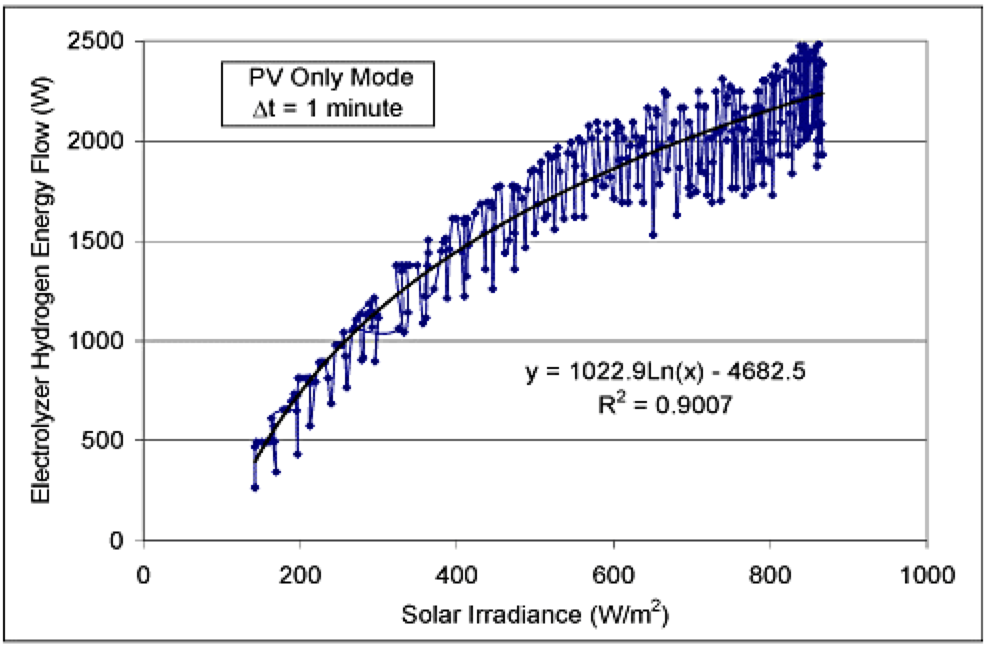
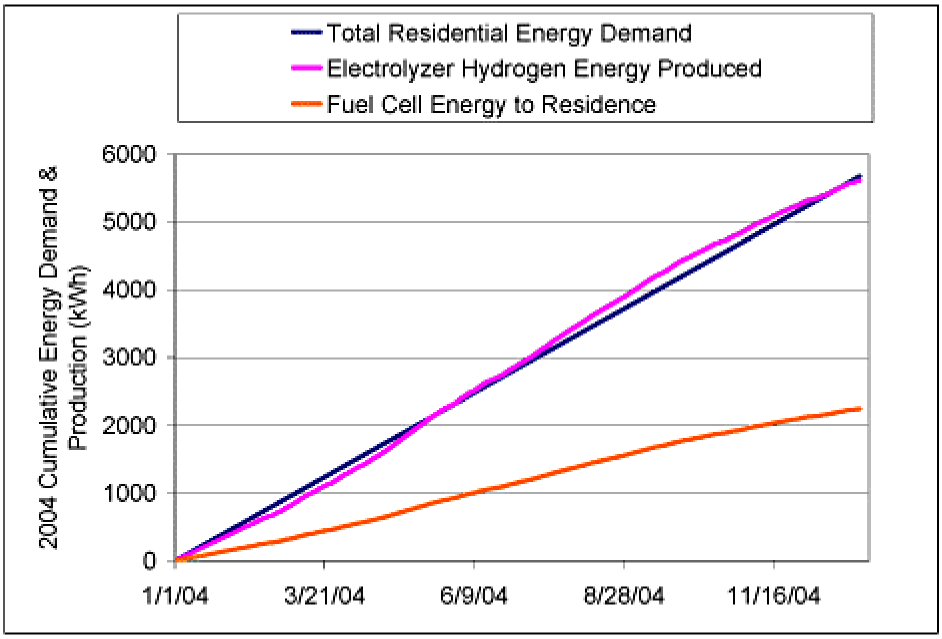
A correlation was determined between electrolyzer H_2 energy production and solar irradiance



Yearly residential energy needs (assuming 15.5 kWh/day demand) can be met in terms of raw H_2 energy produced from a 5 kW PV array. Assuming all H2 can be stored, a 40% efficient fuel cell can meet 40% of residential demand



CONCLUSIONS

- The fuel cell system can meet the dynamics found in typical residential loads
- However, the high power rates were met by the battery in the fuel cell system
- The electrolyzer was able to capture the majority of available PV energy as long as the electrolyzer system pressure is maintained
- Round trip efficiencies of the RFC system were low compared to rechargeable batteries
- A 5 kW PV array can produce H_2 energy equivalent to residential needs
  A fuel cell used to power the residence can meet 40% of energy demand

RECENT PUBLICATIONS

"Understanding the Dynamics of Renewable Reversible Fuel Cell Power for Residential Applications“ J.D. Maclay, J. Brouwer, G.S. Samuelsen, 15th National Hydrogen Association Conference, Paper # 76522, April, 2004.

“Regenerative Fuel Cell Power for Potential use in Renewable Residential Applications” (Submitted to: Int’l Journal of Hydrogen Energy)

PERSONNEL

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SPONSORS

U.S. Department of Energy
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