

# Small Scale Renewable Energy Power System with Hydrogen Combustion

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# Outline

- Background/Rationale
- System Description
- Testing
  - Performance
  - Efficiency
- Suggested improvements
- Applications
- Summary

# Background

- Estimated 10,000 Off-Grid locations in Nevada
- Cost of up to \$500,000 for grid connection in remote locations

# Project Objective

- Design, build and test a small scale renewable energy power system.
  - Solar and wind renewable sources
  - Batteries, hydrogen and propane



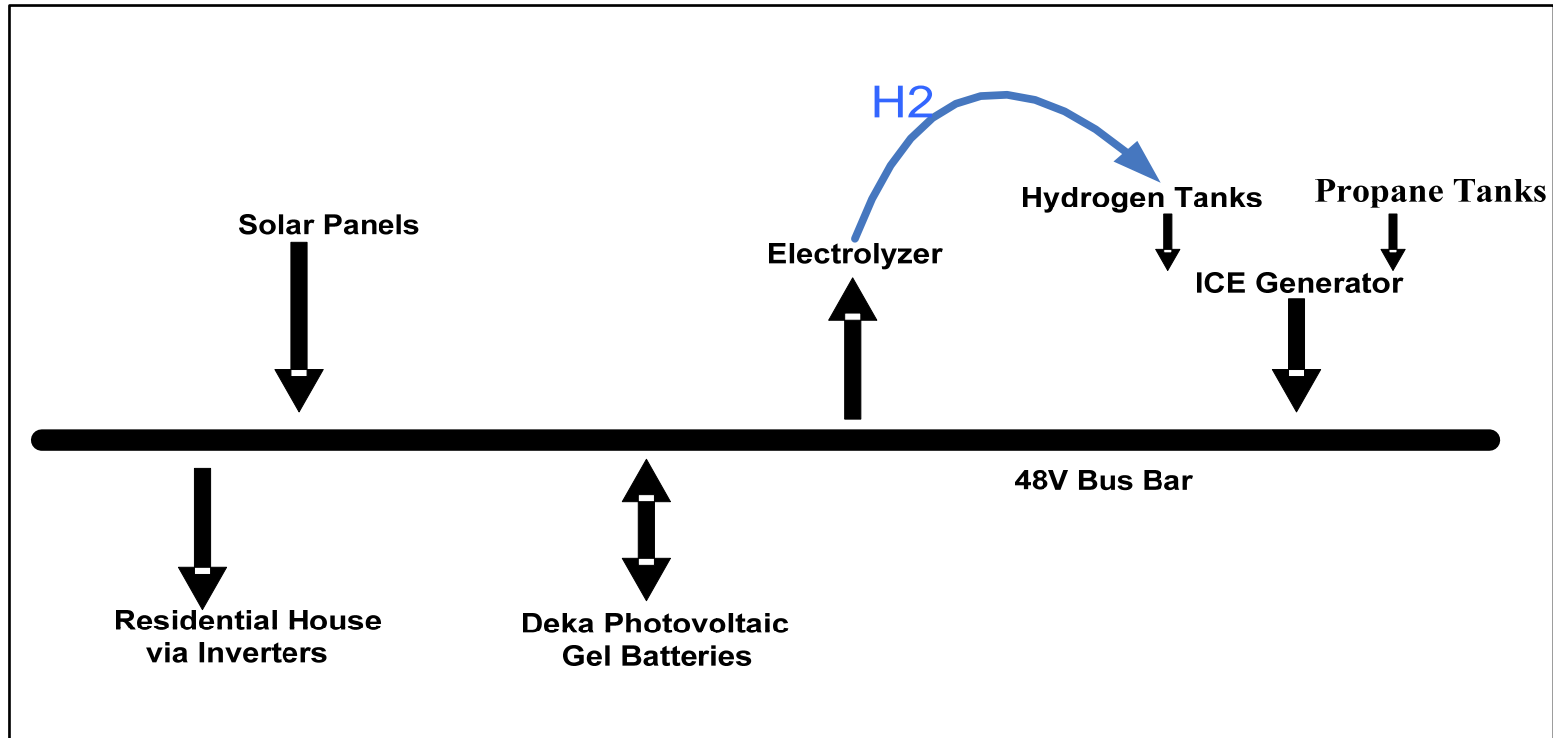
# Applications

- Residential and industrial (i.e. mines) off-grid locations
- Military uses
- Remote scientific experiments requiring energy
- Natural disasters

# System Design

- Existing external renewable energy sources
- Power system located in mobile trailer
- Hydrogen, Propane and batteries for 24/7 power security
- Mobility avoids permitting

# System Schematic



# Trailer Picture



# Components

- Dual inverters (48 VDC to 120 VAC)
- 1.3 kWhr energy in twelve 12 VDC gelled-electrolyte battery bank
- Proton Energy HOGEN 600 Electrolyzer and Stuart KOH electrolyzer
  - Off the shelf, designed for laboratory use
- 4 hydrogen tanks in trailer and 1 permanent hydrogen tank
  - Two propane tanks on front of trailer
- Dual fuel ICE-Hydrogen/Propane
- Solar panels and wind turbine

# Engine vs. Fuel Cell Decision

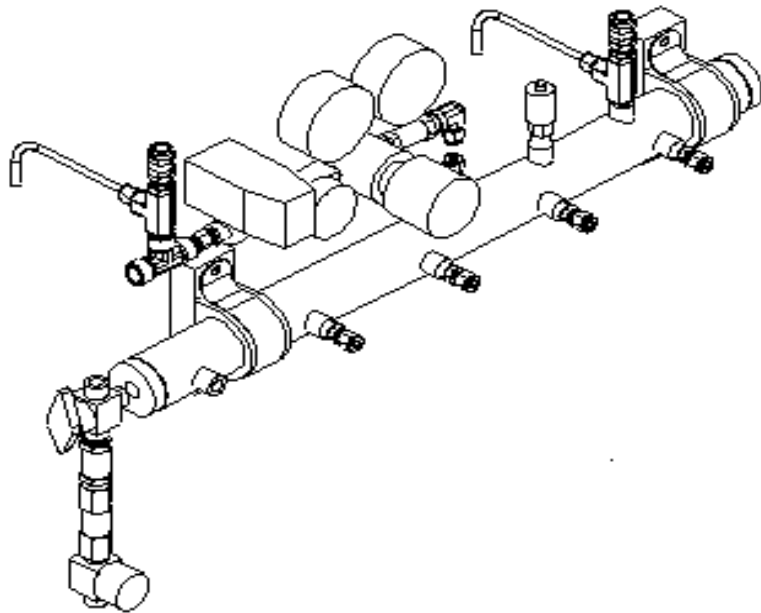
- Based on previous projects and nature of project
- Fuel Cell previously tested
- Cost at start of project 5 years ago
- Customer maintainability
- Power security-multiple fuels
- Longevity/Reliability

# Hydrogen Production

- Proton Energy HOGEN 600
  - Produces 600 cc/min H<sub>2</sub> at observed 500W
  - Backpressure regulator and mass flow control
  - Designed for laboratory use
  - .03 kg/hr at 1500 W consumption
- Stuart KOH
  - Stationary in cargo container at DRI
  - .1 kg/hr H<sub>2</sub> at 5 kW consumption

# Hydrogen Storage

- Four small gas storage tanks
- 200 PSI (from electrolyzer)
- Capacity of .2 kg Hydrogen
- Manifold for distribution and monitoring



# Hydrogen Combustion

- Lister Petter
  - 2 cylinder 4 stroke, carbureted, turbocharged
  - Converted by Collier Technologies
    - Modified ignition system & spark
  - Dual fuel hydrogen and propane
    - Individual spark timing
  - Computer Unit Controls
- Stanford AC Generator
  - 1800 RPM

# Test Location 1

- Residence in SW Reno, NV
  - 1.5 kW tracking solar array
  - HOGEN 600
  - Trailer hydrogen storage tanks
  - 21 kW-hr/day Winter Load demand

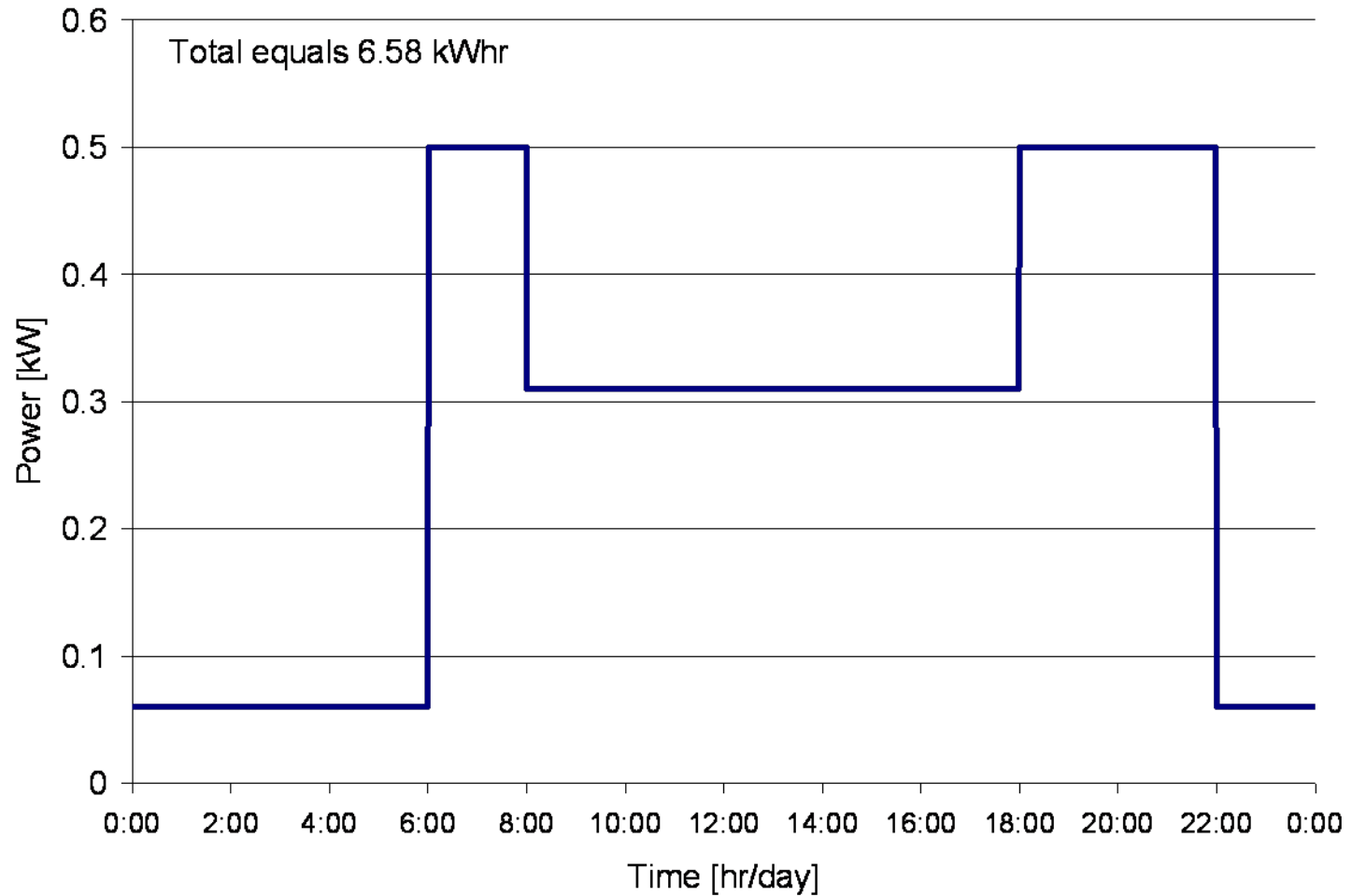


# Test Location 2

- Desert Research Institute
  - Two 1 kW rated tracking solar arrays and two 1.5 kW wind turbines
  - HOGEN 600 and Stuart Electrolyzer
  - Trailer hydrogen storage plus stationary hydrogen tank
  - 6.5 kW-hr/ day summer load demand



# Test Load Demand



# Performance

- Site 1
  - Load demand too large for system
    - No access to second solar array
  - Load bank as demand
  - Some continuous operation and some system faults over 1 month
  - six 40-90 minute engine cycles required per day or ~2 kg hydrogen
- Site 2
  - Appropriate load demand
    - Extra hydrogen production and storage
  - Load bank as demand
  - Power security
  - Two 50 minute minimum engine cycles required per day or ~.65 kg hydrogen
- Future design would require more capacity

# Test Requirements

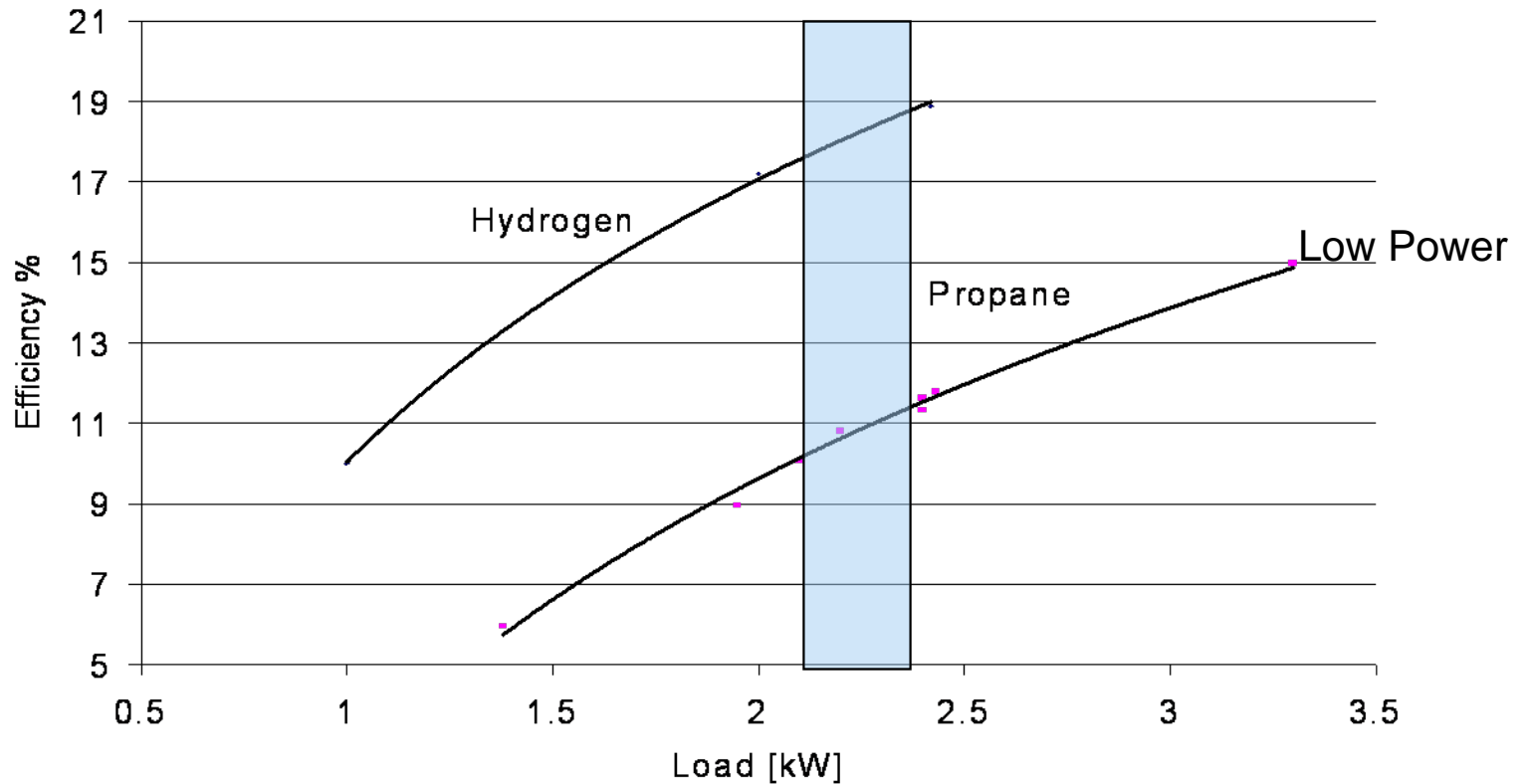
## 6.5 kW 24-hour Summer Load Profile

<u>Item</u>	<u>Description</u>	<u>Quantity</u>	<u>Supplied Power (kW)</u>	<u>Power Consumption (kW)</u>
Renewable Energy	Solar or Wind	3	3.00	
Battery	12 VDC Gelled Electrolyte	12	1.3	
Electrolyzer	Proton Energy HOGEN 600	2		3 kW
H2 Storage	200 PSI storage tank 1 m <sup>3</sup>	1	(.66 kg/day H2 in Summer)	90,000 BTU Hydrogen
Engine	ListerPetter 2 cylinder Genset	1	3- Propane 2.5- Hydrogen	.32 kg/cycle, 1 cycle is 50 minutes, 2 cycles per day
Propane Backup	25 lb. Propane Tank	2		1,000,000 BTU

# Efficiency

Power Output

BTU's of Fuel



# Suggested Improvements

- Simplify for cost reduction
  - Controls
  - Electrolysis
    - Maximize efficiency/Wrong application
- Fuel cell improvement since project began
- New technologies
  - Hydrogen storage
  - Ultra-capacitors
  - Engine improvements

# Summary

A reliable and robust mobile R.E. power system with hydrogen combustion was developed and tested

- Used available technologies
- Integration and mobility key aspects
- Engine reliability biggest issue
- Costs still high
- 1<sup>st</sup> step for production
- Power security for a wide range of applications
  - Energy source on site
- Waste heat for hot water system

# Acknowledgements

- NREL - Financial support
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# Questions

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