Self-recharging fuel cells and the Hydrogen battery :

Homer's contribution in hydrogen adoption for reliable power

Introduction, who am I?

- Horizon, An Asia-rooted international team / founded 12 years ago in Singapore
- The world's largest producer of fuel cells <1kW today; moving to 5-10kW
- Supplies the most competitive and reliable fuel cells in the world today
- Commercial success substantially a result of developing various on-demand hydrogen solutions to overcome the "hydrogen supply problem"
- Began with micro-sized systems and moved towards increasingly larger, complex systems

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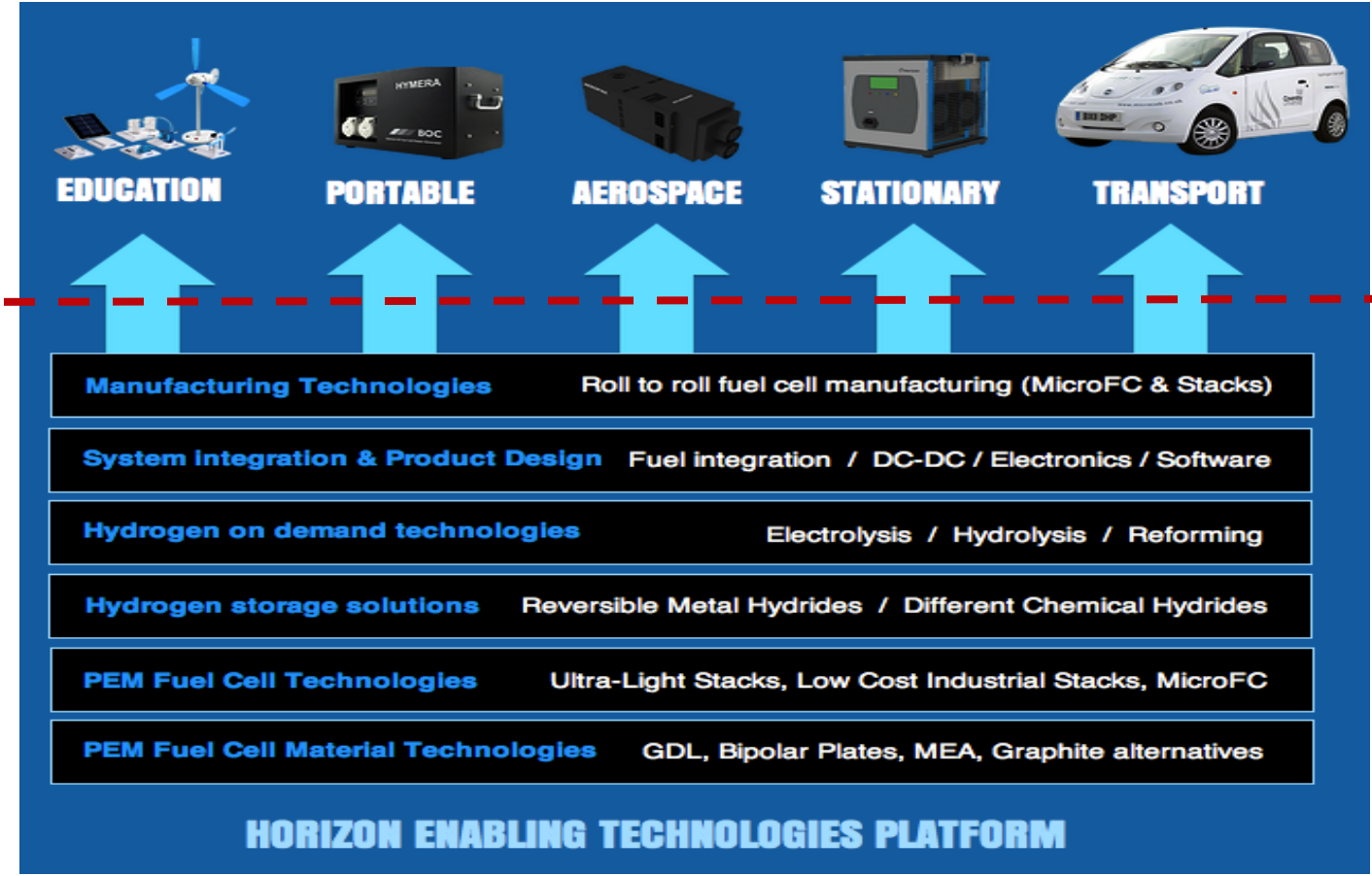
Horizon uses our deep technology platform to serve multiple markets

Markets Being Served



Technology Platform & Component Supply Chain

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Solving the “H2” supply challenge by using other feedstock to create H2

Fuel cell power output (W)

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- Continuous reduction in fuel costs
- Increased environmental benefits
- Opening increasingly large markets

Where we are now

NABH4 $40/cartridge

NABH4 $10/cartridge

H2 generation NABH4 Solution

H2 generation From Alcohols

H2 generation from Propane or Natural Gas

H2 generation From biogas

H2 generation from Liquid chemical hydride

H2 generation from Solid chemical hydride

3L/h

H2 Generation from PEM Electrolysis

50-1000 L/h

$/Wh competition from battery or diesel incumbents

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Back up power requirements only partially satisfied today

Current solutions are predominantly based on lead acid batteries and diesel generators

- **Limitations of lead acid batteries**
  - Short life expectancy, high replacement cost
  - Poor performance at low temp and high temp, air-conditioning sometimes needed
  - Cost increases in linear fashion when more backup time is needed
  - Environmental concerns with used batteries

- **Limitations of diesel generators**
  - Frequent maintenance required
  - Polluting, very noisy, subject to numerous regulations
  - Fuel theft in developing countries
  - Stale fuel replacement costs

Known barriers for fuel cell back up power commercialization

Despite offering a clean solution with longer backup times
and often lower life-cycle costs than batteries,

Today's well-known Fuel Cell systems still have some shortcomings:

- Relatively high CAPEX, requiring substantial payback period, so incentives are not sufficient for many customers to switch to Fuel Cell technology
- **The use of hydrogen cylinders involves complex and costly logistics, especially for remote sites; and storing high pressure hydrogen cylinders involves significant hazmat regulations and restrictions**
- Rooftop and indoor installations **are difficult due to weight, footprint issues and/or fuel storage regulations**

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How do Fuel Cells Work ?

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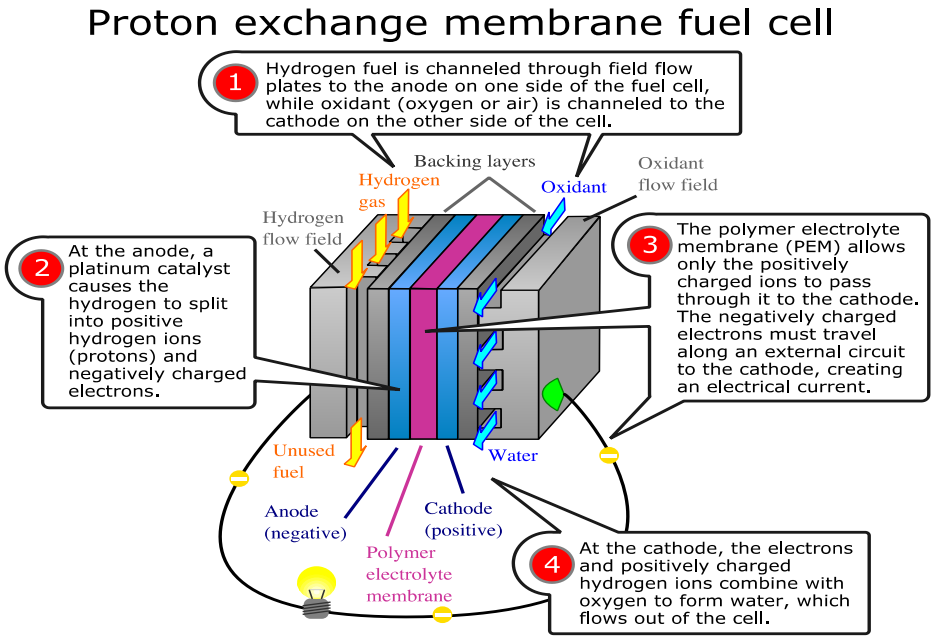
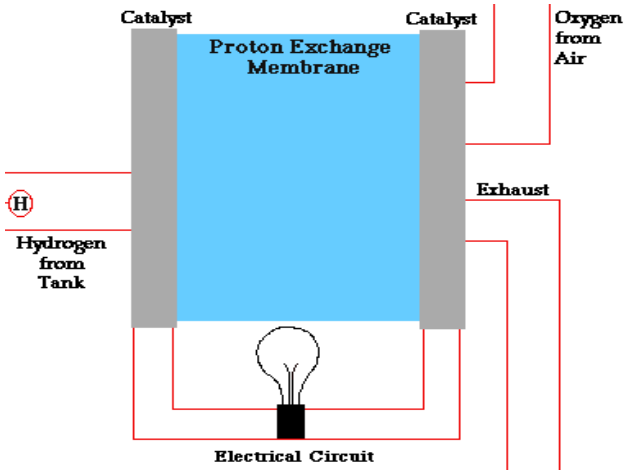
It’s a Electro-chemical reaction !





It’s a generator with no moving parts !

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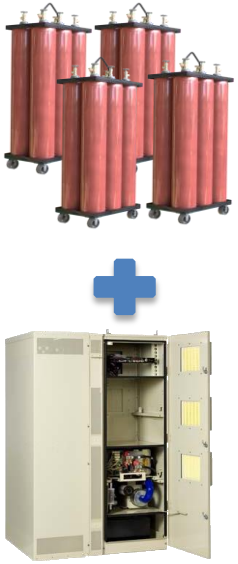
GenSet v's Fuel Cell V's SFRC

40 hours of operation per month at 5 kW load requires one of the following:

GenSet plus Diesel

Diesel tank refilled 2-3 times per month

OR



Fuel Cell plus 24 hydrogen cylinders

H2 cylinders refilled once per month

OR

SRFC

Self-Recharging Fuel Cell

No Fuel Deliveries

Onsite hydrogen – no fuel deliveries

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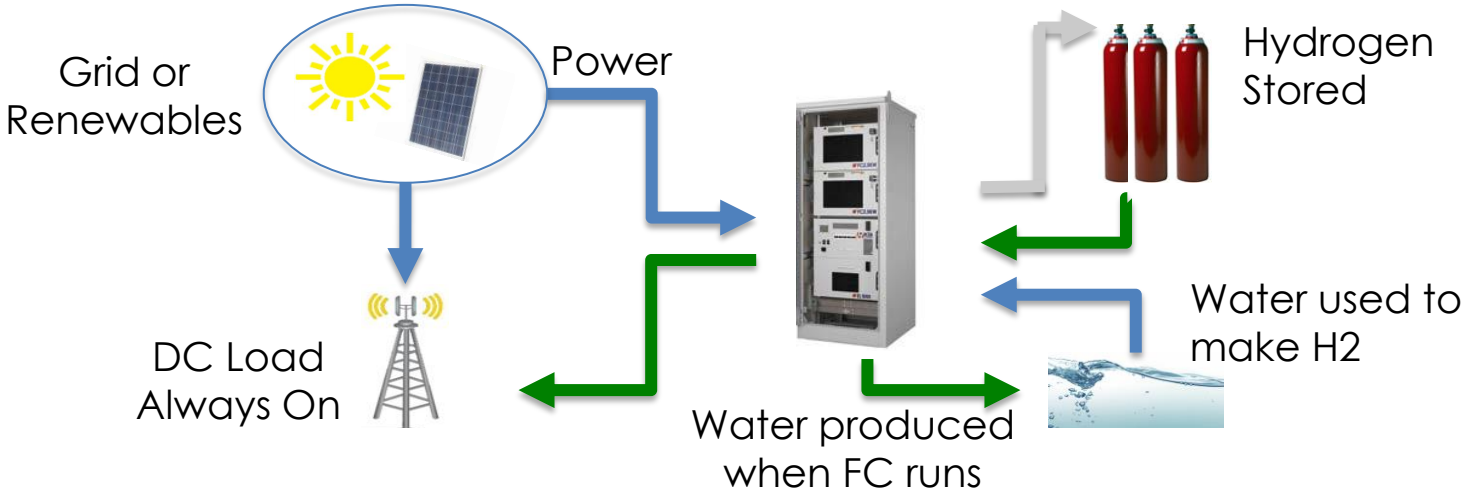
What is a self Recharging Fuel Cell ?



- ✓ SRFC is a closed system which is completely self-recharging.
- ✓ Whenever power is available it automatically generates its own hydrogen (and oxygen) from water using electricity/renewables.
- ✓ When the power not available, the Hydrogen stored is used to power the load
- ✓ There is no limit to the amount of Hydrogen you can store

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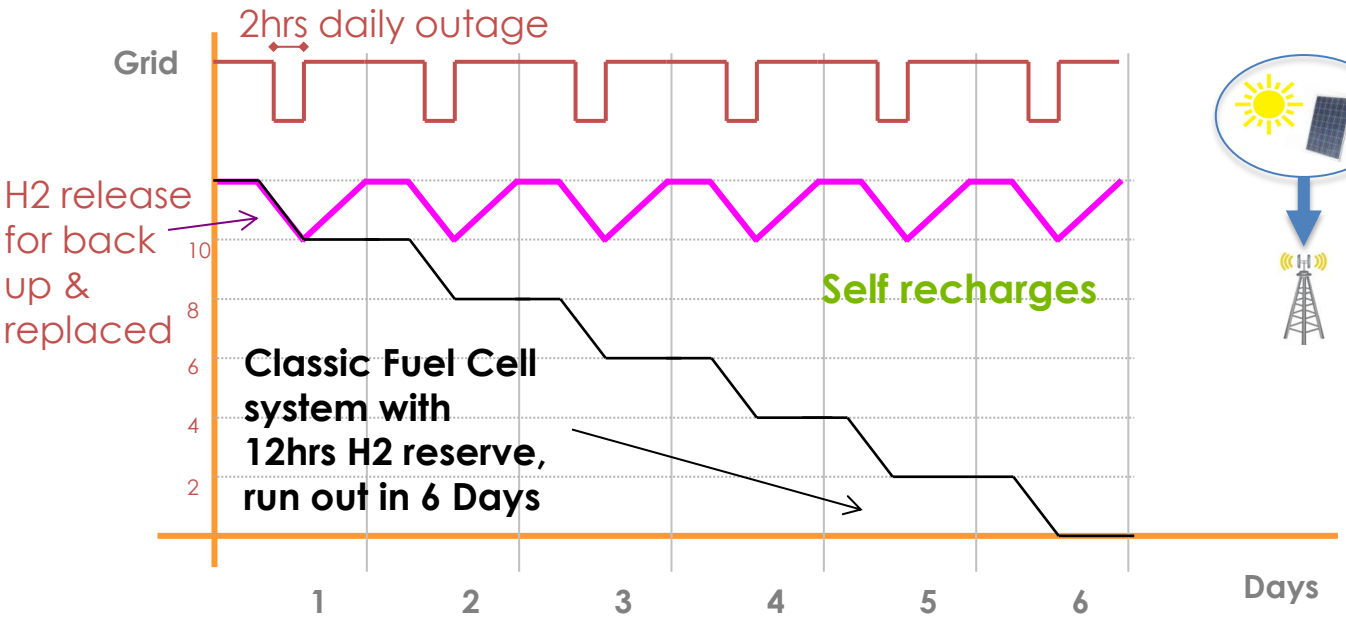
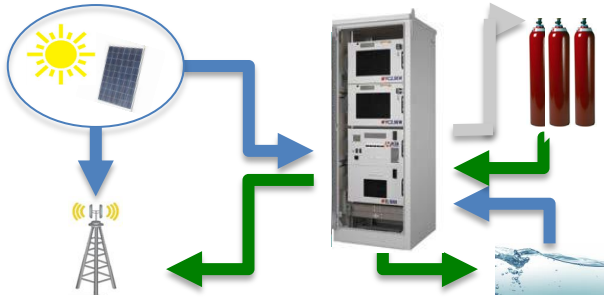
How does it work ?





- ✓ Unlike a classic Fuel Cell SRFC regenerates the fuel locally
- ✓ Well suited for frequent “short” blackouts
- ✓ Well suited to combine with renewable energy sources

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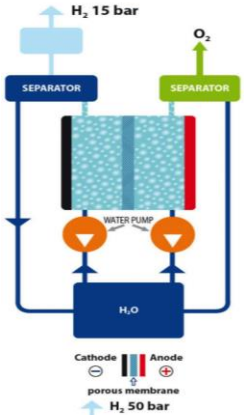
Electrolysis Technologies available today



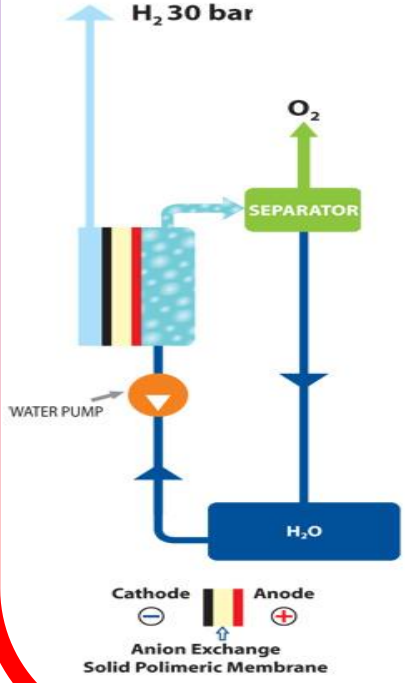
Alkaline Electroliser

- ✓ The work-horse of H2 production
- ✓ Non Noble Metals resulting in low cost
- ✓ Tap, rain water
- ⌘ Limited power fluctuation
- ⌘ Not ideal with renewables
- ⌘ KOH-H20 separation

PEM Electrolyser

- ✓ H2 above 30 bar
- ✓ Renewable power
- ⌘ High cost materials technology
- ⌘ Ultra Pure Water
- ⌘ H2O Separation

ACTA's AEM REVOLUTIONARY TECHNOLOGY



AEM Electroliser

- ✓ Non Noble Metals resulting in low cost technology
- ✓ Tap water, Rain water or Atmospheric water condensation can be used for off-grid
- ✓ Intermittent Renewable Power compatible (solar, wind)
- ✓ Energy efficient
- ✓ High Hydrogen Purity
- ✓ Hydrogen can be safely produced with output pressure above 30 bar without boosters.

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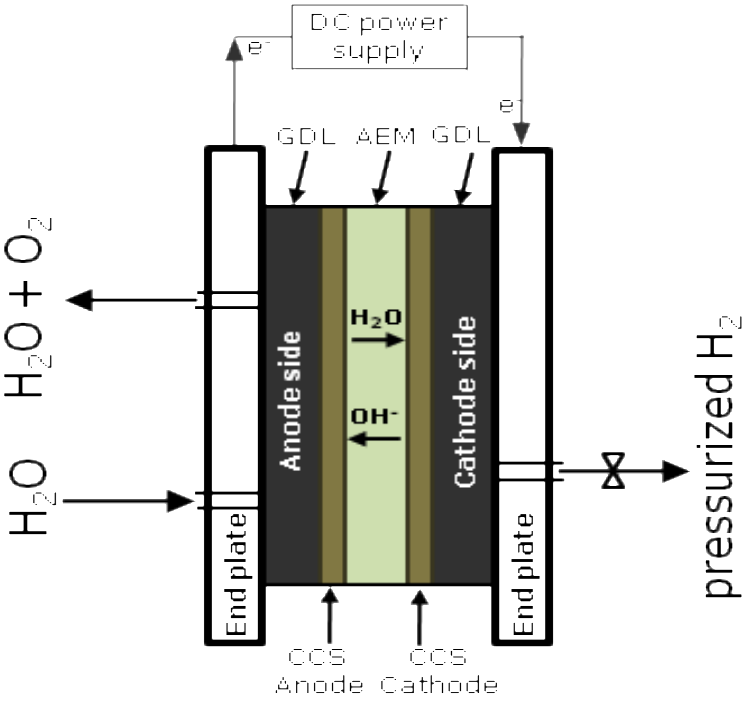
AES Stack technology

- ✓ Directly compressed hydrogen from ACTA's solid alkaline membrane technology
- ✓ Low cost - no noble metals - alkaline technology
- ✓ User friendly - no dangerously caustic electrolyte, filtered rain water possible for off-grid application.
- ✓ System simplicity and hydrogen purity resulting from dry cathode (hydrogen electrode)
- ✓ Flexible - can be directly connected to an intermittent power source (wind and solar)
- ✓ Product range currently from 100 Litres to 10m3 hydrogen production, per hour



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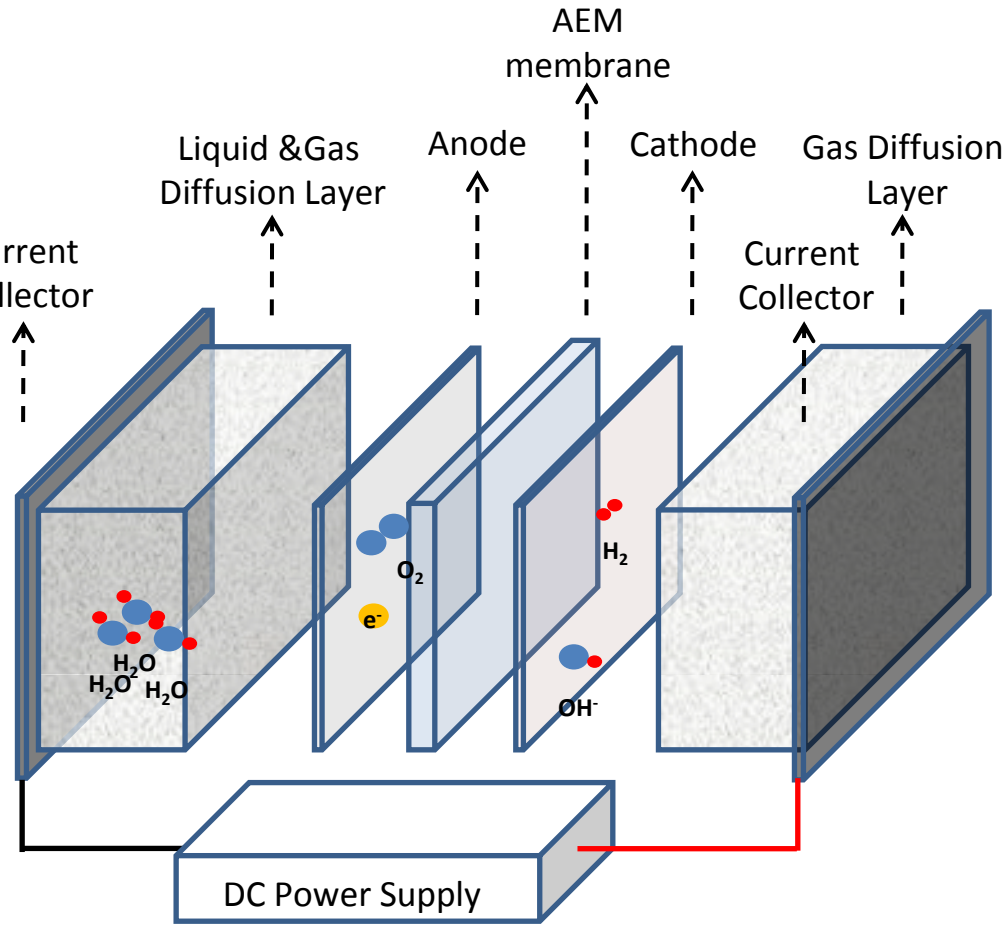
AES Stack technology (Animation)



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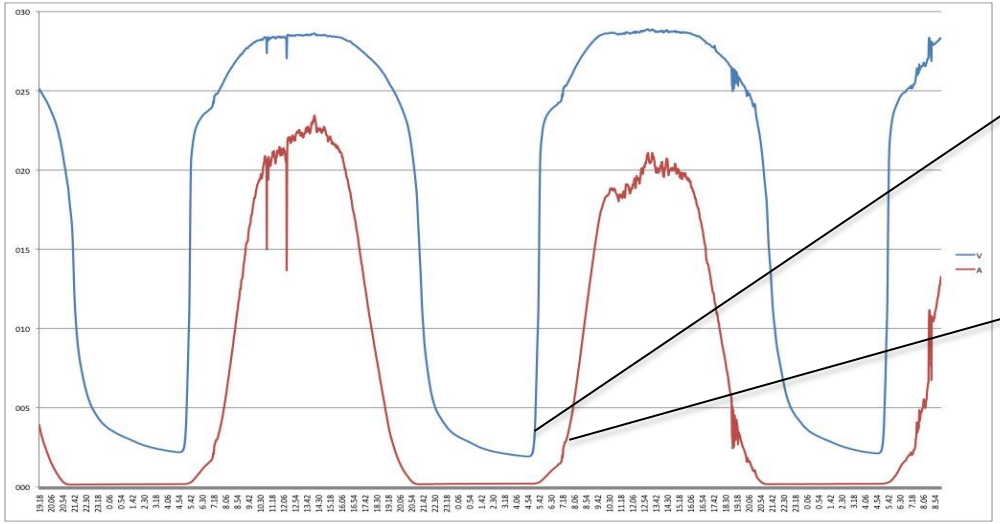
The Challenge !

- Renewable energy is ‘variable’ as a primary source of power, with no power when you need it, or too much at the wrong time. Batteries may be efficient at storing energy but the real issue is the cost and efficiency of charging these, while at the same time providing the autonomy needed.
- We need to use technology that exploits Hydrogen fuel’s potential as a ‘energy store’, in combination with renewables.
- Produce Hydrogen during periods when the available energy from renewables is in excess of the needs of the load
- Use Hydrogen to produce electricity during periods in which the available energy from renewables is available in quantities less than the needs of the load.
- Use of SRFC ability to operate and collect Hydrogen even during times of the day when the energy production is low, thus maximizing renewable efficiency.

Solar & Hydrogen production



Voltage from Solar

Hydrogen production Starts here

- ✓ Solar panels generate power during sunlight hours however much of the time most of this energy is not utilized as there has not been a viable way to do capture and store this. Solar/Battery configurations are designed to make best use of sunlight during the worst days hence large panels and batteries are needed as the site load requirements increase.
- ✓ Existing Batteries are typically recharged in a 3.5 hour window during the peak solar output in a sunlight day. The balance of the solar energy is in effect wasted.

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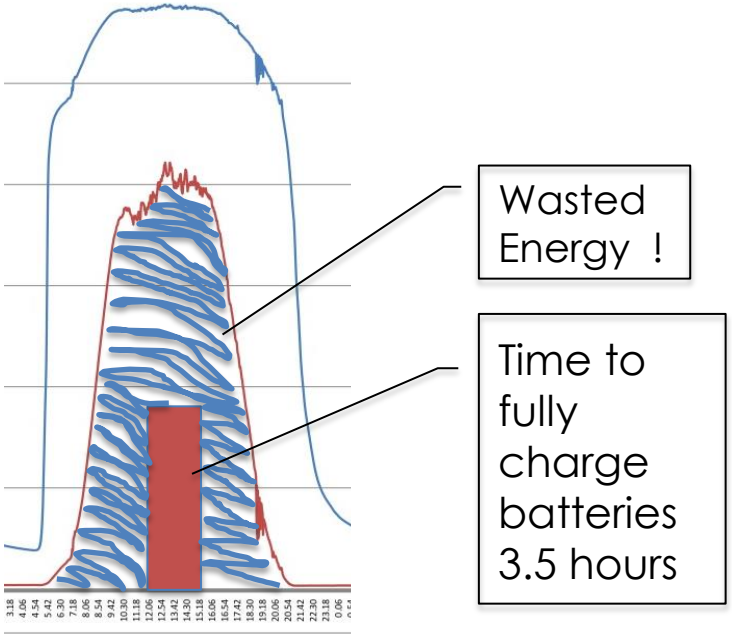
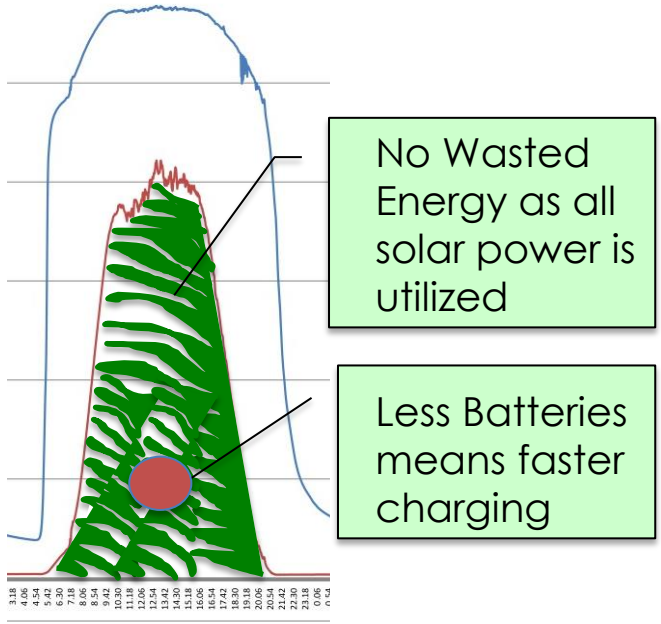
Hydrogen as an energy store





- ✓ The use of Hydrogen as an a energy store and the design of the self recharging Fuel Cell system, allows us to fully utilize all available power available through solar production, even low power generated at the start and end of the day or in cloudy conditions

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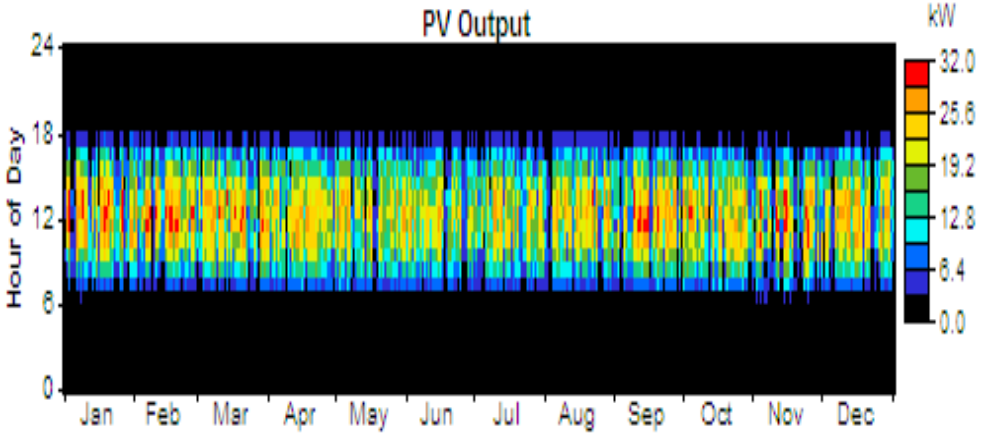
Example - S.E. Asia Off-Grid Schools Project

Daily Energy = 97kWh
Peak Power = 10kW

The hybrid FC-Battery System Includes:

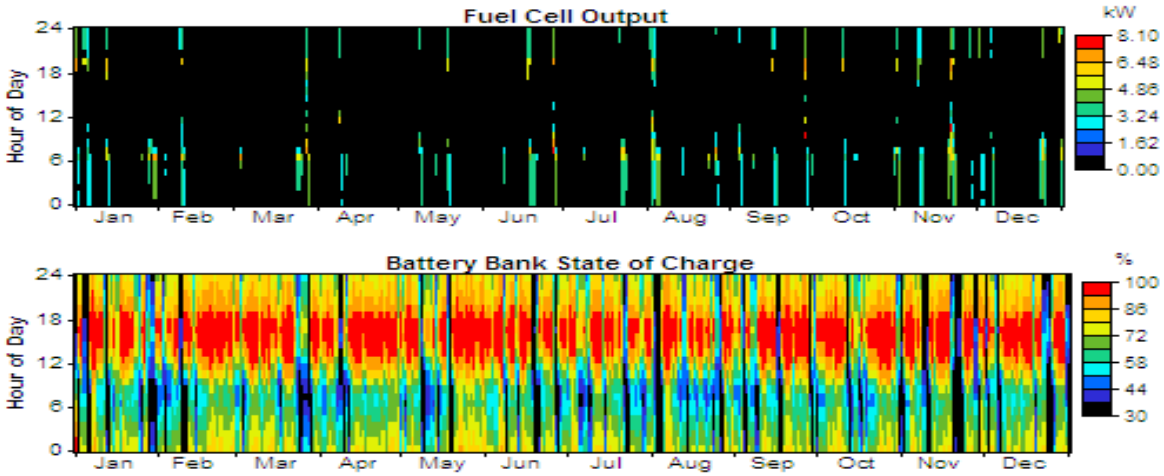
- Rain-water collection and treatment
- 38,5kWp Photovoltaic plant *
- No. 2 x Fuel Cell's (5kW FC modules, 1m3/h Electroliser)
- No. 2 x 3000 liter Hydrogen Tanks
- No. 1 x 1000 liter Water Tank
- modular battery charge controller
- modular 3-phase inverter (18kW,)
- modular 2500Ah Batteries



Quantity	Value	Units
Rated capacity	38.5	kW
Mean output	6.09	kW
Mean output	146	kWh/d
Capacity factor	15.8	%
Total production	53,320	kWh/yr

Fuel Cell Data – FC and Batteries , Hourly Charts

Quantity	Value	Units
Hours of operation	562	hr/yr
Number of starts	94	starts/yr
Operational life	7.12	yr
Capacity factor	2.49	%
Electrical production	2,184	kWh/yr
Mean electrical output	3.89	kW
Min. electrical output	3.00	kW
Max. electrical output	8.08	kW
Hydrogen consumption	100	kg/yr
Specific fuel consumption	0.046	kg/kWh
Fuel energy input	3,348	kWh/yr

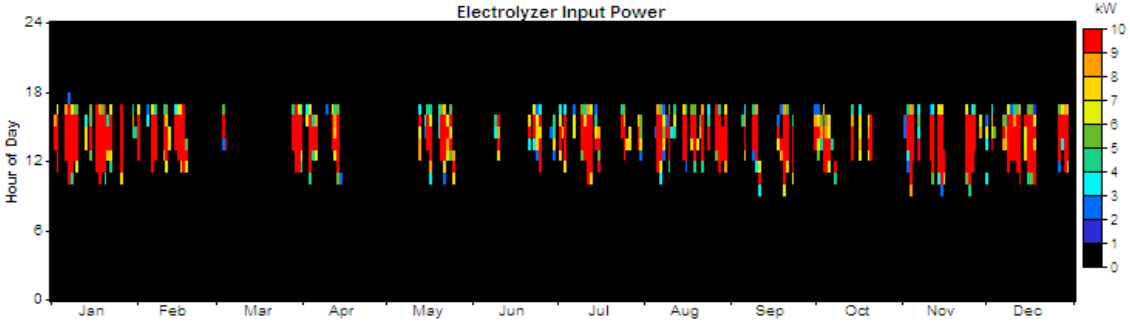


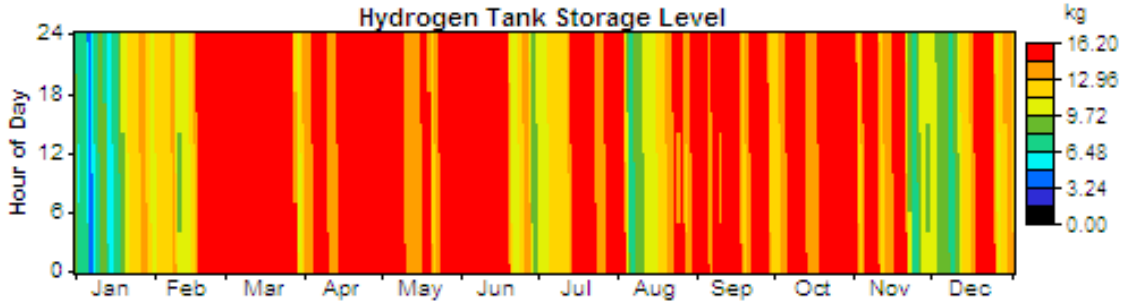
The Fuel Cell starts when the battery's State of Charge is near the 30% set as minimum level. The battery is not recharged by the Fuel Cell that is operating in following the load.

Electrolyser Data - EL and H2 Tanks , Hourly Charts

HYDROGEN TANKS DATA		
Quantity	**Value**	**Units**
Hydrogen production	103	kg/yr
Hydrogen consumption	100	kg/yr
Hydrogen tank autonomy	134	hours

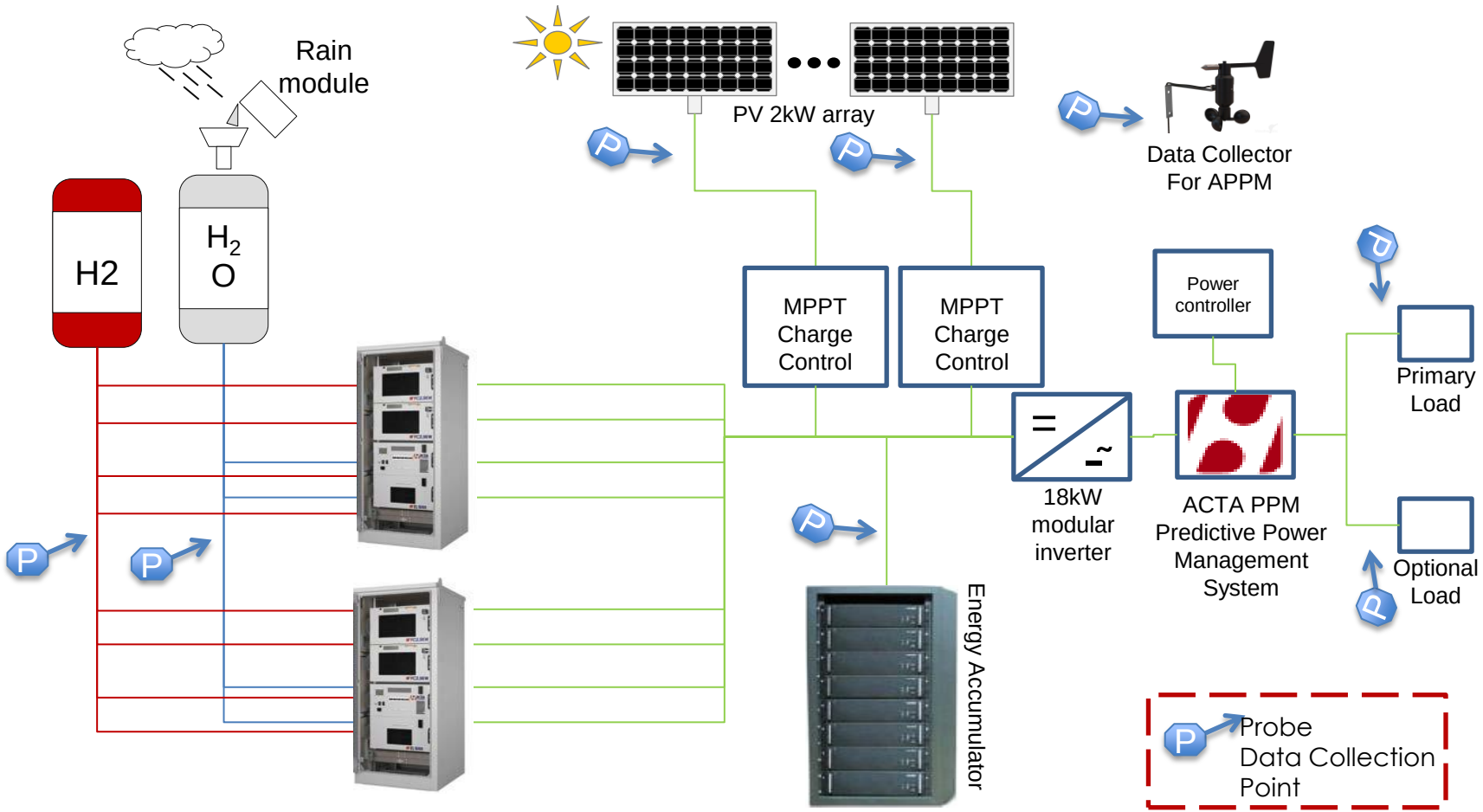
ELECTROLYSERS DATA		
Quantity	**Value**	**Units**
Rated capacity	10.00	kW
Mean input	0.66	kW
Maximum input	10.0	kW
Total input energy	5,757	kWh/yr
Capacity factor	6.57	%
Hours of operation	710	hr/yr





The charts above show the Electrolyser's operation and the Hydrogen stored. At the end of the year the final Hydrogen quantity is higher than the initial condition.

Example - S.E. Asia Off-Grid Schools Project Design



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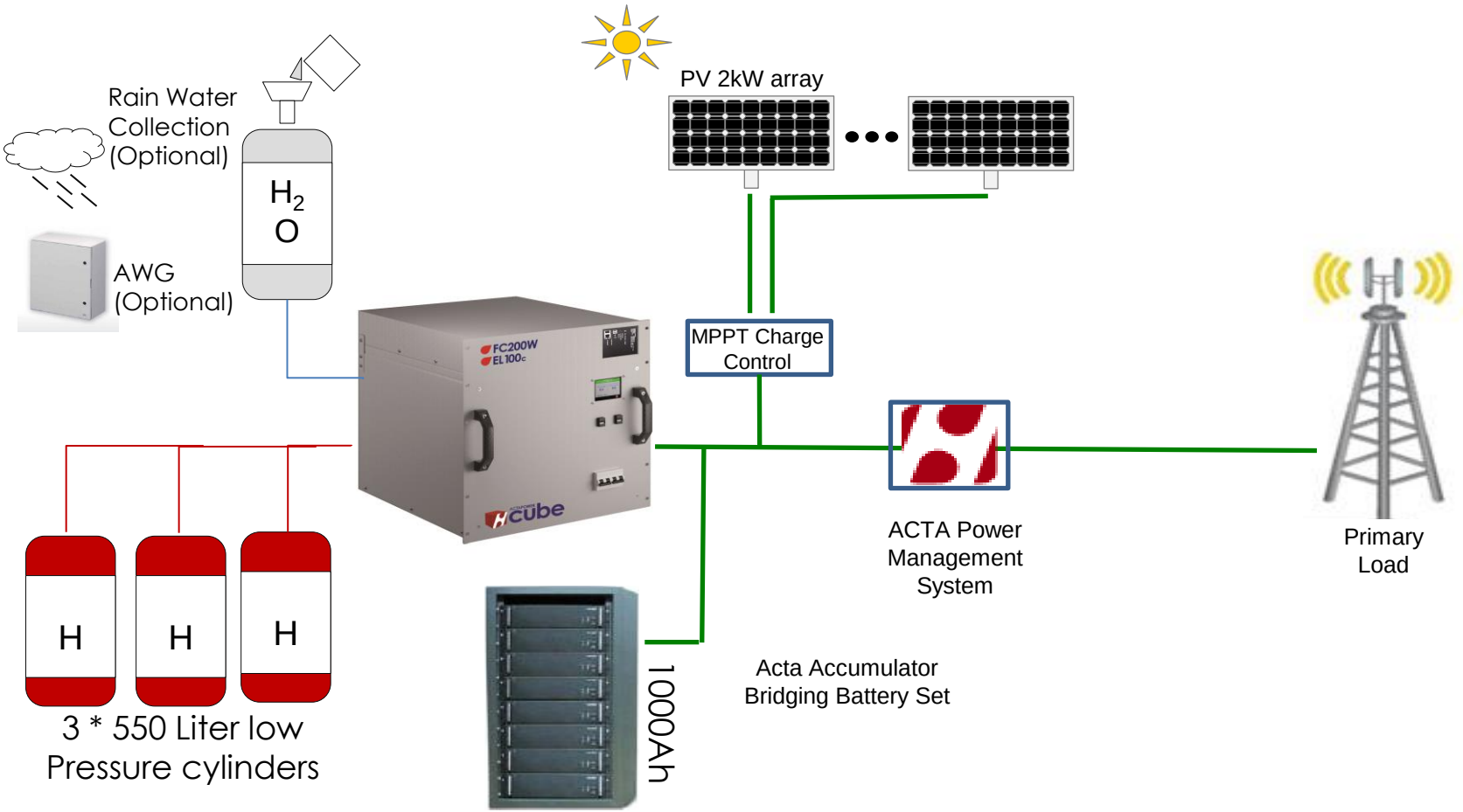
Example Configuration 1kW Off Grid Telecom site



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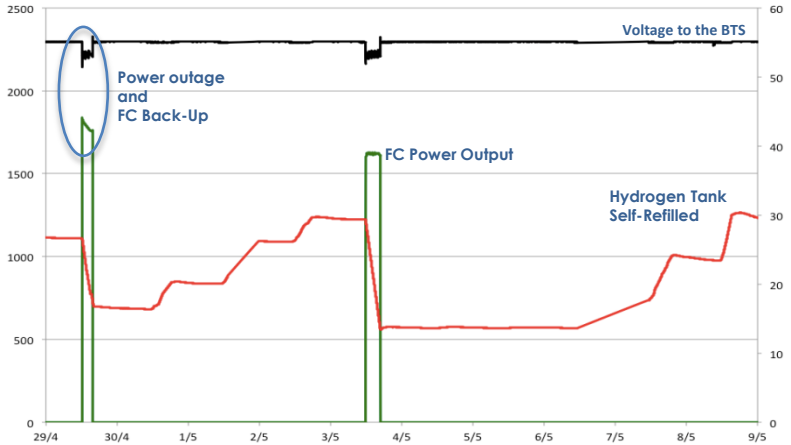
SRFC in Action, Telstra Australia

SRFC has a proven enabling technology for the hydrogen energy market:

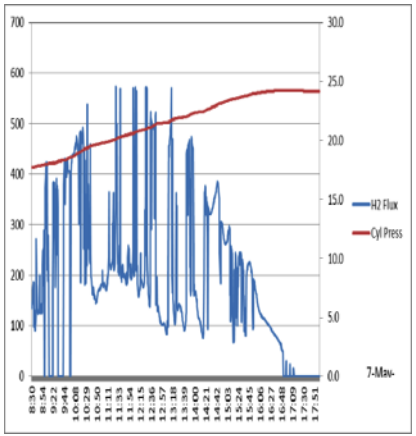
- Low cost, reliable, efficient
- Renewable, grid or intermittent power
- Designed for in-field installation

29 Apr- 9 May Operating data from in-field SRFC

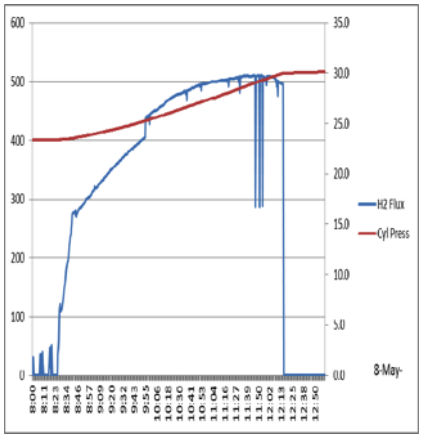
10 Days Graph from Acta Power Web Interface



H2 Production Cloudy Day



H2 Production Sunny Day



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Pui Suea

CHIANGMAI GREEN RESIDENTIAL HOUSING PROJECT

Create a technologically advanced and energy self-sufficient housing complex.

- Sustainable construction
- Using renewable energy
- Reaching high-quality living environment with low CO2-Impact
- Different smart home automation systems
- Large permaculture garden with rice field and fish pond
- Rainwater collection, eco-friendly water treatments
- Growing and planting endangered trees and plants.
- Building process social and ecological

Energy House Building

Total installed PV power 118kW

Family Home
3 PV fields on flat roof:
Field 1: 2 rows to 8 modules and
1 row to 4 modules = 38.80m2;
20 modules x 315W = **6.30kW**
Field 2: 3 rows to 6 modules = 34.92m2;
18 modules x 315W = **5.67kW**
Field 3: 2 rows to 5 modules and
1 row to 4 modules = 27.16m2;
14 modules x 315W = **4.41kW**
(Combined power = 16.38kW)

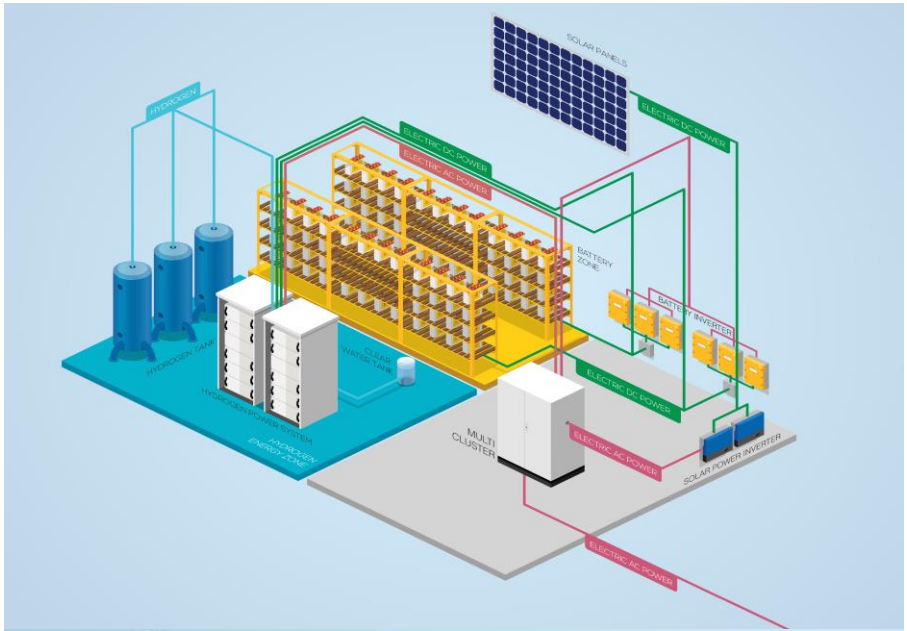
Rental House 1
Upper BIPV: 7.96m x 5.88m = 46.80m2;
24 modules x 315W = **7.56kW**
Lower BIPV: 9.80m x 5.97m = 58.50m2;
28 modules x 315W = **8.82kW**
(Combined power = 16.38kW)

Rental House 2
Upper BIPV: 7.96m x 5.88m = 46.80m2;
24 modules x 315W = **7.56kW**
Lower BIPV: 9.80m x 5.97m = 58.50m2;
28 modules x 315W = **8.82kW**
(Combined power = 16.38kW)

Rental House 3
Upper BIPV: 7.96m x 5.88m = 46.80m2;
24 modules x 315W = **7.56kW**
Lower BIPV: 9.80m x 5.97m = 58.50m2;
28 modules x 315W = **8.82kW**
(Combined power = 16.38kW)

Car port BIPV:
BIPV: Two car ports each for 4 cars,
each port 11.76m x 5.97m =
70.21m2;
2 car ports = 140.42m2 =
72 modules x 315W = **22.68kW**

Service Area BIPV:
BIPV: 7.84m x 23.90m =
187.38m2; 96 modules x
315W = **30.24kW**



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System overview

- Nominal installed PV power: 88 kW
- Peak PV power: 73.6 kW
- Average daytime PV power: 40 kW

- Daily electricity consumption: 200 kWh (less in rainy season)
- Peak load expected: 30 kW
- Average daytime load: 15 kW

- **3x 1000L hydrogen tank at 30 bar**
- **2 * Fuel Cells , each comprising of:**
  - **2 kW Fuel Cell**
  - **4.5 kW Electrolyser (1000 L/hr H2 production)**

- **2 battery banks, each comprising of:**
  - **10 string of 4 lead-acid 200 Ah batteries, 2000 Ah at 48 Vdc**
  - **Nominal capacity 96 kWh per battery bank**

Knowledge Aims

Using industry-proven systems and technologies:

- **Measuring environmental conditions and energy usage**
- **Collect data over two-year period for proof-of-concept**

Sharing Our Experience

- Data collection capabilities provide opportunities for studies about solar energy generation, hydrogen power system integration, energy saving methods, etc
- Information about renewable energy, energy saving, permaculture, organic farming, etc will be offered to interested individuals and organizations

Opportunities information exchange

We are willing to share the date from this project to any interested parties that can contribute to the greater understanding and use of green technology .

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