

# Small commercial Fuel Cells for Long Duration

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## Issues

- DMFC and hydrogen PEM fuel cells - technology review.
- Energy density comparison of selected available technologies, focus on one year (commercial) operation of 20 to 250 W FCs
- Review on other technologies:
  - Hydrogen. **available small FC**
  - Solid Oxide Fuel Cell (SOFC - Propane).
  - Polybenzimidazole (PBI - Hydrogen).
- In house test of two PEMFC:
  - 1) DMFC (Vendor A)
  - 2) Hydrogen FC (Vendor B)
- Summary.

**Goal: To find the best commercially**

# Analyzed technologies so far....



## PEM



# DMFC - Smart Fuel Cell - EFOY 1600



**Power:65W**

**Weight:7.6Kg**

**Volume:24 Liter**

**Fuel: Pure Methanol**

**Tech. : DMFC**

**Warranty: 3000 op. hours;  
24 months**

**Appointed cartridge:**

	<u>M5</u>	<u>M10</u>	<u>M28</u>
<b>Volume [L]</b>	<b>5</b>	<b>10</b>	<b>28</b>
<b>Weight [Kg]</b>	<b>4.3</b>	<b>8.4</b>	<b>24</b>



# Hydrogen PEM Fuel Cell system- H-Series

## H-30



**Power: 30W**

**Weight: 235gr**

**Volume: 0.2 Liter**

**Fuel: Hydrogen**

**Tech. : PEM**

**Claimed durability of 700 op. hours**

# Hydrogen PEM Fuel Cell system- H-Series

## H-100



**Power: 100W**

**Weight: 840gr**

**Volume: 1.2 Liter**

**Fuel: Hydrogen**

**Tech.: PEM**

H-Series : H-12 to H-5000

# MeOH-Reformer PEM Hydrogen FC

**UltraCell**<sup>®</sup>

LEADING A REVOLUTION IN MOBILE POWER™

## XX25 & XX55 MOBILE POWER FOR MOBILE MISSIONS



5 days:

4.9 Kg

14Kg

21.1Kg

(Dedicated cartridge)

Tech. : PEM – Methanol Reformer  
Military use.



# MeOH-Reformer PEM Hydrogen FC



**Power: 250W**

**Weight: 18 Kg**

**Volume: 71.4 Liter**

**Fuel: 60/40 Methanol/Water Mix.**

**Tech.: PEM – Methanol Reformer**





# Sodium Borohydride PEM Hydrogen FC

 **Protonex** Pulse UAV C250



**Power: 250W**

**Weight: 1.2 Kg**

**Volume: 1.35 Liter**

**Fuel: Sodium Borohydride  
(Dedicated cartridge)**

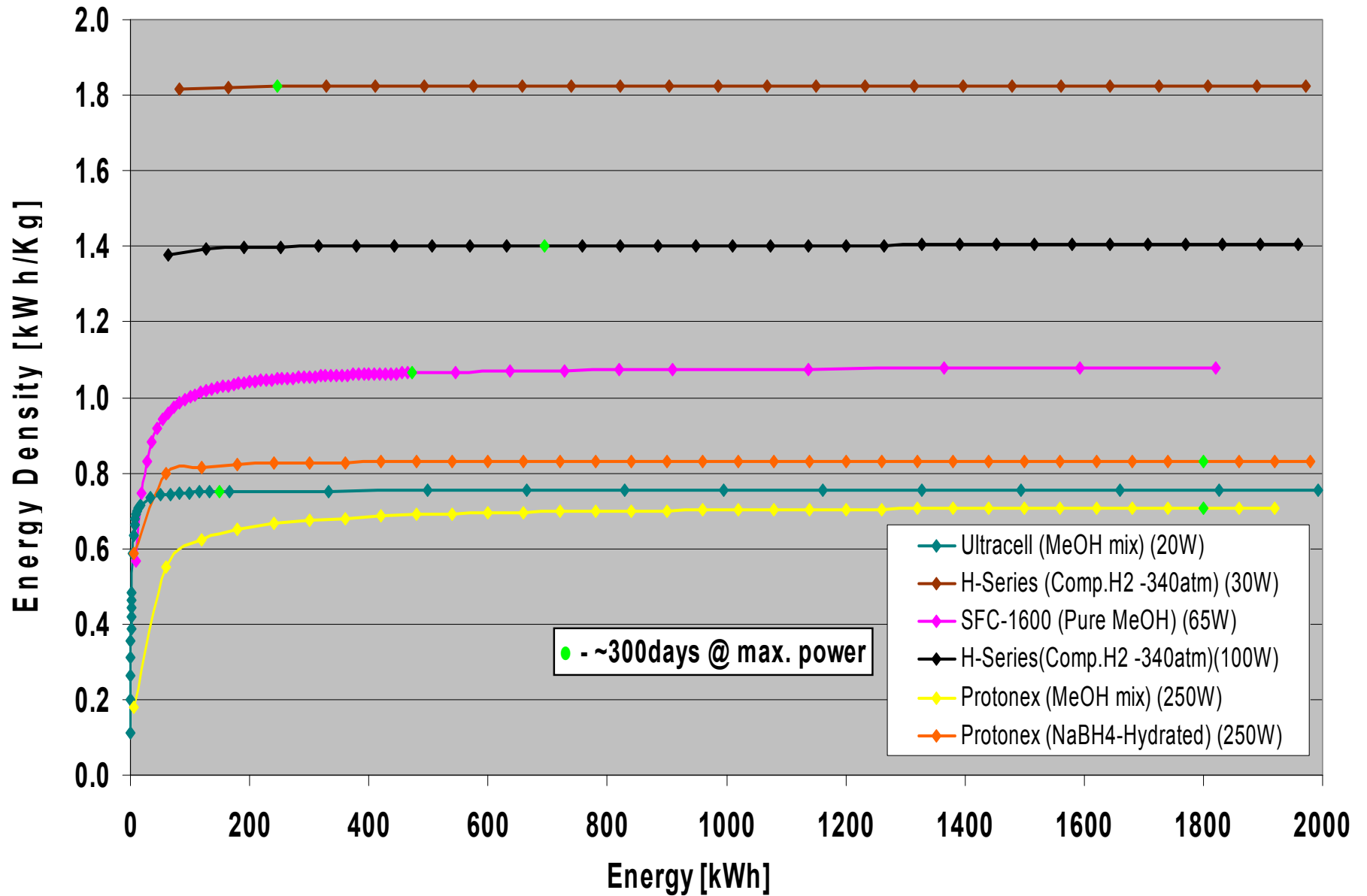
**Tech. : PEM – Methanol Reformer**



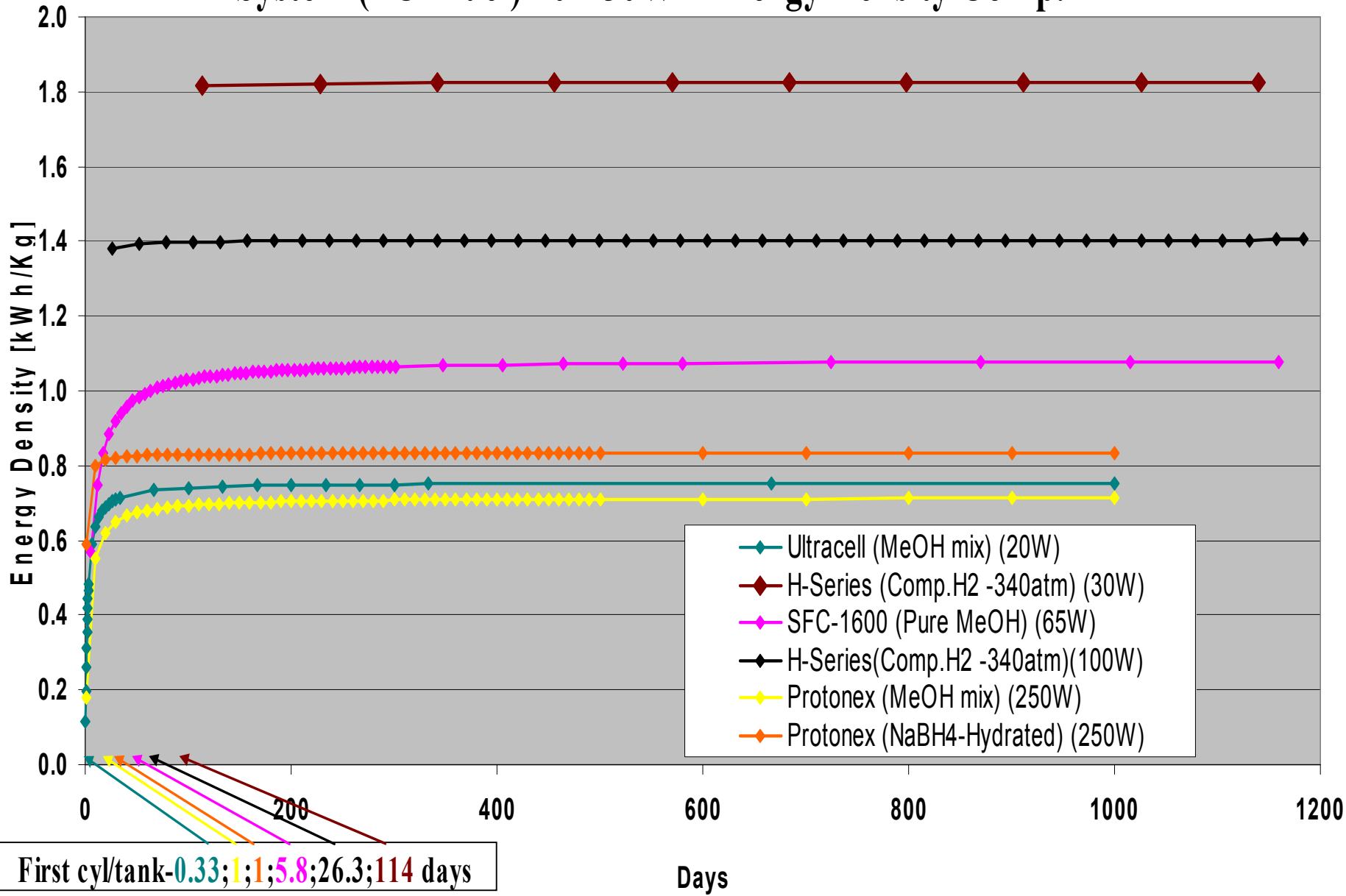
## Fuel cartridge for 20-250W systems

<b>Comp.</b>	<b>FC Power (W)</b>	<b>FC Weight (Kg)</b>	<b>FC Volume (L)</b>	<b>1 Cartridge Weight [Kg]</b>	<b>1 Cartridge Volume [L]</b>
Ultracell (MeOH-Water mix) ●	20	1.24	1.48	0.35	0.24
H-Series (Composite Hydrogen340atm) ●	30	0.235	0.2	45	145
SFC (pure MeOH)-(Cartridge-8.4Kg) ●	65	7.6	24	8.4	10
SFC (pure MeOH)-(Cartridge-24Kg)	65	7.6	24	24	28
Protonex (MeOH-Water mix) ●	250	25	61.44	0.35Kg/hour	0.4L/hour
Protonex(SodiumBorohydride)●	250	1.2	1.35	1.8	2.2

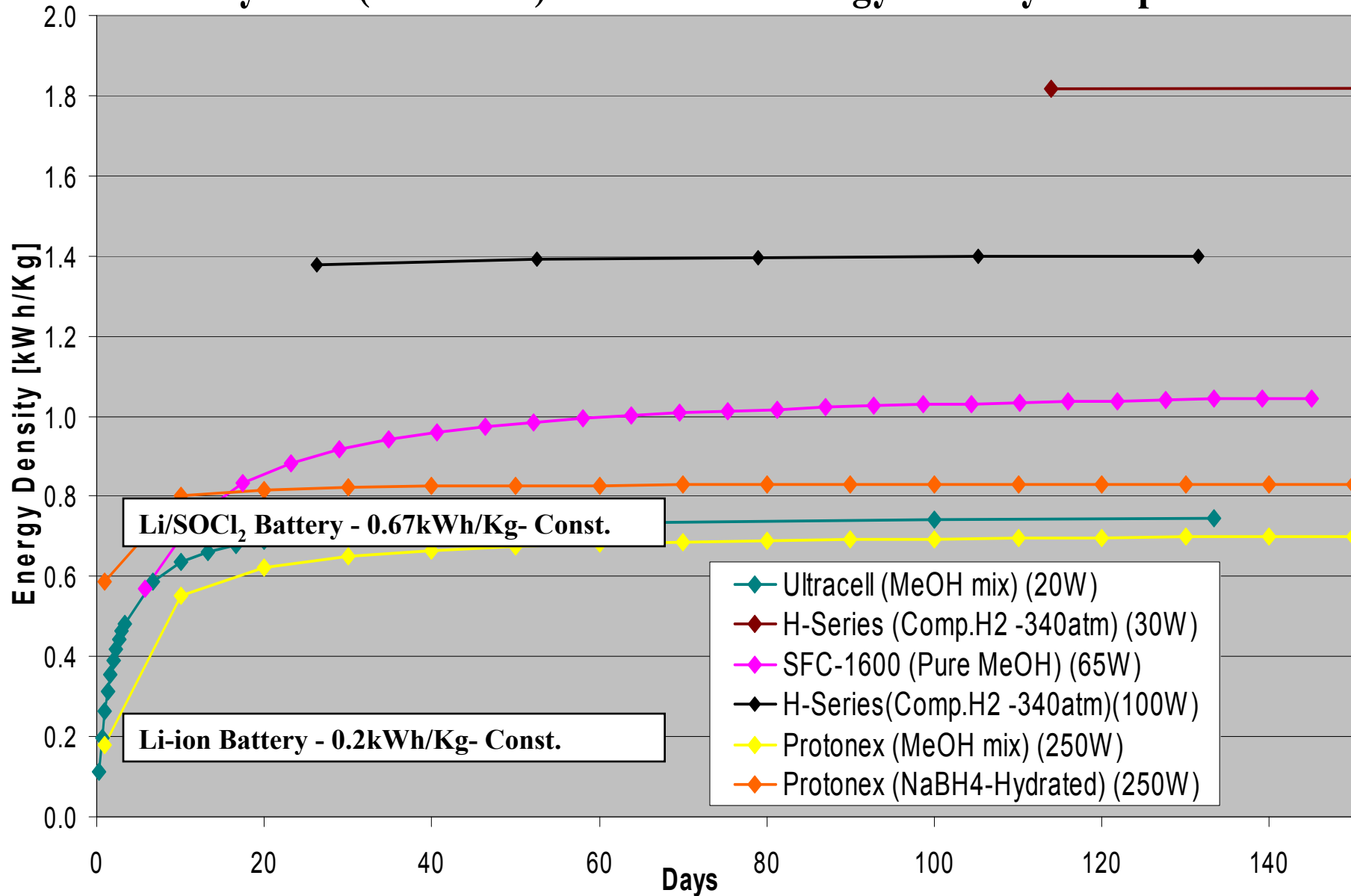
# System (FC+Fuel) Energy Density Comparison (20-250W)







# System (FC+Fuel) 20-250W - Energy Density Comp.






# System (FC+Fuel) 20-250W - Energy Density Comp.



# PEMFC Technologies (were not analyzed so far)

Company	Technology	Power [W]	Performance Decrease	Durability	Availability
<b>Cellkraft</b> 	PEMFC Hydrogen	50-2000		20,000 hours : 99% stand-by and 1% operation	
<b>PEARL HYDROGEN</b> 	PEMFC Hydrogen	20-4000		1500-2500 hours. No guaranty for R&D field	
	PEMFC Hydrogen	10-2000	4 $\mu$ V/h per cell -4.8% after 8000 hours		
<b>NDC Power</b>	PEMFC Ethanol reformer	3-20; 1k-15k	40 $\mu$ V/h	>3700 hours	

# SOFC/PBI Technologies

Company	Technology	Power [W]	Durability
	SOFC Propane	25/150	1500 h of use with 100 restarts
	SOFC Propane	50/60	
	PBI Hydrogen	300-6000	

# **Tests in our laboratory:**

**1) DMFC (Vendor A)**

**2) Hydrogen FC (Vendor B)**



# DMFC – (Vendor A)

Start Operation – 26/08/08

Operation method of the battery – 4 hours discharge at 5A ; 4 hours rest .

## Our findings:

Every 10/15 minutes : Current shut down for 30 seconds.

Temp. Liquid outlet (pH – 4.3) : 60-80°C; About 540ml(1<sup>st</sup> m.)/700ml(3<sup>rd</sup> m.) per day.

Temp. Air outlet : 40-60°C.

Days of operation	Battery disch. Current (A)	Methanol consumption (L/kWh)	System's Energy Density (kWh/Kg)
36	5	0.89	0.89
26	5	1.17	0.89
23	5	1.25	0.89
26	5 ; 4	1.08	0.93

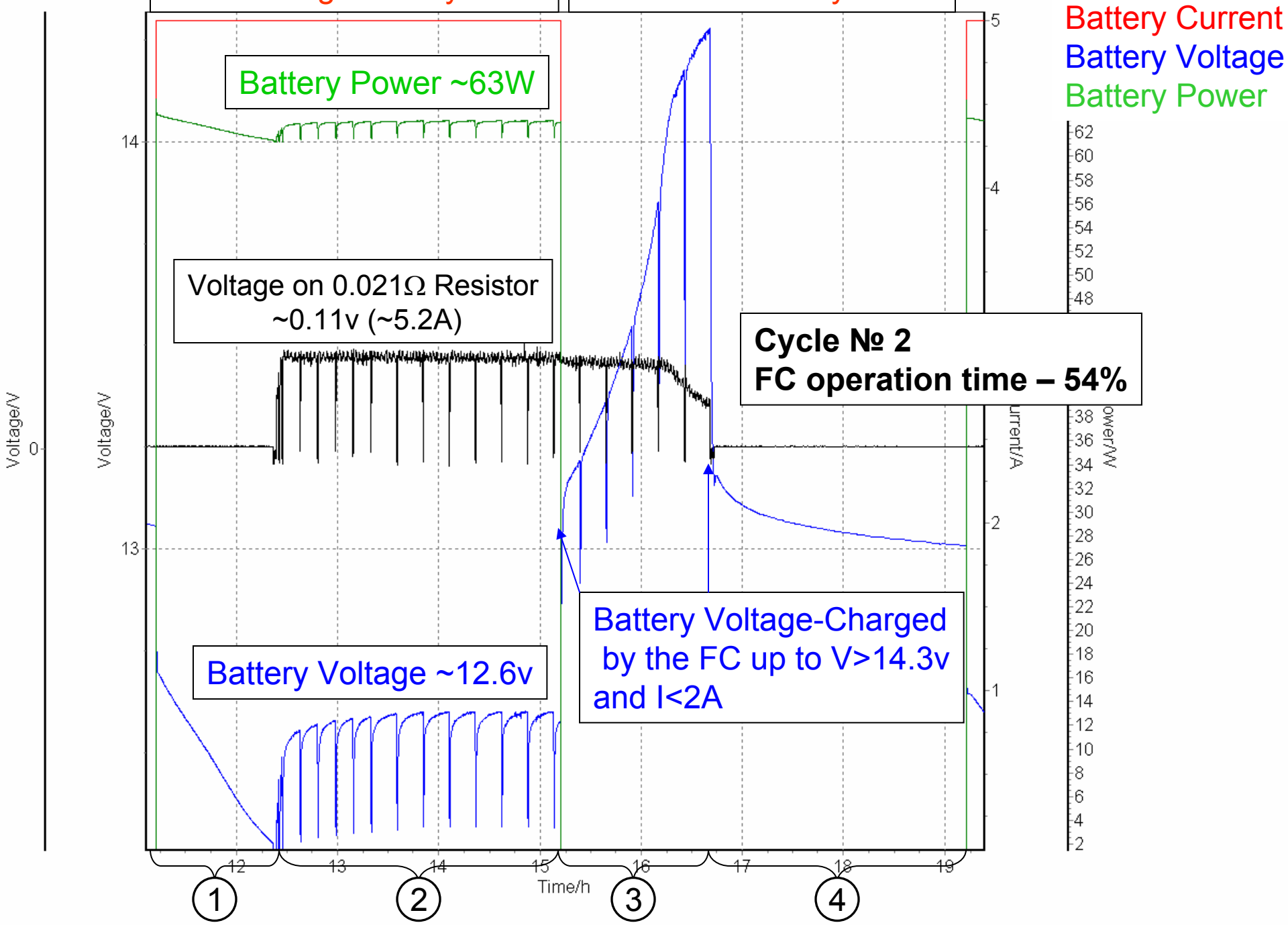
Methanol consumption up to the datasheet: 1.1 L/kWh

## DMFC – (Vendor A) – Cont.

Direct Measured power on the FC		
Cycle	Hours	FC Power (W)
1-90	430	64.1
91-181	381	62.1
182-245	372	56
246-280	265	50.3
281-320	173	45.5

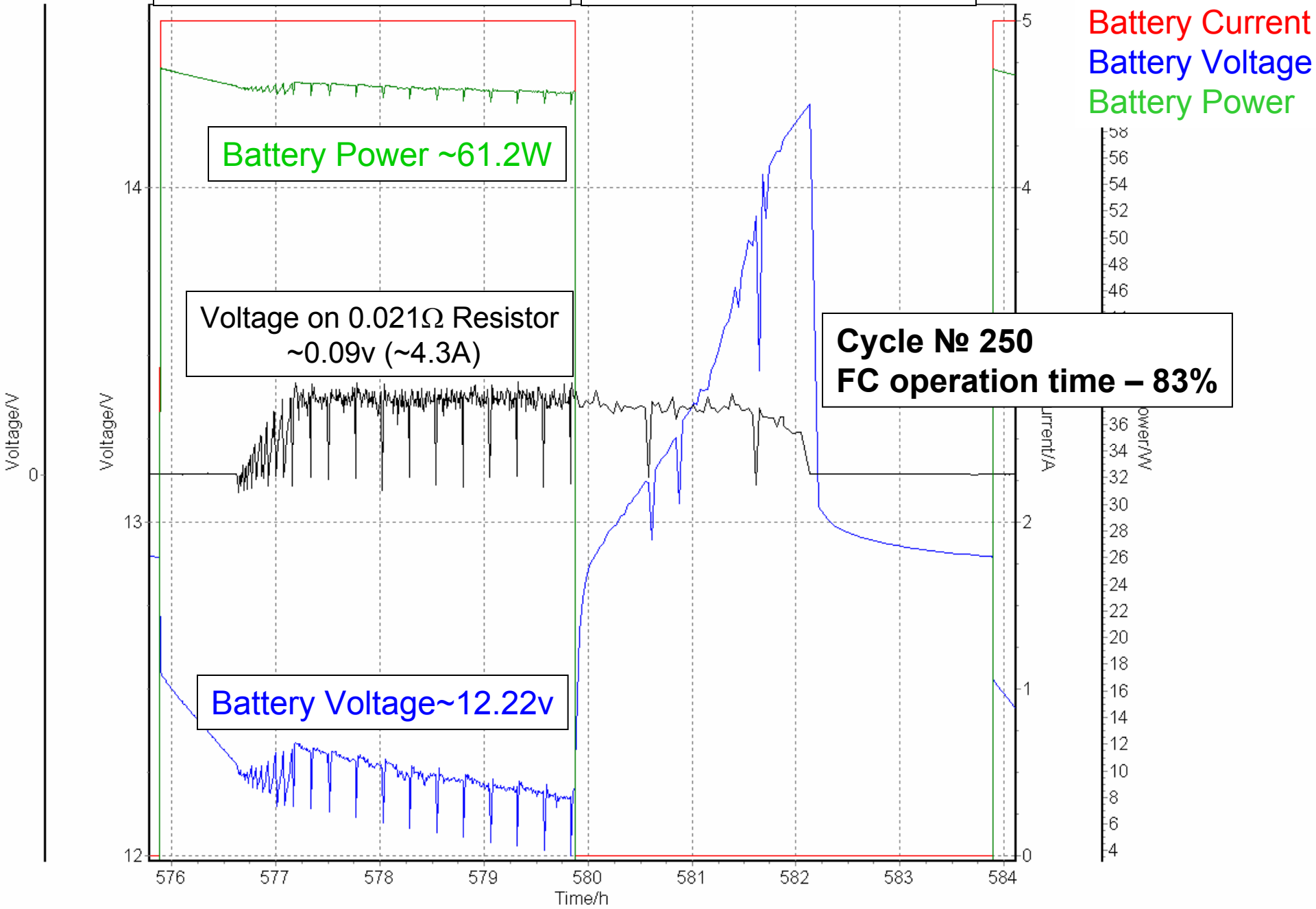
4h Discharge battery at 5A

4h Rest battery 0A

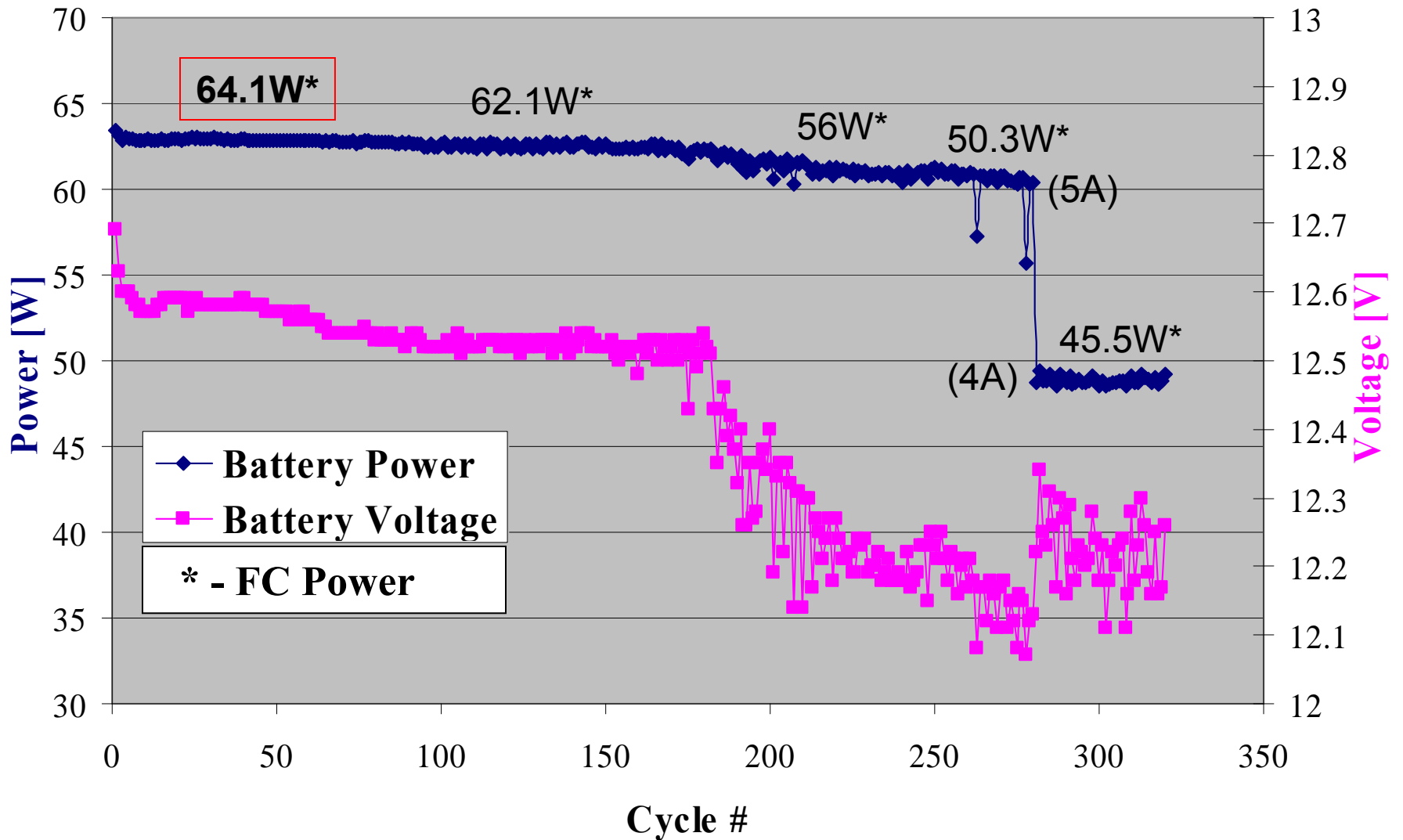


4h Discharge battery at 5A

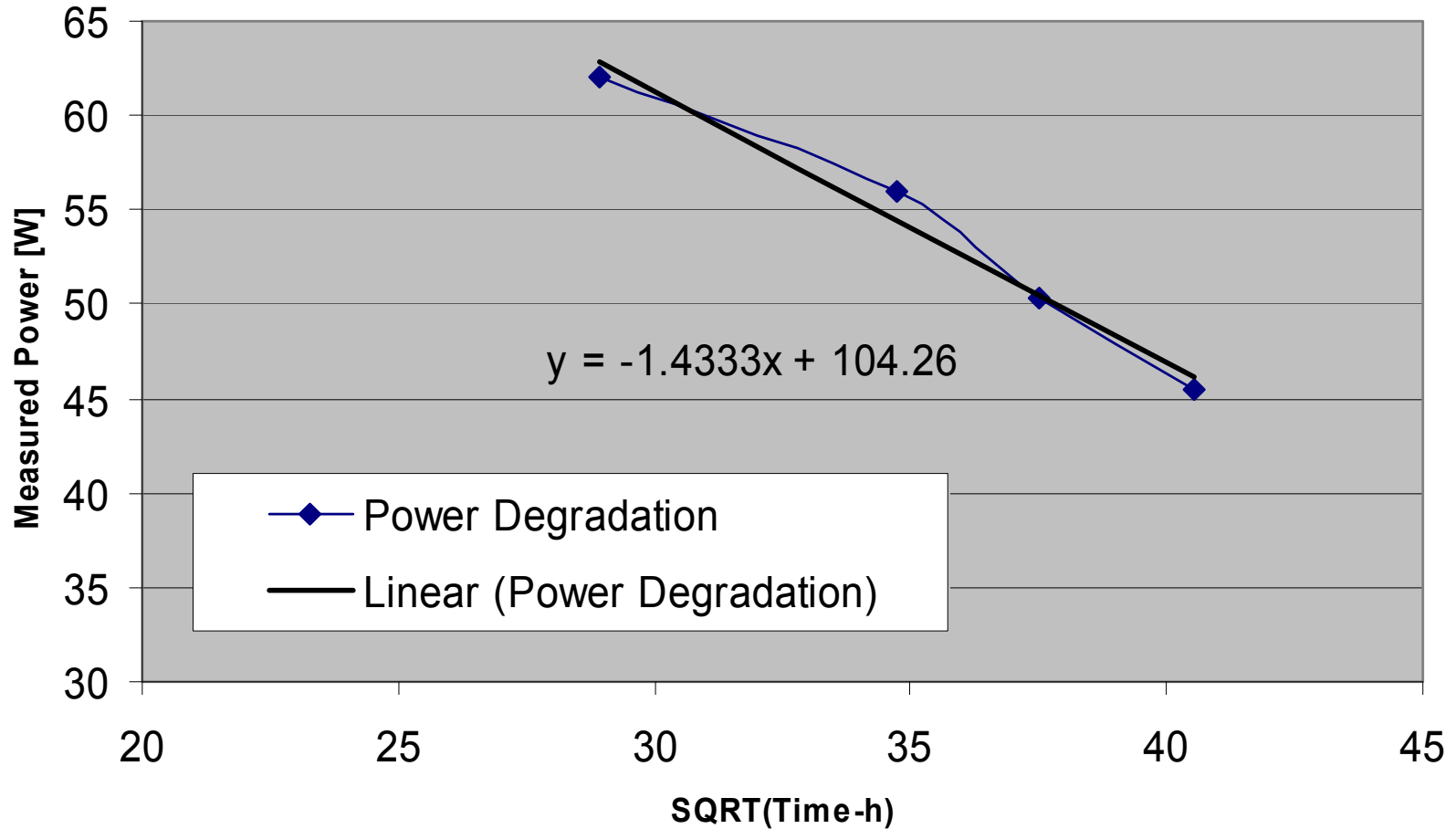
4h Rest battery 0A



# Vendor A - 4 months test



## Vandor A - Power Degradation



Extrapolation : 50% decreased power (32W) after 2542 hours

# Vendor B - Fuel Cell Stack

Start operation: 07/12/08

Operation Mode: Discharge at constant resistor (1.5Ω) for 6 hours every day.

Our findings:

Every 6 minutes 30 seconds current deep.

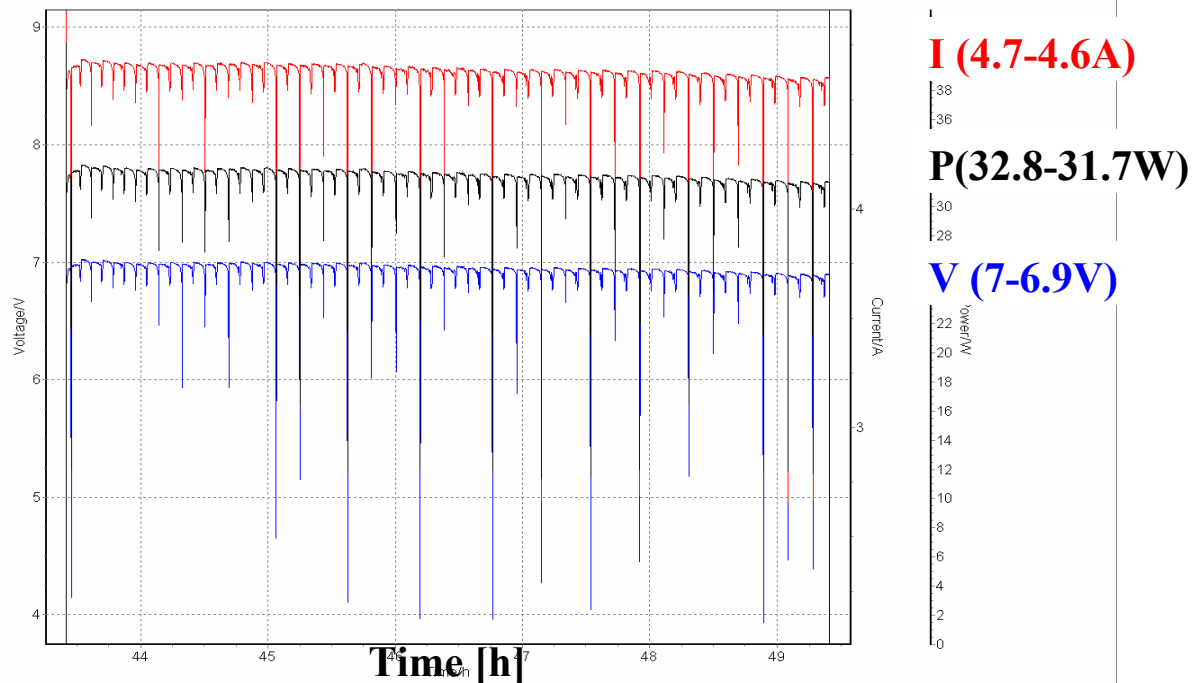
Fuel: Hydrogen from 150 Atm. Cylinder; ~5psi; ~300ml/min.

Every 10 seconds the purge valve releases hydrogen.

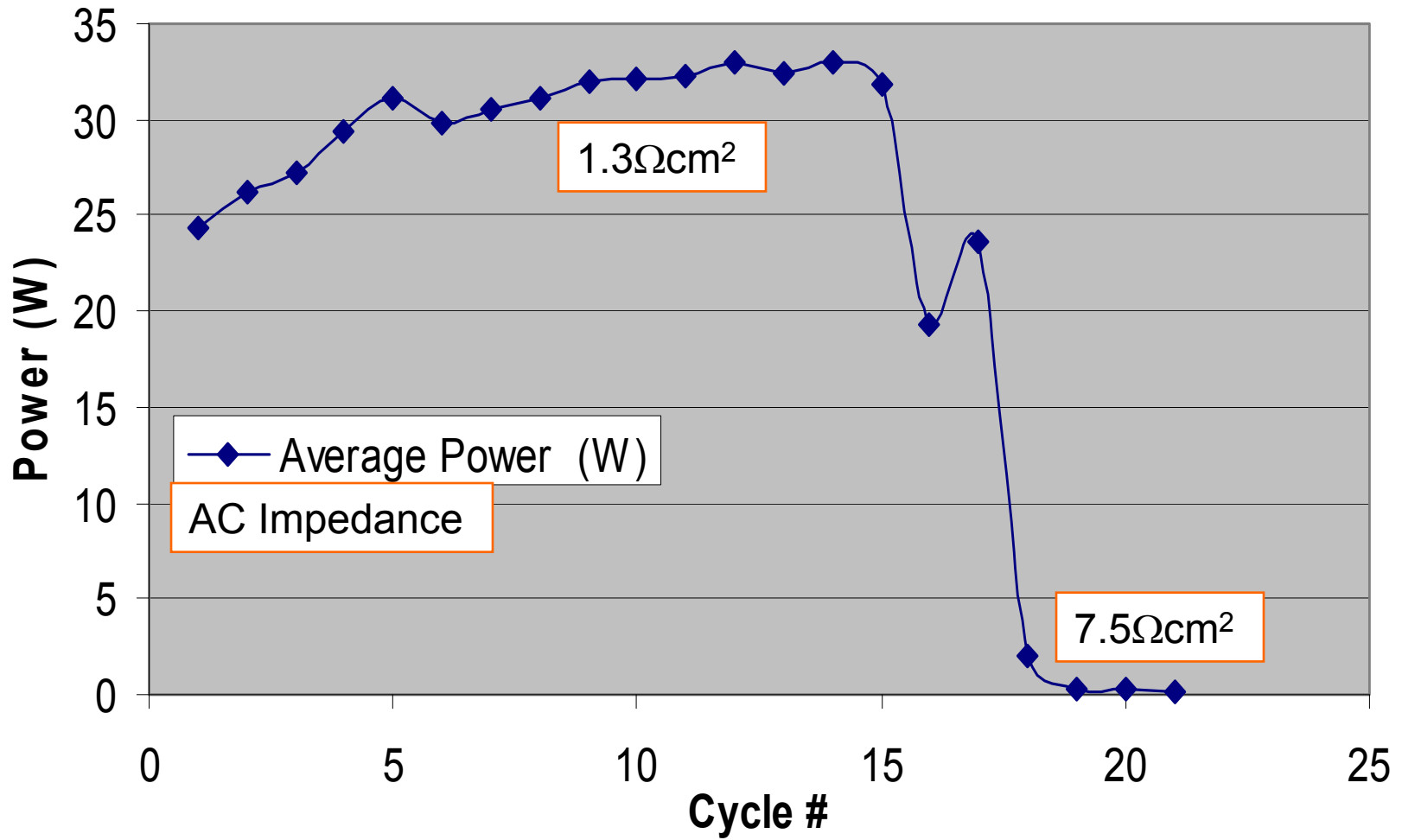
Water outlet ~3gr per hour.

Cell temperature (near the fans) : 50-55°C.

OCV: ~10V.



# Vendor B - Power





# Summary

- For long operation time, H-Series Hydrogen PEMFC has the highest system energy density – 1.4-1.8kWh/Kg.
- Energy Density for FC systems :

H-Series >> SFC > Protonex > Li/SOCl<sub>2</sub> >Li-ion

- Vendor A (DMFC) worked more than 1600 hours (320 restarts).  
Performance decrease : -21.5% after 1450 hours and 280 restarts.  
-29% after 1645 hours and 320 restarts.
- Vendor B hydrogen FC performance degraded too early (80 hours and 15 restarts)
- Comment : We tested only one FC from each manufacture. More tests have to be carried out before making conclusions on their durability.