ELECON
ELECTRICITY CONSUMPTION ANALYSIS & ENERGY EFFICIENCY

OTTO VON GUERICKE UNIVERSITÄT MAGDEBURG

# First ELECON Workshop
# Towards Efficient European and Brazilian Electricity Markets


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ELECTRICITY CONSUMPTION ANALYSIS & ENERGY EFFICIENCY

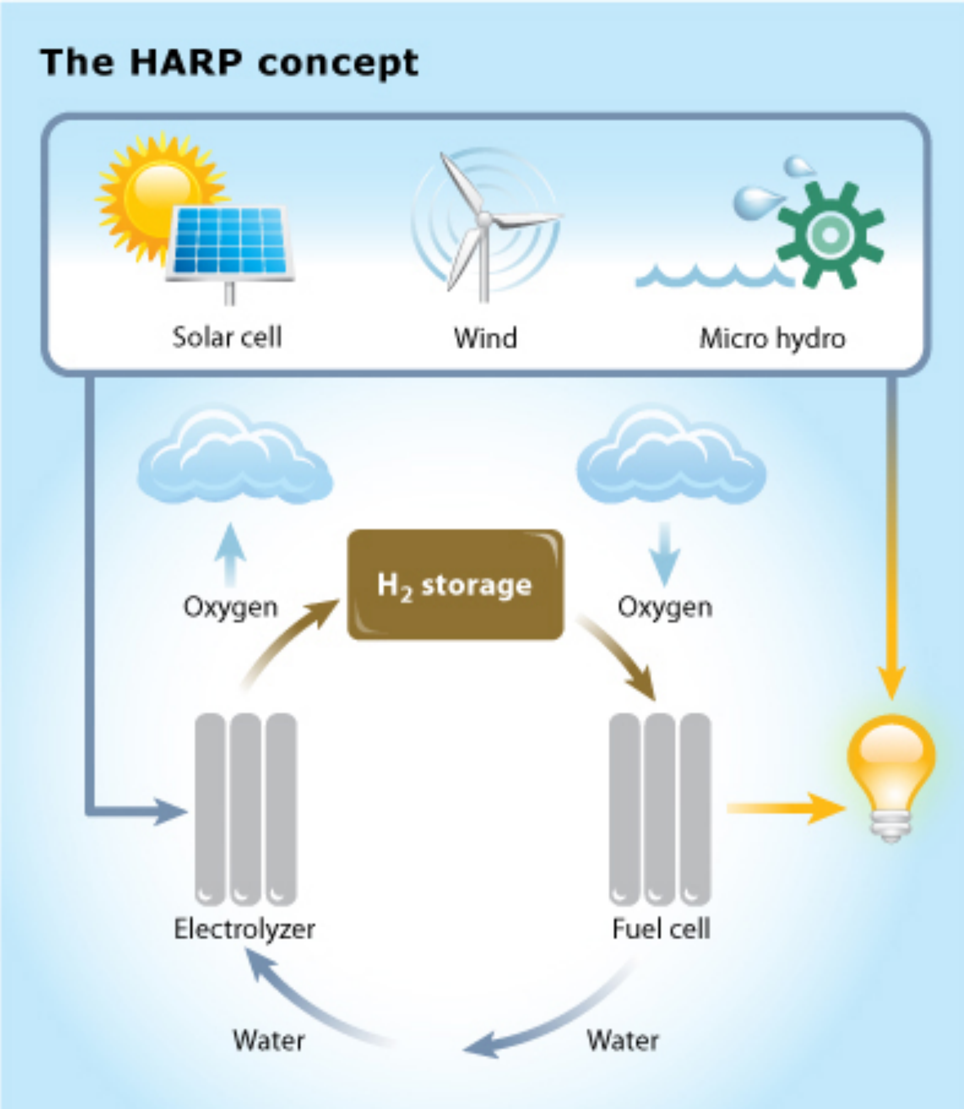

**ISEP, Porto, Portugal**

**24th September 2013**

ELECTRICITY CONSUMPTION ANALYSIS & ENERGY EFFICIENCY

# Fuel Cell System as a Part of the Smart Grid

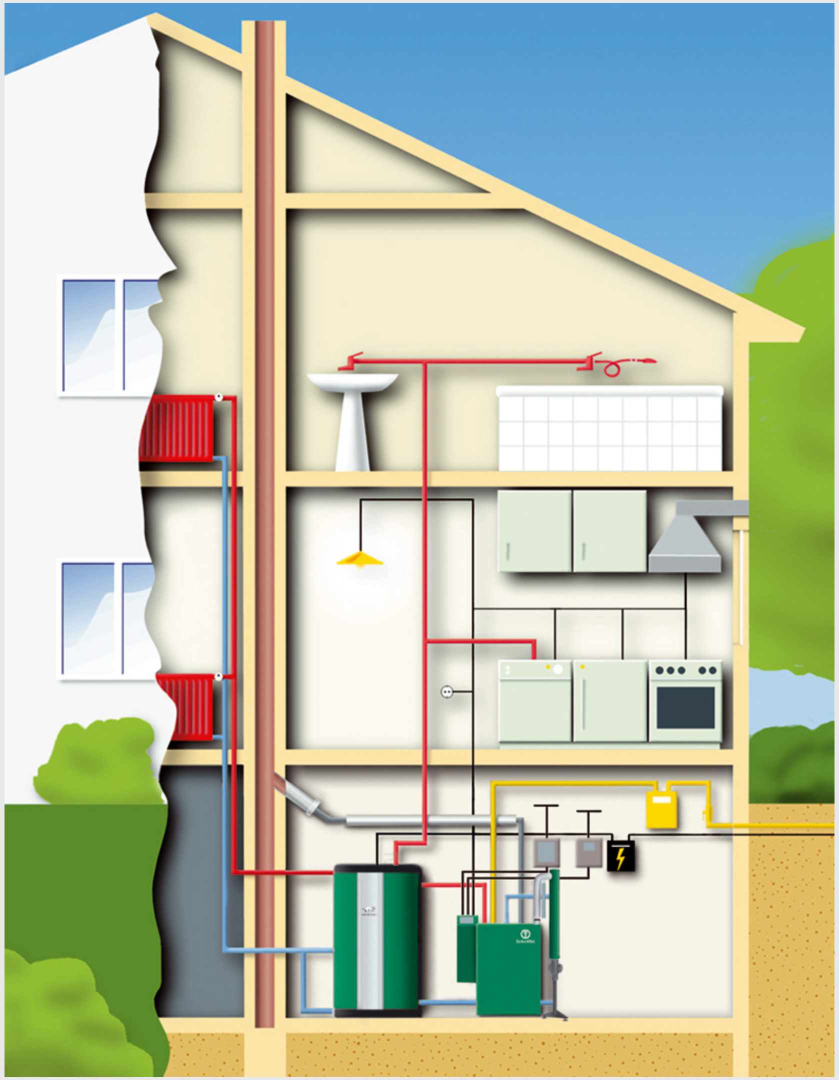
# Motivation

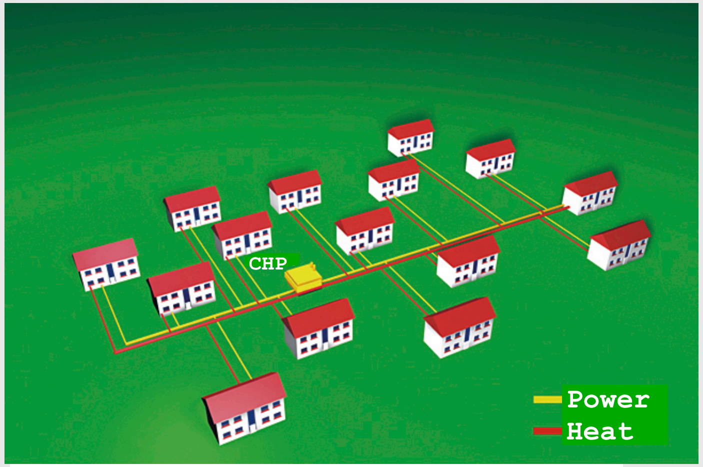


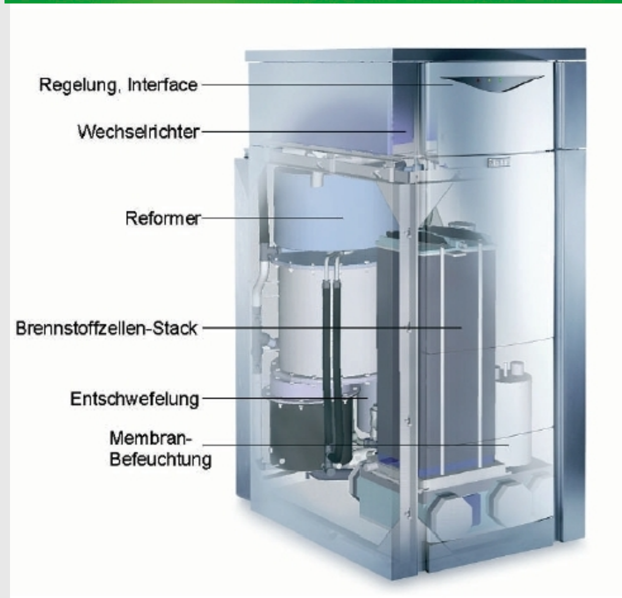

Source: NRC-CNRC Canada

**A smarter grid using hydrogen as a storage increases the utilization of renewables**

# Motivation





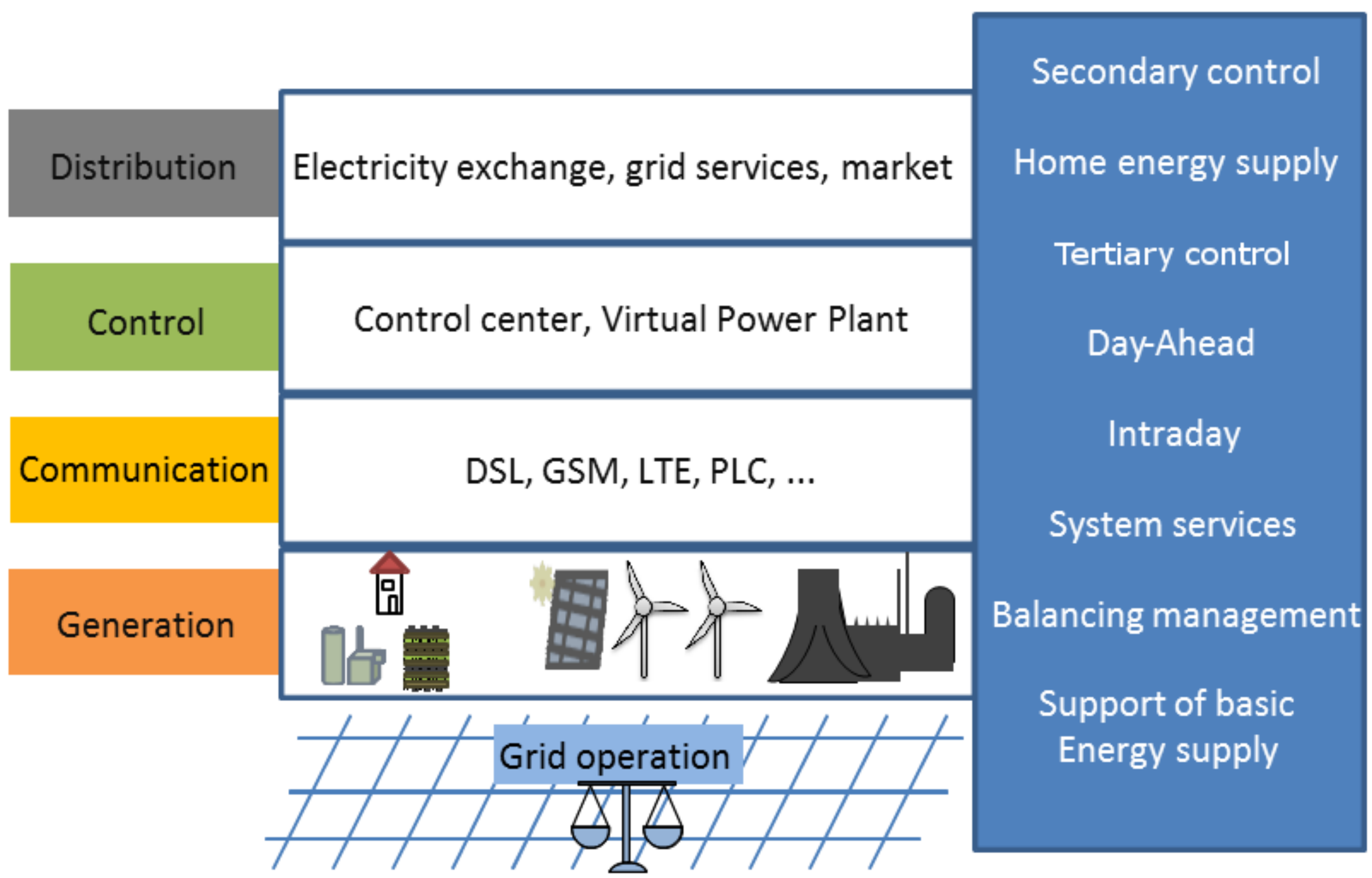




µCHP in households

Example System with Fuel Cell from Valliant, running on natural gas or hydrogen.

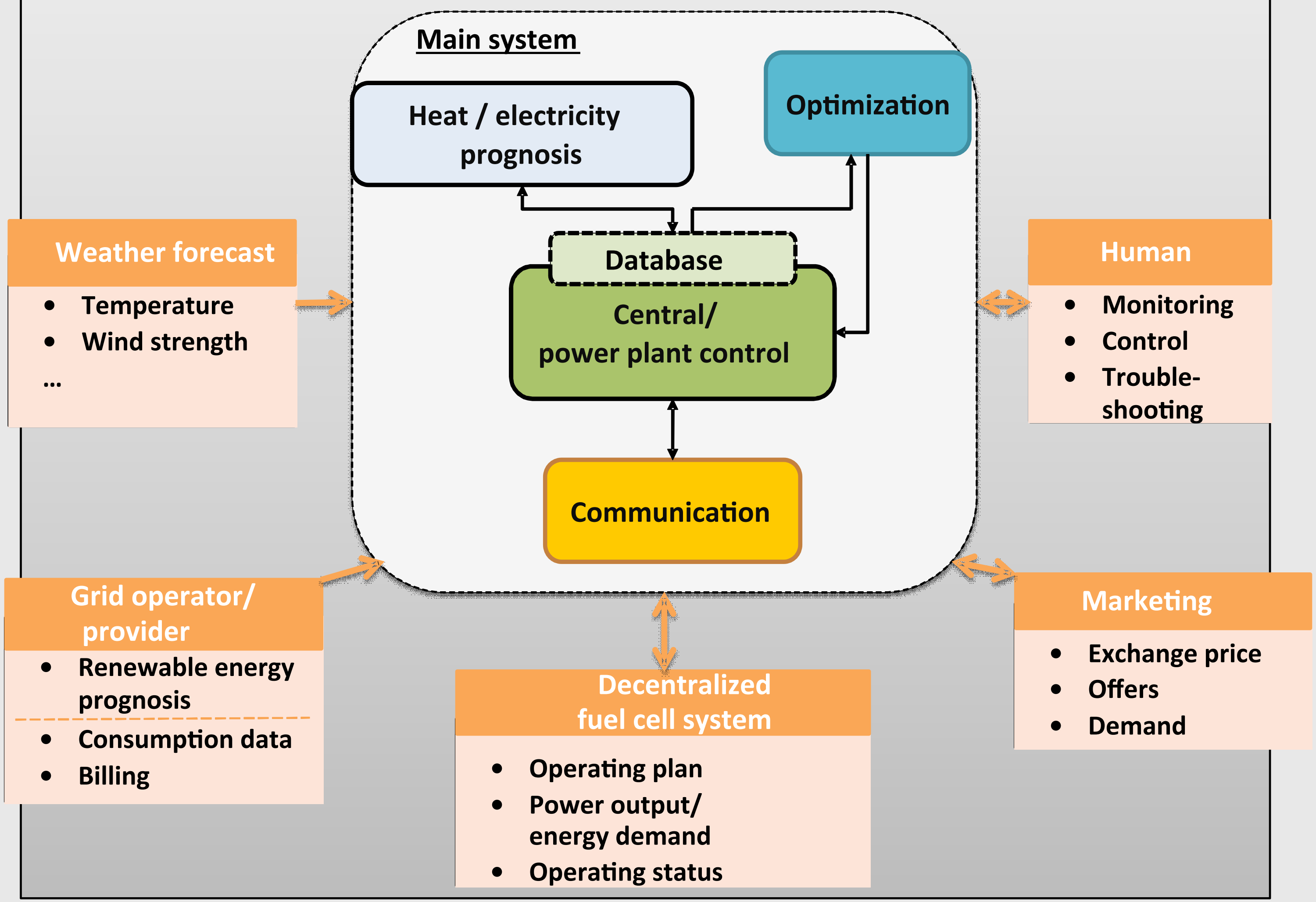
Sources: ABGnova, Firma Valliant GmbH

# Virtual Power Plant



# Virtual Power Plant

**Structure of a Virtual Power Plant**



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# Why Fuel Cell?

- Direct chemical to electrical/thermal energy conversion
- Electr. efficiency between 50-68% → System 30-45%
- Dynamical load
- Thermal energy supply (stationary & automotive)
- High energy density of hydrogen

**Anode:**

$H_2 \rightarrow 2H^+ + 2e^-$

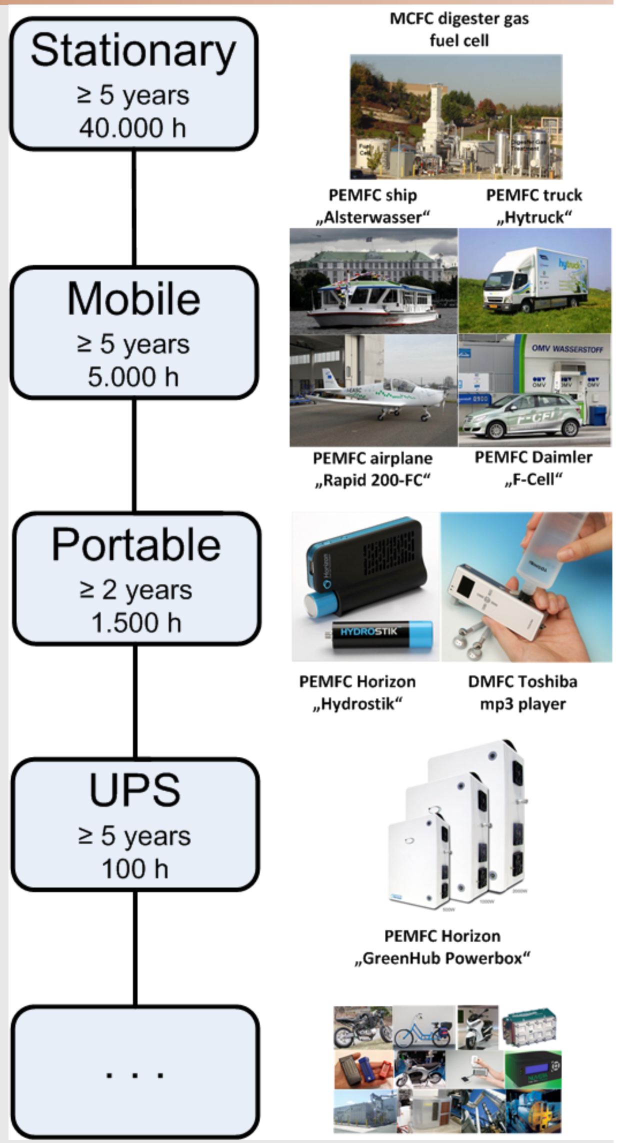
**Cathode:**

$2H^+ + ½\ O_2 + 2e^- \rightarrow H_2O$

**Total reaction:**

$H_2 + ½\ O_2 \rightarrow H_2O$

**PEM Fuel cell stack**



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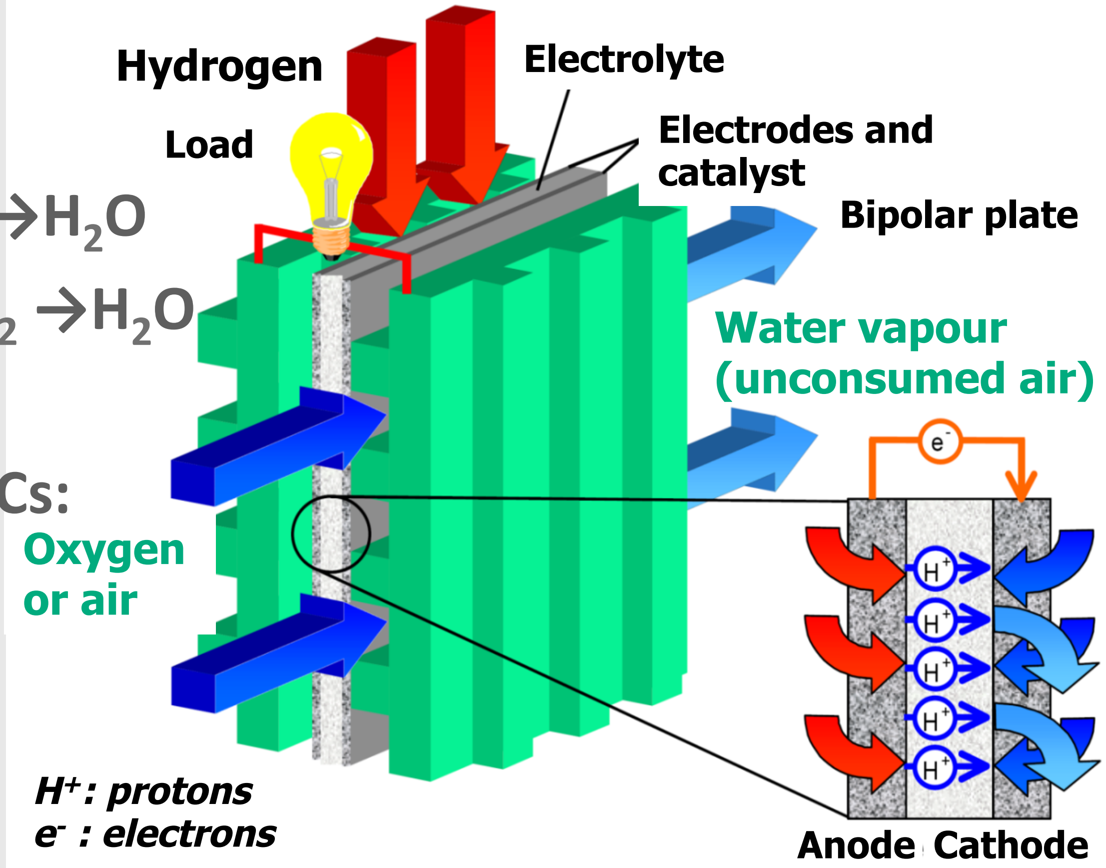
# PEMFC Function Principle

- Anode: $H_2 \rightarrow 2H^+ + 2e^-$
- Cathode: $2H^+ + ½\ O_2 + 2e^- \rightarrow H_2O$
- Total reaction: $H_2 + ½\ O_2 \rightarrow H_2O$




- Advantage over other FCs:
  - Dynamic loads
  - Quick start
- Disadvantage:
  - Low Temperature (50-85°C)
  - Water management

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# Degradation of PEMFCs

## Causes for Aging of Different Components

| Component | Function | Failure | Cause |
|---|---|---|---|
| **Membrane** | Proton transport<br>Media separation<br>Electrically non-conductive<br>Water transport | 1. Puncturing<br>2. Decrease in conductivity<br>3. Platin detachment<br>4. Water adsorption | 1. Hot spots, pressure gradients, dry areas, $H_2O_2$-production<br>2. Increase in contact resistance, contamination<br>3. Swelling and shrinkage<br>4. Increase in pore size |
| **Catalyst layer** | Catalysis<br>Electrically conductive | 1. Carbon erosion<br>2. Agglomeration of platin<br>3. Platin dissolution<br>4. Deactivation / contamination | 1. Undersupply<br>2. High humidity/dynamic stress<br>3. Platin oxidation<br>4. Pollution, high potentials |
| **Bipolar plates** | Media transport<br>Electron transport<br>Thermal conduction | 1. Corrosion of metallic BPP<br>2. Increase in contact resistance<br>3. Crack formation | 1. High humidification<br>2. Oxide layer formation at Cathode<br>3. therm. gradients, Pressing |
| **Gas diffusion layer** | Media distribution<br>Therm. and el. conductive<br>Fixation of the membrane | 1. Material erosion<br>2. Corrosion<br>3. Fiber break | 1. High humidification, temperatures<br>2. Oxidation<br>3. mechanical stress |

**operational management**

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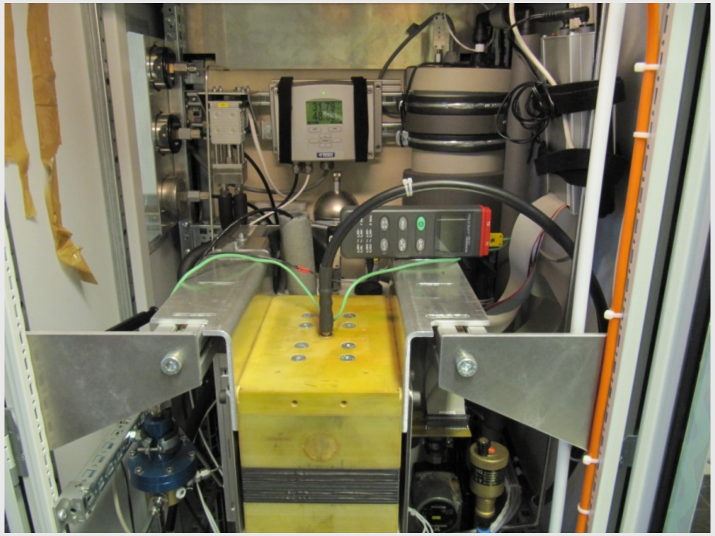
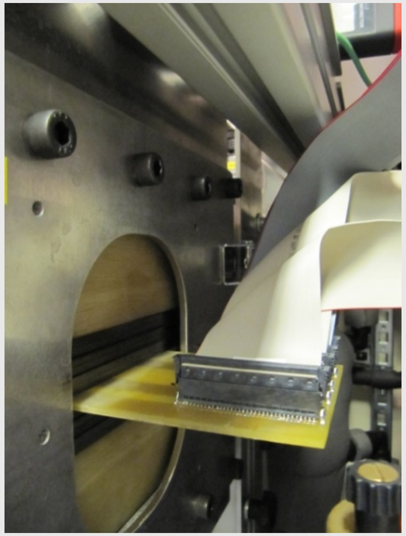
# Current Distribution

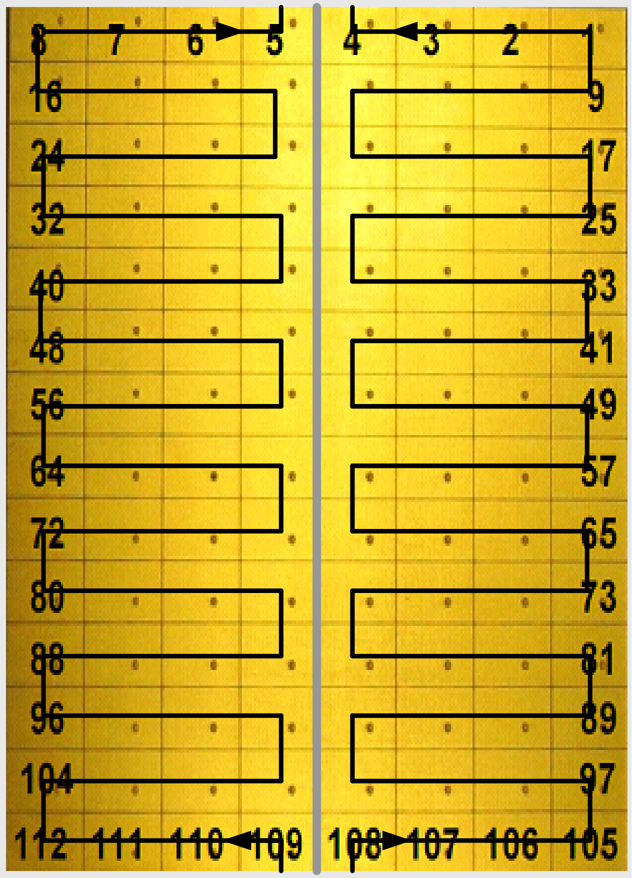


Front - view FC-System

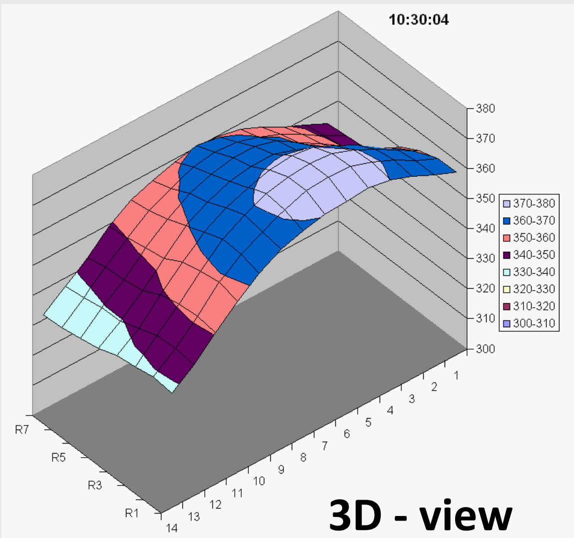


CDM inside stack

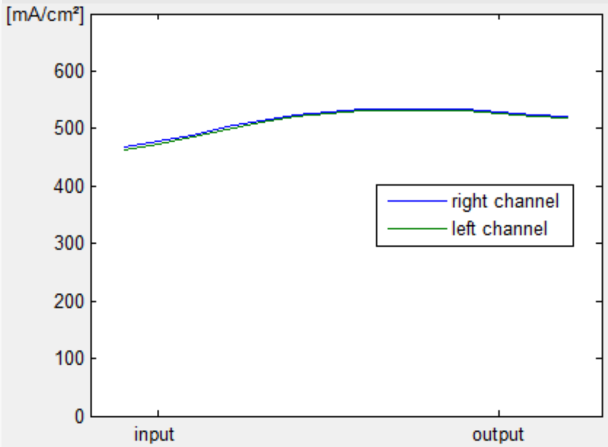
Self-developed Current distribution board with anode channels marked




(left channel) (right channel)



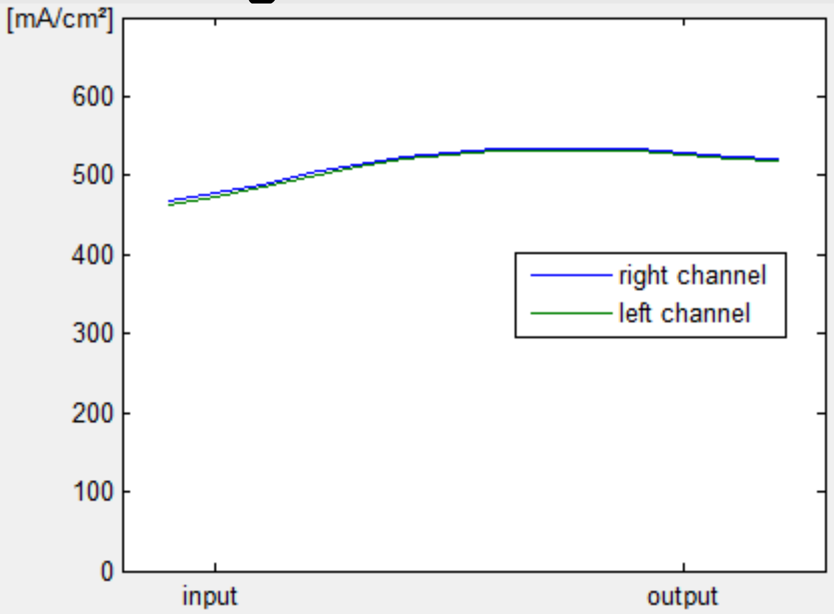

3D - view



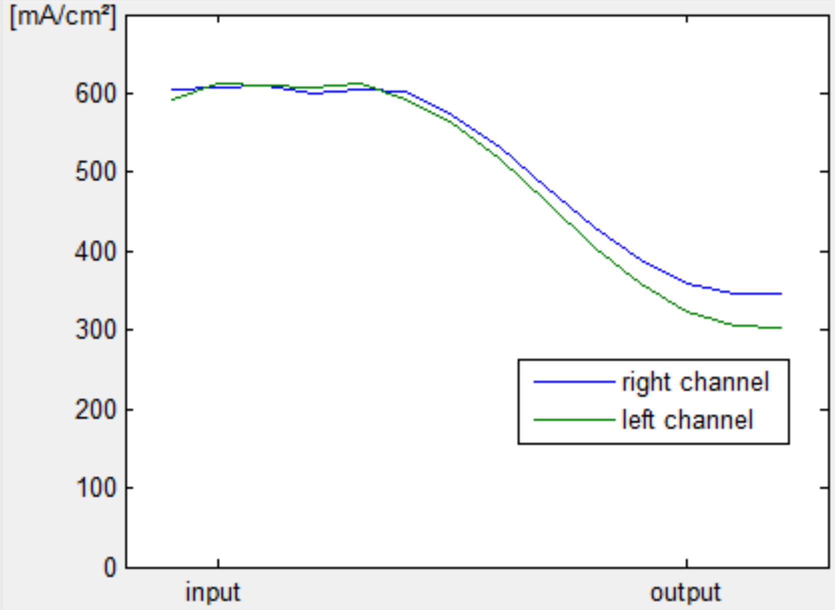

Channel lenght

# Current Distribution

**good condition**




**bad condition**




**Reasons:**

- **Problem with the water distribution / management**
- **Condensation drops at the output hinder the gas transport**
- **Current density drops due to undersupply**

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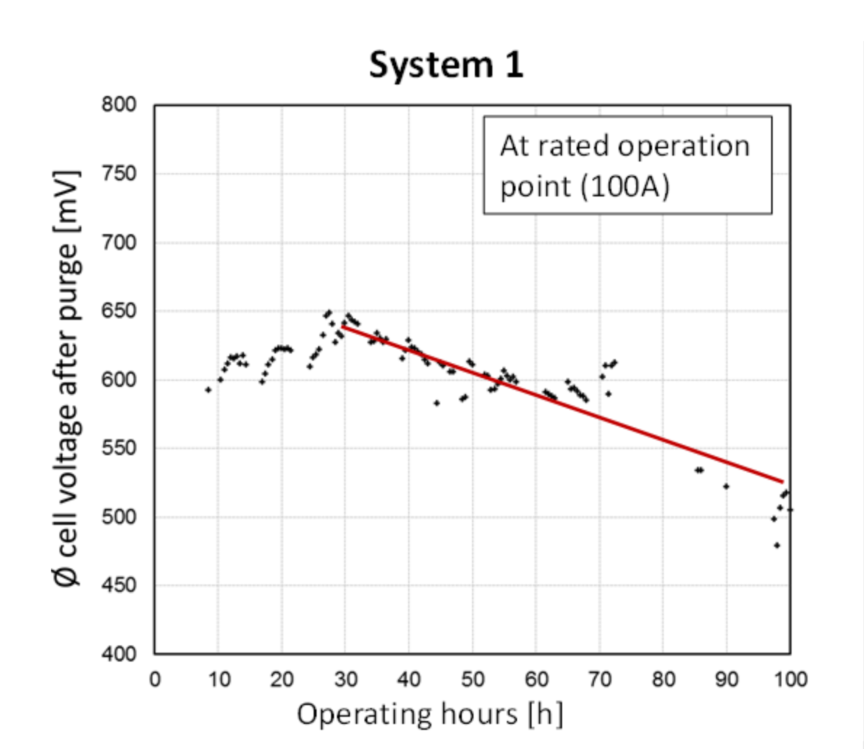
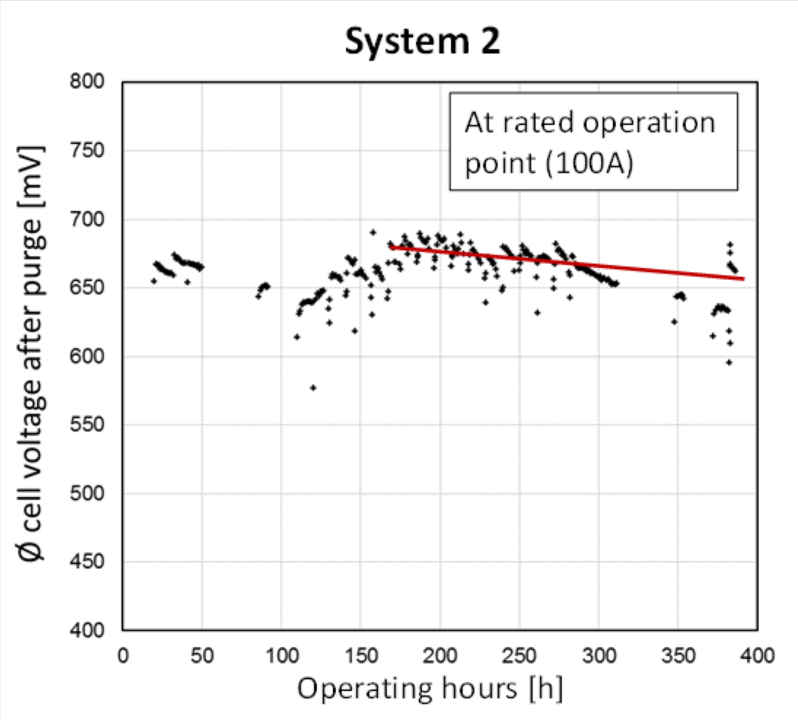
# Results

- **Comparison of two systems to analyze impact on lifetime by different operation strategies**
- **Water Management is Key for PEM-FCs**

| Component | System 1 | System 2 |
|---|---|---|
| Stack | 1. Same initial test procedure;<br>2. Identical components and date of production | |
| Oxygen | 1. Ambient air<br>2. Passive humidification | 1. Conditioned room air<br>2. Active humidification |
| Hydrogen | 1. No preconditioning<br>2. Recirculation<br>3. Dynamic purging | 1. Nitrogen purging before and after operation<br>2. Recirculation<br>3. Fixed interval purging |
| Operation | 1. Dynamic (0-100%)<br>2. Discontinuous<br>3. 100 hours per annum | 1. Stationary (40-100%)<br>2. Discontinuous<br>3. 400 hours (per annum) |



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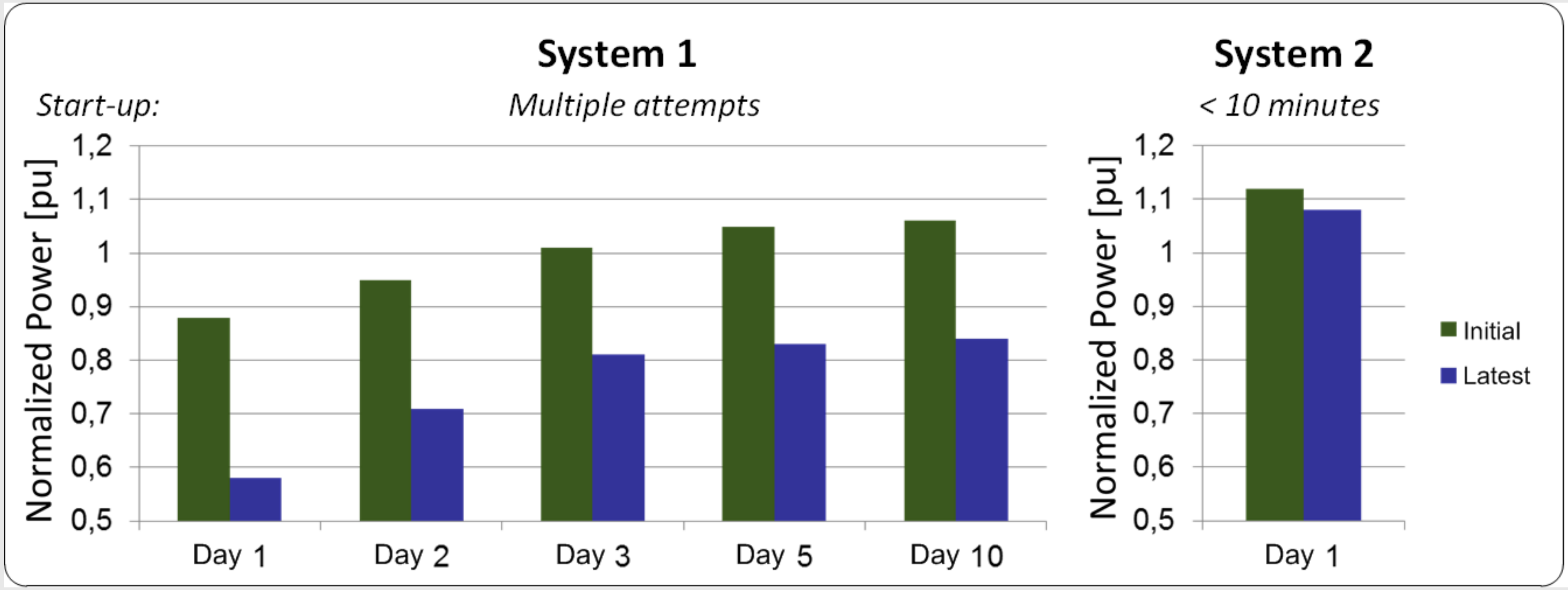
# Results

- system 1 was aging faster than system 2
- System 1 is not working at nominal power anymore
- Both systems need time to recover after long offline periods

**Power output after long offline period (new condition and now)**

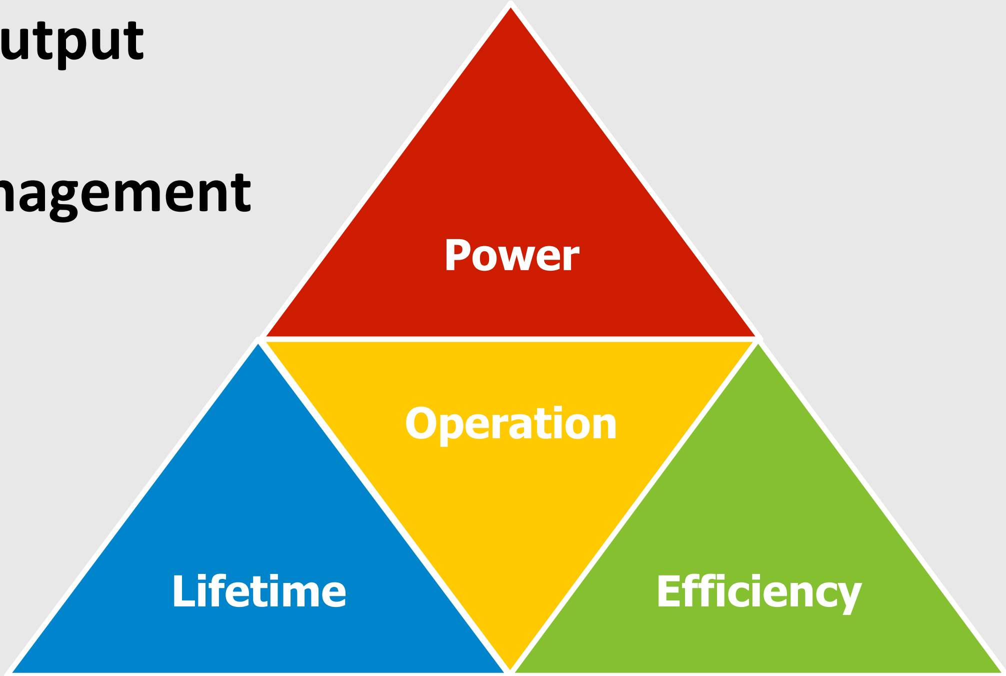


# Conclusion

- **Fuel Cells can contribute to the utilization of renewable energies**
  - **controllable generation, load and energy storage**

- **Virtual Power Plants allow to combine FC-CHPs to generate system services of noticeable total power output**

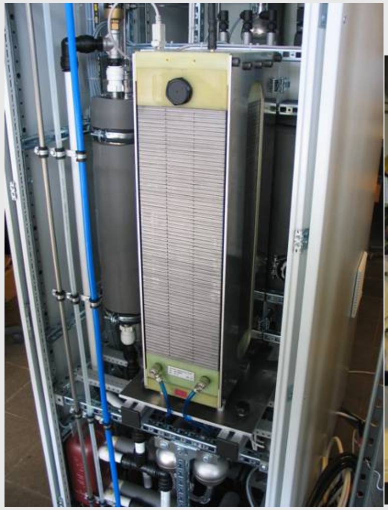
- **Optimized Operational Management is the key to lifetime, maximum power output and efficiency**



# Thank you for your attention

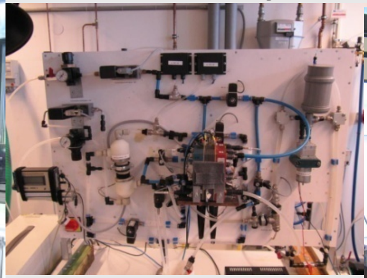
300 W Stationary Systems

5kW System

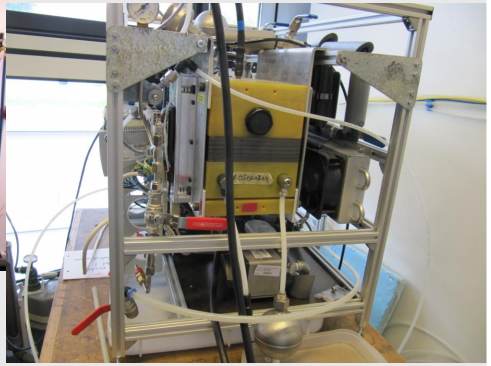


4kW natural gas System

Student Test System



Autonomous System



PEOPLE MARIE CURIE ACTIONS

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