



RAS SAHT

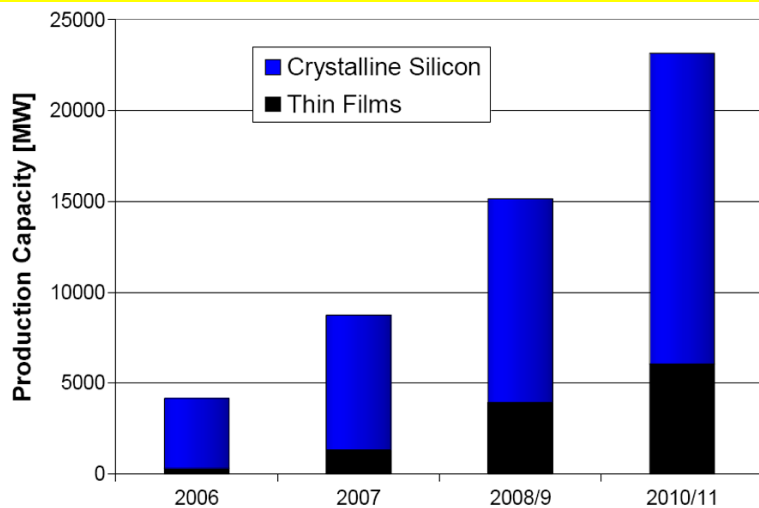
Hydrogen cycle and alternatives for solar cell-based power plants buffer energy storage – technical and economical comparison

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Renewables perspectives

- To 2020 renewables must give 4,5% of generated electric energy in Russia (Government Act from January, 08, 2009).
- About 3,8 GW of solar cells are produced in the world from 2004 to 2008.
- RusNano invested more than \$ 15 mlrd in projects, concerned with Si and photovoltaics
- Problem of buffer energy accumulation is actual for all renewables even in case of in-grid operation.



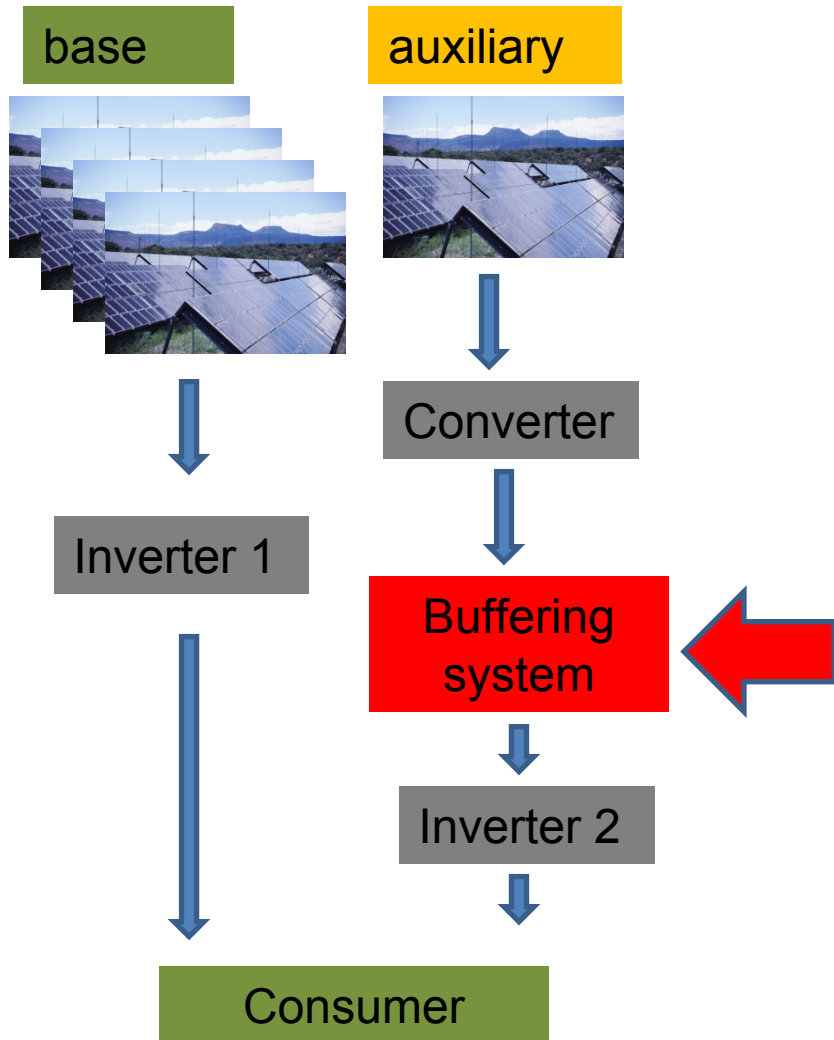
Arnulf Jager-Waldau, PV Status Report 2007 – Research, Solar Cell Production and Market Implementation of Photovoltaics.

H2 STORAGE 2009



Mer'moire concernant la contribution possible de la production e'olienne en re'ponse a` l'accroissement de la demande que'becoise d'er'lectriciter' d'ici 2010. Re'r'gie de l'er'nergie, Quebec, Canada. Dossier R-3526; Avril 2004

2-section power plant



Conditions:

- Buffer accumulator power output– 100 kWe;
- Charge time – 8 h;
- Discharge time – 8 h;
- 40 000 h power plant lifetime

Technologies:

- Hydrogen cycle with PEMFC;
- Hydrogen cycle with AFC;
- Hydrogen cycle with catalytic boiler and steam turbine;
- Flow vanadium-redox system;
- Lead-acid electrochemical accumulators;
- Li-ion electrochemical accumulators.

Calculation results = $\$/\text{kWe}\cdot\text{h}$

Capital costs

Components lifetime

-Calculation includes buffering system efficiency, resulting in additional solar cells (2 euro/We)

-Calculation includes components lifetime through number of spent equipment changes

-Calculation does not include the BoP costs, though for hydrogen cycle they must be noticeable

Why photovoltaics? Because of additional solar cells!



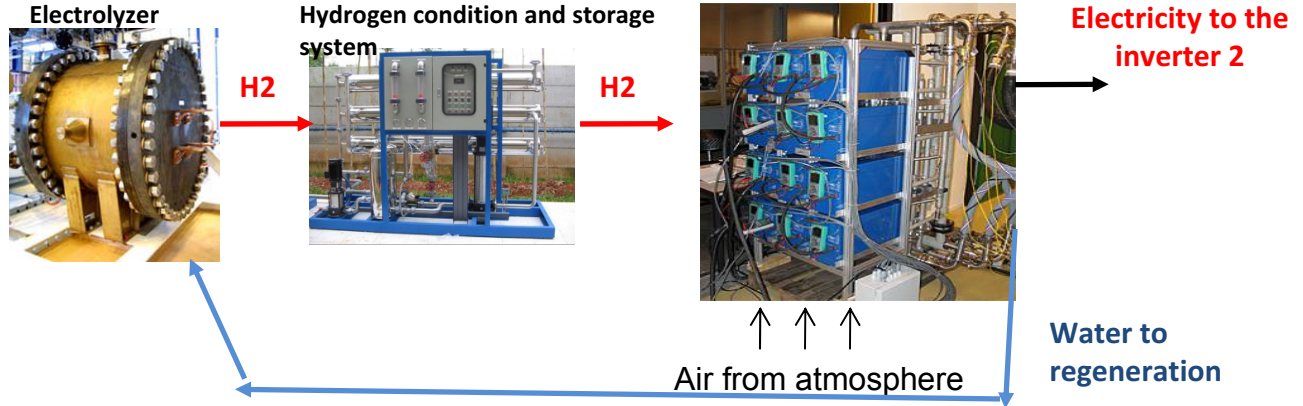


Fuel cells – technical issues

PEMFC – 5000 h resource, 20 000 h resource

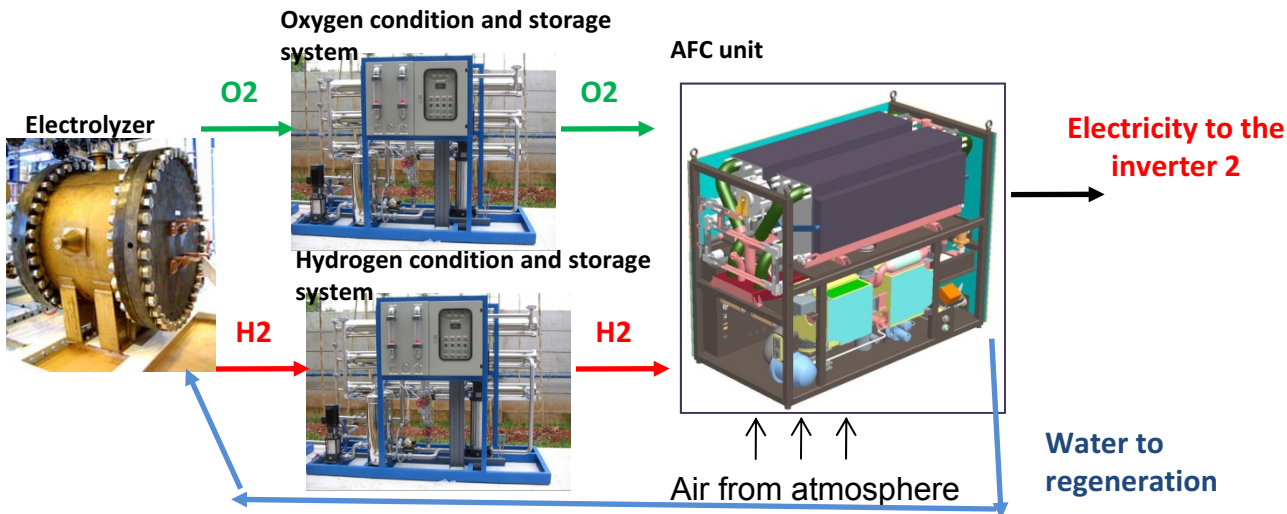
Buffering system

=



- + Higher lifetime, lower cost
- Pure hydrogen
- Relatively low efficiency
- Special inverter

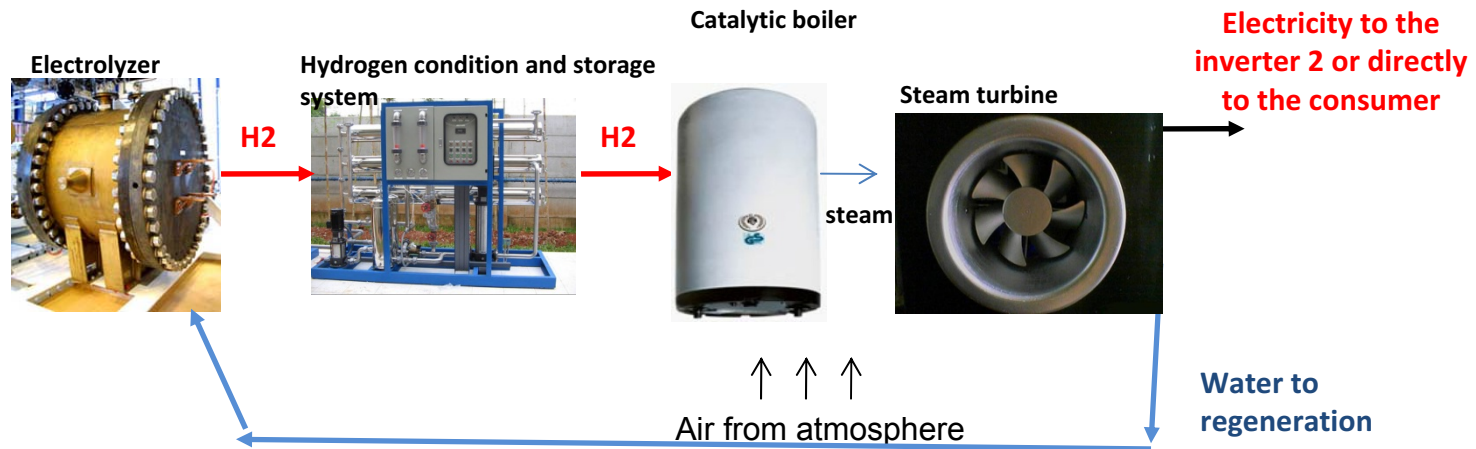
AFC – 5000 h resource



- + Higher efficiency
- +Alkaline vapors are not so critical
- More complicated BoP
- Oxygen safety questions
- Special inverter



Turbine + boiler – technical issues



- + Significantly higher lifetime and lower cost
- + Possibility to avoid inverter 2 or standard industrial system usage
- +Oxygen can be used to increase efficiency
- Very low efficiency in the chosen power range
- +Easy scaling up
- NOx presence
- Start-up issues



Electrochemical accumulators – technical issues

Li-ion batteries

- + Higher efficiency – electricity-to-electricity conversion
- + Much simpler BoP
- + Standard equipment
- + Deep discharge cycles
- High cost
- Complicated control system needed
- Lifetime issues



NIC NEP project

Lead-acid batteries

- + Higher efficiency – electricity-to-electricity conversion
- + Much simpler BoP
- + Standard equipment
- + Low cost
- Low efficiency – 30% discharge
- Lifetime issues



NIC NEP project

Redox flow batteries

- + Higher efficiency – electricity-to-electricity conversion
- + Simpler BoP
- + Lifetime issues
- + Deep discharge cycles
- High cost



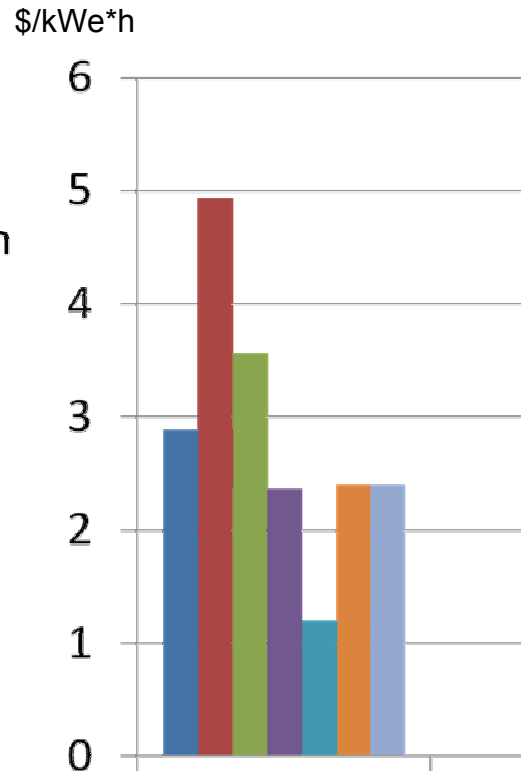
Kashima-Kita power plant (Japan)



Analysis results

100 kW,
40000 h

- PEMFC 20000 h
- PEMFC 5000 h
- AFC
- Boiler+turbine
- VRB
- Li-ion
- Lead-acid



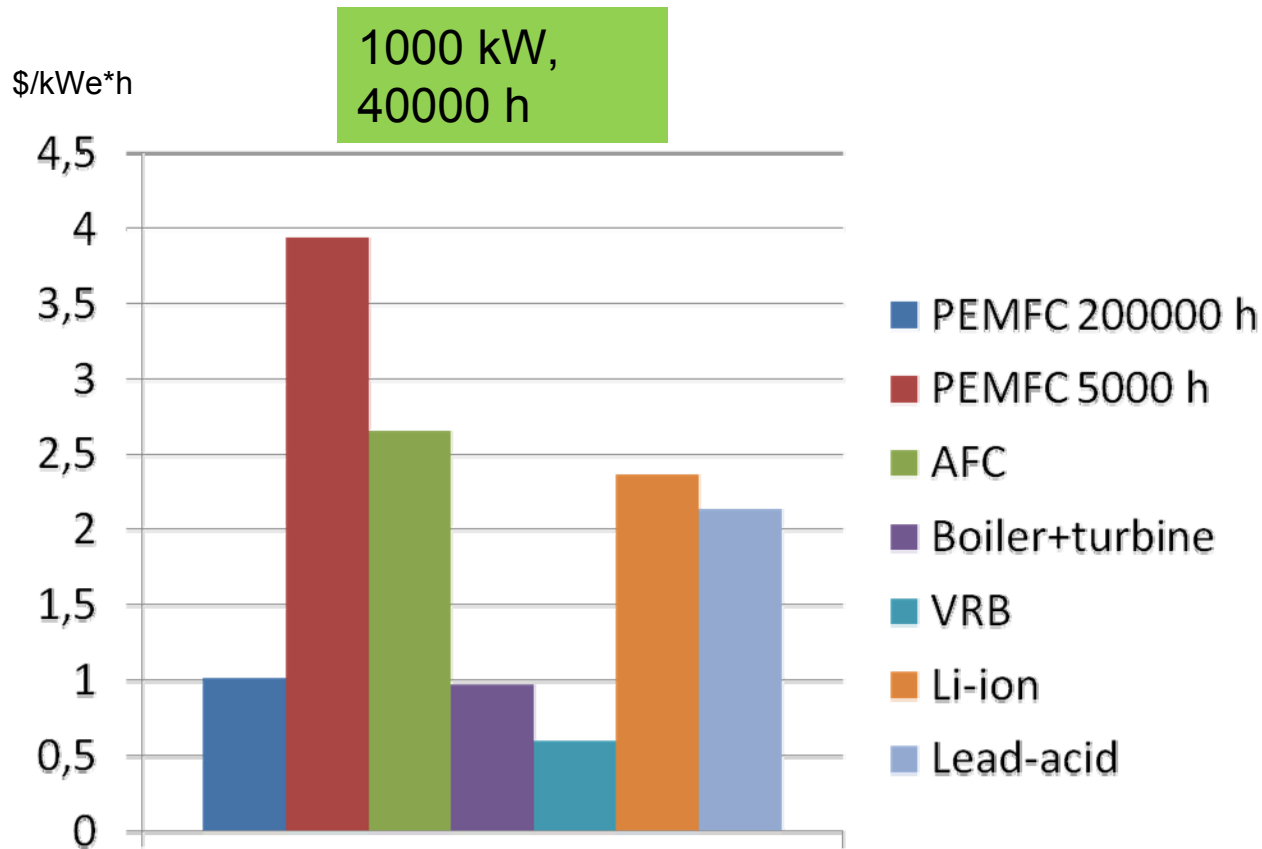
-Best solution is VRB

-Worst solution is 5000 h lifetime PEMFC

-Boiler+turbine scheme is competitive



Analysis results – Power range influence

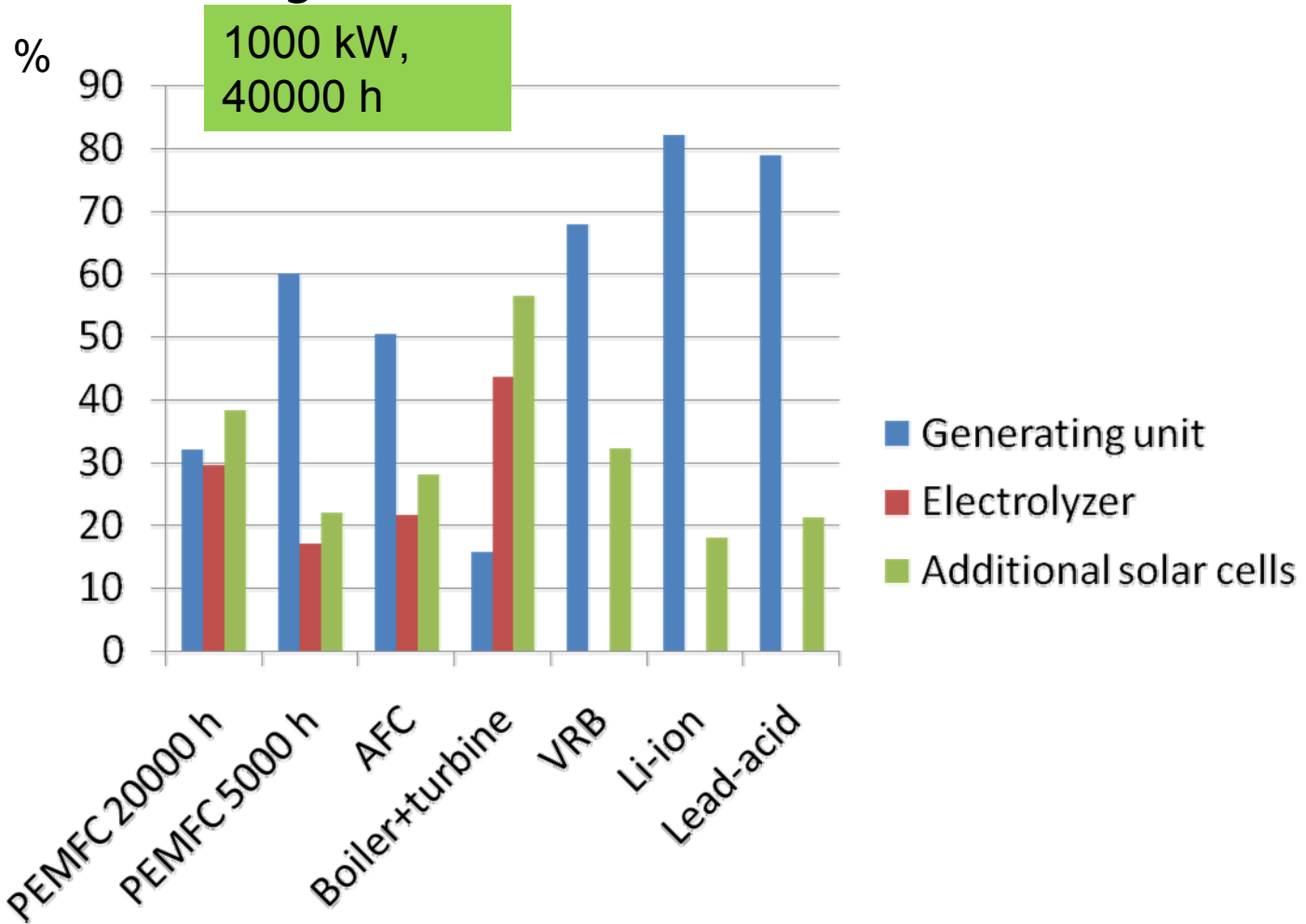


-Best solution is VRB again

-Low-resource systems competitiveness dramatically falls

-Boiler+turbine scheme is competitive to high-resource FCs

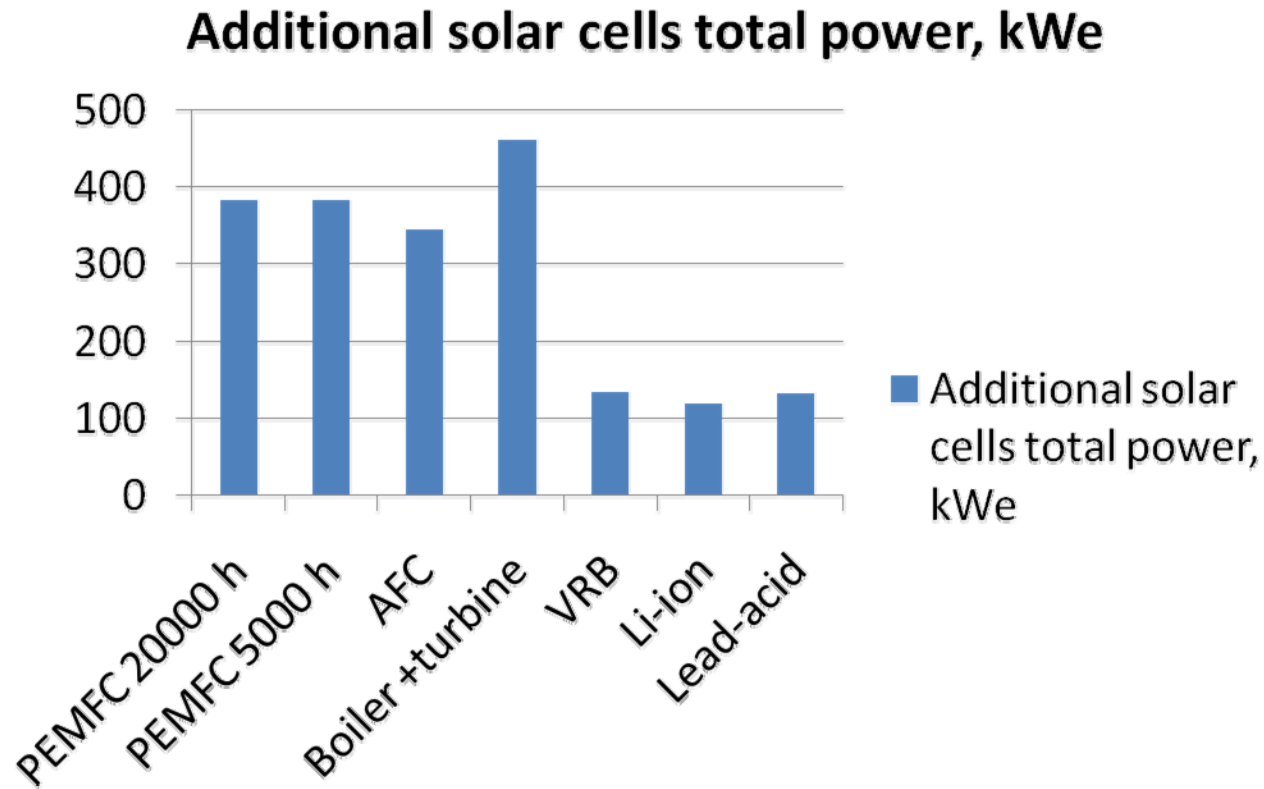
Analysis results - contributions



-Electrolyzer gives significant contribution to cost, especially in case of heat engine
-Main contributor to cost in case of heat engine are solar cells because of low cycle efficiency



Analysis results – efficiency

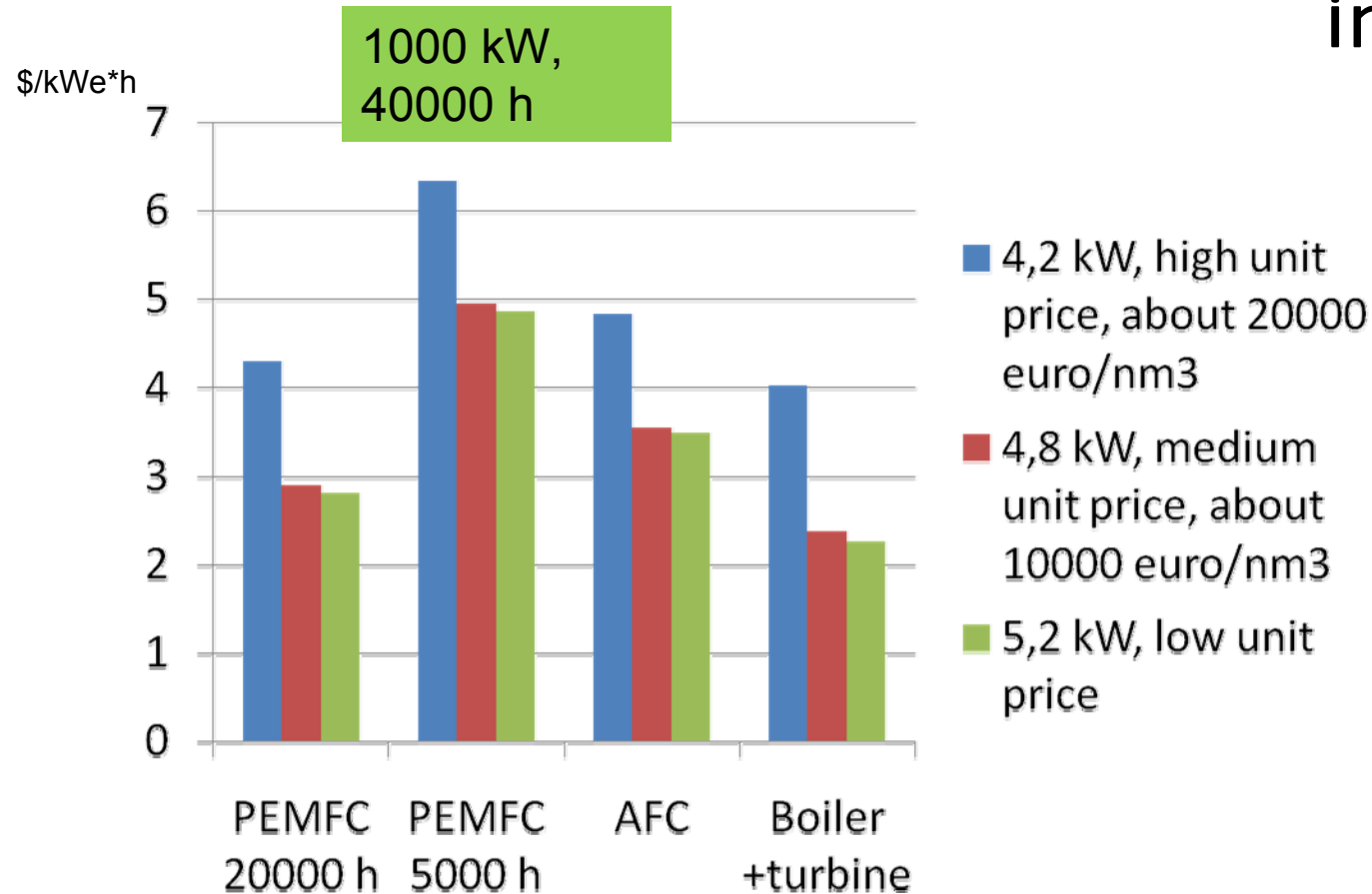


-Application of hydrogen cycle leads to an increase of solar cell amount

-Maximum solar cells amount corresponds to the lowest efficiency



Analysis results – electrolyzer type influence



- Electrolyzer capital cost is more important than energy consumption for these conditions.



Model further improvements

To give more accurate figures we need:

- To introduce PEM electrolyzers into the analysis;
- To estimate costs for BoP systems in each case, especially for FCs

Model can be applied for other renewable-based power plants taking into account their specific features



- Electrochemical accumulators seems to be more attractive than hydrogen cycle because of direct electricity-to-electricity conversion. Double conversion decreases competitiveness of hydrogen cycle.**
- Traditional heat engines are quite competitive, especially in high power range, when large areas for construction are accessible.**
- Fuel cells need increase lifetime to increase their attractiveness for such applications.**
- Electrolyzer capital cost has a significant importance.**
- Developed systems can be used in other fields, e.g. for centralized grids power regulating and for waste hydrogen utilization.**

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Thank you
for
attention!