Hydrogen Technologies
for
Energy Storage

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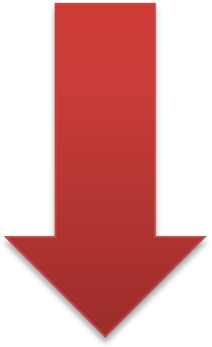
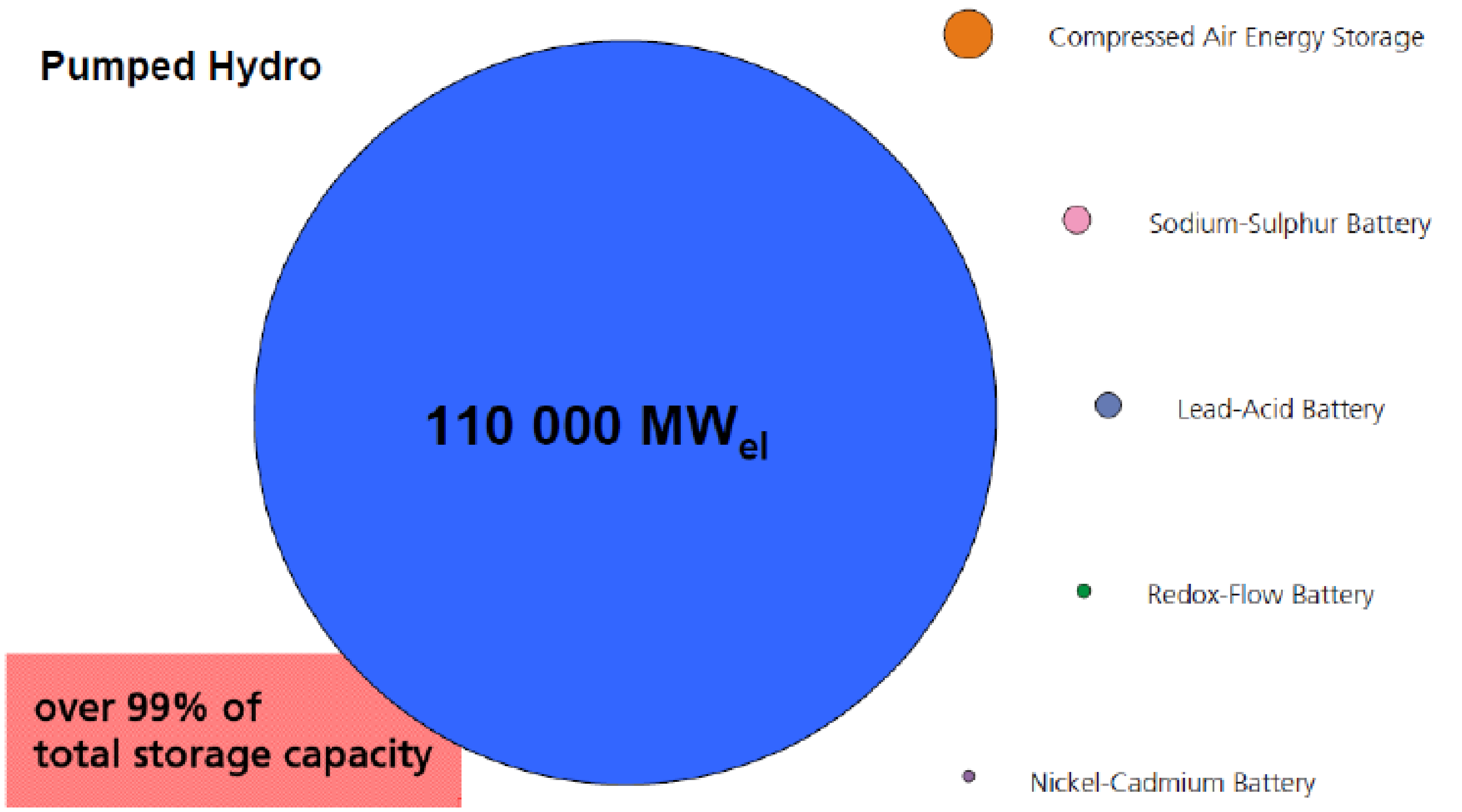
DEMAND for ENERGY STORAGE

- Increase of the share of renewable energy characterized by irregularity;
- Irregularity of energy consumption in a centralized grid;
- Distributed or autonomous power systems;
- Backup power.



All this requires the creation of reliable, efficient and inexpensive energy accumulators

Worldwide installed storage capacity for electrical energy



WHY HYDROGEN?

- Widespread in nature, that allows to build such systems everywhere;
- High specific energy, thus reducing the cost of storage;
- No losses during the storage;
- Reversibility of charge-discharge cycles;
- Environmental friendliness at work;
- Relatively good reactivity and availability in the variety of compounds.

Energy flux limits

Fuel Cells

Energy flux is limited by diffusion of charge carriers in electrolyte
$W^{FC}_{max} \sim 10^3$ W/m^2

Combustion systems

Energy flux is limited by sound velocity in critical cross-section:
$W^{SG}_{max} \sim \alpha\rho\Delta H_T \sim 10^{10}$-$10^{11}$ W/m^2
and
by conversion of mechanical energy into electric energy:
$W^{EG}_{max} \sim \alpha\varpi H_m^2/4p \sim 10^7$ W/m^2

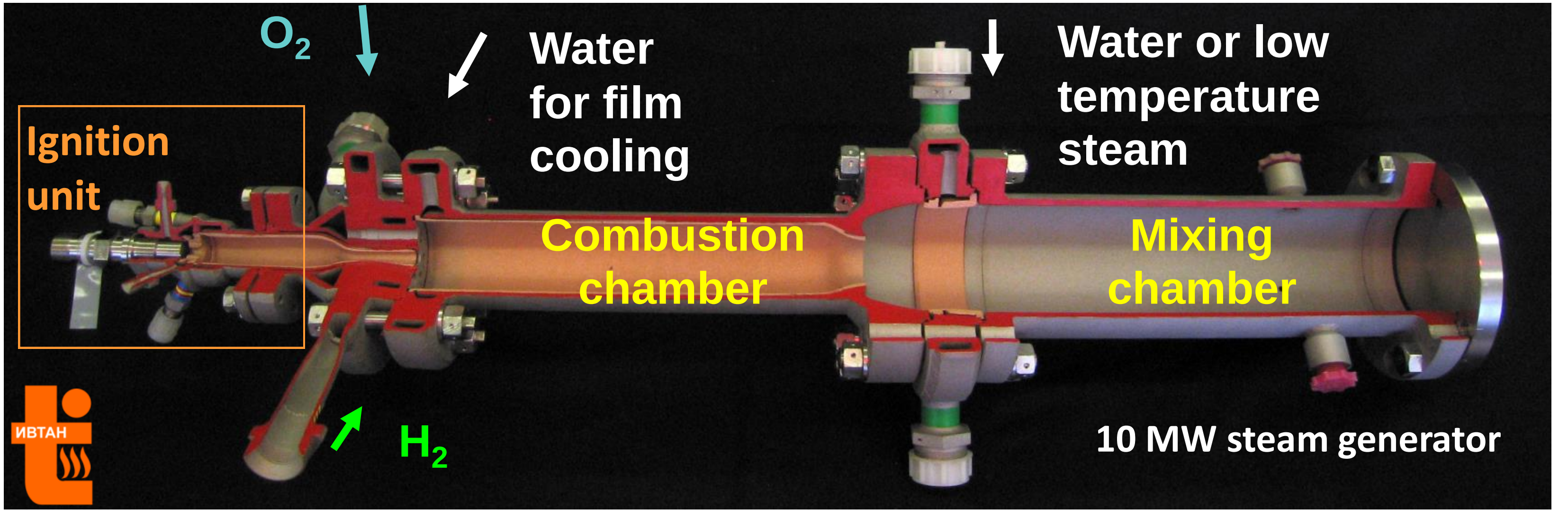
$W^{EG}/W^{FC} \sim 10^4$

critical surface ratio:

$A^{FC}/A^{EG} \sim 10^4$

Small scale preferable	Large scale preferable

H2/O2 steam generators



H2/O2 steam generators practically have no limitations on temperature of superheated steam and do not depend on materials of boiler units and steam pipes.

H2/O2 steam generators

Main technical characteristics:

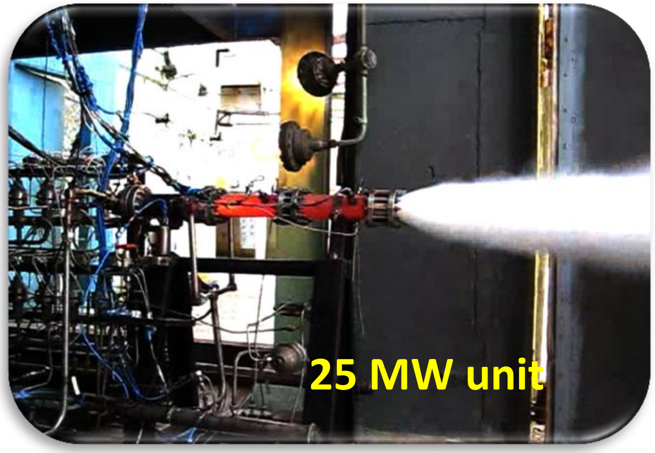
- High specific capacity
- Very fast start
- High temperature and pressure
- High efficiency
- Low cost

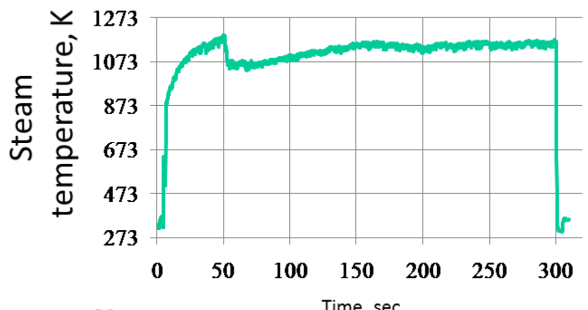
Applications:

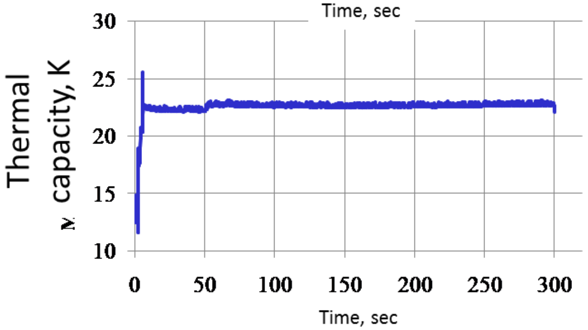
- Compact autonomous power systems for transport
- Modernization of existing power plants (steam superheating and load management)
- Reserve and energy accumulation power systems
- High-temperature steam for technological processes.

Allows to realize this applications

H2/O2 steam generators





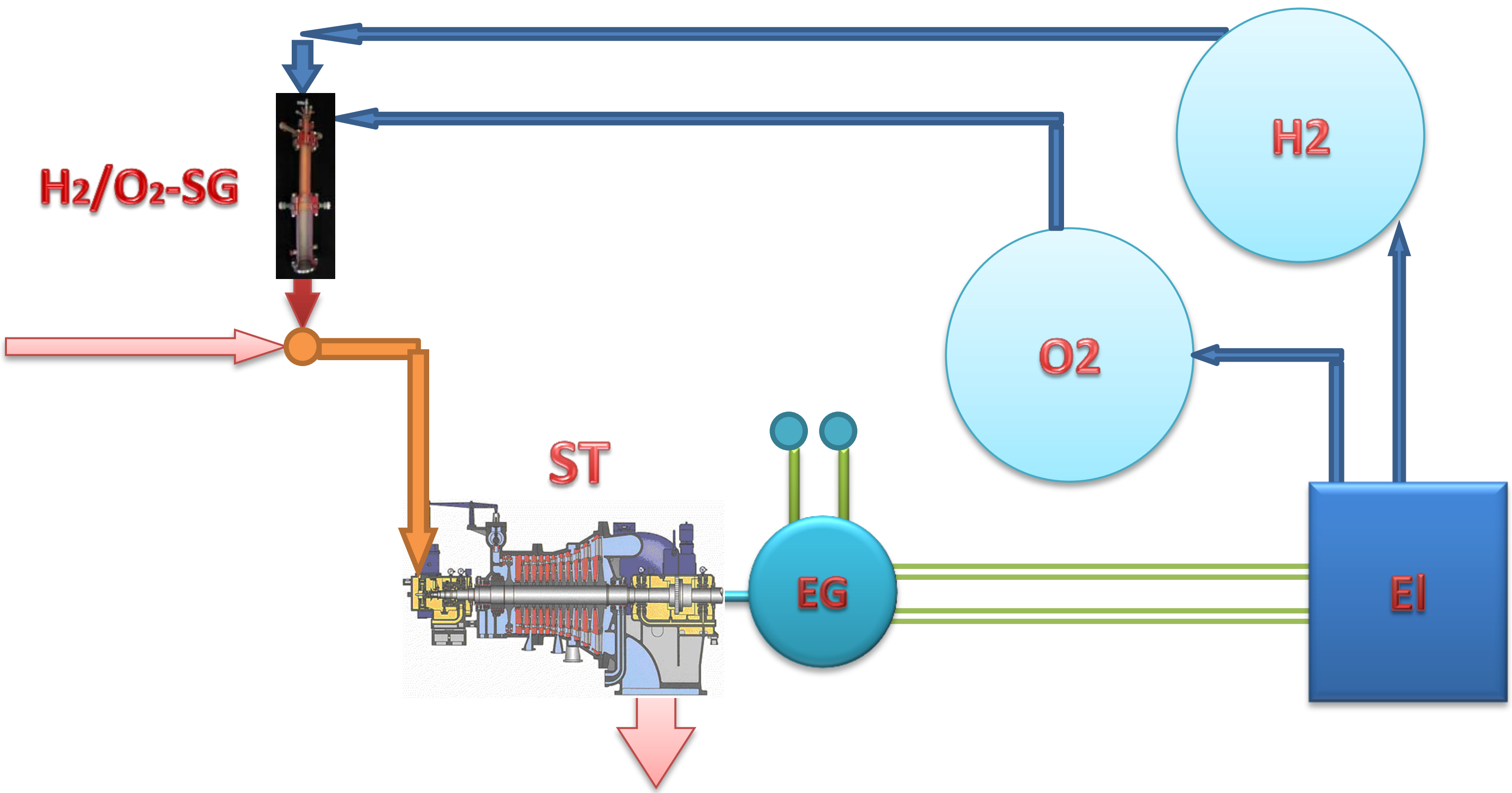


Hydrogen-oxygen steam generator with 25 MW thermal capacity

Technical characteristics

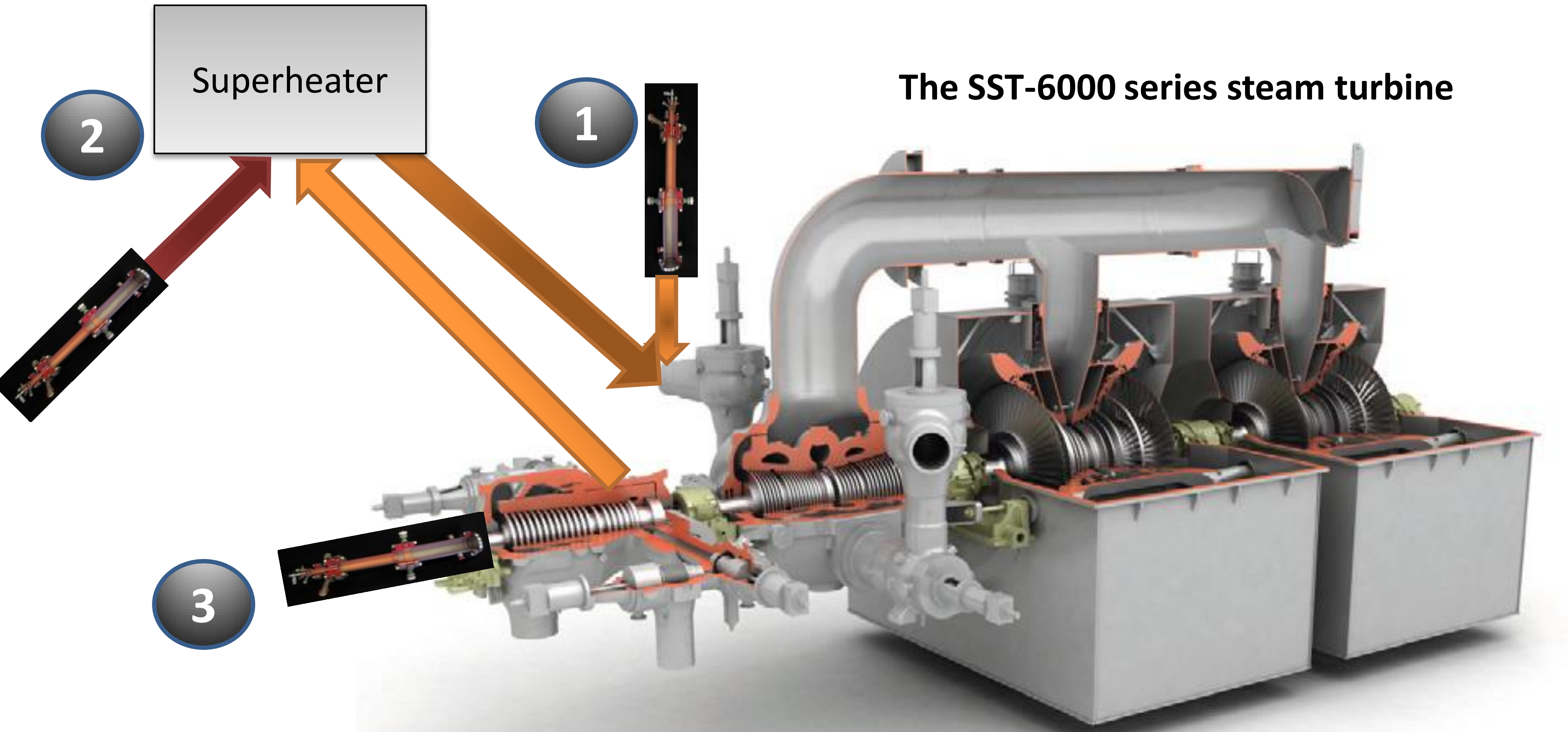
- Efficiency of design was experimentally approved;
- Combustion completeness is higher than 98.5 %;
- Steam temperature up to 1700 K;
- Start up is less than 10 seconds
- **Cost, less than 40 $/kW (thermal)**
- Uniform temperature of steam is obtained (temperature field non-uniformities are less than 15 K)

Peak Power



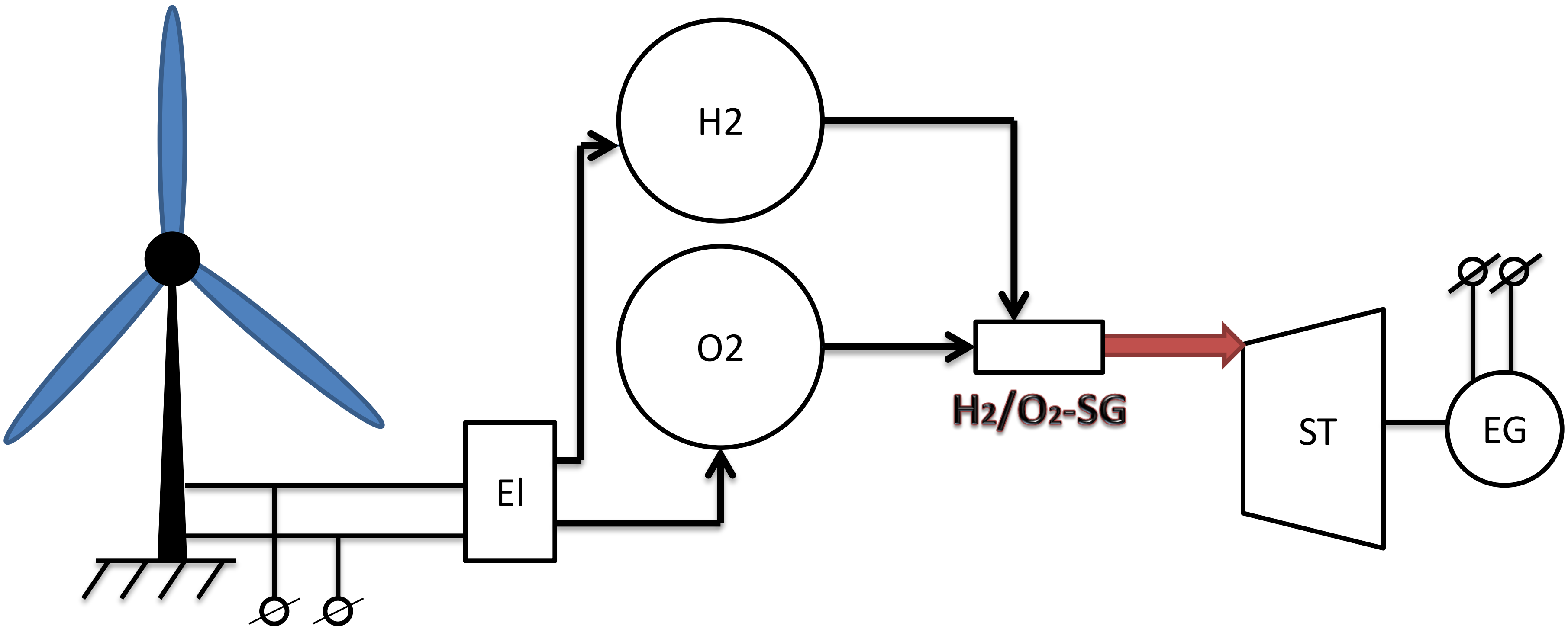
H2/O2-SG – hydrogen-oxygen steam generator
ST– steam turbine
EG – Electric generator
El – electrolyser
O2, H2 – hydrogen and oxygen storage

Hydrogen steam generator for SPI technology



Variant 1: **H2/O2 SPI before middle pressure stage**, 540…620 °C, 70…90 Bar
Variant 2: **H2/O2 Steam superheater before middle pressure stage**, 1500…1800 °C, 70…90 Bar
Variant 3: **H2/O2 SPI before high pressure stage**, 540…620 °C, 240…350 Bar
Variant 4: **Various combinations** with 1-3 variants.

Renewable Energy Storage : autonomous power units



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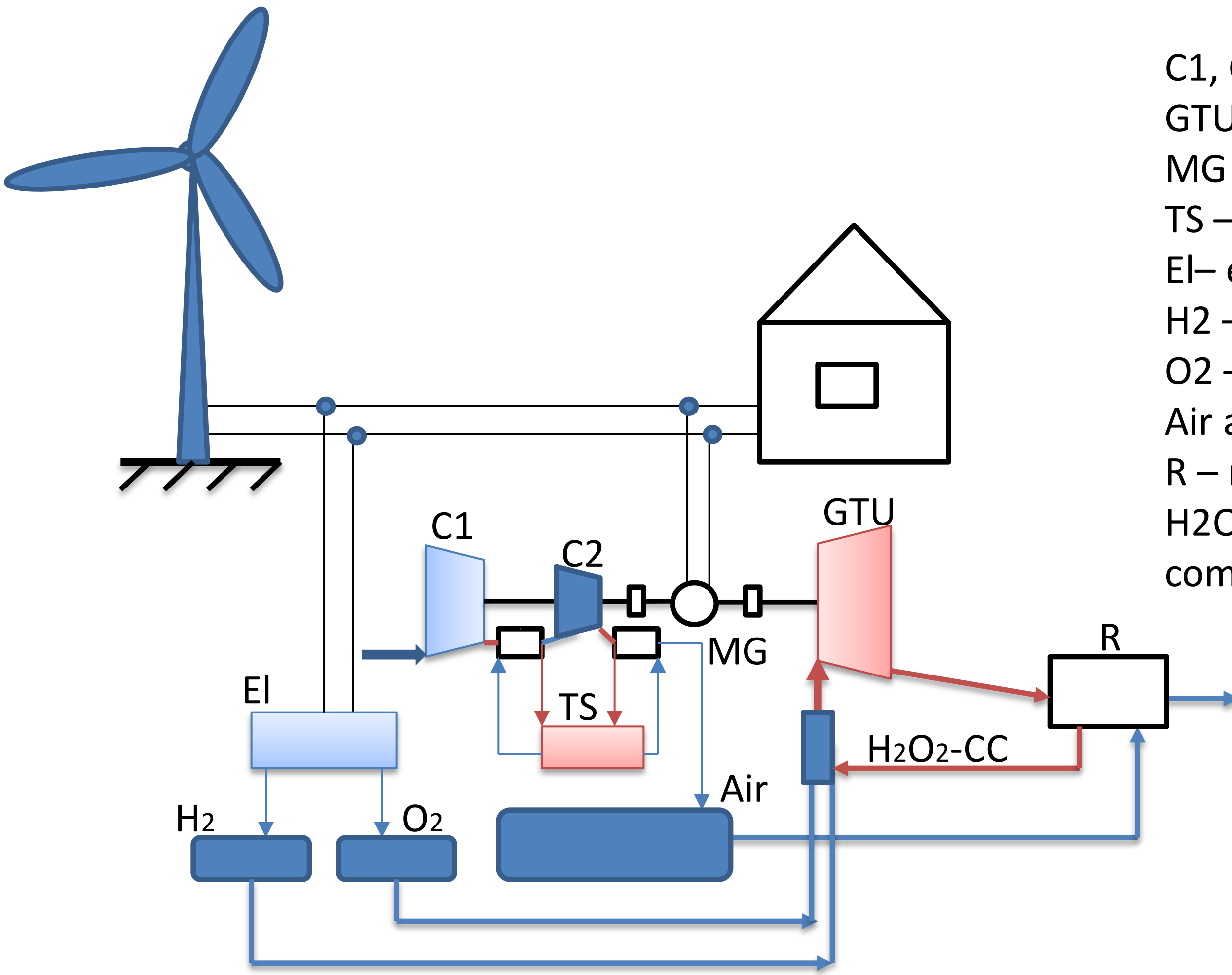
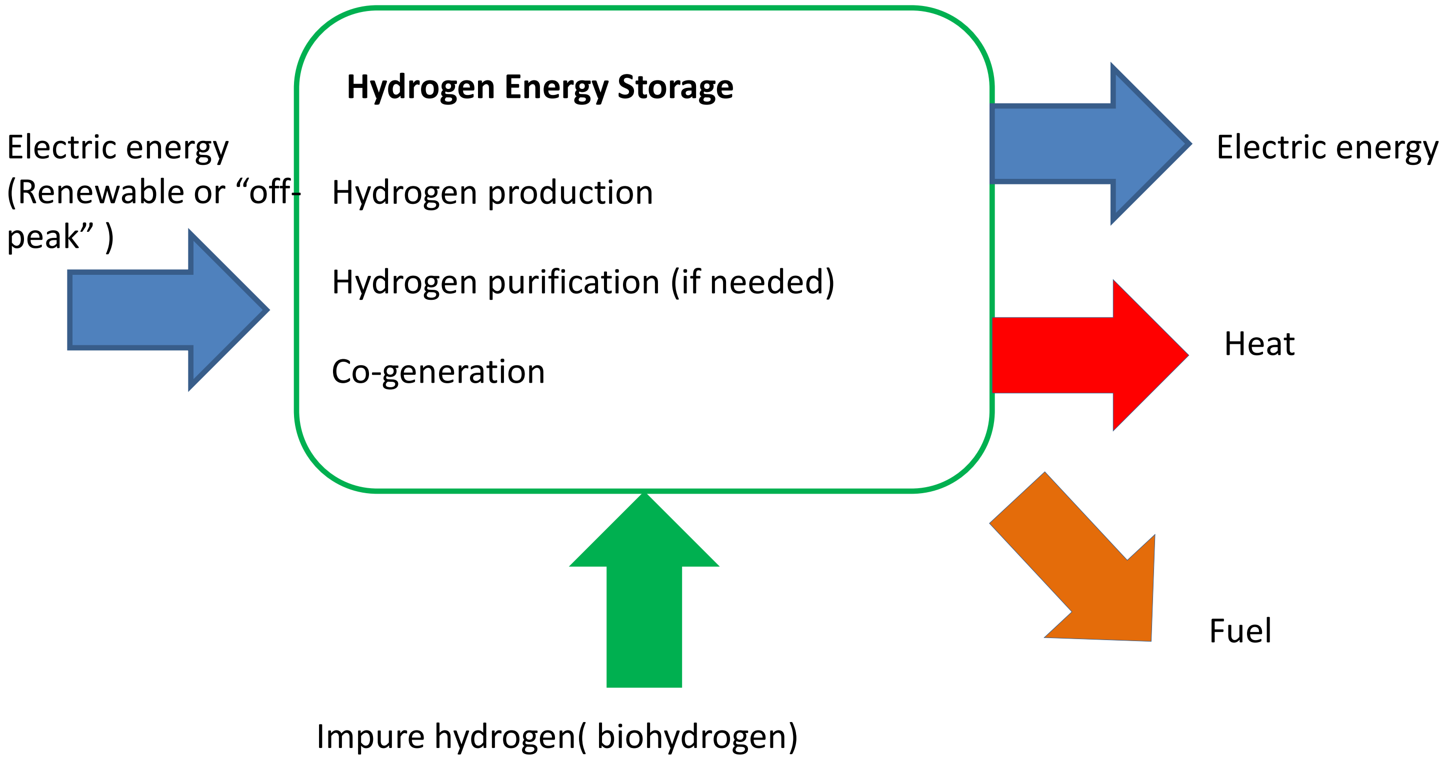
Hydrogen-air energy storage system



C1, C2 – compressors;
GTU – gas-turbine unit;
MG – motor/generator;
TS – thermal storage;
El– electrolyser;
H2 – hydrogen storage;
O2 – oxygen storage;
Air air storage;
R – recuperator;
H2O2-CC – hydrogen/oxygen combustion chamber.

Hydrogen energy storage systems, kW scale



Basic efficiency criteria: electricity recovery coefficient

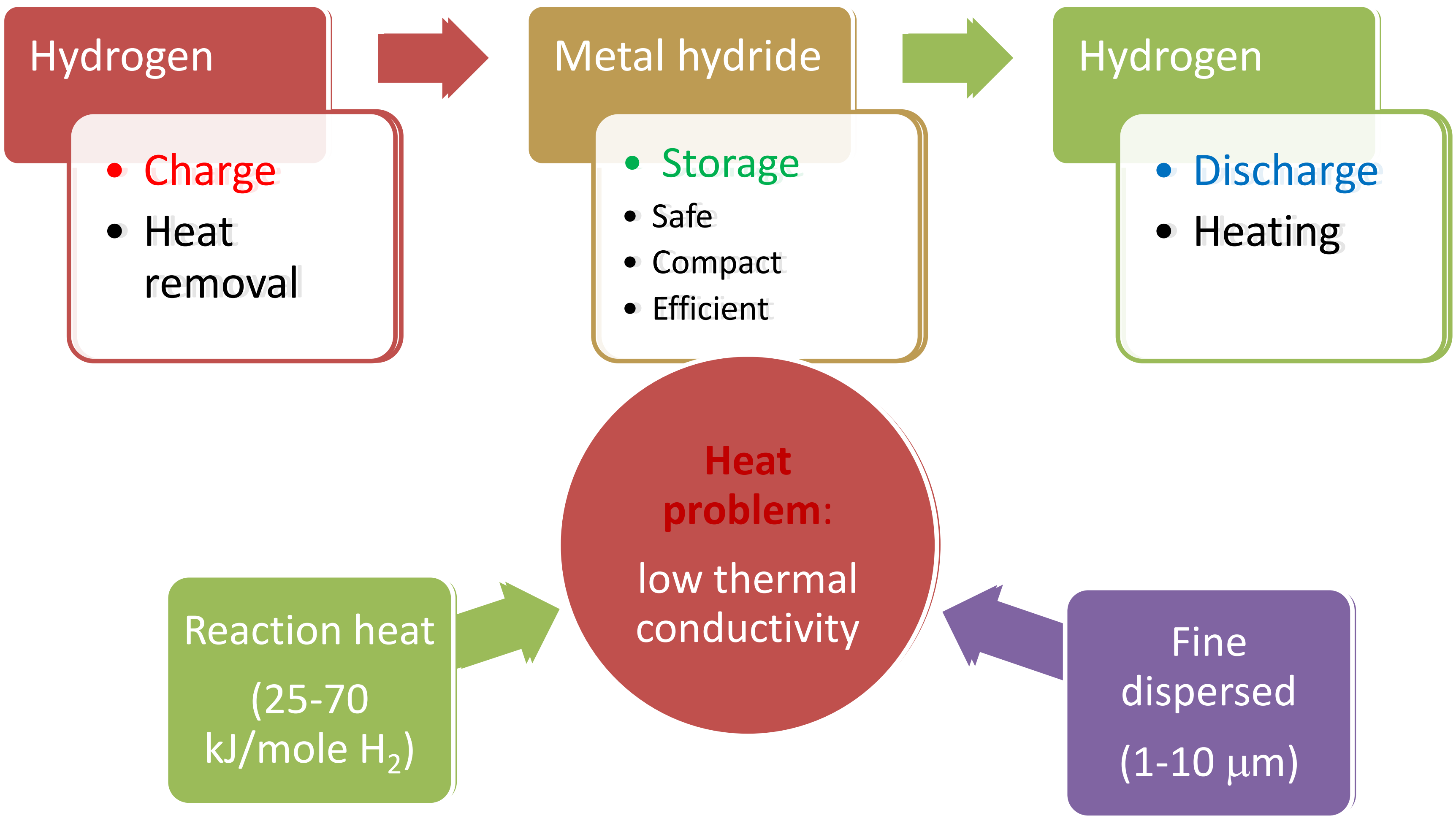
Main problem: integration of components !!!!!!

Back-up power, kW scale

Same structure as storage, but the main efficiency criteria: **reliability .**

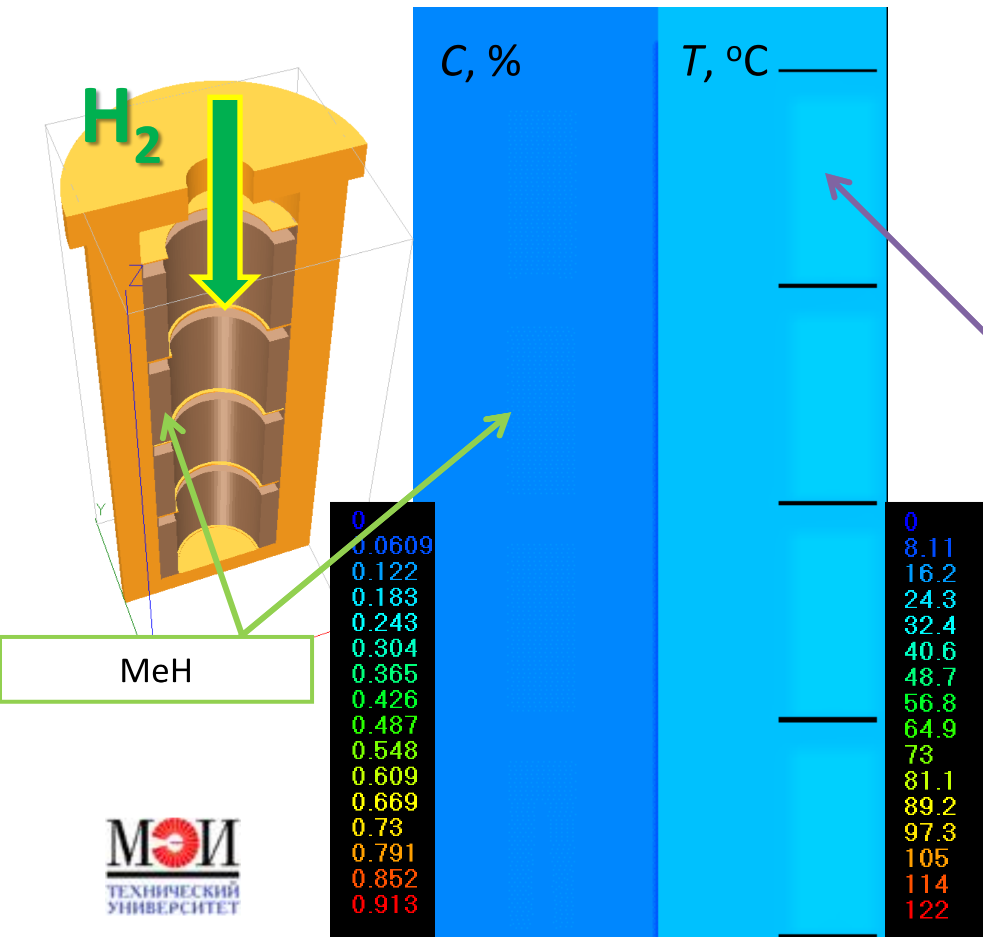
Main problem on the way to commercialization: the necessity to correspond with regulations on safety - any pressure higher than 0.7 bar is the subject for special permissions – long way in Russia, plus certified personnel in case of gaseous storage (high pressure devices).

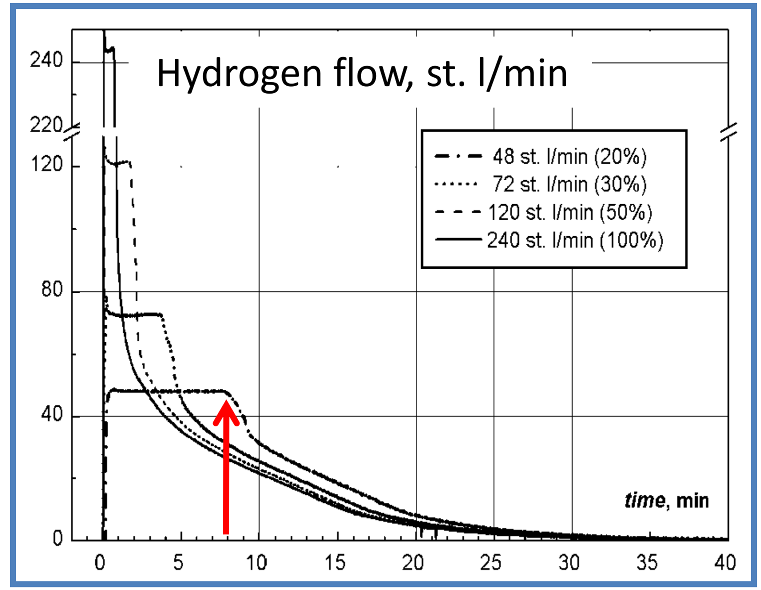
Low temperature metal hydrides



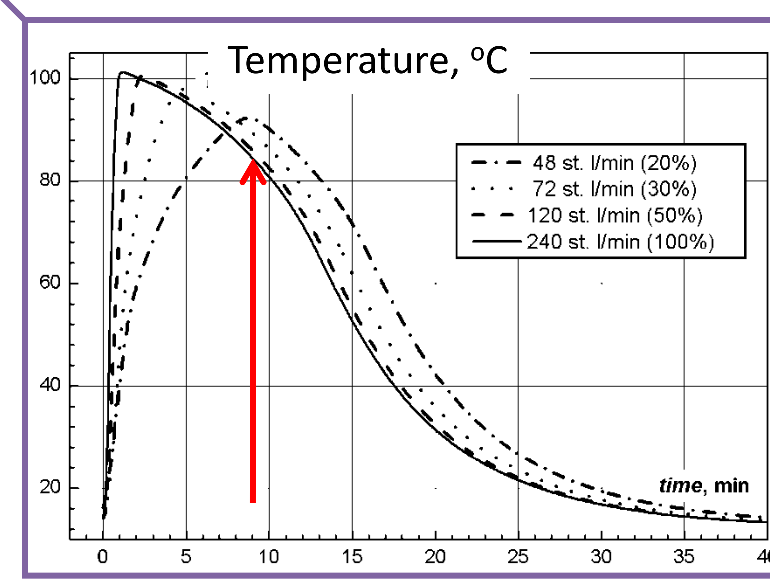
Thermal problem

Low thermal conductivity of metal hydride beds is the cause for overheating and stop of the sorption reaction.





Experiments prove that the charging regime is broken at reaching the temperature maximum in MeH medium

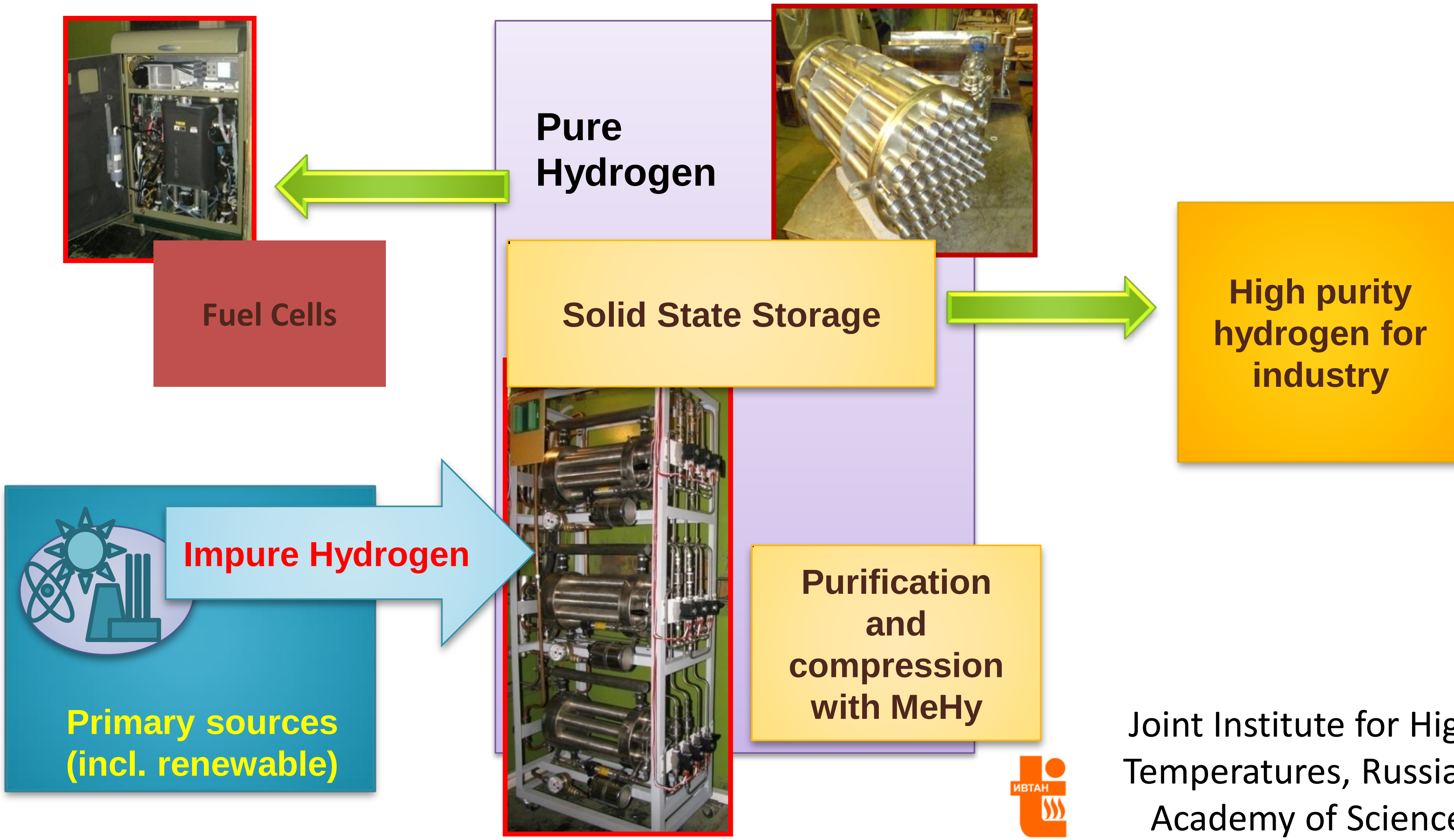


МЭИ
ТЕХНИЧЕСКИЙ УНИВЕРСИТЕТ

Hydrogen mass content C and temperature fields T calculation in reactor.

System Integration:

Hydrogen supply for Fuel Cells, Energy accumulation in Renewable Energy Systems, Hydrogen purification for Turbogenerator Cooling Systems, Heat pumps, Hydrogen thermal compressors, Pure hydrogen for technology processes



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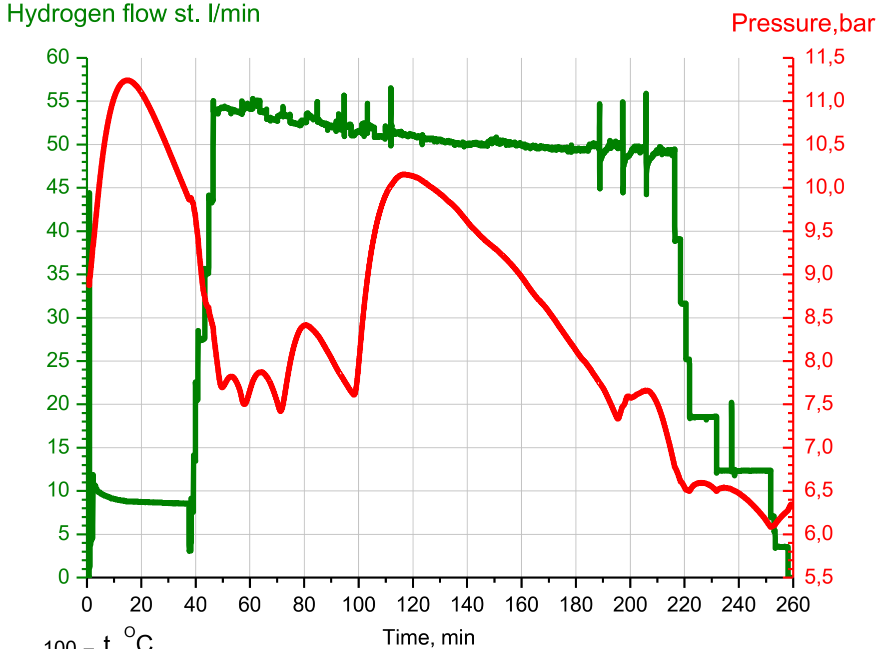
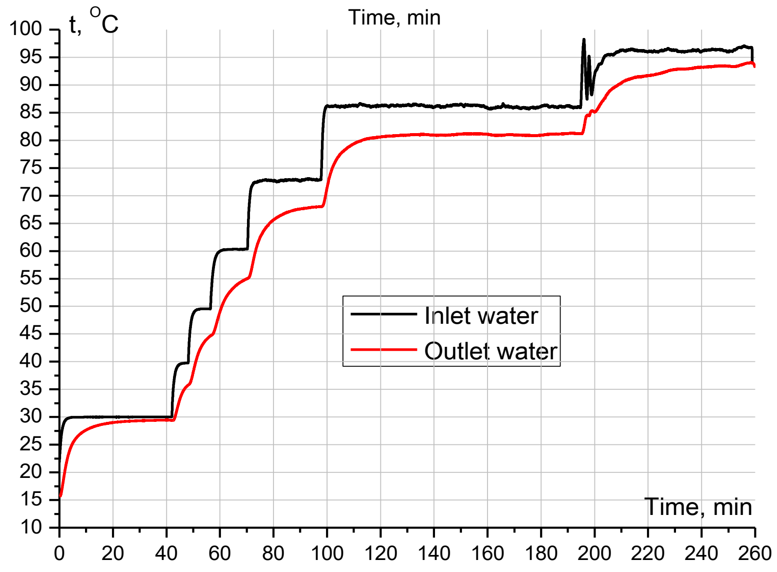
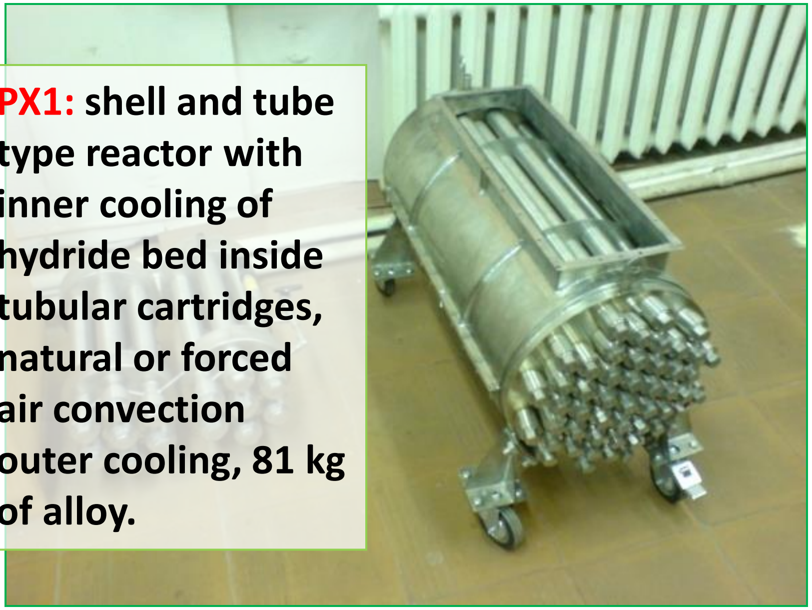
Metal hydride storage tank integration with PEM FC



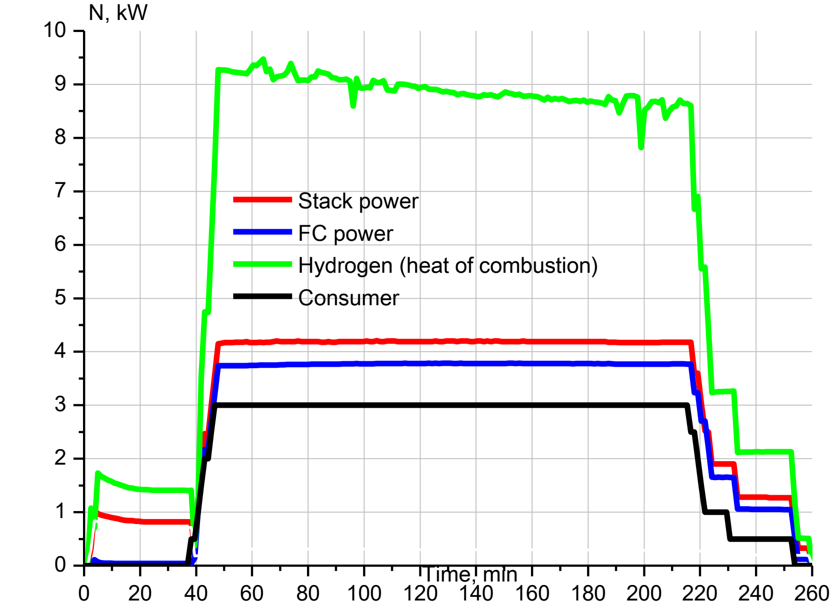


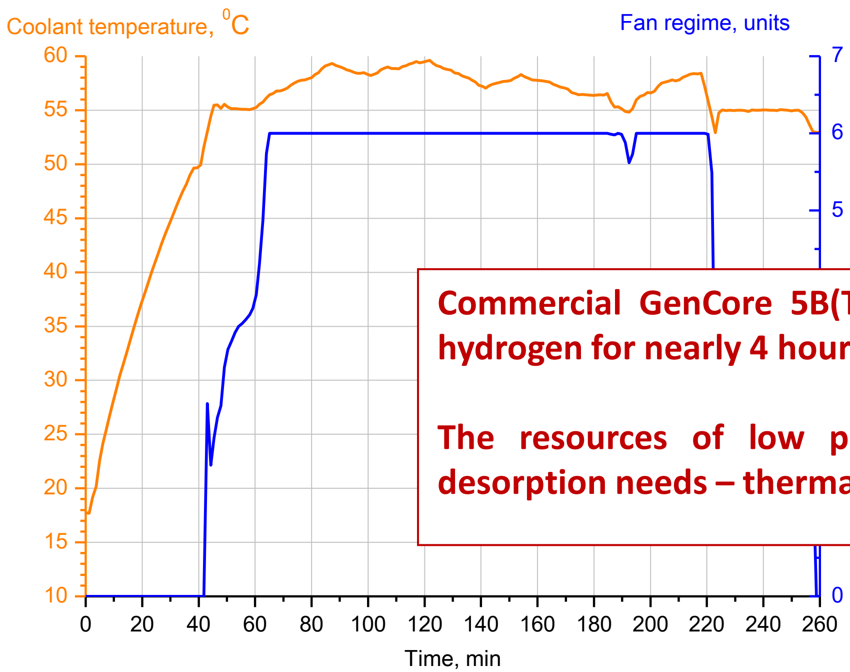
$La_{0.5}Nd_{0.5}Al_{0.1}Fe_{0.4}Co_{0.2}Ni_{4.3}$



PX1: shell and tube type reactor with inner cooling of hydride bed inside tubular cartridges, natural or forced air convection outer cooling, 81 kg of alloy.

Metal hydride storage tank integration with PEM FC





Commercial GenCore 5B(T)48 Fuel Cell system was successfully supplied with hydrogen for nearly 4 hours with total hydrogen volume of up to 12 m^3

The resources of low potential heat (FC coolant) cover the storage tank desorption needs – thermal integration is possible.

25 kWh metal hydride storage for 10 kW PEM FC renewable energy system

H2BioPower – 200 W (e) demonstration power unit using hydrogen +CO_2 mixture as a fuel for PEM FC

Concluding remarks

- Any renewable energy project commercialized is a separate success story depending on initial parameters (power demanded, required load schedule etc), availability of local resources for energy production and storage (geography, climate, infrastructure etc) and there is no universal approach for the technology selection;
- … however hydrogen is one of the most flexible (electricity, CHP, CHHP) solutions covering the power range from kW to GW and time-shift from hours to months with high storage density (170 kWh/m^3 compared to 0.7 at PH or 2.4 CAES);
- Hydrogen potential is also in power-to-gas distribution in existing natural gas networks);
- The growing demand for hydrogen as transportation fuel increases the flexibility of the grid saturated by renewable energy generation and gives advanced business chance for hydrogen energy storage systems;
- Purification and hydrogen (energy) storage are key issues for power production from and metal hydride technology can be one of the solution for kW scale;
- MW and kW scale effective demonstration projects are needed.

THANKS FOR YOUR ATTENTION !

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