НАЦИОНАЛЬНЫЙ ИССЛЕДОВАТЕЛЬСКИЙ УНИВЕРСИТЕТ

1930

МЭИ

BRICS NU World Conference on Electric Mobility

Research and development of promising hydrogen technologies

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2021

Summary of the talk

- Transition to H2 economy in Russia.
- The concept of H2 economy.
- NPP and TPP for H2 production and usage.
- Power generation equipment for the promising NPP and TPP.
- CH4-H2-fired CCGT.
- Oxy-fuel combustion power cycles with NH3 production.
- H2 transportation.
- MPEI R&D plans in the field of H2 technologies.

Relevance of the transition to hydrogen economy in Russia

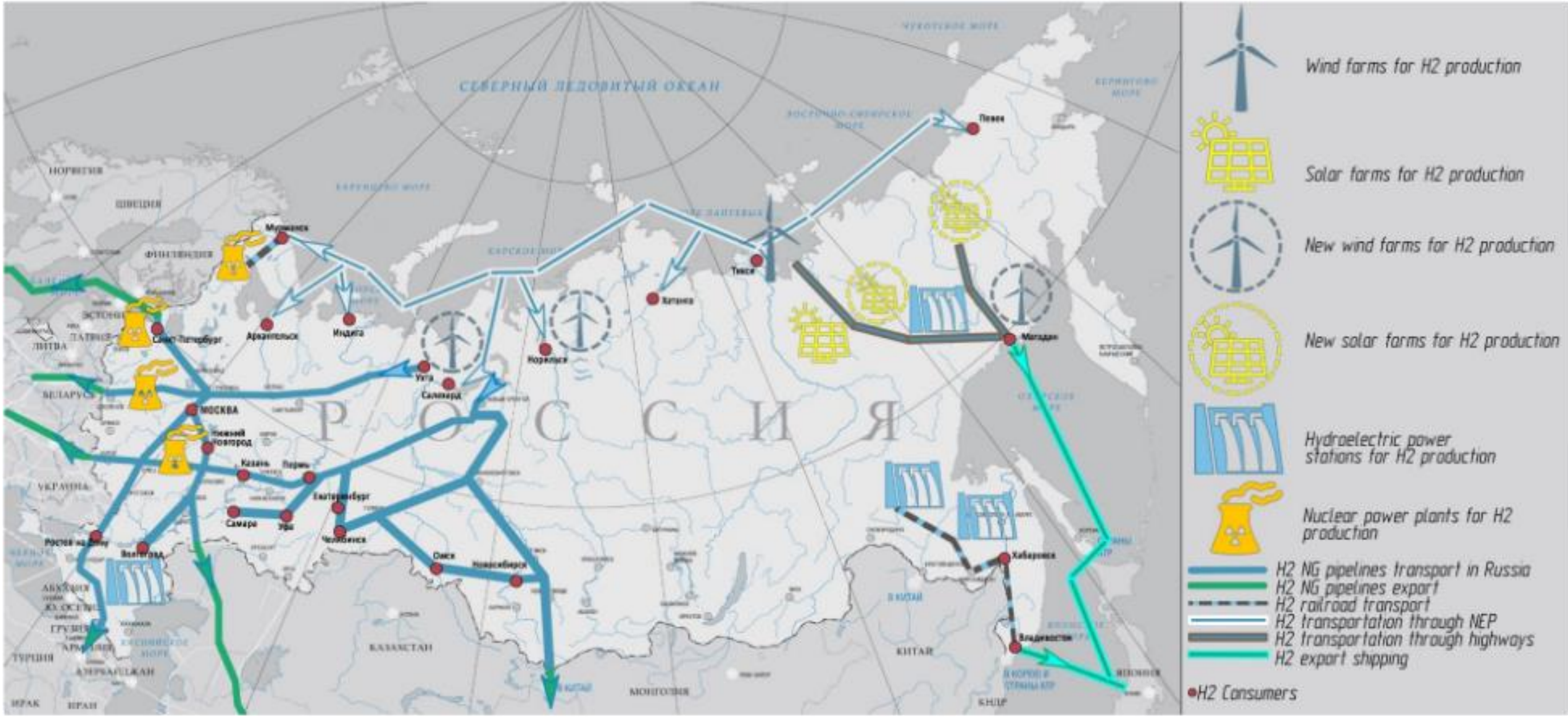
- Russia has a unique geographical location for the production and export of H2: between the European Union and China - two major centers of H2 consumption.
- Available capacity of nuclear power plants, hydroelectric power plants and renewable energy sources for H2 production.
- The Ministry of Energy has developed and sent to the government a roadmap "Development of hydrogen energy in Russia" for 2020-2024 according to which the goal of Russia is to become a leading producer of hydrogen.
- Required investment: $ 2.2–3.9 billion per year; potential profit: $1.7 to 3.1 billion per year (according to experts of the center EnergyNet infrastructure).

GAZPROM H2

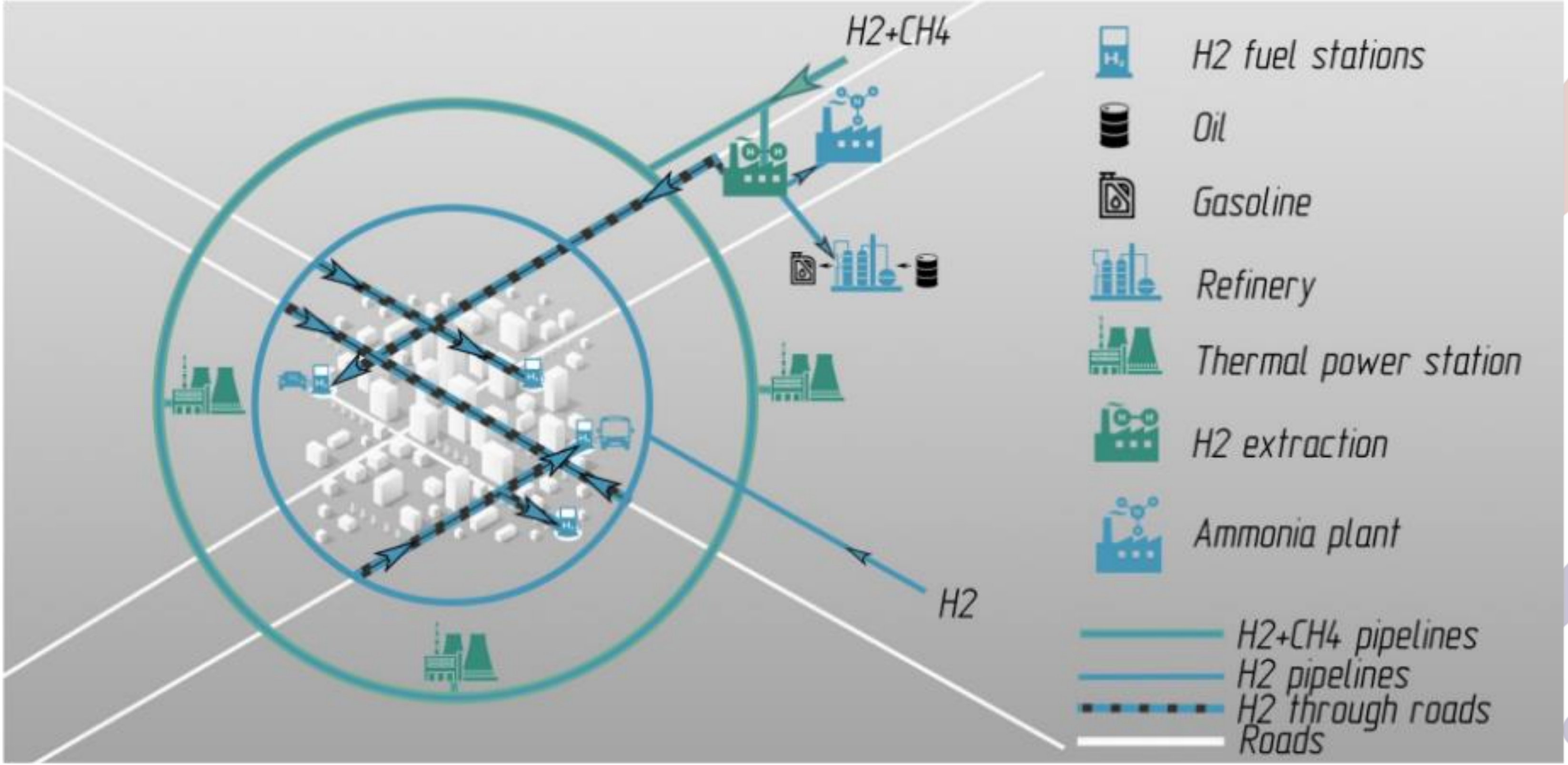
Future main producers of blue and yellow hydrogen in Russia

ROSATOM H2

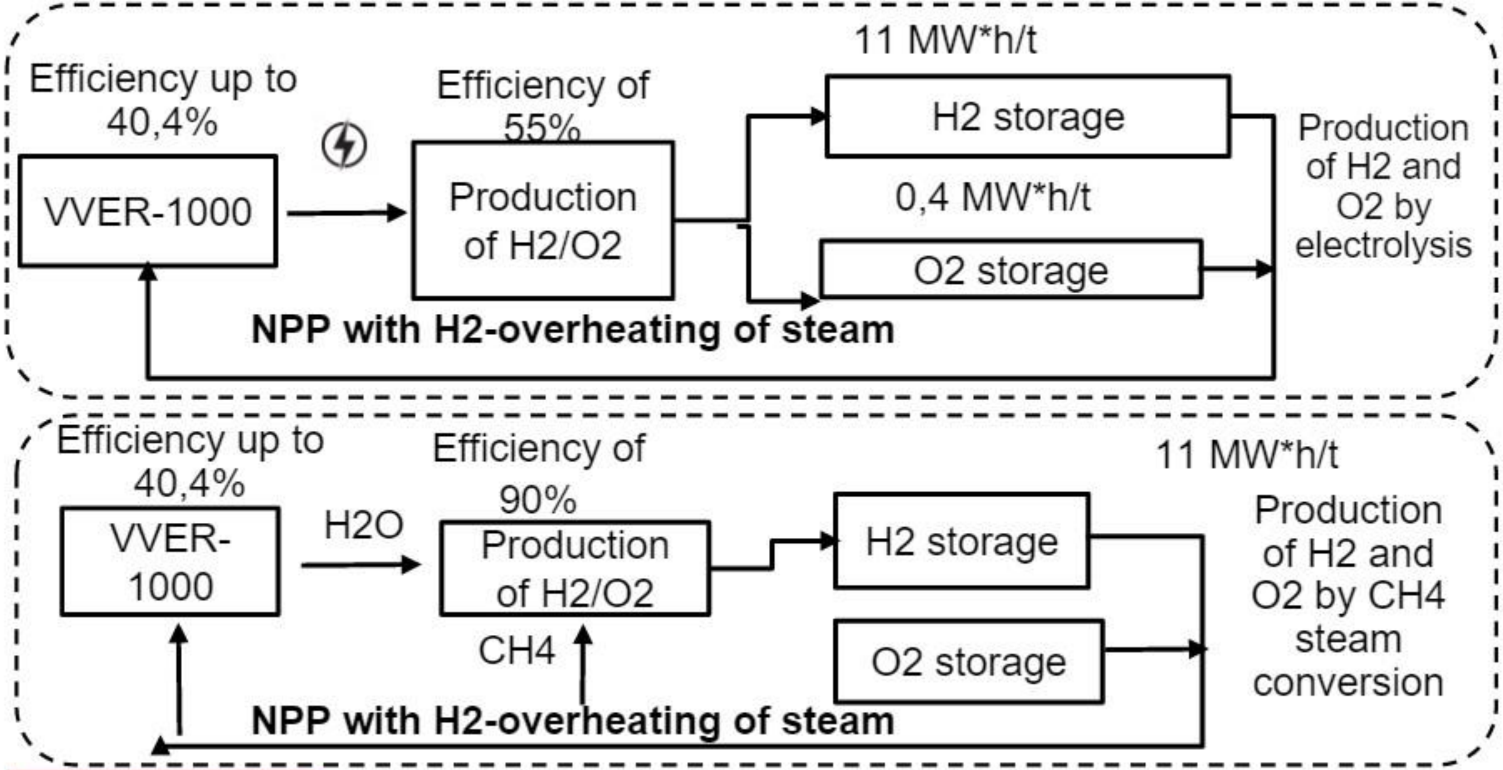
The concept of H2 economy in Russia proposed by the MPEI



The concept of H2 city proposed by the MPEI



Nuclear power plants with the H2/O2 combustion chambers*



Net efficiency obtained from the use of H2:

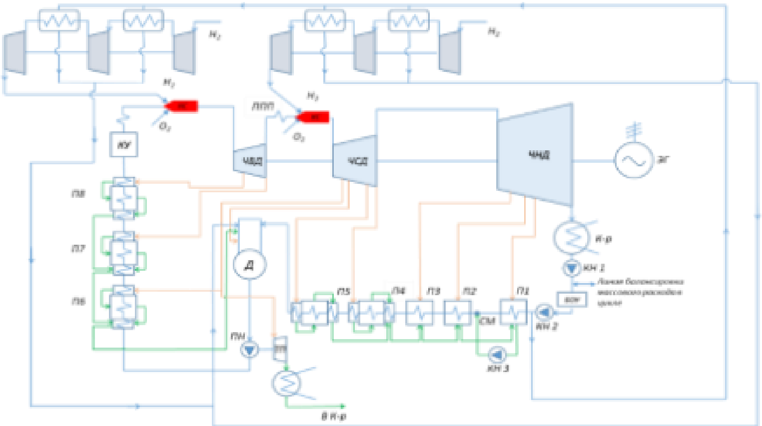
7% (scheme with electrolysis)

20% (scheme with steam conversion of methane).

* - estimations of the MPEI

Thermal power plants with the H2/O2 combustion chambers*

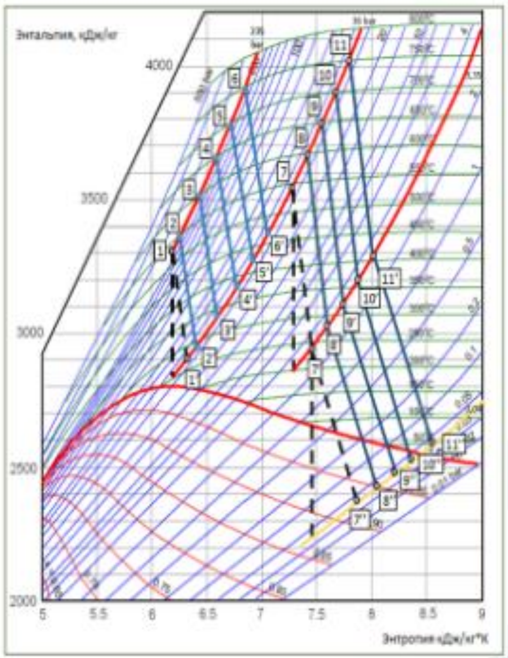
Researchers of the MPEI have considered 3 variants of the location of H2/O2 combustion chambers:
- before high-pressure turbine (HPT);
- before intermediate-pressure turbine (IPT);
- before HPT and IPT simultaneously.



Modeling results*

Overheat, °C	Efficiency, %
640	42,0
740	43,8
840	45,5

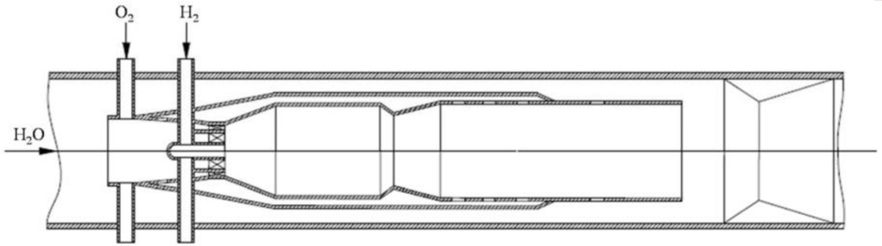
Steam turbine expansion process at different degrees of H2-overheating

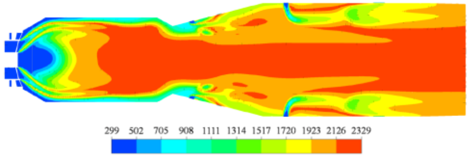


* - MPEI estimations

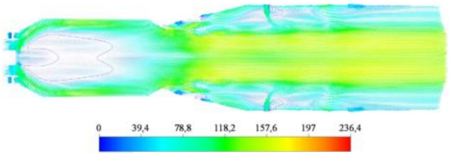
H2/O2 combustion chambers

Combustion chamber with a vane swirler for H2 combustion in a steam-oxygen environment.

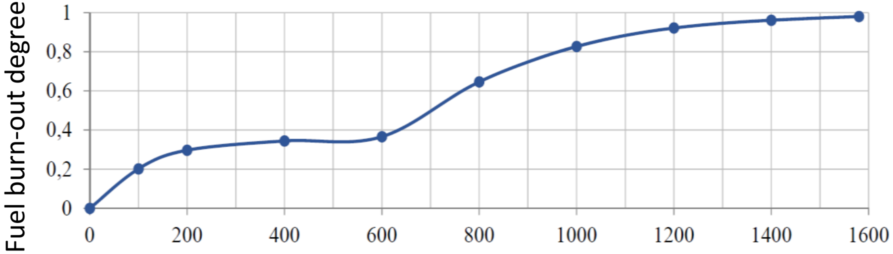




Temperature, K



Speed, m/s

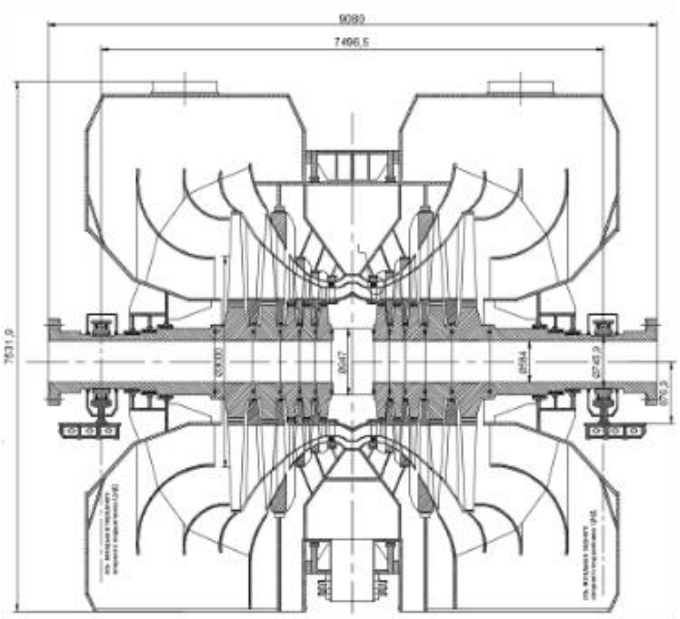


Distance from nozzle, mm

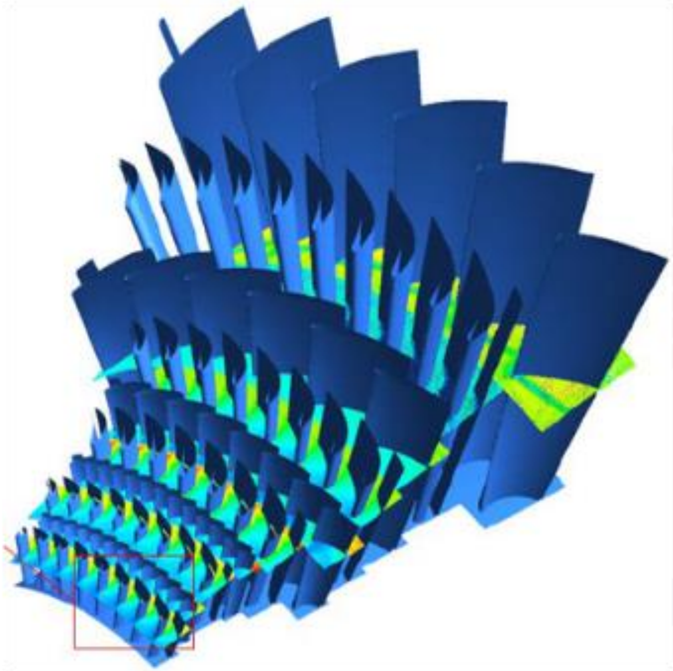
Characteristic	Value
Efficiency, %	98,04
Pressure drop, bar	3,8
Hydrogen consumption, kg/s	2,958
Oxygen consumption, kg/s	23,664
Steam consumption, kg/s	45,58
Maximum combustion temperature, K	2350
Thermal power of the combustion chamber, MWt	355,5
Dimensions: Length, mm Max diameter, mm	 1580 400

Powerful steam turbine with two-tier LPT for the NPP and TPP with H2/O2 combustors*

Double flow LPT with two-tiers of stages



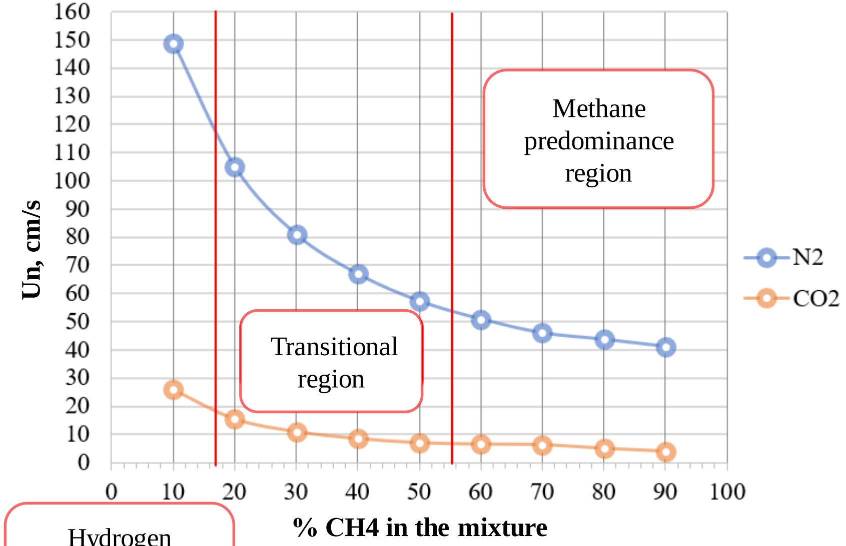
“Flow path of the two-tier LPT ”

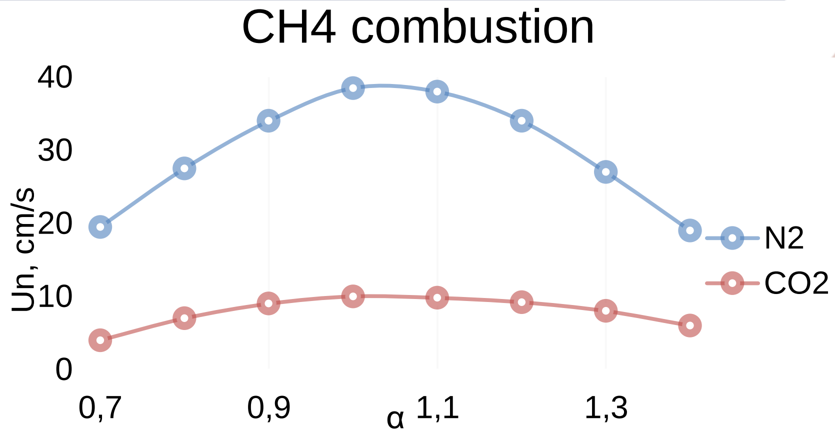


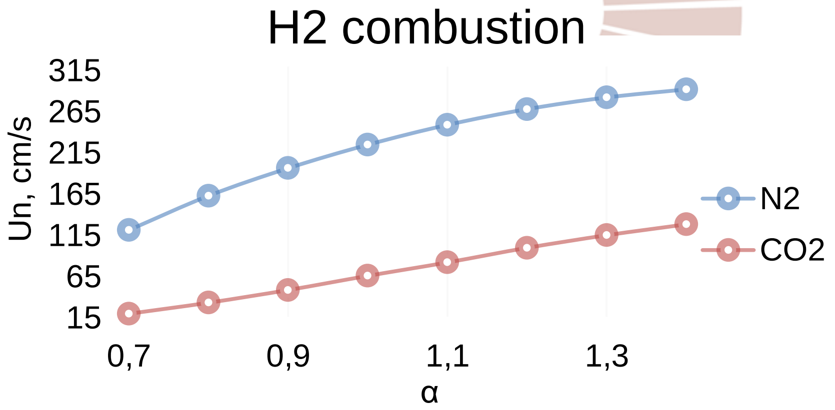
“Fork-blade”

* - MPEI estimations

Methane-hydrogen mixtures combustion features in N2 and CO2





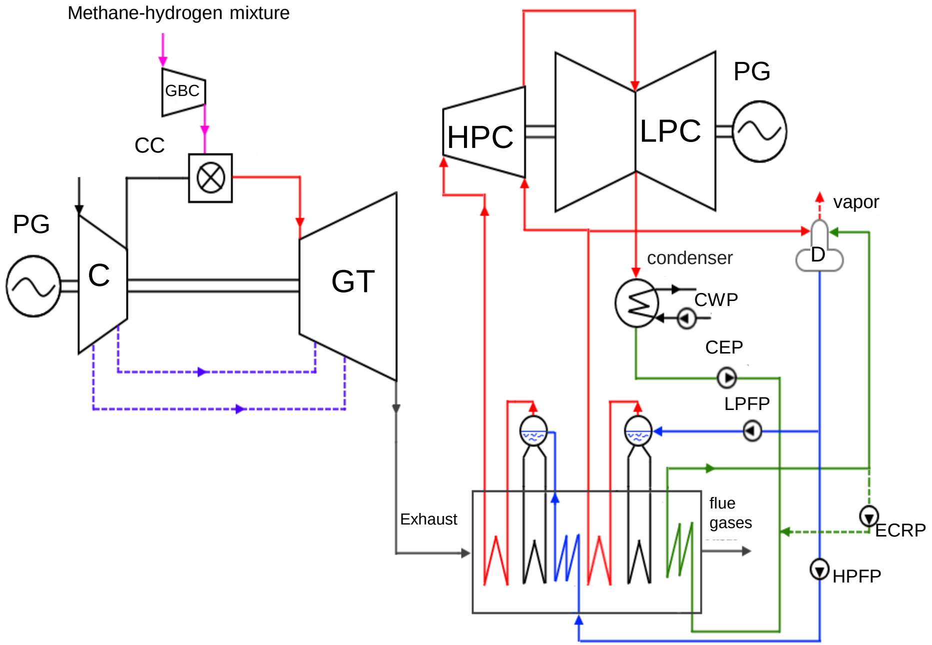


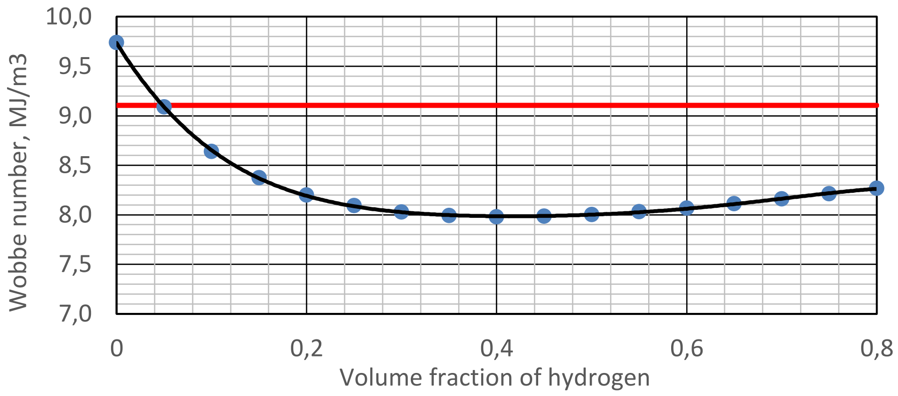
Lewis number (Le)

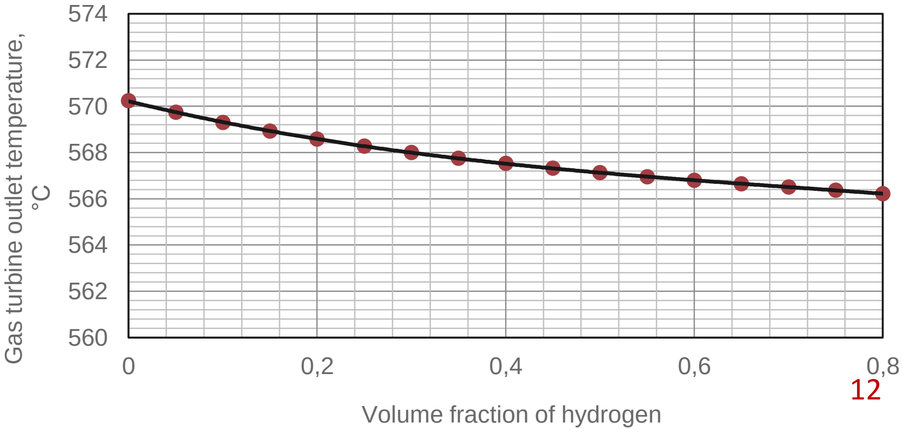
α	CH_4	H_2
1	0.978	0.690
1.05	0.997	0.693
1.9	0.967	0.860
2	0.960	0.816

$$Le = \frac{a}{D}$$

CH4-H2-fired CCGT





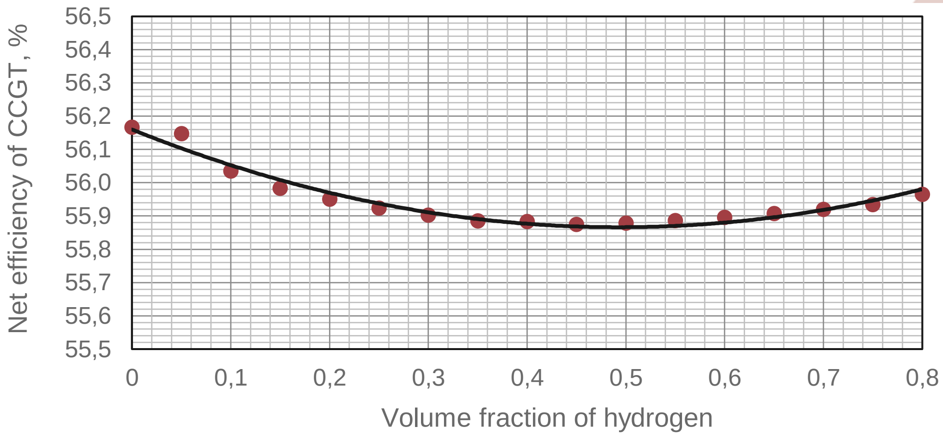


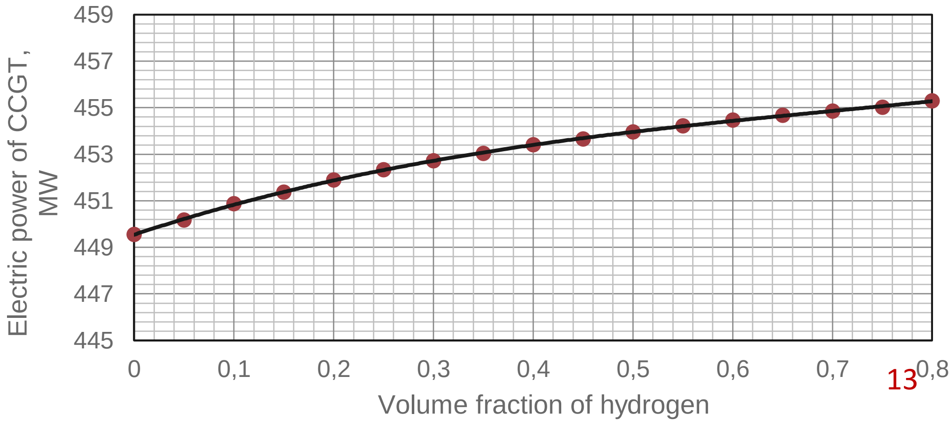
An increase of the H2 concentration to 30 vol. % leads to CO2 emission reduce in the flue gasses by 15%.

CH4-H2-fired CCGT

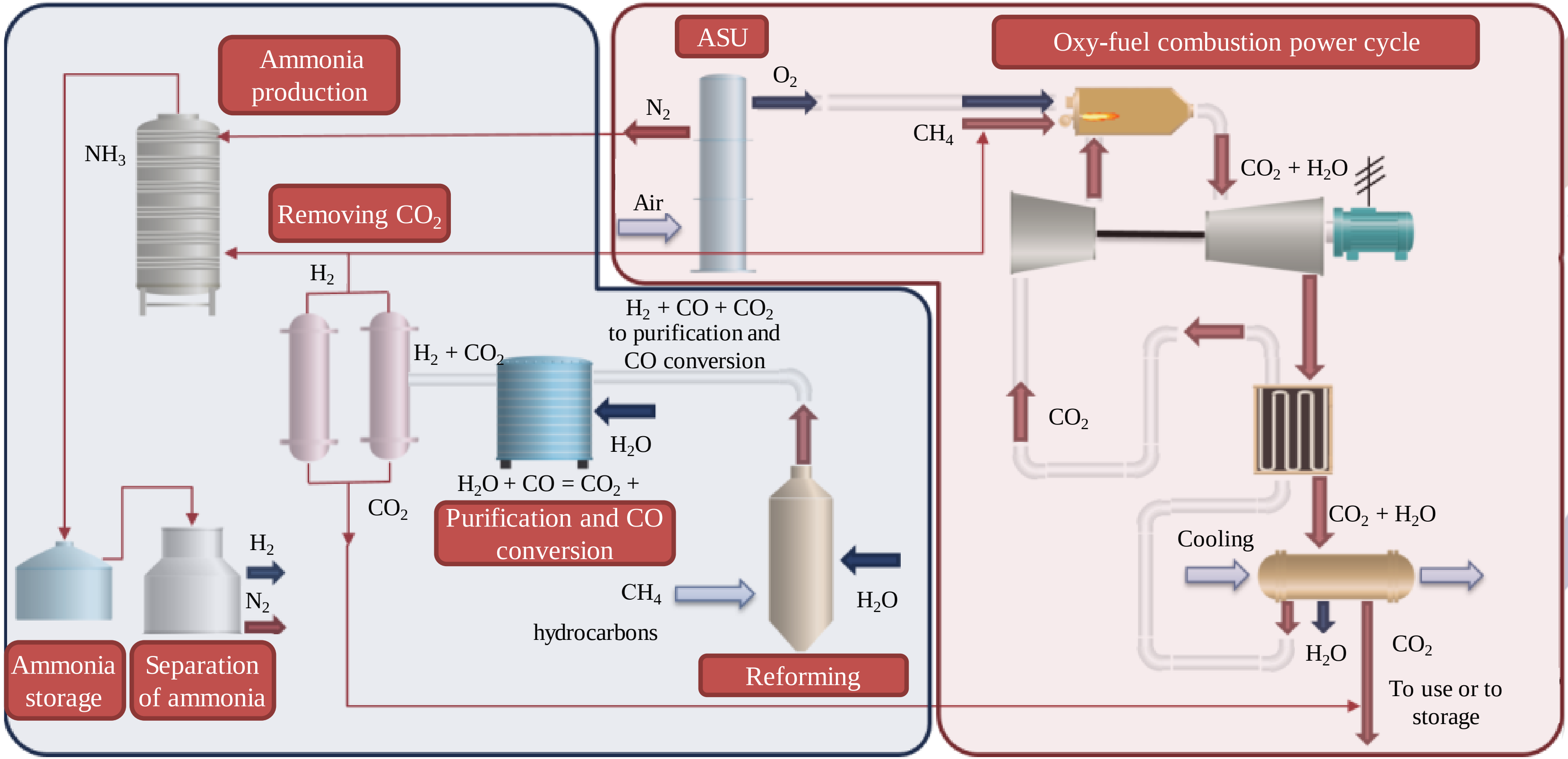
H2 concertation change in the range of 0-80% leads to:

- the electrical power drop of the CCGT by 6 MW;
- the net efficiency decrease by 0,03%.

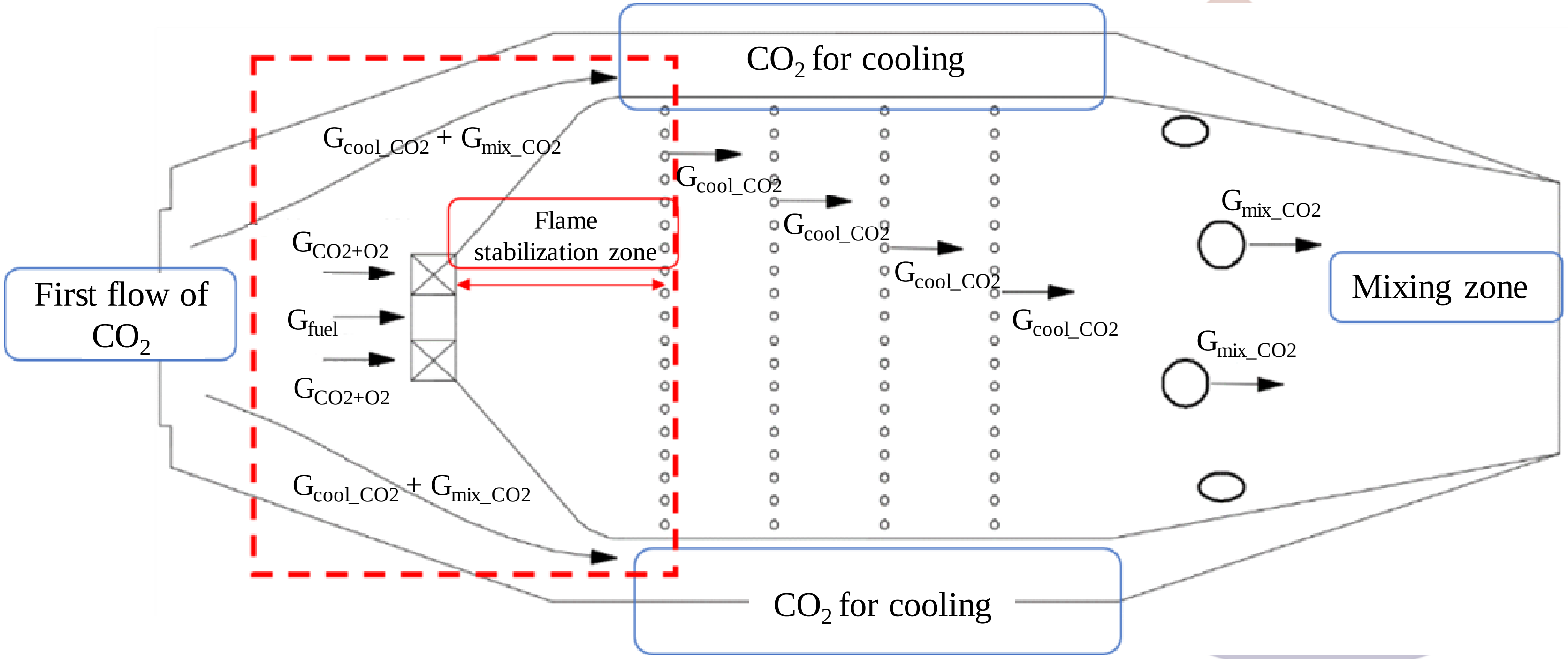




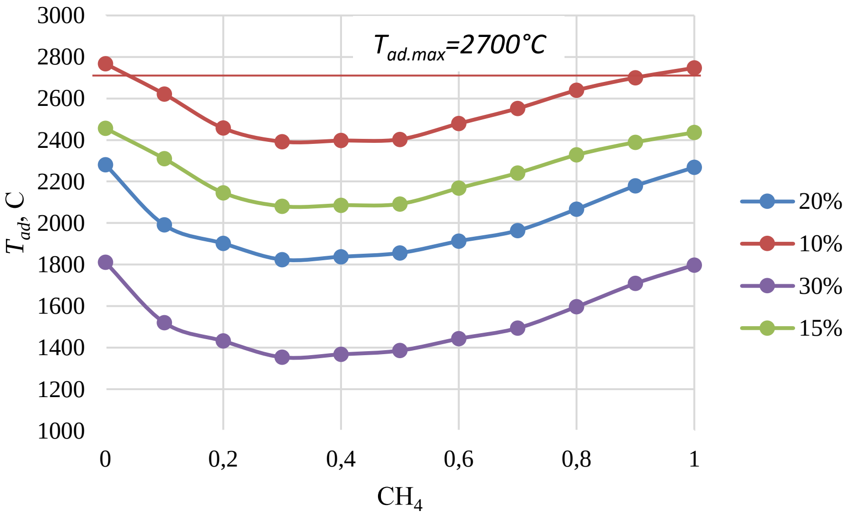
Oxy-fuel combustion power cycles with NH3 production

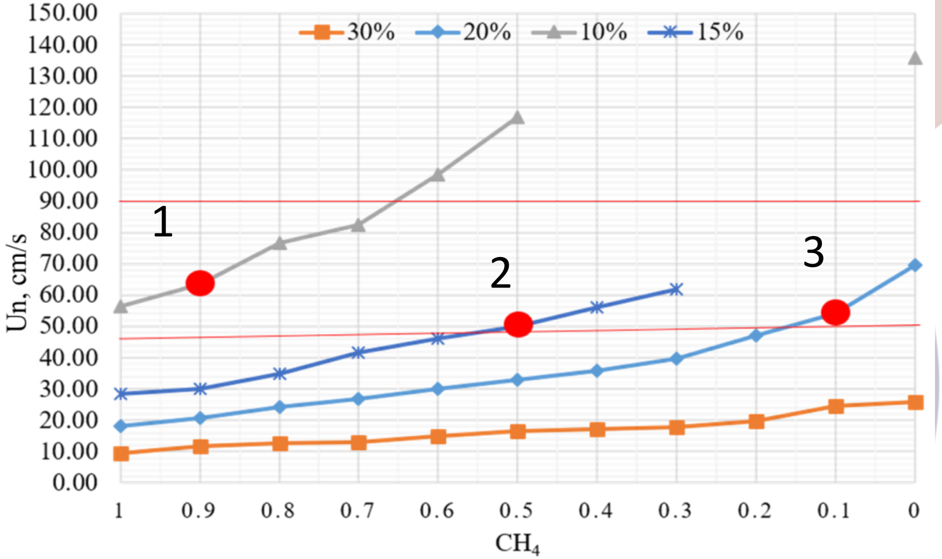


Oxy-fuel combustion chamber



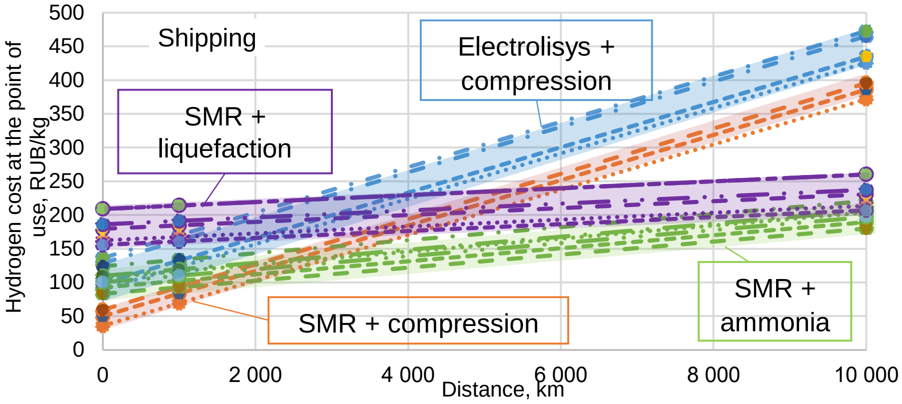
Oxy-fuel combustion chamber

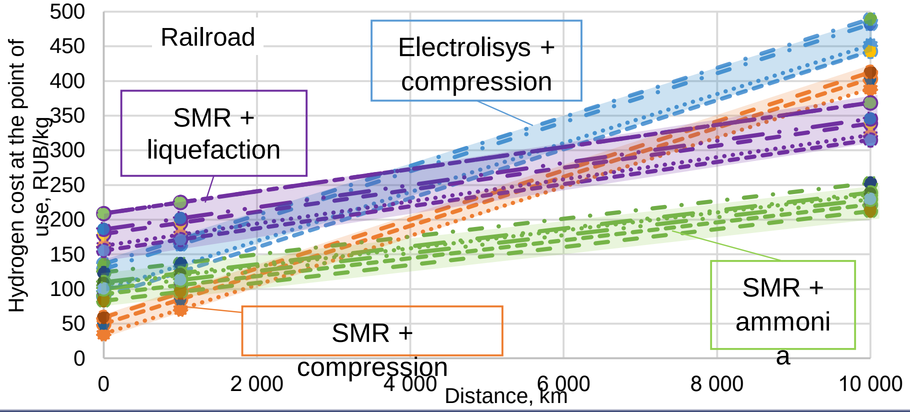


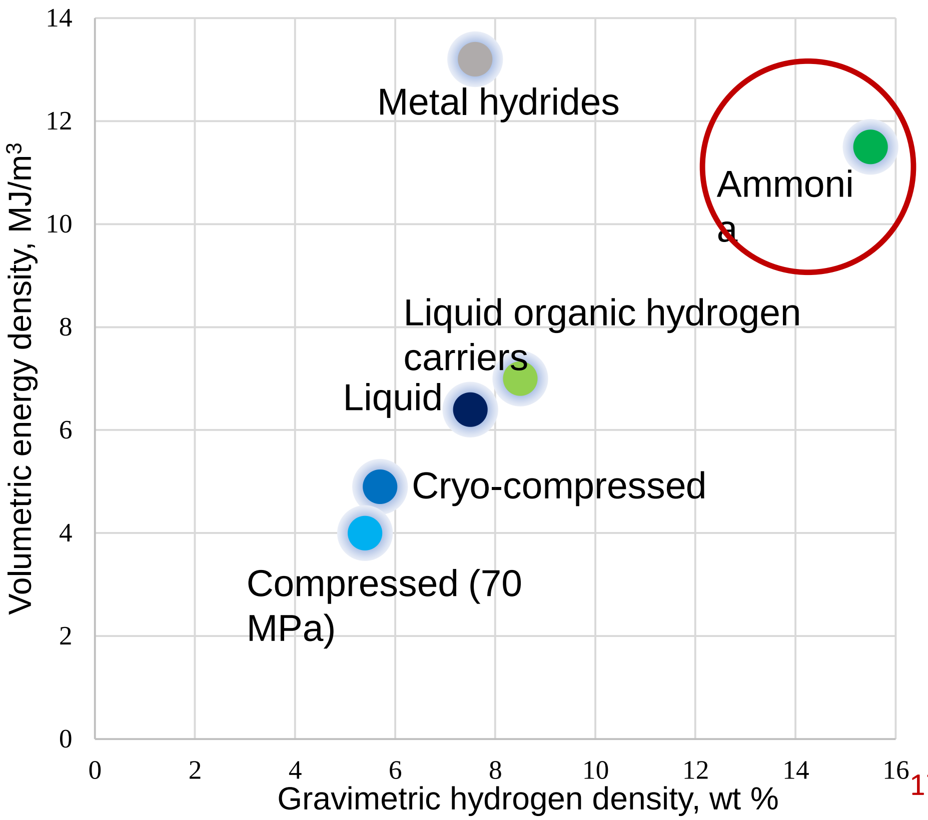


Calculation point	Fuel composition	Fuel flow rate, kg/s	O_2 flow rate, kg/s	CO_2 flow rate, kg/s	U_n, cm/s	T_{ad}, °C	T_{ig}, sec
1	$0.9CH_4+0.1H_2$	0.88	3.55	8.83	54	2,527	0.08
2	$0.5\ CH_4+0.5H_2$	0.54	2.39	10.19	52	2,092	0.061
3	$0.1CH_4+0.9H_2$	0.41	2.54	13.58	54	1,991	0.036

H2 transportation for overseas markets







MPEI R&D plans in the field of hydrogen technologies

1. The development of effective and low-cost technology for H_2 production.
2. Research of H_2 storage and transportation methods for various energy consumers (gas stations, thermal and nuclear power plants, industrial enterprises).
3. Research and development of steam turbine and oxy-fuel combustion power plants fired on CH_4-H_2 mixtures.