DEVELOPMENT OF HYDROGEN ENERGY BASED ON GAS INDUSTRY RESOURCES (NATURAL GAS, HYDROGEN SULPHIDE)

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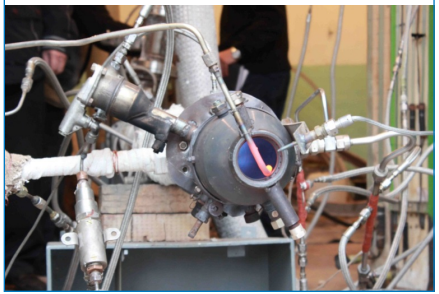
Hydrogen Energy Development Stages at Gazprom PJSC

2008 – 2019

Research on the use of hydrogen and methane-hydrogen fuels to improve gas transportation efficiency



2020 – 2021

Hydrogen Energy Development Concept

Interagency Working Group on Hydrogen Energy Development

Action Plan "Development of Hydrogen Energy in the Russian Federation through 2024"

Agreement of Intentions between the Government of the Russian Federation and PJSC Gazprom for the development of the high-tech area "Hydrogen Energy Development"

Hydrogen Energy Development Roadmap (Gazprom only)

GAZPROM HYDROGEN

2022 – 2025

New Memorandum of Intent between the Russian Federation and Gazprom PJSC on H_2 Energy Development

New H_2 Energy Development Roadmap (Gazprom and Rosatom)

Quarterly reporting in the information systems of the Government of the Russian Federation

2026 – 2030

Update of the Hydrogen Energy Development Concept

Roadmap update (Gazprom, Rosatom, AFK Sistema)

Migration of Roadmap activities into the "Clean Energy" Federal Project

Development of Hydrogen Energy based on Natural Gas in Russia

Key technologies

- Methane pyrolysis
- Hydrogen production from hydrogen sulphide
- Hydrogen purification technologies (membrane technologies, etc.)
- Technical solutions for natural hydrogen production
- Fuel cells based on molten carbonates

January 16, 2023
The House of the Government of the Russian Federation

Agreement of Intentions between the Government of the Russian Federation and PJSC Gazprom for the development of the high-tech area "Hydrogen Energy Development"

Subarea "Development of hydrogen energy and decarbonisation of industry and transport on the basis of natural gas".

Pilot projects, studies:

- proposals to create infrastructure at gas processing facilities to supply hydrogen to potential consumers
- technological experimental and demonstration complex for hydrogen energy
- assessment of the impact of hydrogen on the integrity and sustainability of the gas supply system
- technical solutions in the field of natural hydrogen production, proposals for the implementation of projects in the field of CO_2 capture, storage and utilisation

General Roadmap Activities

Developing the start-up ecosystem

Hydrogen championship for young professionals and students held with Gazprom PJSC partner universities

Business-incubator deployed on the Gazprom Hydrogen LLC website to collect best-solution applications

Developing human capital

Internships for young professionals

Scholarship programme

Cooperation with the Russian Ministry of Labour on professional standards

Developing international cooperation

Organising technical dialogues with foreign partners

CNPC (China)
India
ADNOC (UAE)
Uzbekistan
Kazakhstan
APEC
BRICS
GECF
ESCAP
COP

Hydrogen supply infrastructure at gas processing facilities for potential consumers

Feasibility study for hydrogen production at Gazprom Group gas processing facilities

potential, kt/year

- **4** Sosnogorsk Gas Processing Plant
- **14** V.S. Chernomyrdin Condensate Stabilization Plant (Surgut)

Investment decisions on building hydrogen separation capacities and storage / shipment infrastructure can be made only after:

1. A specific consumer is identified
2. Requirements for commercial H_6 volume and quality are defined

Economic model for low-carbon H_6 production — NIIGAZECONOMIKA LLC

Gazprom Proektirovanie LLC

Pilot industrial membrane unit

Two industrial polyimide-based membrane elements are used (manufactured by Grasys JSC – industrial partner)

hydrogen content in feed gas

0.05 mol%

Stage 1

Stage 2

(permeate)

3.96 mol%

hydrogen content increase

Comprehensive assessment of hydrogen impact on gas supply system integrity and resilience

Gas pipeline transport

- ✓ **Studies of gas pipeline suitability for transporting methane-hydrogen mixtures**
- ✓ **Assessment of hydrogen-containing gas effects on mechanical properties and fracture behaviour of metal in compressor station equipment**

In hydrogen-containing environments, certain compressor station equipment components made of special steels, and several pipe types, fail to deliver the required reliability and service life owing to hydrogen embrittlement

Operating gas transmission system in its current form to transport MHM and hydrogen at high working pressures entails significant risks

Underground gas storage

Effects of hydrogen and its mixtures on samples of reservoir rock, cap rock, cement stone, metal and rubber

Modelling of geochemical and geomechanical processes during hydrogen injection into the reservoir

Modelling of concurrent chemical reactions and microbiological processes during injection of hydrogen and hydrogen-methane mixtures into the reservoir

- Studies and assessment
- Model development and calibration against experimental data

Gazprom VNIIGAZ LLC

Pilot units for hydrogen production from natural gas and hydrogen sulfide

Gazprom VNIIGAZ LLC

Methane plasma pyrolysis unit

arc-discharge plasma at 2,700 – 3,700 °C

Hydrogen sulfide decomposition unit

Gazprom Hydrogen LLC

Mobile natural gas autothermal reforming unit

Metal hydride hydrogen storage and purification system

Technological Experimental Demonstration Complex

Gazprom Neft LLC

Methane catalytic pyrolysis unit

capacity 10 Nm³/h

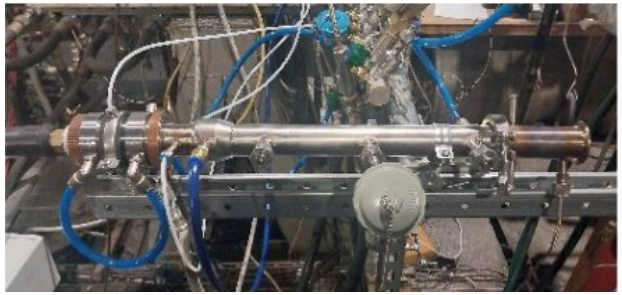
Technologies for hydrogen production from natural gas via plasma-chemical processes (pyrolysis)

Mobile hydrogen generator (hydrogen production from natural gas in non-equilibrium low-temperature plasma)

Performance:
Gas output — up to 1 m³/h;
Hydrogen output — up to 2 m³/h;
Carbon material output — up to 60 g/h.
Hydrogen content in the methane-hydrogen mixture at the outlet — 50–60 vol. %.
Specific energy consumption — 9.3 kWh/Nm³ H_6.

Source: National Research Tomsk Polytechnic University

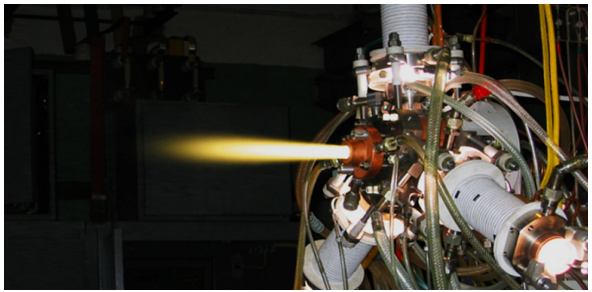
Plasma generator for conducting chemical reactions (plasma pyrolysis of natural gas)



Performance:
Methane consumption — up to 1 m³/h;
Hydrogen production rate — up to 2 m³/h;
Electrical power — up to 10 kW.

Source: Russian State Scientific Center "Keldysh Research Center"

Alternating current plasma generator of megawatt power (plasma pyrolysis of natural gas)



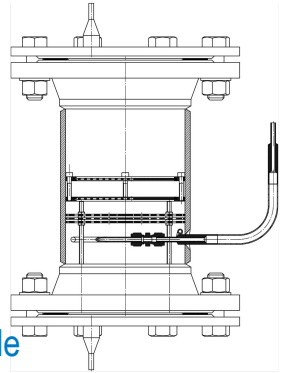
Performance:
Methane consumption — up to 800 m³/h;
Hydrogen production rate — up to 1 600 m³/h;
Electrical power — up to 2 MW;
Specific energy consumption — 1.34 kWh/Nm³ H_6.

Source: Russian State Scientific Center "Keldysh Research Center"

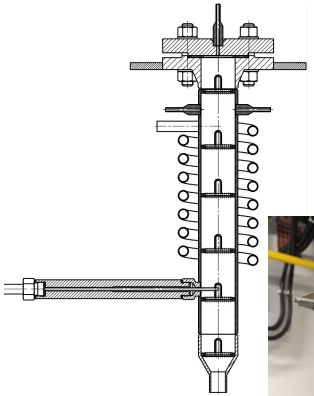
Hydrogen production from hydrogen sulfide with limited GHG emissions

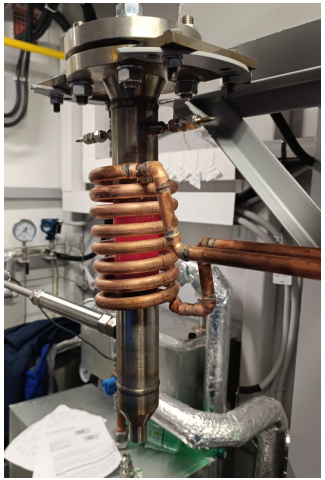
Experimental unit

Low-temperature catalytic conversion of hydrogen sulfide

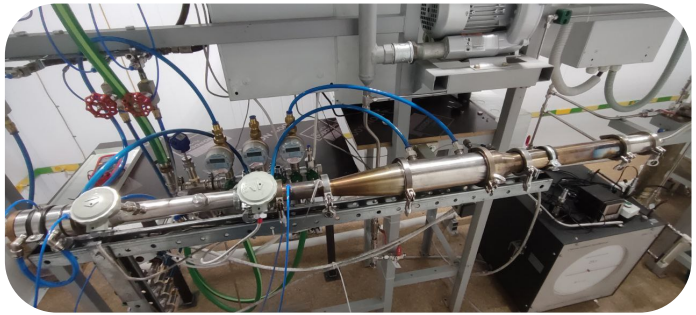


Hydrogen sulfide reforming of methane



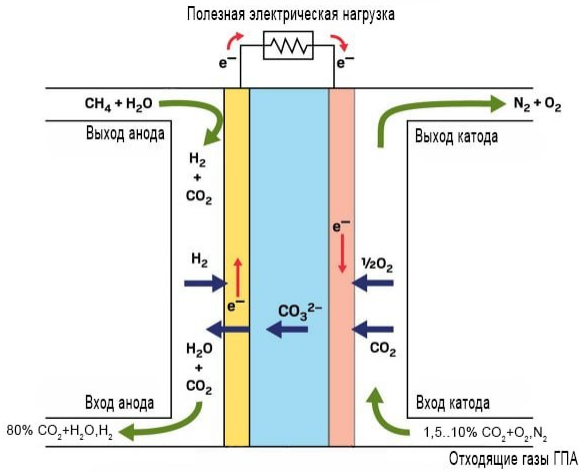


Plasma-chemical decomposition of hydrogen sulfide



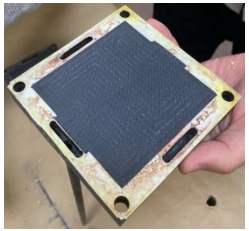
Energy unit based on molten carbonate fuel cells (MCFC) with CO_6 capture

Cell fuel: natural gas + CO_6



Addressed objectives:

- electrification of process operations;
- higher efficiency of natural gas use for compressor station auxiliary needs;
- reduction of greenhouse-gas emissions



Power generation mode
Efficiency 40.5% – in power generation

Flue gas CO_6 removal mode
83% – CO_2 capture rate;
0% – 150% – electrical power turn-down range

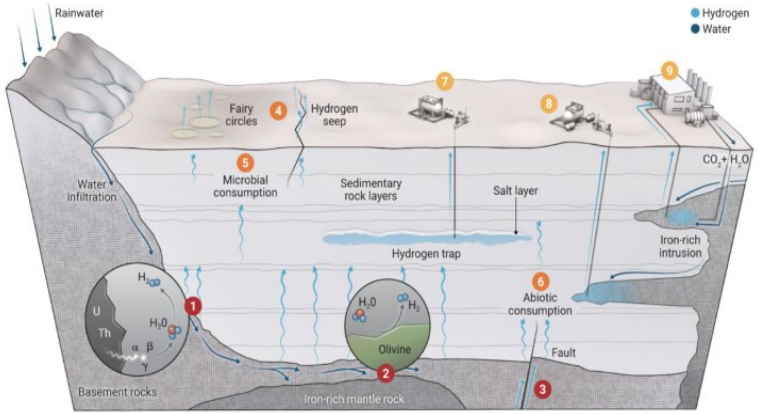
Gazprom VNIIGAZ LLC

Technology:

1. Presented to potential investors under the "Long-term Development, Energy Efficiency, Innovation & Digitalisation" track of the International Business Congress Energy Initiative (Dedovsk, 2025)

2. Proposed for the cooperation programme with the Republic of Sakha (Yakutia)

Natural hydrogen



Hydrogen occurs at low concentrations in gas and gas-condensate fields, with characteristic "antagonistic" behaviour vs. methane

Gazprom Nedra LLC

Plans:

Development of scientific and technical foundations for identifying natural hydrogen occurrences, forms and potential concentration methods for industrial use

Studies on zoning of Siberian sedimentary basins by intensity of hydrogen occurrences and assessment of natural hydrogen geological resources

Study of hydrogen genesis (possible origin)

IPGG SB RAS, JIHT RAS (the Russian Academy of Sciences) and the Technology Partner - Gazprom Hydrogen LLC

Grant from the Russian Science Foundation (RSF)

Development plans for the "Hydrogen Energy" high-tech track

1 **Completion of all R&D activities in 2026 – 2030 and achievement of all targets set out in the Roadmap**

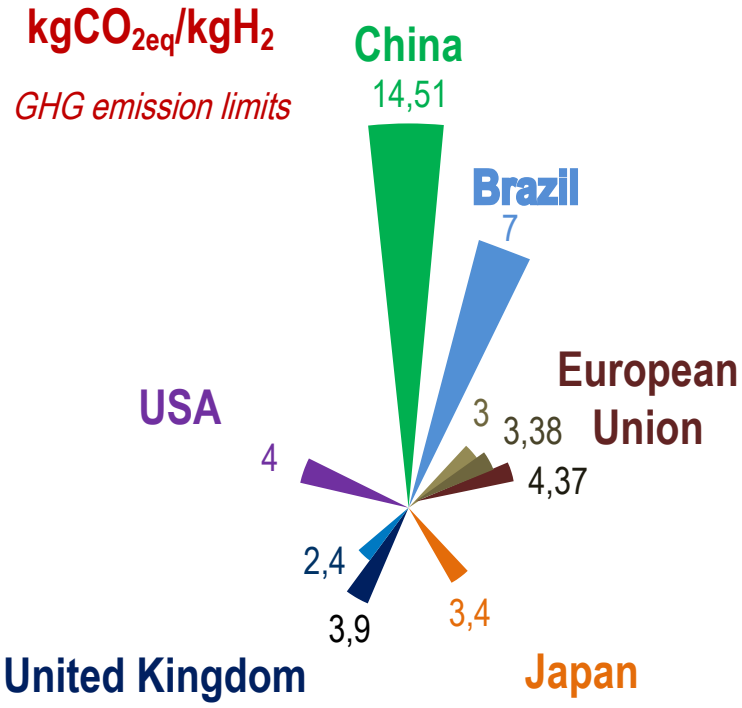
2 **Continued R&D cooperation with partners:**

- KAMAZ
- Rosatom
- foreign companies from friendly countries

3 **Development of gas-processing and gas-chemistry technologies based on hydrogen technologies**

- Methane carbonylation for producing acetic acid and other products with carbon monoxide and dioxide
- Ethylene and propylene from methane via steam pyrolysis through methanol, dimethyl ether and syngas
- Technology for producing light and waxy paraffins and jet-fuel components from natural gas

Certification systems for low-carbon hydrogen



National certification systems
set different criteria
for the low-carbon status of hydrogen

Differences in approaches
to assess low-carbon status of hydrogen
lead to **complications in international cooperation**

Radically low values of low-carbon criteria
severely **limit development**
of hydrogen market

Russia has initiated GOST standard "**Hydrogen Technologies. Methodology for Determining Greenhouse Gas Emissions in the Production, Conditioning and Transportation of Hydrogen to the Point of Consumption**" (harmonized with ISO/TS 19870:2023 "Hydrogen Technologies — Methodology for Determining the Greenhouse Gas Emissions Associated with the Production, Conditioning and Transport of Hydrogen to Consumption Gate"

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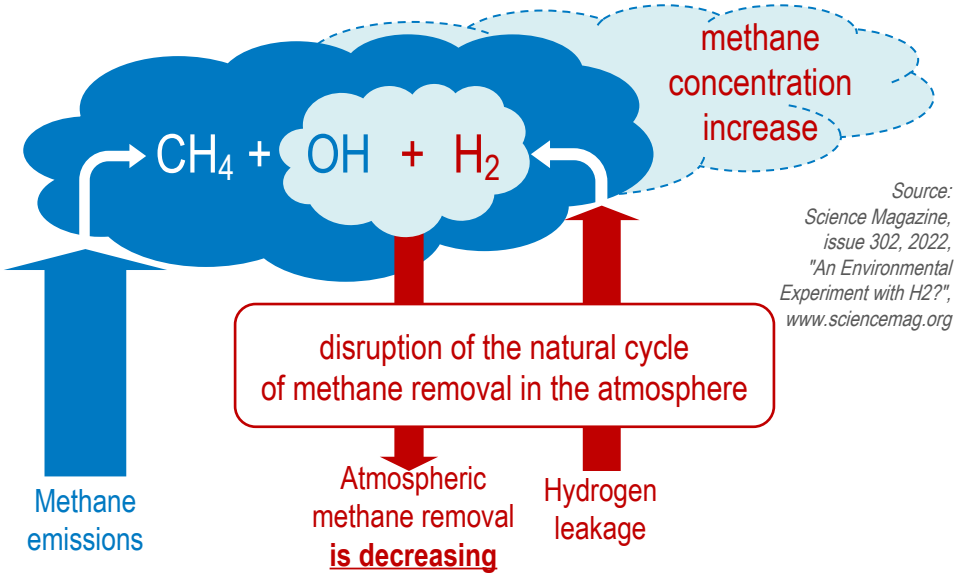
Hydrogen - an indirect greenhouse gas



Source: Science Magazine, issue 302, 2022, "An Environmental Experiment with H2?", www.sciencemag.org

- Advanced materials/infrastructure design
- Early detection and repair

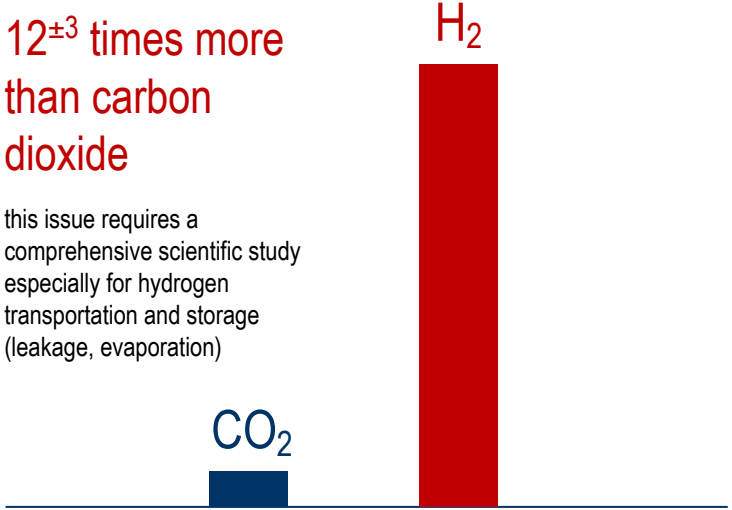
Source: IEA Global Hydrogen Review 2025

Hydrogen's contribution to global warming

on a 100-year horizon

$12^{\pm 3}$ times more than carbon dioxide

this issue requires a comprehensive scientific study especially for hydrogen transportation and storage (leakage, evaporation)



Sources: National Research University" Higher School of Economics. Development of individual high-tech areas: 2023. White Paper; Study by the University of Cambridge, National Centre for Atmospheric Sciences of England, University of Reading, et al. "Atmospheric consequences of increased hydrogen utilization", 2022