



DEVELOPMENT OF THE HYDROGEN ECONOMY

Konstantin Grebennik

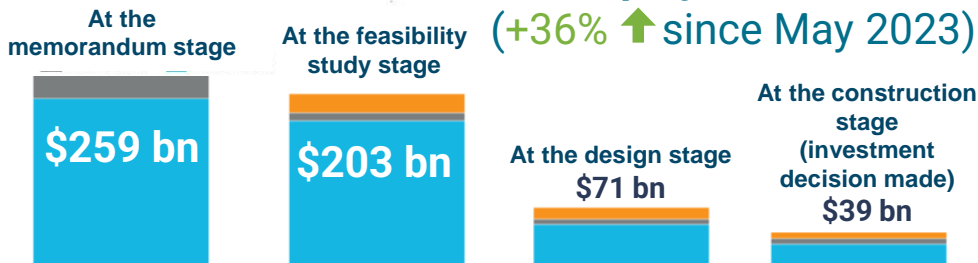
March 2024

The number of announced hydrogen energy projects is growing, but investment decisions have been made only on 7% of them



- 166 Hydrogen gigafactories
- 719 Large-scale industry
- 256 Hydrogen transport
- 144 Integrated hydrogen solutions
- 126 Infrastructure projects

>1400 projects
 (+36% ↑ since May 2023)



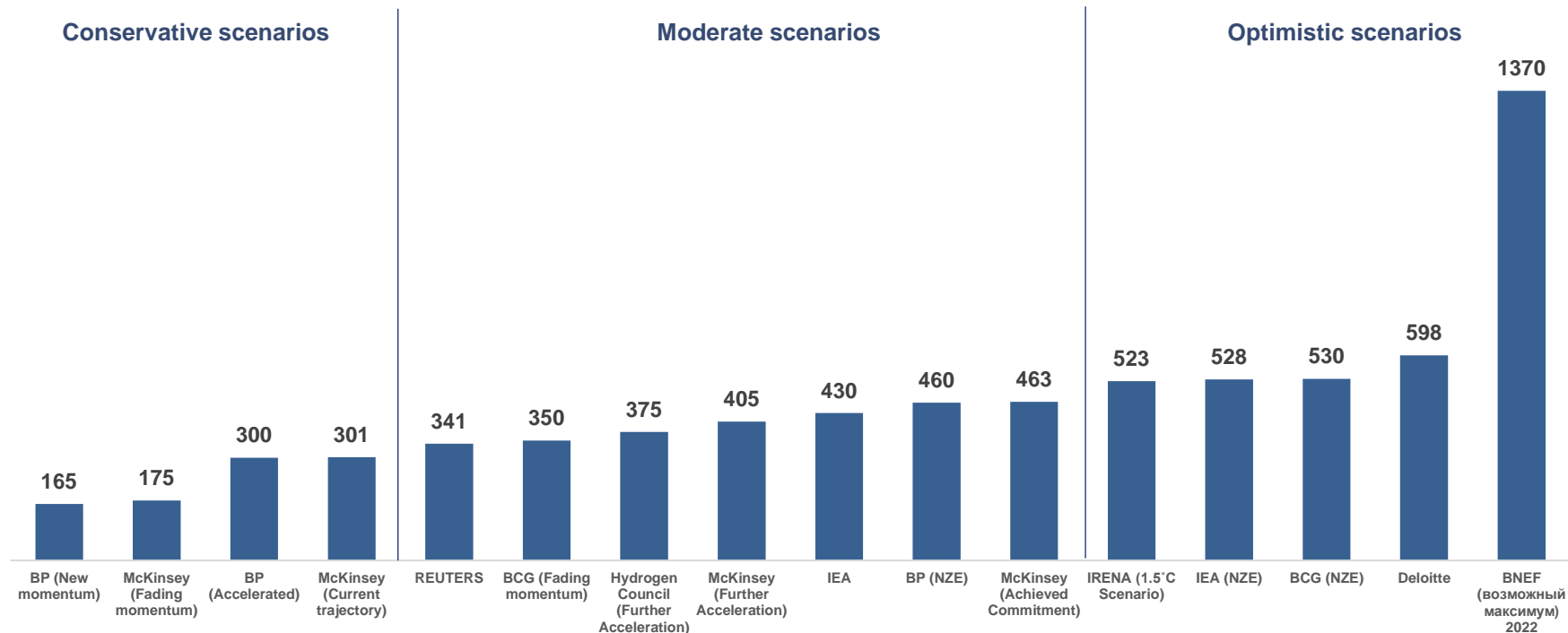
\$570 bn is required to investment in implementation of the announced projects until 2030

\$39 bn of which are confirmed

Source: Hydrogen Insights December 2023, Hydrogen Council, McKinsey & Company

Global hydrogen demand forecasts are subject to significant uncertainty

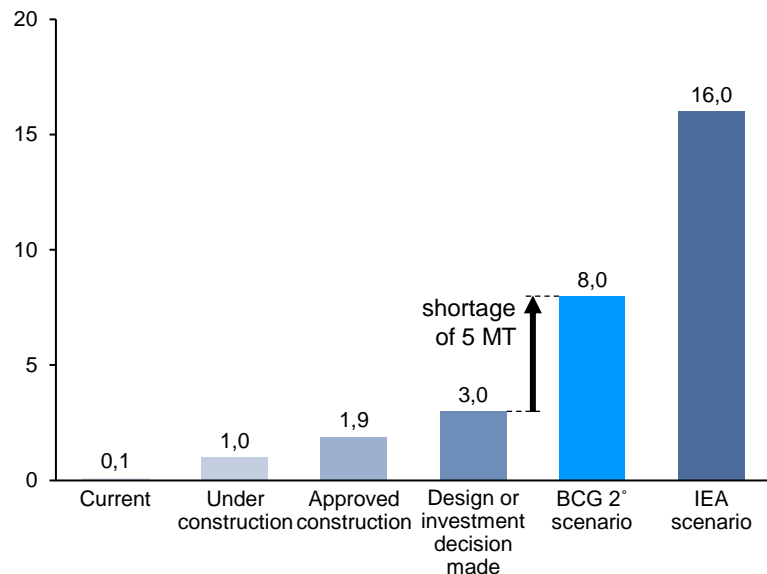
Global demand for hydrogen in 2050 according to various forecasts from 2023, million tons



Prospects for large-scale export of hydrogen and its derivatives

The number of ongoing projects for the production and export of hydrogen and its derivatives currently does not allow achieving the stated goals by 2030

Potential export-oriented projects*, million tons of H2



Пилотный торговый проект	Exporting-importing countries	Carrier	Year	Trade volume
Aramco, IEEJ, SABIC	KSA - Japan	Ammonia	2020	40 tons H2
TOA Oil, Chiyoda	Brunei - Japan	LOHC	2020	102 tons H2
Kawasaki Heavy Industries	Australia - Japan	LH2	2022	75 tons H2
Mitsui, GS и Fertigllobe	KSA - South Korea	Ammonia	2022	25 000 tons NH3
ADNOC	UAE - Germany	Ammonia	2022	13 tons NH3
Haru Oni, Porsche, Siemens Energy	Chile - UK	Synthetic fuel	2023	2 600 liters
SABIC AN, IFFCO	KSA - India	Ammonia	2023	5 000 tons NH3
Ma'aden	KSA - Bulgaria	Ammonia	2023	25 000 tons NH3

Source: BCG «Global Trade in Hydrogen Will Miss 2030 Targets»

A list of priority hydrogen technologies

Production		Storage and transportation		Application	
9	1. Steam methane reforming	9	11. Chemical absorption of CO ₂ by alkanolamines	9	35. Alkaline fuel cells (AFC)
9	2. Autothermal reforming of methane	5	12. Adsorption separation	9	36. Proton exchange membrane fuel cell (PEMFC)
6	3. Carbon dioxide methane reforming	5	13. Membrane separation	7	37. Phosphoric acid fuel cell (PAFC)
7	4. Decomposition of methane (catalytic)	8	14. Cryogenic separation	9	38. Solid oxide fuel cell (SOFC)
7	5. Decomposition of methane (plasma-assisted)	9	15. Alkaline Electrolyzer	8	39. Molten carbonate fuel cell (MCFC)
9	6. Coal gasification	9	16. PEM Electrolyser	7	40. Direct-methanol fuel cell (DMFC)
4	7. Gasification of veg. raw materials and solid waste	5	17. AEM Electrolyser	5	41. Direct Ammonia Fuel Cell (DAFC)
6	8. Processing of veg. raw materials and solid waste	7	18. SO Electrolyser	6	42. GTCC on methane-hydrogen mixture
4	9. Thermochemical cycles	5	19. DO Electrolyser	7	43. Gas burners and boilers on methane-hydrogen mixture
4	10. Thermochemical cycles	4	20. Photolytic decomposition of water	9	44. Ammonia technologies (synthesis of ammonia)
		9	21. Compression H ₂ (CGH ₂)	7	45. Obtaining hot-briquetted iron (HBI)
		9	22. Liquefaction H ₂ (LH ₂)	9	46. Methanol technologies (CO ₂ -based syntheses)
		7	23. Hydrogenation/ dehydrogenation (LOHC)		
		5	24. Ammonia technologies (decomposition of ammonia)		
		9	25. Methanol technologies for H ₂ storage		
		7	30. Metal hydride storage of H ₂		
		5	31. Inorganic hydrogen carriers		
		5	32. Geological storage facilities		
		9	33. Low pressure vessels		
		9	34. Hydrogen pipelines		

Scale of technological readiness levels (TRL)



TRL in the world in 2022

1 Name of the technology

☆ CO₂ capture technologies

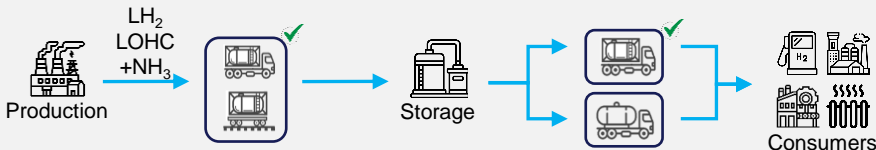
Priority technology

Tank containers are used in a wide range of hydrogen supply options

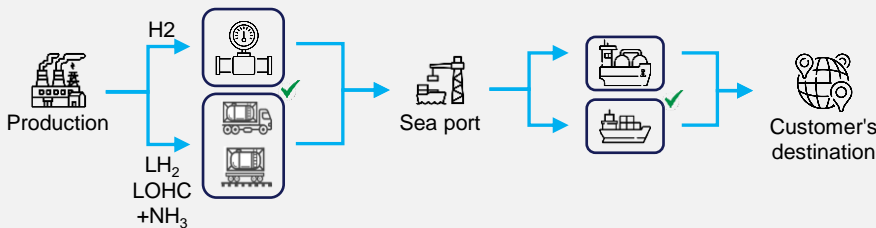
Large-scale direct supply



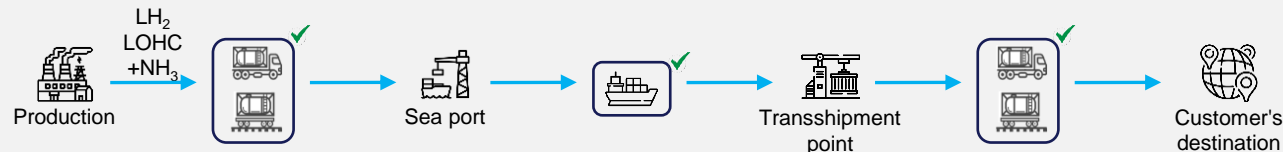
Combined supply (large- and small-tonnage)



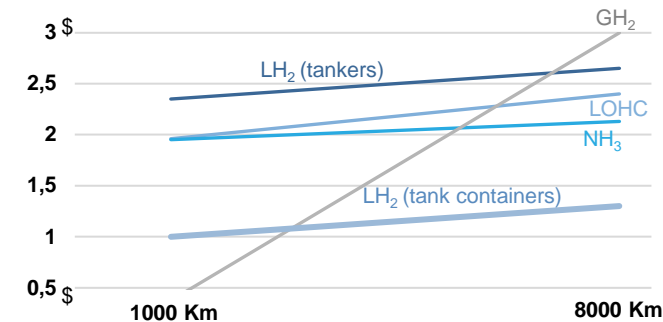
Intercontinental large-scale supply



Large-scale delivery with complex logistics



Average cost of hydrogen transportation by 2030, \$/kg



Tank containers are in demand in almost all possible types of deliveries - both large-tonnage and small-tonnage to the final consumer

In large-tonnage deliveries with complex logistics (for example, with transshipment at intermediate points), tank containers are the only transport unit

Key targets for the development of the hydrogen economy

Current barriers

Technology & Economy

- Low TRL on number of critical technologies
- LCOH is still very high to compete with conventional sources of energy
- Increasing equipment and energy prices
- High transportation costs significantly increase overall hydrogen costs

Hydrogen market

- Insufficient number of long-term offtake agreements among buyers and sellers
- Uncertainty of the volume and parameters of the future hydrogen market

Government policies

- Absence of supportive government policies
- Lack of necessary regulatory framework

Key targets

- Stimulating R&D in hydrogen technologies
- CAPEX/OPEX government subsidies for hydrogen projects
- Implementation of diversified infrastructure projects using various methods of hydrogen transportation
- Cooperation of hydrogen producers and consumers through international platforms, including the UNECE and others
- Implementation of international integrated pilot projects
- Determination of requirements for hydrogen in terms of carbon footprint and guarantee of origin (classification and certification)
- Determination of requirements for the form of transportation of hydrogen (pipeline, liquefied hydrogen, compressed hydrogen, ammonia, LOHC)
- Development of the necessary regulatory framework to support and stimulate the implementation of hydrogen projects
- Consolidation of the best practices of state support for the hydrogen economy based on the UNECE
- Support of international projects by participating countries for a synergistic effect



Thank you!