Green hydrogen technology development in IRAN

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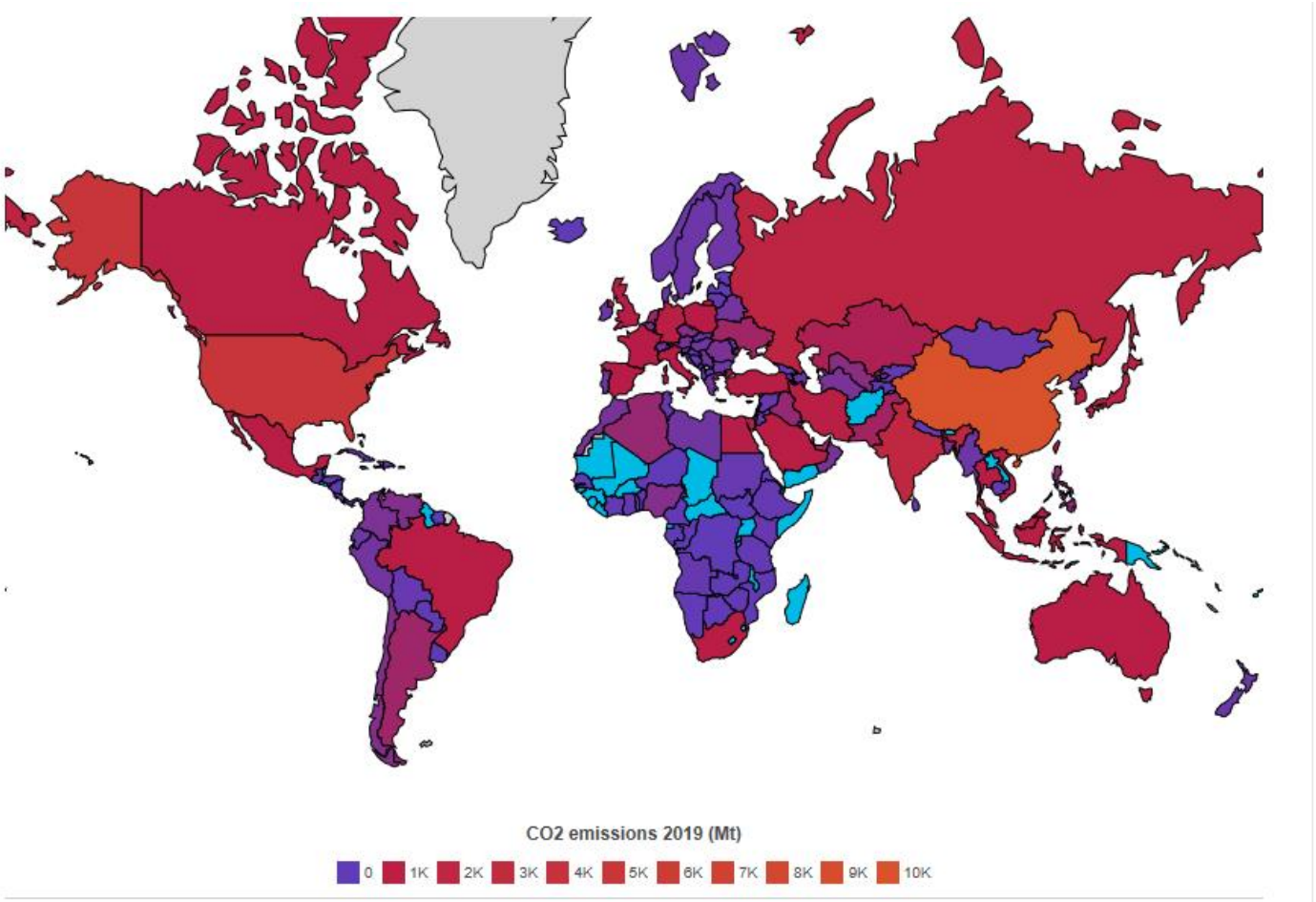
Greenhouse Gas Emissions by Country 2022



Top 10 Countries with the Highest Greenhouse Gas Emissions (in million metric tons, 2019 data)

China — 9,877
United States — 4,745
India — 2,310
Russia — 1,640
Japan — 1,056
Germany — 644
South Korea — 586
Iran — 583
Canada — 571
Saudi Arabia — 495

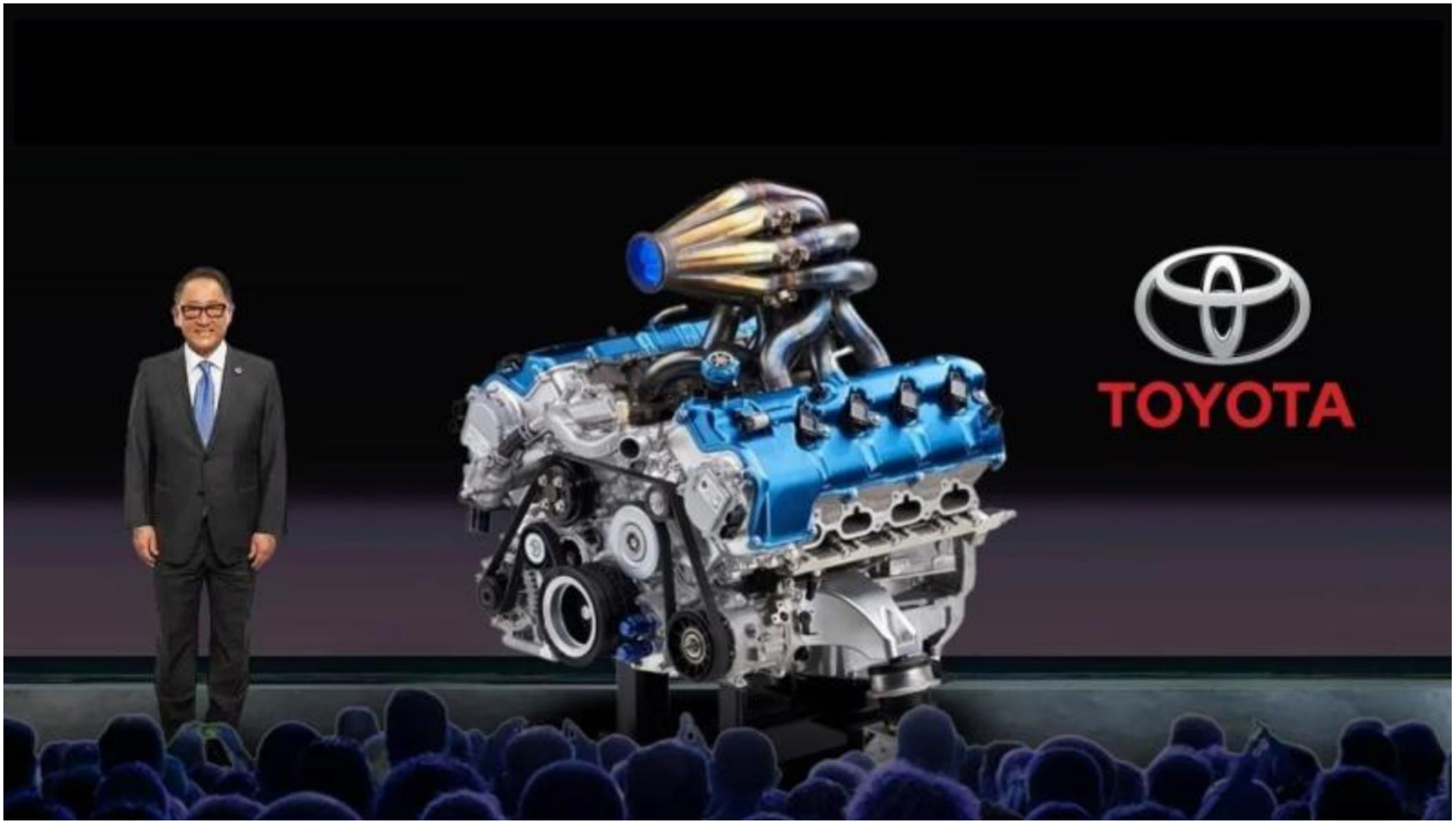
Different shades of hydrogen – from green to blue to grey

- **Green**' hydrogen refers to hydrogen produced via electrolysis based on renewable electricity (RE)
- **Grey**' refers to hydrogen produced with unabated fossil fuels (e.g. natural gas or coal);
- **Blue**' to the production with fossil fuels in combination with carbon capture, utilization and storage (CCUS)
- **Pink**' to the production with electrolysis based on nuclear energy
- **Turquoise**' with Biomass pyrolysis.

Hydrogen strategies of G20 Member States

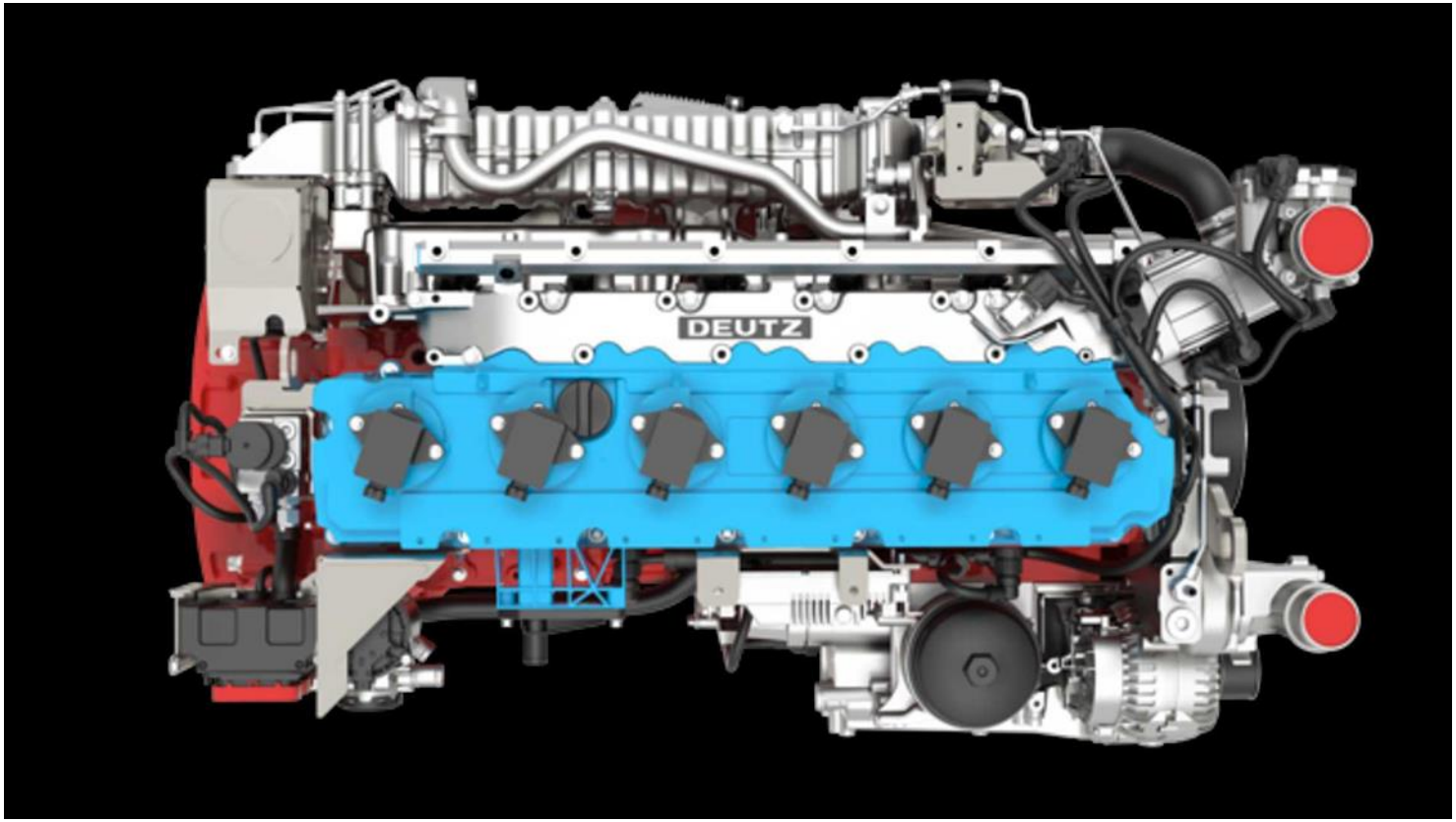
Russia	Hydrogen Roadmap (2021) (*)	Production of 2 million tons H_2 by 2030	Fossil, nuclear and renewables	Export	$1.7 billion by 2030
Saudi-Arabia	Strategy in preparation				
South Africa	Hydrogen roadmap (2021)	Production of 500.000 tons H_2 per year and electrolysis capacity of 12 GW by 2030; 15 GW by 2040	Fossil and renewables	Mobility, industry, power generation, export	
South Korea	Hydrogen Roadmap (2019)	Production of 5.26 million tons H_2 per year. by 2040, 5.9 million fuel cell electric vehicles and 1.200 H_2 refueling stations	Fossil and renewables	Power generation, mobility	$16.26 billion in 2025
Turkey	Roadmap for hydrogen in preparation				
USA	Plans for hydrogen, infrastructure and employment (**)	17 million tons H_2 demand by 2030, 1.5 million fuel cell electric vehicles and 4.300 H_2 refueling stations by 2030	Renewables, fossil and nuclear	Power generation, industry, mobility	
EU	Hydrogen Strategy (2020)	Production of 10 million tons H_2 per year and 40 GW electrolysis capacity by 2030	Renewables and fossil	Industry, mobility	$155 billion by 2030

Hydrogen combustion engine



New hydrogen engine with unprecedented injection: 2 liters and 40% thermal efficiency

BMW Hydrogen 7: Hydrogen V12 engine



Hydrogen car with fuel cell

* Hyosung has initiated full operations of a 1-megawatt hydrogen engine power generator installed at Hyosung Chemical's Yongyeon 2 plant in Ulsan, South Korea.

IROST Project development

- The key component in the implementation of the Program is the Call for Proposals, covering a number of the research and innovation actions. Prioritized actions, consistent with the objectives of the industrial scale Clean Hydrogen production, and are divided primarily into the:

- **-Renewable Hydrogen Production**

- **A target of 1 million tons** of domestic renewable hydrogen production has been set, to replace partially natural gas and oil in hard-to- decarbonize industries and transport sectors.

- **-Hydrogen storage and distribution**

- Hydrogen will have to be used for daily and/or seasonal storage providing buffering functions thereby enhancing security of supply in the medium term.

- **-Hydrogen end uses in transport applications;**

- Clean Hydrogen will support research on novel insulation concepts for liquid hydrogen tanks. In addition, an Innovation Action will support the demonstration of liquid hydrogen (LH2) refuelling stations for heavy duty and heat applications.

- **The project it is expected creation of materials, components, and innovative cell designs that can completely change the paradigm of hydrogen production using devices with improved levels of efficiency, cost, and durability.**

Project results are expected to contribute to the following objectives

- **Innovative electrolysis cells for low temperature hydrogen production and Valorization of by-product O2 and/or heat from electrolysis**.
- These can include novel designs of the cells, as well as application of the disruptive components and introduction of innovative ideas synergistically resulting in systems able, through the continuity of the further research, to fulfil the needs of the gigawatt sized storage of renewable energy.
- **Innovative electrolysis cells can be only achieved by a multidisciplinary approach combining outstanding advances such as materials science, nano-engineering, bio- hybrids catalysts (such as natural or engineered enzymes, peptides and protein based - component's or whole cells interfaced with electroactive materials and/or polymers or combined with organometallics clusters from separate synthesis), and innovative manufacturing approaches**.
- Waste to Hydrogen demonstration plant and Hydrogen use by an industrial cluster via a local pipeline network Retrofitting of existing industrial sector natural gas turbomachinery cogeneration systems for hydrogen combustion.

Iran's hydrogen technology landscape

Hydrogen technology development in Iran

- With over 85 million people living in the country in 2020, Iran has the second largest population among the Middle Eastern states. According to estimates, by 2050, Iran's population will be 98.6 million.
- Iran has the second and fourth biggest natural gas and oil reserves, respectively
- According to a report by BP (2019), Iran's energy consumption is relatively high (1.75 times the global average). In the 2016e2018 period, for instance, energy consumption grew by 8.7% in Iran and 2.4% globally. Usually, the high consumption in Iran is considered to be due to the availability of cheap resources [15]. CO2 emission in Iran is significantly high. Iran produced 532.2 million tons of greenhouse gases (GHGs) in 2012, making it the ninth producer of GHGs in the world
- To reduce GHG emissions, prepare for a future free of fossil fuels, diversify its economy, and protect its environment and climate, Iran has various options to procure energy through sustainable means.

Rahimirad, Z., & Sadabadi, A. A. (2023).. *International Journal of Hydrogen Energy*, *48*(40), 15179-15194.

- Iran enjoys vast resources of sustainable energies, including solar, wind, geothermal, thermal, biogas, and biomass
- by the end of the 1990s, there was no specific plan to develop sustainable energy sources.
- The first document that sets a specific goal for sustainable energy development is the Sixth Economic Development Plan (2017e2021) according to which governments should increase sustainable and clean power plants' share, mainly through private sector investments (foreign and domestic investors), making the most of domestic potentials so that by the end of the plan's period, at least 5% of the country's electricity capacity is produced through sustainable sources
- However, the setting of this goal has been largely ineffective so far and only 900MWof electricity is produced through sustainable sources in Iran

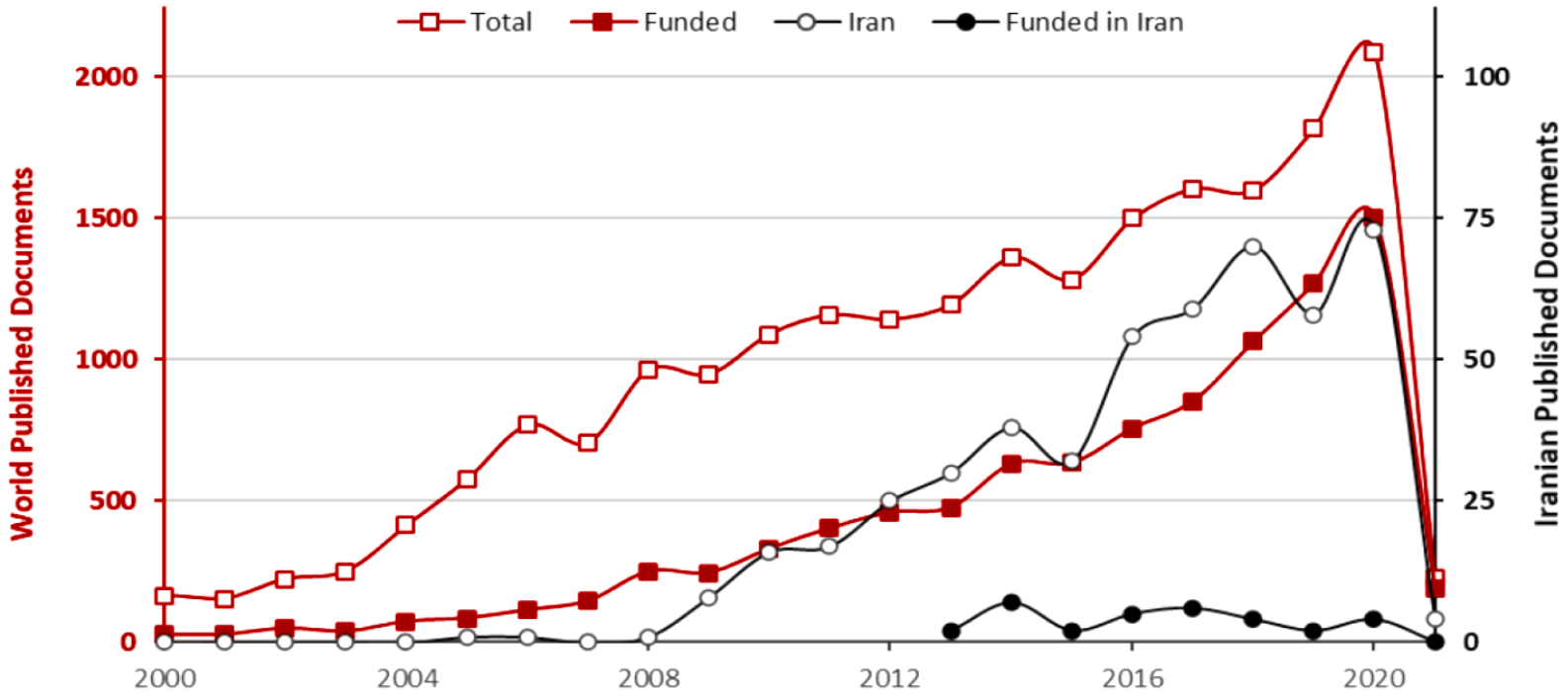


Fig. 7. Comparison of research articles on hydrogen production in Iran and the rest of the world.

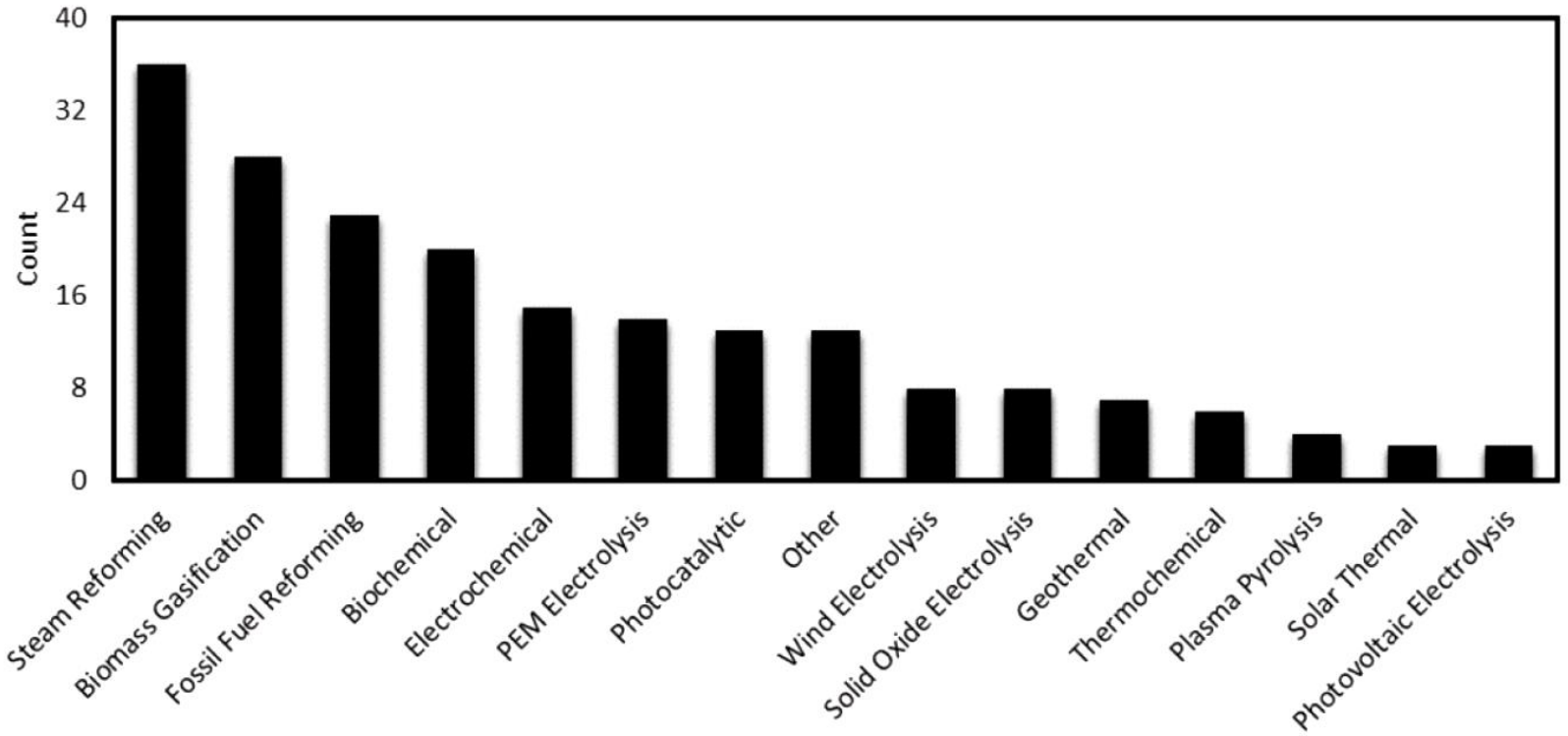
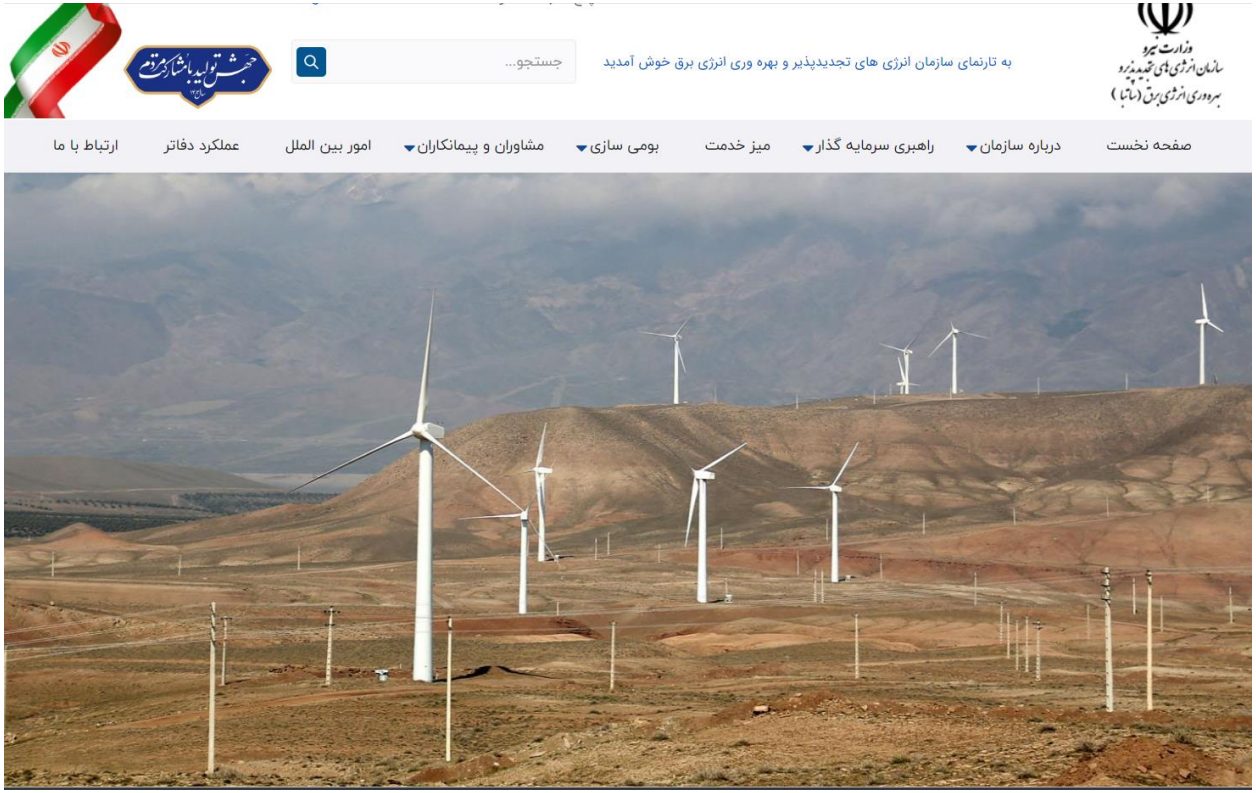


Fig. 8. Attractive research subjects in the field of hydrogen production for Iranian authors 2018 – 2021.

The Satba organization, the main agency responsible for sustainable energy development in Iran, established the Fuel Cell Steering Committee (FCSC) in 2002 to prevent small-scale and decentralized activities.

The committee's goals are:

1) active observation of the latest developments in fuel cell technology;
2) adoption of new policies and defining mechanisms to facilitate research, design, and development (RD&D) activities; and
3) coordinating efforts and plans in different layers.



- "Fuel Cell National Strategic Plan" was enacted in 2007, specifying measures and goals per the 20-Year Perspective Document for Iran
- More important, hydrogen-related technologies were not taken into account when the Fuel Cell National Strategic Plan was devised.
- A few studies have addressed the issue of green hydrogen in Iran, which have mainly focused on it with a technical approach (Kalbasi et al., 2021).
- According to the current situation of renewable energy resources in Iran, protective laws and regulations are necessary as prerequisites for mobilizing financial resources. Therefore, the lack of a comprehensive examination of opportunities and challenges and related policy tools is considered a significant knowledge gap in the development of green hydrogen on a large scale in Iran.
- Iran obviously needs an evaluation of measures and policies designed for green hydrogen, taking the global market's achievements and future goals into account (Nasiri et al. 2015)

Current State of Hydrogen Production in Iran

- **Gray Hydrogen**: All of Iran's hydrogen production is currently gray hydrogen. This method is not environmentally friendly, as it releases carbon dioxide into the atmosphere.

- **Blue Hydrogen**: There are no commercial blue hydrogen facilities in Iran. This type of hydrogen production, which captures and stores carbon emissions, is gaining traction in neighboring countries like Saudi Arabia and the UAE, which are investing heavily in the necessary technology and infrastructure.

- **Green Hydrogen:** The production of green hydrogen in Iran is hampered by a shortage of renewable energy infrastructure and freshwater resources. Competing nations in the region have advanced significantly in both solar and wind energy production, which are essential for generating green hydrogen.

Market Outlook

- The hydrogen market in Iran was estimated at approximately 210,000 tonnes in 2023, with projections of a growth rate of 2.58% CAGR until 2034.
- The ammonia industry is the primary consumer of hydrogen in Iran, accounting for about 41% of the market share[4].
- However, the potential for Iran to become a significant player in the global hydrogen economy, projected to be worth $700 billion annually by 2050.

Key Companies and Initiatives

Iran is in the early stages of developing its hydrogen production and storage capabilities, with several companies and governmental organizations exploring opportunities in this sector.

Here are some key players and initiatives:

- Persian Gulf Petrochemical Industries Development and Investment Group (PGPIDIG)
- Arvand Petrochemical Company
- Petrol Company
- Renewable Energy and Electricity Efficiency Organization (SATBA)
- Nasim sobh Farda Company –Green hydrogen production by alkaline electrolyzers
- Atiye Pardaz Sharif Company- Alkaline Electrolyzers production
- Mapna Group – Hydrogen combustion Turbins
- Turbo Tech Compresor Tak, Production of Tanks for hydrogen Storage

Project collaboration

- **Clean hydrogen will play a key role in accelerating the green and just transition to the economy of the future.**

- To stimulate research and innovation on clean hydrogen production, distribution, storage and end use application , Iranian Research Organization for Science & Technology manage a joint project with Petrochemical Research Center to showcase the synergies between and with the various Commission services/programs, industry and research partners and reflect on the entire hydrogen value chain from production, storage, to transport, distribution and utilization for a the Clean Hydrogen Alliance .

- **Objective was :**

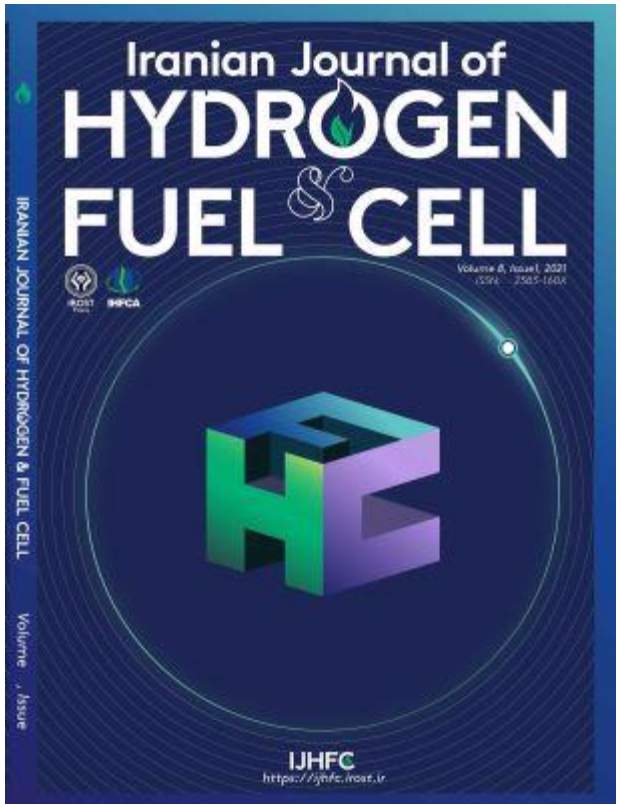
- **Strengthen the knowledge and capacity of scientific and industrial actors along the hydrogen value chain while supporting the uptake of industry-related skills.**

- **Carry out demonstrations of clean hydrogen solutions with a view to local, regional wide deployment, aiming to involve stakeholders and addressing renewable production, distribution, storage and use for transport and energy- intensive industries as well as other applications.**

- **The Strategic Research and Innovation Agenda, work programs and developments in adjacent, as well as Call for Proposals, covering a number of the above research and innovation actions.**

- **Building a large, skilled workforce is key to meeting net zero targets, but labor and skills shortages in expanding clean energy industries are already creating bottlenecks.**

The journal of ***Hydrogen, Fuel Cell & Energy Storage*** (***HFE***) is a peer-reviewed open-access international quarterly journal in English devoted to the fields of hydrogen, fuel cell, and energy storage, published by the Iranian Research Organization for Science and Technology (IROST).



References

- Global Energy Review: CO2 Emissions in 2021 - International Energy Agency
- IEA. 2021a. 'Net Zero by 2050 – A Roadmap for the Global Energy Sector'. IEA. 2021. https://www.iea.org/re-ports/net-zero-by-2050.
- IEA. 2021b. 'Global Hydrogen Review 2021'. IEA. https://www.iea.org/reports/global-hydrogen-review-2021
- IEA (2021b), Ammonia Technology Roadmap, https://www.iea.org/reports/ammonia-technology-roadmap
- IEA (2021c), Enhancing cyber resilience in electricity systems, https://www.iea.org/reports/power-systems-in-transition/cyber-resilience
- IPCC. 2022. 'Climate Change 2022: Mitigation of Climate Change, IPCC Sixth Assessment Report, Working Group III'. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. https://www.ipcc.ch/report/ar6/wg3/.
- IRENA. 2021. 'Majority of New Renewables Undercut Cheapest Fossil Fuel on Cost', 22 June 2021. https://www.irena.org/newsroom/pressreleases/2021/Jun/Majority-of-New-Renewables-Undercut-Cheap-est-Fossil-Fuel-on-Cost.
- IRENA. 2022. 'Geopolitics of the Energy Transformation: The Hydrogen Factor'. Abu Dhabi: IRENA. Clarke, Zoe, Michele Della Vigna, Georgina Fraser, Jerry Revich, Neil Metha, Robert Koort, Alberto Gandolfi, Chao Ji, Ajay Patel, and Bepul Shabab. 2022. 'Carbonomics: The Clean Hydrogen Revolution'. Goldman Sachs. https://www.goldmansachs.com/insights/pages/carbonomics-the-clean-hydrogen-revolution.html
- Minx, Jan C., William F. Lamb, Robbie M. Andrew, Josep G. Canadell, Monica Crippa, Niklas Döbbeling, Piers Forster, et al. 2021. 'A Comprehensive and Synthetic Dataset for Global, Regional and National Greenhouse Gas Emissions by Sector 1970-2018 with an Extension to 2019'. Zenodo. https://doi.org/10.5281/zenodo.5566761.
- World Bank. 2022a. 'GDP, Dataset: NY.GDP.MKTP.CD'. 20 July 2022. https://data.worldbank.org/indica-tor/NY.GDP.MKTP.CD.
- World Bank. 2022b. 'Population, Dataset: SP.POP.TOTL'. 20 July 2022. https://data.worldbank.org/indica-tor/SP.POP.TOTL.

Thank you for your attention