NUCLEAR 21
PERSPECTIVE FOR YOUR DECISIONS

Nuclear hydrogen production

By Ms. Aliki van Heek
Associate - Sustainable Energy Use

vanheek@nuclear-21.net

Perspective

September 2025

Perspectives by Nuclear-21

Our Perspectives aim to bring our views on important developments in nuclear science & technology with potential impact on the development, deployment and overall performance of nuclear science & technology applications worldwide.

Perspectives provide you our insights on such important developments based on our own activities and/or those undertaken by a variety of organisations worldwide.

Nuclear-21 is an independent advisory firm providing expert decisional support driving policy, strategies and business development towards sustainable nuclear-based solutions

On the deployment of nuclear hydrogen production

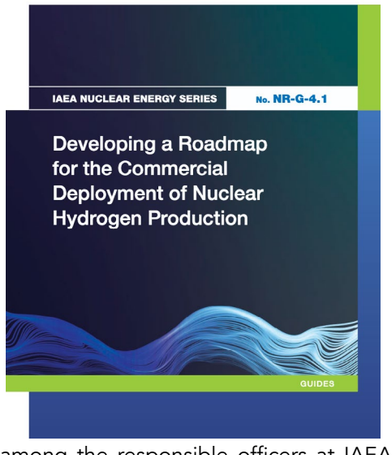
This Perspective addresses the production of nuclear hydrogen and is inpsired by the recent IAEA report "*Developing a Roadmap for the Commercial Deployment of Nuclear Hydrogen Production*"[1]

This recent IAEA report provides a timely and comprehensive overview of the opportunities and challenges in linking nuclear energy with hydrogen production. It underlines hydrogen's growing role in future low-carbon energy systems and highlights nuclear power's potential contribution to producing clean, large-scale, and reliable hydrogen.

In Summary

The report acknowledges that until now nuclear hydrogen has not been competitive with hydrogen from fossil sources, though some nuclear facilities already generate hydrogen for their own needs. It recognises that the **economics of nuclear hydrogen improve substantially if production facilities are co-located with industrial users**, thereby avoiding costly and lossy long-distance transport. Importantly, **the efficiency of nuclear hydrogen production can increase significantly when reactors are able to provide higher temperature heat**, strengthening the overall business case. While the report takes a cautious view of development and deployment timelines, it is important to recognise that after technical or market breakthroughs, both progress and uptake may accelerate faster than anticipated.

IAEA International Atomic Energy Agency



Ms. Aliki van Heek, Nuclear-21 Associate has been among the responsible officers at IAEA for this study. Aliki is currently leading Nuclear-21's Sustainable Energy Use advisory services encompassing the various routes forward for sustainable energy development and deployment among which nuclear energy can be a prime contributor towards sustainable hydrogen production.

Aliki can be contacted via vanheek@nuclear-21.net to address the solutions to your questions.

1 IAEA NR-G-4.1 https://www-pub.iaea.org/MTCD/publications/PDF/p15633-PUB2096_web.pdf

Nuclear & Hydrogen
A winning option in an integrated energy system vision

The report situates nuclear hydrogen within the broader energy transition, where hydrogen is increasingly seen as a versatile vector to decarbonise sectors that are hard to electrify directly, such as heavy industry, refining, chemicals, and some forms of transport. At present, most hydrogen worldwide is produced from fossil fuels, predominantly natural gas, using processes like steam methane reforming. This form of "grey hydrogen" is inexpensive but carbon intensive. Even when combined with carbon capture and storage, producing so-called "blue hydrogen," costs are typically lower than for hydrogen derived from nuclear or renewable electricity. The IAEA is clear in noting that nuclear hydrogen has not yet been competitive under normal market conditions. Nevertheless, as the world commits to ambitious net-zero targets, clean hydrogen sources will become increasingly valuable, and the inherent reliability and scale of nuclear power may position it as a strong contributor once costs can be brought down.

The fact that some nuclear facilities already produce hydrogen for internal consumption demonstrates that nuclear hydrogen is more than a theoretical concept. For instance, nuclear plants have installed small electrolysers to supply hydrogen used in turbine cooling or other on-site industrial processes. Although these volumes are modest compared to future market expectations, they provide useful operational experience. These cases also show how nuclear electricity, particularly during off-peak hours or when demand is lower than capacity, can be redirected towards hydrogen production rather than wasted. Such internal use can be seen as the first practical step in building confidence and competence before moving towards larger commercial-scale operations.

The report stresses the importance of geography and logistics in nuclear hydrogen projects. Hydrogen is difficult and costly to transport over long distances because of its low volumetric energy density, the need for compression or liquefaction, and the risk of losses through leakage or boil-off. Even if pipelines or carrier molecules like ammonia are used, the costs are significant and erode competitiveness. As a result, it makes little sense to locate large nuclear hydrogen plants far from their end users. Instead, the business case is strongest when the facility is co-located with, or close to, hydrogen demand clusters such as steel mills, chemical complexes, or refineries. The IAEA roadmap emphasises this need for integrated planning, where the siting of nuclear hydrogen facilities is matched with industrial users, thereby avoiding the transport penalty and strengthening the economics of the project.

Another critical point highlighted is the efficiency of hydrogen production when reactors are capable of providing heat at higher temperatures. Conventional low-temperature electrolysis powered by nuclear electricity is technically straightforward but relatively energy intensive, with efficiency levels typically around 30–35 percent. If a nuclear plant can supply higher temperature heat, then hydrogen production becomes more efficient, since part of the required energy input is provided directly as heat rather than electricity. High-temperature electrolysis, for example, reduces electricity consumption per unit of hydrogen and can push overall efficiencies into the 40–50 percent range. This improvement translates into lower operating costs, a stronger business case, and greater competitiveness against fossil-derived hydrogen. The ability of advanced nuclear reactors to provide these higher temperatures therefore represents a potentially decisive factor in the long-term commercial viability of nuclear hydrogen.

The report's balanced perspective on economics is particularly useful. While nuclear hydrogen currently cannot compete with cheap grey hydrogen, the introduction of carbon pricing, clean hydrogen mandates, and targeted subsidies can reshape the competitive landscape. In jurisdictions where fossil-based hydrogen faces higher environmental costs, nuclear hydrogen becomes more attractive. Moreover, compared to variable renewable energy sources, the report notes that nuclear reactors operate at high capacity factors, producing stable output around the clock. This reliability makes them well suited to supply hydrogen plants that require steady input, in contrast to renewable sources that are inherently variable. This stability can reduce costs associated with oversized electrolysers, storage, or backup systems, giving nuclear hydrogen a distinct advantage in terms of reliability and integration into industrial supply chains.

It can be done today with Light-Water Reactor technology.
Higher-Temperature reactors will expand the applicability space

It is important to temper the expected opportunities with realism about timelines. The IAEA report is careful in noting that development, licensing, and deployment of new nuclear-hydrogen systems will take time. Although some nuclear facilities currently produce hydrogen on a small scale for their own needs, real demonstration projects must be built, regulatory frameworks adjusted, materials and safety issues addressed, and commercial contracts secured. Such processes are often slow in the nuclear sector, where public acceptance and regulatory conservatism play major roles. Yet caution in projecting timelines should not lead to excessive pessimism. History shows that after certain technical breakthroughs or market shifts, development and deployment can accelerate rapidly. For example, the rapid cost reductions of solar photovoltaics or lithium-ion batteries over the past decade were faster than most analysts predicted. If similar breakthroughs occur in electrolyser manufacturing, reactor deployment, or hydrogen markets, then nuclear hydrogen could scale up much more quickly than conventional linear forecasts suggest.

The challenge of financing and investment also receives attention. Nuclear projects are capital-intensive, and adding hydrogen production capacity requires additional investment. The IAEA report notes that innovative business models, such as public-private partnerships, guaranteed offtake agreements, or contracts for difference, may be necessary to attract private capital. This is especially true in the early stages, when costs are higher and markets uncertain. Successful demonstration projects with clear long-term policy support could then reduce investor risk and pave the way for broader commercial deployment.

The importance of policy frameworks cannot be overstated. The IAEA highlights the need for clear standards and certification schemes for clean hydrogen, so that nuclear-derived hydrogen can be recognised and valued in the same way as renewable hydrogen. Without such recognition, nuclear projects may face an uneven playing field, unable to monetise their low-carbon advantage. Policymakers therefore play a decisive role in enabling nuclear hydrogen to compete fairly in the emerging hydrogen economy.

Safety and public acceptance remain additional challenges. The integration of nuclear reactors with hydrogen production facilities raises questions about regulatory boundaries, accident scenarios, and public perception. Even if the technical risks can be well managed, negative public attitudes toward nuclear projects may slow deployment. The report underlines the importance of transparent communication, stakeholder engagement, and clear regulatory oversight to address these concerns. These aspects will need to be managed carefully if nuclear hydrogen is to receive broad societal support.

Overall, the IAEA roadmap provides a coherent framework for considering how nuclear energy can play a role in the emerging hydrogen economy. It recognises the current economic disadvantages, but also identifies the factors that could shift the balance: policy support, proximity to demand, higher-temperature reactors, demonstration projects, and international collaboration. While the challenges are significant, the opportunities are also substantial. Nuclear hydrogen production could become a major clean hydrogen source, particularly in regions with strong nuclear expertise, high industrial hydrogen demand, and supportive policy environments.

In conclusion, the IAEA report paints a cautiously optimistic picture. Nuclear hydrogen is not yet competitive with fossil alternatives, but internal production at nuclear facilities shows that the concept works in practice.

Transport constraints mean that co-location with users is essential, and higher reactor temperatures will be key to improving efficiency and economics and to enlarge the applicability space.

While development timelines are uncertain, it is important to remain aware that once breakthroughs occur, deployment can accelerate faster than anticipated.

The IAEA roadmap is therefore a valuable guide for policymakers, industry, and researchers to navigate the path toward commercial nuclear hydrogen, recognising both the obstacles and the transformative potential it holds for a low-carbon future.

Contact Us

Nuclear-21

info@nuclear-21.net
www.nuclear-21.net