A Pathway to Kickstarting the Clean Energy Transition
Hydrogen Production through Nuclear

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Nuclear and renewable energy are often portrayed as competitors—frequently, they are viewed as technologies that are mutually exclusive, offering fundamentally different visions of our clean energy future.

Discourse on nuclear-renewables competition is often narrowly confined to electricity markets. However, taking a holistic view of decarbonization—not only emissions from power generation, but also transportation, industry, etc.—it is increasingly evident that the association between nuclear and renewables is not as simplistic as many assume.

According to leading experts and the world's foremost climate scientists, a spectrum of low-carbon energy technologies will be needed to address climate change. Considering this view, framing a zero-sum "nuclear versus renewables" competition is likely to be counterproductive to global carbon mitigation efforts.

Contrary to such widely held presumptions, strong synergies are possible with deploying both nuclear and renewables, enabling truly comprehensive decarbonization strategies that address all sources of anthropogenic carbon. For example, flexible nuclear generation (more feasible with integrated hybrid energy systems and/or certain advanced reactor types) can theoretically allow higher penetrations of renewables.

Another way nuclear could facilitate greater deployment of renewable energy is through accelerating the emergence of the hydrogen economy. As a medium for hydrogen production, nuclear can expedite the development of clean, cost-effective, and scalable energy storage for variable energy resources. By generating hydrogen, nuclear can not only enable greater integration of renewables to electric power systems, but also zero-carbon solutions for transportation, industrial heat, etc.

The Promise of Hydrogen

The advent of viable hydrogen energy technologies would have the potential to replace fossil fuel infrastructure on a large scale. A recent report by BloombergNEF (BNEF) suggests that up to 34% of global greenhouse gas emissions can be cut at a manageable cost using clean hydrogen technologies. The BNEF study estimates that before 2050, hydrogen generated from clean energy sources could be produced at prices of $0.8 to $1.6/kg (equivalent to gas priced at $6-12/MMBtu) in most parts of the world, which would be cost competitive with present natural gas prices in many countries.

In addition to replacing fossil fuels, hydrogen energy technologies can be a keystone to integrating intermittent renewable generation sources into energy infrastructures. The variability of renewable power generation requires sufficient levels of operating reserve, generally run with natural gas or other fossil fuels.

Energy storage can help address intermittency without the use of fossil fuels by storing excess energy during times of surplus and dispatching this stored energy during peak demand. However, currently available energy storage solutions are constrained by both physical and technological limitations. For example, batteries—currently the energy storage technology closest to large-scale commercialization—not only have limitations in storage capacity, they are also prone to storage degradation, whereby the lifespan of the storage medium diminishes significantly with use.

Hydrogen, on the other hand, can theoretically overcome many of these aforementioned limitations. Hydrogen fuel can be stored for extended periods, and the amount of energy stored is limited only by the size/volume of hydrogen storing vessel or facility. Thus, for both short-term and longer seasonal variations, hydrogen-based energy storage possesses significant advantages in smoothly integrating solar, wind, and other variable renewable energy sources.

The Principal Challenge: Clean Hydrogen Production

In order for hydrogen to contribute to the deep decarbonization of energy systems and overall emissions reductions, hydrogen fuel must be generated from clean energy sources. However, more than 95% of hydrogen currently produced globally is through steam methane reforming—a process that utilizes fossil fuels to produce hydrogen and generates carbon emissions.

Alternatively, excess renewable electricity can be used to produce hydrogen through electrolysis, the splitting of water into hydrogen and oxygen using electricity. This production method generates no emissions itself, but its drawback is its cost. Electrolysis from clean electricity such as wind and solar can cost two to three times as much as steam methane reforming.

International Energy Agency (IEA) Executive Director Fatih Birol, during a recent virtual event hosted by the Atlantic Council, echoed much of the above, stating that the "major problem with hydrogen" is its high cost. He further stated that the largest contributor to this cost is the lack of a viable means of electrolysis, and that measures are needed to make electrolyzers more cost-effective.

Generating Hydrogen through Nuclear

Electrolysis is more efficient and economical if the water is first heated to steam before the electric current is applied, which is why nuclear plants are considered ideal platforms for electrolysis as both steam and electricity are available in abundance. Indeed, a select number of U.S. nuclear plant operators, through a U.S. Department of Energy (DOE) sponsored project, will be demonstrating commercial hydrogen production within the next 12-24 months—if the demonstrations are successful, they may unlock new revenue streams for U.S. nuclear plants, crucial as much of the fleet is under competitive stress in domestic power markets due to low cost natural gas and other factors.

While efficiencies are gained by electrolyzing the high-quality steam generated by commercial reactors, hydrogen production can theoretically be even more efficient through the introduction of higher temperatures. Hybrid (heat plus electricity) technologies such as high-temperature electrolysis and hybrid thermochemical cycles can improve the economics of hydrogen production by reducing the required input of electrical energy. Thermochemical processes—which utilize very high temperatures plus chemical reactions to split water—have the potential to be highly efficient in large-scale hydrogen production. According to one study, nuclear thermolysis is comparable to steam methane reforming in terms of cost per unit of hydrogen produced ($2.16-$2.63/kg), even without carbon pricing or additional costs for CCS on the latter process.

For some of the aforementioned processes, the temperatures required are beyond the limitations of today's light water reactors. Thus, as hydrogen demand increases, further attention and focus are likely to be devoted to high-temperature gas-cooled reactors (HTGRs) which are capable of significantly higher outlet temperatures (in addition to greater passive safety and resource utilization). The primary challenge with the HTGR concept is the development of materials that can withstand the high-temperature, high-neutron environments created by reactors of this type. R&D of advanced materials is ongoing at U.S. national laboratories, and testing facilities that can replicate the extreme conditions of the HTGR may be needed to accelerate deployment and commercialization.

Conclusion

Hydrogen energy represents one pathway through which renewables, nuclear, and other low-carbon technologies may interact to produce synergistic effects. In the case of hydrogen, the potential mutual benefits are clear, at least in the U.S. context: hydrogen production could provide new economic opportunities for nuclear plants struggling to compete in existing electricity market structures and conditions, and nuclear-generated hydrogen could ultimately establish the foundations for viable and scalable energy storage solutions, thereby addressing intermittency issues and enabling greater integration of renewables such as solar and wind. Hydrogen can also be combined with captured carbon to produce chemicals, plastics, and pharmaceuticals, theoretically improving the economics of carbon capture technologies.

Such an arrangement, in theory, could initiate a virtuous cycle of decarbonization, not only encouraging the addition of more low-carbon assets to the electric grid, but also providing clean fuels for transportation, industry, etc.

Many of the technologies herein discussed—both existing and in development—have been widely known for years. Yet, utilizing the various technologies that comprise the decarbonization toolkit of today to form a cohesive and complementary strategy for climate mitigation may require some creativity, flexibility, and out-of-the-box thinking. However, such imaginative approaches may not be possible if we remain mired in the dogma and tribalism that has prevailed in contemporary dialogue on climate and clean energy issues.

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