Study Finds LWR Electricity–Hydrogen Hybrids May Improve Profitability

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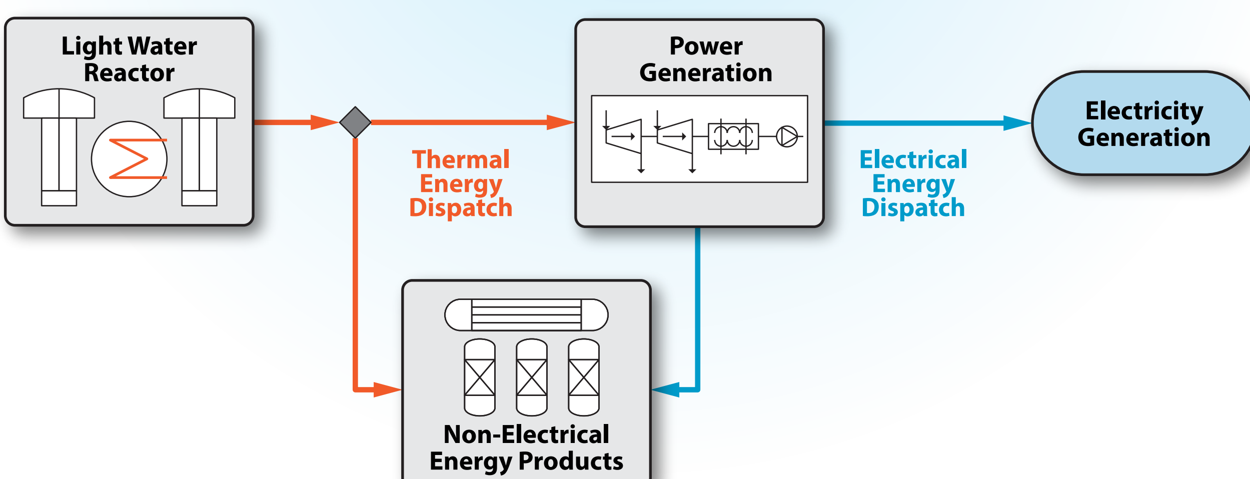
The LWRS Program recently completed a comparative study that finds existing nuclear power plants located in the Midwest can increase their profitability by switching between electricity production and hydrogen (H_2) generation. Figure 7 illustrates how a H_2 plant could be coupled to an existing nuclear plant. This may help nuclear power plants increase their revenue at a time when wholesale electricity prices have fallen to historically low levels. Together with significant contributions from collaborating national laboratories and Strategic Analysis, Inc, the LWRS Program recently completed an in-depth technical and economic assessment of a new business model for a candidate light-water reactor (LWR). The assessment focuses on developing a new market from LWR operations based on coproduction of non-electrical-based products, such as H_2 or other valuable chemicals, by directly using the steam or electricity produced by the nuclear reactor. During periods when the wholesale price of electricity is high, the nuclear power plant can shift to selling electricity to the grid, while reducing the production of H_2 or the other chemicals. This mode of dispatching energy for the production of more than one energy commodity is referred to as a hybrid plant. The idea is to maximize the profitability of the nuclear power plant by selling electricity or steam directly to the secondary user on a schedule that allows both the nuclear power plant and the associated energy user to be profitable.

This study evaluated the market case for producing H_2 in the Upper Midwest. Currently, there is a growing market for clean-burning fuel-cell-powered vehicles. H_2 fuel cell forklifts are becoming popular for warehouse and cargo distribution centers where combustion engine emissions can be a problem. And because H_2 fuel cell vehicles can operate for longer periods of time than electric-battery vehicles, both cars and heavy-duty trucks powered by fuel cells are starting to emerge as society desires to transition clean energy from wind and solar farms to the transportation sector. Nuclear power plants that produce H_2 can also produce clean, zero-emissions energy for the transportation and other sectors. The study found that nuclear power plants can produce H_2 for under $2.00 per kilogram once emerging electrolysis technology becomes commercially available. Each kilogram of H_2 has the equivalent energy of one gallon of gasoline; however, a typical fuel cell car may be driven 60–70 miles on one kilogram of H_2. The overall U.S. Department of Energy (DOE) goal is to produce, deliver, and sell H_2 at filling stations for around $4.00 to $7.00 per kilogram for fuel-cell vehicles to be competitive with the gasoline-fueled automobiles driven today.

Large industrial users of H_2 could also reduce their emissions using H_2 from nuclear power plants. These include fertilizer producers, petroleum and synthetic-fuels producers, and steelmakers. H_2 is combined with nitrogen to make ammonia-based fertilizers, such as ammonium nitrate and urea. Millions of tons of H_2 are used by refineries to produce gasoline and diesel fuel. H_2 can also be used to convert carbon dioxide into important chemicals like methanol or to make synthetic lubricants and fuels. In addition, it can also be used to reduce iron ore to a form of iron that can be refined in an electric arc furnace to produce high-quality iron and steel materials. These are just some examples of H_2 markets that are growing as domestic and foreign demand for each of these chemical products and materials continues to rise. The H_2

Figure 7. Nuclear Power Plant Hybrid Concept.



price target for these industries ranges from about $1.00 per kilogram for competitive steelmaking up to $2.00 per kilogram for fertilizers produced with clean-energy sources.

The approach taken by the study was to compare the cost of producing H_2 using the energy from an LWR against a conventional process that converts natural gas into H_2 through natural-gas reforming with steam. The latter uses up to one-third of the natural gas to produce the required steam and heat necessary for the process; the remaining two-thirds goes into the H_2 product. The nuclear electricity-H_2 hybrids could use either low-temperature alkaline, polymer electrolyte membrane, or high-temperature steam electrolysis to split water into H_2 and oxygen. Natural-gas reforming results in carbon dioxide emissions. Water or steam electrolysis with electricity and steam provided by the nuclear power plant would be free of pollutant emissions.

The study identified two business opportunities for LWR-supported electrolysis. One case is for smaller plants that could produce H_2 for fuel-cell-vehicle filling stations. In this case, low-temperature electrolysis plants are competitive with natural-gas reforming plants. The second case is for industrial plants that use a large amount of H_2. In this case, steam electrolysis was shown to be competitive with large-scale natural-gas reforming plants. The study assumed that H_2 produced near a nuclear power plant would be compressed and put into a pipeline to be sent to end users as far away as 15 miles.

Figure 8 presents H_2 production costs for a large scale, 500 tonne per day, plant based on natural gas reforming versus steam electrolysis. The study found that H_2 can be produced for just over $1.50 per kilogram by either steam electrolysis or a natural-gas reforming plant based on cost projections by the Energy Information Agency (EIA) for high, baseline, and low natural gas price scenarios. The value of H_2 produced by electrolysis with steam and electricity provided by the nuclear power plant considered the value of reducing carbon emissions, as well as a modest capacity payment for sending electricity to the grid during periods when electricity demand is relatively high. A $25 credit for each tonne of CO_2 avoided relative to natural-gas reforming could reduce the cost of H_2 produced by electrolysis by $0.25 per kilogram. For the grid conditions used for this evaluation, a hybrid plant sending electricity to the grid just less than 2% of the year, with a realistic capacity payment, could independently reduce the price of H_2 by $0.20 per kilogram. The combined benefits could reduce the cost of the H_2 produced by the nuclear power plant to around $1.07 per kilogram. This would be game-changing for H_2 markets and would provide incentive to build LWR electricity H_2 hybrids in several places.

This study aligns with Crosscutting Technology Development Integrated Energy Systems research and development activities under the DOE Initiatives Program Offices for Nuclear Energy and Energy Efficiency/Renewable Energy. It complements analysis activities being conducted by the Energy Efficiency and Renewable Energy Fuel Cell Technology Office under an initiative referred to as H_2@ Scale. The LWRS Program is presenting detailed results of this study to LWR owners and operators, H_2-using industries, and electrolysis-technology providers to help promote partnerships that can demonstrate the technical feasibility of the hybrid systems.

Figure 8. Cost of hydrogen production and delivery 500 tonne per day plant.