Clean Nuclear Energy for Industry Webinar Q&A
April 16, 2020

What would be the business model for the non-electricity use of nuclear energy? Who owns/operates the facility? who is the licensee? and what is the role of end users, i.e., the industrial user of steam or high temperature gas?

These questions are still being explored and could have various answers as a function of location, application, etc.

Does Hydrogen generation make economic sense for new built nuclear plant?

The economics of hydrogen generation depends on the electricity price, scale of production, and the efficiency of conversion for the electrolyzer used.

Could the production of hydrogen be used to shape the curve of power production over time, such that nuclear plants can economically act as more than a base load power supplier, increasing production during hours with more power demand?

This is a fundamental tenant of the work being done under the DOE Office of Nuclear Energy (DOE-NE) Integrated Energy Systems program and the related LWR Sustainability Flexible Plant Operations and Generation program in collaboration with industry partners. Dynamic analyses are being conducted to determine optimal energy dispatch to the grid or coupled energy users, including the dynamic operation of electrolyzers for hydrogen production, to determine their use in enhancing operational flexibility of nuclear plants.

Does Exelon have a value stream analysis for these different concepts?

Exelon has explored the economics of hydrogen generation in collaboration with Idaho National Laboratory (INL), the National Renewable Energy Laboratory (NREL), and Argonne National Laboratory (ANL). This work was supported by a cost-shared project funded by the DOE Office of Energy Efficiency and Renewable Energy Hydrogen at Scale program, DOE-NE Integrated Energy Systems program, and Exelon. Partial results of the analysis are available at OSTI.gov:
https://www.osti.gov/biblio/1569271-evaluation-hydrogen-production-feasibility-light-water-reactor-midwest
Results of related analyses supported by the DOE-NE LWR Sustainability program are available at:
https://www.osti.gov/biblio/1559965-evaluation-non-electric-market-options-light-water-reactor-midwest

Could hydrogen produced by nuclear power plants be used for lighter duty transportation like hydrogen fueled cars?

Yes, and this is one of the "use cases" of interest for some regions. The hydrogen would still need to be transported from the production site to the end user site, such as a refueling station, which adds cost – but this is no different than transporting hydrogen produced by tradiational steam methane reforming to various end use sites. However, unlike steam methane reforming, hydrogen produced from nuclear energy is carbon free.

Is there an estimate on how much hydrogen will be required for some of the larger projects? How efficient is this process?

The conversion efficiency of an electrolyzer is roughly 40-60 kWh/kg. The scale of hydrogen demand depends on the chemical process it is used for. Hydrogen customers of interest range in scale, but recent studies supported by the DOE H2@Scale program indicate significant growth potential in hydrogen markets.

What do you [Energy Harbor] mean by "containerized"?

"Containerized" indicates that the electrolysis stacks and balance of plant (supporting) equipment comes pre-assembled by the vendor in a container.

For Energy Harbor: How much H2 will be produced? What will be done with the excess Oxygen? Is there any security risk to the plant with the construction and operation of this system?

The size of the low temperature electrolysis skid being planned for use by the project team will produce between 800 – 1,000 kg per day at maximum operation capacity. The excess oxygen will be vented to atmosphere as the project team currently does not see a cost-effective solution for what to do with the oxygen produced. While the team does not foresee any safety or security risks that would affect the safe and reliable operation of the nuclear unit, our standard design and review process will ensure that all potential risks are properly evaluated.

At what pressure is hydrogen generated through the electrolysis? Will the hydrogen be pressurized before it is transported off site? What is the cost of hydrogen compression?

The hydrogen produced is at 30 barg (or about 435 psig). In order to economically transport this product offsite, it will be pressurized. The cost of hydrogen compression varies with the skid's output capacity factor, required discharge pressure and reliability of the compressor, and can be thought of as an additional electrical load when computing costs.

Is this design for electrolysis scalable?

Yes, the Low Temperature Electrolysis design is scalable.

Around how much would electricity cost decrease by producing H2 on site?

It is difficult to provide an exact number, given that electricity prices vary over time and location; however, average values for residential, commercial, and industrial electricity can be found on the U.S. Energy Information Administration's website. This data can be compared to expected Locational Marginal Prices (LMP) for various regions to ascertain the approximate cost savings by area.

Have you had any conversations with STARK transit that operate fuel cell buses using hydrogen?

Yes, the project team has had conversations with individuals with the Stark Area Regional Transit Authority.

What happened to Xcel's plans to meet emissions goals by overbuilding solar?

Our plans for achieving 100% carbon free emissions by 2050 are not finalized. We are exploring all carbon free technologies to achieve our carbon free goal, keeping in mind the variation in available natural resources across our service territory. For example, wind is much more plentiful in the upper Midwest while solar is much more plentiful in the Colorado and Texas. Each area is reviewing the best paths to becoming carbon free while minimizing overall costs.

Are you [Xcel] planning on building more plants to keep your carbon emissions down through the 2030s?

Our plans for achieving 100% carbon free emissions by 2050 are not finalized. Currently, we have not committed to building any new nuclear plants. However, we are exploring all carbon free technologies to achieve our goal.

Going 100% clean energy would require halting natural gas operations. Is Xcel planning to remove natural gas entirely?

We plan to use natural gas to transition away from coal until suitable carbon free technologies are available. Many new technologies are being explored to achieve that goal and plans remain under development.

What do you anticipate to be the biggest challenge for the nuclear industry in the next 10 years?

A key challenge for the industry is finding ways to keep nuclear cost competitive while coordinating with wide scale penetration of renewable generation.

Does the ability to operate a nuclear power source flexibly increase with nuclear generation capacities? In other words, does a larger nuclear plant (or more, smaller nuclear plants) have more flexibility?

The size of the plant does not affect the ability of flexibly operate, but it does affect the amount (in MW) by which it can flex. For example, there are certain physical plant design parameters that make it undesirable to flex a boiling water reactor (BWR) below a certain percentage of rated power

(depending on the design). An X% drop in power for a large BWR would be more megawatts than for a small BWR, but both plants would be able to flex down by X%.

A factor that does impact the ability to flexibly operate a pressurized water (PWR) would be where the plant is in the fuel cycle. Towards the end of the fuel cycle, a PWR does not have a high enough boron concentration in the coolant to be able to adequately change power levels to the desired levels.

Additional options for flexible operation may be provided by multi-module small modular reactor plants, or by advanced reactors that operate using non-water coolants. More information will be presented on advanced reactor capabilities in future webinars in this series.

Who is providing the high temp electrolyzer [for the Xcel project]?

We are currently working through our procurement process to competitively bid the selection.

Using plant steam for high temp electrolysis—what is the efficiency penalty on the nuclear plant?

Initially, the scope of the project is small (<1MW), which is a minimal impact on the nuclear plant. A long-term possibility would be to build a larger hydrogen skid to accept more steam and electricity. This would improve the overall nuclear plant efficiency by keeping the plant at full rated steam power when full electrical output is not needed due to increased renewable generation. That is, instead of downpowering to accommodate renewable electricity, we will keep the nuclear plant at full power (which is the most efficient way to run the plant and use the fuel) and use excess power (electricity and steam) to run the electrolyzer.

Can you [APS] share which manufacturer you are working with on the electrolyzer side?

APS has requested information from several vendors for Low Temperature Electrolyzers (LTE) for the demonstration project. Evaluation of this information and vendor selection will be completed once the final project scale and demonstration objectives established. We expect to partner with the manufacturer in the demonstration program as opposed to contract for purchase.

Negative hub pricing has been mentioned a few times, so I wanted to ask the speakers: In what ways have their organizations been affected by state and national policies which both promote renewables and sideline nuclear?

Policies that have promote large scale renewable penetration (without storage) have obviously resulted in seasonal low net demand conditions that exert pressures on utilities with large scale nuclear generation to curtail output. In the US southwest, these conditions are typically driven by photovoltaic (solar) generation that ramps down quickly in the late afternoon and evening concurrent with peak demand. Fast ramping of nuclear to provide for the increased demand is not desirable. As a result, commercial solar is often curtailed during the mid-day conditions to keep the nuclear plant at full power. This also increases the demand on natural gas assets for load following.

Is the reversible hydrogen electrolysis plant more expensive than a non-reversible standard electrolysis hydrogen producing plan? If so, what would you estimate as the percent more expensive?

Reversible systems are based on solid oxide electrolysis cell (SOEC) technology (see EERE Fuel Cell Technology Office – Hydrogen Production: Electrolysis https://www.energy.gov/eere/fuelcells/hydrogen-production-electrolysis*.). SOEC "stacks" generate hydrogen when steam and electricity are supplied to the cell. This design can be operated in the reverse direction where hydrogen is supplied to produce an electric potential. The technology is still in development and manufacturing capability for these stacks is small. Only two installations are known (one US and one in Europe) and are believed to be on the order of 150kW. The Xcel installation will use a SOEC system (in the electrolysis mode only) and will be at or below 1MW. Until the manufacturing process is advanced, a reasonable cost comparison cannot be made.*

What is the present cost comparison between H2 and renewable?

This response assumes that the question pertains to the cost comparison of hydrogen derived from nuclear power as compared to the cost of hydrogen from renewable power. Currently, the cost of low temperature alkaline and proton exchange membrane (PEM) electrolysis technology and renewable generation results in a wide range that public sources estimate between $2-5/kg. This price is expected to drop sharply as manufacturer capacity increases in response to demand for clean hydrogen. Comparatively, the cost of hydrogen from nuclear (grid) power is dependent on the market conditions. Assuming low temperature electrolysis (alkaline or PEM) with the cost of power at $30 MWh results in hydrogen costs in the mid-point of the same range. High temperature steam electrolysis results in an approximate 30% increase in efficiency which is expected to create cost parity with hydrogen from renewables (assuming comparable advances in manufacturing capacity).

Are you expecting to have to rush to cleaner energy goals with climate alarmists saying we have 10 years to reach much lower carbon emissions?

Many companies, both electrical generation and large consumers, have already declared their intent to become carbon free within a certain timeframe. We expect this trend to continue.

What is the future of thermochemical hydrolysis, using superheated steam from nuclear instead of electricity?

Thermochemical processes for hydrogen production are still under development by a number of organization around the world.

Is DOE looking at real high temperatures like non-LWR temperatures of 500C for SFR/LFR, HPFR or early MSR at 600-700C, or VHTR & MCFR at 950-1000C?

DOE and private industry are developing a suite of reactor concepts that operate at outlet temperatures that range from LWR temperatures (~300 C) to very high temperatures (~900-1000 C).

If the technology is successful at a few locations, will there be a push for all nuclear facilities to adopt the hydrogen production process across the country? Will it become an expected aspect of future nuclear power plants?

> *Hydrogen usage across the country varies based on the local industries (e.g., refineries, transportation, ammonia production, etc.). Each nuclear plant would have to evaluate local opportunities as the cost of transporting the hydrogen may make it uneconomical to build a hydrogen production plant.*
>
> *The future electrical system will likely be much more integrated with non-electric uses (such as making hydrogen) as increased renewable penetration decreases the need for 100% always on base load generation like how nuclear plants have traditionally been operated.*

What are the NRC regulations on hydrogen production at nuclear power plants?

> *As we make any (not just hydrogen related) modifications to the plant, there is a set process regarding NRC involvement / approval, which is described in 10CFR50.59. NRC regulations that would apply specifically to hydrogen would be in the area of storage of hydrogen on site and the ability of the nuclear plant to withstand a potential explosion of the stored hydrogen.*

Low temperature electrolysis was discussed, and the vendors of that technology are well-known. High temperature electrolysis was also discussed. What/whose technology is being considered?

> *We are early in the process and are currently working through evaluation of vendors with Idaho National Lab, with a desire to use US manufacturing capabilities.*

Could high temperature electrolysis provide an adequate means of energy storage in a green energy market as opposed to batteries?

> *Yes. Hydrogen production and storage can be considered a means of chemical energy storage. The hydrogen can be stored on site, or it can be transported to a different location for use. This stored energy can be accessed for later electricity production or to support other energy users beyond the electrical grid.*