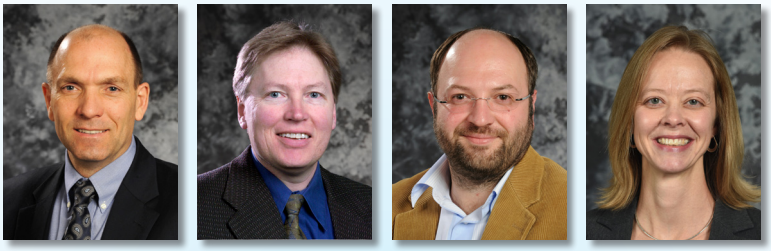
Increasing the Value of the U.S. Nuclear Reactor Fleet



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It is becoming increasingly challenging for operating light water reactors (LWRs) to compete with natural gas combined-cycle power plants in deregulated wholesale electricity markets due to the historically low cost of natural gas. In addition, in areas where wind and solar power generation is being built up, the selling price of electricity is periodically less than the cost of operating nuclear power plants. Consequently, some LWR plants operate at a profit loss during certain periods. A new operating paradigm will benefit the profitability and sustainability of these plants. This new operating paradigm incorporates direct integration with industrial manufacturing processes that help diversify the products and thereby the revenue of LWR plants.

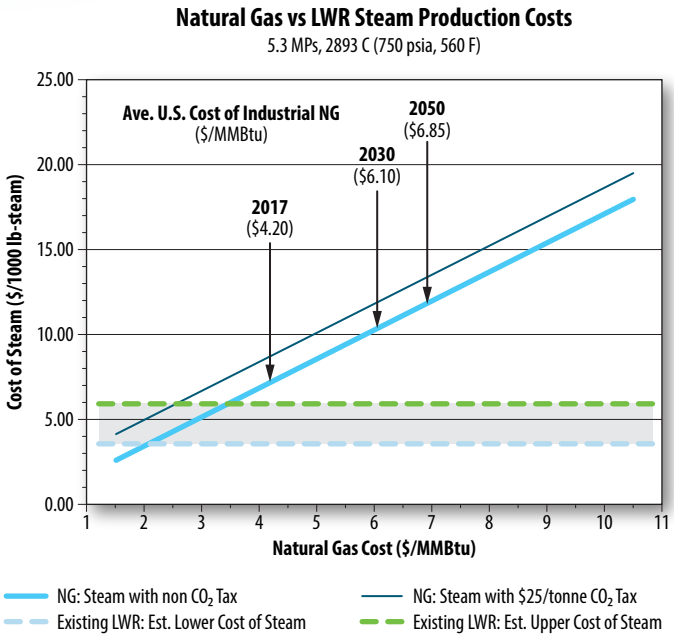
Existing nuclear power plants can provide a reliable and cost-competitive supply of steam and electricity for industrial process use for decades to come.

[1,2] A recent evaluation of the U.S. manufacturing industry indicated nuclear power plants can provide upwards to 75% of the electricity and heat currently produced by industry combined heat and power systems and fossil-fired steam boilers. [3] In addition, energy carriers, such as hydrogen, can be produced with LWRs for energy storage, petroleum refineries, production of fertilizers, chemicals, reduction of iron ore for steel manufacturing, and hydrogen fuel cell vehicles. [4] A comparison of the cost of producing high pressure steam using a natural gas-fired package boiler versus the cost of producing the same quality and quantity of steam using a LWR is illustrated in Figure 10. The cost of steam production by the existing U.S. fleet of LWRs will remain competitive, even accounting for plant upgrades to accomodate a future license extension.

The LWRS Program is evaluating the value proposition and technical challenges of integrating nuclear plants with industrial processes, leveraging interactions and advancements stemming from other DOE-sponsored programs, to enable potential near-term demonstrations and deployments of candidate technologies. In some cases, operating plants could dispatch energy for electricity generation or to a heat application to maximize the profit of these plants. The benefits of LWR integration with industry may include:

- Providing low-emissions energy to the industrial manufacturing and transportation sectors
- Maintaining the stability, reliability, and resiliency of the grid as renewable energy and distributed power generation become more prevalent
- Transitioning a classical baseload supplier into a more flexible operator allowing a higher level of penetration of variable low-cost, renewable energy
- Enabling expansion of variable, low-cost renewable energy by coupling nuclear reactors to energy storage and thermal energy users

Figure 10. Cost of High-Pressure Steam Production Using Natural Gas and Nuclear Energy (Arrows indicate U.S. DOE Energy Information Agency cost projections for natural gas).



- Ensuring U.S. competitiveness by domestically producing more of the most energy-intensive products and services.

Technical and economic assessments of participating operating plants and candidate integrated energy systems are now being conducted. Case studies depend on factors such as electric grid and market conditions and industry process possibilities near the nuclear plant. Process engineering models are being used to design the equipment and control systems that will transfer electricity, steam, or heat from the nuclear plant to the industrial process. Figure 11 illustrates how the heat, steam, and electricity that is produced by an operating plant can be used by all major U.S. industrial processes. Hydrogen and syngas (synthesis gas comprised of chemical building blocks like carbon monoxide and hydrogen) can be produced as intermediate product streams that are used in industrial processes.

Hydrogen production and use by industry is being evaluated for early movers of integrated energy systems. A first case study is evaluating the benefits of dynamically dispatching power to the grid when a profit can be made or for hydrogen production when the price of electricity falls to the point that competitively priced hydrogen can be produced. Initial calculations indicate hydrogen can currently be produced with emerging electrolysis technology for less than DOE's goal of \$2/kg-H_2 for fuel cell vehicles. As LWR operators push the operational cost of energy production lower, the value of producing large volumes of hydrogen at the industrial processe scale looks promising.

In addition to technical and economic assessments, LWRS Program Integrated Energy Systems (IES) program activities focus on enabling the R&D that will help accelerate integrated energy system pilot projects at a currently operating LWR plant. This work builds on the significant investment in modeling and simulation capabilities developed by the Crosscutting Technologies Nuclear-Renewable Hybrid Energy Systems Program since 2014. The challenges of tying into the electrical and thermal delivery systems of a nuclear reactor are being identified through the engagement of LWR plant operators, hydrogen production technology providers, and other stakeholders. This research will help address the necessary technical and deployment aspects of near-term integrated energy system technologies.

In summary, the LWRS Program is undertaking IES research, development, and pilot project activities to address emerging issues associated with expanding the use of LWR power plants. Initial efforts are underway to evaluate the value proposition both generally and for specific applications that can be implemented in the near term to help diversify the products and the potential role of LWR plants in U.S. industry. Technical and economic assessments provide decision makers with information for moving forward on initial candidate technologies. Collaborative partnerships will be key to the execution of the first LWR integrated energy system.

References

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Figure 11. Integration of LWR plants with major U.S. industry processes.