Sustaining the Industrial Sector with Nuclear Energy

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Flexible Plant Operation and Generation Pathway

The Light Water Reactor Sustainability (LWRS) Program has added the Flexible Plant Operation and Generation (FPOG) Pathway to its portfolio of research to address new markets for the United States' (U.S.) nuclear reactor fleet. This Pathway is currently applying process modeling and systems optimization tools to evaluate the technical feasibility and economic benefits of dynamically sending a portion of a nuclear power plant's electricity and thermal energy to nearby industries producing non-electrical products. Flexible operations can maximize the plant's revenue by providing reserve, load-balancing capacity to the grid when the localized marginal price for selling electricity is relatively high. On a holistic level, flexible nuclear power plant operations can help stabilize the grid in regions where the percentage of non-dispatchable, variable solar and wind power generation is becoming significant.

The U.S. transportation sector and manufacturing industries currently expend over 70% of the total energy used by the nation. This amount of energy includes one-fourth of retail electricity provided by the electrical grid. Flexible nuclear plant operations will help sustain U.S. industries and the transportation sector by providing low-cost, low-emissions energy to industries for decades. Several LWR connections to large U.S. industries are shown in Figure 11, where a nuclear power plant is the primary source of energy for producing fuels, ammonia, steel, polymer, and hydrogen. Hydrogen is a key energy currency and can effectively incorporate nuclear energy into existing or new U.S. industries.

Each of the processes featured in Figure 11 is reaching a high technology commercialization readiness level and is benefiting from the interests of technology developers, industrial gas supply companies, and industry associations. For example, manufacturers of heavy-duty trucks, passenger vehicles, and forklifts, have started building hydrogen fuel cell-powered drive systems. Over the past decade, dozens of ethanol plants and biodigesters have been established throughout the Midwest. Nuclear plants in this region can increase the yield of biofuels produced by ethanol and biodigesters when their CO_2 by-product is diverted to a process that makes synthetic motor fuels. These synthetic fuels would be compatible with existing gasoline and diesel fuel supply systems. As domestic and global demand for steel continues to rise, nuclear power plants can provide electricity and hydrogen to produce direct-reduced iron briquettes and to operate electric arc furnaces. With nuclear power, steel making emissions can be reduced 95% as compared to traditional integrated blast-furnace and open-hearth steel plants.

Table 3. Plausible FPOG Market for LWRs.

New Market	Market Size by Indicated Applications	Number of LWRs (nominally 1,000 MWe)
Heavy-Duty Fuel-Cell Trucks	500,000 trucks 10% of U.S. Fleet	8-11
Synthetic Fuels	280,000 barrel/day 2.5% of Market	15-18
Fertilizer-Grade Ammonia	10,000 tonnes/day 25% of U.S. market	2-3
Finished Steel Production	10 Mtonnes/yr (direct reduced iron) 30 Mtonnes/yr (new electric arc furnaces) 10% of market	7-9
Combustion of Hydrogen with Gas	0.1 Quad BTU hydrogen 1% of the total use for power generation	3-4
Ethylene	4 Mtonnes/yr 10% of U.S. market	2-3

The FPOG Pathway plans to address the business case for each of these options, based on the location of individual plants, the surrounding industries, and new market opportunities. FPOG research activities will also help LWR owners prepare their plants for flexible plant operation, that is, alternating between electricity and non-electric product generation, by developing, testing, and implementing the crucial interfaces that will couple LWR plants with the industrial processes. The number of LWRs that could be committed to these new process concepts is summarized in Table 3.

Figure 11. Products made with nuclear energy as a primary input.