



Powering ethanol with steam from nuclear plants

Steam produced at nuclear reactors has the potential to provide a low-cost power alternative to ethanol facilities.

Ethanol plants require large amounts of low-pressure steam at several points in the production process. Natural gas, which has seen wide price swings in the last several years, is currently the dominant thermal source for ethanol production in the U.S. Steam from nuclear power plants is cheaper and doesn't experience the same volatile price fluctuations.

VOLATILE PRICES

Production of 1 billion gallons of ethanol per year requires about 1,000 megawatts (1 billion watts) of steam while a single 100-million-gallon ethanol plant needs 100 megawatts of low pressure steam. Within several decades, the steam demand for ethanol plants in the U.S. is projected to be tens of gigawatts (one gigawatt equals 1 billion watts), with the worldwide demand being several times larger.

During the ethanol production process, distillation columns use low-pressure steam to separate ethanol from fermentation mash. Additionally, steam is one-half of the non-solar energy input in growing maize (corn) and converting it to ethanol.

Compared to natural gas, steam from nuclear facilities is cheaper and doesn't experience volatile price fluctuations by Samuel Rosenbloom

Ethanol producers currently have no control over their energy cost structure because the price of natural gas has increased with highly variable and unpredictable prices.

The use of natural gas to produce ethanol is expected to grow from more than 400 million cubic feet per day in 2006 to a range of 700 million to 1 billion cubic feet per day by 2012. More than 90% of current and proposed ethanol capacity uses natural gas as a thermal source for the production of ethanol.

NUCLEAR STEAM

At a nuclear power plant, nuclear fission provides heat which is used to produce steam. The steam turns the turbines

(Above) Steam from nuclear reactors could provide a low-cost power alternative to ethanol facilities. Photo courtesy of Nuclear Energy Institute.

to produce electricity. When steam is used offsite, a separate intermediate loop system provides the steam. The steam is not radioactive; the molecules of the steam are not the same as the molecules in the reactor.

Steam is not historically sold in the U.S. because there has been no demand near nuclear power plants. However, ethanol production has changed the equation, because there is now a large steam demand in the same rural locations as many nuclear power plants. Eighty nuclear reactors worldwide have sold steam for uses other than electricity generation. This has included selling steam for district heat and to industrial users.

Now, there is almost enough thermal demand from rural-sited ethanol plants to equal the size of a small nuclear reactor.

Nuclear plants have the lowest electricity production costs compared to coal, gas and oil. The production cost is constant in part because the main driver is the initial capital costs, which in most cases has been determined decades prior in the 1970s and 1980s. Electricity production costs from coal and natural gas is more dependent on the daily price of these fuel sources. In comparison, commercial reactors may operate continuously for a year and a half before partially refueling, and future designs may only need to refuel every four to five years. Many plant operators purchased the fuel for the reactor's entire lifespan when the facility first opened so the cost of operation and production are set.

Existing nuclear power plants can provide low-cost steam to ethanol plants at one-half the price of natural gas. The recent average market price for wholesale electricity in the state of Minnesota is \$53.89 per megawatt hour (MWhr) of electricity. It takes a finite amount of steam to generate the electricity. In a sense, the nuclear plant actually sells steam but first converts it into electricity so it can be distributed and utilized. Based on the efficiency of the turbine generator, the price of the steam can be derived at \$3.13 MMBTU, based on \$53 MWhr.

REAL ALTERNATIVE

Nuclear power is a real alternative with two options to consider: partnering with an existing operating facility or constructing a new facility optimized for biomass processing.

Partnering with an existing facility has fewer regulatory hurdles and a shorter timeframe to startup. Existing reactors are in the Corn Belt, where many ethanol plants also are located, and on navigable rivers. The reactors have existing transportation infrastructure and such a partnership would be more affordable.

On the downside, there are a limited number of locales and utilities available for partnership. The economics and terms depend on the arrangement with the nuclear plant owner.

The U.S. has 102 nuclear reactors which have 12,000 megawatts of upgraded power allowed by the Nuclear Regulatory Commission. Sometimes, the nuclear plants are not able to use that power because turbine generators can't match the output.

The advantages of building a new facility include fixed and predictable energy cost and state-of-the-art technology. Gov-

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ernment policy is likely to support such an effort and financial assistance also is likely based on current nuclear incentives and past nuclear programs. The facility would be located, sized and integrated to optimize the efficiency and profitability.

On the downside, a new nuclear plant is very expensive, the lead time would be much longer and there are regulatory considerations.

A new reactor, designed by Westinghouse under a U.S. Department of Energy (DOE) program, was built with cogeneration in mind. The reactor can produce 1,000 megawatts (thermal energy) and needs to be refueled every four years. It has a modular construction and is 33.5% efficient. Such a reactor could provide about 135 megawatts of electricity in addition to 600 megawatts of steam (180 degrees C at 150 psi) enough to produce 600 million gallons of ethanol per year.

Using steam from a nuclear reactor for ethanol production has several benefits including reducing greenhouse gas impacts and lessening the dependence on oil. Half the energy input to grow and transport maize and make ethanol is for steam. Nuclear steam cuts greenhouse gas emissions from ethanol production in half. Fossil fuel input into ethanol is 70% of the energy value of ethanol. Nuclear steam cuts fossil fuel inputs in half.

Steam from nuclear plants also could be beneficial to cellulose-to-ethanol plants. The liquid fuel produced per unit of biomass can be substantially increased if the ethanol plants also have the availability of even higher pressure and temperature steam. Most hydrolysis pretreatments utilize rapid heating at higher temperatures to increase the susceptibility of cellulose and lignocellulose material to acid and/or enzymatic hydrolysis and conversion to ethanol.

Lignin is the non-sugar based component in cellulosic biomass that cannot be converted into ethanol. It is planned to use this lignin as boiler fuel in cellulose ethanol plants. Next generation nuclear reactors would offer even higher temperatures enabling pyrolysis or gasification of lignin. High temperature

gas cooled reactors (HTGRs) operate at around 900 degrees C (1,650 degrees F). The U.S. DOE is currently planning on building such a reactor at its Idaho nuclear laboratory.

In several decades, this could become the largest market for cogeneration of steam from nuclear-electric power plants.



The views in this article are of the author and not necessarily those of the U.S. Department of Energy. Samuel Rosenbloom is with the U.S. Department of Energy in Washington, D.C., U.S. He can be reached at 1.301.903.5749 or samuel.rosenbloom@eh.doe.gov.

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