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The daily double – Betting on desalination and ethanol

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1. Introduction

It is frequently stated that California is the sixth largest economy in the world. That is, if considered an independent country it would be, from an economic perspective, the sixth largest country. However, individual countries have issues other than the size of their economies. Individual countries must ensure the safety and welfare of their citizens, establish a stable currency, provide a defense against potential aggressors, etc. In this modern age, reliable public utilities, e.g. electricity and water are the hallmark of an advanced country. Those of us who live in areas with plentiful water supplies take this for granted. But it would not be particularly wise for an independent country to rely too heavily on external sources of water because in times of turmoil an external source could be cut off. From the perspective of being able to independently supply its citizens with sufficient water, one wonders how California would rank in the family of independent countries. It is tempting to say something clever about the conundrum the almighty created when he distributed the world's natural resources, but it should suffice to say simply that some geographical areas just do not have it all.

Many industries require fresh water and the lack of this basic commodity is therefore an impediment to economic growth. Compounding the problem is that finding sufficient supplies of inexpensive, nongreenhouse gas emitting, environmentally friendly sources of energy is a vexing issue. It is vexing because energy is what makes generation of fresh water possible. Typically, in a reverse osmosis desalination plant, electricity accounts for about 44% of the production costs. While renewable energies such as wind and photovoltaic are growing, it makes eminent sense to use them to displace less friendly sources of electricity presently being delivered to consumers.

One industry of great interest to Californians, but impeded by the lack of available water is ethanol production for motor fuel. It seems there is no way around the fact that ethanol production requires large amounts of fresh water. For each gallon of ethanol produced, multiple gallons of fresh water are consumed at an ethanol production plant. Ethanol production also requires large amounts of energy. In fact, the energy consumption required for ethanol production is the source of much of the debate around ''ethanol.'' Ethanol use displaces fossil fuels but it takes a lot of fossil fuel to make ethanol. State of the art ethanol plants burn about 30,000 British Thermal Units (BTUs) of natural gas and use about 1 kWhr of electricity to produce each gallon. Additionally, it takes 10,000–15,000 BTUs of natural gas to make the fertilizer that is used to grow the corn for each gallon. Although we are moving away from corn toward cellulose, we are presented with another mystery of nature…using cellulose to make ethanol has its own special energy requirements.

Ethanol and fresh water are two liquids that Californians would like to have billions of gallons more of. However, simply maintaining the status quo is challenging due to the unpredictability of drought and the increasing urban and agricultural demand for both water and imported oil.

Nuclear energy is usually not associated with both ethanol production and desalination. However, nuclear cogeneration is very well suited for both of these. Newer nuclear reactors have been designed to be safer and to provide industrial process energy. The process energy can be utilized for desalination, ethanol

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production or a combination of both. Nuclear power plants produce high pressure steam to run the turbine-generators for electricity production. Higher pressure and temperature implies higher efficiency in converting steam energy to electricity. As the steam moves through the turbine, its pressure drops and upon exiting the turbine the now lower pressure steam is piped into a low-pressure turbine and this continues until the pressure is too low to make use of. Low-pressure steam is also low value steam because the efficiency of converting its energy to electricity is low. Low-pressure steam is used in low-pressure, low-efficiency turbines because there are no other alternatives…the nuclear reactor owner has only one business namely the production of wholesale electricity. In a nutshell, the essence of cogeneration is that this low value steam still has relatively high temperature (approximately 300 °F) and can be used in place of the steam normally used for distillation in an ethanol plant created by burning high value natural gas. For distillation the pressure requirements are very modest. Only enough motive energy is required to move the steam through the plant and return it as condensate to the steam generator. Even poorer steam, with temperature lower than used for production of ethanol, is used for water desalination through several processes, such as the multi-effect distillation (MED). Its coupling to nuclear reactors has been proven and nuclear powered MED processes have operated successfully [1,2].

2. Near term

One of the new reactor types identified by the U.S. DOE for possible near term deployment is the integral pressurized reactor system (IPRS). An example of an IPRS is the International Reactor Innovative and Secure (IRIS) an advanced, modular reactor design with enhanced safety and economics. The IRIS is especially well suited for producing both electricity and fresh water [3].

The IRIS project was initiated in 1999 as part of the U.S. DOE Nuclear Energy Research Initiative (NERI). The project is led by Westinghouse Electric Company, and was formed from the outset as an international collaboration of industry, national laboratory, and university partners. Currently, there are 18 organizations from nine countries participating in the IRIS project. As a result of the combined talent and resources of the participants, the IRIS design has progressed rapidly, and the project team initiated in October 2002 a pre-application licensing review with the U.S. Nuclear Regulatory Commission. The IRIS design is based on proven light-water reactor technology, but includes several innovative engineering features that enhance its safety and economics relative to other advanced systems [3]. The total thermal power of IRIS is 1000 megawatt (MW), and with an expected energy conversion of 33.5%, a single IRIS module is capable of producing 335 MW of electrical output (MWe). For producing ethanol one needs electrical energy, low-pressure steam and water. IRIS can produce all three. Using a MED desalination process, 1 MWe of electrical energy produces approximately 2500 m^3/day of fresh water. A rough example of how IRIS might be used is to allocate 400 MW of power to desalination and 600 MW to ethanol production. This would correspond to a production of 90 million gallons of fresh water per day (MGD) and 600 million gallons of ethanol per year (MGY). These quantities illustrate the magnitude of the potential. As a practical matter 600 MGY far exceeds the size of any existing ethanol plant. However, even the production of 600 MGY of ethanol would only require a fraction of the fresh water production; perhaps less than a tenth. Therefore, the majority of the fresh water production would be available for other uses, to serve the public good. As Pope Benedict XVI observed ''Access to water is in fact one of the inalienable rights of every human being, because it is a prerequisite for the realization of the majority of the other human rights, such as the rights to life, to food and to health [4]''. Based on demand, less ethanol or fresh water or more electricity could be produced in whatever proportions are needed, within the design constraints of the plant. Nuclear desalination is a practical and emission-free solution for near term deployment. The cost of nuclear desalination is very competitive, less than \$1.00/m^3. An ethanol plant relying entirely on desalinated water would have a production cost increase of only about \$.02/gallon [5,6].

One of the problems with nuclear cogeneration is that nuclear regulators require that nuclear reactors are built away from populated centers and a restricted population zone to be established outside the plant where evacuation is mandatory in the case of a nuclear accident. While electricity can be easily transmitted, co-generation products are impractical or expensive, or simply impossible (e.g. steam for district heating) to be transferred over long distances. IRIS is designed with such superior safety that it could be licensed with significantly less stringent requirements such that the evacuation zone could be even confined to the plant boundaries.Thus, IRIS is uniquely suited for cogeneration since it can be located in populated areas where the cogeneration products are needed.

3. Ethanol cogeneration

Using steam from a nuclear reactor for ethanol production has several benefits including reducing

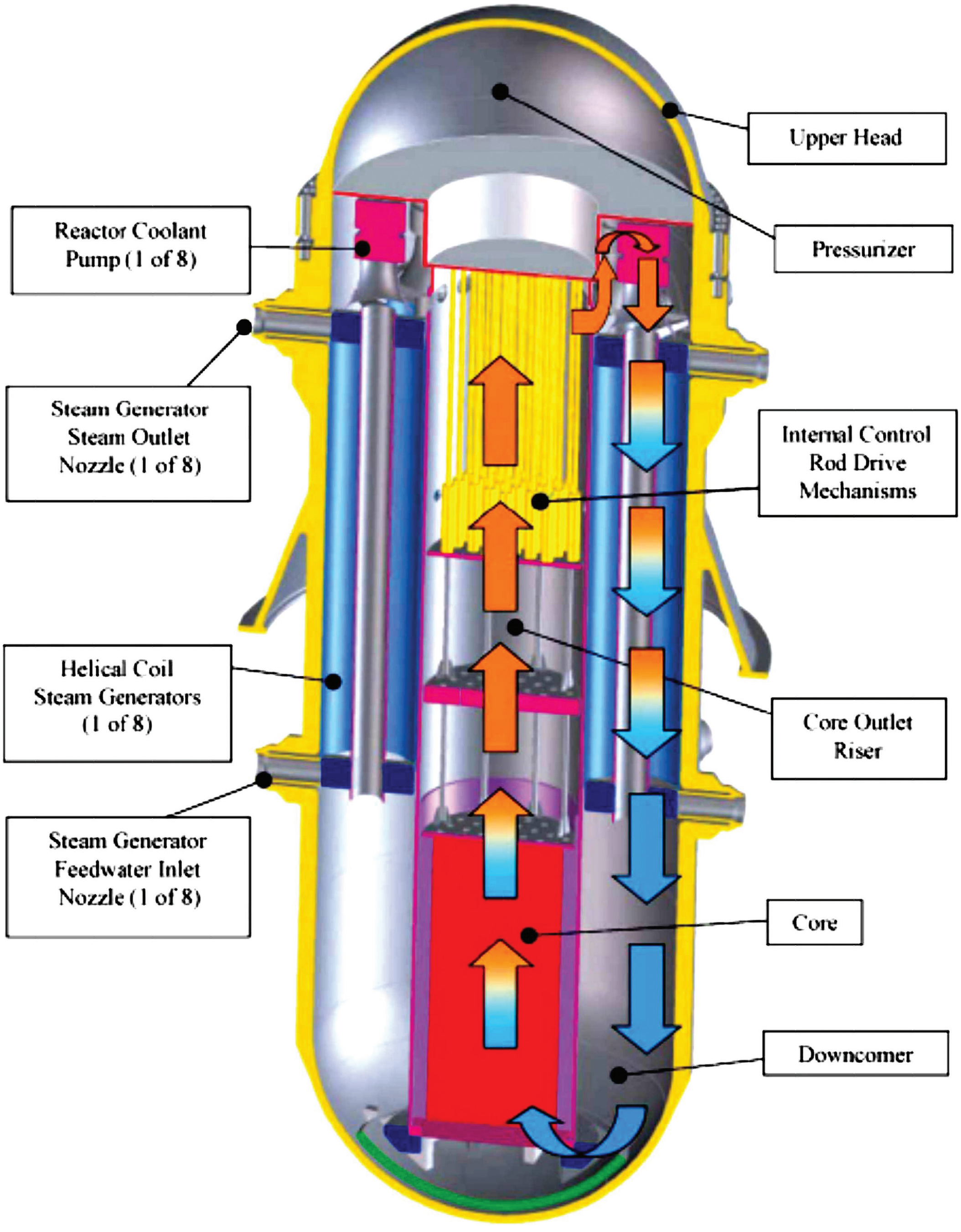

Fig. 1. Model of IRIS reactor vessel and primary coolant system [3].

greenhouse gas impacts and lessening the dependence on oil. Half the energy input to grow and transport corn and make ethanol is for steam generation to distill ethanol at the production plant [7,8]. Nuclear steam cuts greenhouse gas emissions from ethanol production in half [7,8]. 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 and it represents between 20% and 30% of biomass. It is planned to use this lignin as boiler fuel in cellulose ethanol plants. Lignin is potentially valuable, as it is the only source of renewable aromatic chemicals. There are many uses and potential uses of lignin including converting it to an additive for gasoline. Next generation nuclear reactors would offer even higher temperatures enabling pyrolysis or gasification of lignin.

4. Desalination

Of the more than 12,000 desalination plants in operation, only about 10 use heat or electricity provided by nuclear power plants, primarily in Japan and Russia [9]. Fossil energy sources are the dominant choice. However, there is an increasing concern regarding the environmental impact of burning fossil fuels due to the resulting ''greenhouse gases''. These environmental concerns, coupled with concerns over energy supply security and an anticipated growth in energy demands, are driving a growing interest in the development and expansion of the nuclear energy options. Nuclear energy offers a clean and abundant energy supply [3] (Fig. 1).

The coming decades will almost certainly see an expansion in the use of nuclear energy world-wide. This will be driven by the need for increased electricity and also for the desalination of seawater to meet the increasing need for fresh water supplies. For many countries, especially those that have little or no nuclear infrastructure, small modular plants offer the best solution for providing additional power in appropriate increments, and also for matching power and water needs to non-uniform population distributions. The IRIS reactor design is especially well suited for this application. Preliminary studies have shown that combining IRIS with a desalination plant provides attractive economics for both the electricity and fresh water produced by the plants. Investigation of ethanol production via IRIS has just been initiated [10,11].

Nobody can deny that Californians are very technologically advanced, from Silicon Valley to biotechnology. Therefore, moving towards the future, Californians shouldn't deny themselves advanced and safer nuclear technology. Californians should be proud that they implemented a moratorium that checked society's costs of nuclear power. It is time though that advanced and safer technology is used to bridge the present with the future, enabling economic growth in harmony with the environment. Californians should see the lifting of the nuclear moratorium as important leverage to ensure that future technology has an acceptable fuel cycle and that nuclear energy is used for the things Californians really need and want. . .sufficient water, economic growth and a reduced dependence on fossil fuels. With proper planning and with the use of safe technology California should become the fifth largest economy in the world.

Disclaimer

The views and opinions expressed herein are those of the authors and not necessarily those of the U.S. Dept of Energy or Westinghouse.

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