the ENERGY lab

ANALYSIS FACTS

Life Cycle Analysis

Role of Alternative Energy Sources

Nuclear Technology Assessment

Project Description

This analysis evaluates the role of nuclear power in the future energy portfolio of the United States. Nuclear power is evaluated with respect to resource base, growth, environmental profile, costs, barriers, risks, and expert opinions.

Resource Base and Growth

Nuclear power plays an important role in the electricity mix of the United States, with 104 reactors providing 20.2 percent of electricity generation (EIA, 2010). Nuclear power plants provide critical baseload power, and steadily increasing net generation, despite a static number of power plants. Historically, this has allowed nuclear power to maintain a relatively steady 20 percent of net generation, despite increasing annual demand for power, and no new power plant construction (EIA, 2010).

The U.S. resource base of nuclear power includes domestic and imported sources of uranium. The U.S. consumes 16,500 tonnes of uranium per year (IEA/NEA, 2010). With domestic resources of 207,000 tonnes of uranium, current consumption rates will deplete the domestic supply within 12 years, if imports are excluded. Fortunately, the majority of the global supply of uranium is politically stable, so the U.S. can continue to rely on imported uranium. Based on the current world demand and known recoverable reserves, there are approximately 80 years of virgin supply at a recoverable cost of less than $130/kg U. The supply outlook for uranium is not a key driver in the stability of the nuclear supply chain. If the price of uranium increases by 100 percent, the corresponding increase in the cost of nuclear power would be approximately 10 percent.

The growth of nuclear power in the U.S. depends on how many existing nuclear power plants will undergo license renewals, how many are commissioned, and how many are decommissioned. Expert projections range from 110 to 180 GW in 2035 based on a 2010 capacity of approximately 101 GW (EIA, 2011; IAEA, 2010; WNA, 2010).

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Environmental Profile

NETL conducted a cradle-to-grave life cycle analysis (LCA) of nuclear power. The boundaries of this LCA begin with the acquisition of uranium and other raw materials and end with power plant decommissioning and spent fuel management. A key conclusion of this LCA is that the construction of a centrifuge enrichment facility in the U.S. would be more effective than spent-fuel reprocessing at reducing the life cycle greenhouse gas emissions of nuclear power.

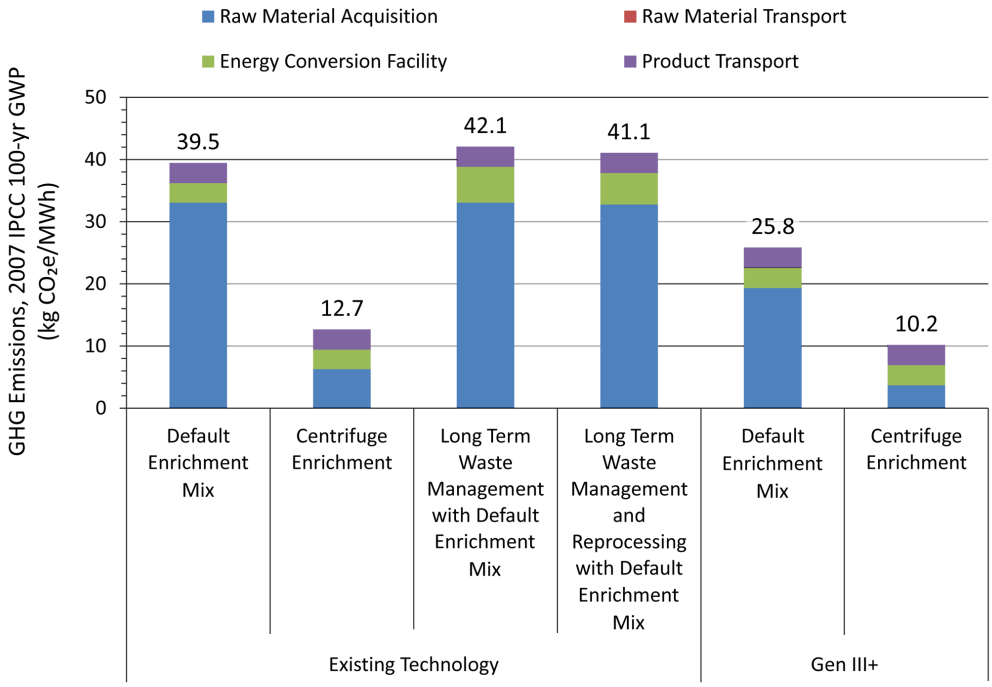
The life cycle greenhouse gas emissions for nuclear power from existing and Gen III+ plants for the default uranium enrichment mix (52 percent gaseous diffusion and 48 percent centrifuge) are 39.5 and 25.8 kg CO_2e/MWh generated and delivered to the end user, respectively. These results do not include long term waste management or reprocessing. The Gen III+ life cycle has lower greenhouse gas emissions than the existing plants due to higher uranium dioxide (UO_2) burnup rates of Gen III+ reactors and higher thermal efficiency.

The addition of long-term waste (which includes low-level waste (LLW) and high-level waste (HLW)) disposition to the existing nuclear power case increases the GHG results of nuclear power by 6.6 percent (42.1 compared to 39.5 kg CO_2e/MWh). The addition of fuel reprocessing to the nuclear fuel cycle reduces the consumption of uranium. However, this reduction only reduces the burdens contributed by uranium mining and milling. Reprocessed uranium requires re-enrichment in order to increase its U-235 concentration to a level appropriate for light water reactor (LWR) operation When the entire LC is considered, reprocessing of nuclear fuel increases the GHG results by 4.1 percent (41.1 compared to 39.5 kg CO_2e/MWh).

Costs

To validate and improve the accuracy of the cost parameter inputs specific to the nuclear life cycle cost (LCC) results, a survey was sent to a cross section of nuclear experts from academia, government laboratories, industry, and trade associations requesting input on the nuclear specific cost parameters. Based on that input, the cost profile of Gen III+ power was based on a discounted cash flow analysis that calculated an expected COE of $85.9/MWh (2007 dollars). This result is based on a capital cost of $4,267/kW, a capacity factor of 90.6 percent, and a seven percent loss of electricity during transmission and delivery.

Nuclear power is capital intensive and the breakdown of the expected COE indicates that the capital portion accounts for 81 percent. The remaining cost components compose the remaining 19 percent of the $85.9/MWh, with 11 percent coming from fixed O&M, 1 percent from variable O&M, and 7 percent from fuel costs. The COE ranges from $42.8 to $186.2/MWh across the range of financial and operations parameters.



Barriers

1. Current U.S. nuclear policy has not resolved the long-term uncertainties for spent fuel disposition and reprocessing. In 2008, the U.S. Department of Energy (DOE) submitted the license application to the U.S. Nuclear Regulatory Commission (NRC) for authorization to construct the repository at Yucca Mountain (NRC, 2012). In October 2010, the NRC began closure of its Yucca Mountain activities, and in 2011 suspended the licensing proceeding (NRC, 2011b).

2. In early 2010, President Obama directed the Secretary of Energy to form a Blue Ribbon Commission (BRC) on America's Nuclear Future. The BRC final report released in January 2012 included an estimate, prepared by EPRI, of current and projected amounts of spent nuclear fuel from commercial nuclear power plants. The EPRI estimate was 65,000 metric tons uranium (MTU) in 2010, increasing to 133,000 MTU by 2050 (BRC, 2012).

Risks

The perception of nuclear power is anchored in three nuclear events: the 1979 Three Mile Island event, the 1986 Chernobyl event, and the 2011 Fukushima event. A comparison of the U.S. and Japanese nuclear programs shows that the U.S. has implemented safety systems that have not yet been implemented in Japan. The risks of implementation include various impacts that are unique to nuclear power, including potential engineering failures, releases of radioactive material, and vulnerability to terrorist attacks. The levels of radiation from steady-state nuclear power are the same magnitude as radiation from natural sources and are hundreds of times lower than the exposure threshold for cancer risks (NRC, 2011a).

Expert Opinions

The World Nuclear Association (WNA) has seen interest in small modular reactors (SMRs) grow substantially in the U.S. and around the world as small and large utilities anticipate the need to replace and augment existing electricity generation assets (WNA, 2011). The U.S. DOE has acknowledged the potential for SMRs to replace aging coal facilities (DOE, 2011).

According to nuclear industry analysts at Standard & Poor's, the cost of natural gas needs to be higher than $6/MMBtu for new nuclear power generation to be economically favorable (S&P, 2010). Estimated construction costs have been increasing at a rate of 15 percent per year (MIT 2009). These high costs relative to other power production options have halted several projects and resulted in temporary setbacks at proposed nuclear installations.

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