Fact Sheet category identification: **Analysis**
NETL program/product Identification: **Life Cycle Analysis**

Power Generation Technology Comparison from a Life Cycle Perspective

Project Description

This analysis evaluates the roles of natural gas, coal and biomass co-firing, nuclear, wind, hydropower, geothermal, and solar thermal in the energy supply of the U.S. All technologies were evaluated based on the following criteria:

Criteria	Description
Resource Base	Availability and accessibility of natural resources for the production of energy feedstocks
Growth	Current market direction of the energy system. This could mean emerging, mature, increasing, or declining growth scenarios
Environmental Profile	Life cycle (LC) resource consumption (including raw material and water), emissions to air and water, solid waste burdens, and land use
Cost Profile	Capital costs of new infrastructure and equipment, operating and maintenance (O&M) costs, and cost of electricity (COE)
Barriers	Technical barriers that could prevent the successful implementation of a technology
Risks of Implementation	Financial, environmental, regulatory, and/or public perception concerns that are obstacles to implementation. Non-technical barriers
Expert Opinions	Opinions of stakeholders in industry, academia, and government

Resource Base and Growth

Growth in some resources is spurred by introduction of new technologies, but policy mechanisms are required for the growth of other resources. Projected growth in natural gas production is due to technological advancements that allow for the development of shale gas. Conversely, the growth of coal and biomass co-firing is related to renewable portfolio standards (RPS) and other policies that encourage the use of renewable fuels. When considering the resource base of a particular energy technology, it is important to balance estimates of technically recoverable resources with economically recoverable resources. This is especially critical when evaluating renewable sources. Finally, the proximity of the supply source to the demand centers matters for renewable technologies, but is not as important for conventional technologies where extensive distribution networks already exist (e.g., natural gas pipelines).

Environmental Profile

NETL conducted cradle-to-grave life cycle analyses (LCA) of power from seven resource types. The LCA boundaries begin with acquisition of raw materials and end with grid transport of electricity to the end user. The LCA results include greenhouse gas (GHG) and other air emissions, water use and quality, and energy return on investment (EROI).

Natural gas power has high upstream emissions from the acquisition of natural gas, but high efficiency at the energy conversion facility results in lower GHG emissions than other fossil systems. Co-firing coal with 10 percent hybrid poplar (by energy) does not significantly reduce GHG emissions for pulverized coal power plants.

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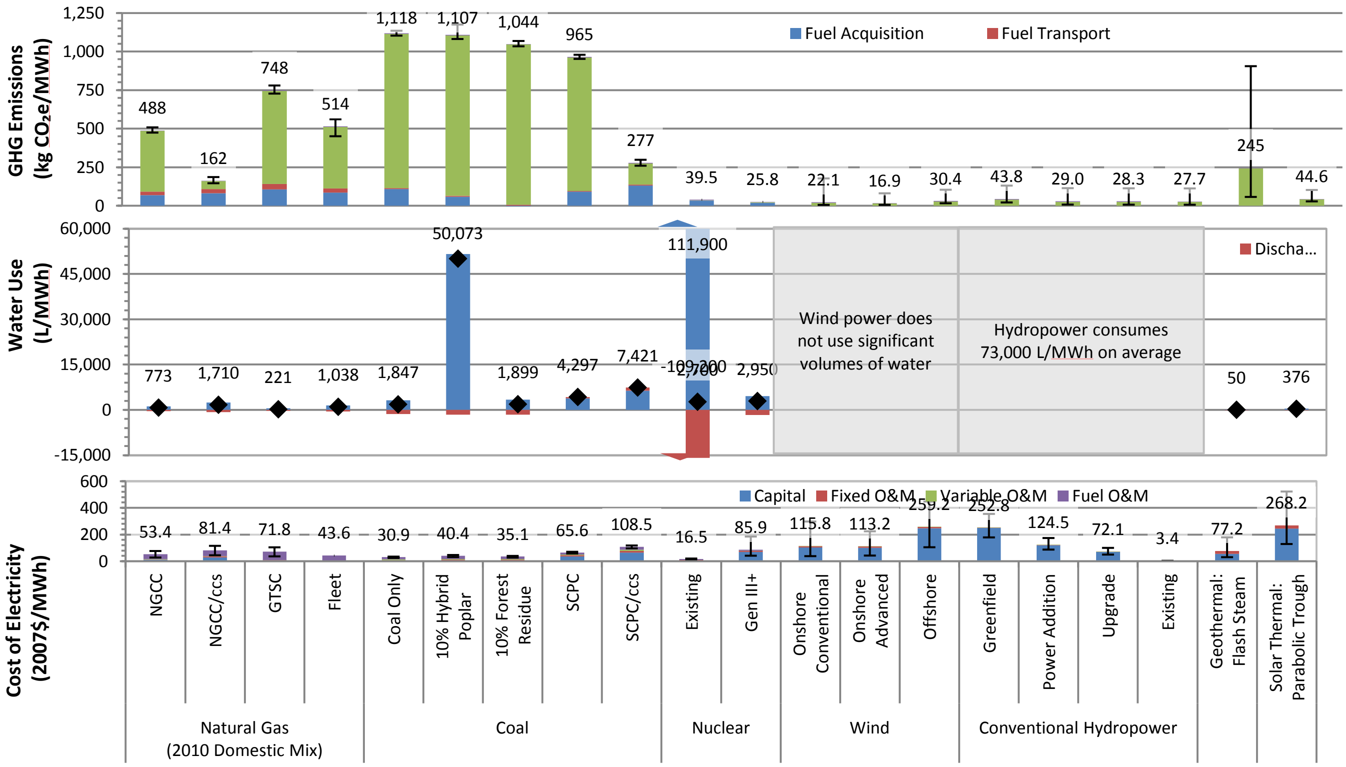

In general, renewable technologies have lower expected GHG emissions, but there is greater uncertainty due to resource variability. The results displayed above show standalone wind power, but it is also important to consider backup power (wind with backup power ranges from 416 to 501 kg CO_2e/MWh).

Costs

A life cycle cost (LCC) analysis was conducted to determine the cost of electricity (COE) per MWh of electricity delivered to the consumer. The COE was calculated based on the same life cycle boundaries as the environmental analysis. It was assumed that the delivered price of fuels to the energy conversion facility accounted for all costs related to the raw material acquisition and transport of those fuels. As indicated by the COE graph above, capital costs are a significant component of the COE for most power systems, except existing systems. Natural gas power has significant capital costs, but fuel costs account for the majority of the COE of natural gas power. The COE of geothermal power is low among the renewable fuels because of its high capacity factor (~90 percent). Ultimately, performance and financing variability are the key drivers of COE uncertainty for renewable options.

Barriers

Limitations in existing infrastructure have the potential to halt future growth of some sources. For example, nuclear power does not have infrastructure for long-term waste disposition and natural gas has limited pipeline capacity in the Northeast U.S. (where production is increasing). For co-firing, hydropower, wind, geothermal, and solar thermal, the resources are not always easily accessible. In some cases, supply chain logistics are the barrier, while in others the resource is too far from an existing grid connection. The final common barrier is cost uncertainty in the form of construction contingencies and learning curves for new technologies.

Risks

Similar to the barriers discussed above, there are risks of implementation that are common across technology categories. One risk, particularly for renewables, is legislative uncertainty regarding incentives for production. For other technologies, such as nuclear, security and safety are the primary risks. The risk of land use change and habitat loss is common across all technologies, but is especially risky for renewable energy.

Expert Opinions

There are technology advancements on the horizon for most energy resources. These technology advancements have the potential to increase efficiency and reliability, while reducing costs. However, experts generally agree that the viability of alternative energy sources strongly depends on future policies regarding production tax credits and the costs of competing technologies.