MAY 2012 TECHNOLOGY

NATURAL GAS IN THE U.S. ELECTRIC POWER SECTOR

CENTER FOR CLIMATE AND ENERGY SOLUTIONS

Discussion Questions

1. **What is the likelihood of future supply disruptions? Weather related? Scheduling related?**
2. **Are there really coal-to -gas or oil-to-gas "conversions" happening or is plant "replacement" more accurate to describe what is happening? Is this economical?**
3. **Are concerns about fuel diversity justified, given that only 27 percent of the fleet is expected to be fueled by natural gas?**
4. **Will competition from other sectors affect power companies' decisions to build new natural gas?**
5. **Companies are making significant investments in pollution mitigation technology for coal plants. Is there a possibility of coal totally going away? In 20 years? In 50 years?**
6. **How do prices and new regulations compare as drivers of decision-making for utilities?**
7. **In what scenarios does carbon capture and storage (CCS) for natural gas plants play a greater role?**
8. **What are the infrastructure challenges with regard to building new natural gas-fired power plants: upgrade natural gas pipeline infrastructure (underground costs) vs building transmission towers (above ground costs, NIMBY)? What is the overall condition of the pipeline infrastructure, and is it ready for large increases in usage from the power sector?**

HIGHLIGHTS

- Electric utilities are showing an overwhelming preference for building new natural gas power plants.
- Distributed or locally generated electricity has lower greenhouse gas (GHG) emissions relative to centralized generation because of avoided transmission losses.
- Significant improvements in power plant thermal efficiencies are feasible by 2030.
- Environmental rules are driving coal plant retirement, providing an opportunity for other forms of baseload generation.

This is a joint project between the Center for Climate and Energy Solutions and the University of Texas's Energy Institute and the Energy Management and Innovation Center

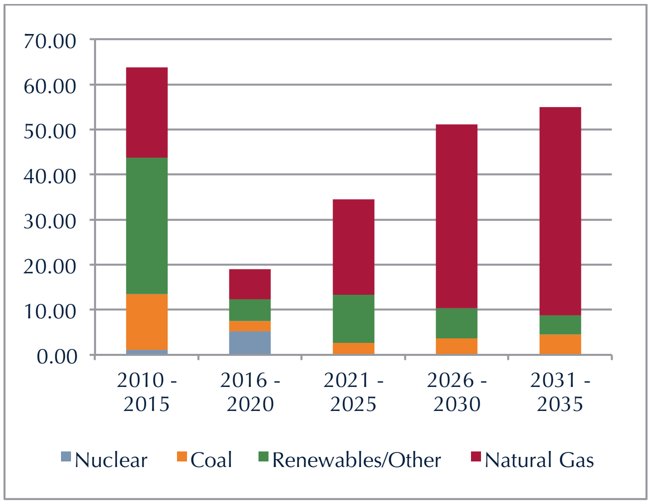
energy institute The University of Texas at Austin

THE UNIVERSITY OF TEXAS AT AUSTIN McCOMBS ENERGY MANAGEMENT AND INNOVATION CENTER

INTRODUCTION

With the increasing likelihood of a carbon-constrained future, cleaner than coal emissions and forecasts of sustained low prices, natural gas has become the fuel of choice for electricity generation by utilities in the United States.[1 2] In 2012, the electric power industry planned to bring 23.5 GW of new capacity on line with 37 percent being natural gas-fired (20 percent wind, 18 percent coal, 12 percent solar, 5 percent nuclear, and 8 percent other sources, including hydro, geothermal and biomass).[3] With growing electricity demand and the planned retirement of 39 GW of existing capacity, 223 GW of new generating capacity (including end-use combined heat and power) will be needed between 2010 and 2035.[4] Natural-gas-fired plants account for 60 percent of capacity additions between 2010 and 2035 in the EIA Annual Energy Outlook 2011 Reference case, compared with 25 percent for renewables, 11 percent for coal-fired plants, and 3 percent for nuclear.[5] Note that Federal tax incentives and state energy programs contribute to renewables competitiveness in the 2010 – 2015 time period.[6] For example, with the Production Tax Credit in place until December 2012, wind generation capacity increases more than 18 GW from 2010 – 2015, and with the Investment Tax Credit in place until December 2016, utility and end-use solar capacity additions are forecast to increase by 6.3 GW (7.5 GW through 2016).[7]

FIGURE 1: Electricity Generation Additions by Fuel Type 2010 – 2035 (GW)



Source: Energy Information Agency, U.S. Department of Energy, 2011 [8]

NATURAL GAS AS A FUEL FOR ELECTRIC POWER

Natural gas can provide baseload, intermediate and peaking electric power. It is a reliable source of power that is capable of supplying firm back-up to intermittent wind and solar.[9] Additionally, natural gas power plants can be constructed relatively quickly, in as little as 20 months.[10] Compared to other forms of electric generation natural gas plants have a small footprint from a land use perspective. However, even though natural gas combustion emits fewer GHGs than coal or oil, it still emits a significant amount of CO_2. It is also important to stress that natural gas-fired electrical plants must be sited near existing natural gas pipelines; otherwise the cost of building this infrastructure must be taken into account.

GREENHOUSE GAS EMISSIONS

The electricity sector contributes about 40 percent of all U.S. carbon dioxide emissions.[11] All other things being equal, a megawatt-hour of natural gas-fired generation contributes around half the amount of CO_2 emissions from coal-fired generation and about 68 percent of the amount of CO_2 emissions from oil-fired generation. Natural gas-fired generation CO_2 emissions levels are still significant, especially when compared to the near-zero emissions of nuclear, hydro, wind, geothermal, and solar power.

TABLE 1: Average Fossil Fuel Power Plant Emission Rates (lbs/MWh)

GENERATION FUEL TYPE	CARBON DIOXIDE	SULFUR DIOXIDE	NITROGEN OXIDES
Coal	2,249	13	6
Natural Gas	1,135	0.1	1.7
Oil	1,672	12	4

Source: U.S. Environmental Protection Agency, 2000[12]

CENTRALIZED POWER GENERATION

Central power stations create large quantities of electricity, which are then transported to end-users via electrical transmission and distribution lines. There are three categories of central power station technologies in which natural gas is a fuel that can be used to generate the electricity. In the order of their historical development, they are: steam turbines, combustion turbines (CT) and combined cycle (CC) power plants. Each plant type has an associated average thermal efficiency. Thermal efficiency measures how well a technology converts the fuel input energy (heat) into electrical energy (power). A higher thermal efficiency, other things being equal, indicates that less fuel is required to generate the same amount of electricity, resulting in fewer emissions. Steam turbines have the lowest efficiency at around 33 - 35 percent. Combustion turbines are around 35 - 40 percent efficient and combined cycle plants have thermal efficiencies in the range of 50 - 60 percent. For more information about these three technologies see Appendix A.

DISTRIBUTED GENERATION (DG)

With distributed generation systems (also referred to as self-generation), as contrasted to central power station generation described above, smaller quantities of electricity are generated at or near the location where it will be consumed, obviating the need for long electrical transmission lines. The potential benefits include: increased electric system reliability, reduction of peak power requirements, and reduction in vulnerability to terrorism.[13] However, from a greenhouse gas (GHG) perspective, the primary advantage of distributed generation is that there are fewer losses in the transmission of the electric power, both in the bulk transmission system and in the local electrical distribution networks.[14] Lowering line losses means less electricity generation (less fuel and fewer emissions) is required to serve the same electrical demand.

In the bulk transmission system (the backbone of the central power station system), line losses depend primarily on the line voltage, line load, weather, altitude and the distance travelled; the higher the line voltage the fewer losses that a line will experience.[15] For example, a 765kV line, the highest voltage currently used in the bulk transmission system, electrical losses are on the order of 0.6 to 1.1 percent for a 1000 MW line load travelling 100 miles in normal weather.[16] A 345kV line under the same conditions would see a loss on the order of 4.2 percent.[17] Since most local distribution companies operate below 35kV[18], higher losses can be expected in the local distribution network.

Examples of DG that would utilize natural gas include microturbines (CT or CC) located on-site for commercial and residential application, and combined heat and power (CHP) for industry. CHP also has additional efficiency benefits beyond those from DG (see companion paper - *Natural Gas in the Industrial Sector*). Higher capital costs are believed to prevent investment in DG technologies and the State of California, among others, provides incentives for self-generation.[19]

FUTURE TECHNOLOGY – SUPPLY SIDE EFFICIENCY

The Electric Power Research Institute (EPRI) asserts that it is technologically and economically feasible to improve the thermal efficiencies of steam turbine technology by 3 percent, increase combustion turbines to 45 percent efficient, and construct combined cycle plants with 70 percent efficiency by 2030.[20] Higher thermal efficiencies translate into less fuel required to generate the same amount of electricity. EPRI's 2009 analysis estimates a potential CO_2 emissions reduction in 2030 of 3.7 percent as a result of increasing the efficiency of new and existing fossil-fueled generation.[21]

POLICY IN PLAY

Arguably, the most significant policy decisions affecting the U.S. electric power sector today are the Cross State Air Pollution Rule (CSAPR), National Emissions Standards for Hazardous Air Pollutants (NESHAP), and proposed New Source Performance Standards (NSPS) issued by the U.S. Environmental Protection Agency (EPA). The installation of pollution control retrofits will be essential to comply with CSAPR and NESHAP, affecting electric generating units, and coal-fired units in particular.[22] PJM, operator of the world's largest wholesale electricity market in the Eastern U.S., predicts that approximately 14 GW of coal-fired generation out of an installed capacity of 78.6 GW of coal-fired generation could be retired by 2015 largely due to EPA rules.[23] Reserve margins, the spare capacity that electricity system or market operators are required to maintain above projected peak loads to ensure system reliability appear sufficient in the short run. However, new, reliable baseload generation will be required in the next ten to twenty years to fill the gap.

Additionally, in late March 2012, the EPA proposed CO_2 pollution standards for the new electric power plants as part of its NSPS program.[24] Under the proposed standard (1,000 pounds of CO_2 per MWh), all new power plants would need to match the CO_2 emissions performance currently achieved by highly efficient natural gas combined cycle (NGCC) power plants.[25] New coal-fired power plants could meet the standard by capturing and permanently sequestering their GHG emissions using carbon capture and storage (CCS) technologies.[26] If adopted, this standard would favor new natural gas-fired generation in the future.

In the past few years, there has been interest in a Federal level Renewable Portfolio Standard (RPS). Most recently, there has been some interest in a broader Federal Clean Energy Standard (CES). A CES is a policy requiring that a certain portion of electricity sold by an electric utility come from "clean energy" sources.[27] Whereas an RPS typically credits only 100 percent renewable generation like wind turbines, solar, geothermal or new hydro, a CES creates a mechanism to credit "cleaner" electricity generation, that is, generation that creates less CO_2. Therefore, new and incremental (upgrades and improvements to) natural gas-fired generation, along with natural gas with carbon capture and storage (CCS), among other cleaner forms of electricity production would be eligible to receive clean energy credits.[28]

NATURAL GAS IN THE ELECTRICITY MARKET

In 1978, in response to supply shortages (the result of government price controls), Congress enacted the Power Plant and Industrial Fuel Use Act (FUA).[29] The law prohibited the use of oil and natural gas in new industrial boilers and new electric power plants. The goal was to preserve "scarce" supplies for residential customers.[30] During the early 1980s, the demand for natural gas declined substantially, which contributed to a significant oversupply of gas for much of the decade.[31] Falling natural gas demand and prices finally spurred the repeal in 1987 of sections of the FUA that restricted the use of natural gas by industrial users and electric utilities.[32] Low natural gas prices in the 1990s stimulated the rapid construction of gas-fired power plants.[33] Since 1990, natural gas has been gaining market share with electricity generation from this source increasing from around 11 percent to 23 percent of the total net generation in 2010, as illustrated in Figure 2.[34]

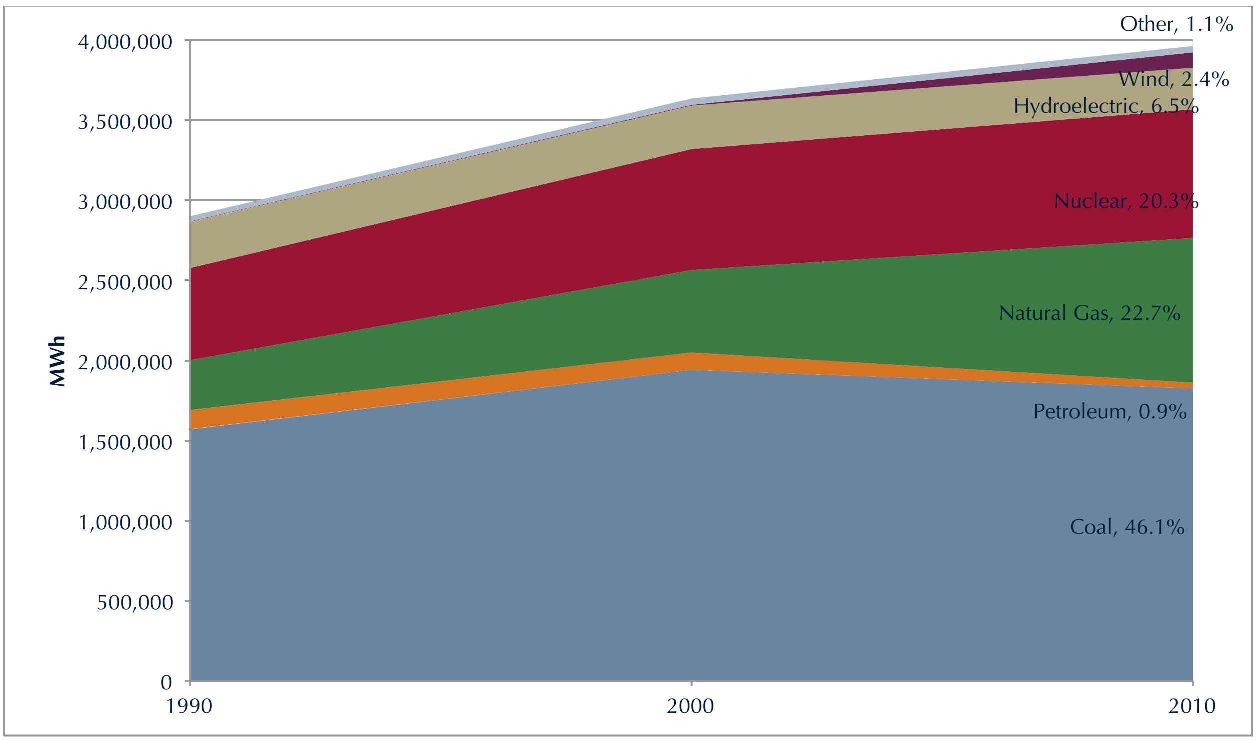
As a result of increased natural gas-fired electricity generation displacing fuel oil and coal-fired generation, total GHG emissions from the electricity sector have decreased since 2000, as shown in Figure 3, while net electricity generation has increased around 9 percent over the same period.[35]

According to the latest Energy Information Administration (EIA) Annual Energy Outlook (AEO), natural gas-fired generation is expected to be just over 25 percent of the total generation mix in 2020, rising to 27 percent in 2035.[36]

Fuel diversity is an important consideration for utilities looking to reduce their reliance on any particular energy source.[37] The trend away from coal toward greater reliance on natural gas creates a potential fuel diversity risk, especially considering the volatile price history of natural gas. Coal will continue to be a significant source of electricity in some regions and for some utilities, but other utilities look increasingly likely to be getting nearly all of their baseload generation from only two sources: natural gas and nuclear power.[38]

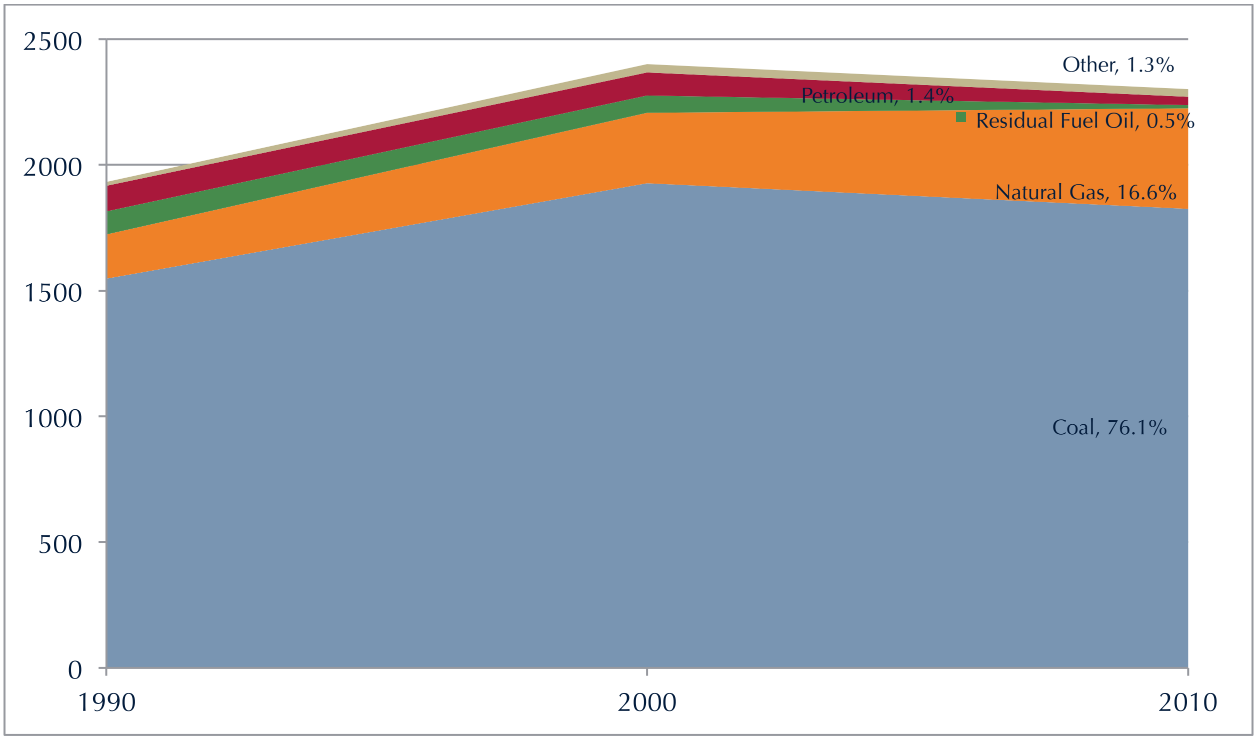
Levelized cost (Figure 4) represents the present value of the total cost of building and operating a generating plant over an assumed financial life and duty cycle, converted to equal annual payments and expressed in terms of real dollars to remove the impact of inflation.[39] It reflects overnight capital cost, fuel cost, fixed and variable O&M cost, financing costs, and an assumed utilization rate for each plant type. The availability of various incentives including state or federal tax credits can also impact the calculation of levelized cost.[40] The values shown in the figure below do not incorporate any such incentives.[41] Natural gas-fired combined-cycle generation technologies are projected to be the least expensive options in the coming years. Utilities looking at their bottom lines and public utility commissions looking for low-cost investment decisions will favor the construction of natural gas-fired technologies, leading to a greater reliance on natural gas in the coming years.

FIGURE 2: Electricity Net Generation: Electric Power Sector (GWh)



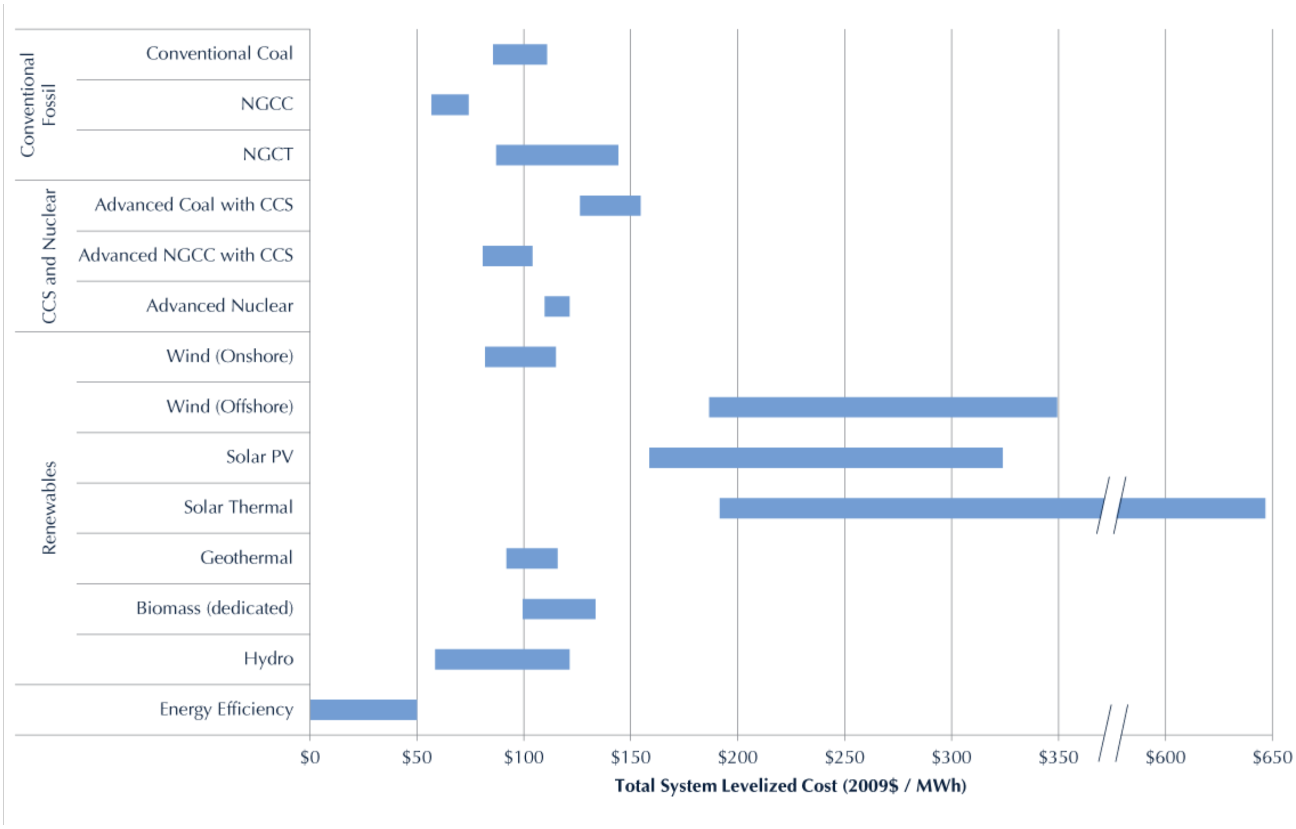
Source: Energy Information Agency, U.S. Department of Energy, 2011[42]

FIGURE 3: Emissions: Electric Power Sector (MMT CO_2)



Source: Energy Information Agency, U.S. Department of Energy, 2011[43]

FIGURE 4: Estimated Levelized Cost of New Generation Resource, 2016[44]



Source: Energy Information Agency, U.S. Department of Energy, 2011[45]

NATURAL GAS WITH CARBON CAPTURE AND STORAGE

In a carbon-constrained future, and with natural gas potentially playing a much greater role in the future of the total generation mix, it makes sense to consider a natural gas plant with carbon capture and storage (CCS) capability. CCS projects have already been initiated and several projects are planned in the next several years to demonstrate the feasibility of the CCS technology.[46] To date, these projects have been undertaken almost exclusively in conjunction with coal-fired power plants or industrial sources.[47] However, one international project in Norway, set to begin in 2012, endeavors to capture CO_2 from a natural gas combined heat and power (CHP) plant (similar to a combined cycle plant) and sequester the CO_2 in an underground saline formation.[48]

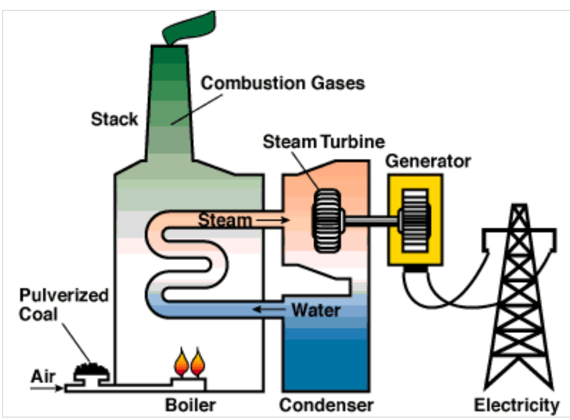
In addition to sequestering CO_2 in saline formations, CO_2 is currently being injected into oil wells as part of tertiary, or enhanced, oil production (CO_2-EOR).[49] This storage option has the added benefit of providing an economic incentive, that is, compensation from the oil-field operator to the captured CO_2 provider. In 2011, the National Enhanced Oil Recovery Initiative (NEORI) was formed to help realize CO_2-EOR's full potential as a national energy security, economic, and environmental strategy.[50] In addition, NEORI suggests federal- and state-level action to support CO_2-EOR.[51]

APPENDIX A: POWER PLANT TECHNOLOGIES

STEAM TURBINES

The principle for generating electricity with steam turbines is depicted in Figure 1. A station uses coal (or oil, natural gas, wood waste, nuclear fission, etc.) as a fuel to heat water in a boiler that creates steam. The high temperature, high pressure steam is piped toward turbine blades that rotate a turbine shaft, which spins a generator, where magnets within wire coils produce electricity.[52] Steam units have a relatively low efficiency. Approximately 33 - 35 percent of the thermal energy used to generate the steam is converted into electrical energy. Large coal and nuclear steam units on the order of 500 – 1000 MW or greater are typically used to provide baseload generation, meaning that they supply low-cost electricity nearly continuously.

FIGURE A1: Steam Turbine

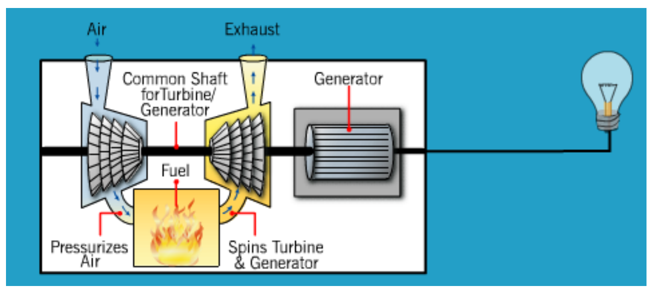


Source: ONCOR, 2012[53]

COMBUSTION TURBINES

Combustion turbines are another widespread central power generation technology. In a combustion turbine, compressed air is ignited by burning fuel (diesel, natural gas, propane, kerosene, biogas, etc) in a combustion chamber. The resulting high temperature, high velocity gas flow is directed at turbine blades that spin a turbine, which drives the air compressor and the electric power generator. Combustion turbine plants are typically operated to meet peak load demand, as they are able to be switched on relatively quickly. Another advantage is that they can provide a firm backup to intermittent wind and solar on the power grid if needed. The typical size is 100 – 400 MW and their thermal efficiency is slightly higher than steam turbines at around 35 – 40 percent.

FIGURE A2: Combustion Turbine

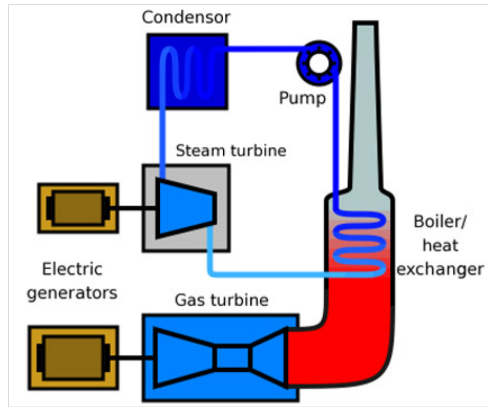


Source: Duke Energy, 2012[54]

COMBINED CYCLE

A basic combined cycle power plant combines a gas turbine and a steam unit all in one, although there are other possible configurations. As combustion turbines became more advanced in the 1950s, they began to operate at ever high temperatures, which created a significant amount of exhaust heat.[55] In a combined cycle power plant, this waste heat is captured and used to boil water for a steam turbine generator, thereby creating additional generation capacity. Combined cycle plants have thermal efficiencies in the range of 50 – 60 percent. Historically, they have been used as intermediate power plants, generally supporting higher daytime loads. However, newer plants are providing baseload support. The newest GE natural gas combined cycle power plant is advertised as a 510 MW unit with a baseload efficiency of more than 61 percent.[56] It has reduced fuel-burn of 6.4Mm^3 natural gas per year, and a smaller carbon footprint (12,700 metric tons of CO_2 per year and reduced NO_x emission on the order of 10 metric tons per year).[57]

FIGURE A3: Combined Cycle Power Plant



Source: Global-Greenhouse-Warming.com, 2010[58]

APPENDIX B: NATURAL GAS POLICY

- 1938 - The Natural Gas Act of 1938 establishes federal authority over interstate pipelines, including the authority to set "just and reasonable" rates. It also establishes a process for companies seeking to build and operate Interstate pipelines. Oversight of The Act is given to the Federal Power Commission.
- 1954 – 1978 Well-head price controls eventually lead to scarcity and shortage.
- 1978 - In response to supply shortages, Congress enacts the Power plant and industrial Fuel Use Act (FUA). The law prohibits the use of natural gas in new industrial boilers and new electric power plants. The goal is to preserve "scarce" supplies for residential customers.
- 1985 - The Federal Energy Regulatory Commission replaces the Federal Power Commission and issues Order 436, intended to provide for "open access" to interstate pipelines that offered transportation service for gas owned by others.
- 1987 - President Reagan signs into law the repeal of the remaining FUA restrictions and incremental pricing; he believes that the country's natural gas resources should be free from regulatory burdens that are costly and counterproductive.
- 1990 - On April 3rd, trading on natural gas futures begins at the New York Mercantile Exchange (NYMEX).
- 2005 - Energy Policy Act 2005 - This bill exempts fluids used in the natural gas extraction process of Hydraulic fracturing from protections under the Clean Air Act, Clean Water Act, Safe Drinking Water Act, and CERCLA. It creates a loophole that exempts companies drilling for natural gas from disclosing the chemicals involved in fracking operations, normally required under federal clean water laws. The loophole is commonly known as the "Halliburton loophole" since former Halliburton CEO Dick Cheney was reportedly instrumental in its passage. The proposed Fracturing Responsibility and Awareness of Chemicals Act would repeal these exemptions.
- 2011 - Tough pollution limits (CSAPR) and limits on Mercury, SO_x, NO_x, emissions (NESHAP) begin to drive older inefficient coal plants out of the market.
- 2011 – A proposed Federal CES credits natural gas relative to coal reference.
- 2012 – New Source Performance Standard (NSPS) for CO_2 is proposed by the EPA.

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