Future Generation Fuels Challenges

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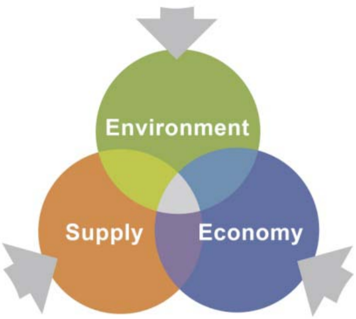
ABSTRACT

An increasingly complex energy economy with growing energy demand and a need to reduce greenhouse gas emissions needs a balanced perspective that considers all three dimensions – supply, economics, and environment – concurrently. Assured, affordable, and sustainable energy supplies will depend on a broad portfolio of proven, new, renewable, and alternative sources coupled with enhanced recovery technologies, greater fuel flexibility, and increased efficiency. An effective policy framework for reducing greenhouse gas emissions ultimately hinges on emissions pricing. Without a policy that places a cost on carbon emissions, everything else possible becomes a way to limit emissions but provides no easy way for the market to absorb the cost burden. One example of the ways that environmental policies can increases energy costs is the application of New Source Review (NSR) requirements that were designed to prevent the degradation of air quality from the construction of new facilities or modification of existing ones that have potentially harmful emissions. But continuing uncertainties in the interpretation of NSR requirements have created a chilling effect for utilities contemplating routine maintenance, repair, and replacement. There is also an unintended disincentive to consider upgrades that would increase plant efficiencies (and, therefore, improve environmental and cost performance) because these changes could trigger a NSR and impose new source performance standards.

New standards that could ultimately require installation of carbon dioxide capture equipment would increase the water requirement per net power generation of a plant, due both to a reduction in the plant efficiency and to the cooling water and process water requirements associated with carbon dioxide capture and compression. Besides changing the projected mix of new electricity generation capacity, compliance with carbon-constraining legislation like the American Clean Energy and Security Act or 2009 could also significantly increase the total amount of new electric capacity that must be added between now and 2030 due to the retirement of many existing coal-fired power plants that otherwise would be expected to continue operating beyond 2030. One of the possibilities for maintaining electric power production while reducing GHG and criteria pollutant emissions is fuel switching from coal to natural gas. However, domestic gas supply is inadequate to meet electric power demand without coal, let along make up the difference and leave adequate supplies to meet all other needs, including home heating and industrial feedstocks.

Energy Strategy Complexity

In order to be truly sustainable, a source of energy must perform in each of the three dimensions of the global energy economy – supply, economics, and the environment. That is, there must be an adequate and assured amount available at an affordable price and with minimal environmental impacts in order to succeed. Aligning these dimensions can present a formidable challenge, as they are often in competition with one another in energy policy making and in technology development. Energy policy discussions often key in on one of the three dimensions as most significant, occasionally to the exclusion of the others. Such a single-sided approach can ultimately lead in directions that impinge on the other dimensions. These pressures can impact the proper functioning and economic sustainability of all energy markets, including electric power, liquid and transportation fuels, and chemical and agriculture feedstocks.



A Venn diagram can be used to represent the challenges in developing a coherent energy strategy may clarify the dynamics at work. Strategies that focus on one area can realize improvements in the chosen area of research or investment, but the difficulties of achieving other equally important objectives are exacerbated in the process. In a zero-sum decision-making environment, competitive tensions pull the spheres in opposing directions. Compatible opportunities, represented by the overlap of the spheres at the center of the diagram, shrink as the spheres are pulled apart but increase as the spheres are brought closer together.

A more effective approach to meeting our energy needs depends on seeking alternatives that provide an equitable balance of attention to all three requirements, seeing them as a single, complex issue that demands our continued attention.

China and U.S. Shares of Energy and Emissions

By 2030, both world primary energy demand and carbon emissions are forecast by the International Energy Agency to grow by 40 percent with continued reliance on fossil fuels for about 80 percent of total energy demand. China's need for energy will approximately double, growing from 16 percent to 23 percent – nearly one quarter – of worldwide energy demand. U.S. consumption will grow by about 11 percent, but at the same time decline from 20 percent to 15 percent of worldwide demand as demand in developing economies continues to increase. Having already surpassed the U.S. as the world's largest emitter of carbon dioxide, China's emissions will also about double, with the contribution to global emissions growing from 21 percent to 29 percent. Over the same period, U.S. emissions remain essentially level while the global contribution drops from 20 to 14 percent.

As two of the largest global economic powers, China and the United States increasingly dominate energy use and share responsibility for the majority of the associated environmental impacts, particularly greenhouse gas emissions. Recognizing this, the two nations have embarked on an unprecedented level of technological collaboration involving all levels of government and leading research institutions, universities and corporations. Through a growing number of multilateral organizations we are expanding our ability to develop, demonstrate, and deploy breakthrough technologies for assured and affordable energy in a sustainable environment. Technology transfer can help drive improved environmental and cost performance even in advance of harmonized policy regimes.

Every Energy Source Faces Challenges

Every energy source faces challenges on multiple fronts. Energy supplies are increasingly constrained by peaking production, increasing global competition, and societal instabilities in major energy producing regions. Deployment of renewable sources is constrained by high costs, intermittencies, distances from population centers, and access to compatible distribution grids. Coal and gas face economic challenges in the costs projected to reduce greenhouse gas emissions. In addition to greenhouse gas emissions, the sustainability of water supplies and the treatment and disposal of waste streams loom as environmental concerns, particularly for each of the major sources of base load electric power generation – coal, natural gas, and nuclear. And, it seems, each source faces questions of public acceptability, either in principle or in local land use decision making.

An increasingly complex energy economy with growing energy demand and a need to reduce greenhouse gas emissions needs a balanced perspective that considers all three dimensions – supply, economics, and environment – concurrently. Assured, affordable, and sustainable energy supplies will depend on a broad portfolio of proven, new, renewable, and alternative sources coupled with enhanced recovery technologies, greater fuel flexibility, and increased efficiency. Energy strategies and technologies are increasingly sensitive to the water-energy nexus where water consumption for thermoelectric power is an emerging environmental issue. Key among carbon abatement technologies is carbon capture and storage (CCS) for large point-source emitters, particularly fossil fuel power generation. And, while CCS technologies have evolved from proven industrial applications, continuing research is needed to resolve issues with scaling, costs, and water use, as well as to demonstrate the widespread availability of storage reservoirs.

Policy Options for Reducing Greenhouse Gas Emissions

An effective policy framework for reducing greenhouse gas emissions ultimately hinges on emissions pricing. Without a policy that places a cost on carbon emissions, everything else possible becomes a way to limit emissions but provides no easy way for the market to absorb the cost burden. Whether a cap-and-trade system is preferable to a carbon tax remains a matter of intense debate. A useful point of comparison might be the European Union Emissions Trading Scheme, which has yet to crystallize in a way that produces the levels of emissions reductions contemplated in EU and member-nation policies, and the Norwegian carbon tax, which is tangibly altering their energy economy and has prompted the deployment of world-class CCS projects.

Beyond emissions pricing, there are really three avenues toward emissions reductions:

- <u>Increase Efficiencies</u> – lower the carbon demand – or intensity – for energy consumption while maintaining an equitable standard of productivity.
- <u>Diversify Fuels</u> – supplement the traditional fuels mix with less carbon-intensive fuels that can deliver the same power and accomplish the same work.
- <u>Store Carbon</u> – complete the carbon cycle (or the fossil fuel cycle) by isolating carbon from the atmosphere after energy consumption.

Interestingly, these avenues are, in principle, three of the tenets of pollution prevention – Reduce, Replace, and Recycle – which strengthens the notion that we have a robust suite of policies that can be applied systematically to manage carbon dioxide emissions in much the same way that we manage the uses of other commodities to ensure environmental sustainability. The other tenet of pollution prevention – Reuse – would apply in terms of beneficial use of CO_2, for example for enhanced oil recovery or for the food and beverage industry. But this is fundamentally an economic decision made by these industries and requires no additional policy initiative. Oil producers, for example, do not need the EPA's underground injection regulation changed to allow EOR. Fundamentally, however, the used CO_2 market is not generally viewed as large enough to make large enough cuts in net emissions to offset the needs for the types of policies outlined in the chart.

An additional set of policies effectively envelopes the possible mechanisms for emissions reductions – government investment in technologies research and development to help make these policies achievable. More than $15 billion was invested in energy programs through the American Recovery and Reinvestment Act, major portions of which went to increased efficiencies through building weatherization programs and accelerated carbon capture and storage research and demonstration programs. These investments supplemented 100 years of Federal energy and technology research that today is led by the U.S. Department of Energy and the National Energy Technology Laboratory. Considered together with an informed, systems-level view of the technological possibilities, these policies become part of the way the government looks to meet the seemingly competing demands for increasing energy supplies while reducing environmental impacts.

New Source Review v. Existing Plant Upgrades

One example of the increasing application of environmental policies is the application of New Source Review (NSR) requirements. Established by Congress as part of the 1977 Clean Air Act Amendments, the NSR was designed to prevent the degradation of air quality from the construction of new facilities or modification of existing ones which have potentially harmful emissions. The NSR process requires power plant operators to undergo a review for environmental controls if they build a new power generating unit. Power plants built prior to 1971 are exempted from the limits on criteria pollutant emissions contained in the Clean Air Act, but may lose that exemption and be forced to undergo an NSR if the U.S. Environmental Protection Agency (EPA) determines that the plant has undergone non-routine maintenance that increases emissions.

Since the 1977 amendments, the EPA has applied a combination of litigation, enforcement, and rulemaking to push power plants into the NSR process. An early and unresolved issue is the definition of "routine maintenance, repair, and replacement" that has created persistent uncertainty as to the nature and level of change in a power plant's physical structure needed to trigger an NSR. On the basis of an April 2007 decision by the U.S. Supreme Court, EPA has also does not have to consider a generating unit's hourly emissions rates, but could instead use the total yearly emissions in its determination of emissions increase. More recently, the EPA has issued and then delayed the effective date of their NSR Aggregation Amendments, which describes when a source must combine nominally-separate physical changes and changes in the method of operation for the purpose of determining whether they constitute a significant emissions increase. And now, with EPA moving to regulate greenhouse gasses under authority of the Clean Air Act (CAA), a Greenhouse Gas Tailoring Rule has been proposed to define when CAA permits under NSR would be required for new or existing facilities.

Taken together, these actions have left a legacy of continuing uncertainty in the interpretation of NSR requirements and created a chilling effect for utilities contemplating maintenance, repair, and replacement. There is also an unintended disincentive to consider upgrades that would increase plant efficiencies (and, therefore, improve environmental and cost performance) because these changes could trigger an NSR and impose new source performance standards.

Greenhouse Gas Control Increases Water and Power Demands

An NETL study evaluated thermoelectric plants with the capability to capture carbon dioxide for each of the fossil energy plant technologies, including both coal- and natural gas-fired plants. Installing CO_2 capture equipment increases the water requirement per net power generation of a plant, due both to a reduction in the plant efficiency and to the cooling water and process water requirements associated with carbon dioxide capture and compression.

The CO_2 capture method for the plants used in the study is an amine solvent-based technology. To meet the specifications of the amine capture process, a scrubber simultaneously cools the flue gas and reduces the SO_2 concentration. The flue gas then contacts the amine solvent, which absorbs the CO_2. The CO_2-laden solvent is then steam-heated to release the CO_2 and the solvent is then recovered and reused while the CO_2 is cooled and compressed for storage. The capture facility requires a significant amount of cooling water for all fossil-based power generation. The addition of CO_2 capture and compression increases water consumption by 50 to 90 percent.

Furthermore, the additional power needed to heat and release the CO_2 from the solvent and then compress the CO_2 for storage reduces the net efficiency of the plant for all technologies. Net plant efficiencies decline from 14 percent for natural gas combined cycle plants to 32 percent for sub-critical pulverized coal plants. Put another way, using current amine solvent-based capture technologies can mean that for every three plants with capture equipment, a fourth plant is potentially needed to make up the power from the efficiency loss.

Increase in Electricity Prices

An Energy Information Administration (EIA) analysis of H.R. 2454, the *American Clean Energy and Security Act of 2009* (ACESA; the Waxman-Markey bill), explored the potential economic impacts of legislation to constrain carbon emissions. Among the results of this analysis, the EIA found that a lack of economic growth keeps emissions down until nearly 2020 and that offsets and "free allowances" mute the price response until 2025.

Emissions reductions from changes in fossil fuel use in the residential, commercial, industrial and transportation sectors are small relative to those in the electric power sector. Taken together, changes in fossil fuel use in these sectors account for between 12 and 20 percent of the total reduction in energy-related CO_2 emissions in 2030. GHG allowance prices are sensitive to the cost and availability of emissions offsets and low-and no-carbon generating technologies. Allowance prices are projected at $32 per metric ton in 2020 and $65 per metric ton in 2030.

ACESA increases energy prices, but effects on electricity and natural gas bills of consumers are substantially mitigated through 2025 by the allocation of free allowances to regulated electricity and natural gas distribution companies. ACESA increases the cost of using energy, which reduces real economic output, reduces purchasing power, and lowers aggregate demand for goods and services. The result is that projected real gross domestic product (GDP) generally falls.

Besides changing the projected mix of new electricity generation capacity, compliance with ACESA will also significantly increase the total amount of new electric capacity that must be added between now and 2030 due to the retirement of many existing coal-fired power plants that otherwise would be expected to continue operating beyond 2030. Unless substantial progress is made in identifying low- and no-carbon technologies outside of electricity generation, the ACESA emissions targets for the 2030-to-2050 period are likely to be very challenging as opportunities for further reductions in power sector emissions are exhausted and reductions in other sectors are thought to be more expensive.

Electricity Generation – Can Natural Gas Displace Coal?

One of the possibilities for maintaining electric power production while reducing GHG and criteria pollutant emissions is fuel switching from coal to natural gas. There are several attractive reasons for considering this as an alternative. Natural gas-fired power plants emit about half the CO_2 of coal-fired plants and the plants themselves are cheaper and easier to construct, particularly as scrutiny of prospective coal plants increases. Despite price volatility that gas markets have seen since the “dash to gas” for power generation in the 1990s, gas supplies are high and the price is currently low. Further, advanced exploration and production technologies may unlock even greater reserves from shale formations. This then begs the question; can natural gas displace coal for power generation in the U.S.?

In 2007, coal and gas met approximately equal shares of U.S. total energy demand: 22 percent coal and 24 percent gas and the EIA forecasts that at least through 2030 this mix is unlikely to change significantly (23 percent coal; 22 percent gas). Within this mix, coal accounted for about half of electric power generation while gas fueled only 20 percent. Combined U.S. electricity generation from coal and gas totaled about 2,700 billion kilowatt hours (BkWh) with 2,000 BkWh from coal and 700 BkWh from 5.6 trillion cubic feet (Tcf) of natural gas. To replace all 2,000 BkWh of coal-fired power generation would take an additional 17 Tcf of natural gas where total U.S. natural gas consumption in 2007 for all purposes was 23 Tcf while total domestic supply was 19 Tcf. Thus, domestic gas supply is inadequate to meet electric power demand without coal, let along make up the difference and leave adequate supplies to meet all other needs, including home heating and industrial feedstocks.