Clean Coal Technology
Thursday, April 26, 2007

Mr. Joseph Chaisson
Director of Research and Technology Clean Air Task Force

Before the Science, Technology, and Innovation Subcommittee

of the

Senate Committee on Commerce, Science, and Transportation

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Introduction

Mr. Chairman and members of the subcommittee,
My name is Joseph Chaisson. I am Technical and Research Director of the Clean Air Task Force (CATF). Thank

you for the opportunity to testify today on advanced coal technology and the environment.

Founded in 1996, CATF is the only major national environmental advocacy organization with an exclusive focus on protecting the Earth's atmosphere and human health from air pollution and climate change. This singular focus enables CATF to field deep analytic and strategic resources equal to the significant and complicated atmospheric challenges we face over the next fifty years.

Over the past several years, one of CATF's major activities has been to work with state and regional environmental groups, state governments and private project developers in several parts of the country to facilitate early domestic deployment of coal gasification technology – with carbon capture and geologic sequestration (storage) where currently feasible. We have briefed numerous Congressional offices – accompanied by state environmental partners -- about the promise of coal gasification technology. Another related CATF focus has been exploring how to remove barriers to promising advanced coal gasification and carbon capture technologies that have not yet entered the market. This "hands on" project facilitation and market entry work provides us with a useful perspective on what is happening on the ground in today's marketplace.

In this testimony, I will briefly restate the importance of moving forward radically cleaner coal technology than is deployed today; highlight current market developments on the ground which the subcommittee may not be aware of; and, finally, discuss key challenges to radically cleaner technology, and what the federal government might do to help tackle those challenges.

I. The Current and Projected Environmental "Footprint" of Coal

Coal-fired power generation is today one of the planet's most environmentally destructive activities. It is responsible for most of the nation's sulfur dioxide emissions that, even after recent regulatory reductions, will still take 15,000 lives prematurely in the US each year by EPA's own estimate. It contributes substantially to nitrogen oxides, which add to smog, haze, and crop and ecological damage. It emits most of the nation's manmade mercury air pollution. Current coal mining practices have scarred land and threatened water and habitat. Coal power generation consumes and discharges enormous quantities of water, while generating nearly 100 million tons of toxic wastes each year, the disposal of which is not regulated by the federal government. Finally, coal power generation is responsible for nearly 40% of the planet's man-made emissions of carbon dioxide that contribute to global warming.

Despite these problems, coal fired power generation is likely to be relied on for decades to come and is projected to expand dramatically. World electric demand is expected to triple by 2050, coming largely from developing countries like China and India. Most analyses agree that this underlying demand growth will substantially outpace even the most aggressive energy efficiency policies. Renewable energy, while it should and will be widely deployed, faces significant physical, environmental and economic challenges that will practically limit its share of total electrical supply for several decades. Natural gas is relatively expensive and its reserves are far more limited than coal. Finally, nuclear power faces considerable hurdles of scale, economics and environmental opposition. For these reasons among others, China is building as much new coal capacity each year as the entire UK power grid, and coal power generation in India is projected to grow rapidly - matching current US coal consumption by 2020 and China's current coal consumption by about 2030. The United States faces both growing demand for electricity and an aging power plant fleet; coal will remain economically attractive to meet some portion of electricity demand growth and to replace some existing power plants.

Turning to climate, numerous analyses performed or commissioned by such bodies as the Intergovernmental Panel on Climate Change, the European Union, the National Commission on Energy Policy, academic institutions such as Harvard, MIT, and Princeton University as well as environmental organizations such as Friends of the Earth-UK have concluded that, even with aggressive energy efficiency, renewable energy development and in some cases nuclear expansion, coal fired power generation is likely to remain a significant part of any 2030-2050 global power supply. Accordingly, each of these studies has identified the critical importance of transitioning coal use to technologies that minimize health-related air emissions and allow for the removal and storage of carbon dioxide, and to begin to demonstrate and scale up those technologies on a commercial basis as soon as possible.

In short, the planet is unlikely to be able to live *without* coal for some time to come. But, at the same time, the planet, from an environmental standpoint, can't stand to live *with* coal as it is currently used to produce electricity. This leaves only one path forward: we need to change how we *use* it – and we need to do so as quickly as possible.

II. What Is to Be Done?

An environmentally responsible coal policy would do the following:

- Ban the construction of new coal combustion plants due to their inherently unacceptable air, water, solid waste and climate impacts.
- Rapidly commercialize the use of integrated coal gasification combined cycle (IGCC) for electric power

generation, because it has a much smaller environmental footprint for air emissions and waste than does coal combustion.
- Rapidly demonstrate the feasibility of large-scale geologic storage of carbon dioxide and then require all new coal power plants to capture and sequester at least 90% of their coal carbon content.
- Demonstrate and deploy advancements such as underground coal gasification, that could further shrink IGCC's environmental footprint by substantially minimizing mining impacts and waste management
- Reform coal mining practices worldwide, impose effective federal regulation of coal plant solid waste disposal and reduce coal generation water use and associated impacts to the minimum practical levels.
- Increase the energy efficiency of IGCC power generation to the maximum practical levels over time.
- Establish effective carbon dioxide emissions controls.

Commercializing IGCC is of special importance. Because it is an inherently cleaner process – the gas it produces from coal must be free of most contaminants to power a gas turbine – IGCC reduces deadly sulfur and nitrogen oxide emissions to very low levels – approaching those achievable by natural gas combined cycle power plants. Gasification is the *only* coal power generation technology that can virtually eliminate mercury air emissions and capture most of the coal mercury content in a concentrated form that can potentially be sequestered from environmental release; IGCC is the only way we can continue to use coal to produce power without adding significantly to the global mercury burden. Total solid waste from gasification is typically half the volume generated by conventional coal plants, and gasification water use is substantially lower as well.

Underground coal gasification (UCG), a promising further advancement in IGCC would gasify the coal directly within the deep, unmineable coal seams. This process can potentially eliminate the environmental impacts of current coal mining and transportation practices, as well as significantly reduce the challenges of coal waste management.

Finally, IGCC is the key enabling technology for capture and storage of carbon dioxide from coal power generation and will be essential to meeting any reasonable climate stabilization target. While it is possible to retrofit a coal combustion plant with carbon capture technology, it is expensive and inefficient to do so today, costing twice as much for plants using bituminous coal as capturing carbon from an IGCC plant and reducing plant efficiency by as much as 40%. While development of more cost-effective coal-combustion carbon capture alternatives is important, current efforts are very early in the technology development stage, and it is unclear whether and when cost-effectiveness will be fully demonstrated for this technology. *If we are to turn the world coal tide to a near-zero carbon footprint in the next 20 years, IGCC power generation is likely to be the most availing path forward based on current information*.

III. Recent Market Developments

The good news about cleaner coal power and carbon capture is the many recent coal gasification market developments, nearly all of which are too new to be reflected in academic studies and many of which are being conducted by companies not well represented by Washington trade groups or research organizations. When we "look out the window" at these market developments, we see a substantially different situation than is typically presented in available studies or by traditional institutions.

Key highlights include the areas listed below. It should be noted that the coal gasification market developments described below do not reflect a complete survey of recent developments, but rather are intended to illustrate the contrast between the relatively static and out-of-date study characterizations of coal gasification technology with today's rapid pace of market development.

Emergence of new "full system" IGCC vendors

Prior to last summer, GE was the sole "full systems" IGCC vendor capable of offering all major IGCC components (that is, gasifier, combustion turbines and steam turbines) in a single package. Since that time, Siemens and Mitsubishi have developed full system commercial IGGC offerings, significantly expanding vendor choice for potential IGCC project developers. Siemens emerged as a full systems vendor last summer when the company acquired the Future Energy gasifier. NRG's recent selection of Mitsubishi as the technology supplier for their proposed domestic IGCC plants introduced the entry of Mitsubishi as a full systems vendor.

Emergence of new coal gasifiers

Up until last summer, there were only three serious commercial coal gasifier offerings: the GE (Texaco technology), ConocoPhillips (E-Gas technology) and Shell gasifiers. These gasifiers have different characteristics that affect their suitability for various coal types, with Shell appearing most suited to low-rank coals (sub-bituminous and lignite). These gasifiers are also estimated to vary significantly in cost. Nearly all IGCC studies and academic literature have been restricted to analysis of these gasifiers.

Several additional coal gasifiers have moved into the marketplace over the past year:

- The *Future Energy* gasifier, developed in the former East Germany and recently acquired by Siemens, should be well suited to low rank coals and shows promise of being quite economically competitive.
- The *British Gas Lurgi* (BGL) gasifier is an evolution of the Lurgi gasifiers used extensively in South Africa and at the Dakota Gasification plant in the US. This gasifier should also be well suited to low-rank coals.
- The *Mitsubishi* gasifier is partially oxygen blown, should also be well suited to low-rank coals and shows promise of being quite economically competitive.

As all three of these gasifiers are well suited to low-rank coals, they provide a much more competitive set of market offerings for projects using these coals and should reduce pre-inflation low-rank coal IGCC project costs. This point is particularly important as some critics have suggested that some conventional gasifiers are not well-suited to low rank coals, and that there may not be an economic path for low-rank coal use.

"Next Generation" IGCC plant development

At least four "next-generation" IGCC projects are moving forward in the US, in addition to the "hybrid" coal gasification plants described below. These projects are AEP's Meigs plant in Ohio and Mountaineer plant in West Virginia, Duke Energy's Edwardsport plant in Indiana and BP's Carson Refinery Hydrogen project in California.

These projects all use the most advanced available combustion turbine (for example, GE's 7FB) and are a major "scale-up" from the several IGCC plants built at refineries in Europe about five years ago. They are also much larger than the two early demonstration plants built in the US (Wabash Station in Indiana and Polk Station in Florida) about a decade ago. These projects will typically have about 600 MW of generating capacity. The BP Carson project will use petroleum coke (a coal-like refinery waste product) and will include 90% carbon capture, which reduces plant output to about 500 MW. The BP Carson project will be the first commercial project in the US to include and demonstrate "full" carbon capture.

Several additional "next-generation" plants may also be moving forward, but at a slower pace, including additional AEP-proposed plants in Kentucky and NRG's proposed Huntley plant in New York State.

These "next generation" plants are important for several reasons, including lower inflation adjusted costs and higher operating efficiencies. They also are driving significant detailed engineering design work, including in the case of Duke and AEP, serious engineering analysis of options for adding carbon capture to these plants at some future time, and provisions that can economically be built into the initial plant to facilitate carbon capture retrofit. The good news is that this very significant amount of engineering work will provide much more detail than is currently available on next generation costs, performance and carbon capture retrofit feasibility. The bad news is that this information remains proprietary and is not yet available in open literature.

"Hybrid" Projects

Some independent IGCC project developers like the ERORA Group and Summit Power are developing coal gasification projects that produce both electric power and substitute natural gas, typically allocating about 50% of the project coal syngas to each of these products. The ERORA group is developing projects in Illinois (Taylorville) and Kentucky (Cash Creek) and Summit Power is developing projects in Oregon and Texas.

These developers are pursing "hybrid" projects because they have economic advantages over next-generation "power only" IGCC plants, including reduced overall project cost, high availability – particularly in projects using several of the new Siemens gasifiers -- and attractive overall project economics for power generating companies that have existing natural gas power plants by allowing them to have coal based fuel pricing for both their new coal generation and some portion of their existing natural gas generation.

Some of these projects are close to final permitting and full financing. Several projects plan to include some carbon capture and will initially use the captured carbon for enhanced oil recovery (EOR). At least one project is exploring full carbon capture and sequestration. In many respects these projects reflect efforts by project developers to overcome current economic barriers to stand-alone IGCC plants.

Advanced Coal Gasifiers

Several innovative coal gasification technologies are conducting process demonstrations and could be commercially available within the next two years. Two examples among several such systems being developed include Great Point Energy's catalytic coal gasifier (a technology originally explored in the 1970's) and Texas Syngas' molten metal bath gasifier. Both technologies can potentially be produced modularly in a factory and both appear to have potential to reduce gasification costs compared with traditional gasifier designs.

Underground Coal Gasification
Underground coal gasification ("UCG") is just beginning to be recognized as a potential option for utilizing coal. UCG is a gasification process conducted in deep coal seams. Injection and production wells are drilled

into the coal seam and are then linked together. Once linked, air and/or oxygen is injected and the coal is ignited in a controlled manner to produce hot, combustible coal syngas that is captured by the production wells, brought to the surface and cleaned for power generation and/or production of liquid hydrocarbon fuels or substitute natural gas. This technology has been used at a minor level since the early 1900's and DOE conducted many pilot UCG projects in the 1970's.

A successful modern pilot project was conducted about six years ago in Chinchilla, Australia by the Ergo Exergy Technologies, Inc. and the first modern commercial UCG electric power production project started up this January in Mpumalanga, South Africa. I understand that two commercial UCG projects producing hydrogen for chemical plants have been developed in China. The GasTech Company is developing the first North American pilot UCG project in Wyoming. The initial GasTech project will be conducted in the Powder River basin and will use a coal seam 950 feet deep. Current estimates are that the *pre-clean-up* syngas will be produced for about $1.90/mmbtu (as compared with current US gas forward prices of about $8.00/mmbtu for the next several years).

UCG technology is potentially quite significant for several reasons:

1. It can avoid most of the adverse environmental impacts associated with coal mining and transportation;
2. It leaves coal residuals (ash and some other constituents) underground;
3. It can potentially reduce coal gasification costs – perhaps significantly; and
4. It can open up large amounts of deep coal reserves that are currently not economic to mine. Lawrence Livermore National Laboratory (LLNL) estimates that UCG could potentially triple domestic economic coal reserves.
5. Carbon capture costs may be somewhat lower than with above-ground gasification and a significant fraction of captured carbon can potentially be stored in the underground gasification cavities created by a UCG project.

Once this technology emerges from the pilot/demonstration stage, which will be necessary to clarify technology costs, it may be deployed rapidly if it proves to be more economic than conventional pulverized coal plants or advanced above-ground gasification system IGCC's. LLNL has recently produced a summary of current UCG knowledge that is available at https://eed.llnl.gov/co2/11.php.

IV. A Key Technology Gap

Developing a practical and very-low cost method of capturing carbon dioxide from existing power plant flue gases would be an enormous boost to global efforts to reduce carbon dioxide emissions and may be the only practical opportunity to significantly reduce future carbon dioxide emissions from the rapidly developing coal power plant "fleet" in China and India. Current technologies that can accomplish this task are too expensive and consume far too much energy to be practical to apply broadly throughout the world. While current research in this area is focused primarily on what are essentially incremental improvements in existing technology systems, a "break through" technology is needed. Potential "high-risk/high-reward" breakthrough technologies, like structured fluids, have been identified (in this case by MIT researchers) but there appear to be no relevant sources of Federal support for such research.

V. Challenges to Advanced Technology Deployment

Several problems are constraining rapid deployment of advanced coal gasification technologies and associated carbon capture, including the recent substantial increase in large energy project costs; the lack of an economic incentive to build IGCC projects with full carbon capture today; and Federal advanced coal research, development and deployment programs that are not adequately funded or sufficiently broad.

Recent large energy-project cost inflation

For several reasons, including massive infrastructure development in China and very large investments in Persian Gulf oil and gas projects, the construction cost of large energy projects has significantly increased over the past two-to-three years. In some cases, this cost inflation may have *doubled* project costs – including some domestic proposed coal plants. While it is not clear how long costs will continue to rise or for how long they will remain inflated, it does not appear that this cost-inflation period will be short.

The current cost-inflation environment will also affect the economics of carbon capture and sequestration for new coal projects, raising the estimated costs from roughly 1.5 cents/kwh to about 2.5 cents/kWh. This suggests that if this cost environment prevails, carbon capture will begin to be economic at a carbon emissions price of about $40 per ton of CO2, at least initially.

No economic incentive to build new coal plants with full carbon capture today

While the technology exists to develop new coal IGCC plants with full carbon capture and sequestration today, as is being demonstrated by BP's Carson project, there is no economic basis to do so except possibly in the very few cases (like BP's Carson project) where all captured carbon can be used for enhanced oil recovery. This disincentive to adding CCS to new coal plants will continue until captured and sequestered carbon is worth roughly $40/ton of carbon dioxide.

Limitations of Federal Advanced Coal Research, Development and Demonstration Programs

We have not conducted a serious review of the relevant Federal "clean coal" research, development and demonstration programs, but we have observed several "disconnects" between such programs and both promising market activity and needed "breakthrough" technology. We note that all EPACT financial support for new IGCC projects has been awarded to next-generation commercial IGCC projects, which in nearly all cases are being proposed by large investor-owned utilities. In contrast, no innovative "hybrid" IGCC/SNG projects being developed by independent project development companies were awarded financial support. We also note that none of the promising advanced coal gasifiers being developed that we are aware of are receiving significant DOE support nor are these advanced gasifier concepts listed in the various technology evolution "road maps" developed by DOE and others. And as we noted above, no Federal programs exist today that would provide financial support for new IGCC project developers seeking to include full carbon capture and sequestration in their projects.

MIT's Future of Coal Study reviewed current DOE clean coal research, development and demonstration programs and outlines one approach to expanding and better targeting these programs. We see MIT's proposals as a good starting point for discussion, but believe they would not be sufficient to address all research, development and demonstration gaps or "disconnects" we have observed.

VI. What Can the Federal Government Do to Accelerate Deployment of Needed Technology?

Several Federal actions could accelerate development and deployment of the advanced coal technology needed to address climate change and dramatically reduce coal's environmental impacts:

1. Establish a production tax credit or some other form of equivalent financial incentives for new coal power plants with full carbon capture and sequestration. These incentives would be in effect until a national carbon emissions reduction program has been established that creates a carbon emissions allowance price sufficient to offset carbon capture and sequestration costs. At current energy project prices, such a production tax credit would likely need to be at least 2.5 cents per kWh.
2. Establish a carbon emissions performance standard at some future date for new fossil power plants that would require significant carbon capture and sequestration for new coal power plants.
3. Establish effective carbon emissions controls.
4. Significantly expand and broaden DOE's advanced coal research development and demonstration programs.

The recent MIT Future of Coal Study outlines one approach for expanding DOE's advanced coal programs and suggests that such programs need to be funded at levels as high as $800-$900 million per year. Beyond MIT's recommendations, it would be useful to review current research and market activity in this field to identify promising technologies that are slipping through the cracks in current DOE programs to help develop more effective programs. It is also critically important that appropriate support be established for developing "breakthrough" technology in critical areas like practical, low cost carbon capture at existing power plants.

In summary, I believe that the technology we need to transition coal use to much more environmentally sustainable systems could be either deployed or developed promptly if effective Federal advanced coal technology policies were implemented.