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# **RESPONSE OF THE CLEAN AIR TASK FORCE TO MIT'S "FUTURE OF COAL" STUDY**

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CLEAN AIR TASK FORCE



**JULY 2007**

Introduction

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Mining, transporting, and burning coal to generate electricity are some of the most environmentally destructive activities on earth, and the vast quantities of carbon dioxide (CO<sub>2</sub>) released by coal combustion threaten the very climate system on which all life depends. At the same time coal is an abundant source of low-cost energy, at least under current regulatory practices, and coal is likely to play a central role in the world's economic systems for decades to come<sup>i</sup>. Finding ways to reduce the environmental impacts of coal, including reducing CO<sub>2</sub> emissions, is a top priority of the Clean Air Task Force (CATF). To this end CATF has engaged in, sponsored, and critiqued original research on coal and climate from many authors over many years<sup>ii</sup>.

### MIT's "Future of Coal" Study

Recently a great deal of new information on coal, coal utilization for electricity generation, and CO<sub>2</sub> emissions has entered the broad public discourse. Of particular relevance is the widely read March 2007 study by the Massachusetts Institute of Technology titled *The Future of Coal: Options for a Carbon-Constrained World*<sup>iii</sup> (MIT Study, or simply, the study). CATF served on the advisory committee to the MIT Study and supports many of the study's findings and recommendations. The conclusions of the study on the necessity for rapid demonstration of geological carbon dioxide sequestration (GCS) and the provision of a 'road map,' including federal funding, to accomplishing this are of particular value and should not be overlooked. In addition, the study makes important contributions to the public debate by recommending against 'grandfathering' CO<sub>2</sub> emissions from coal-fired generating units currently under construction.

A key topic discussed in the study is a comparison of pulverized coal (PC) versus Integrated Gasification Combined Cycle (IGCC) technology. As the MIT Study notes, IGCC plants have a much more acceptable environmental footprint than conventional coal plants. IGCC plants emit substantially lower SO<sub>2</sub> and NO<sub>x</sub> levels compared to pulverized coal. Mercury from IGCC is in a compact form that could be permanently sequestered, and IGCC plants produce 40%-50% less solid waste and 20%-35% less water than pulverized coal. And yet these benefits do not come without a cost, according to the MIT Study. The study reports that without carbon capture, IGCC has a capital cost about 7.5% higher than PC<sup>iv</sup>, and the cost of electricity from an IGCC plant is about 5% more than that from pulverized coal<sup>v</sup>. When 90% carbon capture is factored in, the cost difference reverses. IGCC plants costs 13% less than PC to build<sup>vi</sup>, and the cost of electricity from an IGCC is nearly 20% less than pulverized coal<sup>vii</sup>.

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The MIT Study draws upon its analysis of IGCC and PC technology to make two recommendations with respect to building new coal power plants today. They are:

1. The study concludes that it is “premature to select one coal conversion technology as the preferred route for cost-effective electricity generation combined with CCS” (Finding #4)<sup>viii</sup>, and
2. The study concludes that it is sufficient merely to build the most efficient coal plants possible (Finding #1)<sup>ix</sup>, rather than build plants today that can capture at least some level of carbon dioxide immediately.

These recommendations are significant because they may influence what direction new coal plant technology developers take. Indeed, the recommendations are especially important when considering the rapid development of coal plants in China. Can developers and policy makers truly be indifferent to technology choice? Can developers really build any plant they want as long as it is efficient? If the study recommendations are wrong, and technology choices today do matter, then the wrong choice could lock in high levels of carbon dioxide emissions that constrain options for mitigating global warming. Both recommendations are based upon at least five key underlying assumptions:

1. The MIT study assumes that the 7.5% capital cost and 5% electricity premium of an IGCC plant over PC is significant in the context of building new coal plants without carbon capture. This assumption is important, because if these costs are low enough to be considered “noise,” then there would be no compelling reason to build PC plants. As the MIT report notes, IGCC technology emits lower levels of criteria pollutants, uses less water, produces less solid waste, and enjoys a significant cost advantage today over PC in carbon dioxide capture costs.
2. The MIT report assumes that any existing capital and electricity cost premiums associated with IGCC plant (without carbon capture) will be sustained over time. This assumption is important because, again, if the costs of IGCC and PC are the same, there is no compelling reason to build PC given IGCC’s environmental advantages.
3. The MIT study assumes that absent the regulations that would impose carbon constraints, the only economically feasible option to reduce carbon dioxide from a new coal power plant is to improve plant efficiency. The study did not assess the option of partial carbon dioxide capture at new coal power plants. This option is commercially available on IGCC plants today. If partial capture costs of carbon dioxide (in the range of 15% to 30%) are low enough, state public service commissions may opt to include these added costs as a hedge against future carbon regulations, thereby opening up another significant option besides efficiency to reduce carbon dioxide emissions.

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4. The MIT study assumes that the nearly 2 to 1 carbon capture cost advantage enjoyed by IGCC over PC should not influence technology choice for a new coal power plant today. Future technology advances may narrow or eliminate the gap by the time retrofit is required, or if the gap persists, it may not matter if retrofit costs are so large for both technologies so as to dwarf any difference. These assumptions are important because if advances in carbon capture technology for PC plants cannot close the cost gap with IGCC (or at least not close it in time) the impact could be either stranded investments in new PC plants or continued high emissions of carbon dioxide because the new pulverized coal plant cannot be economically retrofitted.
  5. The MIT study assumes, for the sake of the analysis, that future environmental regulations will be static and not require even lower emissions of sulfur dioxide, nitrogen oxides, mercury from coal plants, or that the solid wastes produced by these plants (including mercury) will not be subject to tighter control. This assumption is important because developers of new coal plants may value IGCC's better environmental performance in hedging the compliance costs of future environmental standards.

The Clean Air Task Force believes that a careful examination of the data do not support either the recommendations that MIT makes for new coal plant construction nor the underlying assumptions that support them. Technology winners and losers are picked in board rooms across the globe everyday as the power sector selects new coal plants to build. These technology choices have a profound impact on our environment now, and can either enlarge or constrain our options to mitigate global warming tomorrow.

First, CATF notes that the 7.5% capital cost and 5% electricity cost premium for IGCC described by the MIT Study are rather small. Given the rather large uncertainties associated with generic cost estimates, the differences may not even exist. But small or large, present costs are not the only economic considerations that must be weighed by the power sector when selecting technology for new coal plants. Developers must consider costs associated with future environmental regulations. Here, as the MIT Study documents, IGCC has a clear advantage over PC technology. The reasonable conclusion to be drawn is that IGCC today has a cost advantage in mitigating risks associated with stricter environmental regulations—both for carbon dioxide and more traditional air, land, and water pollutants.

Second, CATF notes that information about IGCC costs and performance has been changing rapidly over the past 18 months. New technologies have entered the market, detailed

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engineering studies needed to support actual equipment purchases have been completed, carbon capture retrofit options are better understood, and much of this new information is entering the public record as proposed IGCC plants either seek air permits or permission to recover construction costs from state public service commissions. Some of the information relied upon by MIT is now out of date. Other data is simply missing from the study's analysis.

### Information Limitations in the MIT Study

Three broad categories of critical information are missing from or not given appropriate weight in the MIT Study's comparison of the costs and performance of IGCC and PC coal-based power generation systems. These categories are:

1. Real Market Information for IGCC Plants. The general treatment of IGCC technology in Chapter 3 and Appendix A-3 of the study is based on outdated and in some cases, limited information. Therefore the study's conclusions regarding costs for coal-based IGCC, with and without CCS, and especially for low-rank coal, do not reflect current market realities.
2. Non-CO2 Environmental Impacts. The study essentially disregards most non-CO2 environmental costs associated with coal-based power generation and disregards the clear advantages of IGCC in meeting progressively more stringent environmental requirements for criteria air pollutants, mercury, solid waste, and water use.
3. Incomplete Characterization of Carbon Dioxide Capture for PC and IGCC Plants. Several key elements of the study related to technological availability of carbon capture equipment and combustion turbines for IGCC do not correctly represent the advanced status of that technology. Furthermore, the study omits options for partial capture of carbon dioxide (10%--50% capture) that could provide significant steps toward 90% carbon capture. In addition, the study emphasizes the technological potential of novel carbon capture systems for PC plants without acknowledging the significant hurdles those technologies face before they are ready for commercial-scale demonstration and, thus, their practicality and costs remain quite uncertain.

The information missing from the MIT Study is discussed below, along with an evaluation of weaknesses in the study's conclusions due to those omissions.

#### *1.A – Extensive Recent Private-Sector IGCC Engineering Studies*

The treatment of IGCC technology in Chapter 3 of the MIT Study is largely based on conceptual and early feasibility "paper studies" conducted by the Electric Power Research Institute (EPRI), US DOE contractors, and others, that are publicly available and that were largely conducted before the

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study began. In the case of nearly all of EPRI's work, only summary results have been released to the public. None of these older studies address the specific plant configuration (two train, two 7FB turbine 630 MW net generation) being proposed by most IGCC project developers today. As today's configurations will be more efficient and economic than the older configurations, the results of the MIT Study may deviate significantly from true costs and performance.

In contrast, during the time that the MIT Study was developed a very large amount of real engineering work on IGCC was conducted. This work consists primarily of front-end engineering and design (FEED) studies, EPRI CoalFleet project work developing a detailed design manual for first generation commercial IGCCs and exploring the potential to retrofit these plants for carbon capture at some future time, internal engineering analyses conducted by companies such as AEP, who are moving forward to develop first generation commercial IGCC plants, and substantial research and engineering work conducted by IGCC systems vendors like GE Energy and Siemens.

To provide some relative sense of the magnitude of this work, there have been at least five IGCC FEED studies conducted, at an estimated total cost of \$70 million--\$100 million. This represents just one substantial body of engineering knowledge about new IGCC plants and CCS that is not included in the MIT Study.

### *1.B – Significant “Next Generation” IGCC Plant Development*

At least four “next generation” IGCC projects are moving forward in the United States, in addition to the coal gasification plants described below that produce both electricity and chemicals. These projects are AEP's Mountaineer plant in West Virginia, Duke Energy's Edwardsport plant in Indiana, BP's Carson Refinery Hydrogen project in California, and Tampa Electric Company's Polk Power Station Unit 6 in Florida.

The cost information for these “next generation” projects did not become publicly available until months after the MIT study was released. The capital costs associated with these plants, like all major capital projects, has risen due to global commodity price increases and rising labor costs. The impact of this global rise in prices on both IGCC and PC prices may not be fully understood for some time. However, the released cost information may be able to help bracket any cost difference between IGCC and PC. Hearings on Duke Energy's proposed Edwardsport, Indiana IGCC have taken place during the summer of 2007. Also during the summer of 2007, AEP's Mountaineer IGCC plant and Tampa Electric's Polk Power Station Unit 6 filed applications with their respective state public service commissions seeking rate recovery associated with the construction of new IGCC plants.

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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 U.S. (Wabash Station in Indiana and Polk Power Station Unit 1 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 U.S. 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 Ohio 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.

### *1.C – New Market Entry by Major Firms, with IGCC Offerings for Low-Rank Coal*

The MIT Study considered the GE Energy (ex-Texaco), ConocoPhillips (E-Gas), and Shell gasifiers and IGCC systems. A number of new technology vendors have entered the IGCC market since the inception and early work on the MIT Study, however. In the past year, both Siemens and Mitsubishi have developed commercial integrated IGCC packages, offering gasification, combustion turbine with heat recovery steam generator, and steam turbine systems. Siemens acquired the proven gasification technology of the German company Future Energy for use with their turbines, and Mitsubishi developed and tested an air-blown gasifier in Japan for a lower-cost IGCC package now selected by NRG for potential deployment in several locations in the U.S. The performance and cost of these technologies was not considered in the MIT Study, thus rendering obsolete the study conclusion about IGCC costs and performance on low-rank coals.

Of the IGCC systems evaluated in the study, the higher-cost Shell gasifier with dry-feed is generally thought to be best suited to low-rank coals such as sub-bituminous and lignite, and the GE system has generally been considered the least appropriate for low-rank coals. The Future Energy gasifier technology acquired by Siemens has demonstrated many years of operation on low-rank coal, however, and the gasifier developed by Mitsubishi has shown promise on low-rank coals during small-scale tests this year<sup>x</sup>. In addition, GE Energy recently acquired the ability to use a

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new high pressure fuel feeder pump technology that holds promise for allowing use of their gasifier with low-rank coals<sup>xi</sup>. Costs of electricity generation using the Siemens or Mitsubishi IGCC technology, or the new GE process, may well be lower (in relative, inflation-adjusted terms) than those used in the MIT Study, especially for low-rank coals.

### *1.D – Innovative Gasification Systems*

Several companies are developing innovative modular coal gasification systems that may significantly improve gasification performance and lower costs. These include: Texas Syngas (liquid metal bath process), Calderon (adaptation of blast furnace technology), Westinghouse (Plasma arc technology), and Great Point Energy (catalytic process). Another emerging innovative approach to coal gasification that shows promise of lower gasification costs and substantially lower environmental impacts is underground coal gasification (UCG), which is just beginning to enter the commercial market. A successful modern pilot project was conducted several years ago in Australia and the first modern commercial UCG project focused on power production began this January in Mpumalanga, South Africa.

While the future of coal gasification may well be dominated by these innovative processes, *none were even mentioned in the MIT study.*

### *1.D - Polygeneration Offers Potential for Real Cost Reductions and for Sequestration*

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. Recently Eastman Chemical Company announced plans for coal and petcoke-based gasification systems in Texas and Louisiana, where high pressure steam, hydrogen, methanol, and ammonia will be produced<sup>xii</sup>. At the Eastman plants carbon dioxide will be captured and sold for enhanced oil recovery (EOR) as market conditions allow<sup>xiii</sup>.

These developers are pursuing “hybrid” projects because they may have economic advantages over “power only” IGCC plants, including reduced overall project cost and high availability—particularly in projects using several of the new Siemens gasifiers. In addition, the hybrid projects offer attractive overall 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.

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Some of these projects are close to final permitting and full financing. 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.

## *2 – Criteria Air Pollutant Emissions, Mercury Emissions, Water Use, and Solid Waste Generation*

The MIT Study acknowledges the potential benefits of IGCC for reducing emissions of criteria air pollutant and mercury emissions at a lower cost than is possible for PC, but indicates that these reduced costs are not sufficient to reverse the overall cost advantage ascribed to PC over IGCC (without carbon capture). The study is incomplete in this regard, as it does not evaluate the impacts of:

1. costs for emissions allowances purchases;
2. the very real possibility that power plant developers will pay an investment premium to insure against unanticipated environmental controls risks;
3. extant analysis methods capable of placing a value on IGCC's less costly control of conventional pollutants; and
4. Societal costs associated with differences in coal technology environmental performance.

An indication that developers in the power sector may be factoring in these considerations can be seen in recent IGCC air permit application trends. Most paper studies of IGCC suggest that sulfur dioxide control with amines and nitrogen oxide control with diluent injection are the standard pollution controls for IGCC technology. In the fall of 2006, however, five air permit applications were filed for IGCC plants. All of these applications included greater sulfur control through Selexol and about half of the applications included SCR technology to further reduce NOx. Since the release of the MIT Study, two additional IGCC plants have been issued draft or final air permits that include these more effective technologies. These much deeper levels of pollution reduction indicate that developers must be finding some economic reason for seeking pollution reduction levels that are deeper than that which can be achieved today with pulverized coal or have been historically achieved at existing IGCC plants.

### *3.A - Carbon Capture Technologies for PC Plants are not Commercially Available*

The MIT Study projects cost and performance for post-combustion capture of carbon dioxide from air- and oxygen-blown PC plants based on a very limited set of engineering data. While extrapolation from this early data is a reasonable technique, the presentation in the study obscures the fact that neither amine scrubbing at commercial power plant scale nor oxyfuel firing are close to

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commercial availability. Oxyfuel combustion of pulverized coal is in its infancy, with the largest unit in operation a mere 1.5 MW (thermal) test facility in Alliance, Ohio<sup>xiv</sup>. While these technologies should certainly be the subject of continued research, they are not likely to present real opportunities for carbon capture from coal use in the near term.

Other technologies for post-combustion capture of CO<sub>2</sub> from PC plants have been discussed but at present those technologies remain speculative and appear to present significant environmental and/or economic challenges (e.g., chilled ammonia).

### *3.B - Carbon Capture Technology for IGCC is Commercially Available and Proven*

In stark contrast to the undemonstrated carbon capture technology for PC plants, for IGCC plants carbon capture is considered a proven and commercially available technology. The necessary components of a carbon capture system for IGCC (water-gas shift reactors, acid gas removal systems, and CO<sub>2</sub> compression) have been demonstrated at numerous facilities around the world, including the Great Plains Synfuels plant in South Dakota where 1 million tons of CO<sub>2</sub> per year is captured from the gasification of lignite and used for EOR in Canada<sup>xv</sup>. While no existing IGCC captures carbon dioxide, industry confidence in the technology is very high. In recent testimony before the Florida Public Service Commission, Tampa Electric described the state of carbon capture equipment from IGCC in these terms: “CO<sub>2</sub> capture from syngas is a commercially proven process that has been used for decades around the world”<sup>xvi</sup>.

### *3.C – Partial Carbon Dioxide Capture at IGCC Plants*

One option that did not receive any analysis in the MIT Study is partial capture of carbon dioxide. Full capture is normally associated with levels near 90% capture. However, particularly with IGCC plants, lower levels are possible—between 20% and 50%--and they offer distinct cost and learning curve advantages. For example, the proposed Mesaba IGCC plant in MN outlined a strategy before the Minnesota Public Service Commission in the fall of 2006 to capture up to 30% of the carbon dioxide found in the syngas. Likewise, in the summer of 2007, the Indiana Wildlife Federation and the Clean Air Task Force raised the option of partial capture before the Indiana Utility Regulatory Commission. Testimony from the case showed an estimated 15% -20% of the CO<sub>2</sub> in the syngas could be extracted from the syngas without shift reactions. Options for greater than 50% capture are being evaluated as part of NRG’s proposed IGCC plant in New York. In the absence of regulatory constraints on carbon dioxide, partial capture offers several key advantages:

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- Partial capture provides greater carbon dioxide reductions than can be accomplished by relying solely on plant efficiency improvements.
  - Partial capture provides the power sector with early experience with both carbon capture and storage experience.
  - Partial capture can be accomplished at costs that state public service commissions may find acceptable in advance of federal carbon requirements.
  - Partial capture can potentially provide hundreds of thousands of tons per year of compressed carbon dioxide from a plant that may be needed to establish the suitability of storage formations for large-scale carbon dioxide injection.

### *3.D - Combustion Turbines for use with High Hydrogen Syngas are Commercially Available and Proven*

In order to generate electricity in an IGCC plant while also capturing carbon dioxide the IGCC combustion turbine must burn syngas with an elevated concentration of hydrogen. In discussion of carbon capture options for IGCC plants the MIT Study implies that combustion turbines capable of operating on syngas with high hydrogen content present extreme engineering challenges<sup>xvii</sup>. This implication is misleading. In fact, according to GE Energy, a number of different turbine designs capable of burning gas with very high hydrogen concentration are commercially available today. GE Energy recently informed CATF of the following:

*There are 24 GE turbines that are operating with hydrogen content above 50%. We have several F-class machines operating on 44.5% hydrogen. Our hydrogen fleet leader 6B has been routinely operating with 85%-97% hydrogen and with 96.5% availability in uninterrupted operation 24 hours/day since 1997. In 1995, GE completed full scale testing for combustors for our FA-class machines with hydrogen fuel up to 90%. These tests demonstrated emissions, dynamics and component temperatures to be well within design guidelines. Similarly, in 2006 we completed full-scale combustion validation testing with hydrogen for our IGCC FB machine and similarly achieved emissions, dynamics and component temperatures well within design guidelines.*

*We are also able to achieve full output rating on shifted and decarbonized syngas. In the context of an IGCC plant operating with shift and carbon capture and using available nitrogen for diluent NOx control, the turbine will be presented with fuel having approximately 55% hydrogen. The diluent provides benefits by reducing combustion NOx and increasing turbine gross output. After diluent addition, hydrogen fuel is very similar to syngas which normally contains hydrogen as a major component. After combustion, the*

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*physics in terms of hot gas path is well understood and quantified by our detailed performance cycles.*

*Finally, the GE IGCC 7FB has been commercially offered for high hydrogen fuel generated from carbon capture. We would also note that our 9E machines have also been commercially offered for the Peterhead project in the UK that will be operating with hydrogen from decarbonized natural gas. Hydrogen therefore is an acceptable fuel for GE's heavy duty gas turbines.<sup>xviii</sup>*

GE Energy further indicates that retrofitting the 7FB turbines that will be used in some of the proposed IGCC plants will be straightforward:

*These [7FB syngas turbines] are easily retrofitted. No change in HGP excepting combustors. Changes are also required in enclosure instrumentation, monitors and sensors, as well as an increase in purge capacity and skid.<sup>xix</sup>*

*Conclusion: The MIT Study Offers Sound and Useful Recommendations with Respect to Advancing Carbon Storage, but the Study's Recommendations for New Coal Plants Would Harm Rather Than Help Efforts to Reduce the Environmental Impacts From Coal.*

Stripped to its essence, the MIT study concludes that we needn't begin to deploy coal gasification—and needn't discourage construction of pulverized coal plants today—because post-combustion CO<sub>2</sub> controls or oxy-combustion retrofit for pulverized coal plants *may* materialize in the future. In doing so, the study ignores the very risks and timing problems that the study itself documents: the current acceleration of construction of pulverized coal plants in China, and possibly in India a decade from now, along with a likely new generation of coal plant build in the OECD (albeit at a slower pace).

Recently, the International Energy Agency estimated that total world pulverized coal plant construction between now and 2030 would represent another 1.5 Gigatons per year of carbon emissions continuing for decades—a 20% addition to current annual world carbon emission levels and roughly triple the amount currently coming from the U.S. power sector today.<sup>xx</sup> At more realistic rates of China coal plant construction of 50 GW per year (presently the rate is roughly 70 GW), during this period, the total annual incremental carbon emissions would be roughly 2 Gigatons per year.<sup>xxi</sup> The MIT report suggests implicitly that all or most of this new coal capacity can be cost effectively retrofitted with as yet undeveloped carbon capture technology.

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CATF submits that this is an unwise bet, one equivalent to adopting a poor diet on the theory that a “miracle drug” will emerge to undo the inevitable health effects of such a choice. Regardless of what politicians say to “warn” coal plant developers that they must bear the consequences of future carbon policy, those warnings, as the MIT report suggests, will likely be heavily discounted out of disbelief as to the likelihood or the size of any carbon disincentive, or belief that those consequences are likely to materialize well after the plants have returned their investment.

The MIT report may be correct in this assumption, but it seems imprudent to bet 1.5-2 Gigatons/year of carbon on that belief.

### The Way Forward

*In contrast, CATF proposes that a sensible policy towards the future of coal would:*

- ✓ Ban the construction of coal combustion plants due to their inherently unacceptable air, water, solid waste, and climate impacts and the high risk that a practical carbon capture and storage technology will not be available within the next 10-20 years.
- ✓ Rapidly commercialize the use of advanced coal gasification, including integrated gasification combined cycle, because of its significantly smaller environmental footprint as compared with coal combustion.
- ✓ Rapidly demonstrate the feasibility of large scale geologic storage of carbon dioxide.
- ✓ Wherever possible, couple gasification plants and carbon storage at a demonstration scale.
- ✓ Develop a U.S. target for IGCC/CCS projects comparable to EU goal of developing 10 to 12 fossil/CCS projects by 2015<sup>xxii</sup>.
- ✓ Develop an appropriate regulatory framework for carbon capture and storage at the state and federal levels as expeditiously as possible.
- ✓ Set a date certain by which coal and other fossil plant must practice carbon capture and storage; the EU is contemplating such a measure, circa 2020.<sup>xxiii</sup>
- ✓ Reform coal mining practices worldwide, and impose stringent federal regulation of coal plant solid wastes.

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## NOTES

<sup>i</sup> See, for example, *Energy Technology Perspectives 2006*, International Energy Agency, 2006.

<sup>ii</sup> The Clean Air Task Force (CATF) is a national environmental organization dedicated to restoring clean air through scientific research, public education, and legal advocacy. The Clean Air Task Force is comprised of 20 professionals with backgrounds in science, engineering, law, economics, and public outreach headquartered in Boston but located throughout the United States. For more on CATF and CATF's position with respect to coal see *Taming Coal* at [http://www.catf.us/projects/power\\_sector/advanced\\_coal/CATF\\_Taming\\_Coal\\_March\\_2007.pdf](http://www.catf.us/projects/power_sector/advanced_coal/CATF_Taming_Coal_March_2007.pdf)

<sup>iii</sup> *The Future of Coal: Options for a Carbon Constrained World: An Interdisciplinary MIT Study*, Massachusetts Institute of Technology, 2007.

<sup>iv</sup> MIT Study at page 30, Table 3.5.

<sup>v</sup> MIT Study at page 36, Table 3.7.

<sup>vi</sup> MIT Study at page 30, Table 3.5.

<sup>vii</sup> MIT Study at page 36, Table 3.7.

<sup>viii</sup> MIT Study at page 98.

<sup>ix</sup> MIT Study at page 96.

<sup>x</sup> *Development of IGCC Technology with Carbon Capture*, T. Fujii, Presentation to Sixth Annual Conference on Carbon Capture and Sequestration, 2007.

<sup>xi</sup> *GE Advances its Cleaner Coal Solutions for Low Rank Coals*, GE Energy, News Release, June 15, 2007.

<sup>xii</sup> *Eastman Announces Key Role in 2 Major Gulf Coast Gasification Projects*, Eastman Chemical Company, Press Release, July 27, 2007.

<sup>xiii</sup> Personal communication from David Denton, Eastman Chemical Corporation, to Mike Fowler, CATF, July 27, 2007.

<sup>xiv</sup> *State of the Art of Oxy-Coal Combustion Technology for CO<sub>2</sub> Control from Coal-Fired Boilers*, Farzan, H, et al, Babcock & Wilcox Technical Paper presented to Third International Conference on Clean Coal Technologies for Our Future, 2007

<sup>xv</sup> *Special Report on Carbon Capture and Sequestration*, Intergovernmental Panel on Climate Change, 2005

<sup>xvi</sup> Testimony of Mark J. Hornick, *In Re: Tampa Electric's Petition to Determine Need for Polk Power Plant Unit 6*, submitted to the Florida Public Service Commission on July 20, 2007.

<sup>xvii</sup> "CO<sub>2</sub> capture requires higher pressures, shift reactors, and turbines designed to operate with a gas stream that is predominantly hydrogen. Turbines that do this are yet to be deployed." MIT Study at page 98 (emphasis added). "The Design of a high-efficiency combustion turbine for high hydrogen concentration feeds is different from combustion turbines optimized for syngas, requires further development, and has very little operating experience." MIT Study at page 38.

<sup>xviii</sup> Personal communication to Joe Chaisson, CATF, 01/05/2007.

<sup>xix</sup> Ibid.

<sup>xx</sup> IEA, World Energy Outlook, data Tables.

<sup>xxi</sup> CATF calculation from IEA World Energy Outlook Data Tables.

<sup>xxii</sup> <http://www.zero-emissionplatform.eu/website/>

<sup>xxiii</sup> "COMMUNICATION FROM THE COMMISSION TO THE COUNCIL AND THE EUROPEAN PARLIAMENT. Sustainable power generation from fossil fuels: aiming for near-zero emissions from coal after 2020" January 10, 2007.