# Warming Advantage

### 1AC – Warming

#### Advantage \_\_\_ is warming

#### CCS is feasible and is the only way to solve warming – other energy solutions are insufficient

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II. CCS is Critical to a Zero-Carbon World¶ The title of a recent article by two leading climate researchers sums up the message emerging from the latest scientific evidence: “Stabilizing climate requires near-zero emissions.”1 Even the most dramatic, 50–80 percent CO2 reduction goals generally being discussed likely are not enough. We need a near-100-percent reduction by mid-century at the latest. Energy systems need to change faster.2¶ Part of the urgency stems from the reality that warming impacts from today's emissions may last as long as 1,000 years3; we cannot assume that reducing emissions “tomorrow” means we can reverse damage done to date. Worse, we risk passing irreversible “tipping points” that trigger abrupt and catastrophic changes, such as major ice melt in the polar regions, extensive rainforest loss, and radical alterations of critical weather and ocean circulation patterns. Such tipping points could be in sight if current emission trends continue for another decade or more.4¶ Unfortunately, we are moving in the wrong direction fast. In recent years, China has added coal capacity at a rate of one large new plant per week (70–100 GW per year)5 and India – potentially the world's most populous country by 2030 – could ramp up as well. The International Energy Agency (IEA) currently projects that world coal capacity will nearly double by 2030, an increase of 1,310 GW.6 If this build-out occurs without CCS, it will increase world CO2 emissions by about 12.6 billion metric tons annually7—roughly twice current U.S. emissions from all sources. Clearly, China, India, and other developing countries will “make or break” any global effort to cut CO2 emissions—in fact, changes in their emissions trajectory will overwhelm any plausible reductions by developed countries.¶ Numerous studies—including studies by the IEA, the Intergovernmental Panel on Climate Change, the U.S. Climate Change Science Program (CCSP), and several major environmental organizations—have assessed the relative roles that different technologies might play in meeting various climate stabilization targets. This body of work (and more) suggests that CCS has economic advantages relative to other options and is likely to be indispensable in achieving a zero-carbon energy mix. Specifically, these studies (which are reviewed and summarized at the CATF Web site, http://www.catf.us/projects/power\_sector/advanced\_coal/) find the following:¶ • Stabilizing atmospheric CO2 at 450 parts per million by volume (ppmv) could require more than 250 GW of fossil power with CCS globally by 2030 (U.S. CCSP, 2007)8;¶ • Fossil fuels with CCS might need to provide 26 percent of global energy supply under stabilization constraints (WWF, 2007)9;¶ • Combined power sector and industrial CCS could provide the largest single CO2 abatement option in the U.S. in 2030 (McKinsey & Co., 2007)10;¶ • Costs for stabilizing CO2 with widespread CCS deployment could be reduced 30 percent or more compared to the costs without CCS (IPCC, 2005)11;¶ • CCS is likely to play a role roughly equivalent to that of energy efficiency and renewables in climate mitigation (IPCC, 2007).12¶ A. A demanding challenge¶ Figure 1 illustrates the magnitude of the global energy challenge. Each rectangle is drawn with height proportional to average per capita electricity consumption and width proportional to population.13 The area of each rectangle represents total consumption in 2004. Shades are used to indicate what fraction of electricity comes from coal (middle is between one-third and two-thirds, light is less than one-third, and dark is more than two-thirds). Clearly, if a reasonable target were set for per capita electricity consumption, even large reductions in the developed world—say 30 percent—would not offset enormous demand growth in the developing world. Massive capacity additions would still be needed. Continued population growth in developing countries, along with urbanization, industrialization, and income growth on a mass scale will only add to these pressures.¶ As already noted, rapid growth is well underway in developing countries, with China adding more coal-fired capacity in 2006 and 2007 than exists in Western Europe today and India planning 92 GW of new capacity (most of it thermal power) in the next five years.14 The current global economic downturn may moderate these trends, but only temporarily.¶ B. Other zero-carbon energy options: Not betting the farm¶ While it would be convenient if a combination of efficiency, truly “clean” renewable, and other zero-carbon sources15 could suffice to meet all the world's energy needs, common sense casts serious doubt on this proposition.16 First, there will be limits to how far we can reduce consumption with energy-efficiency policies. Policy efforts in the state of California have reduced per capita electricity demand by roughly 10 percent relative to the U.S. average,17 yet each Californian still uses about 7,000 kWh of electricity per year, more than almost anyplace in the world outside North America (and nearly five times the level of the average Chinese). Moreover, California's overall demand is still growing. Meanwhile, other low-carbon supply options confront their own formidable deployment challenges. For example, intermittency, lack of long-distance transmission capacity to remote sites, and land-use requirements remain hurdles to a massive scale-up of renewable sources like wind and solar power, despite continued technology improvements. The scale-up challenge is truly daunting: displacing just 1 Gt of annual CO2 emissions (out of the 7 Gt needed just to flatten global emissions by mid-century) would require 2,000 GW of wind energy—twice the current U.S. base of all installed electrical capacity. Alternatively, it would require a three-fold expansion of current world nuclear capacity.18¶ Meanwhile, movement toward an electrified vehicle fleet, in the U.S. and worldwide, may be desirable on climate and energy security grounds, but it will also contribute to growing electricity demand. Given remaining cost and technology challenges and ongoing concerns about indirect land-use impacts, we cannot count on biofuels to provide truly carbon-neutral solutions for the vehicle sector within the next few decades.19 If electricity therefore has to play a larger role, decarbonizing fossil-based power production becomes that much more urgent.¶ Obviously it is extremely difficult to forecast the deployment trajectory of different technologies decades into the future. But it would be unwise to “bet the farm” that fossil fuels in general, and coal in particular, do not have a significant role to play for some time to come.¶ C. History suggests that rapid scale-up to a gigatonne-scale CCS industry is well within our capabilities¶ For a typical 500 MW coal-fueled power plant, CCS involves separating, transporting, and storing about 4 million tonnes of CO2 each year.20 Compressed to a dense, supercritical state this mass of CO2 would occupy a space roughly 500 meters on each side and 33 meters thick.21 Applying the same technology at hundreds of plants represents the central challenge of CCS: the existing fleet of coal plants in the U.S.—at 320 GW combined capacity—produces more than 2 Gt of CO2 each year.¶ Fortunately, analogues from other industries suggest that this sort of scale-up is feasible over the next two decades. In a single 20-year period between 1950 and 1970, for example, installed electric-generating capacity in the U.S. more than quadrupled, from 69 GW to 316 GW. This matches the scale of the global CCS build-out that some studies suggest is necessary by 2030 to meet some climate targets. And it is significantly less capacity than China is expected to add over the same time period.22 Similarly, approximately 150,000 miles of natural gas pipeline were built in the U.S. between 1960 and 1980.23 The CO2 pipeline network needed to support several hundred GW of CCS-equipped power plants could be much smaller, perhaps less than 30,000 miles in some scenarios.24 Assuming 35 CO2 injection wells per GW implies roughly 10,000 wells would be needed for sequestration in this scenario—a large number, but well below the number of oilfield brine injection wells currently operating in the U.S. (150,00025) and equivalent to just six months of natural gas drilling activity in the Alberta Basin (20,000 wells per year26). Figure 2 compares the CCS infrastructure “lift” to comparable energy-system scale-ups in the past.27¶ In sum, experience suggests that large-scale CCS can be achieved over the next several decades. It also suggests that an entirely new, specialized industry with CO2 as its central, fungible commodity will need to emerge. Similar to the major energy industries that came before, this evolution may occur from the bottom up—as capture systems at individual plants combine to form regional systems with multiple CO2 sources, pipeline networks, and sequestration sites. Moreover, this new industry may need to be organized and governed as a regulated system in its own right.

#### CCS is necessary and sufficient to solve warming – and there is political momentum for it now

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The Purpose of CCS¶ There is a broad political consensus that the global temperature rise should be limited to 2°C, compared with preindustrial temperatures. However, such declarations lack urgency, targets, or specified time scales. The scientific analysis has swung to define CO2 limits not as a tonnage released per year, but as the total mass of fossil carbon released during this geologically short industrial time span (4). CO2 emissions must therefore start to fall from 2020 onward. CCS is unavoidable if fossil fuels continue to be burned at more than 10% of the present rate. It is surprising, then, that so few CCS projects are underway.¶ Fossil fuel combustion supplies more than 85% of energy for industrial activities (5) and is thus the main greenhouse gas contributor. Coal is on a path to supply 28% of global energy by 2030, as part of a 57% increase in CO2 emissions (5). CCS is a direct emissions mitigation option, usually considered as an interim system to enable a 50-year transition away fromfossil fuels. Although current CCS technologies are only at the pilot stage, the scale of the main ambition is massive: to fit all coal and gas power plants with CCS by 2050 and reduce world CO2 emissions from energy by 20% (2). Accordingly, CCS will incur incremental costs. For example, in the U.K., CCS may cost each household an extra 10% per year for electricity. That may seem expensive, but if CCS is developed now as part of a portfolio of global climate protection, the costs of CO2 abatement required in 2050 are predicted to reduce from $500 to $50 per ton (2).¶ CCS strips out, purifies, and concentrates CO2 emissions from fossil fuel combustion at large single sources such as power plants (Fig. 1). Three methods of CO2 capture are currently being investigated (1). Postcombustion capture separates the CO2 with the use of chemical solvents, precombustion capture chemically strips off the carbon, leaving hydrogen to burn, and oxyfuel combustion burns coal or gas in denitrified air to yield only CO2 and water. After leaving the power plant, the captured CO2 is pressurized to 70 bar, forming a liquid that can be transported to a storage site, where the fluid is injected into rock pores deeper than 800 m below the surface (6, 7). Good choices of storage sites will retain CO2 without appreciable seepage for tens of thousands of years. Monitoring will be required for decades into the future, combined with techniques to remediate deficient storage. In principle, CCS can be applied not only to power plants but also to large industrial sites, such as refineries, steel making, fertilizers, ethanol fermentation, and cement manufacture (1). However, these applications are proving to be quite slow to develop on a global level. The present CCS discussion focuses on power plants fired by fossil fuels (coal, gas, and oil) and sometimes co-fired with biomass.

#### The US is ready to fund CCS now

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Looking ahead, the niche for carbon storage from CO2 enhanced hydrocarbons recovery, including CO2-EOR, is poised to grow. Fig. 7 displays the potential volume of CO2 stored through 2025 by announced carbon-storage projects. The projects were broadly grouped by the probability of their completion: currently operating (100% likelihood), possible (estimated 50–90% likelihood), and speculative (estimated 0–50% likelihood) (Rai et al., 2008). The projects are color coded according to the destination of the CO2: enhanced oil recovery (EOR), enhanced coal-bed methane (ECBM), and Natural Gas (NG) operations (Black); saline aquifers and depleted oil & gas fields (White); unknown (Gray). It is clear that most of the “operating” and “possible” projects are related to EOR, ECBM, or NG operations. This is not surprising given that as yet there is no direct economic incentive for CCS operations in most cases; besides government grants, at present the only other way to make CCS projects economically viable is to use the CO2 for producing more hydrocarbons to take advantage of relatively high oil and gas prices (compared with historical levels).¶ More electric-power-oriented CCS projects appear in the pipeline post-2015 (5 Mt CO2/yr in 2010; 65 Mt CO2/yr in 2015; and 90 Mt CO2/yr in 2025). Wider application of CCS to the electric-power industry is essential if CCS is to be a central player in efforts to slash CO2 emissions ( [EPRI, 2007] and [WRI, 2008]). A niche market for commercial-scale carbon-capture technologies—presently by far the most expensive step in the CCS value chain—has been missing so far. The situation is changing as several governments plan to ramp financial support for CCS demonstration projects. Governments’ interest in CCS is generally rooted either in concerns about global warming or in the desire to continue to use coal or unconventional oil reserves even in a carbon-constrained world. Concerned governments, notably the US, European Union (EU), Australia, and Canada (Alberta and British Columbia), are gearing up to provide multi-billion dollar support for CCS-related R&D projects ( [AG, 2008], [Boucher, 2008] and [EPR, 2008]). Based on development of the industries discussed earlier in the paper, the creation of a niche market for large CCS projects based on special government support appears to be the normal course of development.¶ Businesses recognize the strategic value of CCS as well. But given the uncertainties around CO2 regulation and the high capital intensity of CCS (even on a semi-commercial scale), they have been unwilling to take on much of the risk. Markets are most likely to spring up in situations where strong government interest in CCS coincides with strong business interest, for example in industrial gasification applications or in chemicals industries. Here again, those businesses for which CCS is strategically highly important (or who see the ability to leverage an existing competence to grow a new business) will be more likely to share the early adoption risks. Such businesses include coal producers and suppliers of CCS technology. If future regulations constrain carbon emissions more severely than current ones, the success of CCS will be important to maintaining a strong market for coal. The sheer potential scale of CCS applications also make CCS attractive for providers of technology—combustion technology (GE, ConocoPhillips, Siemens), carbon-capture technology (Alstom, Praxair, Fluor, and others), and sequestration technology (Oil majors, Schlumberger, and others).

#### But a pipeline network is a necessary condition for scaling up CCS

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An infrastructure must be developed to move CO2 from its source to the storage site. Transporting large quantities of CO2 is most economically achieved with a pipeline. An important technical consideration in thedesign of CO2 pipelines is that the CO2 should remain above its critical pressure. This can be achieved by recompressing the CO2 at certain points along the length of the pipeline. Recompression is often needed for pipelines over 150 km (90 mi) in length. However, it may not be needed if a sufficiently large pipe diameter is used. For example, the Weyburn CO2 pipeline runs for 330 km (205 mi) from North Dakota to Saskatchewan, Canada, without recompression (Hattenbach et al., 1999).¶ Natural gas pipelines are a good analogue to a CO2 pipeline network for purposes of understanding costs. A survey of North American pipeline project costs yields several pertinent observations. First, for a given pipeline diameter, the cost of construction per unit distance is generally lower, the longer the pipeline. Second, pipelines built nearer populated areas tend to be more expensive. Finally, road, highway, river, or channel crossings and marshy or rocky terrain also greatly increase the cost (True, 1998).¶ The cost data for natural gas pipelines consist of cost estimates filed with the United States' Federal Energy Regulatory Commission and reported in the Oil and Gas Journal (True, 1990, 1998). Costs are broken down into materials, labor, right-of-way, and miscellaneous components. Materials can include line pipe, pipe coating, cathodic protection, and telecommunications equipment. Right-of-way costs include obtaining the right-of-way and allowing for damages. Miscellaneous costs generally cover surveying, engineering, supervision, contingencies, allowances for funds used during construction, administration and overhead, and regulatory filing fees.¶ Based on these data, Heddle et al. (2003) estimated costs for CO2 transport. Fig. 2 shows that economies of scale are reached with CO2 flow rates in excess of 10 million metric tons per year (equivalent to CO2 emissions from about 1500 MWe of coal-fired power). At these flow rates, transport costs are under $1 per metric ton CO2 per 100 km.¶ At scale, one can conclude that transport of CO2 over moderate distances (e.g., 500 km) is both technically and economically feasible. The major challenge is building up the transportation infrastructure. Three questions related to this challenge are¶ • What will the pipeline network look like?¶ • What comes first, pipelines or capture plants?¶ • How will the pipelines be regulated?¶ Currently, there are two regional CO2 pipeline networks in the United States, one centered in West Texas and the other in Wyoming. Their purpose is to deliver CO2 for EOR projects. Because CO2 storage reservoirs are widely distributed, as are coal-fired power plants, one can make the case that future pipeline networks will continue to be regional in nature. The alternative model is that of natural gas pipeline networks, which are national (and even multinational) in nature. At least initially, the regional model is preferred, because regional networks would be more easily implemented and would carry lower total costs than a national network.¶ Implementing pipeline networks is a classic “chicken and egg” problem. It is not worth building a pipeline network without a critical mass of capture plants to feed CO2 into the network. However, without the transport infrastructure in place, it is much more difficult to develop CCS projects. Somerecent studies (e.g., Chrysostomidis et al., 2009)have looked at the feasibility of developing CO2 pipeline networks in the North Sea and in Alberta, Canada. Neither has moved beyond the study phase because of the large investment costs required, coupled with the absence of a strong enough carbon price signal.¶ CO2 pipelines are not (yet) governed by regulatory regimes like those for oil and natural gas pipelines. However, as CO2 pipeline networks grow, they will face increasing regulation. Issues to be addressed include access, pricing, and antitrust. It should be noted that there are significant differences between the regulatory regimes for oil and for natural gas pipelines. The future regulatory regime for CO2 pipelineswill depend in part on the industrial organization of the sector. These issues are discussed in more detail by de Figueiredo et al. (2007).

#### CCS gets modeled globally – it’s the only way to motivate international action

MIT, 7

(“MIT PANEL PROVIDES POLICY BLUEPRINT FOR FUTURE OF USE OF COAL AS POLICYMAKERS WORK TO REVERSE GLOBAL WARMING,” March 14, 2007, http://web.mit.edu/coal)

Washington, DC – Leading academics from an interdisciplinary Massachusetts Institute of Technology (MIT) panel issued a report today that examines how the world can continue to use coal, an abundant and inexpensive fuel, in a way that mitigates, instead of worsens, the global warming crisis. The study, "The Future of Coal – Options for a Carbon Constrained World," advocates the U.S. assume global leadership on this issue through adoption of significant policy actions. Led by co-chairs Professor John Deutch, Institute Professor, Department of Chemistry, and Ernest J. Moniz, Cecil and Ida Green Professor of Physics and Engineering Systems, the report states that carbon capture and sequestration (CCS) is the critical enabling technology to help reduce CO2 emissions significantly while also allowing coal to meet the world's pressing energy needs. According to Dr. Deutch, "As the world's leading energy user and greenhouse gas emitter, the U.S. must take the lead in showing the world CCS can work. Demonstration of technical, economic, and institutional features of CCS at commercial scale coal combustion and conversion plants will give policymakers and the public confidence that a practical carbon mitigation control option exists, will reduce cost of CCS should carbon emission controls be adopted, and will maintain the low-cost coal option in an environmentally acceptable manner." Dr. Moniz added, "There are many opportunities for enhancing the performance of coal plants in a carbon-constrained world – higher efficiency generation, perhaps through new materials; novel approaches to gasification, CO2 capture, and oxygen separation; and advanced system concepts, perhaps guided by a new generation of simulation tools. An aggressive R&D effort in the near term will yield significant dividends down the road, and should be undertaken immediately to help meet this urgent scientific challenge." Key findings in this study: Coal is a low-cost, per BTU, mainstay of both the developed and developing world, and its use is projected to increase. Because of coal's high carbon content, increasing use will exacerbate the problem of climate change unless coal plants are deployed with very high efficiency and large scale CCS is implemented. CCS is the critical enabling technology because it allows significant reduction in CO2 emissions while allowing coal to meet future energy needs. A significant charge on carbon emissions is needed in the relatively near term to increase the economic attractiveness of new technologies that avoid carbon emissions and specifically to lead to large-scale CCS in the coming decades. We need large-scale demonstration projects of the technical, economic and environmental performance of an integrated CCS system. We should proceed with carbon sequestration projects as soon as possible. Several integrated large-scale demonstrations with appropriate measurement, monitoring and verification are needed in the United States over the next decade with government support. This is important for establishing public confidence for the very large-scale sequestration program anticipated in the future. The regulatory regime for large-scale commercial sequestration should be developed with a greater sense of urgency, with the Executive Office of the President leading an interagency process. The U.S. government should provide assistance only to coal projects with CO2 capture in order to demonstrate technical, economic and environmental performance. Today, IGCC appears to be the economic choice for new coal plants with CCS. However, this could change with further RD&D, so it is not appropriate to pick a single technology winner at this time, especially in light of the variability in coal type, access to sequestration sites, and other factors. The government should provide assistance to several "first of a kind" coal utilization demonstration plants, but only with carbon capture. Congress should remove any expectation that construction of new coal plants without CO2 capture will be "grandfathered" and granted emission allowances in the event of future regulation. This is a perverse incentive to build coal plants without CO2 capture today. Emissions will be stabilized only through global adherence to CO2 emission constraints. China and India are unlikely to adopt carbon constraints unless the U.S. does so and leads the way in the development of CCS technology. Key changes must be made to the current Department of Energy RD&D program to successfully promote CCS technologies. The program must provide for demonstration of CCS at scale; a wider range of technologies should be explored; and modeling and simulation of the comparative performance of integrated technology systems should be greatly enhanced.

#### The plan spills over to other emissions cuts and international actions

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further considerations for public policy¶ CCS has considerable potential to reduce CO2 emissions not only by a significant amount but also at a social cost that most economists would not consider prohibitive, particularly in comparison to the social costs predicted for a business-as-usual scenario with unregulated carbon emissions. The certification of known CCS technologies for power plants on a commercial scale should therefore become a priority. In the U.S., one of the most prominent such efforts is the FutureGen project in Illinois which was shelved in 2008 but now seems destined for continuation, with partial funding provided by the Department of Energy. While commercial scale certification is still pending, corporate and public decision makers will have to weigh the costs and benefits of investing in new power plants that lend themselves to being retrofitted with CCS capabilities.¶ The ability to capture CO2 at fossil fuel power plants should also have positive spillover effects on other parts of the emissions pie. For instance, the transition to electric cars could become more attractive once the effective carbon tax passes the mark of $25 per tonne, because CCS effectively shields electricity prices from higher CO2 charges. Similar substitution effects will emerge for the use of coal itself. In other parts of the world coal is still widely used in industrial processes to power machinery and equipment. The emergence of a carbon tax, coupled with the availability of CCS, will provide incentives for these industrial processes to rely increasingly on electric power.¶ In the upcoming negotiations over a global climate agreement, the participation of non- OECD countries, including China and India, is considered crucial. Both of these countries rely heavily on coal-fired power plants and many developing nations envision reliance on fossil fuels for their growing electricity needs. The availability of CCS technology for these countries should be a major factor in their willingness to join an international climate agreement that embraces aggressive CO2 caps.

#### Pilot CCS projects have been successful and storage capacity is high

ICFI 9 (ICF International, a firm that partners with government and commercial clients to deliver professional services and technology solutions, February 2009, “Developing a Pipeline Infrastructure for CO2 Capture and Storage: Issues and Challenges,” http://www.ingaa.org/File.aspx?id=8228)

• The types of geologic formations suitable for CO2 are depleted natural gas and oil reservoirs, saline aquifers, coal beds, and shales.¶ • Despite little experience in large scale geologic storage of CO2 in the United States, developments at the Sleipner in the North Sea, In Salah in Algeria, and Weyburne in Saskatchewan have been successful.¶ • To give a sense of scale, the estimated geological storage capacity in the Lower 48 states is equivalent of over 450 years at recent U.S. GHG emissions rates. The Western Canadian Sedimentary Basin of Canada has a partially estimated geological storage capacity of over 100 years at recent Canadian GHG emissions rates. The full geologic storage capacity in Canada may be about 2,000 years equivalent.

#### Industrial analogs prove CCS could work

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4. Selection of industrial analogs to CCS¶ As mentioned above, we have chosen to analyze the development of the nuclear power, LNG, and SO2-scrubber industries. Table 1 shows how the challenges of each of these industries in their infancy compared with the present obstacles facing the CCS industry. Both LNG and nuclear power projects are very capital intensive, and project costs often reach billions of dollars. Like CCS, the value chain for these two industries also involves several players who coordinate complex activities. For LNG the value chain includes gas production, liquefaction, sea transport, regasification, and supply to consumers. For nuclear power, in addition to the usual steps in power generation and supply, the value chain involves fuel mining and processing, and waste handling and disposal. CCS faces a choice between possible technologies whose relative merits have not yet been evaluated at scale. Similar technology uncertainty was encountered for nuclear reactors (pressurized water or boiling water reactors) and SO2 scrubbers (wet or dry scrubbers, pre- or post-combustion scrubbers). Although SO2 scrubbers are a lot less expensive than CCS, the development of the SO2-scrubber industry shares one significant attribute with the CCS industry that the other two selected analogs do not: for both the SO2-scrubber industry and the CCS industry, the inherent market value of the substance being processed—SO2 for the SO2-scrubber industry and CO2 for the CCS industry—is negligible (leaving aside the CO2-EOR niche). In both cases, unlike LNG and nuclear power, commercial value for the technology is created by regulation. Because of this unique similarity, the SO2-scrubber industry may add important insight to the picture of how CCS might evolve. Finally, in both nuclear and CCS industries large liabilities may arise in the event of a major accident.¶ 5. Achieving scale: stages of technology development¶ The classic S-curve description of a technology lifecycle (Fig. 1) posits that a new technology goes through a phase of innovation in which it is first demonstrated and embraced by early adopters, followed by one of diffusion as awareness of the technology penetrates throughout the potential market space, and finally maturity as the technology saturates its natural market.¶ Fig. 2 shows actual technology adoption curves for the three analogs to CCS that we are considering in this paper. On these curves, we identify the three most salient phases in the deployment of these kinds of technologies. First, there is the technology demonstration period in which the new technology is deployed and shown to work in a limited segment (niche) of the potential market. Second, there is the diffusion phase, when methods are found to sufficiently reduce the business risk of large-scale, commercial applications to allow at least a limited number of such projects to go forward. For the analogs discussed here and CCS (complex, capital-intensive, and risky from a financial and regulatory perspective) the diffusion phase is mostly about reducing financial risk: the barrier to diffusion is less a lack of awareness of the technology than insufficient demonstration that businesses implementing the new technology can reliably do so profitably. The increase in the technology’s market penetration during this phase is (ideally) associated with decreasing implementation costs from experience. Third, there is the period of maturity in which a business model proven to be broadly viable encourage the technology to spread in a self-sustaining way until it hits fundamental limitations to its growth (e.g., the available geological storage potential, in the case of CCS). In reality, of course, there is some fluidity among these three phases, and aspects of more than one may be seen at the same time.¶ At present, CCS remains in the period of technology demonstration, with aspects of the technology partially demonstrated (e.g., carbon storage in depleted oil and gas fields) and others still largely unproven (e.g., carbon capture at large scale after fossil fuel combustion). In the remainder of this paper, we will examine the history of the three analogous technologies in the first two of the three major phases in a technology’s development, namely in the technology demonstration phase and in the diffusion phase. We will not, here, examine possible full maturity of these technologies. Finally, we will consider the lessons that may be drawn for CCS.

#### Err aff on CCS’s ability to solve warming – peer-reviewed literature lags five years behind technical truths

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A comprehensive review of CCS was prepared in 2005 by the Intergovernmental Panel on Climate Change (2005). This is an extremely valuable and detailed reference document but, because it was based on a consensus of peer-reviewed literature, it reflects the understanding of perhaps an average of 5 years ago. Particularly in the field of CO2 capture, however, technology concepts and their evaluation have been moving rapidly so some detailed conclusions have already been superseded (e.g. International Energy Agency Greenhouse Gas Programme, 2006a).

#### Warming is an existential risk – quickening reductions is key

Mazo 10 – PhD in Paleoclimatology from UCLA

Jeffrey Mazo, Managing Editor, Survival and Research Fellow for Environmental Security and Science Policy at the International Institute for Strategic Studies in London, 3-2010, “Climate Conflict: How global warming threatens security and what to do about it,” pg. 122

The best estimates for global warming to the end of the century range from 2.5-4.~C above pre-industrial levels, depending on the scenario. Even in the best-case scenario, the low end of the likely range is 1.goC, and in the worst 'business as usual' projections, which actual emissions have been matching, the range of likely warming runs from 3.1--7.1°C. Even keeping emissions at constant 2000 levels (which have already been exceeded), global temperature would still be expected to reach 1.2°C (O'9""1.5°C)above pre-industrial levels by the end of the century." Without early and severe reductions in emissions, the effects of climate change in the second half of the twenty-first century are likely to be catastrophic for the stability and security of countries in the developing world - not to mention the associated human tragedy. Climate change could even undermine the strength and stability of emerging and advanced economies, beyond the knock-on effects on security of widespread state failure and collapse in developing countries.' And although they have been condemned as melodramatic and alarmist, many informed observers believe that unmitigated climate change beyond the end of the century could pose an existential threat to civilisation." What is certain is that there is no precedent in human experience for such rapid change or such climatic conditions, and even in the best case adaptation to these extremes would mean profound social, cultural and political changes.

### Solves Warming

#### CCS solves the majority of power plant emissions

Parfomak and Folger 8 – \*Specialist in Energy and Infrastructure Policy for the Congressional Research Service AND \*\*Specialist in Energy and Natural Resources for the Congressional Research Service (Paul W.; and Peter; 1/10/08, “Pipelines for Carbon Dioxide (CO2) Control: Network Needs and Cost Uncertainties,” http://assets.opencrs.com/rpts/RL34316\_20080110.pdf)

Congress is considering policies to reduce U.S. emissions of greenhouse gases. Prominent among these policies are those promoting the capture and direct sequestration of carbon dioxide (CO2) from manmade sources such as electric power plants and manufacturing facilities. Carbon capture and sequestration is of great interest because potentially large amounts of CO2 produced by the industrial burning of fossil fuels could be sequestered. Although they are still under development, carbon capture technologies may be able to remove up to 95% of CO2 emitted from an electric power plant or other industrial source.

#### The plan solves the majority of power plant emissions

IPCC 5 (International Panel on Climate Change, 2005, *Carbon Dioxide Capture and Storage*, p. 107, http://www.ipcc.ch/pdf/special-reports/srccs/srccs\_wholereport.pdf)

For all of the aforementioned applications, we reviewed recent studies of the performance and cost of commercial or near-commercial technologies, as well as that of newer CO2 capture concepts that are the subject of intense R&D efforts worldwide. For power plants, current commercial CO2 capture systems can reduce CO2 emissions by 80-90% kWh-1 (85- 95% capture efficiency). Across all plant types the cost of electricity production (COE) increases by 12-36 US$ MWh-1 (US$ 0.012-0.036 kWh-1) over a similar type of plant without capture, corresponding to a 40-85% increase for a supercritical pulverized coal (PC) plant, 35-70% for a natural gas combined cycle (NGCC) plant and 20-55% for an integrated gasification combined cycle (IGCC) plant using bituminous coal. Overall the COE for fossil fuel plants with capture, ranges from 43-86 US$ MWh-1, with the cost per tonne of CO2 ranging from 11- 57 US$/tCO2 captured or 13-74 US$/tCO2 avoided (depending on plant type, size, fuel type and a host of other factors). These costs include CO2 compression but not additional transport and storage costs. NGCC systems typically have a lower COE than new PC and IGCC plants (with or without capture) for gas prices below about 4 US$ GJ-1. Most studies indicate that IGCC plants are slightly more costly without capture and slightly less costly with capture than similarly sized PC plants, but the differences in cost for plants with CO2 capture can vary with coal type and other local factors. The lowest CO2 capture costs (averaging about 12 US$/t CO2 captured or 15 US$/tCO2 avoided) were found for industrial processes such as hydrogen production plants that produce concentrated CO2 streams as part of the current production process; such industrial processes may represent some of the earliest opportunities for CO2 Capture and Storage (CCS). In all cases, CO2 capture costs are highly dependent upon technical, economic and financial factors related to the design and operation of the production process or power system of interest, as well as the design and operation of the CO2 capture technology employed. Thus, comparisons of alternative technologies, or the use of CCS cost estimates, require a specific context to be meaningful.

New or improved methods of CO2 capture, combined with advanced power systems and industrial process designs, can significantly reduce CO2 capture costs and associated energy requirements. While there is considerable uncertainty about the magnitude and timing of future cost reductions, this assessment suggests that improvements to commercial technologies can reduce CO2 capture costs by at least 20-30% over approximately the next decade, while new technologies under development promise more substantial cost reductions. Realization of future cost reductions, however, will require deployment and adoption of commercial technologies in the marketplace as well as sustained R&D.

#### CCS is feasible and solves warming

Plasynski et al. 9 – Sequestration Technology Manager in the Office of Coal and Power R&D within the Strategic Center for Coal at the National Energy Technology Laboratory NETL) of the Department of Energy (DOE) (Sean I., Ph.D. in Chemical Engineering from the University of Pittsburgh, former Division Director of an Advanced Initiatives Systems, Analysis & Planning Division; John T. Litynski, NETL Sequestration Program’s Technology Manager; Howard G. McIlvried, Consulting Engineer in the Science Applications International Corporation at the National Energy Technology Laboratory of the Department of Energy; and R. D. Srivastava, Ph.D. in chemical engineering from the Dalhausie University, lead manager for technical support to U.S. DOE's NETL in the area of greenhouse gas emissions and alternative fuels, former Visiting Professor at the University of Delaware, former Guest Professor at the Swiss Federal Institute of Technology (ETH), former Professor of Chemical Engineering at the Indian Institute of Technology at Kanpur; May/June 2009, “Progress and New Developments in Carbon Capture and Storage” (abstract), *Critical Reviews in Plant Sciences*, Volume 28, Issue 3, pp. 123-138, p. EBSCO)

Growing concern over the impact on global climate change of the buildup of greenhouse gases (GHGs) in the atmosphere has resulted in proposals to capture carbon dioxide (CO2) at large point sources and store it in geologic formations, such as oil and gas reservoirs, unmineable coal seams, and saline formations, referred to as carbon capture and storage (CCS). There are three options for capturing CO2 from point sources: post-combustion capture, pre-combustion capture, and oxy-combustion. Several processes are available to capture CO2, and new or improved processes are under development. However, CO2 capture is the most expensive part of CCS, typically accounting for 75% of overall cost. CCS will benefit significantly from the development of a lower cost post-combustion CO2 capture process that can be retrofitted to existing power plants. Once captured, the CO2 is compressed to about 150 atm and pipelined at supercritical conditions to a suitable storage site. Oil and gas reservoirs, because they have assured seals and are well characterized, are promising early opportunity sites. Saline formations are much more extensive and have a huge potential storage capacity, but are much less characterized. Several commercial and a number of pilot CCS projects are underway around the world. Information from these projects will form the basis for the development of CCS as a climate change mitigation strategy. These projects are contributing to the development of suitable regulations, determining best operating practices, improving mathematical models, and providing information to the public and other stakeholders. Based on current knowledge, CCS appears to be a promising option for reducing GHG emissions.

#### Sequestration eliminates the majority of emissions

Parfomak et. Al, 9-

(Paul, July 31, 2009, Specialist in Energy and Infrastructure Policy, “Carbon Dioxide (CO2) Pipelines for Carbon Sequestration: Emerging Policy Issues,” CRS Report for Congress)

Congress has long been concerned about the impact of global climate change that may be caused by manmade emissions of carbon dioxide (CO2) and other greenhouse gases.1 Congress is also debating policies related to global warming and is examining a range of potential initiatives to reduce manmade contributions to global warming from U.S. sources.2 One approach to mitigating manmade greenhouse gas emissions is direct sequestration: capturing CO2 at its source, transporting it via pipelines, and storing it indefinitely to avoid its release to the atmosphere.3 This paper explores one component of direct sequestration—transporting CO2 in pipelines. Carbon capture and storage (CCS) is of great interest because potentially large amounts of CO2 emitted from the industrial burning of fossil fuels in the United States could be suitable for sequestration. Carbon capture technologies can potentially remove 80%-95% of CO2 emitted from an electric power plant or other industrial source. Power plants are the most likely initial candidates for CCS because they are predominantly large, single-point sources, and they contribute approximately one-third of U.S. CO2 emissions from fossil fuels. There are many technological approaches to CCS. However, one common requirement for nearly all large-scale CCS schemes is a system for transporting CO2 from capture sites (e.g., power plants) to storage sites (e.g., underground reservoirs). Transporting captured CO2 in relatively limited quantities is possible by truck, rail, and ship, but moving the enormous quantities of CO2 implied by a widespread implementation of CCS technologies would likely require a dedicated interstate pipeline network.

#### CCS solves warming

Svensson et. Al, 3-

(Rickard, Department of Energy Conversion, School of Mechanical Engineering, Chalmers University of Technology, “Transportation systems for CO2––application to carbon capture and storage,” Volume 45, Issues 15–16, September 2004, Pages 2343–2353, Energy Conversion and Management 45 (2004) 2343–2353)

Both on a European and a global scale, there are large reserves of fossil fuels, e.g. the coal reserves are estimated to last several hundred years at the current production rate. Carbon capture and storage (CCS), i.e. capture and storage of carbon dioxide (CO2) emitted from large pointsources of emissions, has the potential of a significant and relatively quick response to the anticipated climate change at reasonable cost [1]. Successful commercialization of CCS could, therefore, serve as a bridge to a future during which generation from non-fossil energy sources can grow over time. In order for CCS to reach widespread commercialization, it is crucial to establish large scale demonstration projects, reduce capture costs, build infrastructures for transportation of the captured CO2, establish an appropriate legal framework and reach acceptance by the public. Most research on CCS deals with capture technologies and storage possibilities (e.g. in connection to enhanced oil recovery (EOR) projects and in saline aquifers). Although capture represents the highest cost and storage is critical with respect to security and long time moni- toring, still, there is a need to identify and structure transportation alternatives in order to analyse and evaluate future paths comprising CCS. Previous works on transportation of CO2 have investigated the costs and capacities for pipelines [2–6], but these investigations have not studied different transportation scenarios in order to evaluate paths for development of CCS systems. Other work has investigated the technological aspects for CO2 transportation by pipeline and by specially developed tank vessels at sea [7,8]. The risk and security issues related to pipeline transmission have also been investigated [9,10]. The aim of the present work is to identify and estimate costs for different transportation scenarios assuming that the CCS technology will de- velop from a demonstration plant with a size of 200 MWe to a cluster of several large 1000 MWe power plants. Details on the present investigation are given elsewhere [11].

#### CCS solves warming

Herzog and Golomb, 6-

(December 8, 2006, Howard and Dan, Massachusetts Institute of Technology Laboratory for Energy and the Environment, “Carbon Capture and Storage from Fossil Fuel Use,” <http://sequestration.mit.edu/pdf/enclyclopedia_of_energy_article.pdf>)

Carbon sequestration can be defined as the capture and secure storage of carbon that would otherwise be emitted to, or remain, in the atmosphere. The focus of this paper is the removal of CO2 directly from industrial or utility plants and subsequently storing it in secure reservoirs. We call this carbon capture and storage (CCS). The rationale for carbon capture and storage is to enable the use of fossil fuels while reducing the emissions of CO2 into the atmosphere, and thereby mitigating global climate change. The storage period should exceed the estimated peak periods of fossil fuel exploitation, so that if CO2 re-emerges into the atmosphere, it should occur past the predicted peak in atmospheric CO2 concentrations. Removing CO2 from the atmosphere by increasing its uptake in soils and vegetation (e.g., afforestation) or in the ocean (e.g., iron fertilization), a form of carbon sequestration sometimes referred to as enhancing natural sinks, will only be addressed briefly.

#### CCS acts as a bridge to further renewables

McCoy and Rubin, 8-

(Department of Engineering and Public Policy, Carnegie Mellon University, international journal of greenhouse gas control 2 (2008) 219–229, “An engineering-economic model of pipeline transport of CO2 with application to carbon capture and storage,” Science Direct)

CO2 geological sinks for significant periods of time (Bachu, 2003). CCS requires CO2 to be captured from large-scale industrial processes, compressed to high pressures, trans- ported to a storage site, and injected into a suitable geological formation where it is sequestered and kept from the atmo- sphere. Studies indicate that under appropriate policy regimes, CCS could act as a potential ‘‘bridging technology’’ that would achieve significant CO2 emission reductions while allowing fossil fuels to be used until alternative energy sources are more widely deployed. Moreover, as part of a portfolio of emissions reducing technologies, CCS could substantially reduce the cost of achieving stabilization goals (Herzog et al., 2005).

#### The plan solves emissions

Haszeldine, 9-

(R. Stuart, OBE, BSc (Edin), PhD (Strath), CGeol, FRSE Scottish Power Professor of Carbon Capture & Storage, “Carbon Capture and Storage: How Green Can Black Be?,” Science Magazine, Science 25 September 2009: Vol. 325 no. 5948 pp. 1647-1652)

Carbon dioxide emissions from fossil fuel combustion are a major contributor to climate change (1). The current low price of fossil fuel energy is partly subsidized by unpriced CO2 emissions, exploiting the degradation of natural atmosphere and ocean. Even if the debate on climate change is over, the actions to limit CO2 emissions have barely started. One step toward reducing CO2 emissions is to capture the CO2 generated during combustion and store it in a suitable place. This process of carbon capture and storage (CCS) has the potential to reduce future world emissions from energy by 20% (2). CCS is already operating in trials, with 3 megatons of CO2 (Mt CO2) per year from power plants or natural gas cleanup being captured and stored. CCS technologies are now in a scale-up period. Worldwide, large demonstrations are planned on 36 power plants. However, there is a lamentable lack of financial commitment to real construction. If design and construction of these demonstration plants does not start now, they will not operate by 2014, and learning from these to provide commercial credibility will drift beyond 2020. The worldwide construction of many tens to hundreds of large CCS plants—necessary for a substantial impact on climate mitigation—will then be delayed beyond the deadline set by climate change predictions.

#### CCS prevents CO2 from getting into the atmosphere – solves warming

Hannah Chalmers ’09 (Postgraduate researcher at the Centre for Environmental Strategy at the University of Surrey, Reuters, 10/16/09, “In the fight against climate change, carbon capture is crucial,” http://blogs.reuters.com/great-debate-uk/2009/10/16/in-the-fight-against-climate-change-carbon-capture-is-crucial/)

At the same time, energy and environment ministers were attending a meeting convened by the Carbon Sequestration Leadership Forum. Their final communiqué affirmed CCS as “an important element of any effective response to climate change” and described a series of industrial-scale demonstration projects as “vital”. But, what is CCS? Why does it matter? And can it deliver? The principle is simple. To avoid dangerous climate change it is very likely that we need to avoid a significant proportion of the carbon dioxide emissions that could be produced by fossil fuels that we already know how to access at reasonable cost. It is, therefore, necessary to either (1) convince countries with fossil fuels to leave them in the ground unused, essentially forever, or (2) ensure that the vast majority of carbon dioxide produced by fossil fuel use does not end up in the atmosphere. CCS projects implement the second option. They collect carbon dioxide that is produced by fossil fuels (or biofuels which also contain carbon). In a typical scheme, this captured carbon dioxide is then transported and injected into a geological formation at least 1 kilometre below the earth’s surface. Getting CCS to work matters because it should make it much easier for countries with large fossil fuel reserves, and particularly coal-rich countries such as the USA and China, to sign up to serious global action on climate change. A range of technologies for CCS are under development and are at different stages of maturity. For the options closest to commercial deployment, the main technical challenges tend to centre on adapting, enlarging and integrating proven approaches from existing industries. There are some initial trial units already in operation, but further large-scale demonstration is needed before CCS can be seen as ‘business-as-usual’. Although some engineering challenges remain, most of the significant hurdles to a successful global rollout of CCS are not technical. CCS adds to the cost of using fossil fuels for the sole purpose of reducing carbon dioxide emissions, but it typically receives much less support than other developing low carbon options with similar costs. Implementing CCS also requires that the general public and other key players become comfortable with the risks and opportunities of a new industry. This takes time, but there is general agreement that we must act quickly on climate change. As the Copenhagen negotiations approach, a number of commentators are discussing what a ‘global deal’ might look like. The ministers at the Carbon Sequestration Leadership Forum concluded that the “viability of CCS as a key mitigation technology should be recognized in appropriate international legal frameworks including the United Nations Framework Convention on Climate Change”.

#### CCS solves warming

CBO ’12 (Congressional Budget Office, study was prepared at the request of the Chairman of the Senate Committee on Energy and Natural Resources, June 2012, “Federal Efforts to Reduce the Cost of Capturing and Storing Carbon Dioxide,” http://www.cbo.gov/sites/default/files/cbofiles/attachments/43357-06-28CarbonCapture.pdf)

Concerns about global warming have raised questions about the United States’ continued dependence on coal for producing electricity. About 1,400 coal-fired generating units located in roughly 600 power plants produce 40 percent to 45 percent of the electricity generated annually in this country and in so doing release about a third of the carbon dioxide attributable to human activities in the United States each year. 1 The consensus among scientific experts is that increasing concentrations of greenhouse gases in the atmosphere—including CO2 , which is the most common—are likely to have extensive, highly uncertain but potentially costly effects on regional climates throughout the world. 2 The federal government, through the Department of Energy, is seeking ways to reduce greenhouse gas emissions while preserving the nation’s ability to continue to rely on coal to produce electricity. A policy to reduce CO2 emissions would benefit the United States by lessening the risk of costly changes to the climate. However, such a policy would also impose costs on the U.S. economy because it would limit activities that produce those emissions. Depending on the type of policy that lawmakers chose, electric utilities and their customers, coal producers, or certain areas of the country could bear increased costs or a considerable loss of income and jobs. 3 As a result, policymakers have sought options that would reduce CO2 emissions but also limit the potential impact on the economy and allow the nation to continue to produce electricity from coal. Since 2005, lawmakers have provided DOE with about $6.9 billion to develop and demonstrate the commercial feasibility of technologies that would allow coal-burning power plants to generate electricity without emitting CO2 into the atmosphere. Instead, the CO2 would be removed from a plant’s exhaust stream, compressed into a liquid, and stored underground indefinitely. Collectively, those processes are usually called carbon capture and storage.

### Other Solutions Fail

#### Other solutions to warming fail – CCS is the best feasible technology to solve power plant emissions

Plasynski et al. 9 – Sequestration Technology Manager in the Office of Coal and Power R&D within the Strategic Center for Coal at the National Energy Technology Laboratory NETL) of the Department of Energy (DOE) (Sean I., Ph.D. in Chemical Engineering from the University of Pittsburgh, former Division Director of an Advanced Initiatives Systems, Analysis & Planning Division; John T. Litynski, NETL Sequestration Program’s Technology Manager; Howard G. McIlvried, Consulting Engineer in the Science Applications International Corporation at the National Energy Technology Laboratory of the Department of Energy; and R. D. Srivastava, Ph.D. in chemical engineering from the Dalhausie University, lead manager for technical support to U.S. DOE's NETL in the area of greenhouse gas emissions and alternative fuels, former Visiting Professor at the University of Delaware, former Guest Professor at the Swiss Federal Institute of Technology (ETH), former Professor of Chemical Engineering at the Indian Institute of Technology at Kanpur; May/June 2009, “Progress and New Developments in Carbon Capture and Storage,” *Critical Reviews in Plant Sciences*, Volume 28, Issue 3, pp. 123-138, p. EBSCO)

I. INTRODUCTION¶ Carbon plays an essential role in the biosphere and, in fact, life as human beings know it would be impossible without carbon. Carbon enters the atmosphere from a variety of sources, including respiration/decay, combustion, industrial processes, and volcanic activity. Carbon is removed from the atmosphere by absorption in the oceans, the growth of plants and microorganisms, and the formation of carbonate deposits. For centuries, this cycle has been essentially in equilibrium with the amount of carbon dioxide (CO2) leaving the atmosphere equaling the amount entering the atmosphere and with CO2 concentration in the atmosphere averaging about 280 ppm. However, since the onset of the industrial revolution, more CO2 has been entering the atmosphere than has been leaving, resulting in a gradual increase in the CO2 concentration to a current level of 384 ppm (Tans, 2008).¶ The largest natural sink for CO2 is the ocean, where CO2 dissolves and forms carbonate and bicarbonate ions. As the CO2 content of the atmosphere increases, more CO2 will dissolve in the ocean and increase its acidity, resulting in unknown consequences for marine life. The other major concern relative to increasing atmospheric CO2 is the effect on global climate (IPCC, 2005). One manifestation of this is the melting of glaciers and the disappearance of sea ice in the polar regions of the earth. Melting of the Greenland and Antarctic icecaps could result in a rise in sea level, threatening millions of people living in coastal areas. These potential threats have led many scientists and others to conclude that action is necessary to reduce greenhouse gas (GHG) levels in the atmosphere and in particular levels of CO2, the most important GHG.¶ II. OPTIONS FOR REDUCING CO2 EMISSIONS¶ There are several options for reducing CO2 emissions (Socolowet al., 2004).One is to reduce energy use by improving the efficiency of vehicles, appliances, industrial processes, etc. Another option is to switch to low/no carbon energy sources, such as wind, hydro, solar, nuclear, or biomass. A third option is to cut waste and increase use of recycled materials. All these actions can contribute to GHG reduction, but a major challenge is the large installed base of coal-fired power plants that will be in operation for decades and are major CO2 emitters. An option for reducing GHG emissions from these plants that is receiving considerable attention is carbon capture and storage (CCS). In this concept, CO2 would be captured at a power plant, transported to a storage site, and injected into a geologic formation for permanent storage (Bachu, 2008; Holloway, 2005; Rubin et al., 2007; White et al., 2003).¶ Ocean storage of CO2 has also received considerable study, but because of environmental, legal, and economic concerns, interest in ocean storage has declined. Approaches for ocean storage that have been considered include dispersion as small droplets of liquid CO2 that would dissolve in the ocean water and the creation of lakes of liquid CO2 in deep ocean depressions. The major concern is that ocean disposal would seriously impact the environment in the vicinity of the disposal site. There are a number of international treaties and national laws that may inhibit ocean storage of CO2. Still another option for decreasing atmospheric CO2 buildup is increasing carbon uptake by plants and soil microorganisms. Worldwide vegetation removes about 1 gigatonne of carbon from the atmosphere each year with significant potential for increasing this amount.¶ A. Storage of CO2 in Geologic Formations¶ If the burning of fossil fuels is to continue while limiting CO2 emissions, then the only option is to capture the CO2 and store it. It has been proposed to use the captured CO2 for beneficial purposes, but there are no commercial uses that could absorb the huge volume of CO2 that would be generated if a majority of power plants recovered CO2 from their stack gases. The biggest potential user is enhanced oil recovery (EOR) or enhanced coalbed methane (ECBM) production, but even these uses could not take all the CO2. Growing algae has also been suggested, but this would require a large land area for ponds and high water usage.¶ Upon careful consideration, the only storage option that has the potential to take all the captured CO2 is geologic storage. The three formation types of most interest are depleted oil and gas reservoirs, unmineable coal seams, and saline formations, although basalt and organic shale are also being considered. Geologic storage is discussed in more detail later in this article.¶ B. Terrestrial Carbon Storage¶ An alternative approach to CCS is carbon storage in terrestrial ecosystems through natural processes, such as the growth of plants and microorganisms. There is significant potential for increasing carbon storage in forests, rangelands, and mined lands, through modifications in management practices. For example, planting trees instead of grass when restoring mined lands can result in much higher carbon storage. Also, adding soil amendments can increase the rate of plant growth and the amount of carbon stored. The estimated potential for terrestrial storage of carbon is 290 million tonnes of carbon per year in U.S. soils (Litynski et al., 2006a) and 600–1,200 million tonnes of carbon per year worldwide, totaling to a cumulative sink capacity of 30–60 billion tonnes over the next 25–50 years (Lal, 2003; Lal, 2004).Mined lands, of which there may be as much as 0.63 million hectares in the United States, are particularly interesting, because they are essentially devoid of soil carbon and, therefore, present an excellent opportunity to store carbon in both soil and vegetation.

#### CCS technology is the only way to meet emissions targets

ICFI 9 (ICF International, a firm that partners with government and commercial clients to deliver professional services and technology solutions, February 2009, “Developing a Pipeline Infrastructure for CO2 Capture and Storage: Issues and Challenges,” http://www.ingaa.org/File.aspx?id=8228)

The role that CCS could play in meeting U.S. GHG goals can be illustrated by Figure 3-3 which shows the emission limits of the Lieberman/Warner/Boxer bill overlaid onto projected CO2 emission levels.

Based on the relative economics of GHG abatement options, most analysts believe the initial reductions will come mostly from reductions in non-CO2 gases in industrial processes, conservation in all sectors, international and domestic offsets and changes in the methods of generating power. Because of the limited potential in the first three categories (including a legislative restriction on the use of offsets) the Lieberman/Warner/Boxer targets would lead to largely decarbonizing the power sector sometime after the year 2030. Unless new nuclear power plants were to be constructed on a massive scale and replace older fossil plants, most analysts believe the target will require a large amount of CCS to capture emissions from U.S. fossil-fuel power plants.

### AT: Doesn’t Solve Natural Gas

#### It would be easy for CCS to be used with natural gas

CBO ’12 (Congressional Budget Office, study was prepared at the request of the Chairman of the Senate Committee on Energy and Natural Resources, June 2012, “Federal Efforts to Reduce the Cost of Capturing and Storing Carbon Dioxide,” http://www.cbo.gov/sites/default/files/cbofiles/attachments/43357-06-28CarbonCapture.pdf)

CCS technology could be adopted at plants that use natural gas rather than coal for electricity generation. In fact, the cost of using CCS at natural gas-fired plants would probably be less than the cost of using it at coal-fired plants. In particular, although much of the capture and compression equipment integral to the CCS approach is the same for both types of plants (and the transportation and storage facilities are identical), natural gas-fired plants would require less equipment because they produce fewer CO2 emissions. Similarly, developers of CCS-capable coal-fired facilities face additional challenges to ensure that the new emission-reduction technology is compatible with the plant’s coal-handling and exhaust equipment, some of which limits the emissions of other pollutants.

#### CCS can be applied to natural gas plants too

CBO ’12 (Congressional Budget Office, study was prepared at the request of the Chairman of the Senate Committee on Energy and Natural Resources, June 2012, “Federal Efforts to Reduce the Cost of Capturing and Storing Carbon Dioxide,” http://www.cbo.gov/sites/default/files/cbofiles/attachments/43357-06-28CarbonCapture.pdf)

Most public and private efforts to develop technologies for capturing, compressing, transporting, and storing carbon dioxide (CO2 ) emitted during electricity generation have focused on coal-fired plants rather than on natural gas-fired plants. Until recently, natural gas has been more expensive than coal as a power source and thus has been used less; in addition, coalfired power plants produce more electricity than their natural gas-fired counterparts, and coal combustion produces far more emissions of CO2 per unit of electricity than does the burning of natural gas. But with lower prices for natural gas and its increasing use for electricity generation, carbon capture and storage (CCS) technology could also be developed for use in natural gas-fired power plants. Nevertheless, because demonstration and pilot projects to construct facilities equipped with CCS technology take years to plan and fund, and because the potential benefits of CCS are greater for coal-fired plants, the use of CCS at coal-fired facilities will probably remain at the forefront of the technology’s development for at least the next few years.

### Now Key

#### Acting now is necessary – delays will make warming inevitable

Haszeldine, 9-

(R. Stuart, OBE, BSc (Edin), PhD (Strath), CGeol, FRSE Scottish Power Professor of Carbon Capture & Storage, “Carbon Capture and Storage: How Green Can Black Be?,” Science Magazine, Science 25 September 2009: Vol. 325 no. 5948 pp. 1647-1652)

Climate change predictions show that CO2 reduction must be operating by 2020. Mainstream economic assessments state that CCS is a medium-term, low-cost option that needs to be prepared now (34) and that even a 10-year delay in tackling climate change will be economically serious (35). Yet there is a lack of policies or funds worldwide to support profitable operation of demonstration plants. In the future, industry needs to see and believe in secure, long-term underpinning revenue from low carbon fossil energy, similar to the way that renewable energies have been helped to emerge.

#### Action now is key to create working CCS early enough to solve warming

Haszeldine 9 – Scottish Power Professor of Carbon Capture & Storage at the University of Edinburgh School of GeoSciences (R. Stuart, 9/25/09, “Carbon Capture and Storage: How Green Can Black Be?” *Science*, Volume 325, Number 5948, pp. 1647-1652, http://www.roberts.cmc.edu/159/2010/2010pdfs/5.%20Feb%204%202010.pdf)

One step toward reducing CO2 emissions is to capture the CO2 generated during combustion and store it in a suitable place. This process of carbon capture and storage (CCS) has the potential to reduce future world emissions from energy by 20% (2). CCS is already operating in trials,with 3 megatons of CO2 (Mt CO2) per year from power plants or natural gas cleanup being captured and stored. CCS technologies are now in a scale-up period. Worldwide, large demonstrations are planned on 36 power plants. However, there is a lamentable lack of financial commitment to real construction. If design and construction of these demonstration plants does not start now, they will not operate by 2014, and learning from these to provide commercial credibility will drift beyond 2020. The worldwide construction of many tens to hundreds of large CCS plants—necessary for a substantial impact on climate mitigation—will then be delayed beyond the deadline set by climate change predictions.

#### Government commitment now would lead to the expansion of future projects

Cohen et al. 9 – Co-Founder and Executive Director of the Clean Air Task Force (Armond, former head of the Conservation Law Foundation's Energy Project, member of the Environmental Protection Agency’s Clean Air Act Advisory Committee; Mike Fowler, Technology Coordinator for the Coal Transition Project at the Clean Air Task Force, former New Source Review Supervisor and Enforcement Manager in the Air Quality Bureau of the New Mexico Environment Department, former Project Scientist in the Division of Applied Sciences at Harvard University; and Kurt Waltzer, Carbon Storage Development Coordinator for the Clean Air Task Force’s Coal Transition Project; May 2009, “‘NowGen’: Getting Real about Coal Carbon Capture and Sequestration,” *The Electricity Journal*, Volume 22, Issue 4, pp. 25-42, p. ScienceDirect)

F. NowGens and a CCS industry¶ This article defines NowGens as commercial projects using tested technologies that include some element of CCS. By contrast, the proposed FutureGen project at Matoon, Ill., involves multiple untested components, including 90 percent capture on an IGCC plant, the latest version of a commercial hydrogen turbine, and large-scale geologic sequestration. An SNG plant that captures and sequesters CO2 through EOR clearly qualifies as a NowGen, as does the same plant with a dedicated gas turbine (such a plant would also meet California's new CO2 standard). An IGCC plant with 50 percent capture goes further in utilizing new technology but can still be considered largely commercial. Obviously, what constitutes a NowGen project depends on the market's risk tolerance and will change over time. But the distinction between commercial projects and projects primarily designed to demonstrate future technology is important when considering next steps to develop a viable CCS industry.¶ We believe government support for early commercial NowGen projects, even those with only modest levels of CO2 capture, is necessary to resolve integration challenges in a time frame consistent with meaningful carbon abatement. By bringing together key actors (e.g., technology providers, project developers, off-takers, financiers, insurers, regulators, and the public) and motivating real-world problem solving, such projects can help resolve a number of technical, legal, and regulatory issues—thereby substantially reducing risks for subsequent projects—and can build confidence that success with CCS is possible.¶ Fortunately, the foundations for a nascent industry already exist. In the coal gasification industry, millions of tons of CO2 per year are routinely separated from syngas before it is used; likewise, high-hydrogen fuel gas is already being used in combustion turbines at a number of facilities around the world. As already noted, at least two IGCC projects with plans for partial capture are under construction in the U.S. and China. Meanwhile, the components to build an SNG production plant with CO2 capture have all been commercially proven and integrated at some level. Post-combustion capture is also possible today, though uncertainties exist in scaling up and integrating that technology (especially for retrofits), and the efficiency and cost hurdles with current technology are significant. For these early projects, partial capture likely provides a reasonable balance between technology advancement and financial risk.¶ We target 20 GW of NowGen projects in the U.S. by 2020 because this is a sufficient scale to allow for different combinations of important base technologies for gasification and capture, utilizing a variety of fuels (e.g., bituminous and sub-bituminous coal, lignite, biomass, and petroleum coke). It is likely also sufficient to reduce CCS costs for subsequent projects by reducing the contingency charges associated with first-of-a-kind designs (which tend to multiply throughout the project cost structure) and by driving competition and diversification among suppliers of critical components (such as gasifier pressure vessels).¶ Based on extensive interviews with project developers, we believe that nearly 20 publicly announced projects in the U.S. could break ground as NowGens between 2009 and 2012. These include a mixture of IGCCs with partial and full capture, post-combustion capture, SNG to power, SNG, and chemical production. Of course, not all of these projects will materialize—indeed most of them likely will not be built unless credit markets improve or government assistance is provided.¶ If all these projects were completed, however, they would capture more than 60 million tons of CO2 per year, enough to drive multiple pipeline projects and numerous sequestration demonstrations—including several DSF projects. This level of activity would represent an important step forward in overcoming hurdles to large-scale CCS deployment.

### Modeling

#### CCS technologies generate international cooperation to solve warming

Victor Der ’10 (Principal Deputy Assistant Secretary for Fossil Energy, U.S. Department of Energy. Ph.D., University of Maryland; M.S., University of Maryland; B.S., University of Maryland, UNIVERSITY OF RICHMOND LAW REVIEW 44 U. Rich. L. Rev. 937, 2010, “ENVISIONING ENERGY: ENVIRONMENT, ECONOMICS, AND THE ENERGY FUTURE: ARTICLE: CARBON CAPTURE AND STORAGE: AN OPTION FOR HELPING TO MEET GROWING GLOBAL ENERGY DEMAND WHILE COUNTERING CLIMATE CHANGE”

Advanced CCS technologies are innovative and transformational; they are aimed at providing cost-competitive technology options for controlling CO(2) emissions and enabling the continued use of fossil fuels in a carbon constrained world. They will be [\*974] most effectively utilized as part of a portfolio response to CO(2) emission mitigation that includes wider use of renewable and nuclear energy and increased energy efficiencies. Even as the research toward commercialization and deployment moves forward, simultaneous progress must be made internationally on a legal and regulatory framework for CCS that deals with the varied liability issues connected to long-term CO(2) storage. The previously mentioned CSLF projects n214 are helping to accumulate the data that will assist in this important endeavor. Finally, the cost of deployment - identified as one of the biggest single hurdles for CCS to overcome - must continue to be addressed. Efforts such as the DOE research program are essential to making significant strides in helping reduce the "energy penalty" and other issues associated with today's commercially available technologies. Throughout these and other initiatives, continuous efforts must be maintained to build public understanding, acceptance, and trust, based on accurate and credible information. Without public understanding, CCS is unlikely to reach the goals needed to begin the process of mitigating atmospheric CO(2) buildup. All nations would be affected by the impacts of global climate change. The good news is that technology and energy choices may provide policymakers with the basis for meeting their economic, energy, and environmental needs. Credible studies indicate that CCS technology will help the world reconcile its growing energy demand with the need to mitigate climate change risks while continuing to leverage existing fossil fuel infrastructure investments. Among other benefits, CCS offers stationary carbon dioxide emitters a potential retrofit option. Developing CCS to its full potential is the impetus behind the research, development, and deployment program the United States is pursuing through DOE and its industrial and international partners. Along with other initiatives around the globe, these efforts have helped establish the groundwork for worldwide cooperation and collaboration, but there is still much to do, as the earlier discussion of challenges facing the technology suggests. Innovative CCS technology appears necessary for helping address the paradox of reconciling forecasted fossil fuel consumption with the need for CO(2) emission reductions. n215 CCS can, as part of a [\*975] portfolio solution, provide the international community with a near and long-term opportunity to positively impact the world environment, energy supply, and perhaps economic growth and stability as well. n216 How well and to what extent this opportunity is realized will likely depend to a large degree on the level of cooperation achieved, not only in technical and scientific areas, but also the political and policy arenas, n217 as evidenced by the appeal in the Copenhagen Accord for "enhanced action and international cooperation." n218 This is perhaps the ultimate practical challenge posed by the complex climate change issue. But success is possible by working together globally in common purpose and endeavor. n219 Time is not on our side if we are to stem the tide of climate change; we must collectively act with a sense of urgency in addressing the challenge.

#### The plan creates trust in CCS feasibility – so it gets modeled internationally

Stevens, 6-

(Jennie C., Environmental Science and Policy, Department of International Development, Community, and Environment, Clark University, Fall 2006, Sustainability: Science, Practice and Policy, Volume 2 Issue 2)

The leadership of UK Prime Minister Tony Blair is another important factor contributing to interest in CCS technologies. In addition to being the world leader pushing hardest to reduce greenhouse-gas emissions, in his role as G8 chairman in 2005, Blair advocated for increased governmental support for carbon abatement as a critical part of addressing climate change (Blair, 2003). Recognizing the importance of American involvement in any strategy to tackle the global problem of climate change, Blair has persistently tried to change the Bush administration’s position. This focus on advancing technology rather than pushing for emission-reduction policies can be interpreted as an attempt to find common ground with the United States.¶ Governmental Support of Research and Development¶ Governmental efforts to advance the development of CCS technologies through R&D support vary considerably among countries. The potential impact of the successful deployment of CCS systems is related to a region’s endemic fossil-fuel resources and level of fossil-fuel energy reliance. As a result, different national priorities are apparent when looking at government-supported CCS research programs.¶ In the coal-rich, energy-hungry United States, CCS provides the only way to reconcile increased use of domestic coal with climate-change mitigation, so the American government increasingly touts CCS as part of the future energy infrastructure. The federal government currently supports a suite of CCS R&D programs and has also initiated a large-scale demonstration project named FutureGen. The primary goal of the core CCS R&D program in the United States is to support technological developments that will reduce costs; the Regional Sequestration Partnership Program supports region-specific studies to determine the most suitable CCS technologies, regulations, and infrastructure. The FutureGen initiative is a US$1 billion project planned as the first demonstration of a commercial scale coal-fired power plant that captures and stores CO2. The goal is to establish technical feasibility and economic viability for integrating coal gasification technology (IGCC) with CCS. Although the FutureGen project began in 2003, selection of the location for this power plant is not due to occur until late 2007.¶ European governments have also supported CCS technology advancement in several ways. The European Community (EC) contributed funds to several CCS projects through its Sixth Framework Programme (FP6, totaling an EC contribution of €35 million during the first proposal round) building on the research done under FP4 and FP5 during the early 1990s that initiated European R&D into CCS. This support includes contributions to the Sleipner project as well as to some other R&D and small-scale demonstration projects. Independently of Brussels, EC member states are also providing modest support for CCS R&D. For instance, the British government recently announced a €40 million fund to support CO2 storage in depleted North Sea oil and gas fields. Japan is another country that has been actively encouraging CCS. Interestingly, lacking suitable land-based geologic reservoirs, Japan has focused most of its investment on the potential and limitations of oceanic CO2 storage. Most developing countries have not begun to seriously consider the potential of CCS technologies as a climate change mitigation strategy, so government support for advancing this set of technologies has been minimal or nonexistent.2¶ Recognizing the varied efforts in advancing CCS technology around the world, the United States initiated an international body, the Carbon Sequestration Leadership Forum (CSLF), in 2003. The CSLF provides a forum for collaboration by facilitating joint projects, as well as providing a mechanism for multilateral communication regarding the latest CCS developments and a venue for formulating strategies to transfer technology to developing countries.¶ In addition to the direct impact that government-supported R&D has on the advancement of CCS, public sponsorship motivates involvement of individuals and companies (Stephens & Zwaan, 2005).

### CCS Support Now

#### There is political momentum for CCS deployment

Hamilton et al. 9 – former Research Assistant at the MIT Industrial Performance Center (Michael R., Sales Applications Engineer at FlexEnergy, former Consultant on Irvine Smart Grid Demonstration Project at Southern California Edison, former Research Assistant in the MIT Energy Initiative, former Extern at North American Power at Cambridge Energy Research Associates; Howard J. Herzog, Senior Research Engineer in the MIT Energy Initiative, principal research engineer at MIT; John E. Parsons, Executive Director of the MIT Center for Energy and Environmental Policy Research, Executive Director of the MIT Joint Program on the Science and Policy of Global Change, Senior Lecturer in the MIT Sloan School of Management; February 2009, “Cost and U.S. public policy for new coal power plants with carbon capture and sequestration,” *Energy Procedia*, Volume 1, Issue 1, pp. 4487-4494, proceedings of the 9th International Conference on Greenhouse Gas Control Technologies (GHGT-9), p. ScienceDirect)

3.1. Recent US Federal activity affecting CCS¶ The recent US activity federal activity affecting CCS technology has been a continuation of research and development programs, pilot-scale demonstrations for sequestration, and two major investment tax credits. Over the past few years, the Department of Energy has continued to receive support from Congress for several programs supporting CCS. The Office of Fossil Energy continues to implement the research and development program, mostly through the National Energy Technology Laboratory and the Clean Coal Power Initiative, as well as grant programs for academic and private R&D projects. The DOE also has seven Regional Partnerships to demonstrate sequestration at the 1MtCO2/yr level. Currently, these partnerships are at varying stages, with most in the pilot scale testing phases.¶ The DOE is also working to demonstrate full-scale integrated CCS for electricity through the FutureGen project, a major integrated CCS demonstration program still under development. Currently, the project will support the cost of CCS equipment for several integrated CCS plants. Originally, the project would have been the first integrated carbon capture and sequestration project in the US and possibly in the world. It would have been a 275MW IGCC coal power plant with saline formation sequestration at a site in Mattoon, IL. As of September 2008, The FutureGen Alliance, the industry consortium leading the original FutureGen project, is still pursuing US congressional funding for the project independent of the DOE’s restructured FutureGen plans [15].¶ The two major investment tax credits relevant to CCS are the Advanced Coal Project Investment Credit and the Coal Gasification Investment Credit. Originally these tax credits were introduced as part of the Energy Policy Act of 2005. This program provided up to $800m for IGCC projects and $500m for advanced coal-based generation technologies over three years. Details of the awarded projects can be found at [16].¶ 3.1.1. CCS and Coal Provisions in “Bailout” Bill¶ In response to the credit crisis in 2008, the US congress passed a bill H.R. 1424 entitled the Emergency Economic Stabilization Act of 2008. Besides providing authorization for up to $700b to help ease the effect of the credit crisis on the US financial industry, the bill also included several notable energy provisions with some specifically relevant to advanced coal and CCS technology.¶ The bill contains a modification to both the Advanced Coal Project Investment Credit and the Coal Gasification Investment Credit. The updated Advanced Coal Project Investment Credit program extends the period of application by three years, and provides an additional $1.25b for advanced coal projects capturing and sequestering at least 65% of their CO2 emissions. Up to 30% of the project cost can be awarded the tax credit. The updated Coal Gasification Investment Credit program provides an additional $250m for gasification demonstration projects that capture and sequester at least 75% of their CO2 emissions. The new program also allows credit for gasification projects producing liquid fuels for transportation.¶ The bill also provides a new tax credit for sequestration of CO2 in secure geological storage or for enhanced oil and gas recovery projects. For facilities capturing more than 500,000 tonne (t) of CO2 /yr, a $20/tonne tax credit can be applied to sequestration in secure geological storage which includes deep saline formations and unminable coal seams and a $10/tonne tax credit can be applied to sequestration for purposes of enhanced oil and gas recovery. This credit will apply for the first 75Mt of CO2 sequestered. This credit will likely help support some early private-sector CCS demonstration projects.¶ 3.2. Proposed US legislation¶ There have been numerous attempts to formulate a winning climate bill in the US congress over the past several years. The policy mechanisms proposed in these bills to limit greenhouse gas emissions vary widely. Carbon taxes, emissions performance standards, portfolio standards, cap-and-trade systems, direct subsidies, indirect subsidies such as tax credits, and clean technology R&D have all been proposed, often in combination with each other. Which policy tools will be politically viable remains to be seen.¶ While it is common sense to understand that CCS technology will only be deployed in the presence of a price on carbon, there is much disagreement on what price would be sufficient versus what price would be likely given the current political atmosphere. Combined with the cost update in Section 2 of this paper, an audit of the major current policy approaches affecting CCS will allow some conclusions to be reached about the likelihood of CCS to be deployed under these varying policy scenarios.¶ 3.2.1. US Climate Legislation¶ 3.2.1.1. Lieberman-Warner Climate Security Act of 2008¶ The leading piece of climate legislation being considered in 2008 is S.3036, the Lieberman-Warner Climate Security Act of 2008. This bill would establish a cap-and-trade program for greenhouse gas emissions from all major emitting sector including both electricity and vehicle transportation. The eventual target would be 70% below 2005 emissions levels by the year 2050. This target is similar to goals recommended by climate scientists to achieve a 450ppm CO2 concentration stabilization. A Carbon Market Efficiency Board would be established a sort of “central bank” for carbon markets that could act to contain costs if needed; the most important function of this board would be to allow expanded borrowing of future allowances and/or international offsets (such as CDM credits) if the US economy was in a crisis.¶ There are several notable details in this bill specific to CCS. Initially, 18% of emissions allowance would be freely allocated to the power generation sector, with this amount reduced to zero by 2031. The remainder of emissions allowances would need to be bought through government auction or private purchase in an emissions allowance market.¶ There will be bonus allowances given to power generators choosing to use CCS. The bonus will be 4.5x in 2012 reduced to zero by 2033. These bonus allowances would be valid for the first 10 years of operation of the CCS plant. For example, for each ton of CO2 sequestered in 2012, the company would receive one allowance plus 4.5 additional emissions allowances to either sell or use for their other CO2 emitting plants. There is an emissions standard required to receive this bonus. New plants with CCS must emit less than 800 lbCO2/MWh before 2018, and after 2018, a new plant must emit less than 300 lbCO2/MWh. Plants choosing to retrofit with CCS must emit less than 1200 lbCO2/MWh.¶ Since this program will likely be generating hundreds of billions of dollars of auction revenue every year, a major part of S.3036 is the allocation of this massive fund toward various projects, including CCS technology. In total, 25% of auction proceeds will go to advanced coal and CCS demonstration, with at least 6.25% to advanced coal and 12.5% to CCS demonstration. In total this bill would likely support 5-10 CCS demonstration plants through these revenues.¶ 3.2.1.2. Low Carbon Economy Act of 2007¶ Another major piece of climate legislation is S.1766, the Low Carbon Security Act of 2008 or the “Bingaman-Specter” bill. This bill is based upon final recommendations from the National Commission on Energy Policy. This bill would also establish a cap-and-trade program for greenhouse gas emissions. The target would be to reach 1990 emissions levels by the year 2030. This bill has a cost-containment mechanism called TAP – “Technology Accelerator Payment”; if the market price reaches the current TAP price, then emitters can purchase credits from the government at the TAP price. The TAP starts at $10 in 2012 increasing to ~$25 in 2030 (not including inflation). TAP proceeds would go into a fund to support energy technology deployment.¶ Initially, 28.6% of emissions allowances would be freely allocated to the power generation sector, with this amount reduced to zero by 2043. Similarly to S.3036, this bill also includes bonus allowances given to power generators choosing to use CCS. The bonus will be 3.5x in 2012 reducing to zero by 2040. These bonus allowances would be valid for the first 10 years of operation of the CCS plant. Similar to S.3036, there will be billions in auction proceeds available for energy projects. In total, 5.5% of auction proceeds will go to advanced coal demonstration, 5.5% to commercial CCS deployment, and 11% for early CCS demonstration projects.¶ 3.2.2. CCS Demonstration Support¶ 3.2.2.1. CCS Trust Fund¶ The concept of a trust fund for CCS demonstration projects has been gaining traction recently. Popularized by Prof. Ed Rubin of Carnegie Mellon, the idea would be to charge a small fee per kWh to every electricity consumer in the country. The fee collected would then be put into a trust fund designated for funding CCS demonstration projects.¶ The first legislative embodiment of this idea was recently proposed by Rep. Boucher of Virginia as H.R.6258. This bill would impose a small fee on all fossil power sales for 10 years. The fee would be 0.43 mill/kWh for coal-fired generation, 0.22 mill/kWh for gas, and 0.32 mill/kWh for oil. This fund would aggregate into about $1 billion annually, which would be about $10 billion over 10 years. This fund would be managed by a Carbon Storage Research Corporation, which would be a division of the Electric Power Research Institute. The managing board would be staffed by power industry representatives, with the mission of supporting 3-5 large-scale commercial demonstrations of CCS. The major advantage to this approach would be avoiding the political appropriations process, as well as federal procurement requirements that a DOE-managed project would have to follow.¶ 3.2.2.2. Energy Technology Corporation¶ A second idea for demonstration is an Energy Technology Corporation. Recently proposed by John Deutch, John Podesta, and Peter Ogden [17], this corporation would be a semi-private corporation funded by a large single appropriation to fund energy technology demonstrations for technologies like CCS and cellulosic ethanol production. The corporation would be managed by a board appointed by President. No detail as to the level of initial funding required has been proposed. Similar to the CCS trust fund option, this corporation would be independent of federal procurement rules and the yearly appropriations process.¶ One criticism of this approach is due to the problems encountered by the US Synthetic Fuels Corporation in the early 1980s. The Synfuels Corporation was created in response to the oil shocks of the 1970s with the mission of increasing US energy independence through coal-to-liquids technology. The Corporation was created with fixed production targets, which ultimately led to billions of dollars of spending on projects producing fuel at a cost several times higher than the then market-price of automotive fuel. Proponents of a new Corporation for energy projects say that technology progress targets would either be flexible and reviewed periodically, so that demonstration priorities could be shifted if changing market conditions justified the shift, or they could be based on cost and performance rather than production targets, which would hopefully help avoid the problems encountered by the Synfuels Corporation.¶ 3.2.2.3. Clean Energy Investment Bank¶ A third proposal for CCS demonstration is a Clean Energy Investment Bank. As proposed in S.2730 by Sen. Pete Domenici of New Mexico, this would be a federally-funded bank to provide financial services for clean energy projects. After receiving a large initial endowment for a “clean energy investment bank fund” from the federal government, it would act as normal investment bank acts, by providing loan guarantees, insurance, loans, equity and security investment, and other services. This bank would be backed by full faith and credit of US government. The bank will be managed as a bank by an executive board appointed by the President. This bank would also modify the loan guarantee program as defined by Energy Policy Act of 2005 by taking control of this function from DOE.¶ This bank would support several large CCS demonstrations, as well as other promising energy technology development and demonstration. Just like the first two options, this bank would also avoid the federal appropriations process but may not avoid the potentially difficult federal procurement rules.¶ 3.2.2.4. Cost Sharing - CCS Technology Act of 2008¶ There are several proposals using the government cost sharing method to support CCS demonstration. One recent proposal is S.2323 proposed by Sen. John Kerry of Massachusetts. This bill would provide $1.6 billion to support 3-5 sequestration demonstration projects, as well as $2.4b to support 3-5 capture demonstration projects. Up to 50% of the cost of the project could be supported by government funds. The bill also would provide increased levels of CCS R&D up to $350m for the 2008- 2012 period.

#### CCS has political support now – and it’s a popular way to mitigate warming

Stephens 6 – Assistant Professor of Environmental Science and Policy at Clark University (Jennie C., Ph.D. in Environmental Science and Engineering at the California Institute of Technology, associate with the Energy Technology Innovation Policy research group in the Belfer Center for Science and International Affairs at the John F. Kennedy School of Government at Harvard University, Fall 2006, “Growing interest in carbon capture and storage (CCS) for climate change mitigation,” Sustainability: Science, Practice, & Policy, Volume 2, Issue 2, pp. 4-13, http://sspp.proquest.com/static\_content/vol2iss2/0604-016.stephens-print.html)

A political position that supports the advancement of CCS technology as an alternative to regulations to limit CO2 emissions has clearly influenced CCS development. Nevertheless, proposed CCS approaches were not developed with the intent of eliminating the need for emissions regulations, but, given the magnitude of the CO2 problem, are largely viewed as a supplement (Pacala & Socolow, 2004). Within the political arena, however, support for CCS is often perceived as an alternative to regulating CO2 releases. The current United States administration has opposed any national regulation to reduce CO2 emissions (see e.g., Abraham, 2004), but growing public concern about climate change has forced it to confront the issue and to define actions to mitigate the problem. Supporting CCS as part of the President’s Advanced Energy Initiative appears to be a politically convenient way to demonstrate action on climate change without making policy decisions to ensure actual CO2 emissions reduction (NEC, 2006).¶ The leadership of UK Prime Minister Tony Blair is another important factor contributing to interest in CCS technologies. In addition to being the world leader pushing hardest to reduce greenhouse-gas emissions, in his role as G8 chairman in 2005, Blair advocated for increased governmental support for carbon abatement as a critical part of addressing climate change (Blair, 2003). Recognizing the importance of American involvement in any strategy to tackle the global problem of climate change, Blair has persistently tried to change the Bush administration’s position. This focus on advancing technology rather than pushing for emission-reduction policies can be interpreted as an attempt to find common ground with the United States.¶ Governmental Support of Research and Development¶ Governmental efforts to advance the development of CCS technologies through R&D support vary considerably among countries. The potential impact of the successful deployment of CCS systems is related to a region’s endemic fossil-fuel resources and level of fossil-fuel energy reliance. As a result, different national priorities are apparent when looking at government-supported CCS research programs.¶ In the coal-rich, energy-hungry United States, CCS provides the only way to reconcile increased use of domestic coal with climate-change mitigation, so the American government increasingly touts CCS as part of the future energy infrastructure. The federal government currently supports a suite of CCS R&D programs and has also initiated a large-scale demonstration project named FutureGen. The primary goal of the core CCS R&D program in the United States is to support technological developments that will reduce costs; the Regional Sequestration Partnership Program supports region-specific studies to determine the most suitable CCS technologies, regulations, and infrastructure. The FutureGen initiative is a US$1 billion project planned as the first demonstration of a commercial scale coal-fired power plant that captures and stores CO2. The goal is to establish technical feasibility and economic viability for integrating coal gasification technology (IGCC) with CCS. Although the FutureGen project began in 2003, selection of the location for this power plant is not due to occur until late 2007.¶ European governments have also supported CCS technology advancement in several ways. The European Community (EC) contributed funds to several CCS projects through its Sixth Framework Programme (FP6, totaling an EC contribution of €35 million during the first proposal round) building on the research done under FP4 and FP5 during the early 1990s that initiated European R&D into CCS. This support includes contributions to the Sleipner project as well as to some other R&D and small-scale demonstration projects. Independently of Brussels, EC member states are also providing modest support for CCS R&D. For instance, the British government recently announced a €40 million fund to support CO2 storage in depleted North Sea oil and gas fields. Japan is another country that has been actively encouraging CCS. Interestingly, lacking suitable land-based geologic reservoirs, Japan has focused most of its investment on the potential and limitations of oceanic CO2 storage. Most developing countries have not begun to seriously consider the potential of CCS technologies as a climate change mitigation strategy, so government support for advancing this set of technologies has been minimal or nonexistent.2¶ Recognizing the varied efforts in advancing CCS technology around the world, the United States initiated an international body, the Carbon Sequestration Leadership Forum (CSLF), in 2003. The CSLF provides a forum for collaboration by facilitating joint projects, as well as providing a mechanism for multilateral communication regarding the latest CCS developments and a venue for formulating strategies to transfer technology to developing countries.

### Impact

#### History proves warming causes extinction

Tickell, 8/11/2008 “On a planet 4C hotter, all we can prepare for is extinction,” The Guardian, http://www.guardian.co.uk/commentisfree/2008/aug/11/climatechange]

We need to get prepared for four degrees of global warming, Bob Watson told the Guardian last week. At first sight this looks like wise counsel from the climate science adviser to Defra. But the idea that we could adapt to a 4C rise is absurd and dangerous. Global warming on this scale would be a catastrophe that would mean, in the immortal words that Chief Seattle probably never spoke, "the end of living and the beginning of survival" for humankind. Or perhaps the beginning of our extinction. The collapse of the polar ice caps would become inevitable, bringing long-term sea level rises of 70-80 metres. All the world's coastal plains would be lost, complete with ports, cities, transport and industrial infrastructure, and much of the world's most productive farmland. The world's geography would be transformed much as it was at the end of the last ice age, when sea levels rose by about 120 metres to create the Channel, the North Sea and Cardigan Bay out of dry land. Weather would become extreme and unpredictable, with more frequent and severe droughts, floods and hurricanes. The Earth's carrying capacity would be hugely reduced. Billions would undoubtedly die. Watson's call was supported by the government's former chief scientific adviser, Sir David King, who warned that "if we get to a four-degree rise it is quite possible that we would begin to see a runaway increase". This is a remarkable understatement. The climate system is already experiencing significant feedbacks, notably the summer melting of the Arctic sea ice. The more the ice melts, the more sunshine is absorbed by the sea, and the more the Arctic warms. And as the Arctic warms, the release of billions of tonnes of methane – a greenhouse gas 70 times stronger than carbon dioxide over 20 years – captured under melting permafrost is already under way. To see how far this process could go, look 55.5m years to the Palaeocene-Eocene Thermal Maximum, when a global temperature increase of 6C coincided with the release of about 5,000 gigatonnes of carbon into the atmosphere, both as CO2 and as methane from bogs and seabed sediments. Lush subtropical forests grew in polar regions, and sea levels rose to 100m higher than today. It appears that an initial warming pulse triggered other warming processes. Many scientists warn that this historical event may be analogous to the present: the warming caused by human emissions could propel us towards a similar hothouse Earth.

# Coal Advantage

### 1AC – Coal

#### Advantage \_\_\_ is Coal

#### New EPA regulations hamstring the coal industry --- carbon capture and sequestration is the only solution

Peskoe, 12-

(Ari, associate in the law firm of McDermott Will & Emery LLP and is based in the Firm’s Washington, D.C., office. He focuses his practice on regulatory, legislative, compliance and transactional issues related to energy and commodities markets, April, 2012, “EPA Proposes to Require Carbon Capture and Sequestration; Creates Uncertainty for the Future of Coal,” <http://www.natlawreview.com/article/epa-proposes-to-require-carbon-capture-and-sequestration-creates-uncertainty-future->)

The U.S. Environmental Protection Agency (EPA) proposed the first ever CO2 emissions limits for newly constructed power plants last month. Under the proposal, power plants that have already acquired a preconstruction permit from the EPA and commence construction by March 27, 2013 do not need to comply with the rule. The emissions limit, set at 1,000 pounds per megawatt-hour, would effectively require all new coal-fired plants to cut CO2 emissions in half from current rates. The only plausible technology for enabling such drastic cuts is carbon capture and sequestration (CCS). EPA’s proposed rule allows a new plant to implement CCS ten years after beginning operations, so long as its emissions after CCS are below 600 lb/MWh. That gives the coal industry some extra time to work through the many legal and regulatory issues currently facing the technology. Like any large-scale energy development, a sequestration project would trigger state and Federal environmental reviews. While there is extensive experience around the country reviewing and approving projects that involve injecting substances into the ground, no other project is designed to store vast quantities of gas underground for hundreds of years. It’s not clear how legislators, environmental agencies and the public will evaluate this risk. Long-term liabilities relating to leaks are another legal hurdle. According to a Federal interagency task force report published in 2010, some businesses are uncomfortable with the risk but also unsure of how to quantify it. Insurers, and particularly investors, are fixed on short-term thinking, and 10 or 20 years is considered “long-term” in business decision making. But sequestered carbon must stay underground for centuries. There is no agreement on how to account for this time horizon. A 2010 paper by a Harvard Law School professor and student researchers proposed a range of regulatory incentives to spur development of large scale test projects. The suggestions included establishing a trust fund paid for by industry to cover liabilities, developing sites on Federal land to streamline the approval process, imposing caps on liability and preempting nuisance and trespass claims. Regardless of the specifics, instituting any new regulatory system takes time. Fracing is a multi-billion dollar business in the U.S., and yet after a decade of widespread use its legal framework is not yet firmly established. As EnergyBusinessLaw.com has been documenting, legal norms are still developing, and all three branches of government are issuing new rules and decisions that have major impacts on the industry. Without an impetus to do so, governments will probably ignore CCS, and the lack of legal certainty will hinder development. Perhaps EPA’s rule, if implemented, will motivate action. Until then, rather than urging governments to enact rules that create legal certainty for CCS, the coal industry is likely to fight tooth and nail to kill yet another attempt by Washington to regulate CO2 emissions from the power sector.

#### Coal companies are collapsing in the status quo because they cannot build more plants

Jervey, 5/3-

(Ben, “Exporting Coal: Struggling U.S. Coal Industry Trying to Stay Relevant By Shipping Through the Northwest,” <http://www.desmogblog.com/exporting-coal-struggling-u-s-coal-industry-trying-stay-relevant-shipping-through-northwest>)

U.S. coal companies are facing some tricky math these days. Production levels have remained more or less the same since 2005, according to the Energy Information Agency (EIA), but during that time domestic consumption has dropped nearly 11 percent. Where is all that extra coal going? Some is piling up at power plants, but increasingly, more and more of it is being shipped overseas. The coal industry is hoping to accelerate that export trend, but their ability to keep delivering steady volumes of coal is entirely dependant on their ability to open up new export terminals at coastal ports around the country, particularly in the Pacific Northwest where the dirty rock could be more directly shipped to the burgeoning Asian markets.

#### The coal industry is key to the economy and has a multiplier effect on the economy

Rose, 6-

(PhD at Penn State, Adam, July, “The Economic Impacts of Coal Utilization and Displacement in the Continental United States, 2015,” <http://www.americaspower.org/sites/all/themes/americaspower/images/pdf/penn-state-study.pdf>)

This study projects the extent of the likely impacts of coal utilization for electricity generation on the economies of the forty-eight contiguous states in the year 2015. The projection period covers both current coal-related economic benefits and those that may result from the construction of new coal-fueled electric generating capacity. We first estimate the overall economic benefits associated with the availability of coal as a relatively low-cost fuel resource. This “existence” value reflects the increased economic output, earnings, and employment associated with projected coal utilization for electric generation in 2015. We also estimate the net economic impacts of displacing 33% and 66% of projected coal generation by alternative energy resources, taking into account the positive economic effects associated with alternative investments in oil/gas, nuclear, and renewable energy supplies. We performed our analysis with the aid of an interindustry, or input-output, model. Specifically, we analyzed how coal-based electric generation affects production (output), household income, and employment in other sectors of each state and the continental U.S. as a whole under three alternative displacement scenarios. Our results indicate that the combination “multiplier” and “price-differential” effects are sizeable, amounting to $1.05 trillion ($2005) in total 48-state economic output for the “existence” of coal as a relatively inexpensive fuel for electricity generation. The results illustrate that government policies and private industry decisions affecting coal-based electric generation potentially can affect every major aspect of the American economy. -9The methodology underlying the study is summarized in Section II below, as well as in Appendix A, which also presents major assumptions and some basic computations underlying the analysis. The results for the five regions analyzed are summarized in Section III, with tables of basic data presented in Appendix B and simulation results presented in Appendix C. We simulated cases where coal-based electricity generation is displaced at levels of 66% and 33% by alternative energy supplies, including natural gas, nuclear, and a 10% mix of renewables, reflecting potential Renewable Portfolio Standards (RPS) that could be in place by 2015. The results indicate that for the nation, and for nearly every state individually, this displacement -- even factoring in positive offsetting multiplier impacts of replacement fuels and technologies -- would have a net negative economic impact. We project that national gross output would decline by $371 billion for the 66% case, and by $166 billion for the 33% case. II. Methodology A. Measuring Economic Interdependence With a broad base and high level of technological advancement, the U.S. economy exhibits a great deal of interdependence. Each business enterprise relies on many others for inputs into its production process and provides inputs to them in return. This means that the coal and coal-based electric utility industries’ contributions to the nation's economy extend beyond their own production to include demand arising from a succession of "upstream" inputs from their suppliers and "downstream" deliveries to their customers. The economic value of these many rounds of derived demands and commodity allocations is some multiple of the value of direct production itself. Hence, the coal and coal-based electric utility industries generate "multiplier" effects throughout the U.S. economy.

#### Coal Exports are key to economic competitiveness

Hal Quinn ’12 (writer for the National Miners Association, “WHAT SHOULD U.S. POLICY BE ON ENERGY EXPORTS?”, April 13, 2012, http://www.nma.org/pdf/041312\_quinn\_nj\_blog.pdf)

Exporting U.S. Coal Helps America and Developing World – by Hal Quinn, NMA The United States has an unrivalled self-interest in serving international markets that urgently need coal to grow their economies and improve the livelihoods of their people. In fact, increasing our coal exports is an unusually clear example of how unfettered trade benefits both exporting and importing countries. With the world’s largest coal reserves, the U.S. finds itself in the enviable position of having more of what the fastest-growing countries of the world need. China and India are lifting hundreds of millions of people out of poverty by building vast electricity grids that bring coal-generated power to homes and workplaces. Coal is the only fuel for electricity generation that is sufficiently affordable and abundant to literally bring this power to the people. It is also a vital ingredient for the steelmaking plants in Asia and Brazil that are laying foundations for a 21 st century industrial revolution. American metallurgical coal is a building block of this progress much as it is for our own industrial progress. The benefits of U.S. coal exports are reciprocal. The U.S. has a 265-year coal supply, more than enough to serve its domestic needs. Far from depriving Americans of opportunities, coal exports provide them –high-wage jobs in coal country from Appalachia to the Powder River Basin, in the rail industry that transports coal to ports and in export terminals that exist or are envisioned for the Gulf and both coasts. The $16 billion worth of U.S. coal exported last year also delivered revenue to hardpressed communities across the U.S. heartland. Some critics are blinded by their wealthy lifestyles to the powerful evidence that coal-based generation has greatly improved the lives of millions abroad who are less fortunate. For the 1.4 billion people worldwide who have no access to electricity, efficient coalbased generation provides a healthier and better life. It often offsets the demands for heat and light that heretofore have been met with fuels derived from deforestation, animal wastes and uncontrolled in-home use of kerosene and other fuels. In short, coal exports are a classic example of America’s competitive advantage. Recent history offers grim examples of what happens to countries that only buy from the rest of the world and sell nothing to them. The president appears to understand this lesson with his call to double exports in five years. Presumably he also understands how coal exports, up almost a third last year, are helping him reach this goal.To forego this competitive advantage would be a classic example of short-sighted public policy that will only deepen the economic gloom Americans now face.

#### Economic recovery and boosting competitiveness are key to prevent the collapse of U.S. power---that causes global great-power wars

Khalilzad 11 Zalmay Khalilzad was the United States ambassador to Afghanistan, Iraq, and the United Nations during the presidency of George W. Bush and the director of policy planning at the Defense Department from 1990 to 1992. "The Econom and National Security" Feb 8 www.nationalreview.com/blogs/print/259024

Today, economic and fiscal trends pose the most severe long-term threat to the United States’ position as global leader. While the United States suffers from fiscal imbalances and low economic growth, the economies of rival powers are developing rapidly. The continuation of these two trends could lead to a shift from American primacy toward a multi-polar global system, leading in turn to increased geopolitical rivalry and even war among the great powers.

The current recession is the result of a deep financial crisis, not a mere fluctuation in the business cycle. Recovery is likely to be protracted. The crisis was preceded by the buildup over two decades of enormous amounts of debt throughout the U.S. economy — ultimately totaling almost 350 percent of GDP — and the development of credit-fueled asset bubbles, particularly in the housing sector. When the bubbles burst, huge amounts of wealth were destroyed, and unemployment rose to over 10 percent. The decline of tax revenues and massive countercyclical spending put the U.S. government on an unsustainable fiscal path. Publicly held national debt rose from 38 to over 60 percent of GDP in three years.

Without faster economic growth and actions to reduce deficits, publicly held national debt is projected to reach dangerous proportions. If interest rates were to rise significantly, annual interest payments — which already are larger than the defense budget — would crowd out other spending or require substantial tax increases that would undercut economic growth. Even worse, if unanticipated events trigger what economists call a “sudden stop” in credit markets for U.S. debt, the United States would be unable to roll over its outstanding obligations, precipitating a sovereign-debt crisis that would almost certainly compel a radical retrenchment of the United States internationally.

Such scenarios would reshape the international order. It was the economic devastation of Britain and France during World War II, as well as the rise of other powers, that led both countries to relinquish their empires. In the late 1960s, British leaders concluded that they lacked the economic capacity to maintain a presence “east of Suez.” Soviet economic weakness, which crystallized under Gorbachev, contributed to their decisions to withdraw from Afghanistan, abandon Communist regimes in Eastern Europe, and allow the Soviet Union to fragment. If the U.S. debt problem goes critical, the United States would be compelled to retrench, reducing its military spending and shedding international commitments.

We face this domestic challenge while other major powers are experiencing rapid economic growth. Even though countries such as China, India, and Brazil have profound political, social, demographic, and economic problems, their economies are growing faster than ours, and this could alter the global distribution of power. These trends could in the long term produce a multi-polar world. If U.S. policymakers fail to act and other powers continue to grow, it is not a question of whether but when a new international order will emerge. The closing of the gap between the United States and its rivals could intensify geopolitical competition among major powers, increase incentives for local powers to play major powers against one another, and undercut our will to preclude or respond to international crises because of the higher risk of escalation.

The stakes are high. In modern history, the longest period of peace among the great powers has been the era of U.S. leadership. By contrast, multi-polar systems have been unstable, with their competitive dynamics resulting in frequent crises and major wars among the great powers. Failures of multi-polar international systems produced both world wars.

American retrenchment could have devastating consequences. Without an American security blanket, regional powers could rearm in an attempt to balance against emerging threats. Under this scenario, there would be a heightened possibility of arms races, miscalculation, or other crises spiraling into all-out conflict. Alternatively, in seeking to accommodate the stronger powers, weaker powers may shift their geopolitical posture away from the United States. Either way, hostile states would be emboldened to make aggressive moves in their regions.

Economic decline makes war highly likely

Royal 10 – Jedediah Royal, Director of Cooperative Threat Reduction at the U.S. Department of Defense, 2010, “Economic Integration, Economic Signaling and the Problem of Economic Crises,” in Economics of War and Peace: Economic, Legal and Political Perspectives, ed. Goldsmith and Brauer, p. 213-215

Less intuitive is how periods of economic decline may increase the likelihood of external conflict. Political science literature has contributed a moderate degree of attention to the impact of economic decline and the security and defence behaviour of interdependent states. Research in this vein has been considered at systemic, dyadic and national levels. Several notable contributions follow. First, on the systemic level, Pollins (2008) advances Modelski and Thompson's (1996) work on leadership cycle theory, finding that rhythms in the global economy are associated with the rise and fall of a pre-eminent power and the often bloody transition from one pre-eminent leader to the next. As such, exogenous shocks such as economic crises could usher in a redistribution of relative power (see also Gilpin. 1981) that leads to uncertainty about power balances, increasing the risk of miscalculation (Feaver, 1995). Alternatively, even a relatively certain redistribution of power could lead to a permissive environment for conflict as a rising power may seek to challenge a declining power (Werner. 1999). Separately, Pollins (1996) also shows that global economic cycles combined with parallel leadership cycles impact the likelihood of conflict among major, medium and small powers, although he suggests that the causes and connections between global economic conditions and security conditions remain unknown. Second, on a dyadic level, Copeland's (1996, 2000) theory of trade expectations suggests that 'future expectation of trade' is a significant variable in understanding economic conditions and security behaviour of states. He argues that interdependent states are likely to gain pacific benefits from trade so long as they have an optimistic view of future trade relations. However, if the expectations of future trade decline, particularly for difficult to replace items such as energy resources, the likelihood for conflict increases, as states will be inclined to use force to gain access to those resources. Crises could potentially be the trigger for decreased trade expectations either on its own or because it triggers protectionist moves by interdependent states.4 Third, others have considered the link between economic decline and external armed conflict at a national level. Blomberg and Hess (2002) find a strong correlation between internal conflict and external conflict, particularly during periods of economic downturn. They write: The linkages between internal and external conflict and prosperity are strong and mutually reinforcing. Economic conflict tends to spawn internal conflict, which in turn returns the favour. Moreover, the presence of a recession tends to amplify the extent to which international and external conflicts self-reinforce each other. (Blomberg & Hess, 2002. p. 89) Economic decline has also been linked with an increase in the likelihood of terrorism (Blomberg, Hess, & Weerapana, 2004), which has the capacity to spill across borders and lead to external tensions. Furthermore, crises generally reduce the popularity of a sitting government. “Diversionary theory" suggests that, when facing unpopularity arising from economic decline, sitting governments have increased incentives to fabricate external military conflicts to create a 'rally around the flag' effect. Wang (1996), DeRouen (1995). and Blomberg, Hess, and Thacker (2006) find supporting evidence showing that economic decline and use of force are at least indirectly correlated. Gelpi (1997), Miller (1999), and Kisangani and Pickering (2009) suggest that the tendency towards diversionary tactics are greater for democratic states than autocratic states, due to the fact that democratic leaders are generally more susceptible to being removed from office due to lack of domestic support. DeRouen (2000) has provided evidence showing that periods of weak economic performance in the United States, and thus weak Presidential popularity, are statistically linked to an increase in the use of force. In summary, recent economic scholarship positively correlates economic integration with an increase in the frequency of economic crises, whereas political science scholarship links economic decline with external conflict at systemic, dyadic and national levels.5 This implied connection between integration, crises and armed conflict has not featured prominently in the economic-security debate and deserves more attention. This observation is not contradictory to other perspectives that link economic interdependence with a decrease in the likelihood of external conflict, such as those mentioned in the first paragraph of this chapter. Those studies tend to focus on dyadic interdependence instead of global interdependence and do not specifically consider the occurrence of and conditions created by economic crises. As such, the view presented here should be considered ancillary to those views.

#### **Increased exports to Asia drives up the price of coal**

Walsh, 5/31-

(Bryan, Time Eco centric Magazine Writer, “Drawing Battle Lines Over American Coal Exports to Asia,” <http://ecocentric.blogs.time.com/2012/05/31/drawing-battle-lines-over-american-coal-exports-to-asia/#ixzz1yk57HI8Q>)

But that’s only true if U.S. coal adds to Asian coal consumption, rather than simply displacing more expensive sources. And exporting coal from the U.S. could actually change consumption here at home: Some argue that if increasing demand in Asia pushes up global coal prices, it could actually helps the environment by forcing more coal-burning countries to start looking for cheaper energy alternatives. In the U.S., higher coal prices could accelerate the switch from coal to natural gas, especially in parts of the Midwest that remain heavily dependent on coal. But that will depend on how Asian markets respond to the potential avalanche of U.S. coal.

#### High coal prices forces China to shift to renewables

Birgoren, 6/14-

(Alternative Energy and Sustainability, “Asia needs coal, the U.S. has plenty. Will expanding exports make climate change worse?,” <http://www.xing.com/net/erneuerbareenergien/international-board-3217/asia-needs-coal-the-u-s-has-plenty-will-expanding-exports-make-climate-change-worse-41038559>)

Some argue that if increasing demand in Asia pushes up global coal prices, it could actually help the environment by forcing more coal-burning countries to start looking for cheaper energy alternatives. In the U.S., higher coal prices could accelerate the switch from coal to natural gas, especially in parts of the Midwest that remain heavily dependent on coal. But that will depend on how Asian markets respond to the potential avalanche of U.S. coal. Chinese demand for coal has been inelastic in recent years, meaning that prices--high or low--haven't had much impact on how much coal China burns. That's partly because the Chinese government exerts control over the energy market, says Richard Morse, director of coal- and carbon-market research at Stanford University, making the effect on emissions of cheaper coal from the U.S. "a complex question. And it's not just about China," he says. "You have to net out the global impacts against the U.S. impacts."

#### China is the biggest contributor to global warming- failure to cut emissions accelerates the warming and kills international efforts to limit emissions

Bradsher, 10-

(Keith, NYT, Energy and Environment, “China’s Energy Use Threatens Goals on Warming,” <http://www.nytimes.com/2010/05/07/business/energy-environment/07energy.html?pagewanted=all>)

HONG KONG — Even as China has set ambitious goals for itself in clean-energy production and reduction of global warming gases, the country’s surging demand for power from oil and coal has led to the largest six-month increase in the tonnage of human generated greenhouse gases ever by a single country. China’s leaders are so concerned about rising energy use and declining energy efficiency that the cabinet held a special meeting this week to discuss the problem, according to a statement Thursday from the ministry of industry and information technology. Coal-fired electricity and oil sales each climbed 24 percent in the first quarter from a year earlier, on the heels of similar increases in the fourth quarter Premier Wen Jiabao promised tougher policies to enforce energy conservation, including a ban on government approval of any new projects by companies that failed to eliminate inefficient capacity, the ministry said. Mr. Wen also said that China had to find a way to meet the target in its current five-year plan of a 20 percent improvement in energy efficiency. “We can never break our pledge, stagger our resolution or weaken our efforts, no matter how difficult it is,” Mr. Wen said. Western experts say it will be hard to meet the target, but that China’s leaders seem determined. “No country of this size has seen energy demand grow this fast before in absolute terms, and those who are most concerned about this are the Chinese themselves,” said Jonathan Sinton, the China program manager at the International Energy Agency in Paris. China has been the world’s largest emitter of greenhouse gases each year since 2006, leading the United States by an ever-widening margin. A failure by China to meet its own energy efficiency targets would be a big setback for international efforts to limit such emissions.

### 1AC – Chinese Coal Module

#### \*\*Replace this with the last three cards in the Coal 1AC – don’t read it with them\*\*

#### Coal exports key to Chinese economic growth

Li and Leung 11-

 (“Coal consumption and economic growth in China,” May 2011, Energy Policy, Volume 40, http://www.deepdyve.com/lp/elsevier/coal-consumption-and-economic-growth-in-china-279NjbzsI3)

Coal is the principal primary energy source in China and it is given a strategic role in the economic growth of the country. According to the official figures from the National Bureau of Statistics, in 2009, Coal accounted for 70% of the total energy consumed and 77% of the total energy produced in China. Because of its abundance in proven reserves and its stability in supply, coal will continue to be a key component of the primary energy mix in the country at least over the next few decades\* However, coal also accounts for a large share of greenhouse gas (CHG) emissions generated by anthropogenic activities, and coal is the most carbon intensive fossil fuel. CHG emissions reduction in this carbon-constrained global environment will prove to be inevitable and the Chinese coal industry may experience significant impact from CHG emissions reduction policies.

The relationship between coal consumption and economic growth is an important issue regardless of the direction of causality. First, as coaI is an input to production process, the consumption of coal may influence economic growth. As noted by some other authors (e.g. Apcrgis and Payne.) 20 If causality flows this way, then attempts to curb CHC emissions through energy conservation may be harmful to economic growth.

#### Chinese economy collapse causes global nuclear war

Plate 3, Tom, East Asia Expert, Adjunct. Prof. Communications @ UCLA, 6-28-2003,

Neo-cons a bigger risk to Bush than China, Strait Times

But imagine a China disintegrating- on its own, without neo-conservative or Central Intelligence Agency prompting, much less outright military invasion because the economy (against all predictions) suddenly collapses. That would knock Asia into chaos. A massive flood of refugees would head for Indonesia and other places with poor border controls, which don’t’ want them and cant handle them; some in Japan might lick their lips at the prospect of World War II revisited and look to annex a slice of China. That would send Singapore and Malaysia- once occupied by Japan- into nervous breakdowns. Meanwhile, India might make a grab for Tibet, and Pakistan for Kashmir. Then you can say hello to World War III, Asia style. That’s why wise policy encourages Chinese stability, security and economic growth – the very direction the White House now seems to prefer.

### 2AC – Regulation Now

#### EPA regulation coming now --- destroys coal plants --- CCS is key to solve

Boccia, 3/27-

(Romina, The Heritage Network, “EPA CO2 Regulation Effectively Bans New Coal Facilities,” <http://blog.heritage.org/2012/03/27/epa-co2-regulation-effectively-bans-new-coal-facilities/>)

The Environmental Protection Agency (EPA) released a new rule to regulate CO2 emissions from power plants, which would effectively ban new coal power plants, as its emissions standards are too low to be met by conventional coal-fired facilities. This stands in stark contrast with the President’s supposed “all of the above energy approach” and sends a strong signal that coal is not part of the President’s energy vision for America. In combination with other EPA regulations that contribute to the premature shutdown of existing coal plants, the EPA’s actions represent one of the greatest threats to the electric sector and America’s energy supply. The new rule requires power plants to meet an output-based standard of 1,000 pounds of CO2 per megawatt-hour of electricity produced. Other than natural gas-fired power plants built in recent years, most power plants, and especially coal-fired ones, would fail to meet that standard. Bloomberg reports: The average U.S. coal plant emits 2,249 pounds of carbon dioxide for each megawatt hour of power produced, compared with 1,135 pounds for a natural gas plant, according to the EPA. While existing power plants and those holding EPA permits for upcoming construction would be excluded, the rule would prevent any new coal-fired power plants from being built unless they were outfitted with carbon-reducing technology, such as carbon capture and storage (CCS). CCS is still a very expensive technology, and questions remain about where to store the captured carbon. Although the EPA’s CO2 regulations rest on a shaky “endangerment” finding, they would have far-reaching effects on the American economy. Heritage Foundation research studying the economic impact from EPA’s CO2 emissions restrictions found: Regulating CO2 emissions under the Clean Air Act will burden the economy with higher energy costs, higher administrative compliance costs for businesses, higher bureaucratic costs for enforcing the regulations, and higher legal costs from the inevitable litigation. For average Americans, the expensive EPA rule would mean higher energy costs, fewer jobs, and a less prosperous economy. A recent video by Energy for America shows the real-life impact of regulations and subsidies for alternative energies—designed to reduce coal’s contribution to the nation’s energy supply—on the residents of Craig, Colorado, an economy fueled by coal. It’s important to remember that the greatest progress toward environmental protection has not been accomplished by government regulation but through greater economic growth. Economic freedom and freer trade promote economic growth and prosperity, which provides society with the wealth and resources to pursue sound environmental policies. Increased government regulation, on the other hand, would stifle economic growth and could lead to counterproductive environmental results. As Heritage’s Terry Miller and Anthony Kim explain: Policy efforts aimed at imposing stricter environmental standards…undercut the economic growth necessary for greater efforts to protect the environment. Such regulations only serve as feel-good actions, without generating real “change” that could mitigate climate change and its possible negative impacts.

#### Regulations coming --- threatens to coal industry which is key to the economy

Barringer, 12-

(March 27th, Felicity, Media Report for NYT, “For New Generation of Power Plants, a New Emission Rule From the E.P.A,” <http://www.nytimes.com/2012/03/28/science/earth/epa-sets-greenhouse-emission-limits-on-new-power-plants.html>)

The Obama administration’s proposed rule to control greenhouse gas emissions from new power plants — the first ever — could go far toward closing out the era of old-fashioned coal-burning power generation. The draft rule, unveiled on Tuesday by Lisa P. Jackson, the Environmental Protection Agency administrator, would limit carbon dioxide emissions from new power plants to 1,000 pounds per megawatt-hour. Recently built power plants fired by natural gas already easily meet the new standards, so the rule presents little obstacle for new gas plants. But coal-fired plants face a far greater challenge, since no easily accessible technology can bring their emissions under the limit. Coal-fired plants are a major source of emissions associated with global warming. The new rules do not apply to existing plants. The coal industry is an economic mainstay of many local economies, and the rule was denounced from West Virginia to Wyoming and on the Republican presidential campaign trail on Tuesday. “This E.P.A. is fully engaging in a war on coal, even though this country will continue to rely on coal as an affordable, stable and abundant energy source for decades to come,” said Senator Joe Manchin III, a West Virginia Democrat and former governor. “This approach relies totally on cheap natural gas, and we’ve seen that bubble burst before.

#### Regulations threaten economic collapse

McCarthy and Copeland, 11-

(\*James, Specialist in Environmental Policy AND \*Claudia, Specialist in Resources and Environmental Policy, August 8, 2011, “EPA’s Regulation of Coal-Fired Power: Is a “Train Wreck” Coming?,” <http://www.fas.org/sgp/crs/misc/R41914.pdf>)

Given the central role of electric power in the nation’s economy, and the importance of coal in power production, concerns have been raised recently about the cost and potential impact of regulations under development at the Environmental Protection Agency (EPA) that would impose new requirements on coal-fired power plants. Six of the rules, which have drawn much of the recent attention, are Clean Air Act regulations. Two others are Clean Water Act rules, and one is a Resource Conservation and Recovery Act rule. The majority are expected to be promulgated over the next 18 months. All together, these rules have been characterized by critics as a regulatory “train wreck” that would impose excessive costs and lead to plant retirements that could threaten the adequacy of electricity capacity (i.e., reliability of supply) across the country, especially from now through 2017. Although some question why EPA is undertaking so many regulatory actions in such a short time- frame, supporters of the regulations assert that it is decades of regulatory delays and court decisions that have led to this point, resulting in part from special consideration given electric utilities by Congress under several statutes. Further, several of the current regulatory developments have been under consideration for a decade or longer, or are being reevaluated after an earlier action was vacated or remanded to EPA by the courts. The regulations are supported by proponents and EPA as having substantial benefits for public health and the environment. Recent reports by industry trade associations and others have discussed potential harm of EPA’s prospective regulations to U.S. electricity generating capacity, with emphasis on coal-fired generation. One of these reports, by the Edison Electric Institute, which represents investor- owned utilities, has attracted considerable attention by depicting a timeline in which multiple rules would take effect more or less simultaneously over the next five years. Congress has shown significant interest in these issues, and bills have been introduced that would de-fund or restrict EPA’s ability to develop rules, and which would legislate new regulatory analytic requirements. This report describes nine rules in seven categories that are at the core of recent critical analyses, with background on the rule and its requirements and, where possible, a discussion of the rule’s potential costs and benefits.

#### Regulation threaten coal plants --- they are central to the US economy

McCarthy and Copeland, 11-

(\*James, Specialist in Environmental Policy AND \*Claudia, Specialist in Resources and Environmental Policy, August 8, 2011, “EPA’s Regulation of Coal-Fired Power: Is a “Train Wreck” Coming?,” <http://www.fas.org/sgp/crs/misc/R41914.pdf>)

Given the central role of electric power in the nation’s economy, and the importance of coal in power production, concerns have been raised about the cost and potential impact of numerous regulatory actions that would impose new requirements on coal-fired power plants.

#### Regulations hurt the economy and increase electricity prices

Kerpen, 12-

(March 29, 2012, Phil, Fox News, “Electric rates will soar now that Obama's EPA has crushed coal-fired power plants,” <http://www.foxnews.com/opinion/2012/03/29/electric-rates-will-soar-now-that-obamas-epa-has-crushed-coal-fired-power/#ixzz21V4LpMhf>)

With the country focused on this week’s high drama at the Supreme Court, President Obama’s EPA quietly released long-delayed regulations to apply global warming rules never authorized by Congress to new coal-fired power plants. That Obama’s EPA would release a rule to destroy coal-fired electricity while the president gives stump speeches about an “all of the above” energy policy is an insult to the American people. This rule will effectively block any new coal-fired power plants from being built in America, and a second round of related rules – expected after the election, of course – will shut down existing coal-fired power plants. The result will be steeply higher electricity prices, lost jobs, and lower standards of living. Remarkably, this is all done in the name of global warming, but even EPA Administrator Lisa Jackson admits it will have no discernible impact on global temperatures. Obama’s EPA is crippling the U.S. economy not to accomplish anything, but just to enjoy a nice, warm, green feeling of self-satisfaction.

#### Regulations coming now

MSNBC.com 12-

(March 27, “End of coal power plants? EPA proposes new rules”, <http://usnews.msnbc.msn.com/_news/2012/03/27/10886373-end-of-coal-power-plants-epa-proposes-new-rules?lite>)

While [the proposed rules](http://epa.gov/carbonpollutionstandard/) do not dictate which fuels a plant can burn, they would require any new coal plants essentially to halve carbon dioxide emissions to match those of plants fired by natural gas. The proposed standards have divided the power industry between companies that have moved toward natural gas, such as Exelon and NextEra, and those that generate most of their power from coal, such as Southern Co. and American Electric Power. Record low prices for natural gas and the looming air rules already have pushed many companies to put older coal plants into retirement. "There are areas where they could have made it a lot worse," said Scott Segal, director of the Electric Reliability Coordinating Council, a coalition of power companies. Still, "the numerical limit allows progress for natural gas and places compliance out of reach for coal-fired plants" not planning to capture and sequester carbon dioxide, the chief greenhouse gas. Steve Miller, CEO and President of the American Coalition for Clean Coal Electricity, a group of coal-burning electricity producers, took a more dismal view, saying it "will make it impossible to build any new coal-fueled power plants and could cause the premature closure of many more coal-fueled power plants operating today." Other opponents of the long-delayed EPA proposal say it will limit sources for electricity by making coal prohibitively expensive. "This rule is part of the Obama administration's aggressive plan to change America's energy portfolio and eliminate coal as a source of affordable, reliable electricity generation," said Rep. Fred Upton, R-Mich., who as chairman of the House Energy and Commerce Committee has led the charge against environmental regulations. "EPA continues to overstep its authority and ram through a series of overreaching regulations in it attacks on America's power sector." Republicans in Congress and on the campaign trail have claimed that Obama-era rules affecting power plants in recent years could cause blackouts. Numerous studies and an Associated Press survey of power plant operators have shown that is not the case. Environmentalists were quick to welcome the proposals, which will be finalized after an undetermined period that will include public comments. Frances Beinecke, president of the Natural Resources Defense Council, called it a "historic step ... toward protecting the most vulnerable among us — including the elderly and our children — from smog worsened by carbon-fueled climate change." The American Lung Association agreed. "Scientists warn that the buildup of carbon pollution will create warmer temperatures which will increase the risk of unhealthful smog levels," said board chairman Albert Rizzo. "More smog means more childhood asthma attacks and complications for those with lung disease." The proposed rules would affect only new plants, not existing plants, which was a concession to industry. In addition, they would not apply to units that will start construction within the next 12 months. Still, the proposals could set the stage for the EPA to regulate existing plants in the coming years. The EPA is moving forward on the climate rules, which do not need approval by Congress, after a wide-ranging climate bill died in the Senate in 2010.

#### **New regulations coming now --- threatens the coal industry**

Lemonick 3/27-

-Science/Environment TIME writer (Michael, “EPA To Regulate Coal Plants, Greenhouse Gas Emissions”, Climate Central, 3/27/2012, http://www.climatecentral.org/blogs/epa-takes-aim-at-coal-plants-and-greenhouse-gas-emissions/)

Climate skeptics sometimes insist that putting carbon dioxide into the atmosphere can’t be pollution because CO2 is necessary to life. It’s a seriously bizarre argument: water is also necessary to life, but you can die if you drink too much of it. Decades of research by hundreds of scientists have made it absolutely clear that carbon dioxide generated by fossil-fuel burning traps excess heat, with disruptive effects we’ve already begun to see. That’s why the Environmental Protection Agency ruled in 2009 that carbon dioxide and other greenhouse gases such as methane and nitrous oxide “threaten the public welfare of current and future generations,” and that the agency could therefore regulate them under the Clean Air Act. That ruling was upheld by the Supreme Court and reaffirmed last year, but despite its authority to do so, the EPA hasn’t actually come out with any limits on heat-trapping gases. That's about to change. Tuesday, the EPA released new regulations that will require new power plants to emit no more than 1,000 lb. of carbon dioxide for each megawatt of electricity they generate — the first such regulations ever imposed. Existing or already-approved plants are exempt, but since coal-fired power plants generate around 1,800 lbs. of CO2 per megawatt, this pretty much means that no more coal plants will be built unless they use some form of carbon capture and storage. Since that technology won’t be commercially available for years, though, and since it’s likely to be costly, that doesn’t change matters. Natural-gas plants, by contrast, come in at under 1,000, so they won’t be affected. The companies that dig up coal for profit are naturally not happy. “The rule from our standpoint is a big mistake,” Luke Popovich, a spokesman for the National Mining Association, told the New York Times. “It is virtually calculated to drive coal, a very, very affordable generator of electricity, out of the U.S. electricity market.” So to paraphrase a line from one of the greatest gangster movies of all time, is this the end of coal? Not really, given that the approximately 300 coal-fired plants that already exist can keep chugging merrily along. Since coal accounts for some 40 percent of U.S. carbon emissions, you’d think this would be a big victory for the environment, but environmental activists aren’t falling all over themselves to celebrate their triumph. The reason, as Matthew Yglesias puts it in Slate: “This is both a historic event and in many ways not that big a deal . . . even before the EPA got in the game, new coal was basically dead in the United States. Cheap gas, the falling price of solar, community activism, and the risk of CO2 regulation had already created the situation where no new post-2012 conventional coal was in the pipeline anyway.” Beyond that, as a recent study showed, the shift away from coal to natural gas isn’t going to help all that much with global warming, anyway. Nevertheless, the ruling is still important. By itself, it’s not going to alter the course of climate change significantly. But having established its authority to regulate greenhouse gases, and now having issued the first rules under that authority, the EPA has shown that it’s willing to take action. And that lays the groundwork for future action that could be a lot more stringent.

### 2AC – CCS Key

#### CCS is critical to allowing coal industries to stay open --- that’s key to the economy

ITF, 10-

(Interagency Task Force, August, “Executive Summary: Report of the Interagency Task Force on Carbon Capture and Storage,” <http://www.epa.gov/climatechange/Downloads/ccs/ES-CCS-Task-Force-Report-2010.pdf>)

While CCS can be applied to a variety of stationary sources of CO2, its application to coal-fired power plant emissions offers the greatest potential for GHG reductions. Coal has served as an important domestic source of reliable, affordable energy for decades, and the coal industry has provided stable and quality high-paying jobs for American workers. At the same time, coal-fired power plants are the largest contributor to U.S. greenhouse gas (GHG) emissions, and coal combustion accounts for 40 percent of global carbon dioxide (CO2) emissions from the consumption of energy. EPA and Energy Information Administration (EIA) assessments of recent climate and energy legislative proposals show that, if available on a cost-effective basis, CCS can over time play a large role in reducing the overall cost of meeting domestic emissions reduction targets. By playing a leadership role in efforts to develop and deploy CCS technologies to reduce GHG emissions, the United States can preserve the option of using an affordable, abundant, and domestic energy resource, help improve national security, help to maximize production from existing oil fields through enhanced oil recovery (EOR), and assist in the creation of new technologies for export.

#### CCS allows coal to still be used under regulations

ITF, 10-

(Interagency Task Force, August, “Executive Summary: Report of the Interagency Task Force on Carbon Capture and Storage,” <http://www.epa.gov/climatechange/Downloads/ccs/ES-CCS-Task-Force-Report-2010.pdf>)

CCS can play an important role in domestic GHG emissions reductions while preserving the option of using abundant domestic fossil energy resources. However, barriers hamper near- term and long-term demonstration and deployment of CCS technology. While the largest of these barriers is the absence of a Federal policy to reduce GHG emissions, the Task Force has outlined specific actions the Federal government could take under existing authority and resources to address these barriers. For widespread cost-effective deployment of CCS, additional action may be needed to address specific barriers, such as long-term liability and stewardship. Timely development of cost-effective CCS could reduce the costs of achieving our Nation’s climate change goals.

#### **CCS allows the US to maintain coal production**

Biello, 9-

(David, Scientific American, April 6, 2009, “Can Carbon Capture and Storage Save Coal?,” <http://www.scientificamerican.com/article.cfm?id=can-carbon-capture-and-storage-save-coal>,)

From the International Energy Agency to the United Nations–sanctioned Intergovernmental Panel on Climate Change (IPCC), such carbon capture and storage (CCS), particularly for coal-fired power plants, has been identified as a technology critical to enabling deep, rapid cuts in greenhouse gas emissions. After all, coal burning is responsible for 40 percent of the 30 billion metric tons of CO2 emitted by human activity every year. "There is the potential for the U.S. and other countries to continue to rely on coal as a source of energy while at the same time protecting the climate from the massive greenhouse gas emissions associated with coal," says Steve Caldwell, coordinator for regional climate change policy at the Pew Center on Global Climate Change, a Washington, D.C. think tank.

#### CCS allows coal to continue

Horne 10 – JD @ U of Utah

Jennifer, “Getting from Here to There: Devising an Optimal Regulatory Model for CO<2> Transport in a New Carbon Capture and Sequestration Industry,” 30 J. Land Resources & Envtl. L. 357, Lexis

Concern over climate change has fueled a flurry of scientific studies, Congressional hearings, public debate, and, not insignificantly, corporate research. Climate change mitigation has implications for the business of energy production. Carbon regulation may well mean the emergence of entirely new industries. Carbon capture and sequestration (CCS) is one such industry. CCS is a potential means of assuring the position of coal 1 as a major energy source while reducing its climate change effects. 2

#### CCS allows coal

Katzer 7 – PhD in Chemical Engineering, member of the National Academy of Engineering, Professor @ MIT

James, “The Future of Coal,” http://web.mit.edu/coal/The\_Future\_of\_Coal.pdf

A central conclusion to be drawn from our examination of alternative futures for coal is that if carbon capture and sequestration is successfully adopted, utilization of coal likely will expand even with stabilization of CO2 emissions. Though not shown here, extension of these emissions control scenarios further into the future shows continuing growth in coal use provided CCS is available. Also to be emphasized is that market adoption of CCS requires the incentive of a significant and widely applied charge for CO2 emissions.

### 2AC – Coal Key to The Economy

#### Coal production is a major sector of the US economy --- generates jobs

Rose, 6-

(PhD at Penn State, Adam, July, “The Economic Impacts of Coal Utilization and Displacement in the Continental United States, 2015,” <http://www.americaspower.org/sites/all/themes/americaspower/images/pdf/penn-state-study.pdf>)

Our analysis shows that, in 2015, U.S. coal production, transportation and consumption for electric power generation will contribute more than $1 trillion (2005 $) of gross output directly and indirectly to the economy of the lower-48 United States. Based on an average of two energy price scenarios summarized below, we calculate that $362 billion of household income and 6.8 million U.S. jobs will be attributable to the production, transportation and use of domestic coal to meet the nation’s electric generation needs.

The United States relies heavily on coal to produce electric power. Domestic coal production has expanded from 560 million tons in 1950 to 1.13 billion tons in 2005, while coal consumption for electric generation has increased from 92 million tons to 1.04 billion tons in this period. Historically, coal has provided the lowest cost source of fossil energy in the U.S. Electricity is one of the most prominent commodities traded in the United States, second only to food in annual sales volume.

We based our analysis on state-specific “IMPLAN” input-output tables -- a widely utilized source of data on the composition of state economic activity -- to estimate the basic direct and indirect “multiplier” effects of coal utilization for electric generation. These multiplier effects include the economic impacts of coal mining and of government spending of taxes paid by coal mining for electricity generation, by companies that transport coal, and by coal-fueled electricity generation companies. We calculated results at the state level and compiled regional summaries by dividing the nation into five geographic regions (see Figure S1, below).

The study first presents estimates of the positive economic output, household income, and jobs attributable to projected levels of coal production and utilization in 2015. We used a 2015 base case because electric generation and other projections for this year were readily available from U.S. DOE and U.S. EPA. These estimates measure the “existence” value of coal as the key fuel input into U.S. electricity generation. The analysis includes estimates of the impact of higher electricity rates on individual state economies if utilities were required to utilize fuel sources and generating technologies more costly than coal-based electricity.

#### The coal industry has a multiplier effect on other sectors of the economy

Rose, 6-

(PhD at Penn State, Adam, July, “The Economic Impacts of Coal Utilization and Displacement in the Continental United States, 2015,” <http://www.americaspower.org/sites/all/themes/americaspower/images/pdf/penn-state-study.pdf>)

Coal-based electricity generation provides a significant stimulus to the U.S. economy by increasing output, income, and employment in all sectors through direct and indirect (multiplier) effects. It also increases the purchasing power of the consumer, and enhances the competitiveness of U.S. exports, by avoiding increased reliance on higher-priced fuels and electricity-generating technologies. Even when we take into account the positive economic effects of capital investments and operation of alternative energy generation sources, the replacement of coal-based electricity by relatively more expensive fuels or generating technologies would have a net negative economic impact on every region and on nearly every state. In general, these results reflect the large economic benefits associated with coal’s favorable price differential effect relative to alternative fuels.

### 2AC – No transition now

#### China will not make the transition and stop using coal in the squo

McKillop, 12-

(Former chief policy analyst, Division A Policy, DG XVII Energy, European Commission, re than 30 years experience in the energy, economic and finance domains. Trained at London UK’s University College, he has had specially long experience of energy policy, project administration and the development and financing of alternate energy. This included his role of in-house Expert on Policy and Programming at the DG XVII-Energy of the European Commission, Director of Information of the OAPEC technology transfer subsidiary, AREC and researcher for UN agencies including the ILO, Andrew, March 24, “China Reaches Peak Coal,” <http://samcheekong.blogspot.com/2012/03/china-reaches-peak-oil.html>)

Simply due to more than 66% of China's current electricity being produced from coal, with little potential for raising China's already impressive hydro output, and with the gas alternative currently based only on high-priced LNG imports, China's coal demand growth is locked-on to its economic growth. Breaking that link will in no way be easy and the short timeframe for achieving major change may indicate that China will engage a massive energy transition plan away from coal, and may be constrained to import more oil in the short-term.

#### Alternative energy options fail

McKillop, 12-

(Former chief policy analyst, Division A Policy, DG XVII Energy, European Commission, re than 30 years experience in the energy, economic and finance domains. Trained at London UK’s University College, he has had specially long experience of energy policy, project administration and the development and financing of alternate energy. This included his role of in-house Expert on Policy and Programming at the DG XVII-Energy of the European Commission, Director of Information of the OAPEC technology transfer subsidiary, AREC and researcher for UN agencies including the ILO, Andrew, March 24, “China Reaches Peak Coal,” <http://samcheekong.blogspot.com/2012/03/china-reaches-peak-oil.html>)

 The Chinese government is considering a wide range of alternatives to coal, both on the economic structure side, and on the energy supply side. China's annual growth of windpower and solar electric generating capacity is now running at about one-quarter of its annual 90 GW increase in power capacity, this annual increase being equivalent to two-thirds of Germany's total installed power capacity, and may rise further. This however will not be enough to achieve transition away from coal, and the nuclear option remains dogged by very high costs and long lead times.

#### China wont switch – coal prices

McKillop, 12-

(Former chief policy analyst, Division A Policy, DG XVII Energy, European Commission, re than 30 years experience in the energy, economic and finance domains. Trained at London UK’s University College, he has had specially long experience of energy policy, project administration and the development and financing of alternate energy. This included his role of in-house Expert on Policy and Programming at the DG XVII-Energy of the European Commission, Director of Information of the OAPEC technology transfer subsidiary, AREC and researcher for UN agencies including the ILO, Andrew, March 24, “China Reaches Peak Coal,” <http://samcheekong.blogspot.com/2012/03/china-reaches-peak-oil.html>)

China's NEA says that it is able to expand coal production and import capacity by 750 million tons a year in the short term, and might attain an ultimate peak of 4.1 billion tons a year, by about 2015, of which as much as 200 million tons/year could be imported. The role of China's coal imports, for energy traders, is almost as important as China's ever rising import demand for oil. This is due to both of Asia's giant emerging economies, India and China, being increasingly obliged to import coal due to their overstretched national coal mining and transport industries facing cost and infrastructure limits and their mines facing coal depletion issues. At the same time, coal import demand by Europe is rising, despite its clean energy programs, and import demand remains strong in developed Asia. Coal export prices, which at oil parity would attain about $500 per ton, may however hit a ceiling due to rising LNG gas availability and declining gas prices triggered by US shale gas development, enabling China and India to import more coal at prices that cease to grow.

### 2AC – Coal Key to Chinese Economy

#### Coal is the cornerstone to Chinese economic growth- they are looking to shift towards imports

Tu, 12-

(Kevin Jianjun, Senior associate in the Carnegie Energy and Climate

Program, where he leads Carnegie’s work on China’s energy and climate policies, “Understanding China’s Rising Coal Imports,” <http://www.carnegieendowment.org/files/china_coal.pdf> )

China is home to the world’s second largest proven coal reserves after the United States. In addition, prior to 2009, China was a net coal exporter. Coal is a cornerstone of the Chinese economy, representing 77 percent of China’s primary energy production and fueling almost 80 percent of its electricity. Moreover, China is the world’s top coal consumer, accounting for nearly half of global consumption in 2010. 1 Over the past decade, China’s domestic coal output has more than doubled while its coal imports have increased by a factor of 60—the country’s dependence on other nations’ coal exports is growing. 2 In 2009, the global coal market witnessed a dramatic realignment as China burst onto the scene, importing coal from as far away as Colombia and the United States. With 182 million tons (Mt) of coal sourced from overseas suppliers in 2011, China has overtaken Japan as the world’s top coal importer. 3 Moreover, as the world’s top coal consumer, China’s imports could rise significantly again by 2015. 4 Given the enormous size of China’s domestic coal reserves, why is China moving to import coal from abroad instead of producing all its needs domestically? Might this phenomenon be as superfluous and foolhardy as carrying coals to Newcastle, England’s major exporter of coal in the fifteenth century? Newcastle, after all, had more coal than anywhere else. Several factors could be contributing to China’s sudden entrance into coal import markets, including transportation bottlenecks, environmental and safety considerations, economic factors, and concerns about depleting coking coal reserves. Gaining a thorough understanding of the paradigm shift under way in the international coal trade requires exploring these factors in order to develop policies to best manage burgeoning coal imports in China and beyond. China’s move to import increasing amounts of coal to add to its vast stores of domestic reserves will influence the global economy, geopolitics, and the environment. Effective policy tools and governance structures will be needed for China to manage its coal use and for the international community to deal with repercussions from the burgeoning coal import markets. The outlook for effective policy responses is premised on new knowledge and assessment of coal trade, production, and consumption patterns: First, China will need to enhance its coal value chain—from coal mining to preparation, transport, and end use—to improve efficiency, reduce the environmental and carbon footprint of coal, and address safety in the face of China’s increased global coal utilization and trade. Second, it will be important to gain a better understanding of the relative costs and benefits of China’s emerging coal trade and the differences among Chinese mining companies and between Chinese and foreign mining operations regarding mining practices, regulatory oversight, and operations. Third, the parallels underpinning energy and climate concerns in the United States and China could serve as the impetus for more bilateral cooperation on common coal conditions. Finally, oversight over growing global coal markets could be organized through new governance structures—international forums, regulations and standards, fiscal measures, and information—spearheaded by major coal export and import nations. China’s recent move from being a net coal exporter to a net coal importer portends significant changes on the global stage, especially in terms of climate change. Understanding China’s rising coal imports is crucial for managing their global impact

#### Coal is key to Chinese economy

Holmes, 11

(Frank, CEO and Chief Invest­ment Offi­cer, U.S. Global Investors “Coal Use in China Shines Light on Growth,” <http://advisoranalyst.com/glablog/tag/coal-prices/>)

Coal pow­ers the Chi­nese econ­omy. The coun­try is the world’s largest con­sumer, gob­bling up nearly half of the world’s coal con­sump­tion in 2009. Coal accounted for 71 per­cent of China’s energy in 2008—more than three times the United States’ share. The Elec­tric­ity Coun­cil esti­mates that the country’s coal demand will reach 1.92 bil­lion tons in 2011, up nearly 10 per­cent from 2010. China hasn’t always been such a glut­ton for coal. In fact, coal con­sump­tion actu­ally declined from 1996 to 2000. How­ever, con­sump­tion has shot up 180 per­cent since then and China accounted for 80 per­cent of demand growth between 1990 and 2010, accord­ing to BP. This is because demand for elec­tric­ity exploded over that time. China’s rapid urban­iza­tion and ris­ing mid­dle class has led to an expo­nen­tial num­ber of new refrig­er­a­tors, air con­di­tion­ers and other appli­ances in homes.

# Solvency

### 1AC – Solvency

#### Plan: The United States federal government should invest in a national CO2 sequestration pipeline infrastructure for the purposes of carbon capture and storage.

#### The private sector can’t move forward with CCS developments until the government acts with pipelines – it will spur private activity

Joel Mack ’09 (Energy Policy 38 (2010) 735–743, “Making carbon dioxide sequestration feasible: Toward federal regulation of CO2 sequestration pipelines,” http://ac.els-cdn.com/S0301421509007459/1-s2.0-S0301421509007459-main.pdf?\_tid=aa0b0c56ba6655e1a04a86812ed884d6&acdnat=1342902367\_7636d44b5a371113b4ce7b1340e0a6b6)

The United States is embarking for the first time on examining and reducing CO2 emissions in order to reduce global climate change impacts. Given the large amounts of CO2 emissions from coal-fired power plants, to the extent policymakers envision using geologic sequestration of CO2 to address any appreciable fraction of current and future CO2 emissions, the required infrastructure investment will be massive, and may be required over a limited period of time. In order for cost of CO2 sequestration pipelines to be borne efficiently by the private sector or utility ratepayers, and to accomplish these objectives in a timely fashion, the regulatory structures in place need to assure certainty, efficiency and predictability in the siting and regulatory process, in ratemaking requirements, and in the ability to obtain the necessary real property entitlement to construct such pipelines. The current system, while certainly functioning well over the existing pipeline network, is simply not structured to handle the development in a short period of time of perhaps 50,000 or 100,000 miles of these pipelines at a cost of many billions of dollars. The current system is not structured to attract private equity or debt capital investment, similar to the way the private sector has invested in our electric generation and natural gas pipeline infrastructure. A comprehensive federal program is ultimately what is required for this investment to be made on a timely basis and relying to the maximum extent on private sources of capital and the global capital markets. As the United States moves towards a reduced carbon footprint, the nation will have to deal with the CO2 emissions from our large fleet of coal-fired, base load power plants. Geologic sequestration is a technology that will likely be a major part of the solution to this problem, and in order for that to happen, the United States will have to invest substantially in a massive increase of its CO2 pipeline transportation capacity. The current regulatory regime, consisting of state utility commission oversight and very limited federal regulation over rate complaints and pipeline safety, is likely to prove inadequate to support the massive infrastructure development required to implement this objective in a timely and capital-efficient manner. This article recommends that Congress adopt legislation to provide for preemptive, federal licensing, rate regulation and oversight of these pipelines in order to provide the certainty and clarity that will give the private sector the certainty, predictability and confidence to invest in this very important part of our infrastructure.

#### CCS will happen but won’t be effective unless there is federal support for a pipeline

Cyrus Zarraby ’12 (J.D., expected May 2012, The George Washington University Law School; B.S., 2003, Clemson University. The author is a chemical engineer for the Federal Energy Regulatory Commission (“FERC”), April 2012, Vol. 80 No. 3, “Regulating Carbon Capture and Sequestration: A Federal Regulatory Regime to Promote the Construction of a National Carbon Dioxide Pipeline Network,” <http://groups.law.gwu.edu/lr/ArticlePDF/80_3_Zarraby.pdf>)

Although the technology for capturing and storing CO2 has been proven in operation, 13 the United States does not have adequate infrastructure to implement CCS on a national scale. Specifically, tens of thousands of miles of CO2 pipelines must be constructed to transport the CO2 from the power plants to underground reservoirs. 14 Currently, there is no comprehensive federal regulation of CO2 pipelines and existing state regulations are limited. 15 The uncertainty of this regulatory framework will prevent the development of much-needed CO2 pipelines. 16 Given the harms that will arise because of greenhouse gas emissions and the continued reliance on coal as a source of electricity, it is imperative that Congress pass legislation that promotes the construction of new CO2 pipelines. 17

#### Without the federal government the pipelines can’t get built

Cyrus Zarraby ’12 (J.D., expected May 2012, The George Washington University Law School; B.S., 2003, Clemson University. The author is a chemical engineer for the Federal Energy Regulatory Commission (“FERC”), April 2012, Vol. 80 No. 3, “Regulating Carbon Capture and Sequestration: A Federal Regulatory Regime to Promote the Construction of a National Carbon Dioxide Pipeline Network,” <http://groups.law.gwu.edu/lr/ArticlePDF/80_3_Zarraby.pdf>)

The current lack of a federal regulatory regime coupled with inconsistent state regulations creates three distinct problems that will limit the construction of CO2 pipelines and hinder the development of CCS technology: (1) uncertainty in the regulations of CO2 pipelines, 147 (2) a single state’s ability to prevent the construction of a pipeline due to the uncertainty of eminent domain issues, 148 and (3) a single landowner’s ability to either require a pipeline to incur a substantial cost or prevent the construction of the pipeline altogether because of the lack of universal eminent domain authority. 1

#### Pipelines are the necessary catalyst for CCS deployment

IRGC ’08 (International Risk Governance Council, Geneva 2008, “Regulation of Carbon Capture and Storage,” http://www.irgc.org/IMG/pdf/Policy\_Brief\_CCS.pdf)

Large-scale CCS deployment cannot proceed until extensive pipeline infrastructure is in place. Large volumes of CO2 – a 1,000 MW coal-ﬁred power plant produces 5 to 8 million tonnes of CO2 annually – will need to be transported from source to sink. Linkages are complex, and the business model for pipeline operators includes signiﬁcant risk, as their operations are subject to uncertainties beyond their control at both ends of the pipe. This risk puts upward pressure on pipeline costs, as do recent steel price increases. Transport infrastructure investment requires regional and sitespeciﬁc knowledge of geological storage prospects, as well as knowledge of current and future CO2 source locations, volumes, and characteristics. Pipeline transport of CO2 is successfully regulated for enhanced oil recovery in the US, but with a framework that does not necessarily translate to the industrial organisation of CCS. Regulation of risks related to pipeline transport is straightforward, but more complicated regulatory decisions will relate to funding, siting and construction of pipeline networks off-shore, onshore, and through urban zones, natural monopoly concerns, and issues of eminent domain. Different regulatory models for CO2 pipeline ownership, a privately owned, common carrier approach or a public utility approach could stimulate different levels of investment, potentially inﬂuencing the ultimate organisational structure of the CCS industry.

### Feasibility

#### CCS technology is feasible

Wall 7 – professor in the School of Engineering at the University of Newcastle (Terry F., senior academician of the Australian Academy of Technological Science and Engineering (ATSE), January 2007, “Combustion processes for carbon capture,” Proceedings of the Combustion Institute, Volume 31, Number 1, pp. 31-47, p. ScienceDirect)

Technologies that are being developed for CO2 capture and sequestration from combustion and gasification technologies include [4]:¶ • CO2 capture from plants of conventional pulverized fuel (pf) technology with scrubbing of the flue gas for CO2 removal, here called post-combustion capture (PCC).¶ • Integrated gasification combined cycle (IGCC) with a shift reactor to convert CO to CO2, followed by CO2 capture, which is often called pre-combustion capture, here called IGCCCCS.¶ • Oxy-fuel (Oxyf) combustion, with combustion in oxygen rather than air, and the oxygen is diluted with an external recycle flue gas (RFG) to reduce its combustion temperature and add gas to carry the combustion energy through the heat transfer operations in the current first generation technology.¶ • Oxy-combustion with an internal recycle stream induced by the high momentum oxygen jets in place of external recycle. This technology is now widely used in the glass industry and, to a lesser extent, in the steel industry.¶ • Chemical looping which involves the oxidation of an intermediate by air and the use of the oxidized intermediate to oxidize the fuel.¶ This review covers the first three options, as these are the closest to commercial application involving carbon capture. All three are being developed through planned demonstrations (at 30–300 MW, some involving sequestration), with government and industry funding in the US, EU, Japan and Australia. Commercial availability is targeted from 2015 to 2020. The technologies are primarily based on pulverized coal combustion in entrained flow—the dominant current technology for coal-based power, or gasification in entrained flow, although similar concepts apply to other solid–gas contacting systems such as fluidized beds. PCC and Oxyf involve combustion, IGCC involves gasification, CO2 capture and H2 separation. IGCC uniquely produces H2, which can be utilized for heat and power and also potentially as a transport fuel. All technologies include compression of the CO2 product to a supercritical state, typically 10 MPa, prior to transport and geological storage at a depth (and thereby pressure) retaining this state.¶ Table 1 compares the main characteristics of the CCS options and Figs. 1–3 give flow sheets. PCC and Oxyf may be retrofitted to an existing plant, PCC and IGCC-CCS can be applied to partial capture from the flue gas. IGCC may use O2 rather than air as the oxidant to establish higher proportions of CO2, only Oxyf does not require CO2 capture prior to compression. Entrained flow systems use similar combustion temperatures of 1300–1700 C, IGCC uniquely uses high pressures of 2–8 MPa, with 2–3 MPa typical for IGCC without CCS and 7–8 MPa being proposed for IGCC-CCS.¶ As shown on Fig. 1, PCC can use established technology applied in chemical and natural gas processing for CO2 and SO2 removal, with CO2 scrubbed using chemically active agents that are regenerated by heating to release CO2. Amines such as monoethanolamine (MEA) and methyldiethanolamine (MDEA) are primarily considered. As shown on Fig. 2, in its CCS form the IGCC gasifier product gas is converted to additional H2 and CO2 using a shift reaction, with the H2 burnt in a gas turbine with N2 as a diluent. As shown on Fig. 3, Oxyf involves combustion in an oxygen/recycled flue gas mixture, containing about 30% O2 to maintain similar furnace heat transfer, with the CO2 rich gases being cooled and compressed. No CO2 separation is required. All three technologies are associated with higher generation costs with energy penalties for CO2 compression, for O2 production for IGCC and Oxyf, and for CO2 capture for PCC and IGCC.¶ Many recent studies [5–8] have compared the three technologies in terms of efficiency of generation with and without capture, the contributions to increased costs, and the cost of electricity (COE) with carbon capture with comparisons of COE with a CO2 tax or penalty, as given on Figs. 4–6. Figure 4 indicates that the efficiency penalties vary from 7% to 10%, with efficiencies for technologies with carbon capture being typically 35% LHV (apart from the IGCC-CCS slurry system, which has a lower efficiency due to the additional water addition).¶ Important contributors to efficiency losses are: PCC—solvent regeneration, CO2 compression, IGCC-CCS—oxygen production, CO2 compression, Oxyf—oxygen production, CO2 compression.¶ An implication of the comparisons given on Fig. 4 is that CCS is best applied to high efficiency plant, where the penalties are a lower proportion of the non-CCS efficiency. In addition, efficiencies of power technologies are improving, so that the energy associated with the efficiency penalty will reduce over time.

#### Government investment is key to market confidence in CCS – a government action serves to start growth in the market

DECC ’12 (Department of Energy & Climate Change, April 2012, “Building networks: transport and storage ¶ Infrastructure,” http://www.decc.gov.uk/assets/decc/11/cutting-emissions/carbon-capture-storage/4905-ccs-roadmap--transport-and-storage-infrastructure.pdf)

Key to unlocking investment in CCS infrastructure is market confidence that CCS will ¶ provide the benefits anticipated, that demand for transport and storage will materialise¶ and that commercial arrangements typical for other utility services will emerge. ¶ Government action to facilitate the development and deployment of CCS is designed to ¶ help address each of these points and will ultimately create the right conditions for the ¶ private sector to invest in pipeline and storage infrastructure without Government ¶ intervention.

### Cost

#### Other tech proves – developments allow it to be cost-competitive

CBO ’12 (Congressional Budget Office, study was prepared at the request of the Chairman of the Senate Committee on Energy and Natural Resources, June 2012, “Federal Efforts to Reduce the Cost of Capturing and Storing Carbon Dioxide,” http://www.cbo.gov/sites/default/files/cbofiles/attachments/43357-06-28CarbonCapture.pdf)

CBO has compared the estimated costs of producing electricity at conventional coal-fired power plants with those that would be incurred at facilities equipped with CCS technology. Initially, the cost of generating electricity at a new coal-fired CCS-equipped plant would be substantially higher than the cost of generating it at a plant that produced the same net output of electricity but used conventional technology to do it. However, that premium could decline over time as electric utilities gained experience in installing and using CCS, a pattern seen with other new technologies. Even so, reducing the cost by enough to achieve DOE’s goal of only a 35 percent premium could require a lengthy process of building a large amount of new electricity generation capacity

#### New research will cut CCS costs

ICFI 9 (ICF International, a firm that partners with government and commercial clients to deliver professional services and technology solutions, February 2009, “Developing a Pipeline Infrastructure for CO2 Capture and Storage: Issues and Challenges,” http://www.ingaa.org/File.aspx?id=8228)

Improving Carbon Capture Technologies

It is possible that new technologies to capture CO2 could prove to be less expensive than the processes that have been reviewed thus far. Research is ongoing to find better chemical absorption and physical absorption solvents that would require less space for equipment, be less subject to degradation, and use less energy.

Research is also being conducted in membrane separation technologies to remove CO2. Gas separation membranes are semi-permeable materials that permit the direct passage of CO2 but retain other molecules. While these systems have not been proven in flue gas service, they have had commercial success in the separation of CO2 from natural gas at the wellhead. Research is underway to improve the operating life and other performance characteristics of these membranes. Also improved membrane technology could play an important role in reducing the cost of separating oxygen from air. This would reduce the cost of both oxy-firing and pre-combustion capture technologies.

Another promising option is solid physical adsorption which captures CO2 on a solid material (such as a zeolite) and then releases the captured gas through pressure swing or temperature swing. Pressure swing adsorption (PSA) is a widely used commercial process to separate H2 from H2/CO2 mixtures in H2 production and in other applications. The problem with using PSA now is that power plant and industrial flue gas pressures are too low to cause CO2 to adhere to solid materials and the option of pressuring up the gases would add substantially to capture costs. For this reason, research is underway to find materials that would hold and release CO2 with smaller pressure or temperature swings. Also because zeolite adsorbents for CO2 separation selectively adsorb water, moisture must be removed in a pretreatment step. One focus of current research is to develop novel adsorbents that are less sensitive to water vapor. There is also a need to develop and demonstrate large-scale vacuum pumps and valves for this removal process.

Flue gas CO2 capture could also be achieved by simply cooling and compressing the gas stream until the carbon dioxide condenses into a liquid or dry ice. This cryogenic approach is unlikely to ever be economically viable given the energy requirements. However, in the presence of small quantities of water, the CO2 can be made to condense at a more reasonable temperature and pressure (32o Fahrenheit and 300 psi) in the form of a hydrate, a solid ice-like structure. If conditions are carefully controlled, these CO2 hydrates can be made to form selectively, leaving other gases behind. Once these gaseous components have been separated, the CO2 can be regenerated from the gas phase, or possibly sequestered in the hydrate form.

#### Investment is happening despite high cost

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Today three types of technology can capture CO2 at a power plant. One, as at the Schwarze Pumpe, involves the oxyfuel process: burning coal in pure oxygen to produce a stream of CO2-rich emissions. The second uses various forms of chemistry—in the form of amine or ammonia scrubbers, special membranes or ionic liquids—to pull carbon dioxide out of a more mixed set of exhaust gases. The third is gasification, in which liquid or solid fuels are first turned into synthetic natural gas; CO2 from the conversion of the gas can be siphoned off.

The primary problem with all of them is cost. Simply put, it costs money—and energy—to capture the CO2, ranging from as little as $5 a metric ton at natural gas projects such as In Salah to more than $90 a metric ton for certain gasification technologies.

The Department of Energy estimated in May 2007 that a new power plant burning pulverized coal and equipped with amine scrubbers to capture 90 percent of the CO2 would make electricity at a cost of more than $114 per megawatt-hour (compared with just $63 per MWh without CO2 capture). A similar integrated gasification combined cycle (IGCC) plant—in which coal is turned to gas before being burned—capturing the same amount would produce electricity for roughly $103 per MWh. For the consumer, the extra cost of carbon capture would therefore amount to about $0.04 per kilowatt-hour.

The DOE, for its part, hopes to bring that price down. “In terms of total cost, they want to shoot for $10 per metric ton of CO2,” says CO2 sequestration project leader Rajesh Pawar of Los Alamos National Laboratory. “We are closer to the $50 per ton range right now.”

Nevertheless, even the currently high costs have not stopped utilities and governments from building some carbon capture plants and planning for more. The 180-MW Warrior Run power plant in Maryland already captures 96 percent of its CO2 emissions to sell in fire extinguishers. The Kingsport power plant in Tennessee has been capturing CO2 since 1984 to sell to carbonated beverage makers. Abroad, Vattenfall will expand the Schwarze Pumpe operation and convert several commercial boilers in power plants, such as Janschwalde in Germany and Nordjylland in Denmark, for CCS by 2015, according to Vattenfall’s Görtz. Australia and China are both building what will become zero-emissions coal-fired power plants using IGCC technology, dubbed ZeroGen and GreenGen, respectively.

The Obama administration may even resurrect the FutureGen project—a 275-MW IGCC power plant that would capture 90 percent of its emissions; the Bush administration had canceled it because of spiraling costs (which may have been miscalculated). And the DOE has offered at least $8 billion in loan guarantees for coal-fired power plants with CCS.

Duke Energy is spending $2.35 billion to build a 630-MW IGCC power plant in Edwardsport, Ind., that may become the first commercial CCS project in the country—although as designed (and pending approval), it would capture only about 18 percent of the CO2 it will generate in 2013. “It is our goal to make this one of the first demonstrations of CCS at a working power plant,” says Angeline Protogere, a Duke spokesperson. “Coal powers about half the nation’s electricity, and we have to find ways to burn it cleanly.”

Of course, such a demonstration plant will not address some of the other issues vilifying coal use, such as mountaintop-removal mining to get at coal seams or the toxic coal ash left over afterward. And all (or nearly all) of the greenhouse gas would need to be captured for a coal-fired power plant to be climate-friendly. But IGCC is capable of removing 90 percent or more of the CO2. “Our request is to look at 18 percent capture and sequestration,” Protogere says. “That doesn’t preclude going back and asking for a higher level later on.”

Duke is not alone. American Electric Power will begin capturing at best just over 3 percent of the 8.5 million metric tons of carbon dioxide emitted by its 1,300-MW Mountaineer Power Plant in West Virginia later this year and injecting the CO2 more than three kilometers underground. The Erora Group plans to build a 630-MW IGCC plant with CCS dubbed Cash Creek in Henderson County, Kentucky. Summit Power proposes to build a 170-MW IGCC plant in West Texas that would capture 80 percent of its CO2 emissions. BP and Southern Company have projects as well.

But previous plants, such as two proposed by the utility NRG in New York State and Delaware, have fallen by the wayside. They were killed by the high cost of the technology and a lack of federal policy—a cap-and-trade program, a carbon tax or some other mechanism effectively setting a price on CO2 pollution—to make them economically feasible, notes Caroline Angoorly, head of environmental markets at JPMorgan Chase, who formerly led development of these projects while at NPG.

Nevertheless, Oklahoma-based Tenaska is planning for two plants. One $3.5-billion plant in Taylorville, Ill., would gasify the high-sulfur local coals before capturing at least 50 percent of the CO2. Another $3.5-billion plant planned for Sweetwater, Tex., would burn pulverized coal to generate 600 MW of electricity while capturing its 5.75 million metric tons of emissions postcombustion with amine or ammonia scrubbers or, possibly, with advanced membranes that separate CO2 from other flue gases.

#### Cost reductions will happen over time

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Many of the cost reductions for new technologies are expected to come from learning by doing (Arrow, 1962). Producers will explore new ideas to reduce production costs when they build a new production line – and repeat successful approaches in future investments. This suggests that learning by doing requires some market growth in order to allow for the construction of new production lines. However, the more production lines are built in parallel with the same technology, the fewer the number of additional insights from an extra line. This suggests that growth rates should not be excessive. Reviewing studies across various technologies we observe growth rates rarely exceeding 35% per year, while new technologies exhibit high learning by doing rates up to these growth rates.

The learning by doing methodology has been frequently applied to assess whether public support for new technologies is justified by the future benefits derived from renewable technologies. This paper expands previous work and analyses the marginal benefit of an additional unit of subsidised new technology – with a puzzling result: even where the overall scheme is profitable, the extra subsidy is larger than the discounted future cost reductions that result from it.

The puzzle's solution is the growth constraint for the new technology. Production volume of new technologies can only grow gradually, due to of constraints on production capacity and qualified labour. Also, industry takes time to gather experience from production at a new installation. If too many new installations are built in parallel this will reduce the learning benefit.

Now assume today's investment in the new technology is reduced by one unit, the implication is that all future investments will also have to be reduced by one unit if the future growth constraint is not to be violated. This will delay the time when the new technology becomes profitable and reduces the future market size of the new technology. The marginal value of capturing the full growth potential can be a multiple of the direct value from the cost reductions associated with the new technology.

This is not too surprising. If it is profitable to use a strategic deployment program for a technology, then the discounted future benefits outweigh the additional costs that are born earlier on. If the deployment can be accelerated without compromising the learning by doing rate, then future benefits are delivered earlier and do not need to be as heavily discounted, thus increasing the overall profitability. If costs are too high and output too similar to conventional technologies, feed-in tariffs, traded certificate schemes, and tender auctions are used to create markets for new technologies in order to create sufficient private demand for low-carbon options.

Some analysts argue instead that governments should rely on the carbon price to internalise the environmental externality and incentivise the development of technologies (Manne and Richels 2004). This assumes that investors anticipate high future carbon prices and shoulder the early costs of deploying a new technology, by selling a technology below cost so as to develop the market and gain learning experience. Given the difficulties of appropriate innovation in the energy sector (Stokey 1996), and the sharing of the benefits among many players that may be involved in the development of the technology, this is an unlikely scenario (Neuhoff 2005). It is more likely that technology companies and investors will wait until the carbon price sufficiently increases the costs of competing conventional technologies in order to make the new technology competitive. This will result in a peaky CO2 price. In the model carbon prices will not only peak, but remain at far higher prices for many years until technology costs are reduced via learning by doing.

Due to technology spill over the market outcome will no longer coincide with the social optimal investment pattern. This has also implications for modelling approaches. While the representation of endogenous technological change has become standard for large scale modelling approaches (Koehler et al 2006), the precise formulation of the optimisation function and its implementation can influence the outcomes. This paper suggests a framework to classify different simplifications used to represent endogenous technological change (Sijm 2004). This helps to understand the implications of different model formulations and solution algorithms.

This paper first reviews the empirical evidence for learning by doing and discusses approaches to represent and quantify the effect. Using the learning-curve approach, Section 3 analyses the marginal value of additional learning investment, and Section 4 illustrates the result with a numerical example. Section 5 discusses the implication for public policy analysis and Section 6 concludes.

2. Empirical evidence - improvements through market experience

The cost of new technologies falls with increasing deployment, both for energy technologies and other industry sectors. The IEA (2003) concludes that "there is overwhelming empirical evidence that deploying new technologies in competitive markets leads to technology learning, in which the cost of using a new technology falls and its technical performance improves as sales and operational experience accumulate." Isoard and Soria (2001) identify Grainger causality between installed capacity and capital costs both for wind and PV. McDonald and Schrattenholzer (2001) also show that for emerging technology, the price reduction typically falls between 5-25% with each doubling of cumulative industry output, with most reductions clustered between 15-20%.

However, careful assessments have also illustrated that extremely high improvement rates calculated by some initial studies can be partially attributed to factors such as capital availability or changing product quality (Thompson 2001, Nemet 2006). A survey of several industries indicates that learning effects usually dominate scale economies (Isoard and Soria 1997), for example Watanabe (1999) shows that 70% of price reductions in the Japanese PV industry can be attributed to learning effects.

One fundamental assumption of the improvement through market experience (learning curve) methodology is that the pattern of cost reductions caused by global installed capacity will not undergo fundamental future change. This result requires thorough examination as it has significant implications for government technology policy. Lieberman (1984) shows that in the chemical processing industry time becomes statistically insignificant if log cumulative production is used as an explanatory variable, and Jensen (2004) critically discusses different modelling approaches. In contrast, Papineau (2006) identifies time as a significant explanatory variable for price reductions in a regression of PV module prices. One possible interpretation of this finding is that if we merely wait for a sufficient period of time, the technology cost will fall. However, the estimation did not include the log of global cumulative installed capacity as an explanatory variable. In the observation period, global PV penetration increased exponentially (with constant growth rates). Therefore, the log of global cumulative capacity is almost perfectly correlated with time. In the sample it is impossible to identify whether time or global cumulative installed capacity drives the cost reduction.

#### Short-term investment in CCS creates long-term cost reductions

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Countries implement strategic deployment programs to subsidize investment in renewable technologies. They do not aim only for the direct carbon and energy benefits of the projects, but also expect that increased experience will reduce technology costs and allow for large scale application in the future (Grubb, 1997). This is expected to be a major contribution to low cost mitigation strategies (Edenhofer et al 2006, Stern 2006, IPCC 2007).

If a new technology competes with existing technologies in providing a homogeneous product, then the social value of investing in the technology might exceed the private value of the investment. This is because the investment creates market experience that reduces future investment costs. The investment also results in usage and expansion of production and installation capacity for the technology. If expansion rate of a technology is constrained, early expansion of capacity can create future benefits in the form of higher production capacity. Depending on the sector and the technology, private investors can capture some of these benefits. To the extent that they are not able to capture the benefits, and where they are not in a position to invest in a new technology without these benefits, public support for strategic deployment may be warranted.

### Capture

#### Postcombustion capture solves

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Already Australia and China have demonstrated that such postcombustion capture is possible in pilot plants. At Loy Yang Power Station in Victoria, a pilot plant run by CSIRO will capture 1,000 metric tons of CO2 a year; the Australian research organization has collaborated with China’s Huaneng Group to use an amine scrubber to capture CO2 from a co-generation power plant in Beijing and then sell it. And Statoil is building a CCS research site at its Mongstad refinery in Norway.

If postcombustion capture can be demonstrated commercially, “then the market for those existing coal-fired power plants is very large. There are at least two billion tons of domestic emissions from pulverized coal power plants,” says Greg Kunkel, Tenaska’s vice president for environmental affairs. “You can’t tackle the larger problem [of climate change] unless you deal with those plants in some way.”

And that consideration has brought even environmental groups such as the Natural Resources Defense Council (NRDC) and the EDF to support carbon capture and storage. By their estimations, coal-fired power plants coming online since the turn of the millennium will emit more CO2 than all other human coal burning has since the dawn of the industrial age: 660 billion metric tons over their 50-year lifetime versus 524 billion metric tons between 1751 and 2000. “The next 25 years of investment would produce 34 percent more emissions than all previous human use of coal,” says engineer and scientist George Peridas of NRDC’s climate center. “This is a massive legacy, and we cannot afford to let that happen.”

#### There are lots of feasible options for capture

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III. CAPTURE OF CO2¶ CCS is a three step process: (1) capture of CO2 from a power plant, industrial process, or other source (Yang et al., 2008); (2) transport to a storage site; and (3) injection into a geologic formation. Of these steps, the first (CO2 capture from a power plant) is the most expensive, accounting for approximately 75% of the total cost. There are three basic approaches to capture of carbon from fossil fuels: post-combustion capture, pre-combustion capture, and oxycombustion (EPRI, 2007; Figueroa et al., 2008). These three options are illustrated in Figure 1.¶ A. Post-Combustion Capture¶ Post-combustion capture involves the removal of CO2 from the flue gas produced by burning a fossil fuel. Current power plants burn their fuel in air, which is almost four-fifths nitrogen, and generate a flue gas at atmospheric pressure with a CO2 concentration less than 15%. The thermodynamic driving force (CO2 partial pressure) for CO2 capture from flue gas is low (the CO2 partial pressure is typically less than 0.15 atm). This low partial pressure is a significant technical challenge for the development of cost-effective capture processes. In spite of this difficulty, post-combustion carbon capture has the greatest nearterm potential for reducing GHG emissions, because it can be retrofitted to existing units that generate two-thirds of the CO2 emissions in the power sector.¶ B. Pre-Combustion Capture¶ In pre-combustion CO2 capture, the CO2 is recovered from some process stream before the fuel is burned. If the concentration and pressure of the CO2 containing stream can be increased, thus increasing the partial pressure of CO2, then the size and cost of the capture facilities can be reduced. This has led to efforts to develop combustion technologies that inherently produce concentrated CO2 streams or CO2 containing streams at high pressure for which existing capture processes can be used. One approach is to first gasify the fuel to produce synthesis gas (referred to as syngas), a mixture of hydrogen (H2) and carbon monoxide (CO). The water-gas-shift reaction (CO + H2O ↔ CO2+ H2) is used to convert CO in the syngas into H2 plus CO2. The CO2 is recovered and the H2 is burned as fuel in an integrated gasification combined cycle (IGCC) plant. Since gasifiers can operate at pressures of 65 atm or higher, the partial pressure of CO2 is much higher than in a typical flue gas, and a cheaper CO2 capture process can be used as a result (Kanniche and Bouallou, 2007; Ordorica-Garcia et al., 2006; Pennline et al., 2008).¶ C. Oxy-Combustion¶ An alternative to capturing carbon from fuel gas or flue gas is to modify the combustion process so that the flue gas has a high concentration of CO2. A way to accomplish this is to burn the fuel in nearly pure oxygen (greater than 95%), referred to as oxy-fuel combustion or simply oxy-combustion (Andersson and Johnsson, 2006; Andersson and Johnsson, 2007; Be´er, 2007; Buhre et al., 2005; Davison, 2007; Gou et al., 2007; Haslbeck et al., 2007; Kvamsdal et al., 2007; Simpson and Simon, 2007; Wall, 2007; Zanganeh and Shafeen, 2007; Zhang and Lior, 2008). Typically, a cryogenic air separation unit (ASU) is used to supply high purity oxygen to a pulverized coal (PC)-fired boiler. Because currently available materials of construction cannot withstand the high temperatures resulting from coal combustion in pure oxygen, the high purity oxygen is mixed with recycled flue gas, either prior to combustion or in the boiler, to maintain combustion conditions similar to an air-fired unit.¶ Oxy-combustion produces a flue gas with a high CO2 content, which can be purified relatively inexpensively, if necessary. Conditioning of the flue gas consists of drying, removal of O2 to prevent corrosion in the pipeline, and possibly removal of other contaminants and diluents, such as Ar, N2, SO2, and NOx.¶ Several factors should reduce the cost of carbon capture for an oxy-combustion plant, such as decreased flue gas volume and much higher CO2 concentration in the flue gas than for a conventional PC plant. On the other hand, the need for a cryogenic oxygen plant and flue gas recycle significantly adds to the cost (Figueroa et al., 2008). A further advantage of oxy-combustion is that the low nitrogen concentration in the furnace dramatically lowers NOx production (Kim et al., 2007). A recent report (Haslbeck et al., 2007) compared a variety of oxy-combustion cases with conventional plants with an amine scrubber (Fluor Econamine FG Plus) and concluded that oxy-combustion was slightly cheaper than a conventional plant with amine scrubbing for CO2 removal. Various process options are being considered that could make oxy-combustion more economically attractive. One option is the use of a circulating fluidized bed (CFB) with a reduced requirement for recycled flue gas and easier temperature control (Czakiert et al., 2006; Nsakala et al., 2004). Another is the use of an oxygen ion transport membrane to replace the expensive and energy-intensive ASU (Foy and McGovern, 2007; Yantovski et al., 2004). At high temperature, oxygen can diffuse through this ceramic membrane. Schiestel et al. (2005) have developed a hollow fiber perovskite-structure membrane. In practice, air would be compressed and blown through membrane tubes in a furnace. Oxygen would diffuse through themembrane into the furnace and combust the fuel. The low concentration of oxygen in the furnace would increase the driving force for diffusion. After heat recovery and, possibly, power recovery, the depleted air would be vented to the atmosphere (Shah et al., 2006).¶ Still another alternative to a cryogenic oxygen plant is the use of ceramic autothermal recovery (CAR). CAR technology is based on the ability of perovskite materials at high temperatures to store oxygen. The process involves a two-step operation. In step one, air is passed over the bed that adsorbs and stores oxygen; in step two, a sweep gas, such as flue gas, is passed through the bed to release the stored oxygen. The process ismade continuous by using multiple beds in cyclic operation. The two steps are performed countercurrently for heat management. Oxygen adsorption is exothermic, while oxygen desorption is endothermic, so once initiated, the process operates autothermally. The CAR process is well suited to oxy-combustion with flue gas recycle, because it can be configured to produce low-pressure oxygen at the concentration required for combustion by using recycled flue gas as the sweep gas (Acharya et al., 2005).¶ D. Commercially Available CO2 Capture Processes¶ Several industrial operations require removal of CO2 from a gas stream before the product can be used. A prime example is the natural gas industry; much of the raw gas produced is contaminated with CO2 that must be removed before the gas can enter the natural gas pipeline system and be sold. Another example is the production of hydrogen, which requires CO2 removal to obtain a usable product. Because of these and other needs, commercial processes have been developed, and many CO2 removal units are in operation throughout the world.¶ All the current commercially available processes are similar in concept. Units consist of two vessels. In the first vessel, the CO2-containing gas contacts a lean solvent which absorbs the CO2. In the second vessel, the rich solvent is regenerated by lowering the pressure, raising the temperature, or both and returned to the first vessel. Solvents used in these processes can be broadly grouped into two categories—physical solvents and chemical solvents. Each type of solvent has its advantages and disadvantages.¶ 1. Physical Solvents¶ Physical solvents selectively absorb CO2 without a chemical reaction. The loading that can be achieved (kg CO2 per kg solvent) depends upon the solvent used, the partial pressure of CO2, and the temperature, with higher partial pressures and lower temperatures resulting in higher loadings. Maximum loading is approximately proportional to CO2 partial pressure. Two common commercial acid gas removal processes that employ physical solvents are Selexol, which uses a mixture of dimethyl ethers of polyethylene glycol, and Rectisol, which uses chilled methanol. Regeneration is endothermic and requires the input of energy. The energy required is typically supplied by steam extracted from the turbines and, therefore, represents a decrease in power output. Another common physical solvent used commercially is propylene carbonate (Fluor process). The weaker bonding between CO2 and this solvent allows the CO2 to be separated from the solvent in a stripper by reducing the total pressure. IGCC can use physical solvents because of the relatively high partial pressure of CO2 in the syngas exiting the shift converter and take advantage of the main benefit of physical solvents—lower energy requirement for regeneration.¶ Energy management is a promising area for improving the efficiency of CO2 scrubbers, and they could benefit from higher efficiency gas-liquid contactors and lower energy requirements for regeneration (MGSC, 2004). A significant problem with physical solvents is that their capacity is highest at low temperatures, and it is usually necessary to cool the syngas before carbon capture. A physical solvent with acceptable capacity at a higher temperature would improve the efficiency of IGCC with CO2 capture. Other improvements that would benefit physical solvent-based CO2 capture include modifying regeneration conditions to recover the CO2 at a higher pressure, improving selectivity to reduce H2 losses, and developing a solvent that has a high CO2 loading at a higher temperature.¶ 2. Chemical Solvents¶ Amines react with CO2 to form water soluble compounds. Because of this chemical reaction, amines are able to capture CO2 from streams with a low CO2 partial pressure. However, capacity is limited by chemical equilibrium and the concentration of amine in the solvent. Thus, amine-based systems are able to recover CO2 from the flue gas of conventional PC-fired power plants, however only at a significant cost and power plant efficiency penalty. Amines are available in three forms (primary, secondary, and tertiary), each with its advantages and disadvantages as a CO2 solvent. Examples of commonly used amine solvents of each type are: primary—monoethanol amine (MEA); secondary—diethanol amine (DEA); and tertiary—methyl diethanol amine (MDEA). Primary amines form the strongest bonds with acid gases (CO2 and H2S), secondary amines are next, and tertiary amines form the weakest bonds. Additives are sometimes used to modify system performance.¶ Another chemical solvent in use is potassium carbonate (K2CO3), such as in UOP’s BenfieldTM process. This process is based on the conversion of carbonate to bicarbonate in the presence of CO2. The bicarbonate is converted back to carbonate by heating with release of the absorbed CO2, as shown by the reaction:¶ K2CO3 + CO2 + H2O ↔ 2KHCO3¶ A major advantage of carbonate systems over amines is the significantly lower energy required for regeneration. The solvent formulation sometimes includes additives to improve absorption rate or provide other benefits.¶ In contrast to physical solvents, the capacity of a chemical solvent does not depend strongly on CO2 partial pressure. Rather, it is a function of the concentration of the sorbent and the completeness of regeneration.¶ Many factors need to be considered in optimizing an amine system (Polasek and Bullin, 1985). Many amines are limited to concentrations of about 30% because of corrosion problems at higher concentrations. Another problem with amine solvents is the formation of stable compounds with impurities in the flue gas, such as COS, SO2, SO3, and NOx , with gradual loss of effectiveness. Oxygen in the flue gas can cause degradation, resulting in loss of solvent. Furthermore, amine-based units have yet to be built at the scale commensurate with scrubbing CO2 from the flue gas of a large power plant. Some cost reductions are expected from continuing work to increase capacity and stability and reduce energy requirements and from economies of scale as larger units are built.¶ 3. Improved Chemical Solvent Processes¶ Improvements to amine-based systems for post-combustion CO2 capture are being pursued by a number of process developers; a few of these are Fluor, Mitsubishi Heavy Industries (MHI), and Cansolv Technologies. Fluor’s Econamine FG process (Chapel et al., 1999) is commercially used at a number of plants. An improved version, which includes a reformulated solvent and design changes, is offered as Econamine FG Plus. It has demonstrated greater than 95% availability operating on the flue gas from a natural gas fired turbine at a 320 tonnes/day CO2 capture plant in Bellingham, Massachusetts. MHI has developed a new absorption process, referred to as KS-1. A key factor in this development is the utilization of a new aminetype solvent for the capture of CO2 from flue gas (BP America, 2005).¶ As another example, Cansolv Technologies, Inc. proposes to reduce costs by incorporating CO2 capture in a single column together with processes for capturing pollutants, such as SO2, NOx, and Hg. Their proprietary DC103R amine solvent is reported to have the following advantages over MEA (EPRI, 2007): ultra-low solvent degradation rate, low heat of regeneration, low capital and operating costs, and low maintenance. Improvements that would benefit amine-based systems include modified tower packing to reduce pressure drop and increase contacting, increased heat integration to reduce energy requirements, additives to reduce corrosion and allow higher amine concentrations, and improved regeneration procedures (Rao et al., 2006).¶ The University of Texas at Austin has been developing a K2CO3 based system in which the solvent is promoted with catalytic amounts of piperazine (PZ). The K2CO3/PZ system (5 molar K; 2.5 molar PZ) has an absorption rate 10–30% faster than a 30% solution of MEA and favorable equilibrium characteristics. A benefit is that oxygen is less soluble in K+/PZ solvent. Analysis has indicated that energy requirement is approximately 5% lower with a higher loading capacity of 40% versus about 30% for MEA. System integration studies indicate that improvements in structured packaging can provide an additional 5% energy savings, and multipressure stripping can reduce energy use 5–15% (Rochelle et al., 2006).¶ E. Emerging CO2 Capture Technologies¶ Because CCS shows significant potential for reducing CO2 emissions, there is considerable interest in improving CO2 capture processes. This work covers the gamut from improvements to existing processes, as discussed above, to development of completely new sorbents. The following list, which is not exhaustive, gives some idea of the wide range of options being evaluated: aqueous ammonia, metal organic frameworks (MOFs), ionic liquids (ILs), membranes, solid regenerable sorbents, hydrates, chemical-looping, and mineral formation. Figure 2 puts these options in perspective showing potential benefits vs. estimated time to commercialization.¶ 1. Aqueous Ammonia¶ The general principle of aqueous ammonia scrubbing is similar to that for amine systems. In aqueous solution, ammonia reacts with CO2 to form ammonium carbonate (AC) which can react with additional CO2 to form ammonium bicarbonate (ABC). 2NH3 + CO2 + H2O → (NH4)2CO3 (NH4)2CO3 + CO2 + H2O → 2NH4HCO3 This reaction has a significantly lower heat of reaction than amine-based systems, resulting in energy savings. Ammoniabased absorption has a number of other advantages over aminebased systems, such as the potential for high CO2 capacity, lack of degradation during absorption/regeneration, tolerance to oxygen, low cost, potential for regeneration at high pressure, and the possibility of reaction with SOx and NOx in flue gas to form by-product fertilizer (ammonium sulfate and ammonium nitrate) for sale. Ammonia’s higher volatility compared to MEA means that the flue gas must be cooled to the 15–25◦C range to enhance CO2 absorptivity and to minimize ammonia losses. Process improvements under investigation include process optimization to increase CO2 loading and design modifications to minimize ammonia vapor losses (Resnik et al., 2004; Resnik et al., 2006; Yeh et al., 2005).¶ Alstom is developing an ammonia-based process called the Chilled Ammonia Process (CAP). A 1.7-MW pilot unit commenced operation in 2008 at We Energies Pleasant Prairie Power Plant in Wisconsin. CAP uses the AC/ABC absorption chemistry described above but without fertilizer production. A slurry of aqueous AC and ABC and solid ABC is circulated to capture CO2 (Black, 2006; EPRI, 2006). The process operates at temperatures slightly above freezing (0–10◦C); the flue gas is cooled prior to entering the absorber by chilled water in direct contact coolers. Technical considerations relative to process development include cooling the flue gas and absorber to maintain operating temperatures below 10◦F, minimizing ammonia losses, achieving 90% removal efficiencies, and preventing fouling of heat transfer and other equipment by ABC deposition due to absorber operation with a saturated solution. Economic analyses indicate a significant decrease in parasitic power requirements, relative to MEA.¶ 2. Novel Liquid Sorbents¶ Novel liquids being investigated as potential sorbents forCO2 include ionic liquid salts (ILs) (Anderson et al., 2006; Anthony, 2006; Kanel, 2003). ILs are a broad category of salts, typically containing an organic cation and either an inorganic or organic anion. ILs can dissolve CO2 and are stable at temperatures up to several hundred degrees Centigrade, thus offering the possibility of being able to recover CO2 from flue gas without having to cool the gas first. Since ILs are physical solvents, little heat is required for regeneration. Because ILs are relatively new, there is limited experience in their production and use. ILs are more viscous than conventional solvents, and pumping costs could be significantly higher. Much research is needed before ILs can be considered as a solvent for capturing CO2.¶ 3. Metal Organic Frameworks (MOFs)¶ A novel solid sorbent being investigated is MOFs; MOFs are a new class of hybrid material built from metal ions with well-defined coordination geometry and organic bridging ligands (Banerjee et al., 2008; Muller et al., 2006; Walton et al., 2008; Wang et al., 2008). They are extended structures with carefully sized cavities that can adsorb CO2. High CO2 capacity should be possible, and the energy required for regeneration is low.¶ 4. Regenerable Solid Sorbents¶ Solids can act as physical sorbents (e.g., molecular sieves) or form a chemical compound which is regenerated by heat. Many CO2 capture processes based on solid sorbents parallel liquid sorbent processes by being either amine or carbonate based. Amine-based systems use an amine that is stabilized by being absorbed on a porous substrate (Gray et al., 2005). After absorbingCO2, the sorbent is heated to releaseCO2.Acarbonate system being investigated is sodium carbonate (Na2CO3), which reacts with CO2 to form sodium bicarbonate (NaHCO3). The bicarbonate is regenerated to the carbonate by heating (Nelson et al., 2005; Nelson et al., 2006a; Nelson et al., 2006b).¶ Solid-based systems inherently present more design and operating problems than liquid-based systems because handling solids is more difficult. Two approaches can be used: moving (or fluidized) beds for the solids or fixed beds with periodic gas flow switching. Because of the large volume of flue gas from a typical coal-fired power plant, large equipment will be required.¶ 5. Membranes¶ Membranes offer an alternative approach for recovering CO2 (Bredesen et al., 2004; Falk Pederson et al., 2000; Granite and O’Brien, 2005; Kaldis et al., 2004), but for separating CO2 from flue gas, they suffer from the same problem as physical solvents—a low driving force (the difference in CO2 partial pressure on the two sides of the membrane). Since the partial pressure of CO2 in a typical flue gas is considerably below one atmosphere, a vacuum is required on the permeate side or a sweep gas must be used (e.g., steam), which requires a further separation. Compressing CO2 from subatmospheric pressure to 150 atm (a typical pressure for geologic storage) requires a significant amount of energy. Because of the higher partial pressure of CO2 in the raw syngas, the use of membranes with pre-combustion capture is more promising.¶ An enzyme-based membrane system, which achieves CO2 capture and release by mimicking the mechanism of the mammalian respiratory system, is under development by Carbozyme. The process uses carbonic anhydrase (CA) in a hollow fiber contained liquid membrane. The rate of CO2 dissolution in water is limited by the rate of aqueous CO2 hydration, and the CO2-carrying capacity is limited by buffering capacity. Adding the enzyme CA to the solution speeds up the rate of carbonic acid formation; CA has the ability to catalyze the hydration of 600,000 molecules of CO2 per molecule of CA per second compared to a theoretical maximum rate of 1,400,000 (Trachtenberg et al., 1999). The idea behind this process is to use immobilized enzyme at the gas/liquid interface to increase the mass transfer and separation of CO2 from flue gas. Technical challenges include membrane boundary layers, pore wetting, surface fouling (Boa and Trachtenberg, 2006), loss of enzyme activity, long-term operation, and scale-up.¶ 6. Chemical-Looping¶ Chemical-looping is a variation of oxy-combustion in which the oxygen is provided by an oxygen carrier, such as a metal oxide, rather than an ASU (Hossain and de Lasa, 2008; Naqvi and Bolland, 2007; Wang and Anthony, 2008). The fuel is contacted by the oxygen carrier in a combustor, where the fuel is oxidized to produce a flue gas which is predominantly CO2 and water vapor, while the oxygen carrier is reduced. After reduction, the reduced carrier is contacted with air and reoxidized. This reaction is exothermic, and the hot nitrogen leaving the oxidation stage is used to raise steam for power production. CO2 is recovered by condensing the water in the flue gas. A possible embodiment of the concept is to use two fluidized beds (similar to fluid catalytic cracking units used in petroleum refining) with oxidation occurring in one vessel and reduction in the other. After heat recovery to raise steam, the oxygen depleted air is exhausted to the atmosphere. This approach is away to practice oxy-combustion without requiring an ASU.¶ A wide range of materials has been investigated as possible oxygen carriers, but the most promising appear to be NiO (Gayan et al., 2008; Hossain et al., 2007; Ishida et al., 2002; Linderholm et al., 2008; Mattisson et al., 2006: Sedor et al., 2008; Wolf et al., 2005), CuO (Chuang et al., 2008; de Diego et al., 2004; de Diego et al., 2007), Mn3O4 (Johansson et al., 2006; Zafar et al., 2007), and Fe2O3 (Abad et al., 2007; Cho et al., 2004; Corbella and Palacios, 2007; He et al., 2007). CaSO4 (Shen et al., 2008) and various minerals (Leion et al., 2008; Ryden et al., 2008) have also been proposed as oxygen carriers.

### Pipelines Work

#### Pipeline design is mature technology

ICFI 9 (ICF International, a firm that partners with government and commercial clients to deliver professional services and technology solutions, February 2009, “Developing a Pipeline Infrastructure for CO2 Capture and Storage: Issues and Challenges,” http://www.ingaa.org/File.aspx?id=8228)

2.5 CO2 Transportation

CO2 pipelines are a mature technology and are the most common method for transporting large CO2 volumes. Gaseous CO2 is typically compressed to a pressure near 2,200 psi (15.2 MPa) in order to avoid two-phase flow regimes and increase the density of the CO2, thereby making it possible to pump it as a liquid and thereby easier and less costly to transport. CO2 also can be transported as a liquid in ships, tank trucks, or rail tankers that carry chilled CO2 in insulated tanks.

The first long-distance CO2 pipeline came into operation in the early 1970s in the Permian Basin of West Texas. Today in the United States, over 5,800 km (~3,600 miles) of pipeline transports more than 40 million tonnes of CO2 per year from natural and anthropogenic sources. (Figure 2-8) These pipelines operate in the liquid and supercritical CO2 phases at ambient temperatures and high pressure. In most of these pipelines, there are intermediate (booster) pumping stations to compensate for pressure drop along the pipeline.

The design of a CO2 pipeline is similar to that of a natural gas pipeline except that higher pressures must be accommodated; often with thicker pipe (see Table 2-10). The added thickness requires more steel in the line pipe, adds transportation costs to move the line pipe to the construction site and adds to the cost of welding the line pipe. CO2 pipelines also differ in that they require CO2-resistant elastomers around valves and other fittings and their construction includes fracture arrestors every 1,000 feet to reduce fracture propagation, which is more likely in CO2 pipelines due to their slower decompression characteristics.

#### Large-scale pipeline construction is plausible

Dooley et al. 9 – senior staff scientist with the Joint Global Change Research Institute at the Pacific Northwest National Laboratory (J.J., leads the Joint Global Change Research Institute's and the Global Energy Technology Strategy Project's research related to CCS, senior member of the Joint Global Change Research Institute's Integrated Assessment modeling team, Lead Author and the Cross-Cutting Chairman for Market Deployment for the recently released Intergovernmental Panel on Climate Change's Special Report on Carbon Dioxide Capture and Storage, Associate Editor for the *International Journal of Greenhouse Gas Control*; R.T. Dahowski, researcher and Senior Research Engineer at the Pacific Northwest National Laboratory; C.L. Davidson, Senior Research Scientist at the Pacific Northwest National Laboratory; February 2009, “Comparing Existing Pipeline Networks with the Potential Scale of Future U.S. CO2 Pipeline Networks,” *Energy Procedia*, Volume 1, Issue 1, pp. 1595-1602, p. ScienceDirect)

1. Introduction

Interest and concern are growing regarding the potential size of the future U.S.-dedicated carbon dioxide (CO2) pipeline infrastructure related to large-scale deployment of carbon dioxide capture and geologic storage (CCS) technologies. For example, in early 2008, the Congressional Research Service (CRS) stated, “[t]here is an increasing perception in Congress that a national CCS program could require the construction of a substantial network of interstate CO2 pipelines.” The CRS report lists a number of bills and one recently enacted public law that require assessments of the feasibility of creating a national CO2 pipeline network as well as recommendations for the most cost-effective means of implementing a CO2 transportation system [1]. In trying to understand the potential scale of a future national CO2 pipeline network, comparisons are often made to the existing pipeline networks used to deliver natural gas and liquid hydrocarbons to markets within the United States. This paper assesses the potential scale of the CO2 pipeline system needed under two hypothetical climate policies and compares these to the extant U.S. CO2 pipeline infrastructure (See Figure 1, left-hand panel) and the interstate and intrastate natural gas transmission pipeline infrastructure (See Figure 1, right-hand panel). The analysis presented here suggests that the need to increase the size of the existing dedicated CO2 pipeline system should not be seen as a significant obstacle for the commercial deployment of CCS technologies.

2. The Existing U.S. CO2 Pipeline System

There are currently 3900 miles of dedicated CO2 pipelines in the United States—of varying lengths and diameters—built primarily to serve CO2-driven enhanced oil recovery (EOR) projects. Many of these pipelines deliver CO2 from large natural underground accumulations, while some originate at anthropogenic sources (e.g., natural gas and syngas processing facilities). Eighty percent of the existing CO2 pipeline infrastructure was built to deliver CO2 into and within the Permian Basin of West Texas for the purpose of CO2-driven EOR [4]. The earliest pipelines were built in the 1970s in Texas, where the first CO2-floods were initiated. Other regions with significant CO2 pipeline infrastructure include Wyoming/Colorado, Mississippi/Louisiana, Oklahoma, and North Dakota. The largest of the existing CO2 pipelines is the 30-inch Cortez Pipeline, which was completed in 1983 and runs for slightly more than 500 miles from the McElmo Dome in Southwestern Colorado to the EOR fields in West Texas [5].

Nearly three-fourths of this existing CO2 pipeline infrastructure was built in the 1980s and 1990s, largely driven by energy security concerns and resulting federal tax incentives designed to boost domestic oil production. In the 1980s, the major impetus for development was provided by significant changes to the Windfall Profits Tax that preferentially benefited EOR projects (taxed at 30 percent) over conventional oil production (taxed at 70 percent). During the relatively short period of 1980–1985, major U.S. oil companies paid over $88.5 billion (in constant 2005 dollars) in Windfall Profits Taxes [6]. While CO2-driven EOR oil production was a relatively minor source of domestic oil production at that time, this change in the Windfall Profits Tax was a significant incentive for the commercial development of the large natural CO2 deposits (domes) as well as the construction of the CO2 pipeline infrastructure that continues to supply most of the CO2 used for EOR in West Texas, Mississippi, and Louisiana [7]. These infrastructures, which were being developed in the 1980s, allowed for the quick adoption and expansion of the CO2-EOR production method in the 1990s [8].2

Since 1990, the most significant federal incentive for CO2-driven EOR stems from the Section 43 Enhanced Oil Recovery Tax Credit, which was enacted as a result of the Gulf War and renewed domestic concerns about energy security. The Section 43 tax credit can be applied to 15 percent of the capital costs in starting up a qualified EOR project and capital improvements to an operational flood. Perhaps most importantly, the credit is applicable to CO2 purchases (IRS 2005 [9] describes allowable costs in detail). Over the period 1994–2005,3 an estimated $1.3 to $1.9 billion (in constant 2005 dollars) in tax credits related to CO2-driven EOR have been granted by the U.S. Internal Revenue Service.4 This estimated $1.3 to $1.9 billion outlay is only the cost to the federal government and does not include state tax credits designed to boost domestic oil production through EOR.5

3. Drivers for an Expanded U.S. CO2 Pipeline Infrastructure

The existing pipelines built to deliver CO2 to aging oilfields for EOR may provide a starting point for an expanded national CO2 pipeline system. Nonetheless, a key determinant governing the necessary size of a future U.S. CO2 pipeline network is the proximity of each large industrial facility that will utilize CCS technologies (e.g., power plants, refineries) to suitable deep geologic storage reservoirs. For the United States—because of the numerous large and geographically well-distributed deep geologic CO2 storage reservoirs—fully 95 percent of the largest CO2 point sources lie within 50 miles of a potential storage reservoir [10]. It is, therefore, difficult to envision the need for long transcontinental CO2 pipelines at the scale routinely built and operated to move oil and natural gas from relatively isolated pockets of production or import (e.g., Alaska, Gulf Coast) to distant and dispersed markets.

However, the overriding determinant of the extent of future growth of the nation’s pipeline-based CO2 transportation infrastructure will be the stringency and rate of implementation of future climate policy coupled with the cost competitiveness of CCS-derived emission reductions. Although many potential climate policies are debated in the United States, this analysis will focus on the impact of hypothetical future U.S. climate policies that follow the WRE450 and WRE550 stabilization pathways [11]. Since their original publication, these WRE pathways have become widely used benchmarks of requirements to stabilize atmospheric concentrations of greenhouse gases in an economically efficient manner [12]. The WRE450 and WRE550 climate policies are also useful for the present analysis as the range of costs of complying with these hypothetical policies bound much of the proposed climate legislation actively being considered in the U.S. Congress [13]. Thus, these WRE pathways can shed light on the potential scale of CCS deployment within the United States. The marginal cost of reducing greenhouse gas emissions is represented here as a price on CO2 emissions to the atmosphere. This carbon permit price rises rapidly in the WRE450 case, reaching $29/tonCO2 by 2020, $64/tonCO2 by 2035, and $140/ton CO2 by 2050. In the WRE550 case, carbon permit prices increase more slowly, but these prices are still sufficient to send a powerful signal to the economy to begin decarbonising: $5/tonCO2 by 2020, $10/tonCO2 by 2035, and $21/ton CO2 by 2050. In both cases, carbon permit prices continue to increase after 2050, and investment decisions made before 2050 take this into account (CO2 permit prices taken from Edmonds et al. [14]).

Figure 2 illustrates the resulting commercial adoption of CCS technologies by the U.S. electric utility sector in response to these two hypothetical climate policies. Figure 3 shows the resulting CO2 pipeline infrastructure requirements under each scenario.

4. Estimating the Scale of a Future U.S. CO2 Pipeline System

4.1. WRE450

In the more-stringent WRE450 stabilization case, up to 23,000 miles of dedicated CO2 pipelines must be built and operated in the U.S. between 2010 and 2050. If implemented, a hypothetical stabilization policy such as this could result in approximately 54 GtCO2 of CO2 being captured and stored in deep geologic reservoirs by 2050. Adoption of CCS technologies at this pace and on this scale (along with continued expansion of renewables and nuclear power) would result in a nearly complete decarbonization of the U.S. electricity sector by the middle of this century (See Dooley et al. [14] for more details on these scenarios). It is important to realize that the projected 23,000 miles of new CO2 pipeline would be built incrementally over time as the commercial deployment of CCS systems accelerates in response to the rising CO2 permit price. Thus, only about 25 percent of the total projected 23,000 miles of CO2 pipeline must be built before 2030 under this hypothetical WRE450 scenario.

4.2. WRE550

In the less-stringent WRE550 stabilization case, an estimated 11,000 miles of dedicated CO2 pipeline must be added to the existing CO2 pipeline system between 2010 and 2050. While less stringent than the WRE450 scenario, this hypothetical climate policy results in significant reductions in greenhouse gas emissions—due in part to significant commercial adoption of CCS technologies across the U.S. economy. For example, in this WRE550 scenario, the U.S. electric power sector’s adoption of CCS technologies could result in approximately 19 GtCO2 being stored in deep geologic formations by 2050. Again, this build-up of the CO2 pipeline network unfolds over time in response to the escalating price of CO2 emissions permits. In the near term (2010–2030), the growth in the CO2 pipeline infrastructure across the U.S. economy under the WRE550 scenario equates approximately to a doubling of the current CO2 pipeline system. Table 1 summarizes key data on the build-out of the national CO2 pipeline system under the hypothetical WRE450 and WRE550 climate policies.

5. Discussion

While the size of these future CO2 pipeline infrastructures may seem large, it is important to put the potential demand for CO2 pipelines in some context. Since 1950, more than 270,000 miles of large inter- and intrastate natural gas pipeline were constructed in the United States to move natural gas from areas of production and/or importation to markets across the country (see Figure 1, left-hand panel).6 This is an intentionally narrow accounting of the size of the nation’s total liquid and natural gas hydrocarbon pipeline distribution system and is intended to account only for those aspects of the pipeline infrastructure that would be most analogous to those used for CO2 transport.7

Since 1950, the U.S. economy has developed and maintained a natural gas pipeline transmission system that is significantly larger than the total amount of CO2 pipeline that must be built in the 40-year period, 2010–2050, under the more-stringent WRE450 case. It is also important to note that the U.S. economy, as measured by its gross domestic product (GDP), has grown and is expected to continue growing in the future. Between 1950 and 2000, the U.S. GDP grew from $2 to $11 trillion dollars (in constant 2005 US$). Between 2010 and 2050, the U.S. GDP is projected to double from approximately $13 to $26 trillion (in constant 2005 US$). In this regard, it is particularly noteworthy that in both the 1950s and 1960s, with a much smaller economy than exists today or that might exist between now and mid-century, more than 100,000 miles of these large natural gas transmission pipelines were built without disruption of the nation’s energy infrastructure or macroeconomy.

In both the WRE450 and WRE550 cases modelled here (Figure 4), a handful to a dozen large power plants and other industrial facilities are expected to adopt CCS systems each year, demanding between a few hundred and a few thousand miles of new pipeline constructed per year. Given the scale of the existing natural gas transmission pipeline network and given that much of it was built in a relatively short period during a time that the U.S. economy was significantly smaller, the cost burden imposed by the need to build a CO2 pipeline infrastructure should not pose a significant barrier for the commercial deployment of CCS systems in the United States.

#### The CO2 pipelines will be able to transport CO2 well enough for a comprehensive CCS system

Jennie Stephens ‘05 (Science, Technology, and Public Policy Program Belfer Center for Science and International Affairs John F. Kennedy School of Government, 7/14/05, “CO2 Capture and Storage (CCS): Exploring the Research, Development, Demonstration, and Deployment Continuum,” http://www.clarku.edu/faculty/jstephens/documents/Stephens%20%26%20Van%20Der%20Zwaan%20CCS\_RDDD\_2005\_BCSIA\_Discussion\_Paper.pdf)

After capture and compression, CO2 needs to be transported to an appropriate storage location. CO2 can be transported by pipeline, by truck, by rail, or by ship, but the large volume of CO2 in a CCS system rules out transportation by truck or rail. A network of CO2 pipelines is already in existence in several regions in the United States where CO2 is used to enhance oil production, so building CO2 pipelines does not pose technical or safety challenges although regional siting limitations are possible. Given the similarity of CO2 pipeline technology to that used to transport other gases for which vast networks have been built throughout the world, substantial cost reductions are unlikely from learning-by-doing with CO2 pipelines. CO2 transportation by ship is also an established technology that could become important if CO2 sources and storage locations are far apart; based on estimated costs ship transportation is thought to be favored over pipelines only if CO2 transportation greater than ~1000 kilometers is needed.

#### Natural gas pipelines prove the plan is feasible

ICFI 9 (ICF International, a firm that partners with government and commercial clients to deliver professional services and technology solutions, February 2009, “Developing a Pipeline Infrastructure for CO2 Capture and Storage: Issues and Challenges,” http://www.ingaa.org/File.aspx?id=8228)

The natural gas pipeline industry is frequently mentioned as a model for what a CO2 pipeline network might look like since the North American natural gas pipeline network interconnects thousands of natural gas distribution companies, power plants, and industrial facilities with natural gas producing basins. The technology, scope, operations, commercial structure, and regulatory framework that characterize natural gas pipelines appear to be useful analogues for a CO2 pipeline system. It can be expected that some additional gas pipeline companies beyond those that currently transport CO2 for enhanced oil recovery (EOR) projects may expand into the CO2 transportation business. At the same time, it has to be recognized that the investment needed to support a national CO2 transportation network will require significant capital and may entail competition for the same material and manpower resources as that of the natural gas and oil pipeline industries.

#### CCS could be used for far-away power plants

ICFI 9 (ICF International, a firm that partners with government and commercial clients to deliver professional services and technology solutions, February 2009, “Developing a Pipeline Infrastructure for CO2 Capture and Storage: Issues and Challenges,” http://www.ingaa.org/File.aspx?id=8228)

As is discussed elsewhere in this report, many people interviewed expected that the early sequestration projects would have a dedicated pipeline system and would for the most part use nearby storage sites. This expectation stems from the belief that power plants near sequestration sites would be the most economic and, therefore, would be the first to convert to or be built with CCS. Another factor was the expectation that in the early phases of the CCS industry a single entity would control the entire CCS project (capture, transport and sequestration) to better manage commercial, regulatory and liability risks. Such projects might frequently be expected to be undertaken by a regulated utility that will put the entire project within the jurisdiction of the relevant regulatory commission.

Over time, as more CCS plants are developed there will be a tendency to connect plants that are further away from sequestration sites. However, the greater density of CCS plants and increased imperative to reduce transportation costs for longer distance transportation would lead to more shared pipelines as CCS grows. Under this view, the later CCS development would tend to have larger diameter pipelines than in the early phase. The pipeline network mileage averaged per CO2 source, may be similar between the early and later development phases, since that larger source-to-sink distances in the later phase would be offset by sharing of pipeline capacity.

Another important determinant of the evolution of the CO2 pipeline network will be the degree to which the CO2 will be used for EOR. As is shown in Figure 4-1, the spatial distribution to saline reservoirs is much wider and the estimated capacity is 175 times larger for than for EOR (see Table 2-7). Therefore, it is statistically more likely that a CO2 source will have a suitable saline reservoir closer to it.31 This means that if the sequestration network serves EOR to a very large degree, it will likely be transporting CO2 over longer distance than a system that moves CO2 from sources to saline reservoirs.

#### Tech is mature

Parfomak et. Al, 9-

(Paul, July 31, 2009, Specialist in Energy and Infrastructure Policy, “Carbon Dioxide (CO2) Pipelines for Carbon Sequestration: Emerging Policy Issues,” CRS Report for Congress)

Legislative focus on the capture and storage components of direct carbon sequestration reflects a perception that transporting CO2 via pipelines does not present a significant barrier to implementing large-scale CCS. Even though regional CO2 pipeline networks already operate in the United States for enhanced oil recovery (EOR), developing a more expansive national CO2 pipeline network for CCS could pose numerous new regulatory and economic challenges. As one analyst has remarked,¶ Each of the individual technologies involved in the transport portion of the CCS process is mature, but integrating and deploying them on a massive scale will be a complex task. “The question is, how would the necessary pipeline network be established and evolve?”6¶ A thorough consideration of potential CCS approaches necessarily involves an assessment of their overall requirements for CO2 transportation by pipeline, including the possible federal role in establishing an interstate CO2 pipeline network.

Svensson et. Al, 3-

(Rickard, Department of Energy Conversion, School of Mechanical Engineering, Chalmers University of Technology, “Transportation systems for CO2––application to carbon capture and storage,” Volume 45, Issues 15–16, September 2004, Pages 2343–2353, Energy Conversion and Management 45 (2004) 2343–2353)

Several million tons of CO2 are transported annually, mainly in the USA, over long distances on shore in high pressure pipelines for use in the EOR industry [9]. Using CO2 in EOR projects has the advantage of adding a value to the CO2, e.g. oil producers in the USA are willing to pay between 9 and 18US$/ton of ‘‘end of pipe’’ delivered CO2 [2]. Pipelines for off shore transpor- tation of CO2 have not been applied yet but are technologically feasible [6], and a CO2 pipeline infrastructure off shore is investigated in the CO2 for EOR in the North Sea (CENS) project [5]. Other means of transportation that can be used are motor carriers, railway and water carriers. Experiences from these means of transportation are mainly found in the food and brewery industry, and the amounts transported are in the range of some 100,000 tons of CO2 annually, i.e. much smaller than the amounts associated with CCS.

### Pipelines Key

#### Pipelines are necessary for effective CCS

Saundry, 11-

(Peter, “Pipelines for Carbon Dioxide Control in the United States,” <http://www.eoearth.org/article/Pipelines_for_Carbon_Dioxide_Control_in_the_United_States?topic=54490>)

Carbon capture and storage (CCS) is of great interest because potentially large amounts of carbon dioxide (CO2) emitted from the industrial burning of fossil fuels in the United States could be suitable for sequestration. Carbon capture technologies can potentially remove 80%-95% of CO2 emitted from an electric power plant or other industrial source. Power plants are the most likely initial candidates for CCS because they are predominantly large, single-point sources, and they contribute approximately one-third of U.S. CO2 emissions from fossil fuels. There are many technological approaches to CCS. However, one common requirement for nearly all large-scale CCS schemes is a system for transporting CO2 from capture sites (e.g., power plants) to storage sites (e.g., underground reservoirs). Transporting captured CO2 in relatively limited quantities is possible by truck, rail, and ship, but moving the enormous quantities of CO2 implied by a widespread implementation of CCS technologies would likely require a dedicated interstate pipeline network.

#### Pipelines are necessary to facilitate effective CCS

CBO ’12 (Congressional Budget Office, study was prepared at the request of the Chairman of the Senate Committee on Energy and Natural Resources, June 2012, “Federal Efforts to Reduce the Cost of Capturing and Storing Carbon Dioxide,” http://www.cbo.gov/sites/default/files/cbofiles/attachments/43357-06-28CarbonCapture.pdf)

Once compressed, the captured CO2 must be transported to an underground storage site. If CCS was widely adopted, it would be necessary to substantially expand the existing pipeline network to transport the gas to storage sites that might be hundreds of miles away. Such a network could use pipeline technology that has already been developed to transport carbon dioxide to oil fields, where it is injected into wells to boost their production— a process known as enhanced oil recovery. Currently, about 4,000 miles of pipeline is used for that purpose. Separate Compress Transport Store Fossil Fuel Capture Combustion and Generation (From other gases) (Into a fluid) (By pipeline) (In suitable geologic formations) Exhaust CO2 CO2 CO2FEDERAL EFFORTS TO REDUCE THE COST OF CAPTURING AND STORING CARBON DIOXIDE 3 CBO The market in CO2 for enhanced oil recovery and the network of pipelines to transport compressed gas are expanding, a trend reflected in forecasts by DOE’s Energy Information Administration (EIA) that enhanced oil recovery will increase significantly over the next 25 years.

#### Pipelines are the only practical way of enabling CCS

Plasynski et al. 9 – Sequestration Technology Manager in the Office of Coal and Power R&D within the Strategic Center for Coal at the National Energy Technology Laboratory NETL) of the Department of Energy (DOE) (Sean I., Ph.D. in Chemical Engineering from the University of Pittsburgh, former Division Director of an Advanced Initiatives Systems, Analysis & Planning Division; John T. Litynski, NETL Sequestration Program’s Technology Manager; Howard G. McIlvried, Consulting Engineer in the Science Applications International Corporation at the National Energy Technology Laboratory of the Department of Energy; and R. D. Srivastava, Ph.D. in chemical engineering from the Dalhausie University, lead manager for technical support to U.S. DOE's NETL in the area of greenhouse gas emissions and alternative fuels, former Visiting Professor at the University of Delaware, former Guest Professor at the Swiss Federal Institute of Technology (ETH), former Professor of Chemical Engineering at the Indian Institute of Technology at Kanpur; May/June 2009, “Progress and New Developments in Carbon Capture and Storage,” *Critical Reviews in Plant Sciences*, Volume 28, Issue 3, pp. 123-138, p. EBSCO)

IV. CO2 TRANSPORT

CO2 capture is only the first step in CCS. Once captured, the CO2 must be transported to a suitable storage site. Various transport modes, such as truck, train, barge, and pipeline, have been considered, but because of the large volumes involved, only pipelines will be practical for commercial CCS projects. Large CO2 pipelines already exist, mainly carrying CO2 to EOR operations, where injected CO2 is used to lower viscosity and push residual oil to production wells. One example is the Weyburn project; theCO2 is a purchased by-product from theDakota Gasification Company’s synthetic fuels plant in Beulah, North Dakota, which is transported through a 320-km pipeline to the Weyburn EOR project in Canada. The CO2 is 95% pure and is being transported at a rate of about 5,000 tonnes/day. If a CO2 pipeline system evolves, specifications will need to be developed for CO2 injected into the system (Aspelund and Jordal, 2007). In addition to experience gained pipelining CO2, an extensive natural gas pipeline system is in operation with few problems. CO2 will typically be transported as a supercritical fluid at a pressure of about 150 atm. Some consideration has been given to cosequestration of CO2 with other waste products, such as H2S, SOx, NOx, etc. If this proposal is pursued, pipeline specifications for transporting mixed streams will need to be developed. Pipeline construction should present no problems, but obtaining rights-of-way could present some difficulties.

### Injection/Storage

#### CO2 storage is feasible

IOGCC 10 (Interstate Oil and Gas Compact Commission, multi-state government agency that advocates for environmentally-sound ways to increase the supply of American energy, 9/10/10, “A Policy, Legal, and Regulatory Evaluation of the Feasibility of a National Pipeline Infrastructure for the Transport and Storage of Carbon Dioxide,” http://www.sseb.org/downloads/pipeline.pdf)

II. Geologic Storage¶ Once captured, CO2 can be injected into deep underground formations below the earth’s surface. Rather than being released into the atmosphere, CO2 can be stored 12 permanently in underground geological formations. Natural CO2 traps exist in many places around the globe. It is important to realize that geologic storage is not a new technology but merely an application of technologies developed over decades in the injection and storage of both natural gas and acid gas,13 and the injection of natural CO2 for purposes of enhanced oil recovery (EOR). Similarly, the regulation of CO2 geological storage by the states builds upon the extensive experience of the states in regulating the injection and storage of natural gas and CO2-driven EOR. Although the scale of CO2 geological storage projects will be much larger than the analogues set forth above, the technology is fundamentally the same.14 Ultimately, this technology holds promise of storing between 1.2 trillion to 3.6 trillion metric tons, the equivalent of hundreds of years, of CO2 captured from industrial sources.15¶ There are three primary options for the geologic storage of CO2:¶ 1) Storage in depleted oil and natural gas reservoirs;¶ 2) Storage in deep saline formations;¶ 3) Adsorption within coal-beds that are un-minable because of depth, thickness, or other economic factors. 16¶ Additionally, there is the possibility of storage in organic shales, fractured basalts, and hydrates, although those will not be addressed here.17¶ The primary geological storage options involve injection of CO2 through wells into the receiving formations or coal layers. Figure 1 illustrates the geologic options for underground injection of CO2. There are advantages to injecting into deeper formations (deeper than 2,500 feet), because the CO2 can be emplaced in a supercritical state under pressures exceeding 1,200 pounds per square inch (psi). Supercritical CO2 occupies less pore space for a given quantity of CO2 thereby maximizing the reservoir capacity for storage.¶ Many regions of the United States offer one or more of these geologic options, the most common of which are discussed below.¶ A. Depleted Oil and Gas Fields¶ Depleted oil and natural gas fields offer geologic traps that represent a substantial reservoir capacity available for storage of CO2. Where these reservoirs are below 2,500 feet, they offer tremendous pore volume space for supercritical CO2 injection and storage. These geologic traps by their very nature, having confined accumulations of oil and natural gas over millions of years, have proven their ability to contain fluids and gas. Additionally, if storage pressures of CO2 stay below original reservoir pressures, fluid containment is assured if leakage from wellbore penetrations can be avoided.¶ With many depleted oil and natural gas fields there is also huge potential for EOR at the same time that CO2 is stored in these formations using anthropogenic sources of CO2.19 Injection of CO2 for EOR has been in practice for the past three decades, most widely in the Permian Basin of west Texas and southeast New Mexico. It is important to note that during EOR operations, CO2 produced with the oil is not released into the atmosphere but is captured, separated and recycled back into the reservoir to recover additional oil. While the majority of CO2 currently utilized for EOR in the U.S. comes from naturally occurring CO2 source fields, as anthropogenic sources of CO2 become more available, there is a significant opportunity for storage at the same time that additional oil resources are produced.¶ B. Deep Saline Formations¶ The option offering the greatest potential storage volume among the geologic possibilities nationwide is the injection of CO2 into saline formations significantly below underground sources of drinking water. Access to saline aquifers often occurs close to existing CO2 emission sources, such as coal-fired power plants. The water in some of these formations, for example in the depth range of 4,000 to 5,000 feet in the Illinois Basin, has many times the salinity of sea water and hence is not usable as a potable resource. Research shows that injection of CO2 into these deeper saline formations could be contained through solubility trapping (CO2 dissolution in formation waters), structural trapping (formation of a secondary gas cap within formation boundaries), or through mineral trapping (carbonate precipitation). 20¶ C. Coal-beds¶ Coal-beds or unmineable coal seams provide a potential geologic storage option for CO2 through adsorption. Methane is chemically adsorbed on coal-beds to varying extents depending on coal character (maceral type, ash content, etc.), depth, basin burial history, and other factors and has been produced to an ever greater extent over the last decade to add to the nation’s natural gas supply. The expectation is that the adsorption sites on the coal matrix surface have stronger affinity for the CO2 than the methane and would retain CO2 and liberate producible methane. This is frequently referred to as enhanced coal-bed methane (ECBM). Coals deemed economically unmineable due to depth, limited thickness, or other factors would be the only coals potentially suitable for storage.¶ Commercial storing of CO2 in geologic formations as an incident of oil production has occurred for nearly 40 years. CO2 supplies to this industry have been separated and captured from natural gas processing plants, produced from high-quality naturally-occurring underground formations, captured from a coal-to-gas manufacturing facility, and captured from a few other industrial facilities. Estimates of the injected quantities over the last four decades are in the hundreds of millions of metric tons. There have been only limited amounts of CO2 injected into other types of geologic formations, however. Accordingly, since 2003 the U.S. Department of Energy through its Regional Carbon Sequestration Partnership (RCSP) Program has been actively engaged in CCS research and development in different locations around the country.21 The most recent phase of the partnership program will involve “the injection of 1 million tons or more of CO2 by each RCSP into regionally significant geologic formations of different depositional environments” so as to “demonstrate that CO2 storage sites have the potential to store regional CO2 emissions safely, permanently, and economically for hundreds of years.”22 This program will lay the foundation for the deployment of commercial scale CCS projects as early as 2020.23

#### CO2 injection is based on current technology and is being developed further

ICFI 9 (ICF International, a firm that partners with government and commercial clients to deliver professional services and technology solutions, February 2009, “Developing a Pipeline Infrastructure for CO2 Capture and Storage: Issues and Challenges,” http://www.ingaa.org/File.aspx?id=8228)

Geological storage of CO2 is accomplished by injecting it in dense form into a rock formation below the earth’s surface. Porous rock formations that hold or have previously held fluids, such as natural gas, oil or saline reservoirs, are potential candidates for CO2 storage. Suitable storage formations can occur in both onshore and offshore sedimentary basins. Coal beds and shales also may be used for storage of CO2 where it is unlikely that they will later be mined and provided that permeability is sufficient. The option of storing CO2 in coal beds and gas shales and enhancing methane production is still in the demonstration phase.¶ At depths below 2,600 to 3,300 feet (800–1,000 meters), CO2 remains a supercritical fluid with liquid-like density of about 31 to 50 pounds per cubic foot (500–800 kg per cubic meter). This provides for efficient utilization of underground storage space. Under these conditions, the density of CO2 will range from 50 to 80 percent of the density of water. This is close to the density of some crude oils, resulting in buoyant forces that tend to drive CO2 upwards. Consequently, a well-sealed cap rock over the selected storage reservoir is important to ensure that CO2 remains trapped underground.¶ The injection of CO2 in deep geological formations involves many of the same technologies that have been developed in the oil and gas exploration and production industry. Well-drilling technology, injection technology, computer simulation of storage reservoir dynamics and monitoring methods from existing applications are being developed further for design and operation of geological storage. Other underground injection practices also provide relevant operational experience. In particular, natural gas storage, the deep injection of liquid wastes, and acid gas disposal (mixtures of CO2 and H2S) have been conducted in Canada and the U.S. since 1990 at the megatonne per year scale.¶ Large-scale geosequestration storage projects in operation now include: the offshore Sleipner natural gas processing project in Norway, the Weyburn Enhanced Oil Recovery project in Canada, which stores CO2 captured in the United States, and the In Salah natural gas project in Algeria. Each captures and stores one to two million tonnes of CO2 per year.¶ CO2 is also being injected underground at many locations for the exclusive purpose of enhanced oil recovery. Carbon dioxide enhanced oil recovery is one of several methods to increase the production of oil from mature reservoirs whose output is declining under normal production processes. It has been the fastest growing EOR method in the U.S. and currently accounts for about 37 percent of total 2005 U.S. EOR production. The most common CO2 EOR method is miscible displacement, in which the injected CO2 dissolves fully in the oil, increasing its volume and reducing its viscosity. This increases the mobility of the oil, resulting in the production of oil bypassed by primary and secondary recovery methods. Typical CO2 floods, under the right conditions, can yield an additional 7 to 15 percent of original oil in place (OOIP), extending the life of a producing field by as much as 15-30 years. Much of the CO2 injected for EOR is produced with the oil, from which it is separated and then reinjected. At the end of the oil recovery, the CO2 can be retained for the purpose of climate change mitigation, rather than vented to the atmosphere. This is planned for the Weyburn project.

#### Sequestration is feasibile

ICFI 9 (ICF International, a firm that partners with government and commercial clients to deliver professional services and technology solutions, February 2009, “Developing a Pipeline Infrastructure for CO2 Capture and Storage: Issues and Challenges,” http://www.ingaa.org/File.aspx?id=8228)

CO2 Storage Potential of the U.S.

Over the past several years, DOE and the regional partnerships have carried out an effort to assess and characterize the CO2 sequestration capacity and potential of the U.S. This effort has resulted in the publication of a large amount of information on potential by geologic setting and basin or state. A large amount of Geographic Information Systems (GIS) data have also been compiled on the geology of sequestration potential.

In 2008, DOE published the most recent version of the Carbon Sequestration Atlas of the United States and Canada (NATCARB Atlas).7 This publication contains maps and data tables documenting their assessment of storage potential in the U.S. Much of the data behind the NATCARB atlas are either available in GIS form or will eventually be made available. The major storage reservoir types are summarized below.

Non-Basalt Saline Reservoirs. Most significant sedimentary basins in the U.S. contain regionally significant saline formations that are potential storage reservoirs. These are typically sandstone lithologies with good porosity, containing formation waters of greater than 10,000 mg/L TDS. Salinity may be as high as several times that of seawater. Thus, the water is unsuitable for drinking or agriculture. Saline reservoirs dominate the assessed potential of the U.S. and worldwide. In addition, because of their wide geographic distribution in the U.S., saline reservoirs are often in close proximity to CO2 sources, minimizing pipeline transport distance. It is very likely that saline reservoirs will play a prominent role in future geologic storage.

Storage in saline reservoirs has been shown to be effective. The Sleipner field in the North Sea is the first commercial-scale saline reservoir project. Carbon dioxide is separated from the gas stream and re-injected into a reservoir at about 800 meters depth. The rate of injection is 2,700 tons per day or about one million tons per year.8 It is anticipated that about 20 million tons will eventually be stored. At Sleipner, the plume has been monitored effectively.9

DOE has extensively studied saline reservoirs for sequestration. Projects include the Frio Brine pilot in the Texas Gulf Coast and the Mount Simon Sandstone in the Illinois Basin.10 The Mount Simon is known to have excellent storage potential because of its regional thickness and reservoir characteristics, and because it has been used extensively for natural gas storage in the Midwest.

Depleted Natural Gas Fields and Oil Fields. Depleted natural gas and oil fields can be excellent candidates for CO2 storage. These represent known structures that have trapped hydrocarbons over geologic time, thus proving the presence of an effective structure and seal above the reservoir. These fields have also been extensively studied, there is a large amount of well log and other data available, and the field infrastructure is already in place. This infrastructure could in some cases be utilized in storage. A potentially problematic aspect of using depleted fields for storage is the presence of a large number of existing wellbores, which can provide leakage pathways. Typically, oil fields are developed with a closer spacing than natural gas fields, resulting in a larger number of existing wells per unit area than in natural gas fields. It is possible that in old fields, the original oil and gas wells may have been completed and then -- at the end of their lives --plugged and abandoned using sub-standard materials and practices. In such instances the plugged wells will have to be remediated before CO2 injection can begin at the site. The cost of this process may render an old oil or gas field economically unsuitable.

The In Salah Field in Algeria was the world’s first project in which CO2 is injected at commercial scale into a natural gas reservoir. However, in this case, the natural gas is injected in the lower part of an actively producing gas reservoir. This differs from an abandoned gas reservoir scenario in which the gas field is no longer producing.

Enhanced Oil Recovery Conversion. Under certain reservoir and fluid conditions, CO2 can be injected into an oil reservoir in a process called miscible CO2 enhanced oil recovery. The effect of the CO2 is to mobilize the oil so that it can move more readily to the production wells. As the oil is produced, part of the injected CO2 is produced with the oil. This CO2 is then separated and re-injected. The EOR portion of U.S. CO2 storage capacity represents the amount of CO2 that could be permanently sequestered in association with EOR operations that have been converted from enhanced production to permanent storage.

In the U.S. most CO2 EOR projects are located in the Permian Basin of West Texas, where projects have been in place for several decades. The source of most of the CO2 is natural CO2 from several fields in Colorado and New Mexico.11 Some of the injected CO2 is from gas processing or other sources. The current volume of CO2 injected for CO2 EOR is about 2.2 billion standard cubic feet per day.

In 2005, CO2 EOR operations produced approximately 237,000 barrels of oil per day in the U.S. About 180,000 barrels per day of that occurred in West Texas, with most of the rest produced in the Rockies, Mid-Continent, and Gulf Coast.12

At the Weyburn Field in Saskatchewan, CO2 from the Dakota Gasification Facility in North Dakota is injected into an oil reservoir for EOR and monitoring of CO2 storage. Over the 25 year life of this project, it is expected that about 18 million tons of CO2 will be sequestered.

Enhanced Coalbed Methane Recovery. CO2 potentially can be sequestered in coalbed formations through the process of adsorption. CO2 injected as a gas into a coalbed will adsorb onto the molecular structure and be sequestered. Methane is naturally adsorbed onto coalbeds and coalbed methane now represents a significant percentage of U.S. natural gas production. Major coalbed methane production areas include the San Juan Basin of north-western New Mexico and south-western Colorado, the Powder River Basin of eastern Wyoming, and the Warrior Basin in Alabama.

The concept of enhanced coalbed methane recovery is based upon the fact that coalbeds have a greater affinity for CO2 than methane. Thus, when CO2 is injected into the seam, methane is liberated and the CO2 is retained. This additional methane represents enhanced natural gas recovery. Depending upon depth and other factors, coalbeds may be mineable or unmineable. Because the process of mining the coal would release any stored CO2, only unmineable coalbeds are assessed as representing permanent CO2 storage.13 One of the potential drawbacks to CO2 injection into coal seams is that as the CO2 is absorbed into the coal, the coal can swell, thereby reducing permeability. This phenomenon can make certain coals technically unsuitable or increase the cost of injection.

Gas Shales. The potential to sequester CO2 in organic shale formations is based upon the same concept as that of coalbeds. CO2 will adsorb onto the organic material, displacing methane. Gas shales have recently emerged as a major current and future source of natural gas production in the U.S. These include the Barnett Shale in the Fort Worth Basin, the Fayetteville and Woodford Shales in the Arkoma Basin, and the Appalachian Devonian Shale. These Devonian and Mississippian age organic shale formations represent tremendously large volumes of rock. To date little research has been done on enhanced gas recovery with organic shales. However, should it prove technically feasible, the U.S. could become one of the major areas worldwide for this type of storage.

Basalt. Basalt flows such as those of the Columbia River Basalts in the Pacific West, are believed to have the potential for permanent CO2 storage. The storage process involves geochemical trapping, in which the CO2 reacts with silicates in the basalt to form carbonate minerals.14 While research is being carried out on basalt, it is considered unlikely that any commercial scale sequestration will occur in the foreseeable future due to the unconventional geology and likely difficulty in monitoring.

ICF has reviewed the DOE assessment information as published in the NATCARB Atlas and performed an independent assessment of the Lower-48 storage potential by state and reservoir type. This assessment allows analysis of the volumes of CO2 that can be stored regionally and the characteristics of this storage potential. We evaluated the distribution of storage potential by geologic category, location, and depth interval. In addition, we developed a model to assess the economics of sequestration in the U.S. also by state and reservoir type. The summary results are shown in Table 2-7. This table compares ICF’s independent assessment with NATCARB and estimates by Battelle and the International Energy Agency (IEA).15 16

ICF’s estimate of the Lower-48 potential for storage is 3,375 Gt, which is higher than that of the 2007 NATCARB Atlas, and slightly less than that of the 2008 atlas. There are several reasons for the higher assessment. ICF included a rough estimation of the Gulf of Mexico potential, as well as an estimation of shale storage potential. In addition, ICF has an independent estimate of depleted oil and gas field potential, based upon a methodology of looking at the distribution of historical oil and gas recovery by region, and using this information to estimate CO2 potential in areas not covered in the DOE study.

Table 2-8 presents the state level assessment by geologic category. Storage capacity associated with depleted oil and gas fields occurs where there has been significant natural gas and oil production, including Appalachia, the Gulf Coast, Mid-Continent, and Rockies. Saline reservoir potential occurs in many areas of the country. Coalbed methane potential is concentrated in the large coalbed methane production areas such as New Mexico and Wyoming, while shale gas potential is associated with some of the new gas shale basins that have emerged over the past decade.

#### US carbon storage capacity is high

Parfomak and Folger 8 – \*Specialist in Energy and Infrastructure Policy for the Congressional Research Service AND \*\*Specialist in Energy and Natural Resources for the Congressional Research Service (Paul W.; and Peter; 1/10/08, “Pipelines for Carbon Dioxide (CO2) Control: Network Needs and Cost Uncertainties,” http://assets.opencrs.com/rpts/RL34316\_20080110.pdf)

Under a national CCS policy, a key question is how to establish a CO2 pipeline network at the lowest social and economic cost given the current locations of existing CO2 source facilities and the locations of future sequestration sites. On its face, this may appear to be a straightforward analytic problem of the type regularly addressed in other network industries. The oil and gas industry, among others, employs myriad analytic techniques to identify and optimize potential routes for new fuel pipelines.4 In the context of CCS, however, predicting pipeline routes is more challenging because there is considerable uncertainty about the suitability of geological formations to sequester captured CO2 and the proximity of suitable formations to specific sources of CO2. One recent analysis, for example, concluded that 77% of the total annual CO2 captured from the major North American sources could be stored in reservoirs directly underlying these sources, and that an additional 18% could be stored within 100 miles of the original sources.5 Other analysts suggest that captured CO2 may need to be sequestered, at least initially, in more centralized reservoirs to reduce potential risks associated with CO2 leaks.6 They suggest that, given current uncertainty about the suitability of various on-site geological formations for longterm CO2 sequestration, certain specific types of formations (e.g., saline aquifers) may be preferred as CO2 repositories because they have adequate capacity and are most likely to retain sequestered CO2 indefinitely.

The Department of Energy estimates that the United States has enough capacity to store CO2 for tens to hundreds of years.7 However, the large-scale CO2 experiments needed to acquire detailed data about potential sequestration reservoirs have only just begun. Given current uncertainty about potential sequestration sites, policy discussions about CCS envision various possible scenarios for the development of a CO2 pipeline network. If CO2 can be sequestered near where it is produced then CO2 pipelines might evolve in a decentralized way, with individual facilities developing direct pipeline connections to nearby sequestration sites largely independent of other companies’ pipelines. The resulting network might then consist of many relatively short and unconnected pipelines with a small number of longer pipelines for facilities with no sequestration sites nearby. Alternatively, if only very large, centralized sequestration sites are permitted, the result might be a network of interconnected long distance pipelines, perhaps including high-capacity trunk lines serving a multitude of feeder pipelines from individual facilities. A third scenario envisions CO2 sequestration, at least initially, at active oil fields where injection of CO2 may be profitably employed for enhanced oil recovery (EOR). Indeed, a CO2 pipeline network already exists for EOR purposes in the southwestern United States, although it is limited in geographic reach. Whether CCS policies ultimately lead to one or more of these scenarios remains to be seen; however, the configuration of the resulting CO2 pipeline network, and its associated costs, may have a significant bearing on which CCS policies best serve the public interest.

#### Carbon storage is simple, and there’s lots of space available

Biello 9 – associate editor for environment and energy at Scientific American (David, June 2009, “Can Captured Carbon Save Coal?” *Scientific American*, Volume 19, pp. 52-59, http://www.nature.com/scientificamerican/journal/v19/n2s/full/scientificamericanearth0609-52.html)

Storage may be the simplest part of the CCS challenge. After all, since 1996, the Norwegian oil company StatoilHydro has been stripping CO2 out of natural gas from the Sleipner field in the North Sea and rather than venting it to the atmosphere has been pumping it back into the field 1,000 meters deep for permanent storage.

The basics of carbon dioxide storage are simple: the same Utsira sandstone formation that has stored the natural gas for millions of years can serve to trap the CO2, explains Olav Kaarstad, CCS adviser at Statoil. The 250-meter-thick band of sandstonedash—porous, crumbly rock that traps the gas in the minute spaces between its particlesdash—is topped by a relatively impermeable 200-meter-thick layer of shale and mudstone (think hardened clay). “We aren’t really much worried about the integrity of the seal and whether the CO2 will stay down there over many hundreds of years,” Kaarstad says.

More than 12 million metric tons of CO2 have been injected into the formation, he notes. Statoil monitors its storage through periodic seismic testing, a process that is not unlike a sonogram through the earth, according to hydrologist Sally Benson, director of the global climate and energy project at Stanford University. That monitoring indicates that between 1996 and this past March, the liquid CO2 has spread out as a thin layer permeating a three-square-kilometer expanse of porous sandstone—just 0.0001 percent of the area available for such storage.

“We’re not going into a salt cavern; we’re not going into an underground river. We’re going into microscopic holes,” explains geologist Susan D. Hovorka of the University of Texas at Austin, who has worked on pilot projects in the U.S. “Add it up, and it’s a large volume” of storage space.

Indeed, the Department of Energy estimates that the U.S. alone has storage available for 3,911 billion metric tons of CO2, in the form of geologic reservoirs of permeable sandstone or deep saline aquifers, according to a 2008 atlas. These reservoirs are more than enough for the 3.2 billion metric tons of CO2 emitted every year by the roughly 4,600 large industrial sources in the country. Most of that storage is near where the majority of coal in the U.S. is burned: the Midwest, Southeast and West. “There are at least 100 years of CO2 sequestration capacity and probably significantly more,” Benson says.

The storage seems to be long term as well; the sequestered gas doesn’t just sit in the rock waiting for a chance to escape. Over decades it dissolves into the brine that shares the pore space or, over longer time spans, forms carbonate minerals with the surrounding rock, Hovorka notes. In fact, when she tried to pump CO2 out of her test site using natural gas extraction techniques, the attempts failed completely.

According to the IPCC, which issued a special report on CCS in 2005, a properly selected site should securely store at least 99 percent of the sequestered CO2 for more than 1,000 years. James Dooley, a senior research scientist at Pacific Northwest National Laboratory and an IPCC lead author, considers that to be a reachable goal. “If it took all that energy to shove [the CO2] into that sandstone, it’s going to take a lot of energy to get it out,” he notes. “Like an oil field, where we get out half or less of the original oil in place, a lot of the CO2 gets stuck in there. It’s immobilized in the rock.”

Encouraged by the success of the Sleipner project, Statoil recently began another CO2 injection program at the Snøhvit natural gas field in the Barents Sea, despite the requirement that a 150-kilometer pipeline be built on the seabed to pump the CO2 to where it can be sequestered.

And since 2004 oil giant BP and its partners (including Statoil) in the In Salah gas field in Algeria have been stripping the nine billion cubic meters of natural gas produced there annually of the 10 percent carbon dioxide it contains and pumping a million metric tons of liquid CO2 back into the underlying saline aquifer through three additional wells.

BP uses a variety of techniques, among them satellite monitoring, to observe the impact of the CO2 storage (and natural gas removal) on the land. Whereas some areas sank by roughly six millimeters as natural gas was extracted, near the CO2 injection wells the land rose by some 10 millimeters, says Gardiner Hill, manager of technology and engineering for CCS at BP’s alternative energy arm. The U.S. National Energy Technology Laboratory is also working on developing appropriate monitoring, verification and accounting technologies.

BP and Statoil are not doing these CCS projects for charity, of course. Norwegian government tax on carbon of roughly $50 a metric ton inspired the CO2 sequestration at Sleipner and Snøhvit. “It costs a fraction of the tax,” Kaarstad says. “We are actually making money out of this.”

Both Statoil and BP foresee a bonanza of moneymaking CO2 storage opportunities. Hill notes that if CCS is deployed on a very large scale, society will need the expertise of the oil industrydash—its “100 years of understanding the subsurface,” he says. “We would expect the experience we are building through this to position BP to take advantage of any future business.”

#### CO2 storage technology is proven

Wall 7 – professor in the School of Engineering at the University of Newcastle (Terry F., senior academician of the Australian Academy of Technological Science and Engineering (ATSE), January 2007, “Combustion processes for carbon capture,” Proceedings of the Combustion Institute, Volume 31, Number 1, pp. 31-47, p. ScienceDirect)

V. CO2 STORAGE IN GEOLOGIC FORMATIONS¶ Geologic CO2 storage refers to the injection of CO2 into a geologic formation with the objective that the CO2 remain permanently in place underground (Klara et al., 2003). The most important potential geologic storage formations are depleted oil and gas reservoirs, deep unmineable coal seams, and saline formations. Other possibilities include organic shale deposits and basalt formations. The worldwide capacity of geologic formations is large, with some estimates being as high as 100,000 gigatonnes of CO2. A more realistic estimate is probably in the range of 2,000–10,000 gigatonnes (Bradshaw et al., 2007; IPCC, 2005; IEA, 2006), enough capacity to store decades of emissions at the current emission rate of about 28 gigatonnes per year. Estimated capacity could increase with improved understanding of the many factors that affect CO2 sequestration potential, such as reservoir integrity, volume, porosity, permeability, and pressure. Because these factors vary widely, even within the same reservoir, establishing a reservoir’s storage potential with the desired degree of certainty presents difficulties.¶ Tasks involved in siting a CO2 geologic storage project include subsurface geologic assessment in the vicinity of the site, seismic characterization of the site, borehole drilling to characterize the reservoir and cap rock formations, injection and monitoring system design, permitting, obtaining storage rights, and risk assessment (Kirchsteiger, 2007).Many important issues dealing with geologic storage, such as interactions between injected CO2 and reservoir rock and fluids and monitoring and verification of formation fluids must be addressed. Large-scale field demonstrations are needed to confirm practical considerations, such as economics, safety, stability, permanence, and public acceptance.¶ A. CO2 Storage in Oil and Gas Reservoirs¶ Oil and gas reservoirs are promising early opportunity sinks for CO2 storage for several reasons (Damen et al., 2005). First, they are proven traps that have contained oil and gas for millions of years and should, therefore, trap CO2 permanently with minimum risk of leakage. Second, their geology is well understood because of the extensive characterization carried out during the development and operation of the reservoirs. Third, the injection of CO2 into the reservoir can increase the production of oil and/or gas, the revenue from which can at least partially offset the cost ofCO2 storage.CO2 flooding for EORis being practiced in a number of locations, with over 25 million tonnes of CO2 (the amount remaining stored) being used for this purpose annually (Solomon et al., 2008). Most EOR projects in the United States are in the Permian Basin of Texas, and most of the CO2 for these projects is being transported by pipeline from natural CO2 reservoirs in Colorado, New Mexico, and Wyoming.¶ When CO2 is injected into a petroleum reservoir, a small amount of CO2 will dissolve in the oil, increasing bulk volume and decreasing viscosity. This facilitates flow to the producing wells. Typically, primary oil recovery followed by water flooding produces 30–40% of the original oil in place. A CO2 flood can result in recovery of an additional 10–15% of the oil.¶ Over the past 30 years, EOR using CO2 flooding has proven to be valuable in areas with natural CO2 supplies, because miscible and immiscible CO2 flooding can revitalize mature oil fields. However, lack of CO2 in many regions limits production from CO2-based EOR, but carbon capture applied to electric power plants and industrial processes, such as ethanol production, could generate large quantities of CO2 that could be used for enhanced oil and gas recovery, while simultaneously storing CO2. The volume of CO2 that can be stored in oil and gas reservoirs can be estimated based on reservoir depth and size and produced fluid volumes (Bachu et al., 2007). An initial estimate of CO2 storage potential of oil and gas fields in the United States exceeds 135 billion tonnes (NETL, 2008).¶ Typically, the objectives of CO2-based EOR and CCS are opposite. In EOR the objective is to maximize oil production per tonne of CO2 injected; whereas, with CCS the objective is to maximize CO2 storage. Effort will be needed to reconcile these conflicting goals and optimize both oil production and CO2 storage (Jessen et al., 2005; Kovscek and Cakici, 2005).¶ B. CO2 Storage in Unmineable Coal Seams¶ Another option for disposal of CO2 is storage in deep, unmineable coal seams (Byrer and Guthrie, 1998). Unmineable coal seams are coal seams that are too deep or too thin to be economically mined by current technology. All coal seams have some methane adsorbed on pore surfaces, and wells may be drilled into coalbeds to recover this methane. Initial coalbed methane (CBM) recovery methods, such as dewatering and depressurization, leave a lot of methane in the formation. More methane can be recovered by injecting CO2 into the coalbed. Typically, two to ten molecules of CO2 are adsorbed for each molecule of methane released. Thus, coalbeds have the potential to be excellent sites for CO2 storage with the value-added benefit of ECBM production.¶ Throughout the world, only a few experimental ECBM tests involving CO2 injection have been conducted. These tests show great potential for both CO2 sequestration and ECBM production. Coalbed thickness is of great importance for ECBM production, both because thicker coalbeds have greater volumes and yield more gas and because advanced production techniques are more applicable in thick beds.¶ The world’s CBM reserves are estimated at over 850 trillion Nm3, but much of this reserve is in coal seams deeper than 1,000 m (Thakuc et al., 2002). Because of low reservoir permeability, efforts to produce CBM from these reservoirs have had only limited success.¶ Another option being considered is the injection of CO2/N2 blends into coal seams. The reason for considering N2 in addition to CO2 is that N2 is also an effective methane displacer, and N2 makes up 80–90% of most flue gas. If flue gas could be stored without the need for CO2 separation and capture, costs might be reduced. Technical issues that need to be addressed are flue gas conditioning, compression, delivery, and N2/CH4 separation. Flue gas injection appears to enhance methane production to a greater degree than is possible with CO2 alone, while still sequestering CO2.¶ Mathematical models are being developed to accurately describe the observed adsorption behavior. Combined experimental and modeling results will provide a sound basis for performing reservoir simulation studies that evaluate the potential for injecting CO2 or flue gas into coalbeds to simultaneously sequester CO2 and enhance CBM production. To enable reliable numerical modeling of CO2 ECBM production, the effect of CO2/methane mixing on gas pressure and sorption reactions in deep coalbeds must be known quantitatively. Existing computer models are not adequate for this purpose, and experiments must be performed to obtain the data needed to upgrade these models. Another problem with CO2 storage in coal seams is their typically low permeability, a problem that is exacerbated by the fact that adsorption of CO2 causes swelling of the coal (Mazumder andWolf, 2008). A new approach, combining slant (horizontal) holes, hydrofracing with coiled tubing, and CO2 flooding has been proposed as a way to produce gas from deep, low permeability reservoirs.¶ The suitability of a coal seam for CO2 geologic storage can be evaluated on technical, economic, and regulatory (resource protection) criteria (Bachu, 2007; Bachu et al., 2007; Oudinot et al., 2007). If coal that has been used for CO2 storage is mined, the CO2 will have to be recovered and moved to another storage site or else it will be released to the atmosphere. Although it should be possible to do this, it is still probably not a good idea to use marginally unmineable seams, i.e., seams which may become mineable with advanced technology.¶ Limited operating experience with ECBM technology and poor understanding of CO2/coal interactions under geologic conditions has limited storage applications. A number of pilot projects in coal seams are underway or planned to address gaps in knowledge. An initial estimate of CO2 storage potential of coal seams in the United States is 157–178 gigatonnes (NETL, 2008). Because of coal’s large internal surface area, it can store six to seven times more CO2 than the equivalent volume of a conventional gas reservoir.¶ C. CO2 Storage in Saline Formations¶ The CO2 geologic storage option with the most potential is storage in saline formations. Saline formations are layers of porous rock such as sandstone and limestone that are saturated with brine. They are much more extensive than either oil and gas reservoirs or coal seams and represent an enormous potential for CO2 storage. About two-thirds of the United States is underlain by deep saline formations. Since the water from saline formations is typically not suitable for irrigation or other uses, injection of CO2 should not present a problem for future water use.¶ Storage of CO2 in saline formations results from various physical and chemical mechanisms that act on different time scales. Initial storage occurs through displacement of interstitial fluids, followed by dissolution and finally mineralization. Thus, with time, increasingly secure physical and chemical trapping mechanisms come into play, and the overall security of storage in saline formations increases. However, it is critical to understand the migration of the injected CO2 and the displaced saline water within these deep formations.¶ Because of a lack of characterization data, such as that generated by resource recovery from oil and gas reservoirs and coal seams, much less is known about saline formations. The potential for CO2 to dissolve in the brine enhances the storage capacity of saline formations, but many questions still exist concerning reactions that occur between CO2, brine, and the minerals in the surrounding strata, particularly relative to reaction kinetics. This means that there is greater uncertainty regarding the suitability of saline formations for CO2 storage (Bachu et al., 2007). In particular, oil and gas reservoirs have an assured seal; no such assurance is available for saline formations.¶ The geologic storage potential of saline formations is large, but accurate capacity estimates require significant local refinement and modeling. The publication of the Carbon Sequestration Atlas of the United States and Canada (NETL, 2008) represents significant progress towards developing consistent methodologies for the classification and determination of CO2 storage capacity in saline formations.¶ In stratigraphic and structural traps, CO2 storage capacity can be estimated following procedures similar to those for oil and gas reservoirs, taking into account temperature, pressure and salinity constraints. Bergman and Winter (1995) have estimated the CO2 sequestration potential of saline formations in the United States at up to 500 gigatonnes. Another estimate of the CO2 storage potential of saline formations in the United States is even higher at 3,297 gigatonnes to over 12,600 gigatonnes (NETL, 2008). More research, field testing, modeling, and monitoring are needed to reduce the uncertainties relating to CO2 storage in saline formations.¶ D. Commercial Geologic CO2 Storage Projects¶ Because there are few regulations controlling CO2 emissions or financial incentives, the number of geologic CO2 storage projects is small. There are a significant number of EOR projects, but most of these use CO2 from natural sources and are not being operated with the purpose of storing CO2. An exception to this is the Weyburn project (Monea et al., 2008, Preston et al., 2005). This CO2 monitoring and storage project is essentially a field demonstration of CO2 storage in the subsurface made possible by adding a research component through federal funding to EnCana’s CO2 Weyburn Unit project that has been underway since 2000. Located in the southeast corner of the province of Saskatchewan in Western Canada, the Weyburn Unit is a 180 km2 oil field discovered in 1954. In September 2000, EnCana initiated a CO2 enhanced oil recovery project. The CO2 is approximately 95% pure, and the initial injection rate was 5,000 tonnes per day. A total of approximately 30 million tonnes of CO2 is projected to be injected into the reservoir over the project’s life. The CO2 is a by-product from the Dakota Gasification Company’s synthetic fuels plant in Beulah, North Dakota, and is transported through a 320-km pipeline to Weyburn. Thus, this project is storing anthropogenic CO2 that otherwise would be emitted to the atmosphere.¶ Another important project is the Sleipner project in the North Sea off Norway’s coast. The natural gas produced from the Sleipner field contains about 9% CO2, which is removed by an amine (MDEA)based process (Kaarstad, 1992; Kaarstad, 2004). Because of the high CO2 tax in Norway and because a saline formation was readily available, the decision was made to inject the recovered CO2 into the Utsira Sand, about a kilometer below ground surface (Arts et al., 2004; Bickle et al., 2007; Chadwick et al., 2004; Kongsjorden et al., 1997; Korbøl and Kaddour, 1995; Torp and Gale, 2004). The Sleipner project, which began CO2 injection in October 1996, is the world’s first commercial application of CO2 storage in a deep saline formation (Torp and Gale, 2004). CO2 is being injected into the Utsira formation at a rate of about 1 million tonnes/y. A separate project, the saline aquifer CO2 storage (SACS) project, was established in 1998 to monitor the injected CO2. SACS has been using 3-D seismic surveying to monitor the CO2 in the Utsira formation (Arts et al., 2004).Data from this project is contributing to the growing scientific confidence in the reliability of storing CO2 in saline formations (Bickel et al., 2007; Gaus et al., 2005; Kongsjorden et al., 1997; Korbøl and Kaddour, 1995; Portier and Rochelle, 2005).¶ Another commercial project in Norway is the Snøhvit liquefied natural gas (LNG) operation. Raw natural gas from the Snøhvit field under the Barents Sea is brought ashore through a 160-km undersea pipeline. The gas contains about 5% CO2 that must be removed before the gas can be liquefied. The recovered CO2 is returned through a parallel pipeline and injected into the Snøhvit Tub°aen saline formation (Maldal and Tappel, 2004).¶ A CO2 geologic storage project in a completely different climate is the In Salah gas project in the Algerian desert. The project involves collecting the gas from multiple fields and removing (using an amine-based process) most of the CO2 which is injected into the Krechba Carboniferous formation at a depth of 1,800 m (Haddadji, 2006; Riddiford et al., 2004; Wright et al., 2005). The injection rate is about 1 million tonnes/year.

#### Sequestration projects are happening now

Cohen et al. 9 – Co-Founder and Executive Director of the Clean Air Task Force (Armond, former head of the Conservation Law Foundation's Energy Project, member of the Environmental Protection Agency’s Clean Air Act Advisory Committee; Mike Fowler, Technology Coordinator for the Coal Transition Project at the Clean Air Task Force, former New Source Review Supervisor and Enforcement Manager in the Air Quality Bureau of the New Mexico Environment Department, former Project Scientist in the Division of Applied Sciences at Harvard University; and Kurt Waltzer, Carbon Storage Development Coordinator for the Clean Air Task Force’s Coal Transition Project; May 2009, “‘NowGen’: Getting Real about Coal Carbon Capture and Sequestration,” *The Electricity Journal*, Volume 22, Issue 4, pp. 25-42, p. ScienceDirect)

III. CCS Technologies: Ready for Prime Time, but Scale-Up Needed¶ CCS systems encompass a suite of technologies, including chemical and physical solvents to absorb CO2 from exhaust or fuel gas; technologies for compressing CO2 and transporting it through pipelines; technologies for characterizing, operating, and monitoring geological sequestration sites; gasification and related technologies for producing hydrogen-rich gaseous fuel or substitute natural gas; and technologies associated with CO2-flood enhanced oil recovery. Most of the component technologies needed to implement CCS at the scale of individual power plants are already in commercial service in the U.S. Properly integrated, they can be applied on a much larger scale.¶ The next few sections review the primary technology pathways for CCS, including options for pre- and post-combustion capture, as well as oxy-combustion, underground coal gasification, and geologic carbon sequestration.¶ A. Coal gasification: The leading technology for full CO2 capture¶ Removing CO2 from the synthesis gas (syngas) produced by coal gasification prior to combustion, where it is concentrated and under high pressure, is thermodynamically advantageous compared to separating CO2 from the exhaust of pulverized coal plants after combustion.28 In IGCC plants, syngas may be chemically converted to a mixture composed primarily of hydrogen and CO2. The CO2 can then be removed using conventional acid gas removal technologies developed by the petrochemical industry, leaving a hydrogen-rich syngas that can be burned in a highly efficient combined-cycle power plant.¶ IGCC systems with integrated CO2 capture are available from a growing number of vendors, including Mitsubishi Heavy Industries (MHI), GE, Siemens, ConocoPhillips, and Shell. These systems present larger process integration challenges, especially if equipped with high levels of CO2 capture, than substitute natural gas (SNG) systems (see below), but are expected to be more efficient if electricity production is the ultimate goal. While no IGCC plants currently operate with CCS, Duke Energy plans to implement some level of capture at its new Edwardsport IGCC plant, provided regulators approve the additional expense. There are also plans to phase in capture at a new IGCC project under construction in China.29 Other commercial-scale projects are currently under development in California, Texas, Alberta, and Australia.30 Unfortunately, capital-cost increases since 2006 have caused other projects to be canceled or postponed, raising the question whether more cost-competitive technologies are needed to implement further commercial-scale demonstrations in the early years.¶ B. SNG: A promising platform for early CCS?¶ One potential transition technology involves gasifying coal to produce substitute natural gas (SNG; mostly methane), with a byproduct stream of capture-ready CO2 that contains half or more of the carbon originally in the coal.31 Assuming this byproduct CO2 is captured and stored while the SNG is utilized in a natural gas combined-cycle (NGCC) plant, overall CO2 emissions are on par with those for conventional gas-based generation. Furthermore, recent estimates suggest that SNG production can be cost-competitive with conventional natural gas in some scenarios, making it a potentially attractive bridge technology.32¶ All the technologies needed for SNG have been successfully employed together at the Dakota Gasification Company facility in Beulah, N.D., which daily converts roughly 18,500 tons of lignite into 150 million standard cubic feet (scf) of SNG33—enough to fuel 780 MW of electric capacity.34 As of 2004, this facility was capturing approximately 95 million scf of CO2 per day (more than 1 million tonnes per year), which was being transported by high-pressure pipeline 205 miles north to be used for enhanced oil recovery at the Weyburn oil field in Saskatchewan. By July 2008 approximately 11.4 million tonnes of CO2 had been captured and stored in this way.35 The equipment needed for commercial SNG production is available from multiple vendors and more than a dozen plants have been proposed in the U.S.36¶ C. Post-combustion capture: Big hurdles but potentially big payoffs for existing plants¶ Post-combustion or “end-of-pipe” CO2 capture technology has the advantage that it could potentially be retrofit to existing coal plants. The central process involves bringing flue gas into contact with a regenerable solvent—typically an amine-based solution—which absorbs CO2 from the gas. The solvent is then heated, driving off relatively pure, concentrated CO2. Because these processes must overcome greater thermodynamic hurdles than separation from syngas, the efficiency losses associated with post-combustion capture on a pulverized coal plant are substantially higher than the efficiency losses for pre-combustion capture on an IGCC plant (a relative decrease of roughly 31 percent for PCC, versus 18 percent for IGCC), even though modern versions of both plants could achieve roughly similar levels of efficiency when operated without CO2 capture.37¶ The largest currently operating post-combustion capture system on a coal boiler is in Trona, Calif., where a Kerr-McGee (now ABB Lummus) amine system built in 1978 captures 900 tons of CO2 per day (tpd).38 This is roughly equivalent to the CO2 emissions from a 35 MW coal power plant. The CO2 is used in the production of soda ash. Several additional amine-based systems are also in operation, including two that produce food-grade CO2 at coal plants in the U.S., two in Japan, and several at large industrial facilities that manufacture urea. MHI plans to install a 100 tpd post-combustion capture system on a coal-fired plant in Germany in 201039 and could have a commercial-scale system in operation as soon as 2015.40 Fluor Corporation has experience with post-combustion capture on natural gas power plants, and claims to be ready to provide a commercial-scale system.41 HTC PureEnergy and Cansolv are also developing amine-based post-combustion capture systems. Processes based on chilled and aqueous ammonia are under development by Alstom and PowerSpan, respectively, and these may offer efficiency improvements over amine systems.¶ Another technology, oxy-combustion, may also hold promise for new plants. These systems combust coal with nearly pure oxygen instead of air so that the resulting flue gas is predominantly capture-ready CO2. Oxy-combustion systems are capital-intensive, require larger equipment than IGCC plants, and must recycle large volumes of flue gas to moderate combustion temperatures. Improvements in oxygen production would benefit the technology. A few small-scale trials are currently underway and at least one company is evaluating potential retrofit applications.42¶ Other post-combustion technologies are being explored, some using advanced solvents, but these generally are not expected to reach the market for several years (at least) and are beyond the scope of this article.¶ D. Geologic carbon storage¶ The primary storage option for keeping CO2 out of the atmosphere permanently is likely to involve deep saline formations (DSF)—semi-permeable, geological strata a kilometer or more below ground that contain water too salty to be used for human consumption or irrigation. Such formations are broadly distributed around the world. CO2 injected into properly selected DSFs will dissolve and become trapped in surrounding pore spaces, in some cases eventually mineralizing into solid carbonaceous material. Globally, the storage capacity of DSFs has been estimated at 1,000–10,000 GtCO2 or more43—enough to hold 100–1,000 years (or more) of emissions from the world's existing coal power plants.44 The cost of geological sequestration in DSFs, including transportation, injection, and monitoring, is estimated to range from 7 percent to 16 percent of the total incremental cost of CCS on a 20-year levelized basis (most of the added cost of CCS reflects the capital cost of the capture equipment, followed by increased fuel costs).45¶ DSF sequestration is currently being demonstrated at the Sleipner field off Norway (10 million tonnes, or Mt, stored since 199646), at In Salah in Algeria (1 Mt per year starting in 200447), and offshore, near the Snovit gas processing plant in Norway (injection began in mid-2008 and will rise to 0.7 Mt per year at full capacity48). These projects have been designed and executed as learning exercises involving large petrochemical companies, although the Norwegian projects benefit from incentives in the form of an offshore CO2 emission tax. Numerous smaller projects have also been implemented49 and more are planned. For megaton-scale sequestration, DSF is currently possible though it has not yet been fully commercialized. Companies like Shell, Schlumberger, and others are developing the needed technologies and services.¶ Unlike DSF sequestration, when CO2 is injected as a flooding gas in oil fields to enhance production, a positive revenue stream can result. For this reason enhanced oil recovery (EOR) using CO2 as the flooding gas is a mature technology that is currently practiced at 86 sites in the U.S. alone50 (some dating back to the 1970s). Global sequestration potential for CO2 used in EOR is estimated to be at least 675 GtCO2.51 Notable sites in North America include the Permian Basin of West Texas and New Mexico, the Rangely field in Colorado, the Williston Basin in Canada, the Power River Basin in Wyoming, and the U.S. Gulf Coast. For both DSF and EOR, the retention of CO2 in properly selected and operated repositories is expected to exceed 99 percent over 1,000 years,52 with the potential for leakage decreasing over time.53 Measured leakage at existing EOR sites has been very small: more than 20 million Mt of CO2 have been stored at Rangely to date, and leakage, if present, is below the detection limit of 170 tonnes per year.54

#### Depleted natural gas and oil fields can be used

ICFI, 9-

(February, 2009, “Developing a Pipeline Infrastructure for CO2 Capture and Storage: Issues and Challenges,” <http://www.ingaa.org/File.aspx?id=8228>)

Depleted Natural Gas Fields and Oil Fields. Depleted natural gas and oil fields can be excellent candidates for CO2 storage. These represent known structures that have trapped hydrocarbons over geologic time, thus proving the presence of an effective structure and seal above the reservoir. These fields have also been extensively studied, there is a large amount of well log and other data available, and the field infrastructure is already in place.

### Safety

#### The pipelines will be safe

Jennifer Horne ’10 (third year law student at the S.J. Quinney College of Law, University of Utah. This Note is based in part on research completed for the University of Utah Institute of Clean and Secure Energy (ICSE), Journal of Land, Resources & Environmental Law 30 J. Land Resources & Envtl. L. 357, “Getting from Here to There: Devising an Optimal Regulatory Model for CO<2> Transport in a New Carbon Capture and Sequestration Industry”)

Safety regulation under the PHSMA has worked well for EOR-based pipelines, n286 and no compelling reason has emerged so far for changing the manner in which CO<2> pipelines are regulated for safety. However, regulators should not take CO<2>'s relatively good track record for granted, because it has come from what probably will prove to be a significantly smaller system. The projected difference in size and scope calls for inquiry into whether the current safety standards and oversight processes need to be adjusted for a scale much larger than the existing CO<2> pipeline network. Of course, PHSMA's experience overseeing larger pipeline networks, like natural gas, n287 bodes well for its ability to effectively regulate CO<2> pipelines for CCS.

#### There are no safety issues

Fish and Martin 10 – \*Chair of the Business Department with Stoel Rives LLP AND \*\*attorney with Stoel Rives LLP (Jerry R. and Eric L., 8/10/10, “Carbon Dioxide Pipelines,” California Carbon Capture and Storage Review Panel, http://www.climatechange.ca.gov/carbon\_capture\_review\_panel/meetings/2010-08-18/white\_papers/Carbon\_Dioxide\_Pipelines.pdf)

Carbon capture and sequestration are unlikely to occur on the same site. Pipelines will be needed to transport captured carbon dioxide (CO2) from the capture site to the injection site. This issue paper briefly describes the current regulation of CO2 pipelines in terms of both safety and siting authority. It also discusses tools to acquire or use rights-of-way for CO2 pipeline.

Pipeline Safety

CO2 pipelines have been operating in the United States for almost 40 years, and there are approximately 3,600 miles of CO2 pipelines in operation today.1 The Pipeline and Hazardous Materials Safety Administration (“PHMSA”), which is part of the Department of Transportation, regulates the safety of interstate CO2 pipelines under the Hazardous Liquid Pipeline Safety Act of 1979.2 CO2 is defined under PHMSA’s regulations as “a fluid consisting of more than 90 percent CO2 molecules compressed to a supercritical state.”3 Although CO2 is not considered a hazardous liquid under PHMSA’s regulations, it is effectively treated as if it were a hazardous liquid (i.e., subject to the same regulatory framework).4 These regulations address design, construction, operation and maintenance, corrosion control, and reporting requirements.5

#### Accidents or safety issues are unlikely

IPCC 5 (Intergovernmental Panel on Climate Change, 9/22-9/24/05, “Carbon Dioxide Capture and Storage: Summary for Policymakers,” special report of Working Group III of the Intergovernmental Panel on Climate Change, http://www.ipcc.ch/pdf/special-reports/srccs/srccs\_summaryforpolicymakers.pdf)

21. The local risks24 associated with CO2 pipeline transport could be similar to or lower than those posed by hydrocarbon pipelines already in operation.

For existing CO2 pipelines, mostly in areas of low population density, accident numbers reported per kilometre pipeline are very low and are comparable to those for hydrocarbon pipelines. A sudden and large release of CO2 would pose immediate dangers to human life and health, if there were exposure to concentrations of CO2 greater than 7–10% by volume in air. Pipeline transport of CO2 through populated areas requires attention to route selection, overpressure protection, leak detection and other design factors. No major obstacles to pipeline design for CCS are foreseen (Sections 4.4.2, AI.2.3.1).

22. With appropriate site selection based on available subsurface information, a monitoring programme to detect problems, a regulatory system and the appropriate use of remediation methods to stop or control CO2 releases if they arise, the local health, safety and environment risks of geological storage would be comparable to the risks of current activities such as natural gas storage, EOR and deep underground disposal of acid gas.

Natural CO2 reservoirs contribute to the understanding of the behaviour of CO2 underground. Features of storage sites with a low probability of leakage include highly impermeable caprocks, geological stability, absence of leakage paths and effective trapping mechanisms. There are two different types of leakage scenarios: (1) abrupt leakage, through injection well failure or leakage up an abandoned well, and (2) gradual leakage, through undetected faults, fractures or wells. Impacts of elevated CO2 concentrations in the shallow subsurface could include lethal effects on plants and subsoil animals and the contamination of groundwater. High fluxes in conjunction with stable atmospheric conditions could lead to local high CO2 concentrations in the air that could harm animals or people. Pressure build-up caused by CO2 injection could trigger small seismic events.

While there is limited experience with geological storage, closely related industrial experience and scientific knowledge could serve as a basis for appropriate risk management, including remediation. The effectiveness of the available risk management methods still needs to be demonstrated for use with CO2 storage. If leakage occurs at a storage site, remediation to stop the leakage could involve standard well repair techniques or the interception and extraction of the CO2 before it would leak into a shallow groundwater aquifer. Given the long timeframes associated with geological storage of CO2, site monitoring may be required for very long periods (Sections 5.6, 5.7, Tables 5.4, 5.7, Figure 5.25).

#### CO2 won’t leak

Biello 9 – associate editor for environment and energy at Scientific American (David, June 2009, “Can Captured Carbon Save Coal?” *Scientific American*, Volume 19, pp. 52-59, http://www.nature.com/scientificamerican/journal/v19/n2s/full/scientificamericanearth0609-52.html)

The great fear commonly associated with carbon sequestration is that trapped CO2 might suddenly escape to the surface with deadly consequences, as happened in 1986 at Lake Nyos in Cameroon. That volcanic lake had naturally accumulated two million metric tons of carbon dioxide in its cold depths; one night it spontaneously vented, displacing the oxygenated air, and suffocated more than 1,000 nearby villagers.

Yet in all the decades of commercial CO2 injection for EOR, there have been no dangerous leaks. CO2 from leaks and ruptured injection wells has always dispersed too quickly to pose a threat.

For example, prospectors in Utah drilling for natural gas in 1936 accidentally created a CO2 geyser. It still erupts a few times a day as pressure builds but is “so unhazardous that it’s a tourist attraction, not a risk,” says Stanford’s Benson. In fact, air concentrations of carbon dioxide have to build up to more than 10 percent to be hazardous, which is difficult to achieve, according to modeling at Lawrence Livermore National Laboratory.

The reason is that CO2 belching from a volcanic lake creates conditions very different from those of the gas escaping from a wellhead or seeping into a basement, explains Julio Friedmann, leader of the carbon management program at Lawrence Livermore. At Lake Nyos, an abrupt release of the CO2 allowed dangerous concentrations to pool in low-lying surrounding areas. Pressurized gas escaping from a wellhead or crack simply mixes rapidly with the atmosphere, presenting no danger, much as the use of a fire extinguisher is not hazardous. In situations where atmospheric mixing is minimal, such as for a slow leak into a basement, the problem can be eliminated by simply installing a sensor and a fan, as in apartment buildings today near natural CO2 seepages in Italy and Hungary.

At a demonstration project in Japan, even a magnitude 6.8 earthquake didn’t shake injected CO2 loose from a deep saline aquifer; the wellheads did not so much as leak. Big earthquakes might cause leakage, but in many cases, they will not, Friedmann says.

#### Monitoring CO2 leakage is easy

Gibbins and Chalmers 8 – \*Senior Lecturer in the Energy Technology for Sustainable Development Group within the Mechanical Engineering Department at Imperial College London AND \*\*researcher in the Energy Technology for Sustainable Development Group at Imperial College London (Jon, Principal Investigator for the UK Carbon Capture and Storage Consortium; and Hannah, climate change and energy consultant for SciDev.Net; December 2008, “Carbon capture and storage,” *Energy Policy*, Volume 36, Issue 12, pp. 4317-4322, p. ScienceDirect)

3. Geological storage of CO2

Geological storage of CO2 relies on injection at depths of more than 1 km. Temperatures will be above the critical value for CO2 (31 °C) but pressures are high enough (order 100 atmospheres and above) to give densities of the order of 500 kg/m3. CO2 may be placed into oil reservoirs, where it can also give enhanced oil recovery, into abandoned gas fields or into deep saline aquifers. Total UK offshore storage capacity for regions assessed to date is at least 20 Gt CO2 in depleted oil and gas fields and saline aquifers, representing approximately 40 years of total UK emissions at current rates (Gibbins et al., 2006). Storage capacity in all accessible saline aquifers is expected to be equivalent to several centuries of current total UK CO2 emissions.

The critical factors in geological storage are the potential for CO2 injection, the design of offshore enhanced oil recovery projects, the displacement of ambient porefluids, monitoring to appropriate standards and assurance on leakage. Rapid leakage paths, the most likely of which are failed wells, present an obvious re-emission problem but as such are likely to be identified and remediated relatively quickly. Lower rates of seepage, through unforeseen permeable faults for example, may cause local damage in the terrestrial or marine environment. Additionally, even at low rates (order 0.1% of stored volume per year) such seepage may ultimately lead to increases in atmospheric CO2 concentrations compared to schemes where this does not occur. Key enabling technologies for geological storage are:

● directional and horizontal drilling to give cost-effective injection of CO2, even into relatively impermeable strata, from a limited number of central facilities (particularly for offshore storage)

● modelling techniques to:

 ○ predict deep groundwater displacement

 ○ provide fundamental identification and quantification to predict CO2 migration and dispersion

 ○ describe geochemical processes to predict CO2 distribution and eventual immobilisation, in a wide range of geological rock formations and structural settings

● seismic and other imaging techniques to monitor CO2 location underground and

● borehole logging and smart monitoring techniques to give early warning of seepage.

A comprehensive review, Monitoring Technologies for the Geological Storage of CO2, was published by the UK Government Department of Trade and Industry (2005). Many techniques developed for the oil and gas industry can be applied to modelling and monitoring CO2 storage, although it was concluded that ‘a key requirement is to test these technologies in combination at a variety of storage sites so that their strengths and weaknesses can be evaluated in real situations, and optimal strategies developed,’ another example of the need for ‘learning by doing’ to progress CCS. New developments for monitoring reflect a requirement for low-cost, long-term observations by instruments that can be left in place for a number of decades and will operate semi-autonomously, including borehole and sub-sea CO2 sensors and pH sensors. There is also a need to develop passive seismic monitoring using multiple long-term sensors, such as resistivity or gravimetric monitoring. These may be able to give enhanced resolution of CO2 dissolved in groundwater, which is difficult to resolve seismically. The response of sea-bed marine and terrestrial biological communities to slow leakage of CO2 also needs to be assessed and this could aid the early detection of leaks.

Once further practical experience from CO2 storage projects is available, it is likely that the basic additional requirements for modelling and monitoring will be developed into useable forms relatively quickly. In line with oil and gas industry experience, however, and helped by progress in other areas (e.g. electronics, materials, computing, oil and gas extraction) continuous improvements can be expected through to 2050 and beyond, reducing costs and giving more detailed information on CO2 movements and interactions with the geological, and occasionally surface, environments. Different geological contexts will also require the development of specialised approaches through experience.

# Climate Leadership Add-On

### 2AC – Climate Leadership I/L

#### CCS is key to climate leadership

ITF, 10-

(Interagency Task Force, August, “Executive Summary: Report of the Interagency Task Force on Carbon Capture and Storage,” http://www.epa.gov/climatechange/Downloads/ccs/ES-CCS-Task-Force-Report-2010.pdf)

CCS can also play a major role in reducing GHG emissions globally. Continued leadership to develop and deploy CCS technologies as one option to address global climate change will position the United States as a leader in climate change technologies and markets. However, widespread cost-effective deployment of CCS will occur only if the technology is commercially available at economically competitive prices and supportive national policy frameworks are in place.

### Impact – Hegemony

#### Climate leadership is key to heg

Walter, 2-

(Norbert, Chief Economist – Deutsche Bank Group, The New York Times, 8-28, Lexis)

At present there is much talk about the unparalleled strength of the United States on the world stage. Yet at this very moment the most powerful country in the world stands to forfeit much political capital, moral authority and international good will by dragging its feet on the next great global issue: the environment. Before long, the administration's apparent unwillingness to take a leadership role -- or, at the very least, to stop acting as a brake -- in fighting global environmental degradation will threaten the very basis of the American supremacy that many now seem to assume will last forever. American authority is already in some danger as a result of the Bush administration's decision to send a low-level delegation to the World Summit on Sustainable Development in Johannesburg -- low-level, that is, relative to America's share of both the world economy and global pollution. The absence of President Bush from Johannesburg symbolizes this decline in authority. In recent weeks, newspapers around the world have been dominated by environmental headlines: In central Europe, flooding killed dozens, displaced tens of thousands and caused billions of dollars in damages. In South Asia, the United Nations reports a brown cloud of pollution that is responsible for hundreds of thousands of deaths a year from respiratory disease. The pollution (80 percent man-made) also cuts sunlight penetration, thus reducing rainfall, affecting agriculture and otherwise altering the climate. Many other examples of environmental degradation, often related to the warming of the atmosphere, could be cited. What they all have in common is that they severely affect countries around the world and are fast becoming a chief concern for people everywhere. Nobody is suggesting that these disasters are directly linked to anything the United States is doing. But when a country that emits 25 percent of the world's greenhouse gases acts as an uninterested, sometimes hostile bystander in the environmental debate, it looks like unbearable arrogance to many people abroad. The administration seems to believe it is merely an observer -- that environmental issues are not its issues. But not doing anything amounts to ignoring a key source of world tension, and no superpower that wants to preserve its status can go on dismissing such a pivotal dimension of political and economic -- if not existential -- conflict.

### **Impact - Environment**

Solves the environment --- solves extinction
Harris, 1-

(Paul G., Lecturer – Lignan University, Associate Fellow – Oxford Center for Environment, Ethics, and Society at Mansfield College, Oxford University, The Environment, International Relations, and U.S. Foreign Policy, p. 241-242)

In addition to promoting U.S. global interests, a more robust acceptance by the U.S. government of international equity as an objective of global environmental policy—and indeed of foreign policy generally—has potentially beneficial implications for humankind. Implementation of the equity provisions of international environmental arrangements may reduce human suffering by helping to prevent changes to local, regional, and global environmental commons that would adversely affect people, most notably the many poor people in the economically developing countries who are least able to cope with environmental changes. Insofar as environmental protection policies focus on sustainable economic development, human suffering may be mitigated as developing countries—especially the least-developed countries—are aided in meeting the basic needs of their citizens. Economic disparities within and between countries are growing. At least one-fifth of the world’s population already lives in the squalor of absolute poverty.59 This situation can be expected to worsen in the future. If this process can be mitigated or reversed by international policies focusing on environmentally sustainable economic development, human well-being on a global scale will rise. ‘What is more, international cooperative efforts to protect the environment that are made more likely and more effective by provisions for international equity will help governments protect their own environment and the global environment if they are successful. Insofar as the planet is one biosphere—that it is in the case of ozone depletion and climate change seems indisputable-persons in every local and national community are simultaneously members of an interdependent whole. Most activities, especially widespread activities in the United States and the rest of the industrialized world, including the release of ozone-destroying chemicals and greenhouse gases, are likely to adversely affect many or possibly all persons on the planet. Efforts to prevent such harm or make amends for historical harm (i.e., past pollution, which is especially important in these examples because many pollutants continue doing harm for years and often decades) require that most communities work together. Indeed, affluent lifestyles in the United States, ‘Western Europe, and other developed areas may harm people in poor areas of the world more than they will harm those enjoying such lifestyles because the poor are ill-equipped to deal with the consequences.6° Furthermore, by concerning themselves with the consequences of their actions on the global poor and polluted, Americans and the citizens of other developed countries will be helping their immediate neighbors—and themselves—in the long run. Actualization of international equity in conjunction with sustainable development may help prevent damage to the natural environment worldwide, thereby promoting human prosperity. The upshot is that the United States has not gone far enough in actively accepting equity as an objective of global environmental policy. It ought to go further in doing so for purely self-interested reasons. But there are more than self-interested reasons for the United States to move in this direction. It ought to embrace international equity as an objective of its global environmental policy for ethical reasons as well. We can find substantial ethical justification for the United States, in concert with other developed countries, to support politically and financially the codification and implementation of international equity considerations in international environmental agreements. The United States ought to be a leader in supporting a fair and just distribution among countries of the benefits, burdens, and decision-making authority associated with international environmental relations.61 To invoke themes found in the corpus of ethical philosophy (but without here assuming the burden of philosophical exegesis!), the United States ought to adopt policies that engender international equity in at least the environmental field (1) to protect the health and well-being of the human species; (2) to promote basic human rights universally; (3) to help the poor be their own moral agents (a Kantian rationale); (4) to help right past wrongs and to take responsibility for past injustices (i.e., past and indeed ongoing U.S. pollution of the global environment); (5) to aid the world’s least-advantaged people and countries (a Rawlsian-like conception); (6) and to fhlflll the requirement of impartiality (among other ethical reasons)62—all in addition to the more dearly self-interested justification that doing so will bolster U.S. credibility and influence in international environmental negotiations and contemporary global politics more generally. One might argue, therefore, that the United States ought to be aiding the developing countries to achieve sustainable development because to do so may simultaneously reduce human suffering and reduce or potentially reverse environmental destruction that could otherwise threaten the healthy survival of the human species. Insofar as human-caused pollution and resource exploitation deny individuals and their communities the capacity to survive in a healthy condition, the United States, which consumes vastly more than necessary, has an obligation to stop that unnecessary consumption. From this basic rights perspective,63 the U.S. government should also take steps to reduce substantially the emissions of pollutants from within the United States that harm people in other countries.64 The United States ought to refrain from unsustainable use of natural resources and from pollution of environmental commons shared by people living in other countries—or at least make a good effort toward that end—because the people affected by these activities cannot reasonably be expected to support them (we would not be treating them as independent moral agents, to make a Kantian argument65).

### Impact – US-EU Relations

#### US climate leadership is key to US-EU relations.

Avro in 9-

 founder and Editor-In-Chief of Consumer Energy Report ( April 7, 2009. “ EU, U.S. Positions on Climate Change Beginning to Merge” Consumer Energy Report. http://www.consumerenergyreport.com/2009/04/07/eu-us-positions-on-climate-change-beginning-to-merge)

U.S. President Barack Obama pledged to a public crowd Sunday in Prague that the United States was ready to take the lead in battling climate change after some prodding by EU leaders to adopt their ambitious goals to combat global warming. “To protect our planet, now is the time to change the way that we use energy. Together, we must confront climate change by ending the world’s dependence on fossil fuels, by tapping the power of new sources of energy like the wind and sun, and calling upon all nations to do their part,” Obama said to the crowd gathered outside the medieval Prague Castle .“I pledge to you that in this global effort, the United States is now ready to lead,” he said as cheers erupted from the crowd of tens of thousands of people. The Europeans seem to be taking well to the latest position on climate change that Obama layed out. The change of policy from the stance of his predecessor, former President George W. Bush, is something that the EU was looking to see. The EU has been waiting for the U.S. to make substantial commitments toward cutting its greenhouse gas emissions. “We welcome the steps taken by the new American administration and the increasing convergence between the European and U.S. position on that matter,” European Commission President Jose Manuel Barroso said. “Only together we can convince others to join our common effort to fight climate change.” EU nations have agreed to cut their greenhouse gas emissions by 20 percent by 2020 from 1990 levels, rising to 30 percent if the rest of the developed world — mainly the United States and Japan — agrees to do so. French President Nicolas Sarkozy wants Obama to lead by example and cause other developing powerhouse nations to follow suit. “While we’re happy that the Americans want to take the lead in the fight against climate change, they have to convince more than just the Europeans,” Sarkozy said in comments to AFP. “I told President Obama that it was very important that the United States does more so it would persuade the world, notably China and India, to follow suit.”

#### Relations key to stop proliferation and war.

Haas, 1999

[Richard, Director of Foreign Policy Studies at Brookings, Transatlantic Studies, p. 3-4]

The 1990-91 Gulf War collaboration and the eventual cooperation in Bosnia should not obscure a larger reality. Increased friction (and decreased cooperation) characterizes relations across the Atlantic on policies toward problem countries. This trend has, if anything, accelerated with the passage of time, and with it the gradual passing from the scene of a generation informed by the habit of transatlantic cooperation. This development worked to reinforce trends already accelerated by the demise of the Cold War, the disappearance of the Soviet threat, and the reduction of tension in Europe, all of which reduced the obvious necessity and momentum for transatlantic cooperation, especially in the security sphere.Yet the reduced threat to European security does not mean the absence of stakes. To the contrary, how the United States and the countries of Europe work with one another beyond Europe matters in at least three important ways. First, a good deal hangs in the balance. Four of the five countries examined in this volume are major energy exporters. Three pose major challenges to global efforts aiming to stem the proliferation of weapons of mass destruction. All five offer substantial markets for European and U.S. exports. Second, the United States and Europe are potential partners in shaping the post-cold war world. Their ability to cooperate will have major impact on whether the emerging era of international relations turns out to be one that is more or less violent, prosperous, and democratic. Economic and political sanctions (as well as various supplier or export control arrangements designed to thwart proliferation of weapons of mass destruction) will inevitably have less impact in the absence of transatlantic cooperation; so, too, will diplomacy premised on the notion of providing reward or incentives only if certain behavioral standards are reached. Military action becomes far more expensive (in human and financial terms) and more difficult to sustain domestically if burdens are not shared. Third, disagreements on particular out-of-area issues will inevitably affect the ability of Americans and Europeans to cooperate on other issues, regardless of their venue. Thus, differences over the best approach to one conflict can frustrate cooperation in another if patterns of unilateralism prevail. This concern is anything but hypothetical. At one point, the United States considered abandoning the Bosnian arms embargo. Whatever the merits of a policy change for Bosnia, such a decision could well have led France and others to reconsider their support of Iraqi sanctions. Similarly, secondary sanctions-the introduction of sanctions against third parties who do not participate in primary sanctions against a designated target-by nature expand the area of disagreement. Indeed, several of the cases in this volume look at secondary sanctions and their impact on such common interests as strengthening the capacity of the World Trade Organization to regulate international order.

# AT: States

### Fed Key

#### A nationwide project would need federal action – empirical state successes are irrelevant

ICFI 9 (ICF International, a firm that partners with government and commercial clients to deliver professional services and technology solutions, February 2009, “Developing a Pipeline Infrastructure for CO2 Capture and Storage: Issues and Challenges,” http://www.ingaa.org/File.aspx?id=8228)

Pipeline Siting

Most interviewees see the major role for federal regulatory authority in providing centralized review of routing, siting, and environmental impacts. At present, no such authority resides with any federal agency. DOT provides safety performance regulatory authority over CO2 pipelines. States provide the siting and environmental review, except where pipes cross federal lands or waters of the U.S. Current CO2 pipeline operators do not express a need for federal oversight, given their experience with state review agencies has been satisfactory. However, the existing CO2 pipelines are in the west, where in general there is ample room for routing, unlike eastern states where population is denser.

The granting of the right of eminent domain to CO2 pipelines, a key element of FERC authority over interstate gas pipelines, currently resides in the states. Some states appear to be willing to give CO2 pipelines eminent domain authority in return for greater regulatory oversight. To date this has included review of rates and tariffs conditions. Even with this, economic regulation of the pipelines has been light handed, mainly relying on filed complaints to engage any review of practices. Eminent domain, which allows pipelines to take land for right of way, presumes a FERC style of regulatory oversight, and not common carriage, at least as it is practiced today. That is, in order to receive the right to condemn land the pipeline must demonstrate some public interest. The government then can require rate and tariff oversight, in addition to siting, but may also involve approval of costs and post construction activities.

Eminent domain authority under state law may be adequate for small CO2 pipeline projects in a few states (Texas and California, for example), but state authority will be inadequate for major, multi-state projects. New federal legislation ultimately will be needed, but any expansion of federal rights will be highly controversial and will face possible opposition in Congress. Federal authority could be in the nature of a certificate of public convenience and necessity (similar to the NGA), a licensing approach (similar to Part I of the FPA (this may be more appropriate for privately-owned CO2 repositories), or the sort of “backstop” siting authority (a federal construction permit) that FERC obtained under EPAct 2005, following designation of the corridor as a national interest corridor by DOE.55

#### Federal regulations are key

Cyrus Zarraby ’12 (J.D., expected May 2012, The George Washington University Law School; B.S., 2003, Clemson University. The author is a chemical engineer for the Federal Energy Regulatory Commission (“FERC”), April 2012, Vol. 80 No. 3, “Regulating Carbon Capture and Sequestration: A Federal Regulatory Regime to Promote the Construction of a National Carbon Dioxide Pipeline Network,” http://groups.law.gwu.edu/lr/ArticlePDF/80\_3\_Zarraby.pdf)

The current lack of a federal regulatory regime coupled with inconsistent state regulations creates three distinct problems that will limit the construction of CO2 pipelines and hinder the development of CCS technology: (1) uncertainty in the regulations of CO2 pipelines, 147 (2) a single state’s ability to prevent the construction of a pipeline due to the uncertainty of eminent domain issues, 148 and (3) a single landowner’s ability to either require a pipeline to incur a substantial cost or prevent the construction of the pipeline altogether because of the lack of universal eminent domain authority. 1

#### Disparate pipeline policies destroy investment and turn solvency

Parfomak and Folger 8 – \*Specialist in Energy and Infrastructure Policy for the Congressional Research Service AND \*\*Specialist in Energy and Natural Resources for the Congressional Research Service (Paul W.; and Peter; 1/10/08, “Pipelines for Carbon Dioxide (CO2) Control: Network Needs and Cost Uncertainties,” http://assets.opencrs.com/rpts/RL34316\_20080110.pdf)

Carbon capture and sequestration (CCS) is a three-part process involving a CO2 source facility, a long-term CO2 sequestration site, and an intermediate mode of CO2 transportation — typically pipelines. Some studies have been optimistic about pipeline requirements for CO2 sequestration. They conclude that the pipeline technology is mature, and that most major CO2 sources in the United States are, or will be, located near likely sequestration sites, so that large investments in CO2 pipeline infrastructure will probably not be needed.1 Other studies express greater uncertainty about the required size and configuration of CCS pipeline networks.2 A handful of regionally-focused studies have concluded that CO2 pipeline requirements for CO2 sources could be substantial, and thus present a greater challenge for CCS than is commonly presumed, at least in parts of the United States.3

Divergent views on CO2 pipeline requirements introduce significant uncertainty into overall CCS cost estimates and may complicate the federal role, if any, in CO2 pipeline regulation. They are also a concern because uncertainty about CO2 pipeline requirements may impede near-term capital investment in electricity generation, with important implications for power plant owners seeking to reduce their CO2 emissions.

#### Unified efforts are necessary for technology development

Haszeldine 9 – Scottish Power Professor of Carbon Capture & Storage at the University of Edinburgh School of GeoSciences (R. Stuart, 9/25/09, “Carbon Capture and Storage: How Green Can Black Be?” *Science*, Volume 325, Number 5948, pp. 1647-1652, http://www.roberts.cmc.edu/159/2010/2010pdfs/5.%20Feb%204%202010.pdf)

Third, for rapid learning to help cost reduction, successive generations of equipment have to evolve and improve from the same design. For CCS, there are at least seven different combinations of fuel with the three capture technologies (Fig. 4). Each demonstration project may have distinct transportation systems and individual geological storage sites. Consequently, learning progress in one technology has limited relevance to that of another, and the progress of the “CCS fleet” could be inhomogeneous. So, will CCS globalize? With no price support or communication, CCS will remain limited to interesting but isolated demonstrations. A coherent national and international approach is required to create a new industry that disrupts the status quo.

#### Federal action is key to uniform action

Nordhaus and Pitlick 9 – \*former General Counsel at both the Federal Energy Regulatory Commission and the Department of Energy AND \*\*Associate at Van Ness Feldman law firm (Robert R., member of Van Ness Feldman law firm, member of the adjunct faculty at George Washington University Law School; and Emily; 2009, “Carbon Dioxide Pipeline Regulation,” *Energy Law Journal*, Volume 30, Number 2, pp. 85-104, p. HeinOnline)

VII. LIKELY NEED FOR A FEDERAL ROLE The massive build out of CO2 pipeline infrastructure that will be required for large scale commercial deployment of CCS will likely require substantial change in CO2 pipeline regulation. In particular, it is not clear whether reliance on state-by-state siting processes and eminent domain authority will be sufficient to support construction–over a period of one or two decades–of a network of interstate CO2 pipelines that may be equivalent in size to the current natural gas pipeline system. As a result, some developers will likely need access to a federal siting process and federal eminent domain authority to enable construction of this national CO2 pipeline system. This authority is likely to be particularly needed for multi-state projects and for projects in states that do not provide CO2 pipelines with eminent domain authority.¶ While Federal siting and eminent domain authority is likely to entail significant additional Federal environmental review, these reviews could be integrated into the siting process and performed on a timely basis, were the FERC to be granted siting authority over CO2 pipelines comparable to its authority under the NGA. The FERC could follow the process it now utilizes for interstate pipeline certification. That process entails environmental review under the National Environmental Policy Act of 1969 (NEPA), as well as any necessary actions under the Endangered Species Act, and statutes relating to wetlands, historic preservation, and similar matters. Under current FERC practice, these reviews are conducted in the course of the certification process, which takes an average of fourteen to sixteen months.114¶ In addition, existing law governing access and rate regulation of CO2 pipelines is unclear at best. Greater certainty as to the extent of that regulation will help facilitate project financing. In order to obtain financing project developers (and their debt and equity investors) need to know what regulatory requirements–if any–will apply to the pipeline during its operational phase, so they evaluate potential regulatory risks.115 Moreover, if Congress is asked to grant federal siting and eminent domain authority to such pipelines, it is likely to impose some form of ―common carrier‖ requirements, such as nondiscriminatory access and rate regulation–among other reasons, to avoid a multiplicity of small high unit-cost facilities.¶ Finally, the existing framework for safety regulation of CO2 pipelines–which relies on a federal regulatory program, with delegation of some functions to state regulators–seems clear and workable. 116

#### Fed is key for coordination among the pipelines

ICFI, 9-

(February, 2009, “Developing a Pipeline Infrastructure for CO2 Capture and Storage: Issues and Challenges,” <http://www.ingaa.org/File.aspx?id=8228>)

Federal Jurisdiction The principal need for regulation is to ensure a timely, adequate, and rational pipeline system that meets national policy objectives for carbon sequestration. This could mean a mixture of both state and federal regulatory oversight, as in the natural gas pipeline industry today. Viewing the map at figure 4-2, one can expect that the initial CO2 pipelines might be built to nearby EOR or other storage sites and could be entirely within a single state. In such cases states may regulate the pipelines as are done now. As the system expands, with pipelines receiving CO2 from more facilities, crossing state boundaries to reach more distant storage sites, involving more complex pipeline configurations (such as intermediate short term storage to manage surges in supply), and interconnections with other CO2 pipelines, the need for federal jurisdiction over the system becomes more apparent. The logical agency for overseeing CO2 pipelines may be FERC, given the similar technologies, siting issues, and environmental impacts to those of the natural gas pipeline industry. Similarly, the certification process for CO2 pipeline could be modeled on NGA regulation. Safety jurisdiction can remain with PHMSA, just as it is for natural gas pipelines. A principal focus of regulation would be in constructing and maintaining an efficiently operating pipeline network that ensures the delivery of CO2 to storage sites. FERC could have the authority to direct pipeline interconnections and require the industry to take steps to operate in an integrated fashion. Abandonment of facilities or ownership would have to be approved by the FERC. Similarly, the regulator should ensure open access to pipelines and prohibit any undue discrimination in rates and services.

#### No one will use a pipeline if the states do it

Joel Mack ’09 (Energy Policy 38 (2010) 735–743, “Making carbon dioxide sequestration feasible: Toward federal regulation of CO2 sequestration pipelines,” <http://ac.els-cdn.com/S0301421509007459/1-s2.0-S0301421509007459-main.pdf?_tid=aa0b0c56ba6655e1a04a86812ed884d6&acdnat=1342902367_7636d44b5a371113b4ce7b1340e0a6b6>)

Similarly, on an ongoing financial basis, even though a customer might contract with the pipeline to transport CO2 from Illinois to Louisiana, the rates the company could charge for that service might vary over the different portions of the route that fall within different states, creating (1) uncertainties for the pipeline company in the ability to recover the capital and operating expenses of such pipelines in such a way as to make investment in such companies subject to greater risk than investing in company with a single and consistent rate structure administered by a single entity, and (2) uncertainties for the customer because of the potential for differential rates and “pancaked” rates if an interstate CO2 transportation system is composed of interconnected intrastate pipelines. The risk of differential financial regulation alone would make access to the capital markets difficult for companies developing such pipelines, and for their power plant or CO2 removal company customers. That risk would be exacerbated by potentially differing siting requirements, differing permit conditions, multiple state utility commission proceedings, and other multiple public participation processes such siting requirements would entail, leading to higher transaction costs and potentially conflicting requirements.

#### The federal government is key for economic regulation --- states fail

Saundry, 11-

(Peter, “Pipelines for Carbon Dioxide Control in the United States,” <http://www.eoearth.org/article/Pipelines_for_Carbon_Dioxide_Control_in_the_United_States?topic=54490>)

Economic regulation of interstate pipelines by the federal government is generally intended to ensure pipelines fulfill common carrier obligations by charging reasonable rates; providing rates and services to all upon reasonable request; not unfairly discriminating among shippers; establishing reasonable classifications, rules, and practices; and interchanging traffic with other pipelines or transportation modes. If interstate CO2 pipelines for carbon sequestration are ultimately to be developed, it will raise important regulatory questions in this context because federal jurisdiction over hypothetical interstate CO2 pipeline siting and rate decisions is not clear. Based on their current regulatory roles, two of the more likely candidates for jurisdiction over interstate pipelines transporting CO2 for purposes of CCS are the Federal Energy Regulatory Commission (FERC) and the Surface Transportation Board (STB). However, both agencies have at some point expressed a position that interstate CO2 pipelines are not within their purview. If CCS technology develops to the point where interstate CO2 pipelines become more common, and if FERC and the STB continue to disclaim jurisdiction over CO2 pipelines, then the absence of federal regulation described above may pose policy challenges. In particular, with many more pipeline users and interconnections than exist today, complex common carrier issues might arise. One potential concern, for example, is whether rates should be set separately for existing pipelines carrying CO2 as a valuable commercial commodity (e.g., for EOR), versus new pipelines carrying CO2 as industrial pollution for disposal. Furthermore, if rates are not reviewed prior to pipeline construction, it might be difficult for regulators to ensure the reasonableness of CO2 pipeline rates until after the pipelines were already in service. If CO2 pipeline connections become mandatory under future regulations, such arrangements might expose pipeline users to abuses of potential market power in CO2 pipeline services, at least until rate cases could be heard. Presiding over a large number of CO2 rate cases of varying complexity in a relatively short time frame might also be administratively overwhelming for state agencies, which may have limited resources available for pipeline regulatory activities.

#### **States fail --- regulations**

Parfomak et. Al, 9-

(Paul, July 31, 2009, Specialist in Energy and Infrastructure Policy, “Carbon Dioxide (CO2) Pipelines for Carbon Sequestration: Emerging Policy Issues,” CRS Report for Congress)

Two complications arise with respect to pipeline cost recovery. First, because utility regulation varies from state to state (e.g., some states allow for competition in electricity generation, others do not),56 differences among states in the economic regulation of CO2 pipelines could create economic inefficiencies and affect the attractiveness of CO2 pipelines for capital investment. Second, if CO2 transportation infrastructure is intended to evolve from shorter, stand-alone, intrastate pipelines into a network of interconnected interstate pipelines, pipeline operators wishing to link CO2 pipelines across state lines may face a regulatory environment of daunting complexity. Without a coherent system of economic regulation for CO2 pipelines, whether as a commodity, pollutant, or some other classification, developers of interstate CO2 pipelines may need to negotiate or litigate repeatedly issues such as siting, pipeline access, terms of service, and rate “pancaking” (the accumulation of transportation charges assessed by contiguous pipeline operators along a particular transportation route). It is just these kinds of issues which have complicated and impeded the integration of individual utility electric transmission systems into larger regional transmission networks.57

#### States fail – the uniformity the CP assumes makes it impossible

Joel Mack ’09 (Energy Policy 38 (2010) 735–743, “Making carbon dioxide sequestration feasible: Toward federal regulation of CO2 sequestration pipelines,” <http://ac.els-cdn.com/S0301421509007459/1-s2.0-S0301421509007459-main.pdf?_tid=aa0b0c56ba6655e1a04a86812ed884d6&acdnat=1342902367_7636d44b5a371113b4ce7b1340e0a6b6>)

Given the paucity of federal legislation, the potential problems with a patchwork of state regulations are self-evident. If a company were to attempt to develop a new CO2pipeline from Illinois or Indiana to a Gulf Coast salt dome storage facility, for example, that company would have to obtain state and local approvals in four or five different states (depending on the route and destination), with potentially differing and conflicting siting standards, rate regulation, different scopes and methods of condemnation authority, and other conditions of approval. As the supply of CO2 starts to outpace its valuable uses (i.e., when CO2 changes from a commodity to a waste material), states with less developed statutory regimes may find it difficult to address CO2pipelines under their existing laws. In order for such pipelines to have common requirements, numerous states would have to modify their existing regulatory programs to harmonize them with other states, and many states that do not presently have any regulatory structure for such pipelines would have to pass legislation and promulgate regulations in order to do so. In this environment, constructing such pipelines would, by definition, take longer and pose more development risks than a single federal approval process that preempted state siting.

### Ecology DA to States

#### Disad to the states CP –

#### a. States don’t have to go through an EIA with NEPA when it comes to pipelines

Joel Mack ’09 (Energy Policy 38 (2010) 735–743, “Making carbon dioxide sequestration feasible: Toward federal regulation of CO2 sequestration pipelines,” <http://ac.els-cdn.com/S0301421509007459/1-s2.0-S0301421509007459-main.pdf?_tid=aa0b0c56ba6655e1a04a86812ed884d6&acdnat=1342902367_7636d44b5a371113b4ce7b1340e0a6b6>)

Under federal law, any “major federal action” requires compliance with the National Environmental Policy Act (“NEPA”).53 Under NEPA, before any federal agency can approve a project, it must first conduct an environmental assessment and, if necessary, prepare an environmental impact statement (“EIS”) to determine what the significant effects would be from the project and assess potential mitigation measures.54 This analysis would be documented in the federal agency's official record of decision, and would then be subject to review in federal court. Although many states have a state version of NEPA (US Department of Energy, 2009),55 many other states do not—including many states in the Midwest and Gulf Coast, which would be charged with siting and regulating new CO2pipelines.56 Potentially, a pipeline could be routed through states that, if all lacked any form of state NEPA, would result in such a facility being constructed without a comprehensive assessment of its environmental impact. Even though these facilities would be helping to reduce our carbon footprint, the pipelines themselves have the potential for environmental impacts that warrant study and consideration in the permitting process. If a pipeline were routed through several states, one of that had a state NEPA and others that did not, the process could itself result in differing conditions of approval, route alteration, and similar effects that could increase the cost and complexity of building and operating the pipeline. Many state NEPAs do not, for example, routinely permit the state to consider extra-territorial effects,57 but even if they did, they may not be able to enforce conditions of approval requiring mitigation measures outside their jurisdictional boundaries. Requiring such projects to be reviewed under NEPA (even as compared to state NEPA analogues) confers potentially substantial environmental benefits from federal agency coordination. For example, if a project may have an impact on a species that is listed as endangered or threatened under the federal Endangered Species Act (“ESA”), a federal agency can conduct a consultation under Section 7 of the ESA to assess and mitigate impacts to the species, which is then reflected in the EIS and ROD.58 In the absence of federal review, the project proponent would be required to obtain an incidental take permit under Section 10 of the ESA, which is a much more complex and time-consuming process.59 As a result, project proponents do receive incidental benefits when subject to a federal permitting program.

#### b. That’s necessary for global ecological sustainability

Lynton Caldwell ‘98 (Professor of Political Science @ IU Lynton K. Caldwell, Prof. of Political Science/Public and Environmental Affairs @ Indiana Univ., 22 Harv. Envtl. L. Rev. 203, “Beyond NEPA: Future Significance of the National Environmental Policy Act,”)

A distinguishing feature of any society is its prevailing assumptions about its relationship to the Earth. The history of cultures--especially of religions--reveals a great number of cosmologies, the perceived relationships of people to their planetary environment. Today the survival of living species may depend first, upon the degree to which mankind's concept of its environmental situation corresponds to biophysical realities and second, upon what humans value, and how these values are expressed in relation to these realities. Archeology has recorded the failure of societies that have misconceived the requirements for environmental sustainability. During the earlier centuries of human history the impact of society on its environment was relatively light and local. If an environment, for whatever reason, became unsustainable, people could often move on to new lands, often displacing or destroying the original inhabitants. When degradation of the environment was slow or scarcely perceptible, the consequences of its decline often were not felt until they were irreversible. Where human numbers were small relative to space, migration permitted impaired environments to recover, at least partially. But many areas of the Earth have never recovered from the degradation of centuries-long misuse, and still more are headed toward impoverishment. In a world filled with people and settlements, the option of migration is increasingly unavailable. Recognition of narrowing environmental options has led in recent decades to conservation practices assisted by the growth of science, to the comparative measurement of environmental change, and to forecasts of the probable consequences of present trends. The conservation of natural resources movement has had a paradoxical effect upon human perceptions of environmental realities. While the conservation movement contributed both to the emergence of applied ecology and public environmental concern, many conservationists rejected environmentalism (often called preservationism) as uneconomical, unrealistic and anti-social. Economy and efficiency in the wise use of resources has been the essence of "conservation," which sees the environment as infinitely manageable--capable of sustained productivity under the guidance of experts knowledgeable of science. In this respect, conservationism  [\*236]  is fundamentally consistent with the Western worldview, especially that which prevailed during the era of U.S. Progressivism in the late nineteenth and early twentieth centuries. [n82](http://www.lexisnexis.com/us/lnacademic/frame.do?reloadEntirePage=true&rand=1266374593287&returnToKey=20_T8580560845&parent=docview&target=results_DocumentContent&tokenKey=rsh-20.808858.1203594548" \l "n82) Environmentalism emerged in the latter half of the twentieth century from a convergence of changing perceptions of the human condition in fields as diverse as ecology, public health, demography, climatology, cosmology, and ethics. When its true dimensions, assumptions, and expectations are understood, environmentalism is, as Robert Nisbet observed, revolutionary. [n83](http://www.lexisnexis.com/us/lnacademic/frame.do?reloadEntirePage=true&rand=1266374593287&returnToKey=20_T8580560845&parent=docview&target=results_DocumentContent&tokenKey=rsh-20.808858.1203594548" \l "n83) Its effect upon human society is comparable to the changed views of reality inherent in the Copernican cosmic revolution in the seventeenth century and the Darwinian evolution revolution in the nineteenth century. To some, this conclusion may seem to be an exaggerated estimate of the influence of environmentalism and its future prospects. Following initial successes of environmental protection efforts, there has been in many countries (including the United States) an anti-government reaction that has sometimes been violent. [n84](http://www.lexisnexis.com/us/lnacademic/frame.do?reloadEntirePage=true&rand=1266374593287&returnToKey=20_T8580560845&parent=docview&target=results_DocumentContent&tokenKey=rsh-20.808858.1203594548" \l "n84) It is doubtful that in the long run the "green backlash" will prevail. Its angry proponents are chiefly natural resources industries, land developers and speculators, libertarians, and their allies in public office. Still the counter-intuitive behavior of social systems makes any forecast of the future uncertain. Nevertheless there are ascertainable, measurable trends in today's world that strongly suggest the impending negative impact of powerful coercive environmental events upon human society in the twenty-first century. Adherence to principles like those expressed in NEPA may become more a matter of necessity than of voluntary choice. The way in which people and their governments respond to the prospect of these coercions will shape the future of the world. The timing of effective response is equally important. The longer the delay, the more  [\*237]  difficult the task and the greater the possibility of irremediable damage. Because the future of the world in the twenty-first century cannot be foreseen, we can only conjecture the true location of NEPA on the trajectory of history. I offer the following assessment of the significance of NEPA, fully realizing that, at least in the short run, the world is capable of unpredictable turns. NEPA is most fully understood as a national policy for henceforward into the future. "Environment" may be understood as a surrogate term for a concept more comprehensive than is usually appreciated. Our language tends to lag behind new insights. Among our most persistent and pervasive misconceptions is the artificial dichotomy of economy/ecology. Their true relationship might be suggested by the time-space concept in physics. The concepts of ecology and economy are not the same--they are distinguishable, but, paradoxically, also inseparable.[n85](http://www.lexisnexis.com/us/lnacademic/frame.do?reloadEntirePage=true&rand=1266374593287&returnToKey=20_T8580560845&parent=docview&target=results_DocumentContent&tokenKey=rsh-20.808858.1203594548" \l "n85) In mundane reality there are obvious conflicts within and between the "domains" of economy and the environment. Yet both these aspects of our world are in actuality inextricable--separable by cultural convention and for analytic purposes. In reality they should have a common inclusive name. Achievement of a national policy for the environment requires awareness of the ecology/economy interrelationship, of the direction toward which the world appears to be moving, and a growth of consensus on the kind of future that is desirable and sustainable. A national policy for the future of the environment cannot be achieved in isolation from other major societal issues. Issues of population, material growth, property rights and obligations, and basic social equities involve choices which many people would prefer not to make. But the world today is not a "new age of Aquarius," free from ultimate accountability to nature, if not to humanity. Regardless of what we may deny or resist, our society will in one way or another be compelled to accommodate its behaviors  [\*238]  to the inexorable workings of the world. But apocalypse need not be a preordained outcome for a society that marshals and moves its moral, material, intellectual, and organizational capabilities toward attainment of a preferred and sustainable future. IX. AN AGENDA FOR THE FUTURE The National Environmental Policy Act may be seen as a charter and agenda to guide this nation toward rational strategies for coping with the critical environmental problems that are present and growing. The United States has the material and intellectual capabilities for setting a non-hegemonic example for the world. Whether it can generate a collective moral purpose to do so remains uncertain. As individuals, there is little that people can do to reverse destructive socio-ecological trends. Voluntary local initiatives may help where there is a sense of community purpose. But our fundamental environmental problems transcend manmade boundaries and require solutions commensurate with the problems, which are increasingly seen to be transnational, even global. The 1968 Biosphere Conference and the 1972 and 1992 U.N. conferences on the environment testify to an international recognition of mankind's environmental predicament. Yet in a world governed by nations, national action is necessary, not only for each nation, but for international cooperation. Action on any major social issue requires a credible collective purpose, catalytic leadership, and popular receptivity. There is strong evidence that the last of these--public support for environmental action--already exists. A goal-directed agenda is necessary to focus and activate social effort, for without such a codification of purpose, there can be no concerted action. Translation of social purpose into action is a function of leadership. To cope with the environmental predicament of mankind, leadership must be national and participatory, involving all sectors of society, but with an indispensable responsibility in government which is the affirmingand coordinative institution for nationwide and international effort. For the United States, NEPA provides a comprehensive agenda for the environmental future. NEPA creates a foundation for a unifying national effort and legitimizes its goals and principles as  [\*239]  national policy. Beyond NEPA, specific, targeted action programs are needed to achieve its intent. NEPA may be regarded, in effect, as a constitution for the environment--principles to guide the nation toward an enhanced quality of life and an enduring environmental future.

#### c. Extinction

Jowit 8 (Julien, The Guardian, World is facing a natural resources crisis worse than financial crunch, http://www.guardian.co.uk/environment/2008/oct/29/climatechange-endangeredhabitats)

The world is heading for an "ecological credit crunch" far worse than the current financial crisis because humans are over-using the natural resources of the planet, an international study warns today. The Living Planet report calculates that humans are using 30% more resources than the Earth can replenish each year, which is leading to deforestation, degraded soils, polluted air and water, and dramatic declines in numbers of fish and other species. As a result, we are running up an ecological debt of $4tr (£2.5tr) to $4.5tr every year - double the estimated losses made by the world's financial institutions as a result of the credit crisis - say the report's authors, led by the conservation group WWF, formerly the World Wildlife Fund. The figure is based on a UN report which calculated the economic value of services provided by ecosystems destroyed annually, such as diminished rainfall for crops or reduced flood protection. The problem is also getting worse as populations and consumption keep growing faster than technology finds new ways of expanding what can be produced from the natural world. This had led the report to predict that by 2030, if nothing changes, [hu]mankind would need two planets to sustain its lifestyle. "The recent downturn in the global economy is a stark reminder of the consequences of living beyond our means," says James Leape, WWF International's director general. "But the possibility of financial recession pales in comparison to the looming ecological credit crunch." The report continues: "We have only one planet. Its capacity to support a thriving diversity of species, humans included, is large but fundamentally limited. When human demand on this capacity exceeds what is available - when we surpass ecological limits - we erode the health of the Earth's living systems. Ultimately this loss threatens human well-being." Speaking yesterday in London, the report's authors also called for politicians to mount a huge international response in line with the multibillion-dollar rescue plan for the economy. "They now need to turn their collective action to a far more pressing concern and that's the survival of all life on planet Earth," said Chief Emeka Anyaoku, the president of WWF International.

### AT: Privatization

#### Status quo private efforts don’t solve – potential revenue isn’t enough

Haszeldine 9 – Scottish Power Professor of Carbon Capture & Storage at the University of Edinburgh School of GeoSciences (R. Stuart, 9/25/09, “Carbon Capture and Storage: How Green Can Black Be?” *Science*, Volume 325, Number 5948, pp. 1647-1652, http://www.roberts.cmc.edu/159/2010/2010pdfs/5.%20Feb%204%202010.pdf)

Create Business, Make Learning Rapid

Expecting the translation of all 36 announced demonstrations (Fig. 4) into operation is overly optimistic for three reasons. First, the largest blockage is not technological, but rather the lack of a market to provide revenue that justifies large investment. Each demonstration coal plant requires a system for price support for many years to recover the $1.5 billion extra capital and operational cost of generating decarbonized electricity. The pricing provided by the current carbon market is far too low and erratic. Price support systems are needed to introduce CCS, just as price support is given to introduce renewable energies. But this critical commercial help has been announced only for very few CCS projects. Paradoxically, in markets where renewables have price support to encourage deployment, cost compilations show that CCS will be a cheaper option to deploy (32).

#### Government action is key – the private sector won’t solve

Neuhoff 8 – Research Director of the Climate Policy Impact and Industry Response at DIW Berlin (German Institute for Economics Research) (Karsten, Ph.D. in economics from the University of Cambridge, former senior research associate at the Faculty of Economics at the University of Cambridge, former Director of the Berlin office of Climate Policy Initiative, January 2008, “Learning by Doing with Constrained Growth Rates and Application to Energy Technology Policy,” University of Cambridge Electricity Policy Research Group, http://www.eprg.group.cam.ac.uk/wp-content/uploads/2008/11/eprg0809.pdf)

In this paper we draw lessons for the CCS industry from the history of other energy technologies that, as with CCS today, were risky and expensive early in their commercial development. Specifically, we analyze the development of the US nuclear-power industry, the US SO2-scrubber industry, and the global LNG industry. Through analyzing the development these analogous industries we arrive at three principal observations relevant for the CCS industry.

First, for all of these analogous technologies government played a decisive role in their development. Notably, analogous technologies usually benefitted from substantial government support—often in the form of direct payments—for R&D and then early deployment in attractive niche markets. Today, we observe the early stages of similar government support for CCS. But uncertainties about that support are leading private industry to advance CCS, so far, mainly in niche markets such as EOR or gas processing that align with industry interests. More slowly, direct government support is beginning to attract investment in trial projects and full scale demonstrations in projects to store CO2 in saline aquifers or depleted oil and gas fields. Economically, the most important tests arise with carbon capture, which is much more costly and financially risky than carbon storage. Here, too, government support is emerging slowly.

Second, the successful diffusion of these analogous technologies beyond the early demonstration and niche projects hinged on technical performance and the credibility of incentives for private industry to invest in commercial-scale projects. In theory, such incentives could have been supplied by non-governmental institutions, such as large firms or industry associations that favored the technologies. In practice, the three analogs point strongly to a governmental role because, in contrast with non-governmental institutions, governments are much more able to direct investment decisions through policy decisions. The pivotal factor in these analogous cases is the credibility of government policy since in all these cases the investments were long-lived and financially risky. Credible promises from government are likely to be critical also for CCS as it moves into the diffusion phase. A few governments are crafting diffusion policies already. For instance, the Waxman-Markey bill in the US proposes strong economic incentives (up to $90/tonne CO2) for up to 72 GWe of power capacity (over 100 plants) equipped with CCS. Such policies are necessary. But, of course, the extraordinary ability of government to direct commercial investment must be tempered by the perennial troubles with government policy for pre-commercial technologies, which is the difficulty in ensuring that government managers make wise choices and back the right technologies. Often, government choices are based on the learning curve theory—that experience with technologies inevitably reduces costs.

#### Direct federal investment is key – the private sector won’t take action otherwise

Cohen et al. 9 – Co-Founder and Executive Director of the Clean Air Task Force (Armond, former head of the Conservation Law Foundation's Energy Project, member of the Environmental Protection Agency’s Clean Air Act Advisory Committee; Mike Fowler, Technology Coordinator for the Coal Transition Project at the Clean Air Task Force, former New Source Review Supervisor and Enforcement Manager in the Air Quality Bureau of the New Mexico Environment Department, former Project Scientist in the Division of Applied Sciences at Harvard University; and Kurt Waltzer, Carbon Storage Development Coordinator for the Clean Air Task Force’s Coal Transition Project; May 2009, “‘NowGen’: Getting Real about Coal Carbon Capture and Sequestration,” *The Electricity Journal*, Volume 22, Issue 4, pp. 25-42, p. ScienceDirect)

C. Why a federal investment program?¶ Some have criticized the coal industry for failing to invest in CCS while claiming the mantle of “clean coal”61—and have argued that the public should not support CCS if the coal industry won’t. While this attitude may resonate on emotional grounds, it is based on two shaky premises: first, that a coal industry that fails to de-carbonize will be bypassed by other technologies when tighter carbon constraints kick in; or second, that carbon constraints will themselves trigger the industry investments needed for CCS deployment.¶ As we argued in Section II, however, it is simply not prudent to count on renewables and energy efficiency to fully displace future coal use—even with carbon constraints. The physical and technical limits are simply too daunting, that's why nearly every study concludes that reaching even less protective CO2 targets will require a significant CCS contribution. Politicians may support carbon constraints, but not at the expense of turning out the lights. If CCS is not ready and dirty coal is needed to keep the lights on, dirty coal will be used.¶ The second premise—that carbon constraints alone will spawn a robust CCS industry—is likewise questionable. First, any emission constraints introduced in the near term likely won’t produce carbon prices steep enough to justify the scale of investment needed to advance CCS for some time. Sufficiently high carbon prices are probably even further off in China and India. If we wait for carbon markets alone to deliver CCS, we may spend two more decades locking in emissions whose effects will be with us for centuries. Second, we think it unlikely, even in the U.S., that a near-zero CO2 performance standard for new coal plants would be imposed substantially ahead of the deployment of demonstrated and cost-effective CCS technology. If it were imposed at the plant level, the industry would be more likely to use natural gas plants to fill supply gaps than to deploy CCS.¶ While it might be tempting to challenge the coal industry to de-carbonize itself or die, neither is a likely outcome—especially in the developing world. Simply put, companies are unlikely to invest in CCS on the scale required if doing so incurs costs that are not foreseeably recoverable in the market. The scale of investment likely to be needed—in the range of $7 billion per year, according to some estimates—exceeds the private R&D budget of the entire U.S. energy industry.62 Moreover, most previous energy-technology advances, including the combined-cycle gas turbine and wind energy, have received substantial public support.63 In fiscal year 2007, renewable energy technologies received nearly $5 billion in federal support64 and the wind energy production tax credit alone cost more than $650 million65; renewable technologies have also benefited from policies and subsidies at the state level.¶ In short, denying the public investment necessary to accelerate global deployment of CCS technology is shortsighted and risks hurting the public and the environment.

#### No one wants to be the first to invest in CO2 pipelines – young industry, large initial costs and other risks

Insight Economics ’11 (commissioned by the Global Carbon Capture and Storage ¶ Institute, Report to the Global Carbon Capture ¶ and Storage Institute, March 2011, “Building Essential Infrastructure for Carbon ¶ Capture and Storage,”

Thirdly, one major issue for potential investors in CO2 pipelines is that substantial economies of scale exist, suggesting that it is desirable for pipelines initially to be oversized relative to current demand. Yet in this industry, which is far from being mature, there are a number of factors that militate against investing in excess capacity, including first mover disadvantage and the existence of some major risks, including the possibility of stranding a substantial part of the asset.

#### Current regulatory structures make CCS impossible to safely invest in – no one will do it

Joel Mack ’09 (Energy Policy 38 (2010) 735–743, “Making carbon dioxide sequestration feasible: Toward federal regulation of CO2 sequestration pipelines,” <http://ac.els-cdn.com/S0301421509007459/1-s2.0-S0301421509007459-main.pdf?_tid=aa0b0c56ba6655e1a04a86812ed884d6&acdnat=1342902367_7636d44b5a371113b4ce7b1340e0a6b6>)

The United States is embarking for the first time on examining and reducing CO2 emissions in order to reduce global climate change impacts. Given the large amounts of CO2 emissions from coal-fired power plants, to the extent policymakers envision using geologic sequestration of CO2 to address any appreciable fraction of current and future CO2 emissions, the required infrastructure investment will be massive, and may be required over a limited period of time. In order for cost of CO2 sequestration pipelines to be borne efficiently by the private sector or utility ratepayers, and to accomplish these objectives in a timely fashion, the regulatory structures in place need to assure certainty, efficiency and predictability in the siting and regulatory process, in ratemaking requirements, and in the ability to obtain the necessary real property entitlement to construct such pipelines. The current system, while certainly functioning well over the existing pipeline network, is simply not structured to handle the development in a short period of time of perhaps 50,000 or 100,000 miles of these pipelines at a cost of many billions of dollars. The current system is not structured to attract private equity or debt capital investment, similar to the way the private sector has invested in our electric generation and natural gas pipeline infrastructure. A comprehensive federal program is ultimately what is required for this investment to be made on a timely basis and relying to the maximum extent on private sources of capital and the global capital markets. As the United States moves towards a reduced carbon footprint, the nation will have to deal with the CO2 emissions from our large fleet of coal-fired, base load power plants. Geologic sequestration is a technology that will likely be a major part of the solution to this problem, and in order for that to happen, the United States will have to invest substantially in a massive increase of its CO2 pipeline transportation capacity. The current regulatory regime, consisting of state utility commission oversight and very limited federal regulation over rate complaints and pipeline safety, is likely to prove inadequate to support the massive infrastructure development required to implement this objective in a timely and capital-efficient manner. This article recommends that Congress adopt legislation to provide for preemptive, federal licensing, rate regulation and oversight of these pipelines in order to provide the certainty and clarity that will give the private sector the certainty, predictability and confidence to invest in this very important part of our infrastructure.

### Elections

#### The plan helps Obama in swing states

Thomson 9 – award-winning journalist with the Edmonton Journal (Graham, 9/23/09, “BURYING CARBON DIOXIDE IN UNDERGROUND SALINE AQUIFERS: Political Folly or Climate Change Fix?” Munk Centre for International Studies at Trinity College at the University of Toronto, http://beta.images.theglobeandmail.com/archive/00242/Munk\_Centre\_Paper\_242701a.pdf)

‘Clean coal’ provides politicians with a way to reassure the public that we can mitigate CO2 emissions with as little pain as possible. CCS promises a desperately needed solution to global warming while maintaining an equally desperate addiction to fossil fuels.

‘Clean coal’ and politics are inextricably linked. In the United States, coal states are swing states, as demonstrated in the last election where Barack Obama came out in defense of ‘clean coal’ while campaigning in Ohio, Pennsylvania and West Virginia.

#### Plan appeases key swing states – Ohio, Pennsylvania, Virginia

Feldmann 6/2 (Linda, Staff writer for the Christian Science Monitor, “Four gambits Obama could try to boost election prospects,” 6/21/12, http://www.csmonitor.com/USA/Elections/2012/0621/Four-gambits-Obama-could-try-to-boost-election-prospects/Ease-up-on-coal-regulations)

Easing up Environmental Protection Agency regulation of coal-fired power plants would not be as grabby a maneuver as approving the Keystone XL pipeline or embracing the Simpson-Bowles deficit reduction plan. But if Obama were to make moves to ease new regulations on coal-fired plants, it could curry favor in parts of key battleground states – Ohio, Pennsylvania, and Virginia. Advocates of reduced regulation argue that new federal mandates governing emissions from coal- and oil-fired plants will hurt the US economy as they cause energy prices to rise. Last December, the EPA unveiled standards to limit mercury and other toxic emissions from the power plants. Supporters of the regulations say that the health benefits reduced air pollution. Opponents say that the rules could force the closure of some plants and threaten the reliability of the nation’s power grid. On June 20, a Republican-led effort in the Senate failed to gather enough votes to scuttle the new regulations. Obama has touted the new rules, while promising flexibility to protect industry. But if Obama wanted to ease some of the opposition he faces in coal country, he could take steps to dial back the regulations. That would likely be seen as a desperation move, after billing himself as the “green president.” But if it spells the difference between victory and defeat in Ohio and Virginia, it might be tempting.

#### Ohio key to Obama's reelection

Balz 6/20 (Writer for the Washington Post, "Ohio again at center of presidential election," 6/20/12, From the Journal Gazette, <http://www.journalgazette.net/article/20120620/NEWS11/306209959/1044/LOCAL08>)

Mitt Romney’s campaign bus neared the end of a five-day tour of six potential battleground states Tuesday. Most could be competitive in November, but none looms larger on the Electoral College chessboard than the place where he stumped on Sunday: Ohio. Barack Obama won all of the states on Romney’s itinerary in 2008. One, Wisconsin, hasn’t gone Republican since 1984. Two others, Michigan and Pennsylvania, have been in the Democrats’ column for five consecutive elections. Two others, Iowa and New Hampshire, have gone back and forth over the past 10 years. But of the six, Ohio remains the bellwether. It has been at the center of presidential politics in the past three elections and is once again destined to play a pivotal role this year. If Obama can win Ohio, then he almost certainly will be re-elected. No Republican has won the White House without Ohio. If Romney is hoping to convert some of the other, bluer battlegrounds, his progress in Ohio could be an indicator of how things could break elsewhere in the industrial heartland. Romney’s bus tour is a way to test the viability of some of these more difficult states. A few months ago, Michigan appeared to be leaning strongly toward Obama. That was in the middle of the Republican nomination contest, when Romney scrambled to win the primary in Michigan, his home state, against a surging but ultimately sagging Rick Santorum. Wisconsin also looked challenging as Romney sought, successfully, to finish off Santorum in a presidential primary that was overshadowed by a roiling recall campaign against Republican Gov. Scott Walker that deeply divided the state. At the time, some Democrats thought Wisconsin would be secure for President Obama no matter the outcome of the recall effort. Democrats’ confidence was based on the fact that Obama carried Michigan and Wisconsin by double-digits four years ago. Recent polls show both states a lot tighter than that, although by how much isn’t quite clear. Among the other states on Romney’s tour this week, Iowa is a true battleground. It was the state that launched Obama toward the presidency in early 2008, but Democrats acknowledge that the pounding he took during the Republican nomination battle has left him weakened. Symbolically, Iowa will be hugely important to the president, but it’s clear that he’ll have to fight to hold on to the state. If Obama hopes to get a boost from Iowa’s proximity to his home state of Illinois, Romney hopes that his tenure as governor of Massachusetts will make him truly competitive in New Hampshire. That’s where he began his bus tour on Friday, at the same picturesque farm where he formally started his campaign a year ago. Of the six states on Romney’s tour, Pennsylvania remains the most difficult for him. Republicans had a good year there in 2010, and GOP strategists think Romney can do better than some past nominees in the Philadelphia suburbs. He has yet to prove that. That brings the focus back to Ohio, a state whose 18 electoral votes are a crucial part of the calculus for both campaigns. Obama’s strategy always has been to avoid being trapped in a campaign whose outcome depends on Ohio and Florida. He has other routes to victory, but Florida looks more challenging for him this year. Investing more in Ohio and less in Florida could make sense, although the president’s campaign is likely to spend heavily in both. Ohio aligns closely to the nation in presidential races, with a slight tilt to the Republicans. In the past three elections, the Democratic nominees have been about two percentage points short of their national percentage twice (2000 and 2008) and less than one point above once (2004). Ohio also offers a laboratory for a debate that will play out this week in several other states on Romney’s tour, and that is how voters should assess the economy. Ohio, Wisconsin and Michigan are seeing signs of economic improvement. Ohio’s geography, located in the center of a group of potential battlegrounds, and its history through recent campaigns, gives it once again the special prominence it has had before.

### Politics

#### The plan is popular with fossil fuel industries

Stephens 6 – Assistant Professor of Environmental Science and Policy at Clark University (Jennie C., Ph.D. in Environmental Science and Engineering at the California Institute of Technology, associate with the Energy Technology Innovation Policy research group in the Belfer Center for Science and International Affairs at the John F. Kennedy School of Government at Harvard University, Fall 2006, “Growing interest in carbon capture and storage (CCS) for climate change mitigation,” *Sustainability: Science, Practice, & Policy*, Volume 2, Issue 2, pp. 4-13, http://sspp.proquest.com/static\_content/vol2iss2/0604-016.stephens-print.html)

Increased Interest in the Fossil-Fuel Industry

Interest and investment in CCS has been growing in the fossil-fuel industry, particularly oil and gas companies. During the 1980s and much of the 1990s, many corporate managers, frightened by what climate change could mean to the future of their companies, publicly denied the problem and actively supported research and public campaigns that highlighted uncertainties and weaknesses in the theory of anthropogenic climate change (Levy & Rothenberg, 1999; Kolk & Levy, 2001; Gelbspan, 2004). As the scientific case strengthened during the mid to late 1990s, some firms shifted their strategy away from denial (Kolk & Levy, 2001). This shift was stronger and occurred earlier in European-based multinational companies than it did in United States-based firms (Levy & Newell, 2000; Rowlands, 2000). With this change in corporate strategy, an expansion of interest and investment in R&D of carbon-storage options has occurred. Many companies realized that the possibility of CCS weakened the link between fossil fuels and CO2 driven climate change. The prospect of CCS reduced the threat of climate change mitigation efforts to fossil-fuel industries and made it possible to consider a fossil-based global economy throughout the next century even if controls on CO2 emissions were instituted (Keith & Parson, 2000). The concept of CCS has, therefore, helped the fossil-fuel industries, as well as nations rich in coal, oil, and natural gas, to accept and agree to confront climate change because it allows them to perceive a future that reconciles continued use of fossil fuels in a carbon-constrained world.

Oil and gas companies, in particular, have become very interested in geologic carbon storage because they are familiar with the technologies for dealing with underground reservoirs and CO2 injection, a well-established industry technique for enhanced oil recovery (EOR) (Hill, 2005). In mature wells with declining oil production CO2 injection loosens up residual oil for extraction (van Bergen et al. 2003). Oil companies are therefore already knowledgeable about many critical technologies associated with underground carbon storage. Combining EOR with geologic carbon storage provides low-cost early deployment opportunities for gaining experience with CCS (Holtz et al. 2001; Stevens et al. 2001; van Bergen et al. 2003; Metz et al. 2005).

The Norwegian national oil company Statoil was the first petroleum producer to inject CO2 underground for storage. The firm has been injecting CO2 into a geologic formation under the North Sea since 1996. Managers were motivated to store rather than emit the CO2 extracted from a natural gas stream by a Norwegian tax on the release of CO2 into the atmosphere (Torp & Brown, 2002). The other currently operating large-scale geologic storage projects are at Weyburn in the Canadian province of Saskatchewan, where CO2 has been injected underground since 2000 for the dual purpose of enhancing oil recovery and storage, and In Salah (Algeria) where the first large-scale injection of CO2 into a gas reservoir began in 2004 (Metz et al. 2005). The In Salah project is a joint venture involving Sonatrach (the national oil company of Algeria), BP, and Statoil.

In addition to the In Salah initiative, BP is currently planning, and has begun investing in, at least two other CO2 storage projects—one off the coast of Scotland and another in California. BP stands out among oil companies through investing heavily in the development and demonstration of geologic CO2 storage. Interestingly, these BP carbon-storage projects are not economically justifiable in the short term. The company has chosen to fund these initiatives to advance the technology without any direct and immediate economic benefits, but clearly it is aiming to position itself as an industry leader in this area.

#### A large group of senators love the plan

Reisinger 9 – JD, Attorney @ Ohio Environmental Council

Will, “RECONCILING KING COAL AND CLIMATE CHANGE: A REGULATORY FRAMEWORK FOR CARBON CAPTURE AND STORAGE,” Vermont Journal of Environmental Law, http://vjel.org/journal/pdf/VJEL10107.pdf

Princeton’s dispassionate assessment leads us to the conclusion that coal will not disappear as an energy source in the immediate future. Coal produces such a large percentage of electricity generation that other sources alone cannot meet the country’s demands in the short term. Coal-burning power plants currently provide half of the electricity produced in the U.S. and are responsible for one-fourth of global carbon emissions. 25 Cleaner, carbon-neutral sources such as wind and solar energy, or the more controversial expansion of nuclear power generation, have the potential to replace most or all coal-generated power in the future. But at present, the U.S. is not able to meet its base load power needs solely with renewable or carbon-neutral options. 26 The nation simply does not have the infrastructure to allow renewable energy sources such as wind and solar to replace fossil-fuel power generation in the near term. The expansion of nuclear generation faces still greater opposition across the political spectrum due to concerns over public health and national security. Coal has strong political support throughout the country as America’s only abundant domestic fossil energy resource. The coal industry is responsible for more than 80,000 jobs nationwide, contributing billions to the economies of coal-producing states. 27 Legislators from these regions will fight vigorously to ensure the continued viability of the coal industry. As Mike Morris, Chief Executive Officer of American Electric Power, has stated, “We have 25 ‘coal states.’ That’s 50 Senators whose states depend on this economy.” 28

#### Coal lobbies are pushing CCS

Tady 7 - national political reporter

Megan, “Carbon Capture: Miracle Cure for Global Warming, or Deadly Liability?,” Alternet, http://www.alternet.org/environment/68490/?page=4

"We have to figure out a way to sequester the carbon emissions coming from those plants, or we need to close them down," Morris said. "While people are looking to have a moratorium on new coal-fired power plants, and I agree with that, it's the existing ones that one has to deal with in terms of sequestration." But to others, CCS is a bridge that should never be built because of where it could lead. Matt Leonard, a campaigner with the Rainforest Action Network, a group calling for a coal moratorium, said CCS is a public relations scheme to pave the way for new coal-fired power plants. "The coal industry is grasping at straws trying to find some way to convince the public that they have a place in our future energy policy," Leonard said. "And carbon sequestration is their attempt to brand some kind of PR campaign to have clean coal be a possibility."

#### There is bipartisan consensus to save coal

CDP 6/12 (Congressional Documents and Publications ,“Bipartisan Support Growing For Effort to Stop Obama War on Coal,” Inhofe Exposes Environmental Playbook, June 12, Proquest,)

Washington, D.C. - Senator James Inhofe (R-OK), Ranking Member of the Senate Committee on Environment and Public Works, spoke on the Senate floor today about the growing bipartisan momentum to stop the Obama-Environmental Protection Agency's (EPA) war on coal. Senator Inhofe welcomed the strong support of groups representing business and labor, as well as a growing number of elected officials working across the aisle to save coal. In fact, the momentum for Senator Inhofe's efforts has grown so much that Senators Lamar Alexander (TN) and Mark Pryor (AR) found it necessary to introduce a cover bill for those Senators who need to appear to be reining in the EPA for their constituents back home, but in reality are allowing President Obama to continue to kill coal. Senators Alexander and Pryor are expected to introduce their cover bill as soon as tomorrow, but it is unlikely that it would pass. While Senator Inhofe's resolution would require a simple majority of the members present, the cover bill by Senators Alexander and Pryor would require 60 votes to pass.

# Other

### FYI on CCS

Saundry, 11

(Peter, “Pipelines for Carbon Dioxide Control in the United States,” <http://www.eoearth.org/article/Pipelines_for_Carbon_Dioxide_Control_in_the_United_States?topic=54490>)

Carbon capture and sequestration is essentially a three-part process involving a CO2 source facility, a long-term CO2 storage site, and an intermediate mode of CO2 transportation.**¶** Capture**¶** The first step in direct sequestration is to produce a concentrated stream of CO2 for transport and storage. Currently, three main approaches are available to capture CO2 from large-scale industrial facilities or power plants:¶ pre-combustion, which separates CO2 from fuels by combining them with air and/or steam to produce hydrogen for combustion and CO2 for storage,¶ post-combustion, which extracts CO2 from flue gases following combustion of fossil fuels or biomass, and¶ oxyfuel combustion, which uses oxygen instead of air for combustion, producing flue gases that consist mostly of CO2 and water from which the CO2 is separated.¶ These approaches vary in terms of process technology and maturity, but all yield a stream of extracted CO2 which may then be compressed to increase its density and make it easier (and cheaper) to transport. Although technologies to separate and compress CO2 are commercially available, they have not been applied to large-scale CO2 capture from power plants for the purpose of long-term storage¶ Transportation**¶** Pipelines are the most common method for transporting large quantities of CO2 over long distances. CO2 pipelines are operated at ambient temperature and high pressure, with primary compressor stations located where the CO2 is injected and booster compressors located as needed further along the pipeline. In overall construction, CO2 pipelines are similar to natural gas pipelines, requiring the same attention to design, monitoring for leaks, and protection against overpressure, especially in populated areas. Many analysts consider CO2 pipeline technology to be mature, stemming from its use since the 1970s for Enhansed Oil Recovery (EOR) and in other industries.¶ Sequestration in Geological Formations¶ In most CCS approaches, CO2 would be transported by pipeline to a porous rock formation that holds (or previously held) fluids where the CO2 would be injected underground. By injecting CO2 at depths greater than 800 meters in a typical reservoir, pressure keeps the injected CO2 in a supercritical state and thus less likely to migrate out of the geological formation. Injecting CO2 into such formations uses existing technologies developed primarily for oil and natural gas production which potentially could be adapted for long-term storage and monitoring of CO2.**¶** Other underground injection applications in practice today, such as natural gas storage, deep injection of liquid wastes, and subsurface disposal of oil-field brines, also provide potential technologies and experience for sequestering CO2. Three main types of geological formations are being considered for carbon sequestration:**¶** oil and gas reservoirs;¶ deep saline reservoirs; and,¶ unmineable coal seams.¶ The overall capacity for CO2 storage in such formations is potentially huge if all the sedimentary basins (large depressions in the Earth’s surface filled with sediments and fluids) in the world are considered. The suitability of any particular site, however, depends on many factors, including proximity to CO2 sources and other reservoir-specific qualities like porosity, permeability, and potential for leakage. Marine transportation may also be feasible when CO2 needs to be transported over long distances or overseas; however, many manmade CO2 sources are located far from navigable waterways, so such a scheme would still likely require pipeline construction between CO2 sources and port terminals. Rail cars and trucks can also transport CO2, but these modes would be logistically impractical for large-scale CCS operations.

### Inherency

#### Current funding is insufficient

Haszeldine 9 – Scottish Power Professor of Carbon Capture & Storage at the University of Edinburgh School of GeoSciences (R. Stuart, 9/25/09, “Carbon Capture and Storage: How Green Can Black Be?” *Science*, Volume 325, Number 5948, pp. 1647-1652, http://www.roberts.cmc.edu/159/2010/2010pdfs/5.%20Feb%204%202010.pdf)

Coal and gas combustion can become more sustainable. To change black fuel into green energy, the acceleration and scale-up of CCS is required, from tens of power plants within 5 years, to hundreds of large plants by 2025, and then to thousands of small power plants by 2035. This progression can defer climate change problems and buy time. To do this, bold policies of clear vision to include CCS emissions reductions must be explicit. CCS may be the single most effective and direct climate action available. It is not yet too late, but good words need to be matched by hard actions and good money; the present level of committed funds is too low and needs a 4- to 10- fold increase in order for this climate mitigation to be successful.

#### Right now there isn’t an incentive for CCS – unless we get more funding it won’t happen

CBO ’12 (Congressional Budget Office, study was prepared at the request of the Chairman of the Senate Committee on Energy and Natural Resources, June 2012, “Federal Efforts to Reduce the Cost of Capturing and Storing Carbon Dioxide,” <http://www.cbo.gov/sites/default/files/cbofiles/attachments/43357-06-28CarbonCapture.pdf>)

One much-discussed option for reducing the nation’s greenhouse gas emissions while preserving its ability to produce electricity at coal-fired power plants is to capture the CO2 that is emitted when the coal is burned, compress it into a fluid, and then store it deep underground. That process is commonly called carbon capture and storage (CCS). Although the process is in use in some industries, no CCS-equipped coal-fired power plants have been built on a commercial scale because any electricity generated by such plants would be much more expensive than electricity produced by conventional coalburning plants. Utilities, rather than federal agencies, make most of the decisions about investments in the electricity industry, and today they have little incentive to equip their facilities with CCS technology to lessen their CO2 emissions. Since 2005, lawmakers have provided the Department of Energy (DOE) with about $6.9 billion to further develop CCS technology, demonstrate its commercial feasibility, and reduce the cost of electricity generated by CCS-equipped plants. But unless DOE’s funding is substantially increased or other policies are adopted to encourage utilities to invest in CCS, federal support is likely to play only a minor role in deployment of the technology.

#### Lack of funding means current CCS technologies aren’t cost-competitive

CBO ’12 (Congressional Budget Office, study was prepared at the request of the Chairman of the Senate Committee on Energy and Natural Resources, June 2012, “Federal Efforts to Reduce the Cost of Capturing and Storing Carbon Dioxide,” http://www.cbo.gov/sites/default/files/cbofiles/attachments/43357-06-28CarbonCapture.pdf)

In CBO’s view, current policies are unlikely to achieve the goal of reducing the additional costs for producing electricity with CCS technology to 35 percent more than the cost of producing electricity without CCS. DOE’s present funding for CCS would allow the United States to build only a small number of demonstration plants, which are unlikely to be sufficient to reduce costs through the learning process described earlier. If DOE adhered to its current plan, it would continue to support the R&D and demonstration programs for which the American Recovery and Reinvestment Act provided funding of $3.4 billion, and it would continue to seek annual appropriations of $300 million to $400 million for related efforts. However, unless lawmakers substantially increased support for CCS, probably well beyond even those amounts, federal funding would be likely to contribute only a little to reducing the costs of CCS-equipped coal plants after the initial demonstration projects for the technology had ended. Most investment in electric utilities comes from the private sector. As CBO’s illustrative calculations suggest, the amount of current federal spending is small relative to the magnitude of the investment necessary to make CCS-equipped plants economically competitive, and DOE’s current activities are unlikely to provide the amount of learning that would drive down the technology’s costs. Rather, reductions would have to be spurred by the activities of investors and the efforts of utilities and their customers.

### Framework

#### Public debates on CCS are good

Stephens 6 – Assistant Professor of Environmental Science and Policy at Clark University (Jennie C., Ph.D. in Environmental Science and Engineering at the California Institute of Technology, associate with the Energy Technology Innovation Policy research group in the Belfer Center for Science and International Affairs at the John F. Kennedy School of Government at Harvard University, Fall 2006, “Growing interest in carbon capture and storage (CCS) for climate change mitigation,” Sustainability: Science, Practice, & Policy, Volume 2, Issue 2, pp. 4-13, http://sspp.proquest.com/static\_content/vol2iss2/0604-016.stephens-print.html)

Minimal Public Awareness and the Role of Environmental Advocacy Groups

Throughout the recent period of rapidly growing interest in CCS, it has been acknowledged that public acceptance will influence ultimate advancement and deployment. Nevertheless, public perception of these technologies remains limited. Studies at the Tyndall Centre in the United Kingdom using focus groups and surveys indicate that with adequate information about the climate-change context, the public may look favorably on CCS (Gough et al. 2002; Shackley et al. 2004). A study conducted in the United States, however, using personal interviews and a survey, suggests that Americans may be more skeptical and less accepting than the British public (Palmgren et al. 2004). The study urges careful consideration in devising strategies to inform people about the technology and suggests that how the public debate gets framed will be critical in determining popular perceptions (Palmgren et al. 2004).

Environmental advocacy groups play a critical role in shaping public debate about how best to address environmental problems, so how these organizations portray CCS is likely to influence public reactions. To date, their role regarding carbon storage has been mixed (Stephens & Verma, 2006). While one leading American environmental group, the Natural Resources Defense Council (NRDC), has taken a strong position supporting the development and demonstration of CCS technologies (Hawkins, 2003; 2005), many other organizations, both national and international, have had reservations about the environmental as well as political implications of CCS (Hawkins, 2001; Union of Concerned Scientists, 2001; Greenpeace, 2005; World Wildlife Fund, 2005).

Although public opposition to CCS has been anticipated, little actual resistance has emerged and environmental advocacy groups have been relatively quiet on the issue.1 Despite the rapid advancement of demonstration projects, the environmental community has not voiced a strong position for or against the geologic storage of CO2. Organized environmentalism seems to be trying to balance cautious hesitancy of this “end-of-pipe” “geoengineering” approach with practical acceptance that such carbon-management technologies may be needed to supplement other stabilization measures. Moreover, pervasive resistance to novel technologies within the environmental movement is recognized, and recent work has identified the challenges of overcoming this opposition (Cohen, 2006). Public opposition to the idea of underground storage may be presently minimized due to some awareness (in parts of the world at least) of the successful history of injecting CO2 underground to enhance oil recovery.

Despite the potential that environmental advocacy groups have to influence the public perception of CCS, in the past 15 years these organizations have facilitated minimal public engagement on the subject and they have not developed a strong and consistent public message. This lack of a position regarding geologic storage has likely contributed to the limited public awareness (Verma & Stephens, 2006).

Division regarding CCS technology can be viewed as representative of the larger challenges facing environmental advocacy groups as they struggle to adjust to the unique and daunting challenges of climate change. There has been a great deal of discussion about the capacity of mainstream environmental organizations in the United States to engage meaningfully on the climate-change issue in the past few years as weaknesses in their response have been identified (McCright & Dunlap, 2000; 2003).

### Topicality

#### CO2 pipelines are under the DoT

Jennifer Horne ’10 (third year law student at the S.J. Quinney College of Law, University of Utah. This Note is based in part on research completed for the University of Utah Institute of Clean and Secure Energy (ICSE), Journal of Land, Resources & Environmental Law 30 J. Land Resources & Envtl. L. 357, “Getting from Here to There: Devising an Optimal Regulatory Model for CO<2> Transport in a New Carbon Capture and Sequestration Industry”)

Currently, the Pipeline and Hazardous Materials Safety Administration (PHMSA), an agency within the Department of Transportation (DOT), regulates safety in design, construction, and operation of CO<2> pipelines, often in conjunction with state agencies. n61 The safety record on CO<2> pipelines has been relatively good. n62 Since 1994, serious accidents reported on CO<2> pipelines have resulted in only a single injury and no fatalities. n63 Based on this track record under PHMSA oversight, safety regulation for CCS should require relatively little new innovation, with three possible exceptions: (a) scalability from current EOR use to larger volumes of CO<2>; (b) ownership and liability for the CO<2> while in transit; and (c) accountability for potential CO<2> releases during transport.

#### They are transportation infrastructure

Rickard Svensson ’04 (Department of Energy Conversion, Chalmers Institute of Technology, 11/26/04, “Transportation Infrastructure for CCS – Experiences and Expected Development,” http://uregina.ca/ghgt7/PDF/papers/poster/350.pdf)

C02 Capture and Storage (CCS), i.e. capture and storage of carbon dioxide (C02) emitted from large point sources of emissions, has the potential of a significant and relatively quick response to climate change at reasonable cost. In order to reach widespread commercialization of CCS it is crucial to demonstrate the concept in large-scale projects, reduce costs, build infrastructures for transportation of C02, establish a legal framework and reach acceptance by the public. Most research on CCS deals with capture technologies and storage possibilities (e.g. in connection to Enhanced Oil Recovery (EOR) projects and in saline aquifers). This, since capture represents the highest cost and storage is critical with respect to long-time security and monitoring. Still, there is a need to identify and structure transportation alternatives in order to analyse and evaluate future paths comprising CCS. In a previous work on transportation of C02 [1] the costs and capacities have been investigated by means of analysing type scenarios for different means of transportation, i.e. truck, train, ship and pipeline. It was concluded that transportation by means of pipeline and ship gave feasible logistics and costs. Still, there were large variations in costs depending on the scenario studied (amount of C02 transported). The present paper continues the previous work with the aim to illustrate how a CCS transportation infrastructure can be developed applying pipeline and ship transportation.