German Lignite Industry Confronts Environmental Challenges

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Lignite, or brown coal, is Germany's main fossil fuel resource. Recoverable reserves, estimated by the lignite industry association DEBRIV[1] at 41 billion metric tons,[2] would allow the current mining output of 175 million tons (Mt)[3] per year to be maintained for another two centuries. Over 90 percent of lignite production is dedicated to regional, largely base-load power plants of 22 GW total capacity. Annual electricity generation from lignite of 150 TWh (billion kilowatt-hours) satisfies one fourth of national demand.

Renewable technologies with double the peak rating contribute only around 100 TWh of grid power due to their lower capacity factors, which in the case of wind energy averages about 0.2.[4] Renewable generation was originally expected to provide just 12.5% of total electricity by the year 2010, yet its share of the power market has already grown to over 16%. That result is made more remarkable by persistent delays in offshore wind power realization due to environmental and financing obstacles.[5] The first major wind farm in the North Sea[6] with 208 turbines is now scheduled to deliver 3.5 TWh/a beginning in 2010, with several additional projects nearing completion. The German government supports commercial plans for 40 offshore wind farms of 12 GW total capacity,[7] an essential contribution to the goal of 30% renewable power set for 2020. Wind energy of about 150 TWh in that year would then be equivalent to today's lignite generation.[8] By 2030, a combined capacity of 25 GW in the North and Baltic Seas has been projected.

In former years, lignite generation was outclassed only by nuclear power, which provided about a third of available grid electricity. Germany's nuclear phase-out law, enacted in 2002, as well as frequent operational disruptions reduced the utility market share of 17 remaining reactors to 23% by 2008. Yet the scheduled

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1 DEBRIV, *Unsere Braunkohle* (Cologne: Deutscher Braunkohlen-Industrie-Verein e.V., 2009), p. 9.

2 German lignite reserves of 6.6 billion tons cited by the World Energy Council and Energy Watch Group apparently refer only to licensed mining areas. See: Zittel, Werner and Jörg Schindler, "Coal. Resources and Future Production," EWG Series No. 1/2007 (Berlin: Energy Watch Group, 2007), p. 44.

3 Coal and lignite industry statistics are maintained at www.kohlenstatistik.de.

4 Molly, J. P., "Status der Windenergienutzung in Deutschland - Stand 30.06.2009" (Wilhelmshaven: German Wind Energy Institute DEWI, June 30, 2009), p. 12.

5 Knauer, Sebastian, "Offshore Wind Farms Fall Victim to Financial Crisis" (Hamburg: Spiegel Online, January 30, 2009).

6 Borkum West. A pilot installation with six wind turbines commenced operation in July 2008.

7 "Frischer Wind vom Meer" (Berlin: German Federal Government, September 16, 2009).

8 BEE, *Wege in die moderne Energiewirtschaft. Teil 1: Stromversorgung 2020* (Berlin: Bundesverband Erneuerbare Energie e. V., October 2009), p. 6.

decommissioning of all nuclear installations by 2021 has revealed inadequate preparations for substitute capacity. Gas power generation and electricity imports must be increased during periods of meteorological calm. Supply restrictions necessitate greater reliance on lignite, which emits the highest levels of carbon dioxide per generated kWh and thus countervails climate protection strategies. With no short-term prospect of technological CO_2 remediation, the intention to extend several nuclear power plant licenses has now been indicated by the CDU/CSU/FDP coalition government newly elected in September 2009.

Without carbon restraints, lignite would be unparalleled for low-cost power generation. Originating between 12 and 65 million years ago, Germany's shallow lignite deposits are readily accessible to strip mining using caterpillar tread excavators with bucket wheels up to seventy feet in diameter. Several times the groundwater must first be pumped out of the mining range before extraction begins. Residual moisture nevertheless constitutes approximately half the mass of crude lignite delivered to power stations. Rail transport beyond regional customers is therefore uneconomical, since every second freight car would effectively be carrying water.

Lignite power plants are optimized for site-dependent calorific values of 7.8 to 10.5 MJ/kg, which is only half that of firewood. This inferior thermal rating actually promotes national energy security. Since moist crude lignite is not shipped over long distances, it is unsuitable for export and correspondingly remains unaffected by international fuel trading pricing. Imported hard coal became over three times as expensive in 2008.[9] Impervious to this trend, German lignite remained stably priced at 1,1 euro/GJ,[10] or about $1.70/MBtu. A greater margin of profitability could thus be realized by power plant and grid operators, since final electricity prices in Germany are not differentiated according to fuel, plant location, or transmission distances. By contrast, power rates prevailing in the coal mining regions of North America are less than half those of seaboard states.[11] However, the ultimate contribution of low-priced lignite to energy security in Germany will depend on durable risk containment strategies in the face of CO_2 emissions trading.

Lignite exhibits the highest ratio of carbon to energy output of any fossil fuel. After deducting the water and mineral impurities (including 0.15% to over 2% sulfur) of mined lignite, a scant third remains as elemental carbon (atomic mass 12). With two atoms of oxygen (16) subsequently bound at combustion, the resulting carbon dioxide emissions weigh as much as the crude lignite itself.

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9 Deutsche Steinkohle (Essen: Gesamtverband Steinkohle e. V., 2009), p. 36.

10 Green Budget Germany, "Wirtschaftliche Risiken des Neubaus von Kohlekraftwerken in Deutschland" (Berlin: Forum ökologisch-soziale Marktwirtschaft e. V., September 2009), p. 5.

11 "Average Retail Price of Electricity to Ultimate Customers by End-Use Sector, by State", Table 5.6.A (Washington: Energy Information Administration, June 2009).

Compared with hydrogen-rich natural gas, twice the carbon dioxide is emitted by lignite when burned. Energy losses inherent to using damp fuel and to filtering particulates and sulfur dioxide from plant flue gases contribute additional CO_2 per generated kWh.[12] Owing to slow ignition, lignite power stations are designed for continuous fuel consumption irrespective of grid demand. The surplus power generated during off-peak periods is routinely fed to pumped storage reservoirs for later use, increasing both overall plant-to-customer power losses[13] and incident CO_2 emissions. Since the EU Emission Trading System (ETS) went into effect on January 1, 2005, these factors have combined to impose several times the carbon-related financial burdens on lignite usage compared with load-responsive gas generation.

For many years, the German power industry underplayed the risks imposed by climate protection mandates. When nuclear phase-out was legislated in 2002, lignite appeared predestined to replace a substantial part of the 33.6% electrical power then being supplied by 19 nuclear reactors.[14] The Kyoto Protocol had not yet been ratified by the required 55 signatory states, leaving decisions on greenhouse gas (GHG) reductions to the individual parties. German chancellor Gerhard Schröder rejected the adoption of emissions trading in July 2002 in a speech to the workers' council of the BASF chemical corporation. The ETS was nevertheless enacted on October 25, 2003, in the European Union by Directive 2003/87/EC, independent of the Kyoto process. Ratification of that Protocol in 2004 formally imposed a 21% reduction target on Germany for aggregate GHG emissions by 2012, referred to 1990. Carbon dioxide constitutes 87% of the six Kyoto gases affected by this requirement.

Germany thereupon discarded its own more stringent, while not legally binding, 25% CO_2 reduction goal from the 1990s. The 852 Mt achieved in the target year 2005 constituted only 15.8% lower carbon dioxide emissions than in 1990. Fully 72% of the reductions had ensued in the three eastern German lignite states, Brandenburg, Saxony, and Saxony-Anhalt, owing to the demise of heavy industry and the widespread abandonment of lignite as a heating fuel. Since this post-reunification contribution could not be replicated in the future, broad-based avoidance of CO_2 emissions became necessary for Kyoto compliance. That requirement opened the question of equitable burden sharing between different sectors of the economy.

The lignite industry portrayed the strategic modernization of power plants in eastern Germany as early actions justifying lenient trading obligations. By the beginning of 2005, however, the aggregate energy-related GHG emissions in the

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12 The most recently dedicated lignite power plants achieve efficiency ratings exceeding 40%, compared with up to 60% for combined-cycle gas plants.

13 Germany's most modern pumped storage plant at Goldisthal (1060 MW) is 80% efficient.

14 Deutsches Institut für Wirtschaftsforschung, Energy Environment Forecast Analysis, "Auswertungstabellen zur Energiebilanz für die Bundesrepublik Deutschland 1990 bis 2007" (Berlin: Arbeitsgemeinschaft Energiebilanzen e. V., September 2008), Table 5.

15 Western European EU member states had diminished by only 0.6 % (24 million tons of CO_2 equivalents) below 1990 levels.[15] Since a reduction target of 8% was specified by the Kyoto Protocol for these countries by 2012, emissions trading became essential for penalizing inefficient fossil fuel usage.

In dramatic illustration of policy expediency, the MIBRAG Middle German mining corporation incurred CO_2 allowance obligations of 28 million euro in 2008, largely eliminating profits realized from extracting 19 million tons of lignite.[16] The two American owners, NRG Energy Inc. and URS Corporation, thereupon sold their holdings in June 2009 to a Czech-Slovak consortium consisting of the CEZ subsidiary Severoceske doly ("North Bohemian mines") and the J&T Finance Group.

For years, MIBRAG had announced the planned construction of an advanced 660 MW power plant to replace its three inefficient lignite generation (233 MW total capacity) and processing facilities, criticized by environmental minister Sigmund Gabriel as "Germany's worst power stations".[17] The new plant is now scheduled to be commissioned by 2015, too late to qualify as a subsidized EU pilot project for carbon capture and storage (CCS), but too early to realize CO_2-free generation at full planned capacity. While a considerably smaller facility would suffice for powering MIBRAG excavating equipment, it would not justify opening an additional surface mine that has been decisive for the CEZ/J&T takeover. The projected mining range contains 350 Mt of lignite, some of which is located under a historically significant battlefield at Lützen from the Thirty Years' War. The nearby medieval village of Röcken includes the paternal home and gravesite of the 19th century philosopher Friedrich Nietzsche. Such traditional settings are subject to lignite extraction prerogatives under federal mining law (*Bundesberggesetz*). Some 300 villages and settlements have already been destroyed by the lignite industry since the 1920s.

Surface mining in Germany constitutes an earthmoving task equivalent to digging the original Suez Canal, completed in 1869 after a decade of labor, every three weeks. Neither the highly rationalized mining operations nor subsequent land reclamation projects are able to employ the majority of inhabitants displaced from their former rural livelihoods in the process. Once the excavation pits have been exhausted, they are transfigured into crystalline lakes with water pumped from nearby active mines. Systematic limestone applications are required to offset pyrite acidity and establish rudimentary natural balances in these artificial biotopes.

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15 European Commission, DG Environment, "Annual European Community greenhouse gas inventory 1990–2004 and inventory report 2006", EEA Technical report No 6/2006 (Copenhagen: European Environment Agency, 2006), p. 2.

16 "MIBRAG-Bilanz-Pressekonferenz: Bergbauunternehmen wirtschaftete solide und zukunftsorientiert" (Theißen: Mitteldeutsche Braunkohlengesellschaft, April 28, 2009).

17 "Gabriel weist Vorwürfe der MIBRAG zurück", No. 222/09 (Berlin: Federal Ministry for Environment, Nature Conservation and Nuclear Safety, July 2, 2009).

The Czech CEZ Group possesses distinct operational advantages compared with the former American owners. Lignite mining and power generation are well established in the Bohemian industrial region north of Prague. This area lies only fifty kilometers to the south of a large MIBRAG utility customer in the city of Chemnitz, making trans-border lignite shipments conceivable before the new power plant in Germany can be completed. To reduce the specific emissions of all CEZ-generated electricity, Europe's largest onshore wind farm at Fantanele and Cogealac in Romania was acquired in 2008 with a final capacity of 600 MW.

MIBRAG might ultimately shepherd a rebirth of German coal-based chemical production. Middle German lignite was used in World War I at Leuna and Bitterfeld for synthesizing ammonia by the Haber-Bosch process, enabling explosives to be manufactured despite British blockades of Chilean saltpeter. After territorial losses under the Treaty of Versailles had eliminated one third of Germany's hard-coal mining capacity, the highly bituminous grades of local lignite were additionally employed for synthetic rubber manufacturing at Buna, liquefaction in Böhlen and Zeitz, and tar and coke production. Lignite became the regional mainstay of power generation, electrometallurgy, plastics, and the electrochemical production of carbide and hydrogen peroxide, all of which supported autonomous supply strategies in the Third Reich. Heating briquettes were manufactured by compressing crude lignite into the size of paving stones, reducing the water content, doubling the calorific value, and rationalizing transport and handling.

After 1945, lignite usage was intensified in Marxist East Germany (the German Democratic Republic GDR). When nuclear reactor construction fell behind schedule and the Soviet Union diverted gas and petroleum deliveries from its satellite states to international markets, the GDR affirmed its status as the world's leading lignite producer. In the 1980's, annual mining output exceeded 300 Mt and fulfilled 70% of all energy requirements.[18] A third of this volume was employed for manufacturing briquettes in 49 processing plants. Only one of these facilities survives today within a vestigial distribution network for solid fossil fuels.

A second briquette factory operates in the western Rhineland near Cologne, where RWE AG mines around 100 million tons of lignite per year chiefly for power generation – making RWE the largest aggregate source of GHG emissions in Europe. An array of increasingly innovative power plants is grouped at four locations to provide a combined generating capacity of 10,5 GW. RWE investigated lignite gasification in the early 1990s but abandoned its further development owing to persistent technological difficulties. An experimental plant for post-combustion CO_2 scrubbing has now been installed in cooperation with the Linde Group using a BASF amine-based solvent.

After 1990, most of the eastern German lignite industry was taken over by a

[18] *Statistisches Jahrbuch der DDR* (Berlin: Staatliche Zentralverwaltung für Statistik, 1989), p. 153.

consortium of western utility corporations under the leadership of RWE. However, these partners were unwilling to mine dwindling lignite reserves near Leuna with four times the sulfur content of Rhineland grades. MIBRAG and partial interest in the Schkopau heat and power plant serving a new Dow Chemical facility at Buna were thereupon bought by British and American corporations eager to gain a foothold on the German market. The RWE consortium itself established operations in the Lusatian region near the Polish border, where plentiful deposits of low-sulfur lignite are located. The newly founded VEAG energy corporation constructed the world's most modern lignite power plants employing specially designed turbogenerators of up to 933 MW capacity. Deliveries were rationalized by installing conveyor belts from nearby surface mines owned by the VEAG subsidiary LAUBAG, or by MIBRAG. The high-voltage transmission grid in eastern Germany was also operated by VEAG.

The Treaty of Unity (*Einigungsvertrag*) of 1990 contained no provisions after 1995 for supporting continued economic development of the eastern federal states, since the rapid convergence of industrial production in the formerly divided nation was tacitly assumed. In actuality, average income in the east has remained below four fifths of western levels,[19] a circumstance interrelated with ongoing population decline. The Berlin Institute for World Population and Global Development has concluded that, in view of contrasting economic and demographic trends, "Germany remains divided."[20] The institute compares the MIBRAG mining areas of Saxony-Anhalt with some of the poorest regions of Eastern Europe and southern Italy.[21] This regressive situation has been made intractable by the continuing dispossession of agricultural lands and functional communities for expansive lignite extraction.

In contrast to earlier historic periods in which energy-dependent industries had been clustered around power plants, contemporary lignite usage provides no safeguards against economic erosion. Eastern Germany lost most of its manufacturing infrastructure after 1990, making it impossible for VEAG to realize turnover expectations. A government policy (*Braunkohlenschutzklausel*) for protecting lignite power generation from European market liberalization fixed electricity tariffs at inappropriately high levels for attracting new investment.

After being refused essential bank loans in the year 2000, VEAG appealed for public subsidies to offset annual operating losses of about three quarters of a billion euros.[22] Shortly thereafter, however, the western German corporate

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19 Ragnitz, Jochim, "Angleichung der Lebensverhältnisse in Ostdeutschland: Eine regional differenzierte Analyse," ifo Dresden berichtet 4/2009 (Dresden: ifo-Institut, 2009) p. 29.

20 Kröhnert, Steffen, Nienke van Olst, Reiner Klingholz, "Deutschland 2020. Die demographische Zukunft der Nation," (Berlin: Berlin-Institut für Weltbevölkerung und Globalentwicklung, April 2004) p. 18.

21 "Studie: Ostdeutschland ist 'demografisches Krisengebiet'" (Berlin: Der Tagesspiegel, 21.08.2008

22 "Banken wollen Ost-Versorger Veag keine neuen Kredite einräumen", (Berlin: Berliner Zeitung, January 24, 2000.

shareholders merged to form RWE AG and E.ON Energie AG. The Federal Cartel Office (*Bundeskartellam*t) promptly required all VEAG holdings to be relinquished in the interest of fair competition.[23] HEW in Hamburg, a regional power utility owned by the Swedish Vattenfall AB, successfully bid for major assets in eastern Germany against a number of foreign competitors, including the Atlanta-based Southern Company. The resulting German subsidiary Vattenfall Europe AG was incorporated on January 16, 2002, to integrate four formerly independent operations: VEAG, the Berlin utility BEWAG, HEW, and LAUBAG. In exchange for substantial debt relief from the federal government, Vattenfall committed to selling at least 50 TWh/a of electrical power from lignite until 2011 while insuring employment and apprentice training in the eastern German power industry.[24]

Vattenfall Europe maintains mining output of 58 Mt/a (2008) in the eastern German states of Brandenburg and Saxony for its three power stations near the Polish border with a total capacity of 6,5 GW. A fourth plant (1,874 MW) at Lippendorf south of Leipzig is fueled under contract with MIBRAG. Additional lignite is shuttled on a dedicated train line from MIBRAG's second mine to E.ON, the majority holder of the 980 MW Schkopau industrial plant that also generates electricity for the German railway system. NRG Energy retains 41.1% ownership in this installation, the remaining involvement of the United States in German lignite operations. Derivative lignite products are supplied to regional heating plants and commercial customers, notably the sugar refining industry. Montanic ester wax is manufactured by Romonta GmbH from a field of chemically unique lignite in nearby Amsdorf. Finally, declining lignite deposits are mined by E.ON for a 392 MW power plant at Buschhaus, southeast of the Volkswagen city of Wolfsburg near the former inter-German border.

Despite considerable reduction of lignite usage in Germany from over 420 Mt/a in the mid-1980's, the current output of 175 Mt (2008) represents nearly a fifth of worldwide mining production. The future viability of the industry requires that fuel prices remain low enough to compensate for the added costs of either emissions trading or alternative carbon capture technologies. New capital investments in lignite generation involve compounded risks unanticipated in earlier industry planning.

1. The ETS raises the effective fuel costs of crude lignite by a multiple of the mine-mouth price, narrowing its competitive advantage in comparison with cleaner burning fuels. Recurrent public resistance to strip mining[25] can also delay operating schedules.

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23 Bundeskartellamt, "Hintergrundinformation zur Fusion RWE/VEW" (Berlin: June 13, 2000).

24 "Energiebericht des BMWi: Perspektiven nachhaltiger Energiepolitik aufgezeigt" (Berlin: Federal Ministry for Economics and Labour, July 2002), p. 3.

25 Michel, Jeffrey H., *Status and Impacts of the German Lignite Industry* (Gothenburg: The Swedish NGO Secretariat on Acid Rain, February 2008), pp. 40 – 51.

2. While CCS appears suitable for preempting ETS obligations, the ultimate implementation costs cannot be quantified before the results of pilot testing, technological advances, geological exploration, and public hearings on CO_2 transport and sequestration have been evaluated. The necessary licensing procedures have yet to be drafted. It thus remains impossible to ascertain the required price of ETS allocations that would have to be maintained as the minimal threshold level of commercial CCS realization. The economic determinants of these allocations will be interrelated with the propagation of all carbon-reduced technologies.

3. All power plants with CO_2 separation that have been announced for realization over the next few years are of smaller size than current lignite utility power stations. A Vattenfall demonstration project announced for 2015 near the Polish border at Jänschwalde is to incorporate two 250 MW boilers, one employing an oxyfuel process and the other with post-combustion separation. Rather than culminating the testing phase, the installation will instead serve as a bridge between an initial oxyfuel pilot plant with a thermal capacity of 30 MW "and future commercial power plants, with capacities up to 1,000 MWe". [26]

4. The aspiration of superseding present lignite generation by CCS process chains would intensify the usage of domestic resources. In Brandenburg, Germany's second largest lignite mining state, the Advisory Council for Sustainable Development and Resource Protection has noted that prospectively "more than at third of the primary energy" contained in lignite could be additionally required for "CO_2 separation, liquefaction, and transport."[27] Underground injection for storage would exact further energy demands, as would mining the required added quantities of lignite. The accelerated pace of surface mining would hasten the depletion of accessible deposits, while intensifying ongoing conflicts with affected communities in the mining and sequestration regions.

5. The Advisory Council has concluded that "enormous investment, separation, transport, repository, and safety costs" might make CCS "tremendously more expensive" than an alternative strategy of energy efficiency, renewable energies, and new storage technologies. The technical viability of this prospect is suggested by the advent of intelligent power meters with customer choice options and the introduction of in-home gas motors by the Volkswagen Corporation as distributed combined heat and power (CHP) generators with utility dispatch control.

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[26] "Demonstration Plant in Jänschwalde", Factsheet CCS (Stockholm: Vattenfall AB, October 2008).

[27] Stock, Manfred et al., *Brandenburg auf dem Weg zur Modellregion für Nachhaltige Entwicklung. Endbericht 2009* (Potsdam: Beirat für Nachhaltige Entwicklung und Ressourcenschutz des Landes Brandenburg, September 2009), pp. 21, 22.

6. Under the Renewable Energy Sources Act, renewable power in Germany is granted priority grid feed-in access. Lignite-generated electricity must increasingly compete with wind power both for available transmission capacities and in trading at the Leipzig Power Exchange EEX. With grid parity of conventional and renewable sources anticipated within a few years, including for solar power under appropriate meteorological conditions, renewable generation could consistently underbid lignite in a carbon-constrained ETS regime. The German federal environmental ministry has estimated that the full-load schedule of conventional power plants will be declining to 3,900 hours per year by 2030 and diminish to 3,200 hours by mid-century owing to the inroads of renewable energy.[28] The specific capital expenses of CCS implementation could be reduced, however, by maintaining lignite plant operating hours above these averages. Green Budget Germany, an organization of government-contracted economists, has nevertheless estimated that ETS allowance prices of 30 - 48 euro/t, or 100 euro/t for retrofits, would be required throughout the duration of plant service life to insure investment payback.[29] EEX spot trading prices in 2009 have ranged between 7.98 and 15.41 euro/t CO_2. The extension of nuclear power licenses could reduce prices to even lower levels unless the number of allowances was simultaneously reduced to sustain investments in carbon reduction and efficiency.

An industrial CCS initiative for the European Union has been included in the European Strategic Energy Technology (SET) Plan for the “development and deployment of a diverse portfolio of low carbon energy technologies”.[30] In pursuing the objective for carbon capture and storage to “become cost-competitive within a carbonpricing environment by 2020-2025”, endorsed projects will be subsidized with 10.5 to 16.5 billion euros over the coming decade. Comparable sums are foreseen for wind (6) and solar energy (16), bioenergy (9), sustainable nuclear energy (5 to 10), and smart cities (10 to 12 billion euros). An additional 2 billion euros will be dedicated to electricity grid improvements.

The SET Plan has been drawn up to compensate for “locked-in investments” and “vested interests” that prevent markets and energy companies from delivering “the needed technological breakthroughs within a sufficiently short time span to meet the EU's energy and climate policy goals”.[31] Delays of implementation are intractably inherent to CCS, for which a further decade of technical experimentation and regulatory development will be required to establish reliable

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28 Green Budget Germany, op. cit., p. 3.

29 Green Budget Germany, op. cit., p. 7.

30 *A Technology Roadmap for the Communication on Investing in the Development of Low Carbon Technologies (SET-Plan). Commission Staff Document, SEC(2009) 1295* (Brüssels: Commission of the European Communities, October 7, 2009), pp. 4, 6, 8.

31 *Investing in the Development of Low Carbon Technologies (SET-Plan), COM(2009) 519 final* (Brüssels: Commission of the European Communities, October 7, 2009), p. 3.

implementation standards. The inadequacy of strategic planning was confirmed in November 2009 by the denial of a 1 billion euro public subsidy to RWE for a 400 MW lignite power plant at Hürth near Cologne with CO_2 storage in northern Germany near the Danish border requiring a 530 kilometer pipeline[32] to be built through densely populated regions hostile to the project,[33] causing the venture to be postponed.[34] RWE simultaneously withdrew from CCS bidding in the United Kingdom together with its consortium partners Dong Energy und Peel Power.[35]

In the meanwhile, 29 coal and lignite power plants are being constructed or planned in Germany without provisions for CO_2 capture.[36] With a service life of typically 40 years, these capital-intensive installations constitute structural contradictions to the scientific consensus on required GHG reductions by mid-century. Their comparatively high generating efficiency, however, likewise dismisses considerations of project abandonment in favor of older plants that are due for decommissioning.

European market liberalization has made electricity purchasing a more diverse, but commensurately complex endeavor. German households are able to change utility suppliers monthly if desired at internet contracting websites maintained by consumer interest organizations. With achievable savings often amounting to several hundred euros annually, the technological origins of electricity are frequently ignored. The toleration of nuclear generation under this circumstance is enhanced by the realization that wholesale power imports from France (with 59 nuclear reactors) and the Czech Republic (6) cannot be detected.

The commercial profitability of any prolonged nuclear strategy, however, may be tempered by the operating dividends legislatively apportioned to innovative generation and storage technologies. Renewable generation will unquestionably benefit from this policy. The lignite industry, however, is also availed of specific advantages with which its traditional competitive posture may be sustained.

1. The geographic location of major lignite power plants, each representing at least two percent of German electricity generation, is synonymous with transmission nodes at which supplemental or alternative technologies may be economically brought on line.

2. Lignite power plants can be modified for biomass co-firing. When additionally equipped with CO_2 capture, negative ETS allocations would multiply trading assets.

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32 *Die Klimaschutz-Pipeline* (Hamburg: RWE Dea AG, 2008).

33 "Umstrittene CO2-Pipeline: Aufstand in Nordfriesland gegen RWE (Der Westen, June 24, 2009).

34 "RWE tritt bei CCS-Kohlekraftwerk in Hürth auf die Bremse" (Ruhrbaron, November 12, 2009).

35 "RWE zieht sich in Großbritannien aus CCS-Projekt zurück" (Dow Jones Newswire, November 9, 2009)

36 Green Budget Germany, op. cit., p. 2.

3. Lignite and biomass exhibit particular thermodynamic and chemical similarities. After the traditional site of lignite processing at Leuna was expanded to petroleum refining several decades ago, it now includes a biomass research center for small to medium-size companies.[37] The proximity of the planned MIBRAG mine at Lützen could promote the development of complementary products.

It can nevertheless be noted that any departure from conventional power generation would constitute a venture onto uncharted economic territory. For decades, the German lignite industry prided itself on being the only branch of the energy sector maintaining commercial viability without public funding. Under carbon constraints, however, industry statements now routinely depict government subsidies as essential prerequisites of lignite-based energy security.

[37] "Biomasse aus nachwachsenden Rohstoffen statt Erdöl" (Leuna: leuna_echo, April 27, 2009).