Potential Unforeseen Consequences of Dedicated Renewable Energy Transmission: Implications For the European Energy Market

European Energy Market Conference, Madrid, Spain, June 2010

Dr. Roger H. Bezdek, President
Management Information Services, Inc.
Oakton, VA 22124, USA, 703-620-4120, rbezdek@misi-net.com

***Abstract* -- In the U.S. and Europe, significant growth in renewable electricity generation will require major expansion of electricity transmission grids. In the U.S., this could require the building of 20,000 miles of new transmission over the next decade. To facilitate this, government policy-makers are planning to build "green" transmission lines that would be restricted to electricity generated by renewables, primarily wind and solar. However, state and local jurisdictions are resisting siting of such transmission unless it serves local constituents and existing power plants. We find that the major beneficiaries of renewable transmission may be existing power plants, especially coal plants. Many of these facilities have very low electricity generating costs and their capacity factors are transmission-constrained. Their access to new transmission lines could enable them to sell electric power at rates against which renewable electricity cannot compete. Implications for Europe and for the Desertec initiative are discussed.**

***Index Terms*— coal; power generation planning; power industry; solar power generation; transmission lines; wind power generation**

I. Introduction[1]

It is generally recognized that significant growth in renewable electricity generation will require major expansion of electricity transmission grids. In the U.S., this could require the building of an additional 20,000 miles of transmission over the next decade – double what is currently planned. To facilitate this, government policy-makers are planning to build "green" transmission lines that would be restricted to electricity generated by renewable sources, primarily wind and solar. However, state and local jurisdictions are resisting siting of such transmission unless it serves local constituents and existing power plants. If such transmission is built and local access is allowed, then the major beneficiaries of the added transmission may be existing power generation facilities, especially coal-fired plants. Many of these facilities have very low electricity generating costs and their capacity factors are transmission-constrained. Their access to added transmission lines could enable them to sell electric power at rates against which wind and solar electricity-generated power cannot compete.

II. Design/Setup

In September 2009, J.P. Morgan (JPM) published a study of the proposed U.S. federal renewable electricity standard (RES) and its impact on the growth rate of the renewable energy sector.[2] We used the JPM data to estimate the potential impact of the RES and the transmission required to facilitate it on the existing fleet of conventional electricity generating plants. The focus was primarily on U.S. coal plants because these plants can increase their capacity factors, whereas U.S. nuclear plants already have capacity factors above 90 percent. Given the location of the coal plants throughout the U.S. and their current capacity factors, we estimated the impact of expanded electricity transmission lines on renewable energy electricity generation and costs an on conventional electricity generation and costs.

III. Renewable Energy Locations in the U.S.

One of the most important issues addressed is where in the U.S. the various renewable energy (RE) technologies are likely to be installed. Their locations and distances from major U.S. load centers largely determine the new transmission that will be required. Figure 1 shows the various RE resource maps and indicates where the different types of RE technologies will be located. This figure indicates that:

- Geothermal will be installed in a small number of western states[3]
- Biomass will be installed primarily in the northern Great Plains, the Pacific northwest, and perhaps parts of the south
- Solar thermal will be installed in a small number of western and southwestern states
- PV will be installed in a small number of western and southwestern states -- contrary to

[1]This work was supported, in part, by the U.S. Department of Energy, National Energy Technology Laboratory.

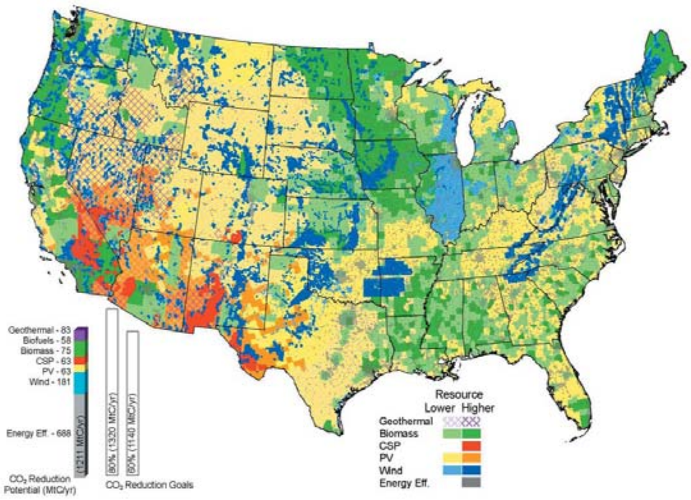
[2]Christopher Blansett, *The Proposed Renewable Electricity Standard and its Impact on the Growth Rate of the Renewable Energy Sector*, J.P. Morgan Securities, Inc., September 1, 2009.

[3]The only currently practical technology is existing geothermal steam, which is available in very few locations, most already being utilized. Hot-dry rock and other technologies are not yet practical or economic.

the popular notion that PV can be practical everywhere

- Wind will be installed primarily in the northern Great Plains

Figure 1
Potential Contributions From Energy Efficiency and Renewable Energy by 2030



Source: American Solar Energy Society.

IV. Load Centers And Transmission Requirements

IV.A. Renewable Resources, Transmission, and the Grid

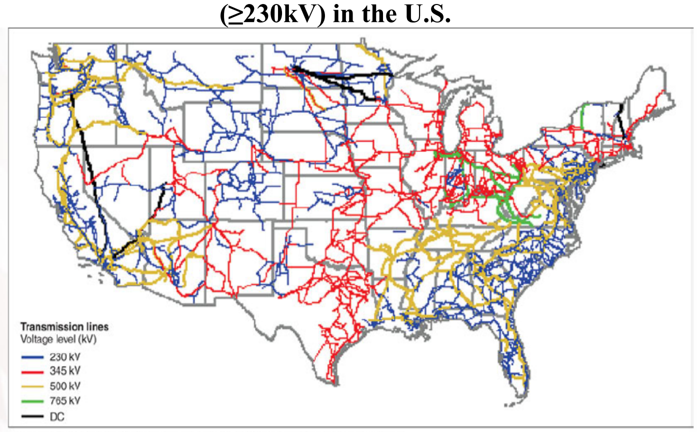
The next question we must address is the location of the major load centers that need electric power. These are primarily in the cities in the coastal states, in particular the Boston-Washington corridor, the West Coast corridor, and major Midwestern cities such as Chicago, St. Louis, etc.

In general, increased transmission capability for the U.S. is highly desirable, because a robust, redundant interstate electric transmission system is in everyone's interest – consumers, power producers, governments, etc. An expanded transmission network will allow for power system growth demanded by economic growth, and provide greater flexibility in the expansion of electric power generation at existing plant sites as well as allowing for the construction of new generating plants at optimal locations across the country.

Nevertheless, examination of Figure 1 indicates that there is a serious mismatch between the RE resources and the load centers: Most of the best RE generation sites are west of the Mississippi river, but most of the load centers are east of the river or on the west coast. Even the west coast load centers are a long distance from the best wind and biomass sites. We have to estimate how much new transmission needs to be built to transmit the RE electricity from points of generation to the load centers. The current U.S. electricity grid is shown in Figure 2.

We had to make major assumptions as to what RE electricity will be transmitted to which load centers. While some of the RE plants can serve load centers in Southern California, Phoenix, Denver, Salt Lake City, etc., most of the RE electricity produced will have to be transmitted to load centers east of the Mississippi. Thus, major new transmission lines will be required from the southwest and northern Great Plains states to load centers in the Midwest and the east. The grid map in Figure 2 indicates that most of these lines do not currently exist, and much new transmission will have to be built over the next 10 years – Figure 3.

Figure 2
Map of AC and DC High Voltage Transmission Lines (≥230kV) in the U.S.



Source: Federal Energy Regulatory Commission, created using Global Energy's Energy Velocity Suite.

Note: The 230, 345, 500, and 765 kV lines listed are all alternating current lines.

Figure 3
Required Green Power Superhighways

Source: American Wind Energy Association and Solar Energy Industries Association

Thus, a very large amount of new transmission will have to be built to transmit RE power from where it is produced – primarily in the northern Great Plains and the southwest – to the load centers in the Midwest and on both coasts. The distances involved are significant; for example:

- The distance from the northern Great Plains to the Midwestern load centers is 700 – 1,000 miles

- The distance from the northern Great Plains to the load centers in the Boston-Washington corridor is 1,200 to 1,500 miles
- The distance from the northern Great Plains to the west coast load centers is 1,000 – 1,300 miles
- The distance from the southwest to the Midwestern load centers is 1,100 – 1,400 miles
- The distance from the southwest to load centers in the Boston-Washington corridor is 1,600 – 2,000 miles
- The distance from the southwest to the west coast load centers is 200 – 700 miles
- The distance from Iowa to the west coast load centers is 1,600 – 1,900 miles

It is extremely difficult to estimate precisely how much additional transmission the mandated RES would require. To estimate this would require knowledge of what RE systems are being installed, at which locations, over what time periods, where the power is being transmitted to, etc. Nevertheless, given the discussion above of the distances between RE generation sites and major load centers and the RE configuration, it is likely that the new, incremental transmission required to enable the RES could total 10,000 to 20,000 miles of transmission lines. To put this in perspective, the North American Electric Reliability Corporation (NERC) estimates that the U.S. will require a total of about 14,500 miles of new transmission lines by 2016.[4] Thus, the transmission lines required by the RES could nearly double U.S. transmission requirements over the next decade.

IV.B. Issues in Siting Transmission

As noted, installation of a large block of RE technologies will require the installation of new transmission lines to both coasts. There are at least two major problems associated with these new lines. First, the lines will have to cross a number of states to reach the coasts. As laws now stand, permitting would require the approval of the states, local authorities, and impacted landowners, who have often thwarted the construction of transmission lines in the past. To avoid such complications and delays, the federal government would have to have clear authority to mandate routes and to be able to declare eminent domain to site the lines. While the Federal Energy Regulatory Commission (FERC) was recently given some related authority, it has yet to exercise it, so it is by no means clear how long challenges to federal preemption might last, slowing final route approvals and transmission line construction. It is expected that granting this kind of federal preemption will cause substantial political controversy, the duration of which is not predictable.

The second issue is of the "chicken and egg" variety. It is unlikely that investors will commit large sums of money to install, for example, large wind farms in the northern Great Plains without the assurance that the transmission lines will be available to move electric power to markets. Some would consider it foolhardy and imprudent to begin wind farm installation without the lines being under actual construction. Thus, a federal role and exercise of eminent domain ahead of RE facility construction will be essential.

Coincident with the construction of the transmission lines and RE plants must be the construction of the backup power plants. If those plants are delayed, then the RE power generated would have no markets, because large quantities of widely varying electric power from wind, solar thermal (ST), and photovoltaics (PV) could not be handled on existing power grids.

The picture that emerges is the federal government exerting unprecedented authority to enable the construction of high power electric transmission lines from the southwest and northern Great Plains to both costs in advance of the construction of both RE plants and large backup power plants. Clearly, this will require herculean efforts and federal government intrusion into state and local prerogatives. In effect, the federal government will have to clear all roadblocks to construction of the new RE plants, the new backup power plants, and the transmission lines, if an integrated system is to result.

IV.C. Transmission Costs

The backup power plants will have to be located near the RE plants in the northern Great Plains and the southwest. The rationale relates to transmission costs and their amortization.

The cost of transmission must ultimately be charged to the consumers of the power delivered by the lines. The capacity of the transmission lines needed to move RE power to the coasts must be sized to at least the ultimate nameplate capacity of the RE technologies, if the maximum amount of RE power is to get to markets. However, the average generation capacity of, for example, wind in the Great Plains is of the order of the 40 percent of nameplate power rating (and may actually be much lower), which means that roughly 60 percent of the capacity of the transmission lines would be unused, resulting in much higher transmission costs than if the lines were near fully loaded. By locating the backup power plants near the wind farms, the transmission lines could be more fully loaded, avoiding the cost penalty associated with the backup power being located further away.

What will the additional required transmission cost? In principle, once we estimated the approximate number of miles of required new transmission, we could estimate the total cost by multiplying by the average cost per mile. Unfortunately, as

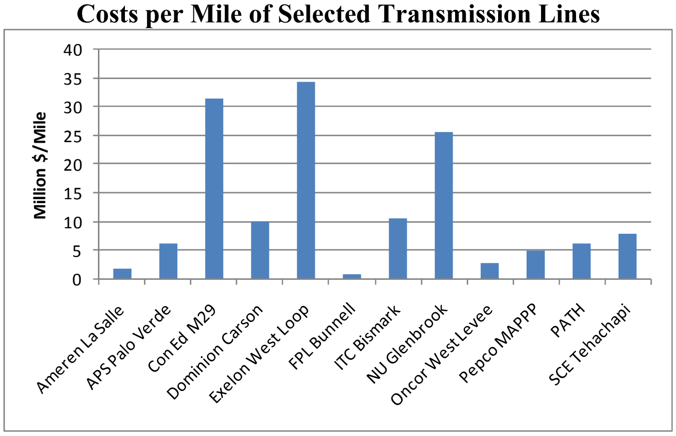
[4] North American Electric Reliability Corporation, *2007 Long-Term Reliability Assessment: 2007-2016*. October 2007.

illustrated in Figure 4, the average cost per mile of transmission varies greatly. Presumably, most of the new RE transmission will be through rural or semi-rural areas. However, as transmission lines approach the major load centers costs will escalate rapidly.

In previous analyses we used FERC estimates of required new transmission and independent estimates of the likely costs of transmission, and estimated that it would cost about $80 billion to construct the 14,500 miles of new transmission FERC feels is necessary by 2016.[5] Using this estimate as a benchmark, we estimate that the new transmission required by the RES could cost between about $50 and $100 billion.

However, even this estimate may be conservative, and the transmission costs to enable the RES may be much higher than currently anticipated. For example, ITC Holdings currently has preliminary FERC approval for a 765-KV transmission line to carry wind energy from Iowa and other Midwestern states from the Upper Midwest into Illinois. The approved cost for this one transmission line alone is $12 billion.[6] As discussed, transmission lines from the northern Great Plains and the southwest to the major load centers on the east cost would be much longer than this line.

Figure 4
Costs per Mile of Selected Transmission Lines



Source: Edison Electric Institute and Electric Power Research Institute.

Nevertheless, our estimate is generally comparable to others that have been developed. For example, a February 2009 study sponsored by the Midwest Independent System Operator, SERC Reliability Region, PJM Interconnection LLC, the Southwest Power Pool, the Mid-Continent Area Power Pool, and the Tennessee Valley Authority found that a substantial increase in the amount of electricity produced from renewable energy would require building a large new transmission system. If the U.S. wants to obtain 20 percent its electricity from renewable energy by 2024, the study found that it would be necessary to build a new electricity transmission system, including 15,000 circuit miles of high voltage lines. The system, which would be laid alongside the existing electric grid infrastructure, would start in the Great Plains and Midwest -- where the bulk of the nation's wind resources are located -- and terminate in big cities along the East Coast, and would cost up to $100 billion.[7] The study also estimated that building the wind turbines needed to generate the desired amount of power would cost about $720 billion. The purpose of the study was "to make clear that if you need large sums of energy that's not carbon-based, these are the kinds of numbers involved to achieve it."[8]

V. Transmission Access

A key issue is, if additional transmission is built to accommodate the RES, whether these transmission lines will be restricted only to RE-generated electricity. This is a serious and relevant issue, and "green transmission" bills have been introduced in the U.S. Congress to restrict new transmission exclusively to RE-generated electricity. Such green transmission legislation has been introduced in House of Representatives by Representative Jay Inslee (D.-WA)[9] and in the Senate by Senator Harry Reid (D-NV).[10]

Congress has already acted to enhance the power of the federal government and thus enable transmission projects with multistate importance to be assessed on more broadly based national interests. EPAct 2005 provided FERC with "backstop" transmission siting authority. States retain the primary siting responsibility, but if the state has "withheld approval for more than one year" for a project in a designated "national interest electric transmission corridor," the applicant may seek siting authority from FERC.[11]

However, it is not clear that EPAct provides a meaningful federal alternative if a state denies a transmission project. For example, Arizona regulators rejected a transmission line to connect Arizona generation with California electric

---

[5]Management Information Services, Inc., "U.S. Electric Reliability: Capacity and Transmission Requirements and Costs," September 2008.

[6]Dan Piller, "Plan Sparks Row Over Wind Transmission," *Des Moines Register*, August 15, 2009.

[7]Rebecca Smith, "New Grid for Renewable Energy Could Be Costly," *Wall Street Journal*, February 9, 2009.

[8]Ibid.

[9]H.R. 2211, a Bill to Facilitate Planning, Construction, and Operation of a Secure National Clean Energy Grid, the ''National Clean Energy Superhighways Act of 2009,'' introduced by Representative Jay Inslee (D.-WA) on April 30, 2009. An analysis of this bill is given in Management Information Services, Inc., "Analysis of HR 2211, the ''National Clean Energy Superhighways Act OF 2009,''' MISI, June 5, 2009.

[10]"Clean Renewable Energy and Economic Development Act," a bill introduced by Senator Harry Reid in the 111th Congress. Also see Management Information Services, Inc., "Comments on a Draft Bill For the Siting of Interstate Electric Transmission Facilities," MISI, May 6, 2009. For example, HR 2211, the ''National Clean Energy Superhighways Act of 2009'' would amend Part II of the Federal Power Act by adding a new section, Section 216a, Sustainable Transmission Grid, to plan and construct STG transmission lines for electricity produced by renewable energy on new or existing rights-of-way.[10] This Bill seeks to facilitate the establishment of a sustainable transmission grid (STG) consisting of long-distance, extra-high voltage transmission lines constructed to transmit electricity generated by renewable energy sources. It would amend the Federal Power Act by establishing multistate transmission planning authorities (MTAs), within the Eastern and Western interconnections to expedite the construction of STGs for renewable electricity. The Bill would prohibit use of an STG to transmit electricity generated from coal-fired power plants.

[11]See the discussion in S. F. Greenwald and J. P. Gray, "Transmission Superhighway or Interconnected Patchwork?" *Power*, April 2009.

consumers, and four years after the filing of the initial application with the California Commission, this transmission project remains suspended. In 2005, Edison International, owner of California's largest electric utility, proposed a power line that would stretch from a substation about 50 miles west of Phoenix, Arizona to Palm Springs, California. The company contends that the line would ensure reliable supplies of electricity for southern California and bring the region renewable energy, including solar power from the Mojave Desert and western Arizona.

However, Arizona regulators do not favor Edison's proposed power line to transport solar electricity across their state to Palm Springs. They called it California's "230-mile extension cord" and oppose it. The unresolved dispute over the $774 million project has helped fuel a fight in Washington over whether the federal government should seize more authority from states over the approval of high-voltage power lines. State regulators in Arizona (and elsewhere) want to protect their authority. Kris Mayes, chairwoman of the Arizona Corporation Commission, the state's utility regulator, stated that placing the issue in the hands of officials in Washington instead of regulators located in Phoenix and San Francisco is "really silencing the voices of a whole lot of people."[12] It is noteworthy that, after Arizona regulators rejected the proposal, Edison offered concessions that would give all Arizona utilities access to the line. This may indicate the ultimate fate of "green transmission" mandates.

Further, a federal court ruling in *Piedmont Environmental Council v. FERC* may have effectively negated FERC's backstop authority. The majority rejected FERC's interpretation that the state's denial of a transmission project constitutes its "withholding approval for more than one year." Thus, this decision enables states to deprive FERC of any backstop siting authority by timely rejection of a transmission project application. An underlying policy preference for the states' long-held permitting authority emerges from the majority opinion: "FERC's reading would mean that... state commissions... will lose jurisdiction unless they approve every permit application in a national interest corridor."[13]

Thus, there may be no practical way to prevent existing coal plants from using the transmission lines constructed for RE power:

- The wind and solar capacity factor is usually taken to be about 30 percent.
- However, it can vary between 0 percent and 100 percent.
- At times of greatest need during summer peaking periods, it is often closer to 5 percent.
- This implies that, most of the time, there will be a huge amount of excess capacity on the new transmission lines being built that will not be utilized by RE.
- Further, due to its unreliability and intermittency, RE requires almost a 100 percent backup of reliable generation.[14]
- There is no way to practically or technically enforce the RE requirement, nor is it economically desirable to do so.
- The important thing is to get the transmission lines built; once they are they can be used.

VI. New Transmission And Existing Coal Plants

VI.A. Existing Coal Plants and Renewable Transmission

It is not known precisely how much unused coal plant generation capacity would be available for use if current transmission constraints were alleviated. A meaningful calculation would require a detailed analysis of the entire electric power system as it currently exists and as well as how it is likely to evolve. Further, the proper management of the electric system requires a roughly 15 percent excess capacity margin. Again, a detailed analysis of the whole system would be needed to determine how much of the reserve capacity in various parts of the country is assigned to coal plants versus other power sources. Clearly, part of current U.S. capacity underutilization is associated with the current economic recession, which, according to the Federal Reserve, has already ended.[15]

In recent years, the construction of a number of planned new power plants have been delayed or cancelled, and these actions have put the U.S. electric power system in jeopardy, as recently noted by NERC. In their 2007 report, which preceded the current recession, NERC noted, "… projected increases in peak demands continue to exceed projected committed resources beyond the first few years of the ten-year planning horizon." NERC went on to state, "A major driver of the uncertain or inadequate capacity margins is the industry's relatively recent shorter-term approach to resource planning and acquisition, relying heavily on unspecified, undeveloped, and/or uncommitted resources to meet projected demand."[16] In their 2008 report, before the full force of the recession was

[12] S. F. Greenwald and J. P. Gray, "Can FERC Deliver Transmission?" *Power*, November 2007.

[13] S. F. Greenwald and J. P. Gray, "Transmission Superhighway or Interconnected Patchwork?" op. cit.

[14] A recent WAPA study found that, due to this backup requirement, the environmental impacts of RE projects approach those of the required backup facilities. See Scientific Certification Systems, Inc., Life Cycle Impact Assessment of Renewable Electrical Generation Technologies Compared to the WECC Baseline, prepared for the Western Area Power Administration and Tri-State Generation and Transmission Association, March 2009.

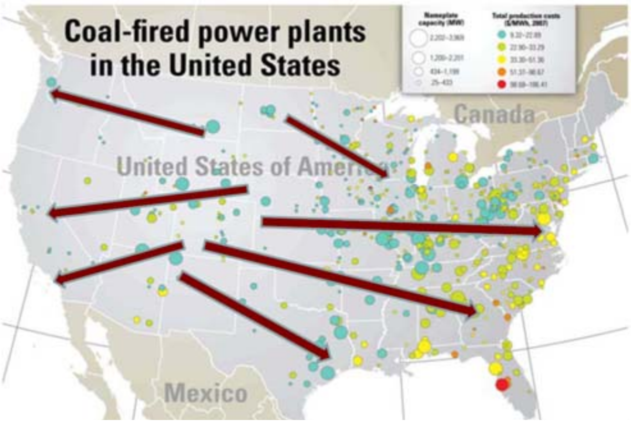
[15] Sara Murray and Ann Zimmerman, "Bernanke: Recession 'Likely Over,'" Wall Street Journal, September 16, 2009.

[16] North American Electric Reliability Corporation, 2007 Long-Term Reliability Assessment: 2007-2016. October 2007.

understood, NERC stated, "… while some progress has been made, action is still needed on all of the issues identified in last year's report to ensure a reliable bulk electric system for the future."[17]

On this basis, the excess generation capacity that currently exists is almost certain to be fully utilized as the economy recovers, and additional new generation capacity will almost certainly be needed. We wished to estimate the potential implications of the new transmission lines for existing coal plant burn (capacity factors). To estimate this, we need to compare the likely locations of the needed new transmission lines with the location of existing coal plants – see Figure 5.

Figure 5
Required Green Superhighways and Coal Plants



Source: Management Information Services, Inc.

This map clearly indicates that RE transmission lines:

- For biomass and wind generation going from the northern Great Plains states to the Midwest load centers, the lines would have to pass in relatively close proximity to existing coal plants located in North Dakota, Minnesota, Wisconsin, Iowa, Missouri, Illinois, Indiana, Kentucky, Ohio, and West Virginia.
- For biomass and wind generation going from the northern Great Plains states to load centers in the Boston-Washington corridor, the lines would have to pass in relatively close proximity to existing coal plants located in North Dakota, Minnesota, Wisconsin, Iowa, Missouri, Illinois, Indiana, Kentucky, Ohio, West Virginia, and Pennsylvania.
- For biomass and wind generation going from the northern Great Plains states to west coast load centers, the lines would have to pass in relatively close proximity to existing coal plants located in North Dakota, Minnesota, Montana, Utah, Colorado, Wyoming, and Arizona.
- For geothermal, ST, and PV generation transmitted from the southwest to the Midwestern load centers, the lines would have to pass in relatively close proximity to existing coal plants located in Arizona, New Mexico, Utah, Colorado, Kansas, Nebraska, Missouri, Illinois, Indiana, Kentucky, Ohio, and West Virginia.
- For geothermal, ST, and PV generation transmitted from the southwest to the west coast load centers the lines would have to pass in relatively close proximity to existing coal plants located in Arizona, New Mexico, Utah, and Colorado.

VI.B. Potential Implications for Coal Plant Utilization

What does the proximity of new transmission lines to many existing coal plants mean for utilization of these plants? Ideally, we would estimate the carrying capacity of the different lines, how close they are to which coal plants, the capacity utilization of each coal plant, the cost of electricity output from each plant, projections of all of these, etc. However, this is a substantial task that was outside the scope of the current project.

Alternately, we can use estimates of the average coal plant capacity factor and an average coal levelized cost of electricity (LCOE). Existing coal plants are, except for some large hydro projects, the least expensive means of electricity production. Coal-fueled power plants produce about 50 percent of U.S. electricity, and 23 of the 25 power plants in the U.S. that have the lowest operating costs (and therefore provide power to their consumers at the lowest prices) are powered by coal. In states where coal is used for the highest percentage fuel mix, electricity production costs and rates are the lowest. In general, states that use coal to generate most of their electricity have electric rates that are only about half as large as those of other states. Thus, the current fleet of coal plants produce cheap electricity -- 4¢/kWh - 6¢/kWh, and we can use this as an average.

[17] North American Electric Reliability Corporation, 2008 Long-Term Reliability Assessment: 2008-2017, October 2008.

VII. The Real Costs Of The Renewable Technologies

The actual costs of electricity generation from RE technologies may be higher than is generally realized. Here we first discuss wind power in order to illustrate the complications and high costs of utilizing renewables -- wind is generally considered to be the leading option for the renewable production of electric power. We then present a more generic discussion of other RE technologies

VII.A. The Example of Wind

It is generally recognized that the best land-based wind conditions exist in the northern Great Plains, while the largest U.S. electric power utilization is along the two coasts. It is also recognized that transmission lines to carry large amounts of wind power from the center of the country to the coasts do not now exist and would have to be built. Thus, there is great interest in the installation of high capacity transmission lines in both directions from the Great Plains in order to deliver wind power to the two coasts. Accordingly, for our simple example we consider the construction of large wind farms along the middle of the country and transmission lines going to both coasts. Our considerations are relatively general but are believed to be representative of the issues and costs involved.

Consumers require power-on-demand, i.e., reliable power that is available at all times. In the jargon of the electric power industry, this is called dispatchable power, which is broken down into load demands called Base (24 hours per day), Intermediate (8-10 hours per day), and Peak (a few hours per day). Base and Intermediate load generators are currently fueled primarily by coal and nuclear, with some contributions by natural gas. Peak power is typically provided by natural gas.

Electric power from wind generators varies according to the cube of wind speed. But wind speeds vary dramatically over the course of a day, week, month, and year. Variations in wind power thereby range from zero (no or very little wind blowing) to full nameplate capacity of the wind generators (during excessive wind speeds, generators are shut down to avoid damage). Thus, wind power is not dispatchable, which is a huge problem since consumers require power-on-demand.[18]

One consequence of these realities-of-nature is that wind power requires near 100 percent backup by power plants that are dispatchable. These backup plants must be capable of quickly ramping up or down to compensate for wind variations so as to provide power-on-demand to the consumer. Further, wind backup plants must be maintained in a fully operational state at all times in order to be able to quickly respond to wind variations. This operational state is called "spinning reserve," which requires some consumption of fuel.

When wind power is a small fraction of total generation in an electric power sector, its inherent nature-related variations can be managed by adjustments in other existing generators. However, when wind power is planned to be a large fractional source in a power sector, then the backup power burden can no longer come from tweaking other dispatchable power plants. Rather it must come primarily from dedicated power plants in spinning reserve. On this basis, the cost of large-scale wind generation must include not only the cost of the wind generators themselves but also the cost of dedicated dispatchable backup generators. When viewed in this context, wind power is in effect a fuel saver for those dispatchable generators.

The location of backup generators for wind power must be relatively close to the wind generators, otherwise large blocks of backup electric power would have to be shuttled over long distances at non-trivial costs. The effective use of wind power transmission lines argues for the siting of backup generation plants near wind farms.

VII.B. Realistic Estimates of Electricity Prices for Renewable Technologies

Deriving accurate, consistent, and comparable LCOE estimates for renewable technologies such as wind, solar thermal, and PV is extremely difficult and subject to much uncertainty, and it may not even be possible to meaningfully compare the levelized costs of dispatchable and non-dispatchable energy sources. Renewables suffer of the interrelated problems of low and highly variable capacity factors, intermittency, unreliability, need for storage and backup, requirements for expanded transmission, and heavy reliance on government subsidies and government-mandated utility subsidies.

For example, while coal plants can have capacity factors above 85 percent, the estimated capacity factor that the U.S. Energy Information Administration (EIA) uses for wind is 34 percent, for solar thermal is 31 percent, and for PV is 22 percent. Table 1 shows that JPM used slightly lower capacity factors: 30 percent for wind, 30 percent for ST, and 20 percent for PV. While these may be generally reasonable as national averages, they also may be somewhat high – e.g., other estimates of wind capacity factors are in the range of 25 – 30 percent.[19] Thus, an accurate LCOE for these renewables must, at a minimum, take into account these low capacity factors. However, even such an adjustment may not fully

[18]James Schlesinger and Robert Hirsch, "Getting Real on Wind and Solar," *Washington Post*, April 24, 2009.

[19]They could be even lower. For example, Boccard notes that "For two decades, the capacity factor of wind power measuring the mean energy delivered by wind turbines has been assumed at 35 percent of the name plate capacity. Yet, the mean realized value for Europe over the last five years is closer to 21 percent thus making levelized cost 66 percent higher than previously thought." Nicolas Boccard, "Capacity Factor of Wind Power: Realized Values vs. Estimates, October 2008, available at: http://ssrn.com. The actual capacity factors for wind in Germany ranged between 14 and 21 percent over the period 2000 – 2007; see *Windenergy Report Germany 2008*, ISET, Univ Kassel, Deutschland, 2008.

account for the fact that few renewable resources may actually be available when they are needed the most.

Table 1
J. P. Morgan Estimates of Renewable Capacity Factors

Renewable Energy Type	Average Capacity Factor
Geothermal	80%
Biomass	65%
Solar Thermal	30%
Solar Photovoltaic	20%
Wind	30%

Source: J. P. Morgan, 2009.

During the California heat wave in July 2006, which resulted in significant increases in electricity demand, actual wind generation was at only about five percent of available capacity. Thus, in this case, the capacity factor for wind was closer to five percent than 34 percent.

The U.S. Energy Information Administration (EIA) contends that its RE LCOE forecasts (shown in Table 2) include a capacity factor for wind of 34 percent, for solar thermal of 31 percent, and for PV of 22 percent.[20] However, if actual capacity factors are lower than this, the LCOE estimates for these RE technologies may have to be increased significantly.

Table 2
EIA Forecasts of Estimated Costs of Electricity Generation Alternatives
¢/kWh (2007 dollars)

Plant Type	2020
Conventional Coal	92.6
Advanced Coal	99.8
Advanced Coal with CCS	113.5
Natural Gas-fired	
Conventional Combined Cycle	85.8
Advanced Combined Cycle	81.4
Advanced CC with CCS	113.5
Conventional Combustion Turbine	143.4
Advanced Combustion Turbine	125.6
Advanced Nuclear	101.8
Wind	138.8
Wind – Offshore	219.8
Solar PV	369.5
Solar Thermal	247.3
Geothermal	96.8
Biomass	103.0
Hydro	111.5

Source: U.S. Energy Information Administration, 2009.

At least as important, it is not clear how the required costs of backup power should be accurately incorporated into the RE LCOE estimates. Given the inherent unreliability and intermittency of RE technologies, near 100 percent backup may be required – as has been the case in Germany.[21] Further, given that RE resources may not be reliably available when they are needed the most, 24x7 spinning reserve may be often required. Because of this need for full fossil fuel backup, there is a large premium for solar and wind -- paying once for the solar and wind system and again for the fossil fuel system, which must be kept running at a low level at all times to be able to quickly ramp up in cases of sudden declines in sunshine and wind. Thus, the total cost of such a system should include the cost of the solar and wind machines and the cost of the full backup power system running in spinning reserve.[22]

Backup charges for RE systems can be substantial and they are already being imposed. For example, in the USA in 2009 Bonneville Power Administration (BPA) ruled that wind generators will face a new charge over the next two years. Pending likely approval by FERC this fall, a new wind integration charge will be levied on all wind generators at a rate of 5.7¢/kWh.[23] In the past, BPA charged some of its utility customers for conventional power reserves to back up intermittent wind power; however, the amount of wind on BPA's system has grown rapidly in recent years, increasing both the need for reserves and the risks to system reliability. BPA has found that increased size of the wind fleet was compounded by the wind generators' inability to accurately account for wind ramp events in their schedules, thereby requiring BPA to hold a significantly larger amount of reserves in order to provide balancing services. This 5.7¢/kWh is a very significant charge:

- EIA estimates that the average annual electricity price in 2010 will be 8.3¢/kWh, and 5.7¢/kWh thus represents an increase of 69 percent
- Current electricity rates in the Pacific Northwest range between 5¢/kWh and 6¢/kWh, and a rate surcharge of 5.7 ¢/kWh is about 100 percent.

Thus, the costs need to include the costs of the wind generator plus the imputed costs of backup power. Including backup would provide a dispatchable system, whose costs could be legitimately compared with coal and other baseload options. While comprehensive analysis of the required backup issue is outside the scope of the current research, it is clear that if such costs are incorporated into the LCOE of RE, these cost estimates would increase significantly.

In addition, there is the question of how the costs of the increased transmission requirements of RE systems should be

[20]U.S. Energy Information Administration, *Annual Energy Outlook 2009*, Washington, D.C., March 2009.

[21]M. Frondel, N. Ritter & C. Vance, *Economic Impacts From The Promotion Of Renewable Energies: The German Experience*; Rheinisch-Westfälisches Inst. f. Wissenschaftsforschung, October 2009.

[22]Schlesinger and Hirsch, op. cit.

[23]Charles Redell, "NW Utilities Get Wind of Integration Charge," Reuters, August 12, 2009,

included in the LCOE of these systems. As noted, this issue is often framed as the difficulty of getting power from RE sites, such as the southwest for solar thermal and the northern Great Plains for wind, to the major demand centers in cities on the coasts. Costly transmission lines will be needed to move solar and wind energy to the major U.S. population centers, and there must be considerable redundancy in those new transmission lines to guard against damage due to natural disasters and terrorism. All of this leads to considerable additional costs.[24] As noted, legislation has been introduced in the U.S. Congress for "green transmission" lines that would be restricted exclusively to electricity form RE sources.[25] While the feasibility of such proposals is questionable, if such lines are actually built it may be that all of their costs would have to be incorporated into the LCOE for RE.

VIII. Potential Impacts On Coal Generation And Utilization

Added transmission could greatly impact the existing fleet of coal plants.[26] Specifically:

- The utilization of the existing coal fleet is currently about 72 – 74 percent
- However, this may be increased to about 85 percent if there is enough load and transmission to transmit the added coal generation to the load at nights and over weekends.[27]
- Much of the current night and weekend load is handled by natural gas.
- Natural gas is not cost-competitive with coal, and is only used due to the lack of adequate transmission from coal plants.
- Most of the underutilized coal capacity is in the middle U.S. and is stranded from the East Coast (up and down the entire region including Florida) and kept outside Texas as well.
- According to EIA, current U.S. coal capacity is about 310 GW, coal furnishes about 2 trillion kWh annually, and the U.S. consumes about 1.13 billion tons of coal.
- If added transmission could increase the utilization of the existing coal fleet by about 10 percent, then coal could provide about an additional 200 billion kWh and coal demand would increase by about 100 million tons – even assuming no new coal plants are built.
- This would be analogous to what happened in the U.S. nuclear power industry over the past two decades, where nuclear capacity factors increased from less than 80 percent to the current 90 percent+.

Scenarios

We conducted two scenarios here (and two sensitivity analyses for each) to estimate the potential impact of additional transmission on coal plant utilization:

- First, as a minimum estimate we assumed that the additional transmission built for the RE generation would enable capacity increases in 25 percent of the existing coal fleet. We then examined the potential impact of capacity increases of five percent and of 15 percent.
- Second, as a maximum estimate we assumed that the additional transmission built for the RE generation would enable capacity increases in 50 percent of the existing coal fleet. We then examined the potential impact of capacity increases of five percent and of 15 percent.

The results of these analyses indicated the following. If the additional transmission built for the RE generation enabled capacity increases in 25 percent of the existing coal fleet, the average capacity of the entire coal fleet could be increased by about 1.5 percent to four percent – about 4 GW to 12 GW. This could increase annual coal-fired generation by about 30 billion kWh to 80 billion kWh and coal demand would increase by about 25 to 75 million tons – even assuming no new coal plants are built.

If the additional transmission built for the RE generation enabled capacity increases in 50 percent of the existing coal fleet, the average capacity of the coal fleet could be increased by about three percent to eight percent – about 10 GW to 25 GW. This could increase annual coal-fired generation by about 60 billion kWh to 160 billion kWh and coal demand would increase by about 50 to 150 million tons – even assuming no new coal plants are built.

[24]Schlesinger and Hirsch, op. cit.
[25]For example, see the "Clean Renewable Energy and Economic Development Act," op. cit.
[26]Management Information Services, Inc., "Green Transmission and the Reid Bill," March 2009.
[27]This is a complex issue, since some older coal plants may not be able to operate a full capacity because of mechanical and environmental limitations. Further, upgrading older coal plants could run into regulatory restrictions via New Source Performance Standards; see Edison Electric Institute, "What You Should Know About Electric Companies and New Source Review," July 2002.

For purposes of analysis, here we used the means of these estimates and found that the expanded transmission required by RE technologies would enable:

- An increase in the average capacity of the entire existing coal fleet of about 15 GW – about five percent
- An increase in annual coal-fired generation by about 100 billion kWh
- An increase in annual coal demand of about 57 million tons

Thus, the expanded transmission required by RE technologies could essentially enable the expansion of coal-fired generation by the equivalent of about 30 new coal plants by 2020. This expansion could be very rapid, since no new siting, permitting, or construction would be required. As discussed, the electricity produced could be produced very cheaply – at about 5¢/kWh.

IX. Results and Implications for Europe

Our findings indicate that the RES mandate could cause serious problems and economic and policy dilemmas. The mandated RES requires not only a massive build of RE electric generating facilities over the coming decade but also, of necessity, a very large increment in transmission lines and requirements for near-100 percent backup. This will be very costly: The total, actual costs of achieving the RES by 2020 – instead of the JPM estimate of $275 billion, could actually be over $500 billion. This is nearly twice the JPM estimate. These are actual cost estimates and include the implicit costs of RE, such as federal and state government subsidies and mandated utility cross-subsidies.

This raises the question of what the actual, unsubsidized cost of the RE-generated electricity in 2020 is likely to be. Taking reliability, capacity factors, transmission requirements, and need for backup power into account, the actual 2020 costs of the RE technologies – especially wind, ST, and PV, could be about twice as high as current EIA estimates. Thus, the actual 2020 levelized cost of energy (LCOE) costs (2007 dollars) could be as high as:

- For onshore wind, about 28¢/kWh
- For offshore wind, about 45¢/kWh
- For PV, about 75¢/kWh
- For ST, about 52¢/kWh
- For geothermal, which requires less backup, about 15¢/kWh
- For biomass, which requires less backup, about 16¢/kWh

This presents some interesting dilemmas.

The increased electricity generation from existing coal plants enabled by the new transmission would probably cost in the range of about 5¢/kWh, which is from three to 15 times cheaper than the potential costs of the RE generation. Even if some of the coal plants had to be retrofitted with carbon capture and storage (CCS), they would produce electricity at prices that would still be an order of magnitude lower than the RE-generated electricity. By way of contrast, EIA projects that the average price of electricity in 2020 will be 9.3¢/kWh. Thus, in 2020, the newly-enabled coal generation could be about 50 percent cheaper than the average electricity price, whereas the RE-generated electricity could be from 50 percent to 800 percent higher than the average electricity price.

We found that total RE generation in 2020, rather than the 612 billion kW estimated by JPM, may be closer to about 475 billion kWh – about 11 percent of the U.S. total. Increased transmission would enable an increase in annual coal-fired generation of about 100 billion kWh – about 21 percent of the incremental RE generation.

The dilemma arises from the fact that the coal-fired electricity could sell for an actual price that is from three to 15 times less expensive than the RE-generated electricity. The rational consumer would obviously prefer to purchase the coal-fired electricity instead of the RE-generated electricity, and the 100 billion kWh of coal-generated electricity could potentially displace 100 billion kWh of RE-generated electricity. Of course, it is not nearly as clear cut a case, since in the real regulatory world actual electricity prices are weighted averages of costs from different sources and include various charges, fees, taxes, etc. Nevertheless, given the enormous cost differentials involved, there is no way to hide the fact that consumers would prefer to purchase coal-fired electricity. Further, large industrial and commercial customers may have the clout to enforce their desires.

What is likely to occur, and how would regulators react? First, if an additional 100 billion kWh of coal-generated electricity comes on line, what would happen to the (more expensive) RE-electricity? Would 100 billion kWh of it become undesirable and underutilized?

If regulators choose to enforce the RES mandate, how would they set overall electricity prices? Would they “blend” the costs of the RE-generated electricity with those of the enabled coal-generated electricity? Would this even be realistic in states like Indiana, Ohio, Missouri, and West Virginia? These states already obtain almost all of their electricity from coal, and would stand to benefit greatly from the newly enabled expansion of existing coal generation. These industrial states have already suffered severe job losses, and significantly increased electricity rates to satisfy the RES would not help their prospects for economic recovery.

However, if certain large, coal-dependent states would be largely exempt from paying for the RES costs, then electricity costs in other states would have to increase all the more. Again, federal RE subsidies could only disguise this fact for so long.

Another question that arises is the potential impact of the new transmission on prospects for new coal plants. While this is outside the scope of the current research, it is worth noting that even new coal plants with CCS could produce electricity more cheaply than the RE technologies. The expanded transmission could enable these new coal plants to achieve capacity factors in the range of 80 - 85 percent, compared to the current average of about 72 – 75 percent. EIA projects that coal costs to electric generators will become increasingly cheaper than the alternatives through 2030,[28] and the cost advantages of new coal plants over the RE plants would thus be substantial.

Yet another question that arises concerns the relationship between the RE plants and the required backup plants – most of them likely to be natural gas. Once the backup plants and the expanded transmission lines are in place, there will be enormous economic pressure to maximize the less expensive electricity generation from the backup plants and minimize generation from the RE plants. The reason for this is that, when actual costs are considered, in 2020 RE also cannot compete with natural gas in the generation of electricity. Again, mandates could force the generation of the much more expensive RE electricity, but how long ratepayers would be willing to put up with this is questionable, since "economic laws have a way of enforcing themselves."

The bottom line is that the new transmission required by the RES could enable a large new tranche of inexpensive electricity generation from existing coal plants at about 5¢/kWh. New RE LCOEs are between 15¢/kWh and 75¢/kWh. So, once the transmission is in place, unless RE is mandated by law, there will be strong incentives to use RE much less than anticipated.

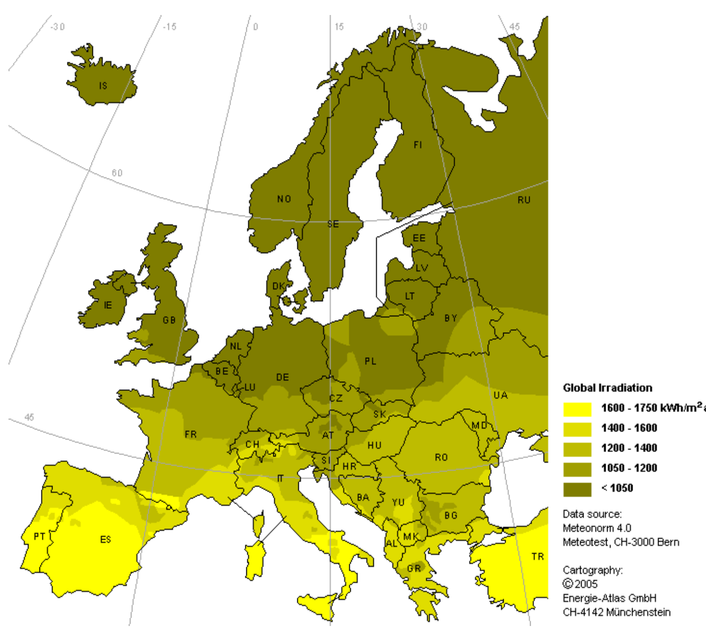
The RE technologies may be necessary to get the additional transmission built. However, once the transmission is in place, the RE plants will not be able to compete economically and may give a new definition to the term "stranded assets." At best, they may be used as fuel savers, but the costs of the fuel saved would be very high.

In sum, the mandated RES and the vast expansion of transmission lines required to achieve it could result in a large expansion in the generation of inexpensive electricity. However, this expansion may not be from the RE sources as the proponents of RES contend. Rather, the expanded, low cost electricity generation would result from the increased capacity utilization of the existing coal fleet enabled by the building of this new transmission – and perhaps by new coal plants facilitated by the additional transmission. These plants will be able to generate electricity at prices that are significantly cheaper than those of the RE technologies. Once this occurs, electricity consumers will strive to obtain access to this low cost electricity at the expense of the RE-generated electricity. How this inexpensive electricity and the costs of the RES are distributed among consumers, ratepayers, and taxpayers will likely be the subject of much legislative and regulatory debate.

These issues and concerns are not unique to the USA, and must be addressed if proposals for large additions of new transmission lines are made to facilitate expansion of renewable electricity generation in Europe. For example, as shown in Figure 6, Europe's solar energy resources are concentrated in the south and will require extensive transmission from the southeast and southwest to the industrial and population load centers in the northern and central parts of the EU. These transmission lines will, by necessity, pass in proximity to many conventional power plants, and this will raise the same issues for Europe as discussed here for the USA.

More specifically, our work has potential implications for the proposed Desertec Industrial Initiative (DII) -- a concept for making use of solar energy and wind energy in the deserts in North Africa and Middle East that was officially initiated in July 2009. Under the proposal, concentrating solar power systems, PV systems, and wind parks would be located on 17,000 km^2 in the Sahara Desert, and electricity would be transmitted to European and African countries by a super grid of high-voltage direct current cables – Figure 7. It would provide continental Europe with 15 percent of its electricity, and by 2050 investments in RE plants and transmission lines would total €400 billion.[29]

Figure 6
Europe Solar Energy Resource Map



[28]U.S. Energy Information Administration, op cit.

[29]The Desertec concept was initiated under the auspices of the Club of Rome and the German Trans-Mediterranean Renewable Energy Cooperation (TREC). It will be implemented by the consortium DII GmbH/Desertec Industrial Initiative, formed by a group of European companies and the Desertec Foundation. See www.desertec.org .

As shown in Figure 7, DII would require extensive transmission from Africa and the Middle East throughout Europe, and much of this additional transmission will be located in proximity to existing conventional power plants. This again raises the issues discussed here, and these must be thoroughly analyzed and vetted prior to investing €400 billion in the project.

Figure 7
The Desertec Initiative