2

Transmission bottlenecks affect national interests by increasing the cost of electricity to consumers and the risk of transmission system reliability problems in various regions throughout the United States. Relieving transmission bottlenecks is a regional issue. DOE will work in partnership with FERC, states, regions, and local communities to designate significant bottlenecks as national-interest transmission bottlenecks and take actions to ensure that they are addressed.

The National Interest in Relieving Transmission Bottlenecks

DOE believes that identifying and eliminating major transmission bottlenecks is vital to our national interest. National-interest transmission bottlenecks create congestion that significantly decreases reliability, restricts competition, enhances opportunities for suppliers to exploit market power, increases prices to consumers, and increases infrastructure vulnerabilities.

Transmission bottlenecks and the options to address them are regional in nature. When the consequences of bottlenecks become large, it is in the national interest to ensure that they are addressed in a timely fashion. Since no state has control or authority over regional transmission systems, the federal government has a role to play in identifying major bottlenecks and ensuring that they are addressed. The national interest is best served if DOE and FERC together work with states and regions to identify and address the most significant bottlenecks.

To begin the process of analyzing the effects of transmission bottlenecks on national interests, DOE conducted an independent analysis focusing on the impacts of transmission on regional electricity markets. Through the use of the POEMS model (see text box), DOE determined the location of major bottlenecks in both the Eastern and Western Interconnections and estimated the costs of these constraints to consumers.[10] DOE also estimated the benefits consumers currently receive from regional electricity markets.

Over the past year, there have been several national and regional studies that have highlighted congested transmission paths. DOE has also developed a list of congested paths and has compared it to those recently identified by FERC. Even though the studies were conducted using different methods, the patterns of congestion found in both studies are very similar.

DOE's current tools have identified a number of bottlenecks that may have significant impacts on national interests. More work and additional public input are required to develop a comprehensive set of tools and data needed to capture the full range of impacts of transmission bottlenecks on national interests, including the impacts on reliability and on the competitiveness of wholesale electricity markets.

[10]DOE's model does not consider congestion within single control areas such as ERCOT.

Policy Office Electricity Modeling System (POEMS)

DOE estimated the benefits of interregional wholesale power markets using the Policy Office Electricity Modeling System (POEMS). POEMS is a full-scale national energy model designed specifically to examine the impacts of electricity industry restructuring. The model includes significant economic, regional, and temporal detail that is needed to analyze the economics of interregional trade.

POEMS aggregates individual transmission lines to create a network of transmission paths that connect 69 subregions. The model represents the transmission system as a highway system—a series of paths between regions with a fixed amount of transmission capacity along each path. Trades are executed among the model's subregions based on the relative costs of generation in each subregion as well as the costs of executing each trade. A more detailed description of the model and its use in this study is provided in Appendix A.

POEMS is an important tool for assessing the economic consequences of electricity trade and identifying major transmission bottlenecks. However, it does not explicitly represent the physical flows of electricity over paths in response to the combined effects of all other flows on the system. Also, because it is national in scope, the model does not consider trade within subregions.

For the National Transmission Grid Study, POEMS was used to study:

- **Transmission bottlenecks as evidenced by the costs of transmission congestion among subregions**
- **The benefits of regional electricity markets today**
- **The benefits of regional electricity markets that would be enabled by eliminating rate pancaking.***

Results from the first two analyses are presented in this section; results from the third analysis are presented in Section 3, "Relieving Transmission Bottlenecks by Completing the Transition to Competitive Regional Wholesale Electricity Markets."

*In many regions, when electricity must be transmitted over multiple transmission systems, users must pay each owner/operator a separate fee for use of its transmission system. This is generally referred to as rate pancaking.

2

Major Eastern Transmission Bottlenecks

DOE's analysis confirms the tendency for transmission congestion to develop at many locations within the Eastern Interconnection. Out of a total of 186 transmission paths modeled in the East, 50 are used to their maximum capacity at some point during the year, and 21 paths are congested during more than 10 percent of the hours of the year.[11] The highest levels of congestion are found along transmission corridors from Minnesota to Wisconsin, the Midwest into

[11]As noted previously, POEMS generally does not represent individual transmission lines. Thus, the results presented in this study do not suggest that there is congestion on any particular transmission line but rather that there is congestion along transmission paths or corridors between subregions.

the Mid-Atlantic, from the Mid-Atlantic to New York, and from the Southeast into Florida.

In general, DOE's findings are very similar to historical data on transmission congestion, which also indicate that there is substantial congestion in the Midwest and upper Midwest, and from the Mid-Atlantic to the Northeast.[12]

DOE also found congestion in some areas where there have been few TLR events called, such as in the Southeast. DOE's analysis suggests that substantial congestion would result in these areas if there were greater volumes of economic wholesale electricity transactions. In particular, all of the transmission paths out of the Tennessee Valley Authority (TVA) would be congested at some point, and some would be congested roughly 15 percent of the time. Even more striking are the electricity flows that would take place from the Southeast into Florida; these lines would be congested during 40 to 80 percent of the hours of the year. (Figure 2.1)

DOE's findings are consistent with the comments of market participants who offered input to a recent FERC staff report on bulk-power markets in the Southeast.[13]

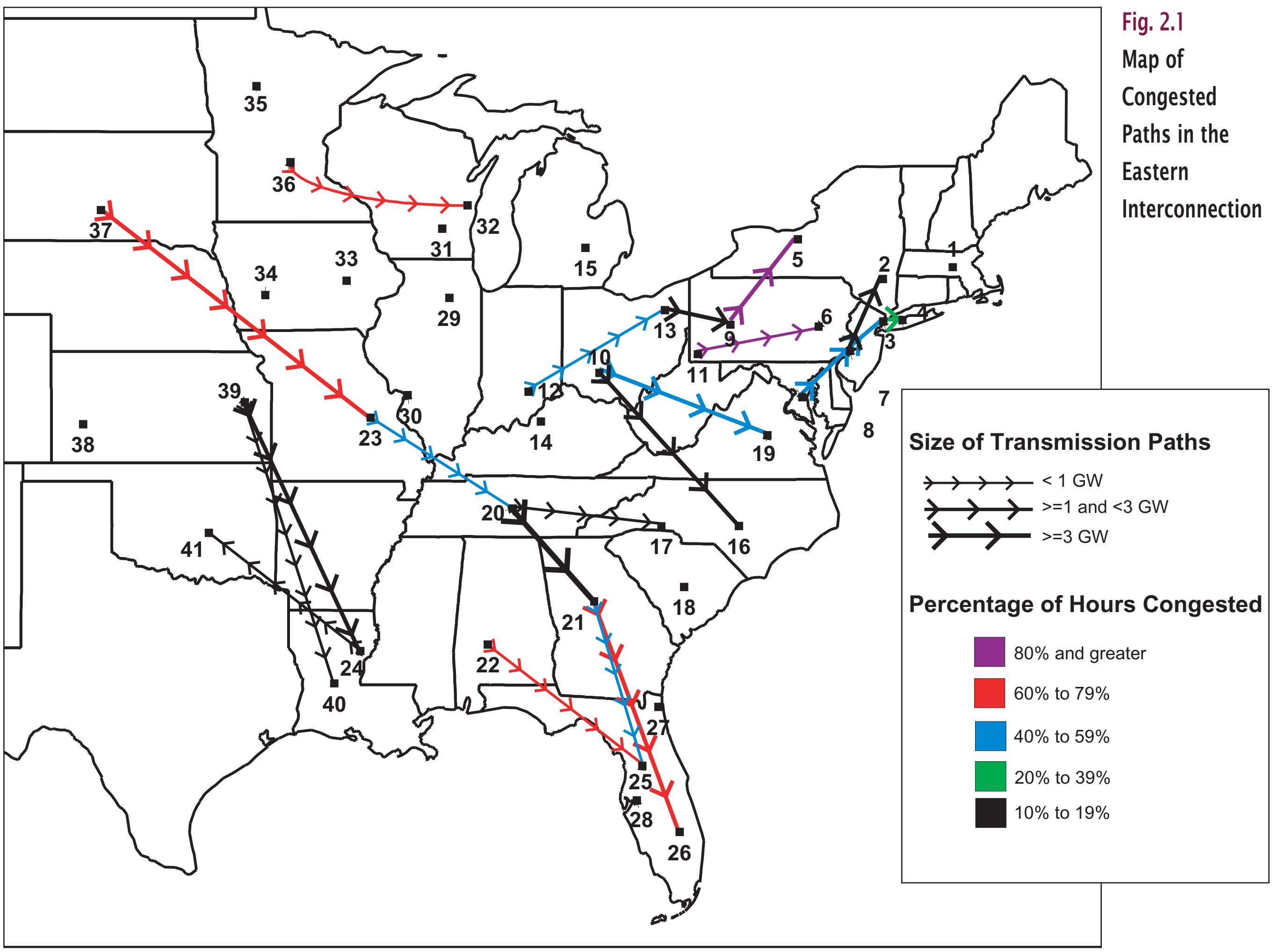


Fig. 2.1
Map of Congested Paths in the Eastern Interconnection

[12]This finding is based on a comparison of POEMS results and information on transmission loading relief (TLR) incidents that is routinely reported to NERC.

[13]FERC. 2000. *Investigation of Bulk Power Markets: Southeast Region*. Staff Report. Download from http://www.ferc.gov

Table 2.1

Hours of Congestion for Twenty Most Congested Paths				
EAST	Exporter*	Importer*	%Hrs Congestion per year	Path Size (GW)
1	ECAR	MAAC	89%	0.176
2	MAAC	NYPP	85%	2.605
3	SERC	FRCC	78%	0.536
4	MAPP	MAIN	73%	0.202
5	SERC	FRCC	71%	2.837
6	MAPP	SERC	65%	1.178
7	ECAR	SERC	58%	2.175
8	MAAC	NYPP	50%	2.797
9	ECAR	ECAR	48%	0.765
10	MAAC	MAAC	48%	2.866
11	SERC	FRCC	44%	0.581
12	SERC	SERC	43%	0.408
13	NYPP	NYPP	22%	1.143
14	SERC	SPP	19%	0.866
15	SPP	SPP	19%	0.398
16	ECAR	MAAC	16%	1.643
17	MAAC	NYPP	16%	1.191
18	ECAR	SERC	14%	1.500
19	SERC	SERC	14%	0.552
20	SERC	SERC	14%	3.468
WEST				
1	NWP	NWP	59%	0.044
2	NWP	NWP	51%	0.337
3	NWP	CNV	41%	1.200
4	NWP	CNV	39%	3.100
5	NWP	CNV	38%	0.300
6	CNV	NWP	36%	0.083
7	NWP	NWP	35%	0.300
8	NWP	NWP	32%	1.250
9	NWP	NWP	26%	0.044
10	NWP	RA	22%	0.390
11	CNV	NWP	19%	3.100
12	RA	RA	19%	0.485
13	CNV	CNV	17%	0.637
14	CNV	CNV	16%	3.000
15	NWP	NWP	14%	0.359
16	CNV	CNV	8%	3.000
17	RA	RA	6%	0.690
18	CNV	RA	5%	1.300
19	NWP	NWP	4%	1.560
20	RA	NWP	3%	0.900

*See Appendix A for acronyms.

The Southeast includes more generation owned by vertically integrated, investor-owned utilities than any other region of the country, and many independent power producers and marketers believe these utilities are preventing equal and open access to the transmission systems in this region.

In its report, FERC identified a number of barriers to wholesale electricity trade in this region, including: uncertainty in transmission access, inconsistent posting and withholding of available transfer capability, and the lack of consistency when implementing transmission loading relief protocols. Utilities in the Southeast report that the absence of coordinated generation and transmission planning has led to new generation that has been built in areas that contribute to congestion. Hence, although FERC could not verify the basis for all of the concerns expressed, market participants perceive that these problems exist and discourage investment and wholesale trade in the region.

In addition, trading into the Southeast power market is difficult. Due to its location, the Tennessee Valley Authority (TVA) controls the majority of transmission access into and out of the region. Although TVA is largely exempt from FERC regulation, it voluntarily provides open access to its transmission system. However, TVA and various suppliers in the market continue to disagree over access to the transmission system.

Strengthening the Interconnection between ERCOT and the Eastern Interconnection

In 1999, the Texas Public Utility Commission completed a study evaluating the most economical, reliable, and efficient means to interconnect the transmission facilities in the Electric Reliability Council of Texas (ERCOT) with those in the Southwest Power Pool within the Eastern Interconnection. The study determined the costs and reliability concerns associated with a hypothetical scenario of six inter-ties. It also discussed the state and federal jurisdictional issues that would need to be addressed. The final report, while very detailed, was not able to draw a firm conclusion regarding the desirability of greater interconnection.

The study found that total costs for the interconnection facilities alone would be between $300 and $350 million in 1997 dollars. It also identified additional costs, which are difficult to quantify, that would be imposed upon utilities and generators based on operating characteristics of the combined grid.

Since the study was completed, between 10,000 and 20,000 megawatts of new generation have been brought on line in Texas, new transmission lines have been completed, and the retail market has opened.

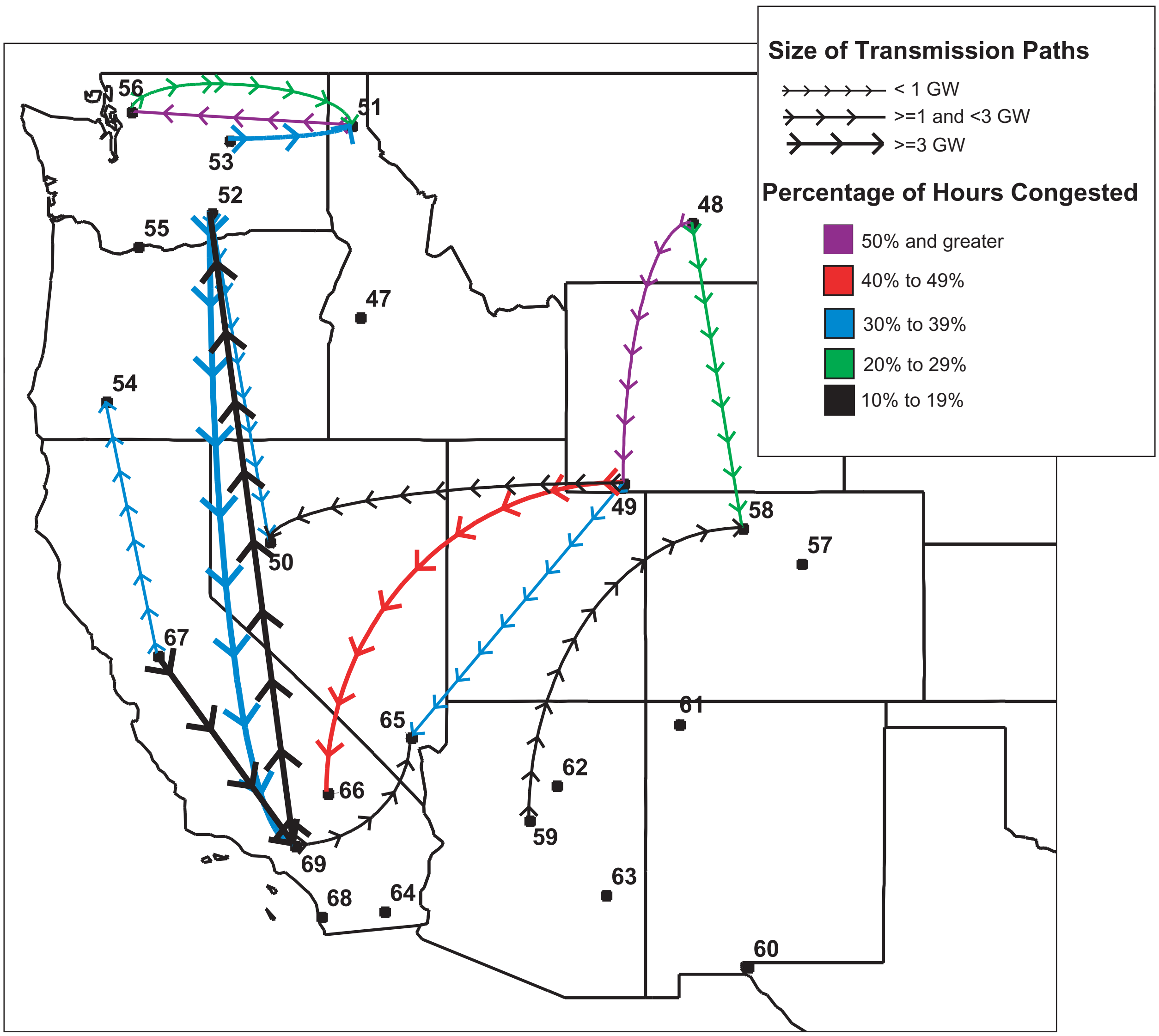
With reserve margins as high as 31 percent in ERCOT, generators may begin a renewed push for the opening of additional markets for their power. It may be time to conduct a new study that evaluates alternatives, including additional AC interconnections, new DC interconnections, as well as expansion of existing ties.

Source: Synchronous Interconnection Committee. 1999. *Feasibility Investigation for AC Interconnection between ERCOT and SPP/SERC.* Report to the 76th Texas Legislature.

Major Western Transmission Bottlenecks

Electricity trading patterns and transmission congestion are somewhat different in the West than in the East for several reasons. First, the transmission system in the West, unlike the one in the East, was built primarily to carry power over long distances. Several large power plants in the West were intentionally built in remote locations; along with these plants, owners constructed high-voltage transmission lines to ship power to densely populated load centers.[14]

Fig. 2.2
Map of Congested Paths in the Western Interconnection



[14]For example, the Palo Verde nuclear plant was built in southern Arizona in part to serve load in southern California. Similarly, the Intermountain Power Project, a 1,640-megawatt coal plant in Utah, was built to serve a number of municipalities in Utah and in California, including Los Angeles. A 490-mile transmission line connects the plant to southern California.

In addition, the Pacific Northwest is dominated by hydroelectric power. The amount of water available for hydropower generation in this area is greatest during the spring and summer when runoff from snow pack is highest; however, electricity demand in the region is greatest during winter. During spring and summer, the Pacific Northwest sells its excess electricity to California and other western states. During the winter, the Pacific Northwest purchases excess power from these areas. For the purpose of these transactions, a large direct current (DC) transmission line links southern California and the Bonneville Power Administration (BPA) in Oregon.

As a result of these patterns of supply and demand, utilities in the West rely substantially more on transporting electricity over long distances to meet local demand than is commonly the case in the East. Electricity trade as a percentage of demand in the West reaches nearly 30 percent during some periods, compared to only 15 percent in the East. Because the transmission system in the West was specifically designed to support these imports and exports, there is less interregional congestion overall in the West. Of the 106 western transmission paths represented in POEMS, 37 are congested at some point during the year, half of these are congested less than 10 percent of the time, and no path is congested more than 60 percent of the hours during the year.[15] (Figure 2.2)

2

The Costs of Transmission Congestion

DOE estimated in two steps the costs of congestion in four U.S. regions where independent system operators manage wholesale electricity markets: California, PJM, New York, and New England.[16] In the first step, DOE used POEMS to examine the cost reductions that would occur if increased electricity transfers across congested paths were allowed in these four regions, under the assumption that all generators bid their marginal operating cost. Under this assumption, consumer costs for electricity decline by $157 million per year.

In the second step, DOE calculated the increase in congestion costs (costs to consumers) under the assumption that generators bid above their marginal operating costs when supplies are tight and additional electricity cannot be imported, leading to price spikes. For this calculation, price spikes were assumed to occur during the hours when at least one transmission link

[15]POEMS does not consider congestion within the subregions in the West. Consequently, congestion on California's Path 15, which is within a subregion, is not assessed by POEMS.

[16]Since ISO New England is represented in POEMS as a single subregion, increased costs resulting from congestion within New England are not reflected in the analysis. Instead, the estimates reported here include only the increased costs due to congestion into New England. For the other three regions, the estimates reflect costs arising from congestion into and within the region. See Appendix A for additional discussion of DOE's analysis using POEMS.

into a subregion was congested and demand was greater than 90 percent of peak demand. When prices spike an additional $50 per MWh (above the price predicted when generators bid their marginal operating cost) during these periods, congestion costs nearly double to $300 million. When prices spike an additional $100 per MWh during these periods, congestion costs nearly triple to $447 million. This calculation is a conservative estimate of congestion costs. Recently, FERC estimated costs for 16 individual constraints that ranged up to more than $700 million for a handful of recent summer months (see text box).[17, 18]

It is important to note that DOE's findings do not address transmission bottlenecks that may exist within subregions. For example, all of New England is represented as a single subregion within the model, so benefits from trade within New England are not reflected in the analysis. ISO New England estimates the costs of congestion in New England are $125–600 million per year.[19] California's Path 15, which is often congested, is also not specifically represented in POEMS. The California ISO (CAISO) estimates that the cost of congestion created by a single transmission corridor, Path 15, was $222 million over the 16 months prior to December 2000.[20]

FERC Electric Transmission Constraint Study

On December 19, 2001, FERC presented findings from an analysis of transmission constraints in the U.S. FERC staff identified 16 constraints (see map) across the nation characterized by either:

- **A large number of Transmission Load Relief (TLR) events (instances when market sales cannot be executed because of transmission constraints, which forces operators to use more expensive local energy rather than less expensive imported energy), or**
- **High price differentials across an interface (where the delivered energy price inside an area is higher than the price of energy at the same moment outside that area).**

FERC estimated the economic cost of transmission congestion during the months of June through August 2000 and 2001 using actual data on the number of hours during which a specific transmission interface was constrained, the amount of energy that was redispatched in each congestion event, and the costs of imported and replacement energy in each of these hours.

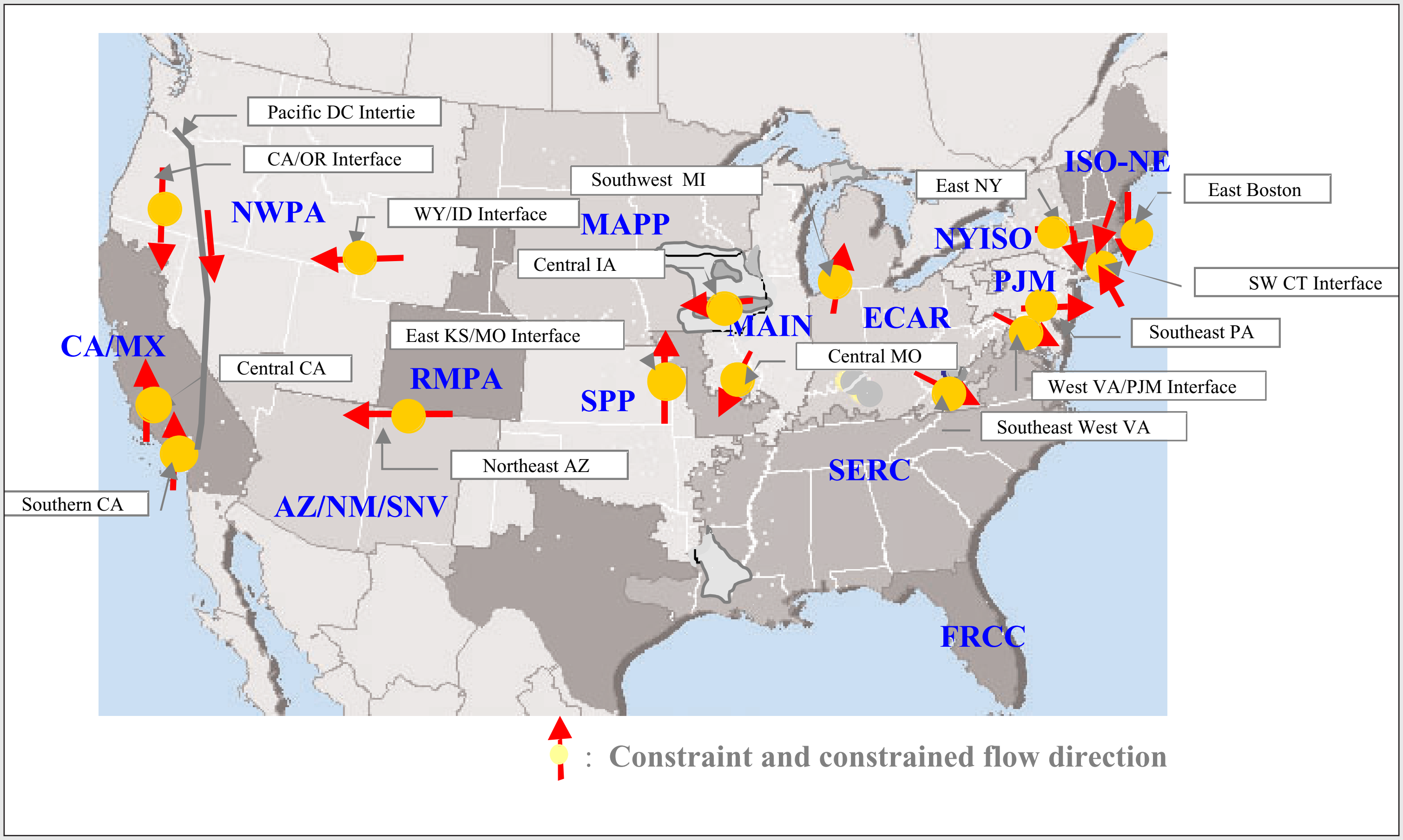
[17]Federal Energy Regulatory Commission. 2001. *Electric Transmission Constraint Study*. Division of Market Development. Download from http://www.ferc.gov

[18]Although DOE's analysis and FERC's analysis are not strictly comparable because of differences in the methods used, their findings are generally consistent. FERC's analysis is based on actual market prices and does not reflect price changes that would occur on both sides of a constrained transmission link if additional electricity could be traded. As a result, FERC's estimates are likely to be somewhat higher than DOE's.

[19]ISO New England. 2001. *2001 Regional Transmission Expansion Plan*. Download from http://www.iso-ne.com

[20]California Independent System Operator. 2001. *Testimony of Armando J. Perez, Stephen Thomas Greenleaf, and Keith Casey. Conditional Application of Pacific Gas and Electric Company for a Certificate of Public Convenience and Necessity Authorizing the Construction of the Los Banõs-Gates 500 kV Transmission Project. Application 01-04-012*. California Public Utilities Commission. Download from http://www.caiso.com.

Transmission Constraints in Contiguous U.S.



FERC found that the costs of individual constraints for these months generally ranged from less than $5 million to more than $50 million. However, for one particular set of conditions in the eastern portion of New York during the summer of 2000, FERC estimated a cost of more than $700 million.

Source: FERC. 2001. *Electric Transmission Constraint Study.* Division of Market Development. Download from http://www.ferc.gov

Finally, POEMS does not analyze reliability benefits. Increased transmission capacity will generally improve the overall reliability of the grid and allows regions to share capacity reserves. Although the risk of blackouts is generally small, blackouts usually entail very high economic costs. As such, even a small reduction in the risk of a blackout will have substantial benefits.

The POEMS analysis offers minimum estimates of the benefits of vibrant wholesale markets to the consumer. However, the trend is clear: transmission bottlenecks today compromise important national interests in efficient regional wholesale electricity markets and reliable transmission systems.

The Benefits of Wholesale Electricity Markets Today

In addition to the costs of specific bottlenecks, DOE found that today's wholesale electricity markets save consumers nearly $13 billion per year in electricity costs. In other words, the nation's current $224 billion annual electricity bill would be $13 billion higher without these wholesale shipments of electricity. On average, wholesale power transactions reduce generation costs by approximately $370,000 per hour in the East and by more than $1,000,000 per hour in the West. These savings translate directly to lower prices for consumers. Average wholesale electricity prices are roughly 12 percent lower as a result of interregional trading.[21] (Figure 2.3)

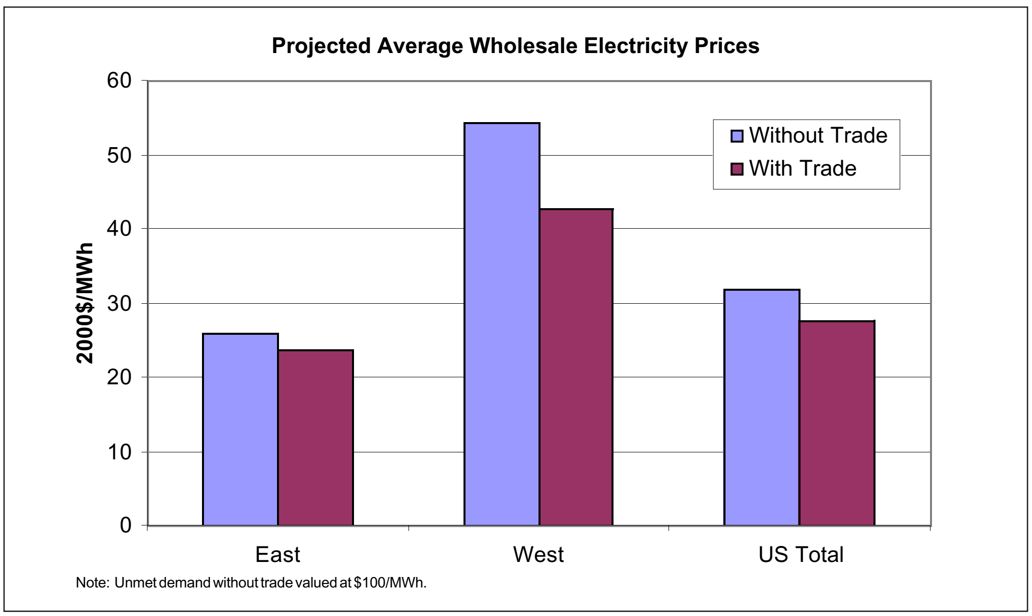


Fig. 2.3
Electricity Prices (by Interconnection) With and Without Interregional Electricity Trading

Next Steps Toward Relieving Transmission Bottlenecks

DOE's analysis has confirmed the tendency for transmission lines to become congested in many locations across the U.S. The consequences of this congestion warrant additional scrutiny to determine the extent to which national interests are jeopardized. In particular,

[21]This estimate includes the savings due to all electricity trade among the 69 subregions in the model. It does not distinguish increased trade due to wholesale competition from economy trades that routinely occurred among neighboring utilities prior to FERC Orders 888 and 889.

DOE has not assessed the impacts of congestion on market power and reliability.

Successfully addressing transmission bottlenecks requires careful analysis and consideration of their impacts on both market operations and system reliability, as well as analysis of the costs of transmission and non-transmission alternatives. In other words, removing bottlenecks is not simply a matter of finding "congested" transmission paths and then reinforcing existing transmission facilities along those paths or constructing new facilities. Because the system is a network, reducing congestion in one part of the system may shift it to another (the next-most-vulnerable) part. Congestion also tends to move around the system from year to year and in response to weather and other seasonal factors.

In addition, solving the problem of transmission constraints within the United States will also require cooperation with Canada. Many scheduled power transactions within the U.S., particularly east-to-west transactions within the Eastern Interconnection, flow over transmission lines located in Canada before reaching loads in the U.S. This is a particular problem at points in the upper Midwest where the transmission systems of the two countries interconnect. These unintended flows (or "loop flows") often require transmission service curtailments in the U.S.

The benefit of increasing transmission capability to increase economic trade depends on relative electricity prices in the regions linked by the additional capacity and on the additional amount of electricity that

The Cost of Reliability—August 10, 1996, Power Outages in the Western States

The blackout in the western states on August 10, 1996, was a complex and dramatic reminder of the importance our modern society places on reliable electricity service. Ultimately, power was interrupted to approximately 7.5 million customers, for periods ranging from a few minutes to about nine hours. Immediate costs to the region's economy were estimated at $2 billion.

The August 10 outages were caused by multiple transmission line failures over a period of several hours. A single transmission line failure is a contingency that is routinely considered in reliability planning. However, the failure of several lines, combined with the day's pattern of operation, caused the system to become unstable (which had not been anticipated by reliability planners), which in turn, caused automatic controls to open the California-Oregon Intertie, a major link between the northern (Pacific Northwest) and southern (California) portions of the western system. Opening the Intertie produced a power surge from the Pacific Northwest through the eastern portion of the grid toward Arizona and southern California, causing many lines to disconnect automatically and eventually fracturing the western grid into four separate electrical "islands." Within each island, large blocks of customers lost power when their electricity demands suddenly exceeded available local generation. The situation was worst in the southern island where automatic controls disconnected over 90 generators to prevent them from being further damaged. Some of the larger units were out of service for several days.

Source: J. Hauer and J. Dagle, 1999. *Review of Recent Reliability Issues and System Events*. Report PNNL-13150.
Download from http://www.eren.doe.gov/der/transmission/pdfs/reliabilityevents.pdf

would be traded on the new lines. If price differences are small and the added transmission capacity would be used during only a small percentage of the hours during the year, then the cost of a new transmission line may not be justified.[22]

However, the benefits of increasing transmission capability to ensure reliability, even if this insurance is used only once to prevent a system-wide blackout, would be enormous and could far outweigh any potential gains from increased trade. Similarly, increasing transmission capability to reduce the ability of a competitor to exert market power could lead to benefits far in excess of those gained from increased trade.

Because assessing these issues will involve tradeoffs, for example, commerce versus reliability, and local versus regional benefits, it is critical that DOE develops an open public process to weigh the various interests. Once it is determined that the benefits of addressing bottlenecks outweigh the costs, DOE must work with regions, states, and localities to ensure that these bottlenecks are remedied appropriately.

Path 15—Example of Federal Leadership

Path 15 is an 84-mile stretch of electrical transmission lines in the central valley of California connecting the northern and southern portions of the state. The federal government's recent efforts to increase transfer capacity on this path illustrate both the role for responsible federal leadership to address bottlenecks affecting national interests and how these bottlenecks might be addressed through private investment.

Capacity on Path 15 is sometimes insufficient and has contributed to rolling blackouts in the state. The California ISO has estimated that congestion on Path 15 resulted in up to $222 million in increased electricity costs to customers in California during the 16-month period ending December 31, 2000.

In May 2001, U. S. Energy Secretary Spencer Abraham directed the Western Area Power Administration (WAPA) to complete planning for upgrading Path 15 and to determine whether outside parties would be interested in helping finance and co-own the new transmission line.

In June, WAPA requested Statements of Interest and 13 entities responded. In October 2001, Secretary Abraham announced a $300 million agreement to upgrade Path 15 with WAPA and other participants from the public and private sectors.

The proposed upgrade will add a third 500-kilovolt transmission line to the existing two lines and make other improvements. The upgrade will increase the capacity of Path 15 by an estimated 1,500 MW, enough power for two million households, and could come on line as early as summer 2004.

[22]Building new transmission lines is not the only strategy to reduce congestion; as subsequent sections in this report discuss, many steps can be taken to relieve transmission bottlenecks that may avoid or delay the need to construct new transmission facilities.

DOE believes that the federal government should facilitate the process of energy-market participants seeking appropriate solutions to transmission bottlenecks. The recommendations in the following sections of this report identify actions that are needed to address transmission bottlenecks, based on this perspective.

DOE expects that these actions alone will go a long way toward addressing the most important of transmission bottlenecks—those affecting significant national interests. In view of the national interests at stake, the federal government must stand ready to take additional action if the efforts of others prove inadequate. Toward this end, DOE has an ongoing responsibility to assess how transmission bottlenecks affect the national interests as well as to monitor progress in addressing bottlenecks.

RECOMMENDATIONS

- DOE, through a rulemaking, will determine how to identify and designate transmission bottlenecks that significantly impact national interests.
- DOE will further develop the analytic tools and methods needed for comprehensive analysis to determine national-interest transmission bottlenecks.
- In an open public process, DOE will assess the nation’s electricity system every two years to identify national-interest transmission bottlenecks.