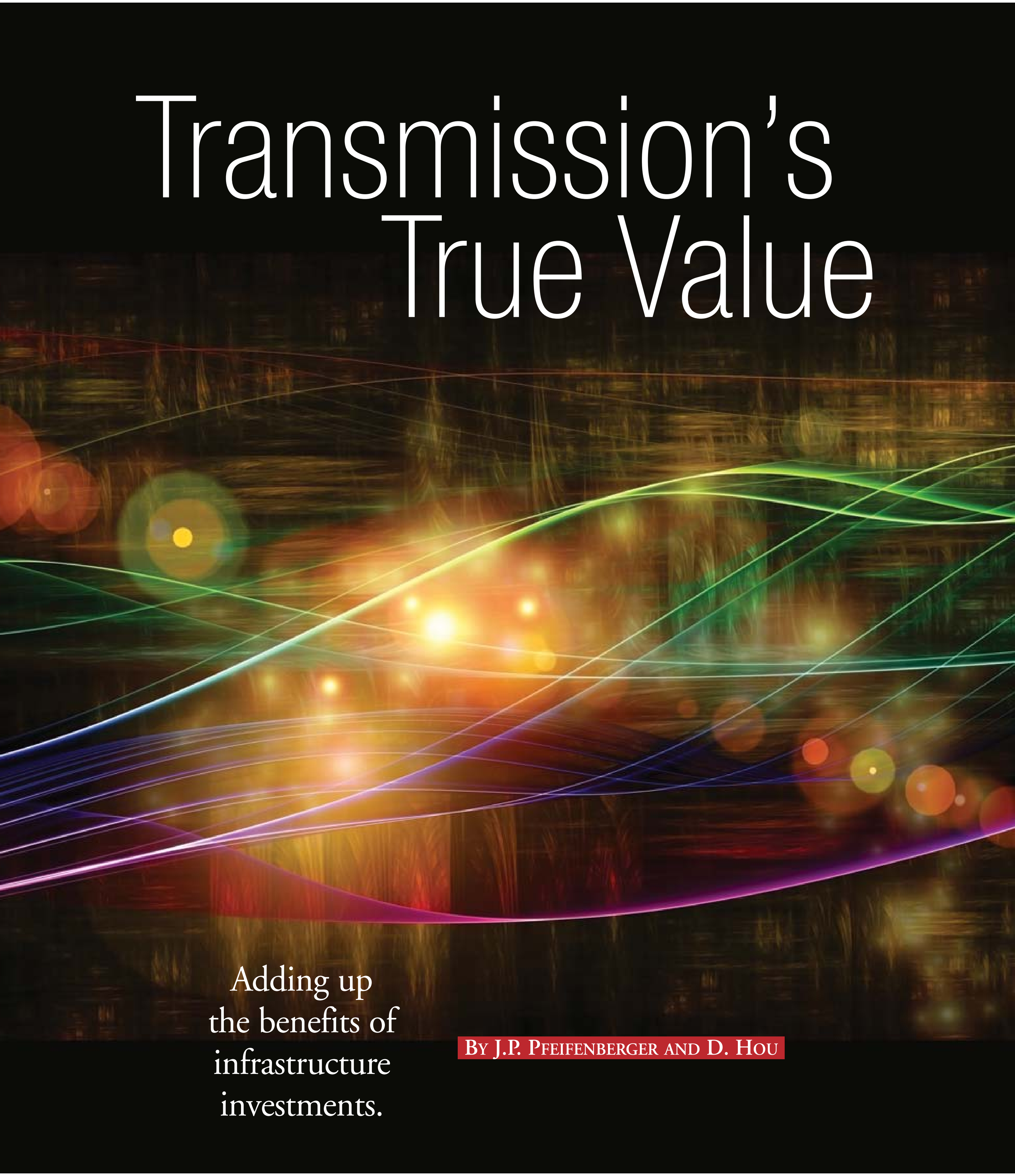
Transmission's True Value



Adding up the benefits of infrastructure investments.

By J.P. Pfeifenberger and D. Hou

The allocation and recovery of transmission costs has proven to be a significant barrier for major regional and interregional transmission projects in many power markets. Attempts to address this barrier often lead to heated discussions over the merits of beneficiary-pays approaches and "socialized" recovery of the transmission investments. In that context, FERC Order 1000 now requires that the allocation of transmission costs be "at least roughly commensurate" with estimated benefits. With the additional mandate that regional and interregional grid planning efforts also consider transmission needs driven by public policy requirements, this places new emphasis on the identification and quantification of transmission benefits.

Benefits of transmission investments range from increased reliability to decreased transmission congestion and generation costs, as well as risk mitigation, renewables integration, economic development, and increased competition in power markets. These benefits often are spread geographically across multiple utility service areas and states, and are diverse in their effects on market participants. They also occur and change over the course of several decades. In fact, the benefits we derive from today's transmission grid, such as the ability to operate competitive wholesale electricity markets, could barely be imagined when the facilities were built four or five decades ago.

Relying solely on easily-quantifiable production cost savings can lead to the rejection of otherwise beneficial transmission projects.

The post-construction assessment of the Arrowhead-Weston transmission line in Wisconsin, which was energized in 2008 by American Transmission Co. (ATC), exemplifies the broad range of benefits associated with an expanded transmission infrastructure. The primary driver of the Arrowhead-Weston line was to increase reliability in northwestern and central Wisconsin by adding another high-voltage transmission line in what the federal government designated at the time as "the second-most constrained transmission system interface in the country."[1] The project addressed this reliability issue by adding 600 MW of carrying capacity and improving voltage support, the impact of which was noticeable in both Wisconsin and in southeastern Minnesota.

ATC estimated that by also reducing congestion, the line allowed Wisconsin utilities to decrease their power purchase costs, saving $94 million in net present value terms over the next 40 years. Similarly, ATC estimated that $1.2 million have been saved in reduced costs for scheduled maintenance since the Arrowhead-Weston line went into service. The high voltage of the line (345 kV) also reduced on-peak energy losses on the system by 35 MW, which reduced new generation investments equivalent to a 40 MW power plant. The reduced losses also avoid generating 5.7 million MWh of electricity, which reduces CO_2 emissions by 5.3 million tons over the initial 40-year life of the facility. In addition, the transmission line has the capability to deliver hydro resources from Canada and wind power from the Dakotas and interconnect local renewable generation to help meet Wisconsin's RPS requirement. The construction of the line supported 2,560 jobs, generated $9.5 million in tax revenue, created $464 million in total economic stimulus and will provide income to local communities of $62 million over the next 40 years. The increased reliability of the electric system has provided economic development benefits by improving operations of existing commercial and industrial customers and attracting new customers. Lastly, the Arrowhead-Weston line also provides insurance value against extreme market conditions, as was illustrated in a NERC report noting that if Arrowhead-Weston had been in service earlier, it would have averted blackouts in the region which impacted an area from Wisconsin and Minnesota to western Ontario and Saskatchewan, affecting hundreds of thousands of customers.

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The range of the benefits addressed in ATC's study substantially exceeds the range of benefits typically quantified or even discussed in most transmission benefit-cost analyses. Too often, such analyses leave out important transmission benefits simply because the broad range of the benefits and long time frame over which they accrue makes it very difficult to quantify their full extent. As the FERC noted: "[C]ost-benefit analyses often evaluate benefits at a distinct point in time. Because power flows change constantly with fluctuations in generation and load, as

Fig. 1 Often-Overlooked Transmission Benefits

1. Enhanced market competitiveness 2. Enhanced market liquidity	Additional market benefits
3. Economic value of reliability benefits 4. Added operational and A/S benefits 5. Insurance and risk mitigation benefits	Reliability and operational benefits
6. Capacity benefits 7. Long-term resource cost advantage 8. Synergies with other transmission projects	Investment and resource cost benefits
9. Impacts on fuel markets 10. Environmental and renewable access benefits 11. Economic development and public policy benefits	Economy-wide benefits

well as the addition of new transmission facilities, generation resources, and loads to the system, such static analyses cannot capture all benefits over time. Therefore, relying solely on the costs and benefits identified in a quantitative study at a single point in time may not accurately reflect the [benefits] of a given transmission facility, particularly because such tests do not consider any of the qualitative, (*i.e.*, less tangible) regional benefits inherently provided by an EHV transmission network. No single analytical study can reflect future needed expansions to the electric grid to support regional power flows as system conditions change and the manner in which the function of earlier expansions will change once integrated with future expansions."[2]

In fact, the industry has tended to over-rely on formulaic analytical frameworks that capture easy-to-quantify benefits such as production cost savings, but generally don't consider the fuller range of benefits that improved transmission infrastructure can provide. This is exacerbated by the fact that types and magnitudes of transmission benefits are highly specific to the nature of individual projects and the regional power market in which they operate.

As examples from transmission benefit-cost analyses show, while formulaically derived or easily quantified benefits often are too low to justify an investment, the sum of all identified benefits often significantly exceeds the cost of the projects.

Production Cost and Load LMP

The most commonly quantified economic benefits of transmission investments are reductions in simulated fuel and other variable operating costs of power generation, generally referred to as "production cost" savings, and the impact on wholesale electricity market prices at load-serving locations of the grid—*i.e.*, locational marginal prices (LMP). These production cost savings and load LMP benefits typically are estimated with models that simulate generation dispatch and power flows subject to defined transmission constraints. In a recent assessment of RTO performance by the FERC, the majority of RTOs cited reduced congestion as a main benefit from expanding transmission capacity. For example, PJM noted that market simulations of recently approved high-voltage upgrades indicate that the upgrades will reduce congestion costs by approximately $1.7 billion compared to congestion costs without these upgrades.[3]

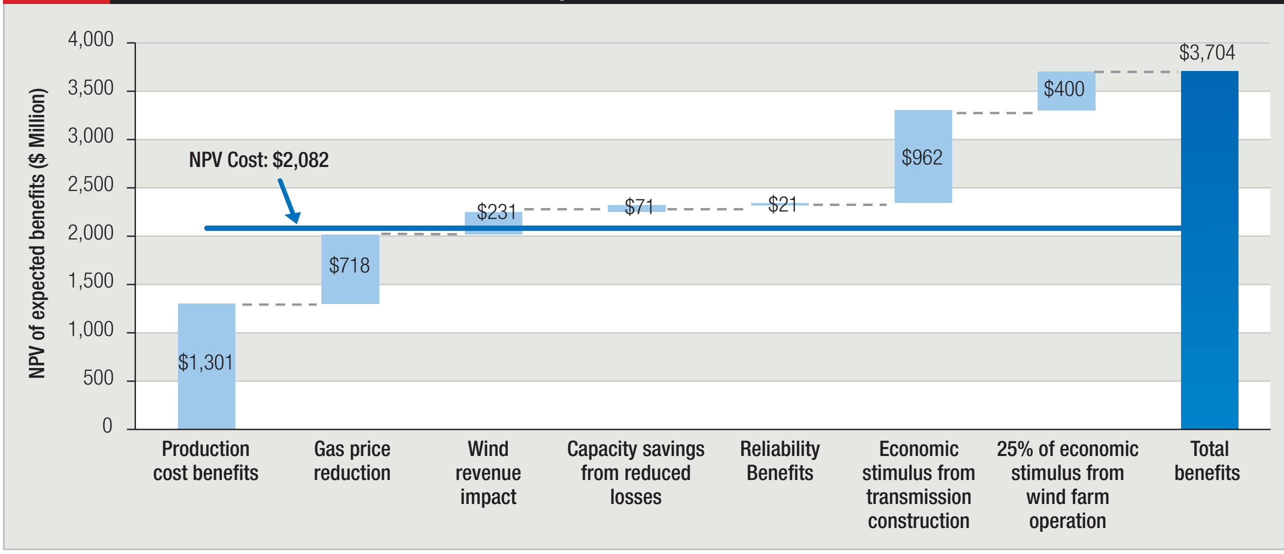
The addition of new transmission facilities often also will reduce energy losses incurred in the transmittal of power from generation resources to loads. Due to limitations in simulation models, the full benefits associated with reduced transmission losses generally aren't captured in estimates of production cost savings.[4] The economic benefits associated with the extent to which major transmission projects reduce transmission losses can be surprisingly large. For example, the economic benefits of reduced losses associated with a single 345 kV transmission project in Wisconsin were sufficient to offset roughly 30 percent of the project's investment costs.[5] Similarly, in the case of a recently proposed 765 kV transmission project, the present value of reduced system-wide losses equated to roughly half of the project's cost.[6]

Benefits from the grid today, such as competitive electricity markets, could barely be imagined when the facilities were built four or five decades ago.

While production-cost savings are easily quantified with standard production cost simulation models, often it isn't understood that these models quantify only the short-term dispatch-cost savings of system operations. They can't capture a wide range of other transmission-related benefits, including generation-related investment-cost savings. For example, a Western Electric Coordinating Council (WECC) planning group recognized, "The real societal benefit from adding transmission capacity comes in the form of enhanced reliability, reduced market power, decreases in system capital and variable operating costs and changes in total demand. The benefits associated with reliability, capital costs, market power and demand are not included in this [type of production cost simulation] analysis."[7]

In fact, the "benefits associated with reliability, capital costs, market power and demand" often are omitted entirely in transmission cost-benefit analyses because they aren't readily quantifiable with standard simulation tools. Because these benefits often are more difficult to quantify than production cost and load LMP impacts, they are sometimes discounted as so-called "soft" benefits and often dismissed as "unquantifiable" or "intangible" *(see Figure 1)*.[8]

FIG. 2 **TOTAL BENEFITS QUANTIFIED FOR SPP'S PRIORITY PROJECTS**



Source: The Brattle Group

Competition and Liquidity

Production cost simulations generally assume generation is bid into wholesale markets at variable operating costs, which doesn't account for the fact that bids will include mark-ups over variable costs, particularly in real-world wholesale power markets that are less than perfectly competitive. Thus, wholesale power market benefits of transmission investments generally will exceed the benefits quantified in cost-based simulations.

Transmission investments can enhance the competitiveness of wholesale electricity markets by broadening the set of suppliers that compete to serve load. While the magnitude of savings depends on market concentration and how much load is served at market-based rates—rather than through cost-of-service regulated generation—studies have found that the economic value of increased competition can reach 50 percent to 100 percent of a project's costs.[9] This benefit is explicitly considered in the California ISO's economic transmission planning methodology. ISO New England also recently noted that increased transmission capacity into constrained areas such as Connecticut and Boston have significantly reduced congestion, "thereby significantly reducing the likelihood that resources in a submarket could benefit from the exercise of market power."[10]

Similarly, limited liquidity of wholesale electricity markets also imposes transaction costs and price uncertainty on both buyer and sellers. These transaction costs and price uncertainties are higher in markets with less liquidity. Transmission expansion can increase market liquidity by increasing the number of buyers and sellers able to transact with each other. This will lower the bid-ask spreads of electricity trades, increase pricing transparency, and provide better clarity for long-term planning and investment decisions. For example, bid-ask spreads for bilateral trades at less-liquid hubs are 50 cents to $1.50 per MWh higher than the bid-ask spreads at more liquid hubs.[11] At transaction volumes ranging from less than 10 million to over 100 million MWh per quarter at each of more than 30 electricity trading hubs, even a 10 cent per MWh reduction of bid-ask spreads due to a transmission-investment-related increase in market liquidity saves $4 million to $40 million per year and trading hub, which would amount to transactions cost savings of approximately $500 million annually on a nationwide basis.

Reliability and Operations

Transmission investments, even if not driven by reliability concerns, will generally increase reliability on the power system. This increase in reliability provides economic value by reducing service curtailments and avoiding high-cost outcomes during extreme system conditions. The cost of reliability problems and their expected unserved energy can be measured with estimates of the value of lost load, which can exceed $5,000 to $10,000 per curtailed MWh.[12] The high value of lost load means that avoiding even a single reliability event that results in a blackout would provide savings that range from tens of millions to billions of dollars.

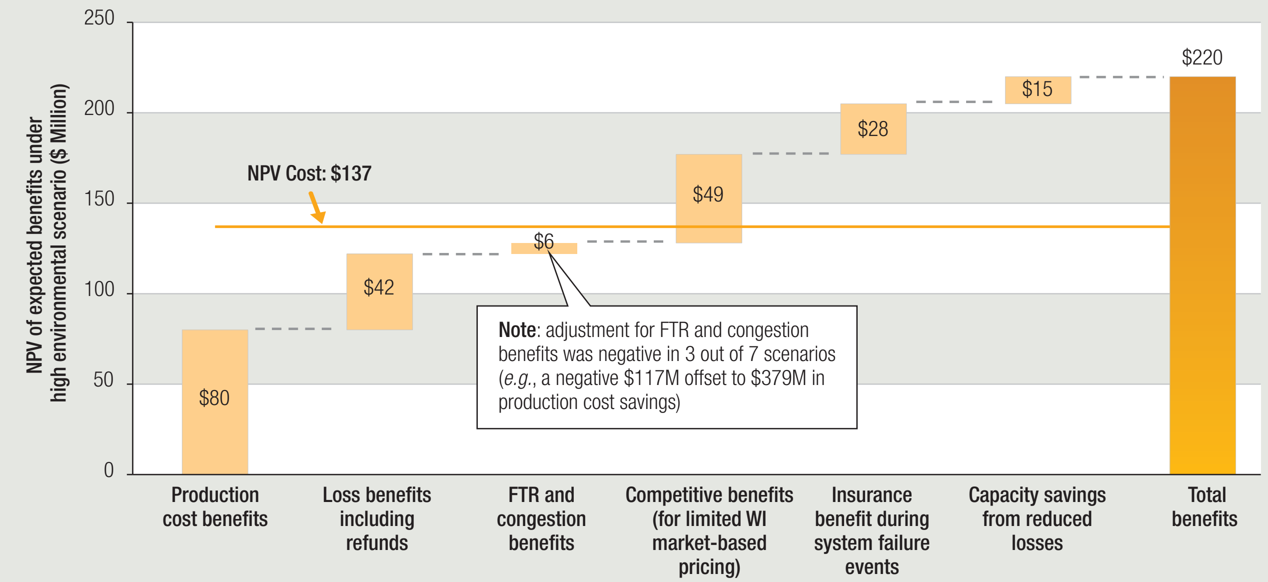
Transmission investments can easily reduce the cost of wind generation by one quarter.

In addition to reducing the frequency and magnitude of possible blackouts, transmission investments can reduce reliability-related operating costs, which tend to add significantly to congestion costs but often aren't captured in production cost simulations.[13] Transmission also can reduce the demand and cost of ancillary services, a benefit that will grow in importance as the penetration of variable generation resources such as wind expands.

By also reducing the high generation dispatch and power pur-

FIG. 3 TOTAL BENEFITS QUANTIFIED FOR ATC'S PADDOCK-ROCKDALE PROJECT

(Note: Shows results for only one scenario; production cost benefits alone exceeded project costs in 5 out of 7 scenarios)



Source: The Brattle Group

chase costs incurred during reliability events or challenging market conditions, transmission upgrades provide insurance against the impacts of extreme events, such as unusual weather conditions, fuel shortages, or multiple generation and transmission outages. For example, the chair of the CAISO Market Surveillance Committee estimated that if significant additional transmission capacity had been available during the California energy crisis from June 2000 to June 2001, its value would have been as high as $30 billion over this 12 month period.[14] Similarly, a detailed analysis of the insurance benefit of a 345 kV transmission project found that the project's probability-weighted savings from reducing the impacts of extreme events equated to approximately 20 percent of the project's costs.[15]

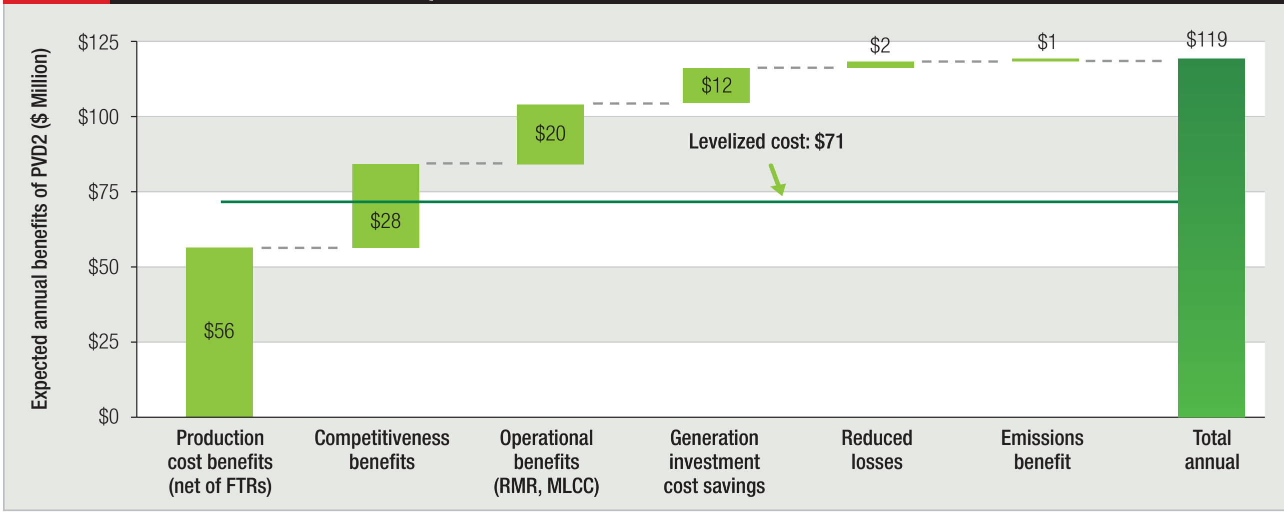
Investment and Resource Costs

Transmission projects can provide investment and resource cost benefits by displacing or delaying otherwise needed capital investment, allowing the integration of lower-cost generation resources, and reducing the cost—or increasing the value—of subsequent transmission projects. For example, transmission investments that allow the integration of wind generation in locations with a 40 percent average annual capacity factor reduce the investment cost of wind generation by one quarter compared to the investment requirements of wind generation in locations with a 30 percent capacity factor.[16] Transmission investments also might allow the development of generation with lower fuel costs—*e.g.*, mine-mouth coal plants or natural gas plants built in locations that offer higher operating efficiencies; better access to valuable unique resources—*e.g.*, hydroelectric or pumped storage options; or lower environmental costs—*e.g.*, better carbon sequestration and storage options. Similarly, a robust transmission network provides additional resource planning flexibility in addressing unexpected shifts in fuel costs, changes in public policy objectives, or uncertainties in the location and amount of future generation additions and retirements.[17] This also includes optionality and flexibility in terms of leveraging lowest-cost supply and demand-side resources in the future.

Additional generation capacity investment savings also are provided by reducing losses during peak load and, through added transfer capabilities, the diversification of renewable generation. Recent studies show that peak-loss-related capacity benefits can add 5 percent to 10 percent to estimated production cost savings.[18] The Eastern Wind Integration and Transmission Study (EWITS) showed that regional transmission overlays can increase the capacity value of wind generation by roughly 5 percentage points—from an average of 23 percent without regional transmission upgrades to 28 percent with regional upgrades.[19] Similarly, regional overlays can diversify the geographic footprint of intermittent renewables and balancing generation resources, which leads to lower renewable balancing costs. If we conservatively assume that the renewable generation balancing benefit of an expanded regional grid reduces balancing costs by only $1/MWh of wind generation, to a range of $3 to $5 per MWh,[20] nationwide annual savings would exceed $250 million for 100,000 MW of wind generation at 30 percent capacity factor.

Added regional transfer capacity also can allow reductions in local reserve margin requirements while maintaining reliability standards. For example, the Public Service Commission of Wisconsin found that "the addition of new transmission capacity strengthening Wisconsin's interstate connections" was

FIG. 4 TOTAL BENEFITS INITIALLY QUANTIFIED FOR SOUTHERN CALIFORNIA EDISON'S PALO VERDE-DEVERS 2 PROJECT



Source: California ISO, *Economic Evaluation of the Palo Verde-Devers Line No. 2* (PVD2), February 24, 2005.

one of three factors that allowed it to reduce the planning reserve margin requirements of Wisconsin utilities from 18 percent to 14.5 percent.[21]

Finally, individual transmission projects can provide significant investment cost benefits through synergies with other facilities, or by reducing the cost of future transmission projects. While projects might be proposed to reduce congestion or integrate renewable generation, they also might avoid, delay, or reduce the cost of future reliability and other transmission projects. For example, the California ISO found that its renewable integration-driven transmission project in the Tehachapi region of southern California also allowed the low-cost upgrade of a congested transmission path—Path 26—and provided additional options for future transmission expansions.[22] The sizing and configuration of projects built today also can create valuable options that allow for more flexible and lower-cost transmission expansion in the future.

Economy-Wide Benefits

Transmission investments often create economy-wide benefits beyond reducing the delivered wholesale cost of power. First, these benefits include impacts on fuel markets, through reduced fuel prices. They also include environmental benefits, with reduced emissions, and they can significantly reduce the cost of public policy requirements, such as the cost of renewable generation. For example, the Southwest Power Pool estimated that transmission investment that allows for the interconnection of additional wind generation would lead to a reduction of regional natural gas prices, a customer benefit that offsets approximately one quarter of the transmission costs.[23]

Second, and perhaps more importantly, transmission benefits that are external to the overall cost of electricity also include economic development benefits. A robust transmission infrastructure supports economic growth and development in the same way that investments in highways and other infrastructure do. As with the ATC project in Wisconsin, business decisions on whether to locate in a particular region or utility service area and to expand existing operations can be made only when there's reasonable assurance of access to an adequate supply of electricity at competitive prices. In fact, the economic development aspect of providing a robust transmission grid often can be the most important reason for the infrastructure investment—particularly in regions with significant potential for economic growth, where the lack or delay of supporting infrastructure would dampen the growth.

The value of increased competition and reduced system losses can exceed 50 percent of a transmission project's costs.

The economic development benefits of transmission investment also include the employment and economic activity stimulated by the transmission construction activity itself. Analysis shows that every $1 billion in U.S. transmission investment directly and indirectly supports approximately 13,000 full-time-equivalent (FTE) years of employment and $2.4 billion in total economic activity. While such economic development benefits can't simply be added to a benefit-cost analysis that looks solely at transmission costs and benefits from the perspective of electricity consumers, they often are an important public policy benefit that shouldn't be ignored.

Figures 2 through 4 summarize examples of transmission benefit-cost analyses, combining a full range of benefits that contribute to the value of these transmission investments. The total economic benefits quantified for these transmission projects exceed their costs by 60 to 70 percent. Thus, the projects are expected to result in wholesale electricity market benefits significantly in excess of transmission rate increases.

These examples also show that relying solely on easily-quantifiable production cost savings would often lead to the rejection of otherwise beneficial investments.

Endnotes:

1. American Transmission Co. LLC, *Arrowhead-Weston Transmission Line: Benefits Report*, Feb. 2009, p. 7.
2. Federal Energy Regulatory Commission, *Order Accepting Tariff Revisions*, Docket No. ER10-1069-000, June 17, 2010 for SPP's "Highway/Byway" cost allocation methodology (Highway/Byway Methodology).
3. Federal Energy Regulatory Commission, *2011 Performance Metrics for Independent System Operators and Regional Transmission Organizations*, Appendix H: PJM, April 7, 2011, p. 275.
4. The benefit of reduced transmission losses generally isn't reflected in estimates of production cost savings because such market simulations are almost universally based on static transmission loss assumptions that don't reflect the fact that transmission upgrades will reduce the total quantity of energy that needs to be generated to make up for these losses.
5. American Transmission Co., LLC, *Planning Analysis of the Paddock-Rockdale Project*, April 5, 2007, pp. 4 (project cost) and 63 (losses benefit).
6. Pioneer Transmission, Formula Rate and Incentive Rate Filing, FERC Docket No. ER09-75, at p. 7 (January, 26, 2009). These benefits include both the energy and capacity value of reduced losses.
7. SSGWI Transmission Report for WECC, October 2003.
8. For a more detailed discussion of the benefits listed in Table 8 see, for example, Pfeifenberger, "Transmission Planning: Economic vs. Reliability Projects," EUCI Conference, Chicago, Oct. 13, 2010.
9. For example, see California ISO, *Transmission Economic Assessment Methodology* (TEAM), June 2004.
10. Federal Energy Regulatory Commission, *2011 Performance Metrics for Independent System Operators and Regional Transmission Organizations*, Appendix F: ISO New England, April 7, 2011, p. 106.
11. Before the Arizona Power Plant and Transmission Line Siting Committee, Docket No. L-00000A-06-0295-00130, Case No. 130, Oral Testimony on behalf of Southern California Edison Co. re: economic impacts of the proposed Devers-Palo Verde No. 2 transmission line, September and October, 2006, p. 39.
12. *Id.*, pp. 30-32. This reliability cost can be thought of as: (expected unserved energy) x (value of lost load).
13. Examples are out-of-merit dispatch costs, reliability-must-run costs, and reliability unit commitment costs (referred to with acronyms such as RMR, MLCC, RSG).
14. Professor Frank Wolak, as quoted in California ISO, *Transmission Economic Assessment Methodology*, June 2004, p. ES-9.
15. American Transmission Co., LLC, *Planning Analysis of the Paddock-Rockdale Project*, April 5, 2007, pp. 4 (project cost) and 50-53 (insurance benefit).
16. For example, see *Wind Energy Transmission Economics*, prepared for WPPI Energy by Burns and McDonnell, March 2010, page 1-2, Figure 2.
17. For example, *Brattle Group* experts estimated that emerging environmental regulations likely will result in the retirement of over 50,000 MW of coal-fired generation, with much of it located in the Midwest and Texas. (Celebi *et al., Potential Coal Plant Retirements Under Emerging Environmental Regulations*, The Brattle Group, Dec. 8, 2010.)
18. Based on *Brattle* analysis of CAISO, *Economic Evaluation of the Palo Verde-Devers Line No. 2* (PVD2), Feb. 24, 2005; and American Transmission Co., *Planning Analysis of the Paddock-Rockdale Project*, April 2007.
19. National Renewable Energy Laboratory, *Eastern Wind Integration and Transmission Study* (EWITS), January 2010, p. 203. 23 percent is the average across a range of 19 percent to 27 percent and 28 percent is the average across a range of 26 percent to 30 percent for the existing and overlay results, respectively.
20. *Id.*, estimating renewable generation balancing costs after regional transmission upgrades on p. 46 (in 2009 dollars) and p. 163 (in 2024 dollars). See also U.S. Department of Energy, *2009 Wind Technologies Market Report*, August 2010, p. 65, reporting renewable integration balancing costs from various studies ranging from \$2/MWh to \$8/MWh.
21. Public Service Commission of Wisconsin order in Docket 5-EI-141, filed Oct. 10, 2008, p. 5. Two other changes that contributed to this decision were the introduction of the Midwest ISO as a security constrained, independent dispatcher of electricity and the development of additional generation in the state.
22. California ISO, *Transmission Economic Assessment Methodology*, June 2004, p. 9-21. Tehachapi region referred to as Kern County.
23. Southwest Power Pool, *SPP Priority Projects Phase II Report, Rev. 1, Summary of Economic Result*, April 2010.