Profiting From Transmission Investment

A holistic, new approach to cost/benefit analysis.

By Kojo Ofori-Atta, Elliot Roseman, Bansari Saha, Scott Stuart, Marc Lipschultz & Jonathan Smidt

The still-fresh memories of last year's Northeast blackout coupled with rising congestion nationwide have increased awareness of the electric transmission investment shortfall in the United States. Such investment, in the right locations, would have a highly positive benefit-cost ratio. But how much should be spent?

To answer this question, ICF Consulting recently conducted a holistic forward-looking analysis of transmission investment, assessing transmission along with new generation, plant retirement, and load management options.[1] We integrated all factors affecting power production and delivery, including air emissions requirements, fuel market dynamics and expected prices, power plant economics and financing, costs of congestion, and network reliability. We also provided a new application of the value of lost load (VoLL) to electric transmission as a recommended means for assessing future transmission benefits.

Insufficient transmission capacity can impose costs on consumers in several ways, by:

- Creating transmission "islands" and preventing sharing of generation reserves, so isolated markets must carry excessive reserves;
- Raising the capital costs of generation in isolated markets (*e.g.*, New York City);
- Compelling the mothballing of less expensive generation due to inaccessibility;
- Making consumers in congested markets pay more for power at times; and
- Making reliability margins of overburdened transmission networks higher than they are for lightly loaded networks.

An examination of the wholesale incremental costs and benefits of various levels of transmission investments, in the context of generation and other options for satisfying the need for power, can lead to reduced costs.

Tricky Business

Estimating optimal transmission investments is challenging because of the complexity of power flows on the grid and because of network externalities such as loop flows. Analyses that examine historical declines in transmission investment are too simplistic. There are two main categories of investment needs—those needed for reliability and those desired to lower power costs. These reliability and economic needs are complementary; that is, by adding economic transmission to reduce congestion, system reliability improves as well. ICF Consulting uses different analytic approaches to capture each factor.[2]

In this study, we calculated economic transmission benefits by modeling the complex future interactions of generation, transmission, environmental, and fuel markets over 27

years (2004 to 2030), compared with not making such investments. We evaluated three scenarios, with variations on the second one.

- **Base Case.** In the Base Case, we restricted capacity additions to generation only, assuming that all projects that have broken ground would be completed.
- **Optimal Case.** We analyzed an Optimal Transmission Investment Case in which economic generation and transmission additions compete to serve load. In many cases, the model still builds significant generation, as incremental energy and capacity are also required. As we know, transmission is a challenge to site, so we also analyzed four cases where optimal transmission builds were scaled down by 10, 25, 50, and 75 percent, respectively, in which generation would instead meet the additional resource requirements. We also modeled two above-optimal cases, in which transmission builds were scaled up 10 and 25 percent.
- **Lower Reserve Margins.** We analyzed the economic impact of reducing reserve margins below the Base Case level, since incremental transmission capacity could require less investment in generation to meet the same level of reliability for the grid as a whole.

Forecast Results

After substantial work to properly specify and run our models, we addressed the key question: What is the optimal level of incremental economic transmission investment (*see Figure 1, p. 74*)? All levels of investment yield substantial benefits, but the optimal level can be identified. Specifically, we project an optimal economic investment of $12 billion in transmission capital, though just $8.2 billion in net present value (NPV) terms. We further project that if these investments are made, and made in the right locations, the period's gross benefits are about $12.6 billion NPV, yielding net system benefits (including financing costs) of $4.4 billion NPV. Note that we do not assert that the goal should be to eliminate congestion; indeed, some congestion may be cost-effective. As explained below, this forecast of the level of cost-effective investment is in addition to transmission investments made to maintain system reliability and to interconnect power plants, which we assume to be made regardless.

Figure 2 details the gross, net, and marginal benefits per dollar for each case. As per economic theory, system planners should continue investment until the marginal economic benefit is zero. At 25 percent of the optimal investment, the gross savings per dollar invested is approximately $1.90, and the marginal benefit about $0.90. At the optimal level, these figures reach $1.50 in gross savings per dollar and about zero in marginal net savings.

But incremental economic investment in transmission is far from all the transmission investment required. Transmission investment to increase throughput of the grid must be accompanied by hook-up costs for new generation, estimated at $15/kW-year in year 2003 dollars. With more than 600 GW of new generation additions expected in the study horizon, we estimate total hookup costs of approximately $9 billion, with an NPV of about $3 billion. Including both generation hookup costs and new development, total transmission investment needed in the study horizon is more than $20 billion.

In addition, we expect normal transmission capital investments largely to maintain existing reliability and transfer capabilities, which was estimated by the Edison Electric Institute in 2000 at approximately $2 billion annually in 1997 dollars ($2.5 billion in 2003 dollars). Over the study period, this amounts to an NPV of $31.7 billion in 2003 dollars. Figure 3 shows the breakdown of these investments. Thus, including optimal transmission that will lower wholesale power costs, the NPV of overall transmission investment needed is projected at $43 billion in 2003 dollars.[3]

Further, transmission builds will occur over time. Figure 4 shows that the optimal transmission builds would provide a cumulative 60 GW of transfers from 2004 to 2030. Of the $12 billion, about $4 billion would be optimal by 2007, providing 20 GW of economic transfer capability. Less economic transmission investment is required between 2008 and 2011. Between 2012 and 2017, an incremental 6 GW is economic at a cost of $1.5 to $2 billion. From 2017 to 2030, as demand grows, about 35 GW of transfer capability is economic at a cost of $7 billion.

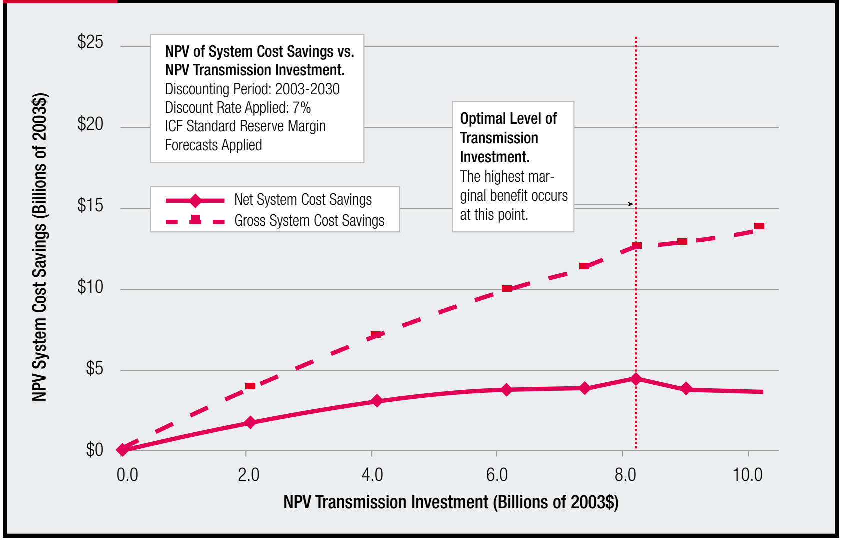
Benefits From Reserve Sharing

The economic benefits of transmission would be even larger if we incorporate benefits from reserve sharing. In the optimal case, we allowed reserve margins to decline over time to a minimum level of 13 percent, while in the Reserve Sharing Case, we assumed reserve margins declining to a minimum of 12 percent and remaining flat thereafter. With this modest 1 percent reduction, economic benefits increase sharply, from an NPV of $4.4 billion to as much as $9.7 billion.

This analysis shows significant economic benefits of investing in new transmission capacity:

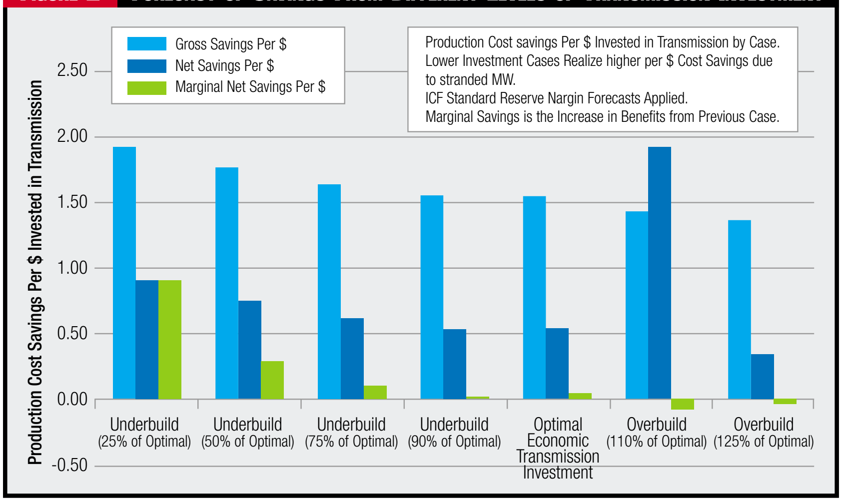
- Overall, approximately $8.2 billion NPV in 2003 dollars of incremental transmission investment is optimal between 2004 and 2030. These investments would yield economic benefits of $12.6 billion in real 2003 dollars and net benefits of $4.4 billion, for a benefit-to-cost ratio of over 1.5 ($12.6 billion divided by $8.2 billion).
- With a 1 percent reduction in reserve margins, economic benefits more than double, for a benefit-cost ratio of 2.2 at the optimal transmission investment levels.

FIGURE 1 — ESTIMATED U.S. ECONOMIC BENEFITS AT VARIOUS LEVELS OF TRANSMISSION INVESTMENT



- Including investments in generation hook-ups in maintaining existing economic transfer capabilities, the NPV of transmission investment is estimated to be $43 billion in year 2003 dollars.
- There are first-mover advantages. Early investors are more likely to achieve their desired return on equity, while providing substantially more benefits.

FIGURE 2 FORECAST OF SAVINGS FROM DIFFERENT LEVELS OF TRANSMISSION INVESTMENT



The Energy Information Administration (EIA) indicates that there were about 133 million U.S. residential, commercial, and industrial customers in 2002, so net savings per current customer would be approximately $33 in present value dollars ($4.4 billion of net benefits divided by 133 million), though the number of customers would tend to grow over time. With the benefit of reserve sharing, the present value benefit per current customer increases to $73.

Thus, in the United States, it is economic to invest billions in transmission, as consumers would realize a substantial benefit (in conjunction with billions invested in power generation). ICF Consulting's analysis confirms that the national transmission shortfall is quite large.

Further, these results indicate that public policies, regulations, and statutes should favor transmission-line development. When we include the substantial additional benefit to the overall economy from lowering system outages, the case for encouraging new transmission becomes even more compelling.

FIGURE 3 TOTAL PROJECTED U.S. INVESTMENT IN TRANSMISSION, 2004 TO 2030 (2003$)

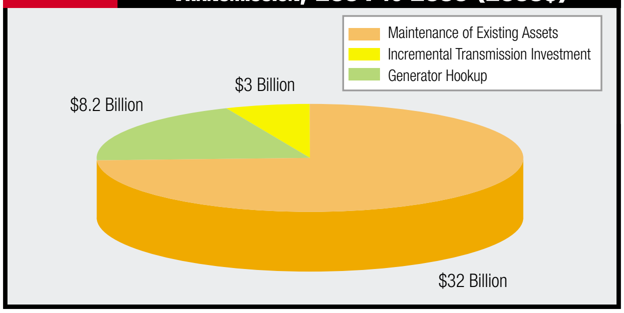
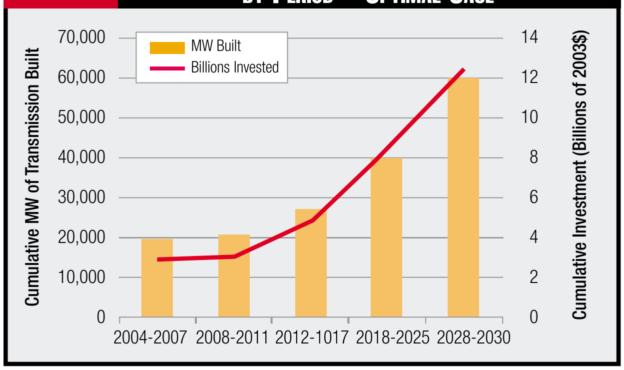


FIGURE 4 CUMULATIVE ECONOMIC TRANSMISSION BUILDS BY PERIOD – OPTIMAL CASE



Value of Lost Load: A Large Additional Benefit?

Appropriate transmission investments will help reduce transmission-related outages (TROs), which, despite their lower frequency when compared with distribution-related outages, generally have much greater consequences. Our study also estimated the economic value of the load not lost by making the right transmission investments. VoLL[4] is defined as the value placed by an average consumer on an unsupplied unit of electric power.

Key steps in such analysis include:

- Determining the past frequency of TROs and making a reasonable projection of their likely occurrence and severity in the future;
- Assessing the extent to which TROs affect each sector (residential, commercial, industrial), and the value of power to each sector;
- Estimating the potential reduction of TROs from appropriate transmission investments, and the load that would be "saved"; and
- Calculating the value of that load saved over a period of time.

Regardless of the sector, the economy virtually shuts down when the power goes out unexpectedly. Unless the outage is short-term, the shopping malls close, the fast-food establishments cannot make food, the computers stop working, and offices send their workers home (if they are not stuck in the elevator). Manufacturing comes to a halt (including some businesses that lose entire production lines), and homeowners lose perishables in their freezers and refrigerators within a few hours. Some costs may be recoverable once the outage ends, but the vast majority of the value is simply lost. The state of our economy and the supply of electric power are inextricably linked.

To estimate the VoLL, we used EIA data on TROs.[5] We believe this data provides a conservative estimate of TROs, since it is not clear that all such outages are reported, particularly those of short duration, which can still have significant economic impacts. Our assessment of this historical record showed that over the past five years, TROs averaged about 2,150 GWh per year, or about 0.06 percent of average annual retail sales in the United States of more than 3.4 million GWh. Nevertheless, as shown below, the cost of these outages is significant in an $11 trillion economy. The worst years for TROs in this period were 1999 and 2003 (the year of the major blackout), with approximately 7,290 GWh lost to TROs in 2003, while the lowest year was 2001.

We then divided the total annual TROs into four sectors to determine the worth of power to each. Though utilities have very different mixes of customers (*e.g.*, FPL sells more than 90 percent of its power to residential customers), we used the national sales averages. Nationwide, 35.6 percent of electricity sales is to residential customers, 31.6 percent to commercial accounts, 29.6 percent to industrial customers, and 3.2 percent to other (*e.g.*, street lighting, etc.) on average in the past five years.

The next key step was to determine the value of power to each sector.[6] Previous studies used detailed surveys to measure this value, so we did not "reinvent the wheel." Those studies are dated, but current figures would almost certainly be higher, since the economy has become more power-dependent in recent years, with higher computerization and automation levels. Those studies provided the following VoLL multiples, as a multiple of the retail price of power:

SECTOR	"VoLL Multiple" of the Retail Price
Residential	54
Commercial	82
Industrial	119
Other	100

We used these values, multiplied by the average nationwide retail cost of power for each sector, and derived the value of power to each sector for each kilowatt-hour lost, as shown in Figure 5.

As expected, because of its high dependence on power, the commercial sector has the highest per kilowatt-hour value, while the residential sector has the lowest value. Using the outage share for each sector and the VoLL multiples for today's retail electricity price, we calculated the economic value of lost load for 1999 to 2003. This gives us a baseline measure of the cost to the economy of transmission-related outages for the last five years, as shown in Figure 6.

In the long run, optimal transmission investment could reduce transmission-related outages 50 percent from its normalized levels.

To estimate future losses, we then escalated the "baseline" average of about $12 billion each year to reflect anticipated increases in electricity consumption (1 percent for residential, 1.7 percent for commercial, 1.3 percent for industrial, and 1.9 percent for "other," as projected by EIA's *Annual Energy Outlook 2004*). By 2012, we determined that the baseline amount would rise to $14.1 billion, and to $16.9 billion by 2025.

Finally, we measured the economic benefit of transmission investment through projected reductions in TROs and the consequent economic savings to consumers. The key was estimating the extent to which outages would decrease as a result of the optimum level of transmission investment. Given the absence of hard data on this topic, we made reasonable estimates in five different time periods, based on this logic:

- Initial transmission investments would take a few years to materialize, so the impact in reducing outages in 2005-2006 would be relatively small;
- By 2007-2008, some of the "best" initial transmission investments would occur with a higher benefit;
- For 2009-2014, reduced outages should be substantial, as major transmission investments would take place; and
- In 2015-2020, incremental benefits may decline, with a smaller benefit compared with 2009-2014. Benefits would remain constant for 2021-2030.

The exact size of this benefit is debatable, but we believe that the overall shape of the curve should follow this logic. In this light, compared with the baseline, we hypothesized a pattern for outage reductions in outages related to transmission (*see Figure 7*).

Thus, we project that in the long run, optimal transmission investment could reduce transmission-related outages 50 percent from its normalized levels, taking growth in electricity consumption into account.

The final step was to translate these projections into their economic value by multiplying the VoLL in each year by the cumulative reduction for that period to find the savings. For example, in the year 2012, when the overall economic value of outages would be $14.1 billion, a 30 percent reduction would save nearly $4.2 billion. We then added up the projected annual savings for a cumulative savings over the entire period of $149 billion, with an NPV of $50 billion, at a 7 percent discount rate.

Using the approach described above, the VoLL would provide nominal benefits of more than $1,100 per current customer from incremental transmission, and an NPV savings of $376 per current customer. The benefit-cost ratio when including VoLL rose to more than 8.0.

The Benefits of Transmission Investment

This study has answered some key questions. Is substantially more transmission needed? Could optimum transmission investment reduce the cost of power by facilitating economic transfers (in addition to interconnecting generation and maintaining reliability)? Would such investment reduce the likelihood and severity of outages, with corresponding benefits to the economy? The answer to all these questions is emphatically "yes." Figure 8 provides our findings regarding the optimal level of incremental transmission investment.

Benefits to the economy from reducing transmission-related outages clearly would justify billions of dollars in additional transmission investment. We recommend that the VoLL approach be incorporated into future utility, RTO, and regulatory assessments of proposed transmission facility development. F

Messrs. Ofori-Atta, Roseman, and Saha are senior staff with ICF Consulting of Fairfax, Va., and Messrs. Lipschultz, Stuart, and Smidt are with Kohlberg Kravis Roberts & Co. (KKR) in New York City, which sponsored this analysis. *The authors gratefully acknowledge the editing support of Faith Welling of ICF Consulting.* *Contact Roseman at Eroseman@icfconsulting.com.*

FIGURE 8 — Results of ICF Incremental Transmission Analysis – Optimal

	2004-2030 Total (Billion 2003$)	NPV1 2004-2030 (Billion 2003$)	Benefit/Cost Ratio
Optimal Transmission Investment Cost	$12.0	$8.2	-
Net Savings in Production Costs Compared to ICF's Base Case	$9.7	$4.4	1.5
Net Savings with Benefits from Reserve Sharing	$26.5	$9.7	2.2
Net Savings with Reserve Sharing and Value of Load Lost (VoLL)	$175.6	$59.7	8.3

FIGURE 5 — Estimated Sector-Specific Value of Electric Power

Sector	Retail Price (cents per kWh in 2002)	Value ($ per kWh)
Residential	8.40	$4.54
Commercial	7.84	$6.43
Industrial	4.80	$5.71
Other	6.74	$6.74

FIGURE 6 — 1999-2003 Value of Lost Load From Transmission Outages (2003$ Millions)

	1999 – 2003 (aggregate)	Annual Average
Residential	$17,906	$3,581
Commercial	$22,162	$4,432
Industrial	$17,996	$3,599
Other	$2,295	$459
Total	**$60,388**	**$12,078**

FIGURE 7 — Estimated Incremental and Cumulative Outage Reductions from Optimal Transmission Investment

Period	Incremental Reduction	Cumulative Reduction
2005-2006	5 percent	5 percent
2007-2008	10 percent	15 percent
2009-2014	15 percent	30 percent
2015-2020	10 percent	40 percent
2021-2030	10 percent	50 percent

Endnotes

1. This analysis primarily used ICF Consulting's proprietary resource planning model, the Integrated Planning Model (IPM®). This is the only model we know of that can optimize the mix of supply options by making "entry and exit" decisions while integrating other key market dynamics. Such a framework requires hundreds of inputs, which the authors can summarize for interested parties.
2. For example, we use tools such as PowerWorld to assess grid reliability, and IPM® to assess resource planning needs.
3. Not included in this analysis is the amount of investment required to maintain reliability for the incremental economic transmission investment.
4. The concept is not new. VoLL was utilized in the 1980s and early 1990s to help utilities determine the optimum level of generation reserves they should hold. Our assessment is to our knowledge the first time this concept has been applied to transmission planning.
5. *Electric Power Monthly*, 1999-2003, Appendix B, Table B1, "Major Disturbances and Unusual Occurrences," which records any equipment failure, system operational action, or event that disconnects customer load of greater than 100 MW or that initiates voltage reductions by more than 3 percent. Where data was unavailable, ICF Consulting used the average number of megawatts affected and the average number of hours per outage in that year to fill in for missing data.
6. There are differences within a sector (*e.g.*, differences between a shopping mall and a school, while homeowners are more homogeneous), but we did not go into this level of detail.