ESTIMATING MACROECONOMIC BENEFITS OF TRANSMISSION INVESTMENT WITH THE REMI PI+ MODEL

Prepared for REMI Webinar
May 2, 2018

Jinglin Duan
Julia Frayer
LEI is a global economic, financial, and strategic advisory firm specializing in energy, water, and infrastructure

About LEI

LEI’s Analytic Approach
- Combines a detailed understanding of specific networks and commodity industries, such as electricity generation and distribution, with sophisticated analysis
- Uses a suite of proprietary quantitative models to produce reliable and comprehensible results
- Advises private sector clients, market institutions, and governments on privatization, asset valuation, deregulation, tariff design, market power, and strategy in virtually all deregulated markets worldwide, particularly in Canada and the Northeast US

Key Practice Areas
- Regulatory Economics and Market Design
- Asset Valuation and Market Analysis
- Litigation and Expert Testimony
- Strategy and Management Consulting
- Renewables
- Procurement

Continuous Modeling Initiative (“CMI”)
- LEI performs “multi-client” forecasts for eleven regional wholesale markets across North America
- CMI’s include an examination of recent market developments, key assumptions used in the modeling, and a 10-year wholesale electricity price and, where relevant, capacity price forecast

Key Facts
- LEI entered the North American market in 1996 during the birth and development of many competitive electricity markets worldwide
- LEI’s subject matter experts come from over a dozen countries with degrees in economics, finance, public policy, engineering, mathematics, and business
- LEI Staff are located in Toronto, Boston, Chicago, Hong Kong, and Taipei, with strategic partners globally
LEI prepared two papers to raise public awareness about the need for transmission investment and its economic benefits.

**A WIRES Report**

**The Truth About the Need for Electric Transmission Investment: Sixteen Myths Debunked**

London Economics International LLC
Julia Frayer
Eva Wang
Marie Fagan
Barbara Porto
Jinglin Duan
SEPTEMBER 2017


**A WIRES REPORT**

**How Does Electric Transmission Benefit You?**
Identifying and Measuring the Life-Cycle Benefits of Infrastructure Investment
JANUARY 8, 2018

London Economics International, Inc.
Julia Frayer
Eva Wang
Ruyun Wang
Jerome Leslie
Jinglin Duan
Tianying Lin

LEI incorporated its proprietary electric market simulator with the REMI PI+ model to analyze energy infrastructure investment’s impact on local economic activity

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Proprietary natural gas model based on the levelized cost of pipeline (“LCOP”) is used to forecast future prices</td>
<td>LEI’s proprietary dispatch simulation model is used to develop wholesale energy price forecasts</td>
<td>REMI PI+ utilized to measure the economic impact (i.e. GDP and jobs) of infrastructure investments on the economy</td>
<td></td>
</tr>
<tr>
<td>Retirements take place when expected profits are insufficient to cover going forward fixed costs</td>
<td>Merit order based on marginal costs to dispatch plants, using algorithms that consider maintenance scheduling, dynamic constraints, and daily reserve margins</td>
<td>Model inputs based on LEI’s energy and capacity market simulators, with inputs related to project costs and characteristics</td>
<td></td>
</tr>
<tr>
<td>New renewable entry assumed to satisfy policy objectives (Renewable Portfolio Standards), which is also reflected in REC revenue streams</td>
<td>Used for competitive plant valuation, emission credit market analysis, M&amp;A, and transmission congestion analysis</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Modeling Tools

- Capacity Market Modeling
- Natural Gas Modeling
- Energy Market Modeling
- Macroeconomic Impact Modeling
LEI used simulation-based methods to estimate the benefits of transmission investment over its “lifecycle”

**WHAT**
- **Boost to local economy and job creation due to construction activities**
- **Boost to local economy & job creation due to operations activities and electricity cost savings**
- **Increased “quality of life” from reduced carbon emissions in the region**
- **Reliability benefits – Consumer savings for a “supply shortage”**
- **Reliability benefits – savings from avoided costly blackouts**

**WHO**
- Workers, residents, local businesses
- Electricity consumers, generators, workers, local businesses, local and new residents

**WHERE**
- States where the transmission line is built
- Regions at the receiving end of the transmission line
- Regions economically and geographically connected to the affected states

**WHEN**
- **Short term**
  - Electricity market cost savings
  - Generators’ net revenues
  - Savings from efficient production

- **Medium term**
  - Boost to local economy & job creation due to operations activities and electricity cost savings
  - Increased “quality of life” from reduced carbon emissions in the region

- **Long term**
  - Reliability benefits – Consumer savings for a “supply shortage”
  - Reliability benefits – savings from avoided costly blackouts
<table>
<thead>
<tr>
<th></th>
<th>The two hypothetical transmission projects and LEI’s modeling scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Methodological approaches in the macroeconomic analysis</td>
</tr>
<tr>
<td>3</td>
<td>Modeling outcomes</td>
</tr>
<tr>
<td>5</td>
<td>About LEI</td>
</tr>
</tbody>
</table>
To demonstrate that benefits are quantifiable, LEI evaluated two hypothetical, inter-regional transmission investments.

The hypothetical Trade-Enhancing Project harnesses trade opportunities between two markets, allowing buyers and sellers to benefit.

The hypothetical Resource Delivery Project brings together suppliers and consumers, culminating in a mutually beneficial outcome.
Local economic impacts from the construction and operation of the transmission project and associated generations were studied sequentially using REMI PI+ customized to specific geographical areas.

<table>
<thead>
<tr>
<th>Economics impact period studied</th>
<th>Regions studied</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trade-Enhancing Project</strong></td>
<td>Resource Delivery Transmission Project (Transmission component)</td>
</tr>
<tr>
<td><strong>Construction period (2018-2020)</strong></td>
<td>Indiana</td>
</tr>
<tr>
<td><strong>Operations period (2021-2035)</strong></td>
<td>Affected PJM-West zones and MISO Central zone</td>
</tr>
</tbody>
</table>

* Construction for the wind component of the New Resource Delivery Transmission Project is 2019-2021

- **LEI used a combination of 70-sector, state-level and customized ISO subregion-level REMI PI+ models in this study**
  - Geographical dimensions in REMI PI+ are easily customized to reflect market boundaries and nuances of electric networks

- **Construction period and operations period were studied separately because economic activities associated with these two periods are different in nature**
  - Project capital cost is the main contributor for local economic growth, whereas electricity cost savings are the main driver of economic benefits during the operations period

- **Economic impacts are presented in the form of incremental jobs and Gross Domestic Product (“GDP”), which reflects economic benefits from different perspectives but usually goes hand-in-hand**
# Table of contents

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The two hypothetical transmission projects and LEI’s modeling scope</td>
</tr>
<tr>
<td>2</td>
<td>Methodological approaches in the macroeconomic analysis</td>
</tr>
<tr>
<td>3</td>
<td>Modeling outcomes</td>
</tr>
<tr>
<td>5</td>
<td>About LEI</td>
</tr>
</tbody>
</table>
Project capital spending is the primary driver for local economic benefits during the construction phase.

**Construction period**

- **Expected total capital cost**
  - Construction material & labor costs on the transmission line, substations and project support spending
  - Spending not included in the analysis (land costs, contingency, taxes, etc.)

**Policy Variables:**

(Detailed) industry Sales (Exogenous production)
- Primary metal manufacturing
- Communication and energy wire and cable manufacturing
- Ready-mix concrete manufacturing
- Motor and generator manufacturing (for equipment)
- Logging (for site preparation)
- Construction (Power and communication structures)

**Policy Variables:**

(Detailed) industry Sales (Exogenous production)
- Administrative and support services
- Legal services
- Professional, scientific, and technical services
- Advertising, public relations, and related services
- Environmental and other technical consulting services

**Inputs into REMI PI+ model**

- Assumptions/data to derive inputs
- Inputs into REMI model
- Project cost not directly in REMI model
Project operations and maintenance ("O&M") spending and electricity cost savings generate economic benefits when the project starts commercial operations.

**Commercial operations period (short & medium term)**

- **Expected annual O&M spending during commercial operations**
- **Modeled wholesale energy and capacity market impacts by state using POOlMod**
- **Expected local O&M labor costs**
- **Expected local O&M non-labor costs**
- **Residential retail electricity price change**
- **Commercial retail electricity price change**
- **Industrial retail electricity price change**

**Policy Variables:**
- **(Detailed) industry Sales (Exogenous production)**
  - Electric power generation, transmission, and distribution
  - Nonresidential maintenance and repair
- **Fuel Cost**
  - Electricity, Commercial
  - Electricity, Industrial
- **Consumer Price**
  - Electricity

**Policy Variables:**

- **Inputs into REMI PI+ model**

**Assumptions/data to derive inputs**

**Inputs into REMI model**
In the longer term, new transmission investment can also protect consumers against electric service interruptions and attendant economic losses.

- Interruptions of electricity supply will have serious impacts on consumers, especially in the commercial and industrial sectors. LEI used two models to estimate the insurance value (or avoided expected economic loss) of the new transmission.

- The expected avoided economic loss due to enhanced grid reliability due the transmission project =

\[
\text{Energy Unserved (MWh, POOLMod)} \times \text{Value of Lost Load ($/MWh, REMI PI+)}
\]

Using LEI’s energy market simulation model, LEI estimated the magnitude of unserved load (blackout) and how much of this service interruption is “avoided” by the construction and operation of the transmission project.

- Step (a): In a given region, looking at commercial and industrial sectors that would be negatively impacted from a supply interruption using REMI PI+ statistics on the marginal effect of electricity as a fuel to economic output of that industry.
- Step (b): identifying the expected GDP contribution of these industries for a typical year in REMI PI+ baseline.
- Step (c): identifying the industrial & commercial customers consumption of electricity over a typical year for the region using LEI’s models and EIA data.
- Value of lost load (“VoLL”) is calculated as dividing step (b) by step (c).
Achievements in reducing carbon emissions will create a “socio-economic” boost to the local economy due to the region’s relative “quality of life” attractiveness.

- Policies and socially responsible statements that are in favor of reducing carbon emissions will create *(Non-Pecuniary) Amenity Value* in the region, and will attract people to move to the region and benefit the economy:
  - The *(Non-Pecuniary) Amenity Value* in REMI PI+ relies on the “quality of life” attributes that affect population trends and the “attractiveness” of a local economy.
  - Higher Amenity Value attracts new residents (often highly educated and care about environmental and social appreciation) to the region because it’s a “better place to live”.
  - The increased Amenity Value is quantified in terms of a real compensation change equivalent for Economic Migrants.
  - These migrants will enrich the local labor pool and create increase in employment and GDP.

\[
\begin{align*}
\text{Incremental social benefits of carbon reduction} &= \text{Amount of carbon reduction from the project (POOLMod)} \times \text{Social Cost of Carbon ($/metric ton carbon emission)} \\
&= \text{Increased Amenity Value (REMI PI+)} \\
&\quad \text{Increased compensation} \\
&\quad \text{Economic migrants to the local economy}
\end{align*}
\]


*Note: This social benefit is not additive to the energy market benefits, because it does include some portion of carbon emissions reductions that are already remunerated for in the energy market.*
# Table of contents

<table>
<thead>
<tr>
<th>1</th>
<th>The two hypothetical transmission projects and LEI’s modeling scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Methodological approaches in the macroeconomic analysis</td>
</tr>
<tr>
<td>3</td>
<td>Modeling outcomes</td>
</tr>
<tr>
<td>5</td>
<td>About LEI</td>
</tr>
</tbody>
</table>
Transmission investment during the construction and operations periods can have measurable positive impacts on many sectors of the local economy through the “multiplier effect”

**Direct economic impacts** are created in the industries where the project has direct labor and material demand. During the construction period, the majority of the direct impacts from transmission investments are generated in the construction sector. During the operations period, the direct impacts come from the O&M spending.

**Indirect economic impacts** are generated in the industries that supply materials (e.g. retail sales, manufacturing) and by workers that provide supporting services (e.g. administrative, professional services) for construction and operations of the project.

**Induced economic impacts** are the result of spending on goods and services that support a wide variety of nearby businesses, such as clothing, dining, accommodations, educational services, etc. During the construction period, the induced impacts are created by increased salaries of workers; during operations, the induced impacts are driven by consumers’ savings on electricity bills.
Trade-Enhancing Transmission Project: A small scale transmission project can have large and long-lasting impacts on the local economy.

Outputs - GDP increase during construction and operations periods of the project

Inputs - Project costs and electric market benefits of the project
Long-term Reliability Benefits (VoLL) and Carbon Reduction Benefits

Trade-Enhancing Transmission Project: In the long term, the local economies benefit from enhanced grid reliability and improved “quality of life”

- The avoided economic loss from severe blackouts is expected to be $477 million for affected regions in PJM and $546 million for affected regions in MISO

**Economic benefits from avoiding blackout events in PJM**

<table>
<thead>
<tr>
<th>Value of Lost Load (VoLL)</th>
<th>Energy Unserved</th>
<th>Avoided expected economic loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>$16,672/ MWh</td>
<td>26,822 MWh</td>
<td>$447 million</td>
</tr>
</tbody>
</table>

**Economic benefits from avoiding blackout events in MISO**

<table>
<thead>
<tr>
<th>Value of Lost Load (VoLL)</th>
<th>Energy Unserved</th>
<th>Avoided expected economic loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>$12,926/ MWh</td>
<td>42,256 MWh</td>
<td>$546 million</td>
</tr>
</tbody>
</table>

- The economic benefits from improved “quality of life” due to carbon emissions reduction in affected regions of PJM and MISO range from $2.3 million to $11.1 million per year (under different social cost of carbon (“SCC”) pricing scenarios), estimated using the Amenity Value approach

**Economic benefits from carbon reductions under three SCC pricing scenarios**

**SCC: $22/ metric ton**
- GDP increase by $2.3 million/year
- 18 new jobs/year

**SCC: $71/metric ton**
- GDP increase by $7.6 million/year
- 58 new jobs/year

**SCC: $104/ metric ton**
- GDP increase by $11.1 million/year
- 85 new jobs/year
Resource Delivery Transmission Project: Investment in transmission and wind generations boosts local economy and expands local GDP as a consequence of lower electricity cost.

Outputs - GDP increase during construction and operations periods of the project

*Introducing wind resource into California energy market might result in deferral of local solar and wind investment. Such impacts are modeled as decreased capital and labor investment in California.

Inputs - Project costs and electric market benefits of the project
Resource Delivery Transmission Project: LEI considered potential negative economic impacts of deferred local renewable energy investment in California due to the transmission project with external generation investment.

- Introducing wind energy generated from the Rocky Mountain region into California will defer renewable investment in California.
- LEI estimates a total of 1,500 MW of new wind generation capacity and 6,000 MW of new solar generation capacity in California will be deferred during the modeling period.
- Deferred local material spending is modeled as losses in industry sales in the relevant sectors.
- Deferred local labor spending is modeled as foregone compensation for labors in relevant sectors.

Modeling impacts of deferred renewable investment in California:

- Expected deferred solar and wind capacity
- Expected total capital cost of the deferred solar and wind capacity if they were to be constructed
- Construction material & labor costs for solar and wind constructions
- Spending not included in the analysis (land costs, contingency, taxes, etc.)
- Expected local labor spending for construction and installation sectors
- Expected local non-labor spending in relevant sectors
- Forgone Compensation for labors in relevant sectors
- Losses in Industry sales in relevant supporting sectors (for material)

Inputs into REMI PI+ model:

- Assumptions/data to derive inputs
- Inputs into REMI model
Resource Delivery Transmission Project: In the long term, new transmission benefits the local economies through mitigation of power interruptions and reducing carbon emissions.

- The avoided economic loss from severe blackouts is expected to be $566 million for affected regions in California.

\[
\text{Value of Lost Load (VoLL)} = \frac{\$19,501}{\text{MWh}} \times 29,024 \text{ MWh} = \$566 \text{ million}
\]

- The improved “quality of life” due to carbon emissions reduction in affected regions in California are expected to create 1,144 - 5,655 new jobs per year, and boost local GDP by $180 - $891 million per year (under different social cost of carbon (“SCC”) pricing scenarios), estimated using the Amenity Value approach.

**Economic benefits from carbon reductions under three SCC pricing scenarios**

<table>
<thead>
<tr>
<th>SCC: $22/metric ton</th>
<th>SCC: $71/metric ton</th>
<th>SCC: $104/metric ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP increase by $180 million/year</td>
<td>GDP increase by $604 million/year</td>
<td>GDP increase by $891 million/year</td>
</tr>
<tr>
<td>1,144 new jobs/year</td>
<td>3,832 new jobs/year</td>
<td>5,655 new jobs/year</td>
</tr>
</tbody>
</table>
Empirical results for two hypothetical projects can be generalized to other transmission investments and other regions

<table>
<thead>
<tr>
<th>Benefit type</th>
<th>Generalized economic benefits</th>
</tr>
</thead>
</table>
| **Total local project spending**                 | • About $70 million for the Trade Enhancing Transmission Project; • Over $2 billion for both transmission and generation components for the Resource Delivery Transmission Project  
(40% of project cost is assumed to be spent locally for transmission projects; 12% of project cost is assumed to be spent locally for wind generation investment) |
| **Short term - Construction (Hosting states)**    |                                                                                                                                                                                             |
| GDP                                              | Boosts GDP by about $0.35 million/year for every $1 million spent locally                                                                                                                      |
| New Jobs                                         | Creates about 3 to 4 jobs/year for every $1 million spent locally                                                                                                                             |
| **Medium term - Commercial Operations (Electricity market)** |                                                                                                                                 |
| Electricity cost savings                         | • Saves $100-$390 million/year for PJM and MISO consumers for the Trade Enhancing Transmission Project                                                                                          
• Saves $1.2 billion/year for California consumers for the Resource Delivery Transmission Project |
| GDP                                              | Increases GDP by about $1.4 million to 1.5 million/year for every $1 million electricity cost savings                                                                                           |
| New Jobs                                         | Creates 8 to 11 jobs/year for every $1 million electricity cost savings                                                                                                                       |
| Carbon emissions reduction                       | • Avoids 3 million metric tons of carbon emissions cumulatively over 20 year for the Trade Enhancing Transmission Project                                                                  
• Avoids 18 million metric tons of carbon emissions cumulatively over 20 year for the Resource Delivery Transmission Project |
| Improved quality of life  
(Social cost of carbon/Amenity value)              | Boosts GDP by $1.5 million to $7 million/year and creates jobs by 7 to 300 for every metric ton of carbon emissions reduction                                                                 |
<p>| <strong>Longer term (Electricity market)</strong>             |                                                                                                                                                                                             |
| Reliability benefits to economy by avoiding supply interruptions | • Saves $600 million - $1 billion for electric consumers in affected regions for at least one hour long of blackout                                                                 |</p>
<table>
<thead>
<tr>
<th>1</th>
<th>The two hypothetical transmission projects and LEI’s modeling scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>Methodological approaches in the macroeconomic analysis</td>
</tr>
<tr>
<td>3</td>
<td>Modeling outcomes</td>
</tr>
<tr>
<td>5</td>
<td>About LEI</td>
</tr>
</tbody>
</table>
In the electricity sector, LEI is active across the value chain:

- Exhaustive sector knowledge and a suite of state-of-the-art proprietary quantitative modeling tools:
  - Wholesale electricity market models
  - Valuation and economic appraisal
  - Due diligence support
  - Cost of capital database
  - Contract configuration matrices

- Market design, market power and strategic behavior advisory services:

- Incentive ratemaking:
  - Quantify current and achievable efficiency levels for regulated industries
  - Convert findings into efficiency targets mutually acceptable to utilities and regulators

- Reliable testimony backed by strong empirical evidence:

- Expert witness service:
  - Material adverse change
  - Materiality
  - Market power
  - Contract frustration

- Creating detailed market simulations to identify beneficiaries and quantify costs and benefits from proposed transmission lines:
  - Valuing transmission
  - Transmission tariff design
  - Procurement process and contract design

- Renewable energy policy design, procurement, modeling, and asset valuation:
  - Solar, wind, biomass, and small hydro
  - Demand response
  - Energy efficiency
  - Cogeneration
  - Micro-grids
  - Emissions credits trading
  - Energy storage technologies

- Designing, administering, monitoring, and evaluating competitive procurement processes:
  - Auction theory and design
  - Process management
  - Document drafting and stakeholder management
LEI publishes semi-annual price forecasts and market studies for all restructured regional power markets in North America.

LEI performs “multi-client” forecasts for eleven regional wholesale markets across North America. The energy, and where applicable, capacity market price outlooks are updated every six months. These forecasts include an examination of recent market developments, key assumptions used in the modeling, and a 10-year wholesale electricity price and, where relevant, capacity price forecast.

**Contents:**

An overview of the market and recent developments - a discussion of the key market drivers, and developments in the previous six months, including any new entrants and retirements, new transmission lines, market rule changes, market auction outcomes, mergers and acquisitions, new state policies or initiatives, and environmental rules.

Modeling assumptions in the LEI price forecast - a detailing of assumptions used for each region, including market topography, future fuel prices, emission costs, the cost of generic new entry, import and export flows, demand levels, and the breakdown of supply. For regions with multiple zones, assumptions are broken down by zone.

10-year price forecast - a price forecast for wholesale electricity prices, and capacity market prices (for those regions where this is applicable). Where relevant, these price forecasts are broken down by zone.

**Available markets**

- Alberta
- California (CAISO)
- Midwest (MISO)
- New England (ISO-NE)
- New York (NYISO)
- Pennsylvania-New Jersey-Maryland Interconnection (PJM)
- Ontario
- Southeast Reliability Council (SERC)
- Southwest Power Pool (SPP)
- Texas (ERCOT)
- Western Electric Coordinating Council (WECC)