London Economics International LLC

Estimating Macroeconomic Benefits of Transmission Investment with the REMI PI+ Model

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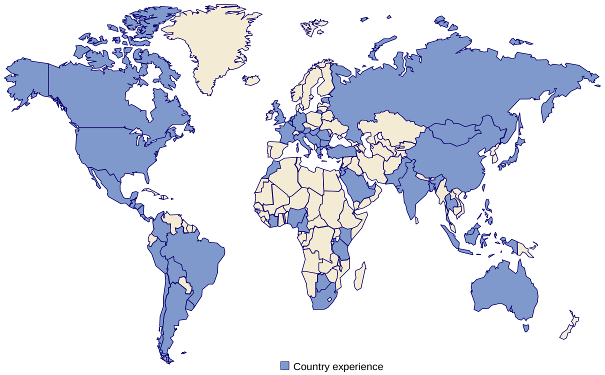
LEI is a global economic, financial, and strategic advisory firm specializing in energy, water, and infrastructure

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
  - CMIs 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

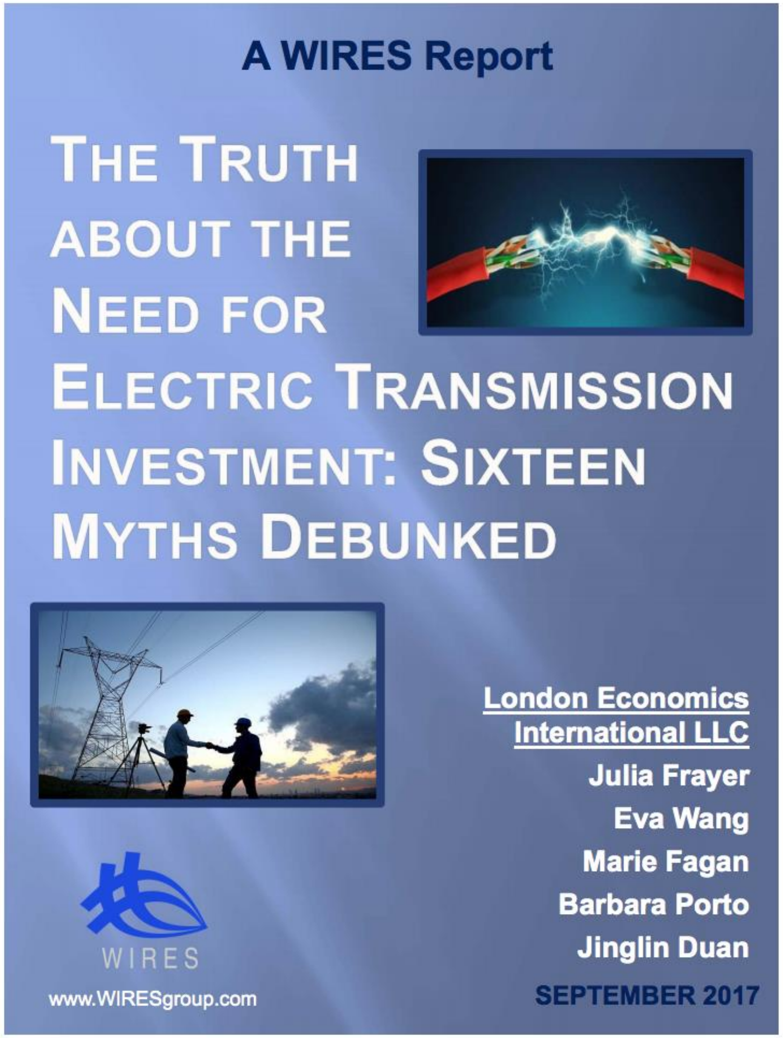
Key Facts

- **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**

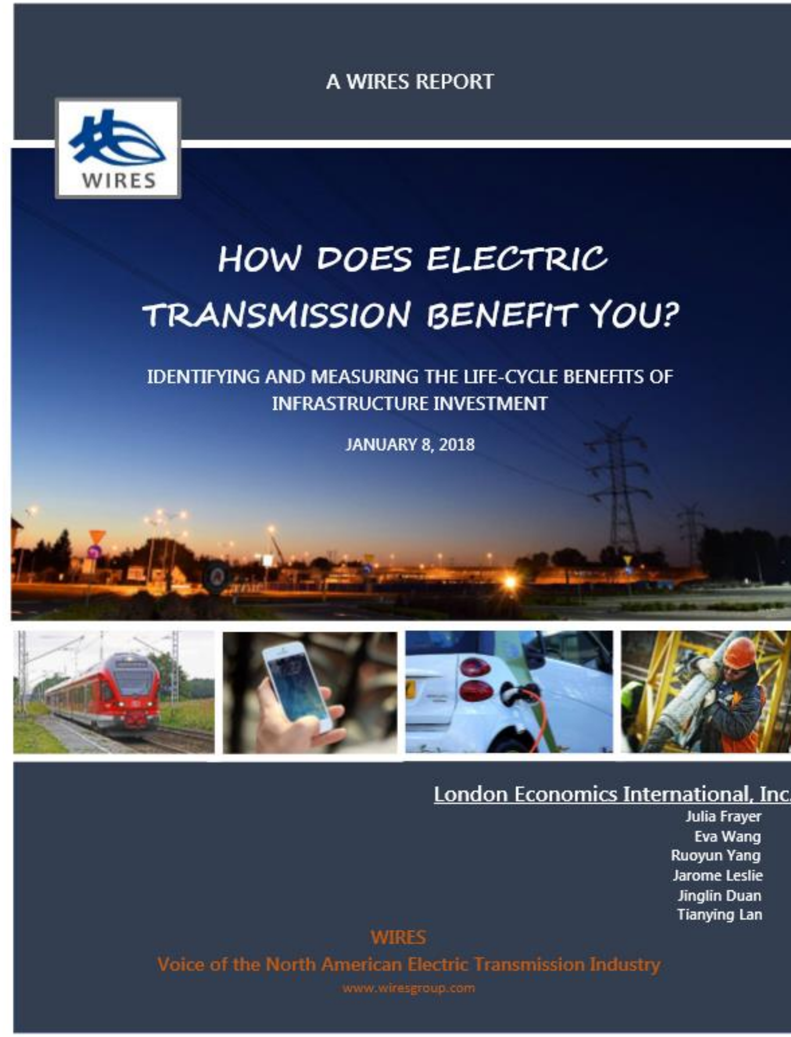


- **LEI Staff are located in Toronto, Boston, Chicago, Hong Kong, and Taipei, with strategic partners globally**

LEI prepared two papers to raise public awareness about the need for transmission investment and its economic benefits



Full report is available at:
http://www.wiresgroup.com/docs/reports/WIRES_LEI_Report_TransmissionMyths_Sept2017.pdf



Full report is availlable at:
http://www.wiresgroup.com/docs/reports/WIRES_LEI_TransmissionBenefits_Jan2018.pdf

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

Capacity Market Modeling

- Capacity market clearing prices are set according to rules and basic supply-demand dynamics (demand curve or target reserve margin)
- Retirements take place when expected profits are insufficient to cover going forward fixed costs
- New renewable entry assumed to satisfy policy objectives (Renewable Portfolio Standards), which is also reflected in REC revenue streams

Natural Gas Modeling

- Proprietary natural gas model based on the levelized cost of pipeline ("LCOP") is used to forecast future prices
- The LCOP approach looks at the tipping point in basis – when it is sufficiently high to cover the expected cost of new capacity
- LEI has also used pipeline network models like GPCM

Energy Market Modeling

- LEI's proprietary dispatch simulation model is used to develop wholesale energy price forecasts
- Merit order based on marginal costs to dispatch plants, using algorithms that consider maintenance scheduling, dynamic constraints, and daily reserve margins
- Used for competitive plant valuation, emission credit market analysis, M&A, and transmission congestion analysis

Macroeconomic Impact Modeling

- REMI PI+ utilized to measure the economic impact (i.e. GDP and jobs) of infrastructure investments on the economy
- Model inputs based on LEI's energy and capacity market simulators, with inputs related to project costs and characteristics

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LEI used simulation-based methods to estimate the benefits of transmission investment over its "lifecycle"

WHEN	Short term	Medium term	Long term
WHAT	Boost to local economy and job creation due to construction activities	Electricity market cost savings Generators' net revenues Savings from efficient production 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	

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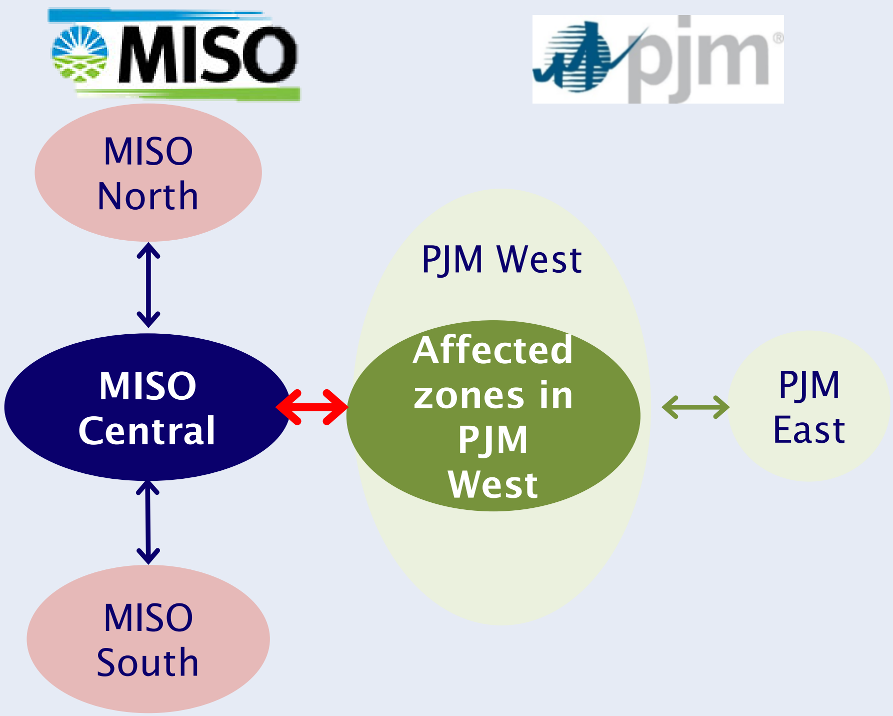
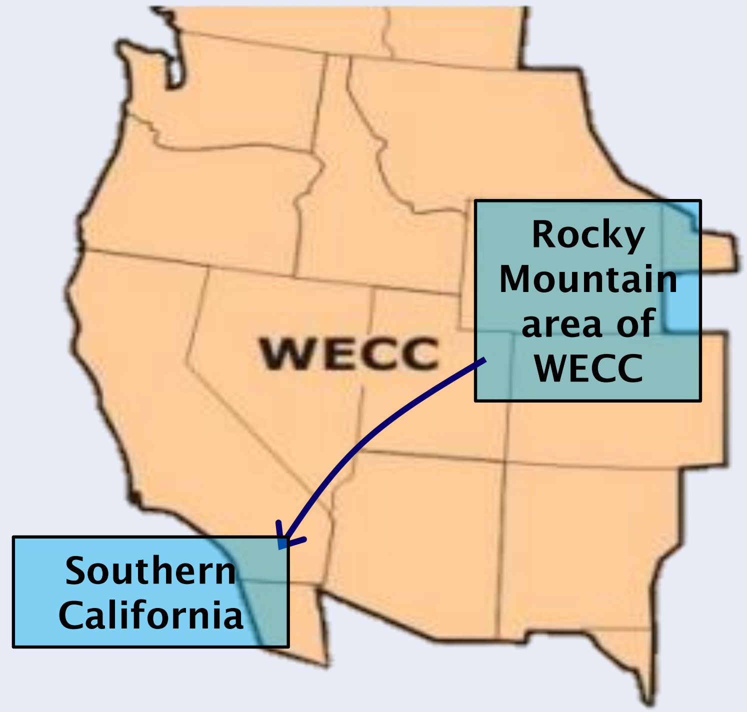
To demonstrate that benefits are quantifiable, LEI evaluated two hypothetical, inter-regional transmission investments

Trade-enhancing Transmission Project



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

Resource Delivery Transmission Project



The hypothetical Resource Delivery Project brings together suppliers and consumers, culminating in a mutually beneficial outcome

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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

Geographical and time scales studied using the REMI PI+ model

Economics impact period studied	Regions studied		
	Trade-Enhancing Project	Resource Delivery Transmission Project (Transmission component)	Resource Delivery Transmission Project (Wind component)
Construction period (2018-2020)*	Indiana	California, Wyoming, Utah, Nevada	Wyoming
Operations period (2021-2035)	Affected PJM-West zones and MISO Central zone	California, Wyoming, Utah, Nevada	Wyoming

* 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**

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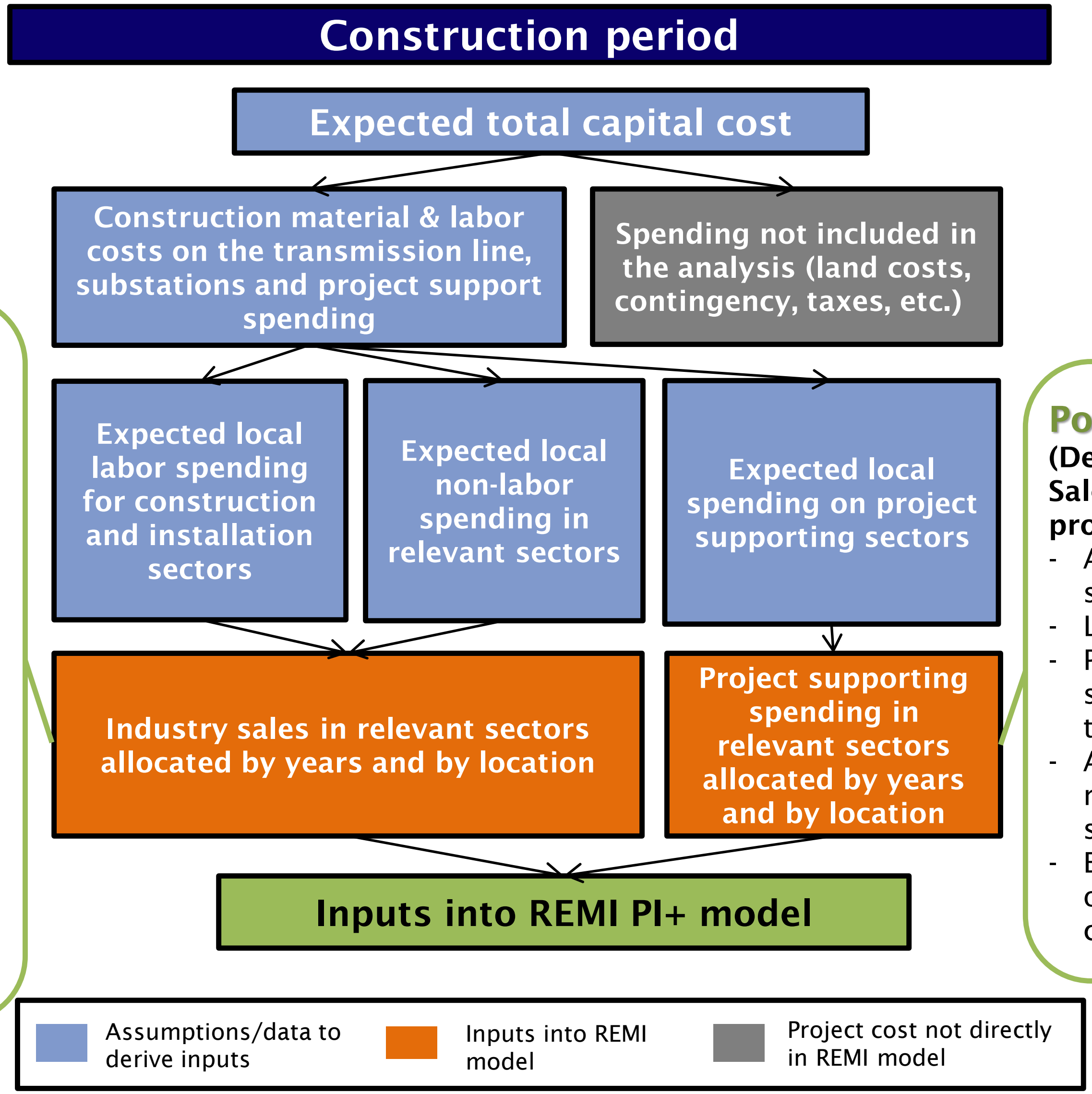
Project capital spending is the primary driver for local economic benefits during the construction phase

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)

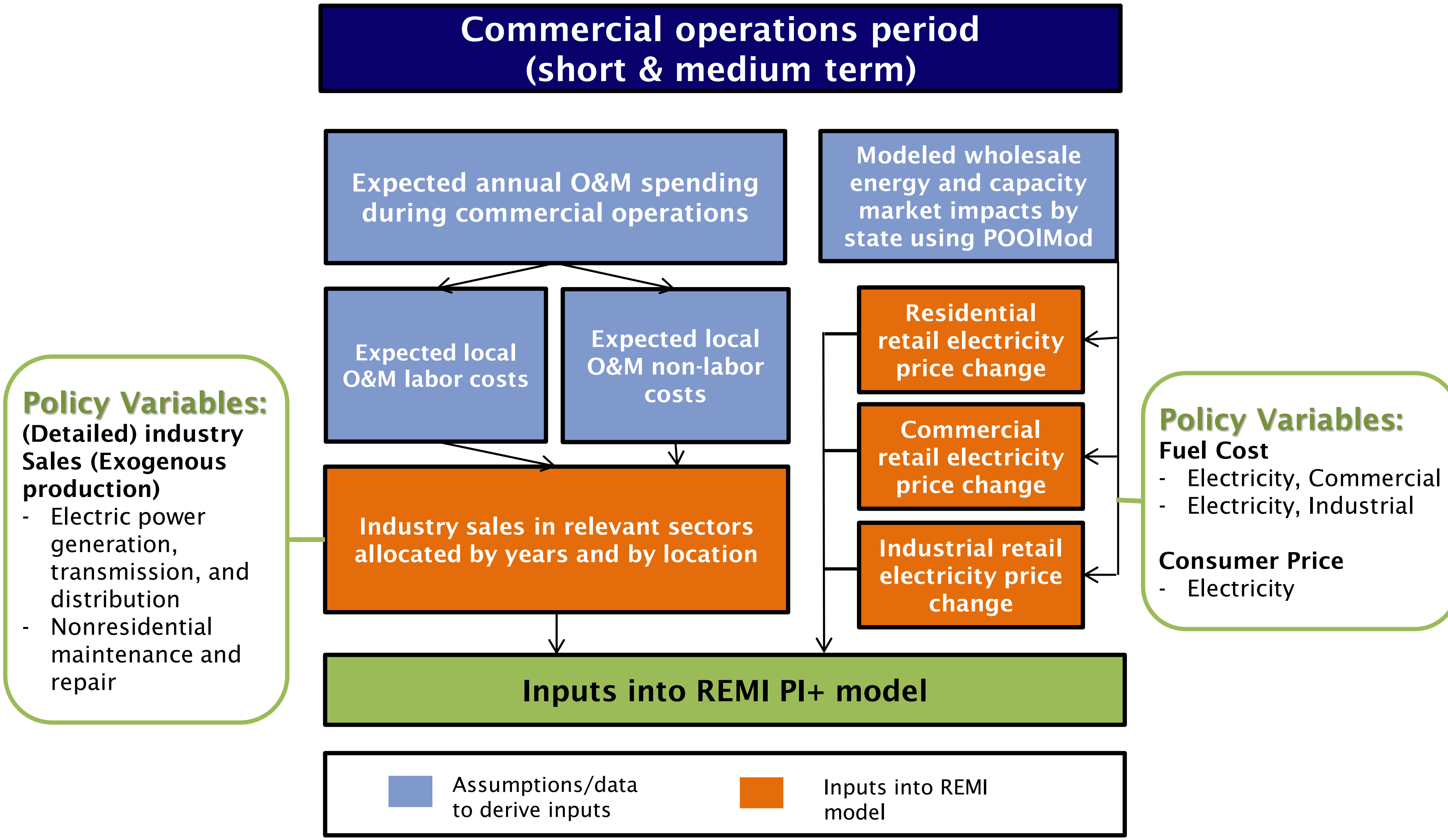


Policy Variables:

(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

Project operations and maintenance ("O&M") spending and electricity cost savings generate economic benefits when the project starts commercial operations



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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 =**

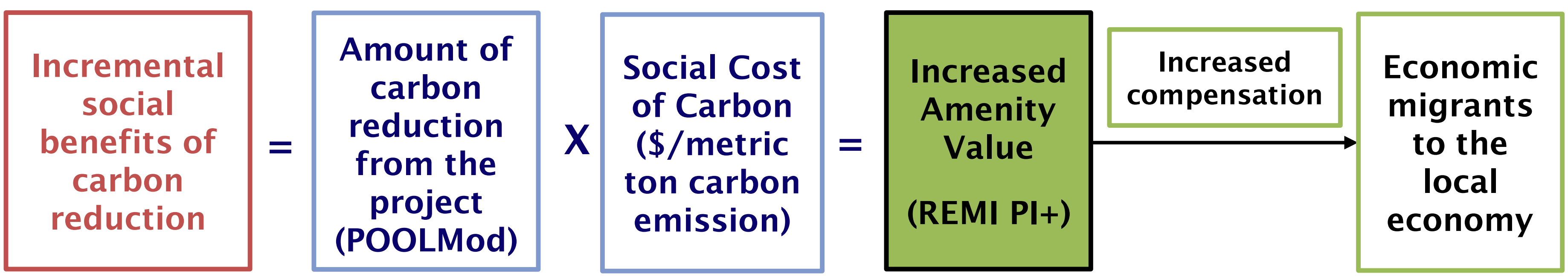
Energy Unserved (MWh, POOLMod) x Value of Lost Load ($/MWh, REMI PI+)

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



Source: <https://www.epa.gov/sites/production/files/2016-12/documents/social_cost_of_carbon_fact_sheet.pdf>
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

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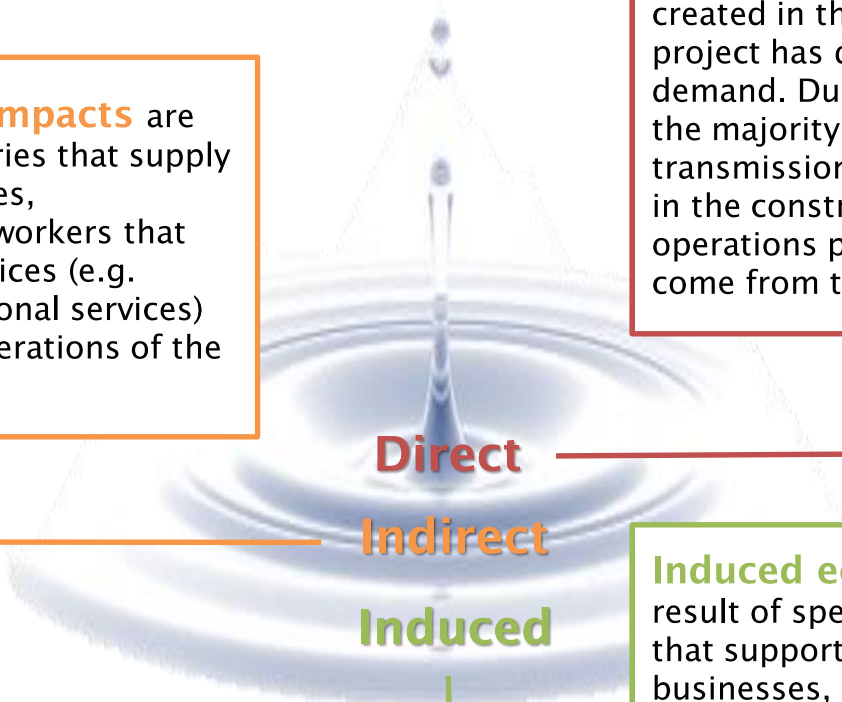
Transmission investment during the construction and operations periods can have measurable positive impacts on many sectors of the local economy through the “multiplier effect”

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

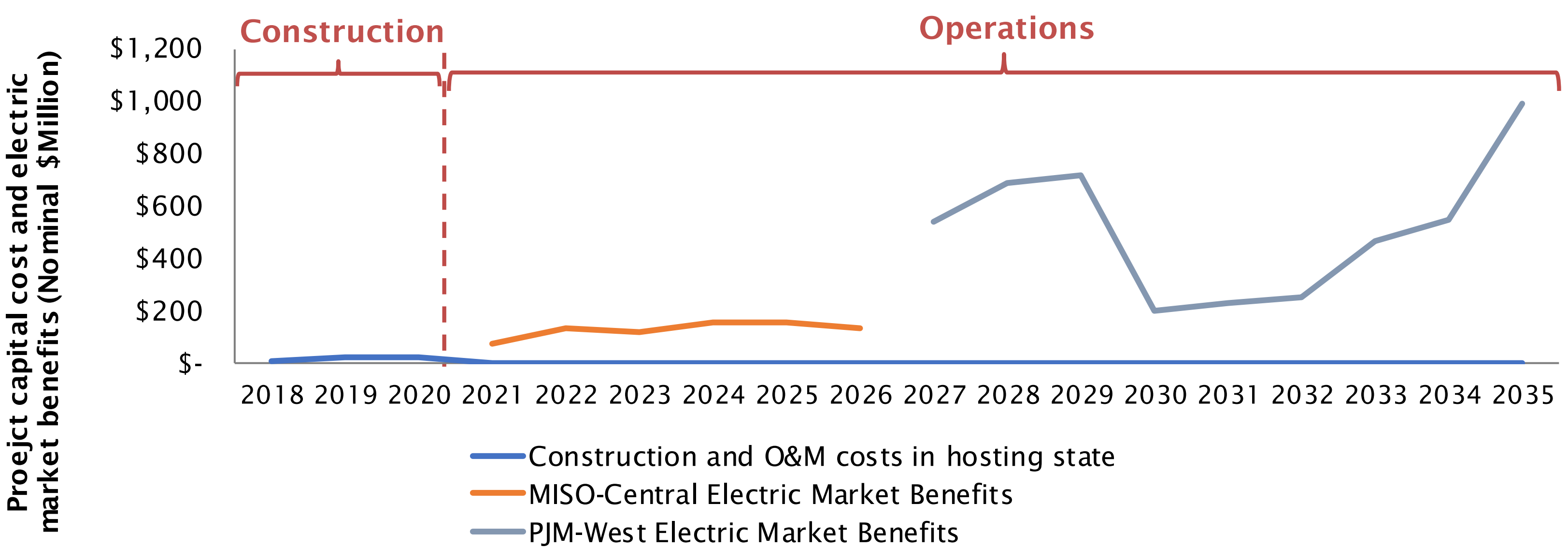


Induced economic impacts are the result of spending on goods and services that support a wide variety of nearby businesses, such as clothing, dining, accommodations, educational services, etc. During the construction period, the induced impacts are created by increased salaries of workers; during operations, 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



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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

Value of Lost Load (VoLL) =	x	Energy Unserved	=	Avoided expected economic loss
$16,672/ MWh		26,822 MWh		$447 million

Economic benefits from avoiding blackout events in MISO

Value of Lost Load (VoLL) =	x	Energy Unserved	=	Avoided expected economic loss
$12,926/ MWh		42,256 MWh		$546 million

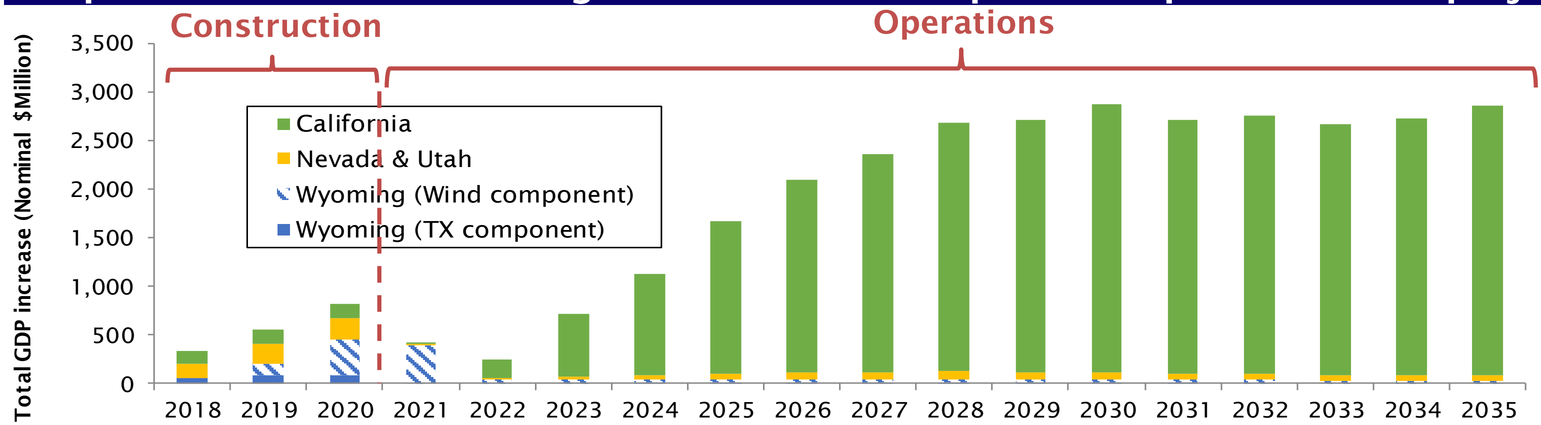
- **The economic benefits from improved "quality of life" due to carbon emissions reduction in affected regions of PJM and MISO range from $2.3 million to $11.1 million per year (under different social cost of carbon ("SCC") pricing scenarios), estimated using the Amenity Value approach**

Economic benefits from carbon reductions under three SCC pricing scenarios

SCC: $22/ metric ton	SCC: $71/metric ton	SCC: $104/ metric ton
GDP increase by $2.3 million/year	GDP increase by $7.6 million/year	GDP increase by $11.1 million/year
18 new jobs/year	58 new jobs/year	85 new jobs/year

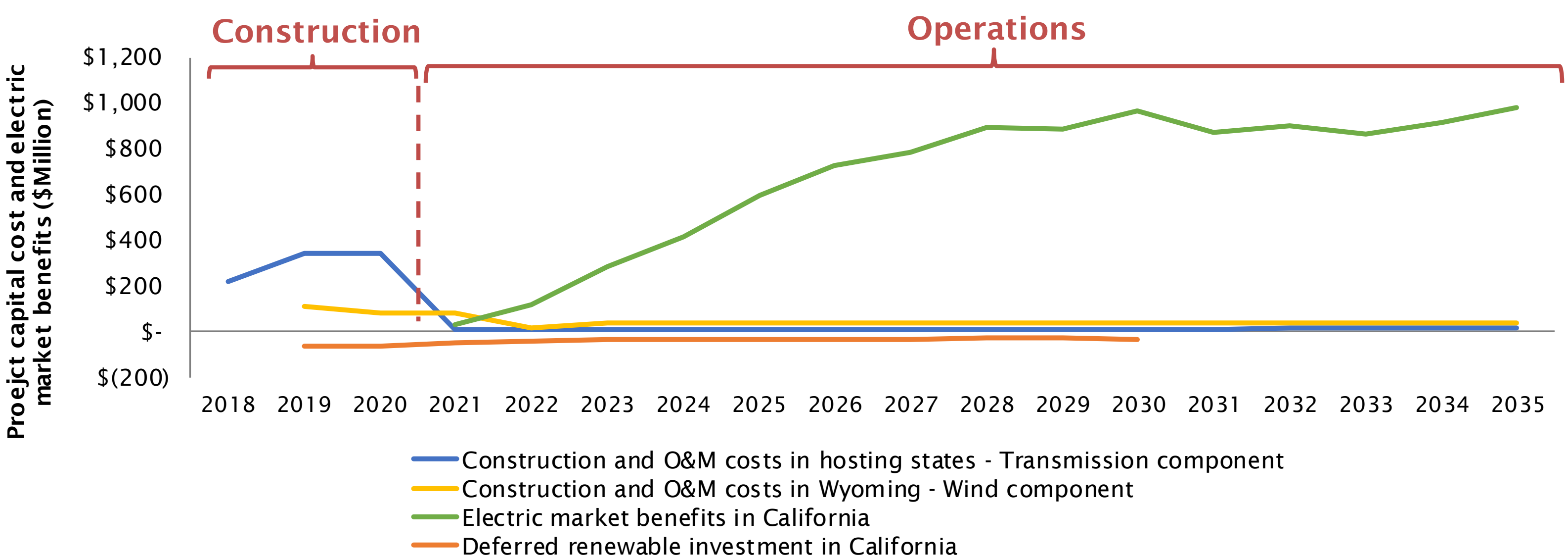
Resource Delivery Transmission Project: Investment in transmission and wind generations boosts local economy and expands local GDP as a consequence of lower electricity cost

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



*Introducing wind resource into California energy market might results 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



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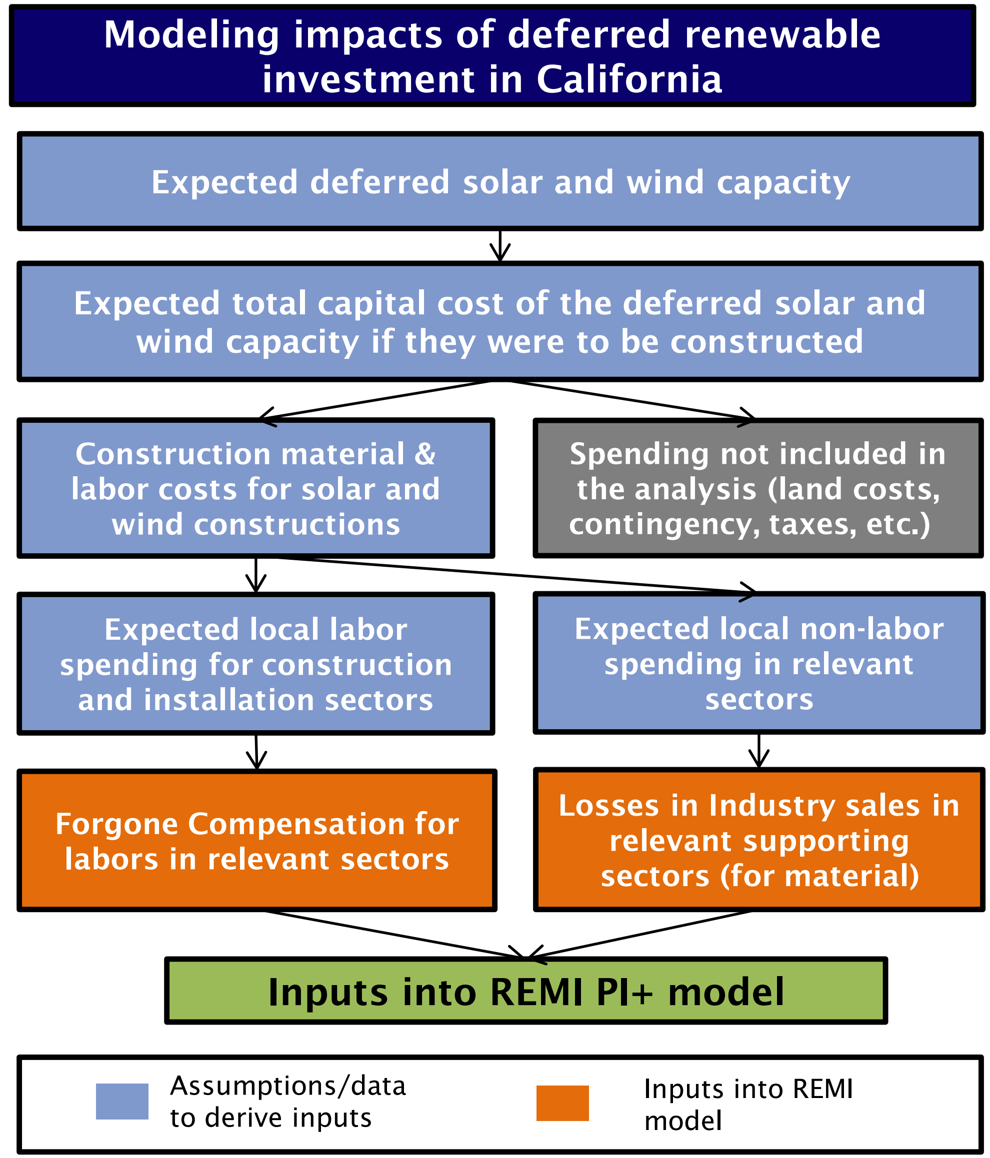
Resource Delivery Transmission Project: LEI considered potential negative economic impacts of deferred local renewable energy investment in California due to the transmission project with external generation investment

- 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



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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**

Economic benefits from avoiding blackout events

Value of Lost Load (VoLL) =	x	Energy Unserved	=	Avoided expected economic loss
$19,501/MWh		29,024 MWh		$566 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

SCC: $22/ metric ton	SCC: $71/metric ton	SCC: $104/metric ton
GDP increase by $180 million/year	GDP increase by $604 million/year	GDP increase by $891 million/year
1,144 new jobs/year	3,832 new jobs/year	5,655 new jobs/year

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Empirical results for two hypothetical projects can be generalized to other transmission investments and other regions

Benefit type	Generalized economic benefits
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 (Electricty 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 to1.5 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
Longer term (Electricty market)	
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

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In the electricity sector, LEI is active across the value chain

Asset Valuation, Price Forecasting & Market Analysis

- 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

Regulatory Economics, Performance-based Ratemaking & Market Design

- 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

Expert Testimony & Litigation Consulting

- Reliable testimony backed by strong empirical evidence
- Expert witness service
  - Material adverse change
  - Materiality
  - Market power
  - Contract frustration
  - Cost of capital
  - Tax valuations

Transmission

- 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

- 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

Procurement

- Designing, administering, monitoring, and evaluating competitive procurement processes
  - Auction theory and design
  - Process management
  - Document drafting and stakeholder management

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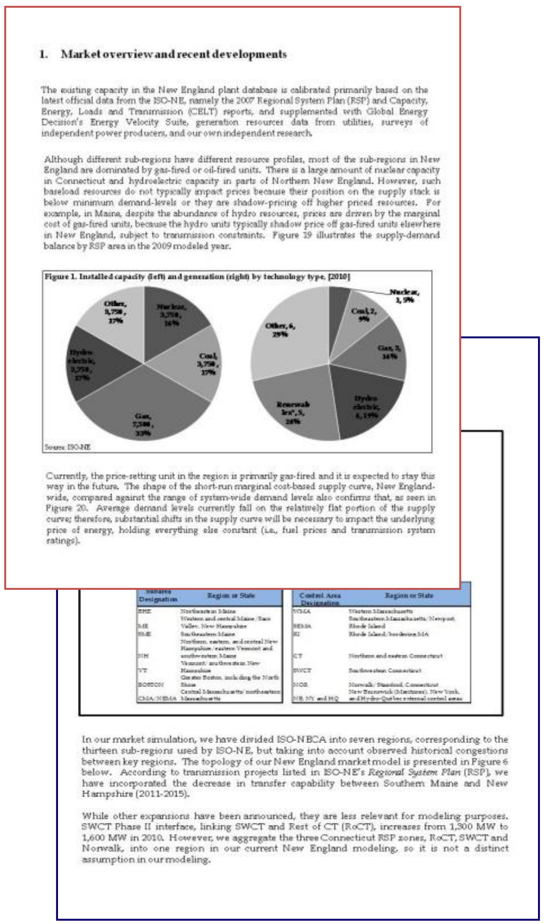
LEI publishes semi-annual price forecasts and market studies for all restructured regional power markets in North America

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



1. Market overview and recent developments

The existing capacity in the New England plant database is calibrated primarily based on the latest official data from the ISO-NE, namely the 2007 Regional System Plan (RSP) and Capacity, Energy, Loads and Transmission (CELT) reports, and supplemented with Global Energy Decision's Energy Velocity Suite, generation resources data from utilities, surveys of independent power producers, and our own independent research.

Although different sub-regions have different resource profiles, most of the sub-regions in New England are dominated by gas-fired or oil-fired units. There is a large amount of nuclear capacity in Connecticut and hydroelectric capacity in parts of Northern New England. However, such baseload resources do not typically impact prices because their position on the supply stack is below minimum demand-levels or they are shadow-pricing off higher priced resources. For example, in Maine, despite the abundance of hydro resources, prices are driven by the marginal cost of gas-fired units, because the hydro units typically shadow price off gas-fired units elsewhere in New England, subject to transmission constraints. Figure 19 illustrates the supply-demand balance by RSP area in the 2009 modeled year.

Figure 1. Installed capacity (left) and generation (right) by technology type, [2010]

Source: ISO-NE

Currently, the price-setting unit in the region is primarily gas-fired and it is expected to stay this way in the future. The shape of the short-run marginal cost-based supply curve, New England-wide, compared against the range of system-wide demand levels also confirms that, as seen in Figure 20. Average demand levels currently fall on the relatively flat portion of the supply curve; therefore, substantial shifts in the supply curve will be necessary to impact the underlying price of energy, holding everything else constant (i.e., fuel prices and transmission system ratings).

Subarea Designation	Region or State
BHE	Northeastern Maine
ME	Western and central Maine / Saco Valley, New Hampshire
SME	Southeastern Maine
NH	Northern, eastern, and central New Hampshire / eastern Vermont and southwestern Maine
VT	Vermont / southwestern New Hampshire
BOSTON	Greater Boston, including the North Shore
CMA/NEMA	Central Massachusetts / northeastern Massachusetts

Control Area Designation	Region or State
WMA	Western Massachusetts
SEMA	Southeastern Massachusetts / Newport, Rhode Island
RI	Rhode Island / bordering MA
CT	Northern and eastern Connecticut
SWCT	Southwestern Connecticut
NOR	Norwalk / Stamford, Connecticut
NB, NY and HQ	New Brunswick (Maritimes), New York, and Hydro-Québec external control areas

In our market simulation, we have divided ISO-NE BCA into seven regions, corresponding to the thirteen sub-regions used by ISO-NE, but taking into account observed historical congestions between key regions. The topology of our New England market model is presented in Figure 6 below. According to transmission projects listed in ISO-NE's *Regional System Plan* (RSP), we have incorporated the decrease in transfer capability between Southern Maine and New Hampshire (2011-2015).

While other expansions have been announced, they are less relevant for modeling purposes. SWCT Phase II interface, linking SWCT and Rest of CT (RoCT), increases from 1,300 MW to 1,600 MW in 2010. However, we aggregate the three Connecticut RSP zones, RoCT, SWCT and Norwalk, into one region in our current New England modeling, so it is not a distinct assumption in our modeling.

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)