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
Ruoyun Yang
Jarome Leslie
Jinglin Duan
Tianying Lan

WIRES

Voice of the North American Electric Transmission Industry

www.wiresgroup.com

Contents

WIRES Preface

How Does Electric Transmission Benefit You?

Identifying and Measuring the Life-Cycle Benefits of Infrastructure Investment

Technical Appendices

WIRES

WIRES PREFACE

Many of the studies sponsored by WIRES[1] have been devoted to explaining the kinds of benefits to society and consumers, local economies, and businesses that accrue from investments in electric transmission infrastructure. Those studies have contributed substantially to an understanding of the role transmission plays in facilitating efficient electric markets, in supporting the deployment of new technologies, in placing downward pressure on electricity prices, and in providing access to the diverse energy resources increasingly sought by industry and consumers.

While there is growing recognition that a robust transmission grid provides multiple benefits over time, this principle has not always been reflected in regional efforts to plan and share the costs of new transmission investment. Indeed, there is still insufficient acknowledgement of how a more integrated, robust grid will facilitate new technologies and provide a wide range of benefits to energy consumersover its lifespan. Consequently, the industry and its regulators have been slow to implement the lessons about forward-looking planning reflected in the previous WIRES' studies and confirmed by our experience with the lasting benefits of previous transmission investments. Instead, the uniquely long and complex planning and permitting processes which govern transmission infrastructure development generally focus on cures for short-term, sub-regional reliability challenges which, while entirely real, are only one set of problems that adequate transmission is capable of solving. Studies such as the one

---

[1] WIRES is an international non-profit association of investor-, member-, and publicly-owned entities dedicated to promoting investment in a strong, well-planned, and environmentally beneficial high voltage electric transmission grid. WIRES members include integrated utilities, regional transmission organizations, independent and renewable energy developers, and engineering, environmental, and policy consultants. WIRES' principles and other information are available on its website: www.wiresgroup.com.

we introduce today are key to overcoming many of the common objections to infrastructure investment. LEI's work and the other studies sponsored by WIRES provide a basis for new and innovative approaches to system planning and cost allocation and demonstate the importance of preparing our energy delivery systems to serve a future economy that will be driven by unprecedented demands for energy, bold new technologies, and policy priorities different than today's.

Among the biggest challenges for regulators and planners of electric transmission is the determination of the future benefits that an investment today is likely to provide tomorrow and beyond, and who will realize those benefits. To aid in this process, WIRES commissioned the following analysis by expert economists from London Economics International to demonstrate the benefits associated with making investments in electric transmission. In this case, economists at London Economics International ("LEI") has focused their analysis on the significant benefits that would be provided by inter-regional transmission investments by demonstrating and, to the extent possible, quantifying the benefits of two hypothetical inter-regional projects. It is critical to note,however, that the analytical approach utilized by LEI in this paper can be adopted by planners and industry participants to estimate the benefits of any transmission infrastructure.

LEI's Approach

If the public interest is best served by identifying, planning, and building electric transmission infrastructure to serve the greatest number of consumers and the economy overall during its entire useful life, what do transmission advocates need to demonstrate to policy makers and planners in order to build support for the optimal build-out of the system? In general, the answer involves identifying and quantifying the various kinds of benefits that the project creates during its planning and construction and during various periods of its operation. WIRES' previous studies[2] identified all

[2] The Brattle Group: (Chang, Pfeifenberger, and Hagerty) "*The Benefits of Electric Transmission: Identifying and Analyzing the Value of Investments*" (July 2013); (Pfeifenberger, Chang, and Sheilendranath) *"Toward More Effective Transmission Planning: Addressing the Costs and Risks Of An Insufficiently Flexible Electricity Grid*" (April 2015); (Chang and Pfeifenber) "*Well-Planned Electric Transmission Saves Customer Costs: Improved Transmission*

possible transmission-related benefits and how, in theory, to calculate them. LEI now puts those theories and suggestions to the test. Because transmission facilities typically last for more than 40 years, LEI's analysis uses advanced simulation-based modeling techniques to project the overall economic value of new transmission facilities at various points during the lives of those assets.[3]

The LEI analysis focuses on two hypothetical projects that are representative of the types of new transmission projects that are currently being planned or contemplated in various parts of the country. To demonstrate how a benefits determination can be made for a transmission project that extends beyond one regional market or regional transmission organization ("RTO") boundary and whose principal initial purpose is market efficiency, LEI formulated a project in the Eastern Interconnection designed primarily to expand market access for lower-cost generation and enhance interregional electricity trading. That project (called the Eastern Interconnection Project, for ease of reference) would be located between PJM and MISO. A second hypothetical project (called the Western Interconnection Project) is constructed for delivery of "new resources" from widely separated parts of the country or existing system to serve customer demands for lower carbon energy, for example from new wind or solar resources that are instrumental in implementing state policy goals. In both cases, LEI projects specific kinds and levels of transmission benefits.

Why use hypothetical projects? LEI determined that use of "real" projects for these illustrative purposes would mire the analysis in debates about the characteristics and merits of specific proposals and competing alternatives. All transmission projects are unique in certain ways. Therefore, it made more sense to extrapolate and

---

Planning Is Key to The Transition to a Carbon-Constrained Future" (June 2016). All studies were prepared for WIRES and are readily available on its website.

[3] LEI's technical Appendices explains its analysis, the modeling tools employed, and its underlying assumptions in detail.. We contend that, armed with this kind of information, planners and the regulators who make various decisions about the value and merits of infrastructure projects will find it possible to determine which projects deliver the greatest benefits over time. Of course, this does not ignore the challenging siting and other issues in the multiple regulatory processes that projects must navigate. We nevertheless highlight the central importance of benefits calculations to any understanding of transmission development.and how little regulators have done to date to advance that understanding.

generalize about the benefits of reasonably representative hypothetical projects, and thereby to demonstrate the strength of the analytical methodology, than it did to analyze proposed projects that may change or have characteristics that affect its beneficial nature positively or negatively. In WIRES' view, the principal accomplishment of LEI's study is to show that tools exist with which to make more sophisticated forecasts about the benefits of transmission. With such tools,planners can design or select transmission investments that will be most beneficial for consumers and other stakeholders over the lifecycle of those projects.

LEI's Bottom Line

The reader of the following transmission benefits analysis will find LEI's answers to some very basic questions quite helpful in gaining an understanding of why WIRES and other groups believe so strongly that expanding and upgrading the North American transmission system is a win-win for all economic segments:

What are the benefits of transmission investment? Transmission can lower customers' energy bills, advance the benefits of competitive wholesale power markets, reduce the system cost of producing electricity, reduce emissions from certain forms of electric generation, generate new jobs at various stages of development and operation, and expand local economic activities.

Whom does transmission benefit? Transmission caters to many diverse and geographically dispersed beneficiaries, including households, retail and commercial businesses, power producers, small and large industrial customers and governments.

Where do we see transmission benefits? Transmission investment can provide widespread benefits that are distributed over large geographical distances due to the increasingly integrated nature of the grid and the expansion of electricity markets.

When do transmission benefits arise? Transmission can create benefits over many years, starting while projects are under construction and continuing well into the later years of operation. Benefits arise, dissipate, and change over time but, based on simulation-based modeling and scenario planning, we can say with greater certainty that the benefits over a project's useful life is very likely to exceed the costs many times over.

* * * * * * *

WIRES submits this LEI analysis for consideration by planners, policy makers, regulators, and all persons interested in how to ensure a robust North American grid that will sustain and grow economies as they become increasingly dependent on electric power and new technologies in areas like manufacturing, transportation, personal comfort, convenience, and security during the coming decades. We therefore solicit our readers' comments on this work; they can be submitted to www.wiresgroup.com.

We also acknowledge the expertise of analysts at London Economics, led by Julia Frayer and Eva Wang, and thank them for their care and objectivity in preparing this study. WIRES views this as more than a scholarly treatment of this critical component of the power industry; it is also a call-to-arms for planners and policy makers who have often found it difficult to conceive and authorize infrastructure projects because the life-cycle benefits and beneficiaries of such assets are so difficult to understand and quantify. LEI has demonstrated that the significant benefits that transmission provides over its useful life can be identified and quantified. This simply means that projects that will prove most beneficial in the long run can be planned today for maximum long-term benefit and then cost-effectively built. But because the approval processes for major electric transmission .projects are typically long and risky, it is incumbent on industry and policy makers to begin now to work toward a grid that will sustain the new economy of 2030 and beyond.

KATHLEEN SHEA
Eversource Energy
WIRES President 2017

JAMES J. HOECKER
Husch Blackwell LLP
Hoecker Energy Law & Policy PLLC
Counsel & Advisor, WIRES

January 8, 2018

HOW DOES ELECTRIC TRANSMISSION BENEFIT YOU?

IDENTIFYING AND MEASURING THE LIFE-CYCLE BENEFITS OF INFRASTRUCTURE INVESTMENT

Prepared for

WIRES

By

Julia Frayer
Eva Wang
Ruoyun Yang
Jarome Leslie
Jinglin Duan
Tianying Lan

January 8, 2018

LONDON ECONOMICS

www.londoneconomics.com

SYNOPSIS

WIRES commissioned London Economics International LLC ("LEI") to prepare a study demonstrating the benefits of transmission investment. The benefits of transmission are frequently seen as uncertain by many policymakers and regulators; system planners have also found it a challenge to comprehensively measure benefits and identify beneficiaries. This study shows that a variety of benefits can be quantified robustly through forward-looking, simulation-based analysis. Moreover, these benefits are substantial, widespread, and long-lasting – putting dollars in the pockets of households, businesses, and governments.

The modeling approach LEI uses to estimate the benefits of transmission utilizes two hypothetical transmission investment projects. LEI presents the projected benefits of each transmission project by category and by beneficiary, showing as well where and over what timeframe these various benefits arise during the lifetime of a typical transmission investment. Although the hypothetical projects analyzed in this study are created to highlight the benefits of two specific types of inter-regional transmission investments in two diverse market settings, the methodology for estimating benefits and the overall magnitude of the benefits are indicative of all transmission investments – reliability projects, economically-motivated projects, and policy-driven initiatives. Therefore, the analytical approach illustrated in this study applies not just to inter-regional transmission projects but also to various other types of well-conceived transmission investments.

DISCLAIMER

The analysis LEI provides in this this study is intended to demonstrate the benefits of a well-designed transmission investment. LEI relies on hypothetical projects, with notional characteristics and indicative construction dates and investment costs. While LEI has taken all reasonable care to ensure that its analysis is complete, power markets are highly dynamic, and thus certain recent developments may or may not be included in LEI's forward-looking analysis in this study. LEI does not evaluate all possible benefits, nor does LEI present a full cost-benefit analysis of any specific transmission project. This report is not intended to be an evaluation of any specific transmission investment. The opinions expressed in this report as well as any errors or omissions, are solely those of the authors and do not represent the opinions of other clients of London Economics International LLC.

Table of Contents

Note: Additional detailed information of the modeling tools, assumptions, and modeling results can be found in the Technical Appendices. These Technical Appendices are available upon request, or can be downloaded from the WIRES website (http://www.wiresgroup.com/).

London Economics International LLC
717 Atlantic Ave, Suite 1A
Boston, MA 02111
www.londoneconomics.com

Table of Figures

Acronyms

C&I	Commercial and Industrial
CREZ	Competitive Renewable Energy Zones
EPA	Environmental Protection Agency
GDP	Gross Domestic Product
kV	Kilovolt
LEI	London Economics International LLC
LMP	Locational Marginal Price
MISO	Midwest Independent Transmission System Operator, Inc.
MRAs	Market Resource Alternatives
NPV	Net Present Value
NTAs	Non-Transmission Alternatives
O&M	Operations and Maintenance
PJM	PJM Interconnection LLC
REC	Renewable Energy Credit
REMI	Regional Economic Models, Inc.
RPS	Renewable Portfolio Standard
SCC	Social Cost of Carbon
TRTP	Tehachapi Renewable Transmission Project
VoLL	Value of Lost Load
WECC	Western Electricity Coordinating Council

1 Executive Summary

Large transmission investments are often challenging for system planners and policymakers to assess. The benefits of such projects can be widespread, but the regional nature of system planning often overlooks the full spectrum of wide-ranging benefits that emerge during different stages of a transmission project's life cycle. For this paper, LEI conducts a comprehensive analysis of benefits by evaluating two hypothetical, yet realistic, inter-regional transmission projects in different parts of the US. LEI analyzes these projects with well-accepted forward-looking modeling techniques to show the ways in which the benefits of transmission emerge and evolve.

1.1 Approach

The purpose of this study is to demonstrate that transmission benefits can be quantified, and would provide system planners and decision-makers with important baseline information to properly plan for the grid of the future. LEI's approach for estimating the benefits of transmission is based on projections of future electricity market conditions, with and without the hypothetical transmission projects. Although the two hypothetical transmission projects are variations on inter-regional projects, the approach could easily be employed to understand the benefits of any well-conceived transmission project during its entire useful life.

The benefit calculus in this paper is based on empirical analysis and utilizes a suite of simulation-based modeling tools. LEI's modeling covers the construction phase of the project and the first 15 years of the operations under a "base case" or "most likely" forecast for the future electricity market conditions. LEI also examines alternative supply conditions to measure longer-term reliability benefits.

The modeling in this study demonstrates that the uncertainties faced by transmission planners and policymakers with respect to economic impacts of these long-lived assets should not deter them from undertaking a benefit analysis. Only with a comprehensive economic examination of benefits will decision makers be able to optimize the value of transmission projects to consumers and the wholesale power market.

1.2 Two hypothetical projects

The hypothetical projects LEI analyzes in this study reflect two common commercial drivers for transmission investments:

(i) increasing market efficiency through additional trade of electricity, and
(ii) accommodating delivery of lower cost and cleaner energy resources (that may be in remote locations) to consumers.

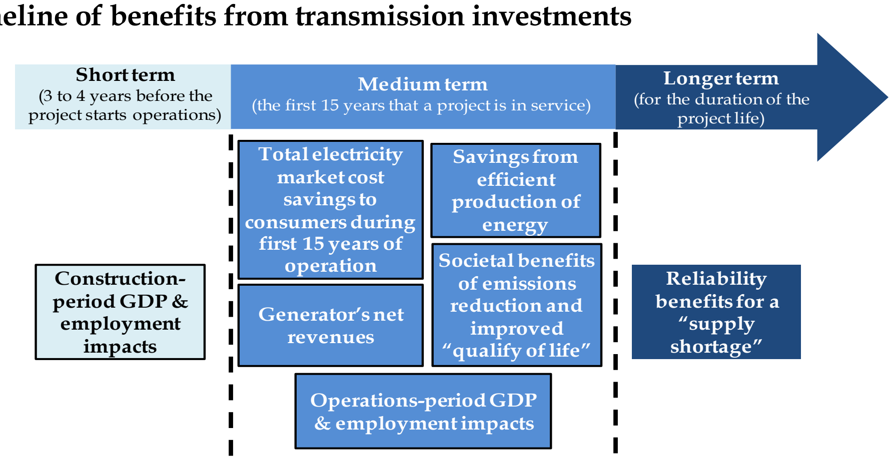
The first hypothetical project, located in the Eastern Interconnect, increases the transmission capacity between two regional markets operated by PJM Interconnection LLC ("PJM") and Midwest Independent Transmission System Operator, Inc. ("MISO"). This "**Eastern Interconnect project**" aims at enhancing market efficiency through trade. The other hypothetical project involves a new transmission line extending from the Rocky Mountain area to southern California (the "**Western Interconnect project**"). This hypothetical project demonstrates the value of transmission investment in bringing energy and associated products and services (such as capacity and reduced carbon emissions) from new resources located at some distance from electricity consumers.

While the primary business drivers, configuration and market conditions of these two hypothetical transmission projects are different, LEI's findings suggest that the magnitude and variety of benefits is broadly similar for different types of transmission projects, once adjusting for the scale of the transmission project and the volume of energy deliveries. As such, this study can serve as an indicator of benefits for many types of transmission projects. Furthermore, LEI's approach and conclusions are generalizable to other projects – interregional or intra-regional – and call out the multiple benefits that have often been overlooked as system planners focus more on reliability considerations or only narrow categories of economic benefits, like efficiency improvements to system operations (also known as "production cost savings" or, as referenced in this study, "savings from efficient production of energy").

1.3 Findings regarding benefits of transmission

This study estimates the benefits of transmission chronologically: starting from the initial days of transmission project development and construction, through the first fifteen years of commercial operations[1] (see Figure 1). The two hypothetical projects, like their real-world counterparts, are projected to provide electricity consumers, electricity generators, electric power markets and the economy generally with a range of benefits over their useful lives. To demonstrate the variety of benefits and diversity of beneficiaries, LEI has presented all the benefit streams individually in dollar terms. Furthermore, given the focus of this study on benefits, LEI has not netted these benefits against the costs of the project, although that would be a standard procedure in the real-world for purposes of a complete evaluation of a project.

Figure 1. Timeline of benefits from transmission investments



Note: The diagram presents only those benefits that LEI has quantified in this study. Examples of benefits not explicitly examined by LEI include indirect effects on natural gas markets, indirect effects on carbon allowance markets and/or REC compliance markets, benefit of additional tax revenues for local communities and states. There may also be other benefits that are more difficult to quantify, including increased competition and facilitation of technology development in the longer term.

[1] Certain benefits will extend beyond the 15-year timeframe.

1.3.1 Benefits in the Short Term

In the **short term,** properly-conceived transmission investments, like other large infrastructure projects, create benefits by boosting the local economy (commonly measured by Gross Domestic Product ("GDP")[2]) and creating new jobs through local spending on construction-related services. The new jobs are not limited to the construction sector because of the "ripple effect" of investment. The short-term benefits are shown in Figure 2 below. The magnitude of these benefits is largely driven by the capital costs of a project and the amount of local spending associated with the construction of the project in the short term. The **Eastern Interconnect project** is estimated to cost $200 million on an indicative basis, while the **Western Interconnect project** is estimated to be a $3 billion project. Therefore, we observe a proportionately higher level of project benefits from the **Western Interconnect project** in the short term.

Figure 2. Short-term benefit summary for the two hypothetical projects

Benefit type	Eastern Interconnect project	Western Interconnect project
Project local spending	$69 million	Over $2 billion for both transmission and generation components
GDP	GDP increase by $22 million/year	GDP increase by about $700 million/year
New Jobs	250 new jobs/year	More than 5,500 new jobs/year

1.3.2 Benefits in the Medium Term

In the **medium term,** the modeled transmission investments create the following benefits, with results summarized in Figure 3 and further detailed in Section 4.2:

- These transmission investments **lower the costs of electricity** to consumers by allowing more cost-effective energy and capacity resources to reach consumers.
- These transmission investments also economically benefit some **generators**, allowing them to earn higher revenues by making possible sales to new markets consumers through the new transmission capacity.
- Transmission investments can paradoxically both lower the market price paid by consumers for electricity and increase some generators' revenues. This can be explained by the overall **efficiency improvement** in the energy market brought about by transmission investment and the expansion of the market that system operators can use to optimize dispatch of resources.

---

[2] Gross domestic product ("GDP") is the monetary value of all the finished goods and services produced within a specific region (for example, within the borders of a state or country) and over a specific period. Typically, GDP is measured and reported on an annual cycle. GDP also commonly includes all private and public consumption, government outlays, investments, private inventories, paid-in construction costs, and the foreign balance of trade (exports are added, imports are subtracted). As such, GDP is a broad measure of overall economic activity, and is the common metric for analyzing a country's or state's economic condition.

- The lower electricity costs for consumers also catalyze another category of benefits - regional economic growth. Lower electricity costs make the **local economy** more attractive to industrial and commercial businesses and spur investment that then leads to an expansion of operations of these businesses. Meanwhile, lower electricity bills increase residents' household income and increase demand for various consumer goods and services.
- Thanks to the increased level of trading accommodated by the new transmission line, cleaner and lower-cost energy is used by consumers, which **reduces carbon dioxide emissions**[3] in the receiving or importing region(s).
- Achievements like reduced carbon emissions are highly valued by some residents and households. To some individuals, these achievements signal a "**quality of life**" improvement, creating a more favorable living environment and attracting new residents to relocate to the region. Expansion of the labor market (as people move to the region) gives rise to another wave of expansion in the local economy.

Figure 3. Medium-term benefit summary for the two hypothetical projects

Benefit type	Eastern Interconnect project	Western Interconnect project
Project local spending	$69 million	Over $2 billion for both transmission and generation components
Electricity market cost savings	$275 million/year	Nearly $1,200 million/year
Increase in some generators' net revenues	About $80 million/year in MISO (2021-2026), $300 million/year in PJM (2027-2035)	$960 million/year
Savings from efficient production of energy	Nearly $30 million/year in PJM*	$120 million/year
GDP	GDP increase by $150 million/year in MISO (2021-2026), and by $560 million/year in PJM (2027-2035)	GDP increase by nearly $2 billion/year
New Jobs	1,200 new jobs/year in MISO (2021-2026), and 3,000 new jobs/year in PJM (2027-2035)	About 9,400 new jobs/year
Carbon emissions reduction	Avoid 3 million metric tons cumulatively of carbon emission for PJM and MISO	Avoid 18 million metric tons of carbon emission cumulatively for the California grid system
Emissions reduction benefits	$4 million to $20 million/year	$23 million to $112 million/year
Improved quality of life	GDP increase by $2-$11 million/year, and create 20-90 new jobs/year in PJM and MISO	GDP increase by $180 - $890 million/year, and create 1,100 to 5,700 new jobs/year in California

Note: The Net Present Value ("NPV") of benefits from improved efficiency of producing energy in MISO during 2021-2026 is positive, although the simple average rounds to zero.

The benefits listed in Figure 3 arise across a large geographic area. For example, as residents and local businesses in the directly affected region (where electricity costs decline) purchase additional products and services, the economies *in other states* that provide such additional products and services also benefit from the increased demand. In addition, as market conditions evolve, LEI's modeling shows that transmission can accommodate changes in various external

[3] For the purpose of simplicity, carbon dioxide emissions are referred to as carbon emissions in this study.

market conditions and help system operators more cost-effectively adapt to new circumstances. This does not mean that benefits of transmission are diminished as a consequence of evolving market conditions, but rather that the beneficiaries or the timing of benefits may change (see Section 4.2.1 for additional details).

1.3.3 Benefits in the Longer Term

In the **longer term**, well-planned transmission brings significant reliability value. For example, transmission investment can serve to dampen or neutralize the cost impacts of unexpected events in the market, much like an "insurance" policy. The insurance value of new transmission over its long term described in Figure 4 (and fully described in 4.3) is estimated by modeling the energy system with and without the new investment. The benefits of **avoiding higher energy costs** can be very large for consumers, as energy market costs rise quickly in the face of supply constraints. In addition, the economic consequences of **avoiding supply interruptions** are significant, even if such events are rare. Unexpected events can occur at any time and such events – especially if they lead to supply interruptions – can be immensely expensive. Well-placed transmission investment can reduce the frequency of supply interruptions (blackouts) and temper rising energy market costs from supply constraints. Such reliability benefits exist over the lifetime of a transmission project. LEI's modeling results (see Figure 4) indicate that both hypothetical transmission projects can reduce the cost impacts of supply constraints and economic losses of blackouts under specific circumstances, thereby creating significant value to energy consumers and the local economy in the long run.

Figure 4. Longer-term benefit summary for the two hypothetical projects

Benefit type	Eastern Interconnect project	Western Interconnect project
Project local spending	$69 million	Over $2 billion for both transmission and generation components
Reliability benefits to consumers by avoiding higher energy costs	Over $22 million savings in MISO and almost $40 million savings in PJM	Over $100 million savings to electric consumers in California
Reliability benefits to economy by avoiding supply interruptions	Over $1 billion in MISO and PJM for at least one hour long of blackout	Nearly $600 million in California for at least one hour long of blackout

1.4 Observations and recommendations

The empirical analysis in this study demonstrates that well-conceived transmission can provide benefits that are quantifiable, substantial, widespread and long-lasting. To ensure effective decision-making and investment appraisal, system planners, policymakers, and decision-makers should consider the full spectrum of benefits provided by transmission. LEI recommends that such considerations need to be made in concert with the design and development of the project (rather than as a 'postscript' in the description of the project, or in response to a request of a policymaker or regulator). Quantified benefits then can be compared to the costs[4] of the project

[4] Costs of transmission projects are not studied in this report because LEI relies on hypothetical projects and investment costs are not based on accurate, project-specific data. Rather, the assumed costs are indicative of typical project costs for transmission with characteristics similar to the two hypothetical projects.

to assess the investment thesis. The goal should be to build the infrastructure and deploy capital to secure an optimal range of benefits for consumers and the economy.

LEI suggests integrating economic valuation methodologies, similar to those demonstrated in this study, within current transmission planning processes. The system planning process should not only be looking at the technical needs and engineering characteristics of new transmission (e.g., costs), but should also consider the numerous economic benefits that are derived from making the investment. When the full range of benefits is considered in transmission planning, projects can be optimized to provide the highest level of value to customers.

The benefits of transmission investments take many forms and affect many stakeholders in different ways, over varying timeframes. Uncertainties around economic trends, technology improvements, and public policy add challenges in predicting a future world. Scenario analysis, and other probabilistic modeling techniques, can allow estimates of impacts from new investment in the face such uncertainties. Decision-makers should refrain from *assuming* that there are no economic benefits from transmission investment simply because of uncertainties about future conditions. Rather, rigorous analysis of the full range of short-term, medium-term and long-term benefits should provide decision-makers more confidence in selecting the most valuable transmission investments for the future.

2 Introduction

The bulk electric transmission system is like a highway for electricity – it helps bring electricity to our homes and businesses. In 1956, President Dwight D. Eisenhower embarked on a monumental program to expand the national highway system.[5] It was the most costly and ambitious infrastructure project to ever be undertaken in the US at that time, and one characteristically designed to serve the overall public interest. Over time, it has been shown that the benefits of the interstate highway system far outweigh the costs, catalyzing interregional commerce and trade, and boosting productivity in nearly all sectors of the economy, in all regions of the country and over multiple decades.[6,7]

2.1 Understanding the value of transmission is important

Like transportation, electricity is integral to almost all sectors of the economy and essential to most individuals' daily activities. The US electric transmission system is the nation's highway for electrons, connecting consumers with suppliers, even if they are a great distance from our homes and businesses. Investment in transmission, like other well-designed infrastructure networks – whether interstate highways, the rail system, energy pipelines, or the Internet – supports and expands economic growth. However, unlike the federal highway system, there is no US-wide national electric transmission system. Most lines are like country roads or state highways, supporting transmission within a state or within a specific geographically-defined power market. Few transmission lines reach across multiple states or regions, the way the superhighways of the US interstate highway system do. This means that bottlenecks in the electric power system (akin to traffic jams on roads) can prevent the flow of cost-effective energy to consumers when they want it and value it most. This paper demonstrates how expanding our electric system can deliver social and economic benefits like those created by investment in the interstate highway system years ago.

In essence, a transmission line creates a larger market, like a bridge between two cities, by allowing lower cost supply to reliably flow where it is needed and valued most (as illustrated in Figure 5). By allowing for direct trade between two cities, a bridge melds or integrates local economies. New transmission causes the same thing – regions once limited to their own internal supplies become part of a larger market. This "larger market" then allows system operators more flexibility; they can better optimize their decision-making on which supply resource to dispatch and when, creating efficiencies and opportunities for consumers and suppliers.

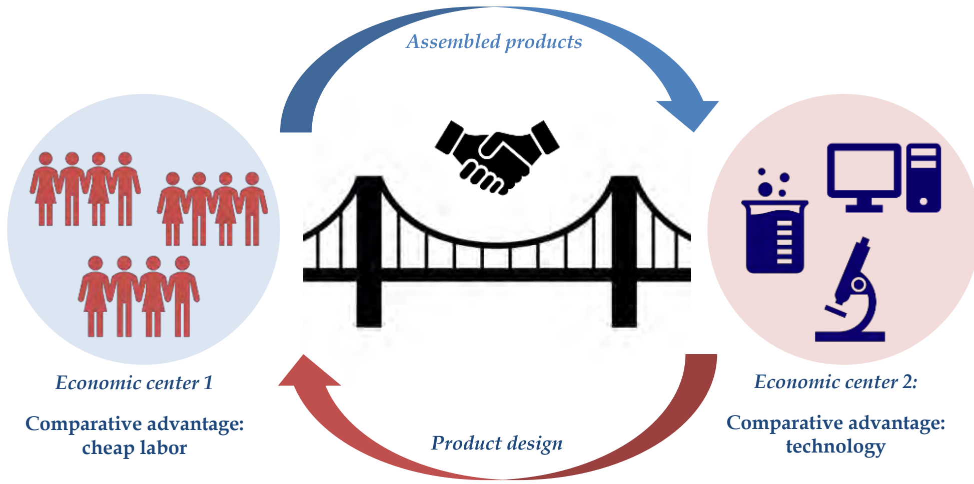
---

[5] Through the *Federal Aid Highway Act* of 1956.

[6] The Economist. "America's interstate highways. America's splurge, was this the model?" February 14, 2008. <http://www.economist.com/node/10697196>

[7] Cox, Wendell and Jean Love. "40 Years of the US Interstate Highway System: An Analysis of The Best Investment a Nation Ever Made." June 1996

Figure 5. A bridge allows two cities to benefit from trading



2.2 Key questions to be answered

Continued investment in transmission requires long-term planning and coordination among many different parties. However, as mentioned in the transmission myths paper recently published by WIRES,[8] some benefits of new transmission are often only narrowly considered or are overlooked entirely by decision-makers.

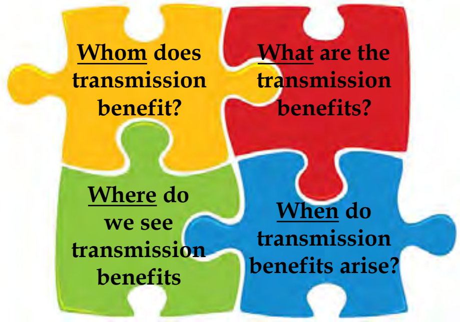
In an effort to make the benefits of transmission more understandable to a broader audience, this paper aims to demonstrate the value proposition of transmission by modeling two hypothetical projects and then answering four questions:

- **Who** benefits from transmission investment? Transmission caters to many diverse beneficiaries, including households, retail and commercial businesses, power producers, small and large industrial customers and governments.
- **What** are the transmission benefits? Transmission can lower customers' energy bills, reduce system cost of producing electricity, increase reliability and flexibility of the grid, reduce carbon emissions, create job opportunities, and expand local economic activity.
- **Where** do we see transmission benefits? Transmission investment has widespread impacts – benefits are distributed over large geographical distances.
- **When** do transmission benefits arise? Transmission investment can create benefits over many years, starting before the project goes into commercial operation and continuing for many years.

---

[8] "The Truth About the Need for Electric Transmission Investment: Sixteen Myths Debunked." September 2017. < http://www.modernizethegrid.com/2017/09/21/a-wires-report-the-truth-about-the-need-for-electric-transmission-investment/>

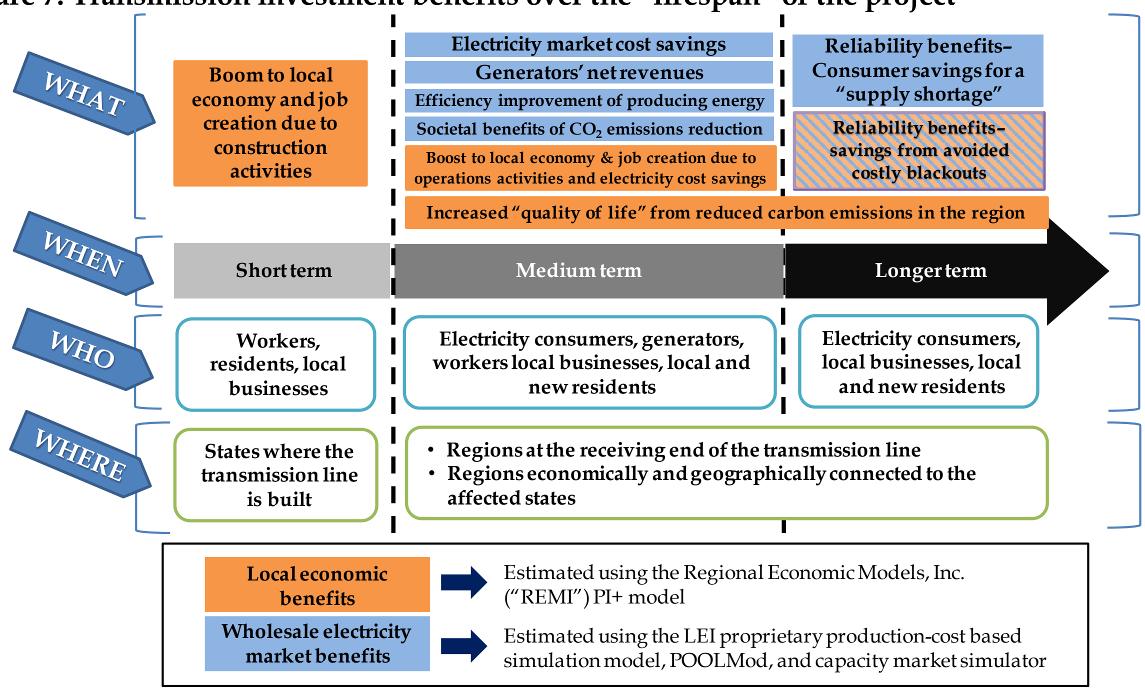
Figure 6. The "Who, What, Where, and When" of transmission benefits



2.3 Basic overview of approach and methodology

LEI's analysis follows the natural chronology of a transmission investment over the "lifespan" of a project, that is, from the initial days of project development and construction through commercial operations and the life of the project. Transmission lines typically have a useful life well over 50 years. The grid we rely on today was largely build in the 1960s and 1970s, with some operating transmission facilities dating back to 1940s and 1950s. Because these facilities provide service over such a long time and benefit consumers and the economy in ways that were not anticipated when built, LEI believes that planning should determine the likelihood and nature of these benefits over the long term. LEI presents the benefit metrics in their natural chronological order in Figure 7 below.

Figure 7. Transmission investment benefits over the "lifespan" of the project



Note: "Reliability benefits – savings from avoided costly blackouts" is estimated through both the REMI PI+ and POOLMod models so we use a two-color coded system here

In the **short term**, three or four years before a transmission project is commissioned, the development-and-construction period will see many new jobs created for the construction and installation of the new transmission facilitates. These new jobs and associated spending in the local economy will boost all sectors of the economy– although some industries will see more significant improvement than others. Even though these jobs and economic impacts are temporary, they are not trivial.

In the **medium term** (the first 15 years since a project is in service), transmission investment results in lower costs of electricity to consumers, additional revenues for some generators, improvements in the efficiency of the wholesale energy market as measured by lower production costs of energy, and carbon emissions reductions. Achievements in reducing carbon emissions also provide for a perception of an improved "quality of life" in these localities, which attracts new workers and creates yet another boost to the local economy.

In the **longer term**, transmission investment delivers benefits to electricity consumers in the form of improved electric system reliability and flexibility. These types of benefits are traditionally measured through engineering tools and models, but can also be monetized and presented in economic terms. Consumers gain access to reliable electric supply that may not otherwise be available to them, and notably, such reliability benefits can arise at any time over the lifetime of a transmission project.

2.4 Why do we have to "model" benefits of transmission investments?

LEI uses simulation tools to model benefits of transmission investment because we cannot otherwise observe them directly today since the infrastructure is not currently in place. Benefits will arise in the future once construction begins and the transmission infrastructure is put into service. The empirical modelling and analytical tools and methodologies employed here to evaluate benefits are also widely used for decision-making processes and evaluation practices in the real world, beyond just transmission projects.

LEI models the benefits of transmission investment using a suite of modeling tools: LEI performs a detailed hourly simulation of future electricity market impacts using LEI's proprietary electricity modeling tools,[9] and performs macroeconomic impact analysis using the widely recognized REMI PI+ model.[10] In this study, LEI explicitly models a three-year timeframe for the

---

[9] To quantitatively measure how these transmission investments change electricity market outcomes and reduce the costs of electricity, LEI employs its proprietary electricity network simulation model, POOLMod, along with proprietary simulators for other wholesale electricity market-related products like capacity and Renewable Energy Credits ("RECs"). These models are customized to the specific wholesale market design of each region. POOLMod is also used to measure carbon emissions changes in the power sector. Additional documentation of the modeling mechanics related to the wholesale electricity market can be found in the Technical Appendices.

[10] In this study, LEI analyzes the local economic benefits of transmission investment using a dynamic regional economic model licensed from Regional Economic Modeling, Inc. ("REMI"). REMI's PI+ model can simulate the direct,

construction of the project and the first fifteen years of operation for measurement of the benefits. However, some of the benefits will extend over a longer timeframe because supply events such as the reliability benefits modeled in this study can happen any time during the project's useful life.

In the long run, transmission investment benefits the society through enhancing the reliability of the grid as well as preventing energy supply shortages and interruptions. Energy supply shortages and interruptions are especially harmful for the commercial and industrial sectors, whose production may be forced to be suspended during such events. Simulation-based modeling and scenario analysis helps identify the electricity market effects of such uncertainties. Then, these costs, or the benefits through avoiding such economic costs, are estimated through a combination of the energy market and socio-economic modeling tools.

---

indirect and induced effects of transmission investment during the short, medium, and longer term. The indirect and induced effects are commonly referred to as "multiplier effects". Additional detail around the REMI PI+ model can be found in the Technical Appendices.

3 Description of the hypothetical transmission projects

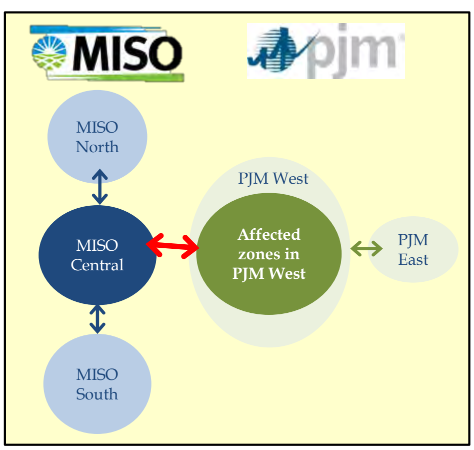
LEI has studied the impacts of transmission investment through two hypothetical projects - driven by varied commercial considerations and located in different regions of the US (each region may have its under unique market rules and industry structures). However, there are similarities in the benefits achieved and the estimated value that the transmission projects provide. Therefore, even though the magnitude of the value of transmission projects inevitably varies based on the specific characteristics of the project and where projects are located, findings from this study with respect to these two hypotheticals tells us a lot about the general scope for benefits of transmission projects.

3.1 Trade-enhancing Transmission Project in the Eastern Interconnect

The hypothetical Trade-enhancing Transmission Project in the Eastern Interconnect (referred to as the "**Eastern Interconnect project**") represents a transmission investment that is primarily intended to expand market access for lower-cost generation by increasing trade of electricity and adding supply resources into higher-energy-cost regions.

The **Eastern Interconnect project** would enhance electricity trading between PJM and MISO regions, which leads to efficiency improvements. The direction of energy flows on the new transmission line is not static – the flows may change to reflect evolving market conditions and supply-demand balances within and between the two regions, and LEI observes this dynamic in its modeling. By harnessing trade opportunities between PJM and MISO, buyers and sellers on both sides of the new transmission line receive benefits at varying times. The enhancement of trade between PJM and MISO creates savings to customers on their electric utility bills, as well as other benefits. For example, this new transmission project is projected to help achieve decarbonization goals in PJM more cost-effectively. By leveraging spare capacity with a lower carbon footprint in MISO, the combined systems' carbon emission level is reduced without additional investment in low or zero-carbon emitting generation resources.

Figure 8. The Eastern Interconnect project



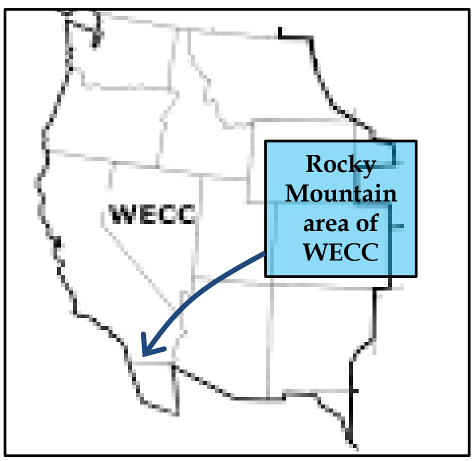
Descriptions	Transmission expansion on the interface between MISO-Central and the AEP zone of PJM, for the purpose of enhancing system efficiency and increasing trade between these two markets
Size (MW)	1,300 MW of additional capacity on the PJM-MISO interface
Capital investment costs	$200 million ($32 million annual levelized cost)
Wholesale electricity markets affected	MISO, PJM
Associated (new) generation capacity	Transmission project does not specifically trigger/require new generation investment in MISO or PJM

3.2 Resource Delivery Transmission Project in the Western Interconnect

The Resource Delivery Transmission Project in the Western Interconnect (referred to as the "**Western Interconnect project**") represents a transmission investment that brings energy from remotely-located resources to load centers. Such a transmission project would be another example of "trade" because it creates a bridge between suppliers and consumers, culminating in a mutually beneficial outcome.[11]

The **Western Interconnect project** is assumed to deliver wind-based energy from the Rocky Mountain area of Western Electricity Coordinating Council ("WECC") to load centers of southern California by utilizing an approximately 700-mile new transmission line passing through multiple states. In contrast to the other hypothetical project, this project includes the development of new generation in conjunction with the new transmission line. The electric consumers in southern California benefit from lower electricity costs, while the generators and residents in or near the remote resource location can also benefit from higher revenues (for those new wind generators) and more job opportunities (for residents in the Rocky Mountain area).

Figure 9. The Western Interconnect project



Descriptions	New transmission line delivering energy and associated products to consumers from new generation being built in a remote area (where there are excellent natural resources)
Source (location)	The Rocky Mountain area of WECC
Sink (location)	Southern California
Size (MW)	3,000 MW capacity rating for the new transmission line
Capital investment costs	$3 billion (for the transmission, $480 million annual levelized cost); wind generation investment costs are additional
Associated (new) capacity	4,400 MW nameplate capacity of new wind in the Rocky Mountain area of WECC

[11] LEI's analysis considers economic impacts on both the delivery side and the receiving side. Specifically, the local generation investment displacement in the receiving state, i.e., California, due to new imports from the Rocky Mountain area is included.

4 Projected Benefits of new transmission investment

In making an investment decision, investors and planners usually have a far better understanding of the costs of an investment than the potential benefits that the investment will yield, especially beyond a typical 10-year planning horizon. The cost of an investment can usually be estimated with some level of precision and will be incurred promptly once construction begins. The immediate nature of some benefits, for example when a project is designed only to fill a demonstrable reliability problem, makes them more tangible than the estimated future benefits, which can arise much farther in time and can vary in scope. Some of the economic benefits of transmission investment are difficult to quantify using common planning techniques and are often seen as uncertain by policymakers and regulators. Planners, therefore, face challenges about how to comprehensively measure benefits and identify beneficiaries.

In this chapter, LEI presents the projected benefits of two hypothetical transmission investment projects using a robust, forward-looking simulation-based analysis. This rigorous empirical analysis of transmission investment shows that benefits are **quantifiable** and **measurable**.

Transmission benefits may also be **substantial** even if the market price consequences are minor. The diverse and long-lasting benefits of transmission infrastructure projects to the economy and to generations of consumers are highly consequential. A small reduction in the market price of electricity affects thousands of customers and can accumulate to be hundreds of millions of dollars of electricity market cost savings to electric consumers. Similarly, improved reliability can benefit many electricity consumers. Transmission investment can also benefit some generators, by increasing their access to markets, and governments, by providing new pathways for the buying and selling of electricity (e.g., trade) to achieve policy goals more quickly and cost-effectively (and some governments may also benefit from increased tax revenue collections).

Finally, transmission benefits can be **long-lasting**. Benefits start to accrue even before construction of a transmission project is completed (the demand for construction, labor, and materials expands local economies and creates new jobs) and certain benefits last through the longer term (for example, the value of reliability benefits can arise at any point of time in life of a transmission project – even 50+ years after construction).

4.1 Short-term impacts of construction and development of new transmission

Short-term economic benefits arise when a transmission project directly creates new jobs and boosts the local economy, especially in the construction-related sectors. In addition, as a result of indirect and induced effects of the local spending, most sectors of the economy will benefit from the project investment.

Local economic benefits can be categorized as direct, indirect, and induced. Specifically, for the construction period of a transmission project, the following benefits will arise as an outcome of the investment and the "multiplier effect" as illustrated in the Figure 10 below:

- **Direct benefits** – During the construction period, the main driving force of economic benefits come from construction activities and project spending on labor and material that directly boost the local economy and create new jobs.
- **Indirect benefits** – Construction activities will drive up demand for supporting goods and services and indirectly boost sales in relevant sectors, such as manufacturing and transportation.
- **Induced benefits** – Workers and professionals that are hired to construct the transmission project will spend (part) of their salaries on consumer goods and services, such as housing, healthcare, and food, thus creating induced benefits for the local economy across a wide range of sectors.

Figure 10. Illustration of the "multiplier effect" from the local economic benefits

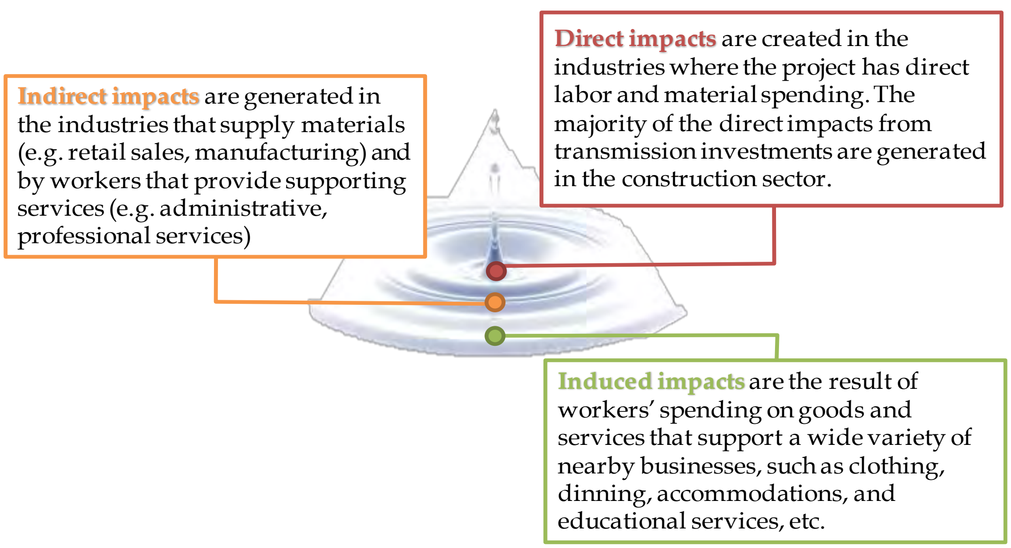
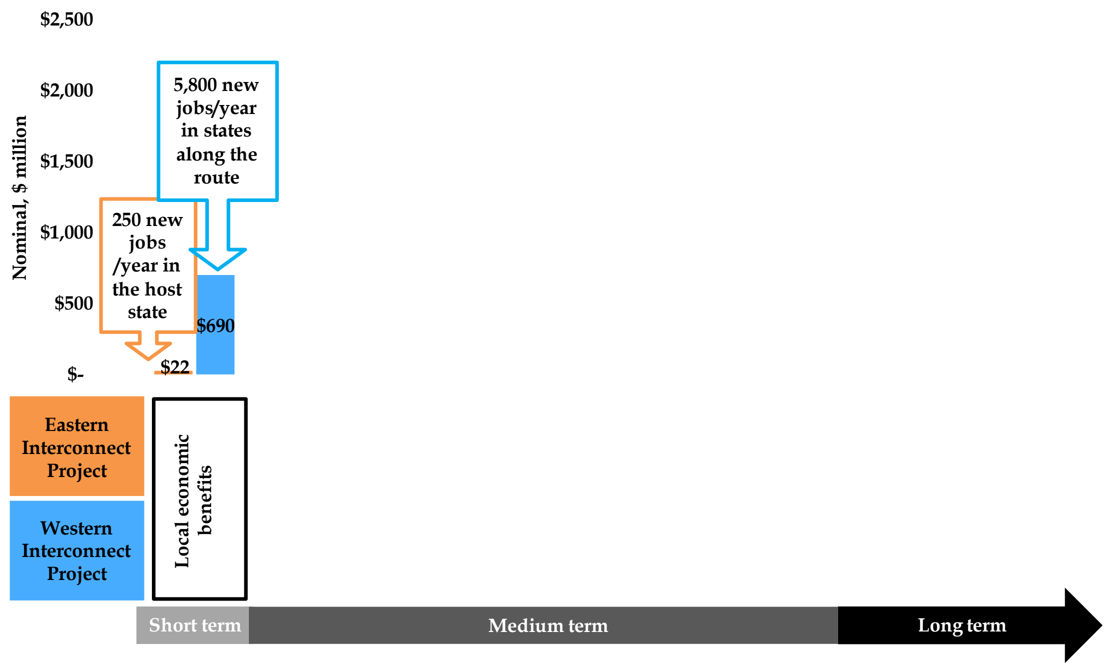


Figure 11 below provides a summary of the short-term economic benefits for the two hypothetical projects. A general finding is that for every $1 million spent on construction of the project, local annual GDP is projected to increase by more than $1 million, and there will be 10-20 new jobs created each year of the construction period.

London Economics International LLC
717 Atlantic Ave, Suite 1A
Boston, MA 02111
www.londoneconomics.com

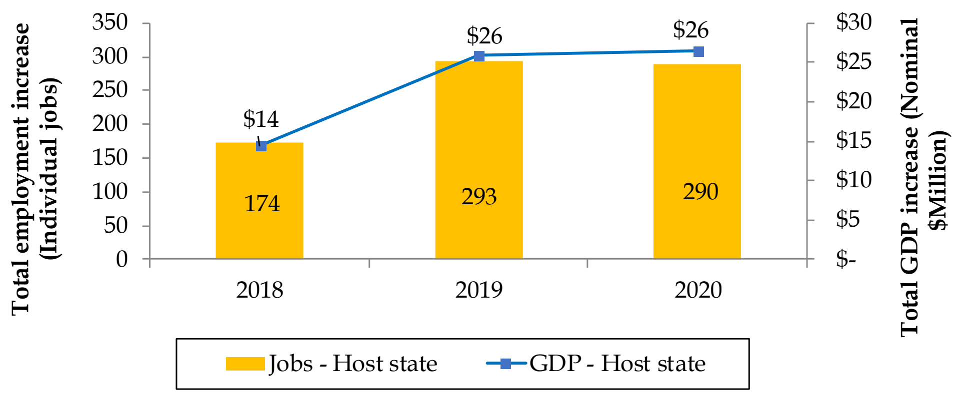
Figure 11. Transmission investment boosts the local economy directly through labor and material spending in the short term (2018-2021)



Note: Construction period for the wind generation of the Resource Delivery Project is 2019-2021

The **Eastern Interconnect project**, although a smaller-scale investment and situated in a smaller geographic footprint, generates notable economic benefits to the host state (LEI assumes, for the purposes of the modeling, that the host state is Indiana, which lies in both PJM and MISO). During the peak years of the construction activities, local GDP is forecasted to rise by an average of $26 million per year, and local jobs are expected to increase by more than 250 per year.

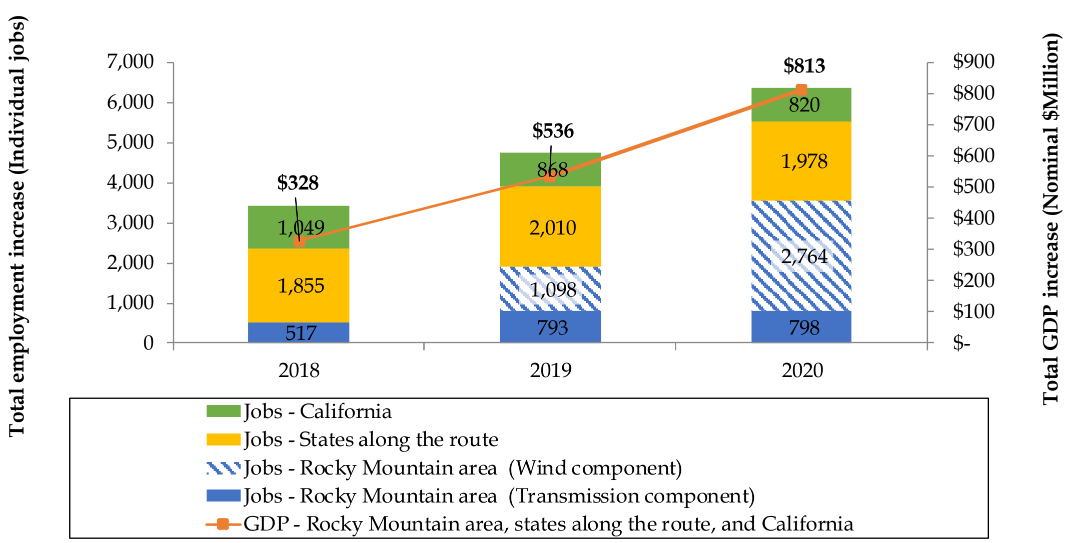
Figure 12. Projected increase in host state's local economy and employment during construction of the Eastern Interconnect project



London Economics International LLC
717 Atlantic Ave, Suite 1A
Boston, MA 02111
www.londoneconomics.com

For the **Western Interconnect project**, both the construction of the 3,000 MW transmission project and the accompanying 4,400 MW of new wind generation in the Rocky Mountain area will benefit the economies of the host state and other states along the route. Local spending over the three-year construction cycle is estimated to amount to nearly $2 billion of direct spending (for transmission and generation). The states along the route are expected to see an increase in GDP of nearly $400 million and jobs are anticipated to grow by about 3,500 per year on average during the construction period. In addition, construction of the wind generation in the Rocky Mountain area will benefit the local economy by increasing the local GDP by an estimated average of nearly $300 million per year and creating nearly 2,300 new jobs per year.[12] Although these jobs come to an end once the construction is completed, they are nonetheless important to the workers and local economies.

Figure 13. Anticipated increase in four states' local economy and employment during construction of the Western Interconnect project



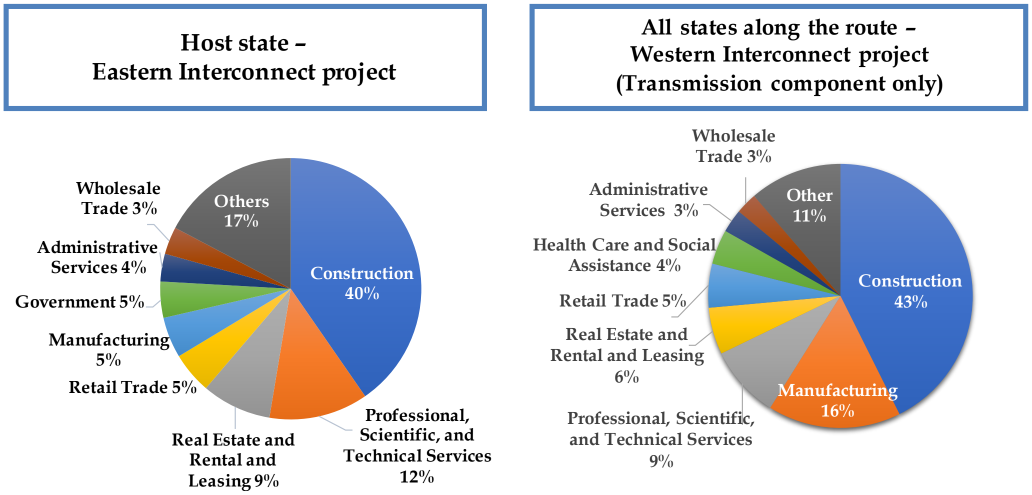
Note: For the **Western Interconnect project**, the GDP increase by regions follows a similar pattern as the job increase in each host state.

The construction sector, manufacturing sector, and professional, scientific and technical services sector benefit the most from the transmission investment during the construction period as they provide the materials and workers needed for the various construction activities (see Figure 14).[13] Other sectors will also experience economic expansion by supplying supporting goods and services to the construction activities, or as a result of increased local spending of workers hired to construct the project.

[12] The construction of the wind generation facilities for the Western Interconnect project is from 2019 to 2021. Figure 13 shows the construction period of the transmission component of the project.

[13] The magnitude of changes in economic output (and GDP) of each sector is primarily determined by the relative size of that sector to the entire (local) economy, as well as personal consumption and investment activities.

Figure 14. Projected breakdown of the local economy improvement (GDP increase) by sector during construction of the transmission projects

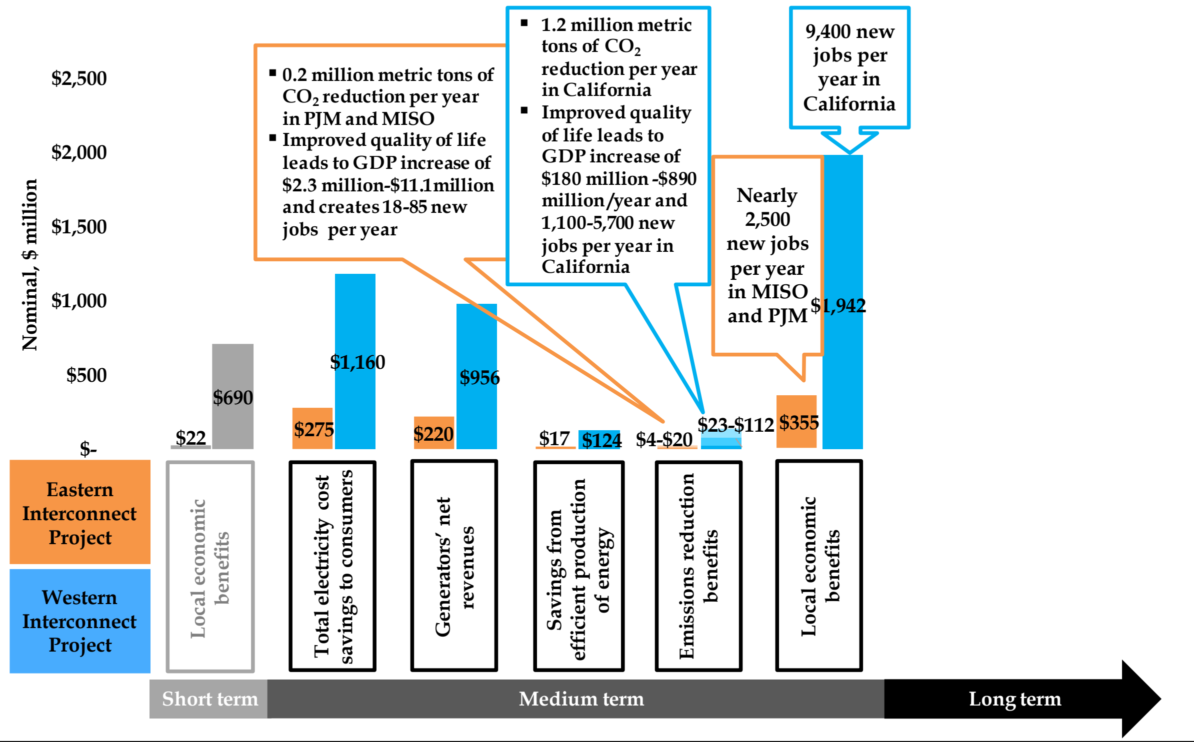


4.2 Medium-term impacts – electricity market impacts and local economic benefits

Medium-term economic benefits are modeled explicitly over the first 15 years of the project operations. New transmission capacity will provide access to cheaper resources, and therefore reduce the costs of electricity through more efficient operations of the energy market and the capacity market, where relevant. The lower electricity costs for consumers then catalyze economic growth and new job creation in the energy receiving regions. Transmission projects can also enable access to cleaner and lower-cost renewables in other markets or remote areas, thereby benefiting generators in these areas and helping the importing regions to achieve their carbon reduction targets and Renewable Portfolio Standard ("RPS") goals in a more cost-effective way.

Once a transmission project begins its operations, it will create numerous benefits for different stakeholders, including electricity consumers, generators (in the exporting region), utility workers, as well as local residents and businesses. The electricity market savings to consumers and the project spending on operations will benefit and expand the local economy. Figure 15 below shows the multiple aspects of benefits during this period. Each of these benefits will be discussed in detail in this section.

Figure 15. Medium-term operations of the transmission projects create numerous benefits for different stakeholders (2021-2035)



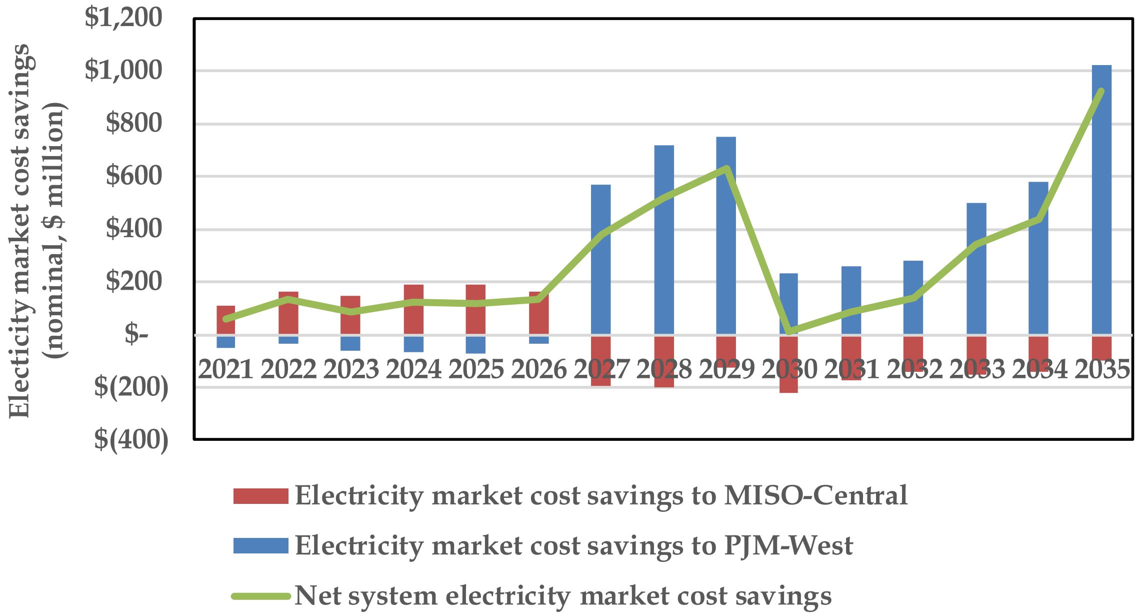
4.2.1 Benefits to electric consumers

Benefits occur when a transmission project reduces the wholesale market price of energy and capacity market clearing prices, which eventually lowers the monthly electricity bills of electric consumers.

Where there is a price difference between two regions, new transmission projects can provide an opportunity for lower cost resources to reach consumers. The result is a lower price of electricity for those consumers and increased revenues for those suppliers (generators). The new transmission will lower the costs of electricity for all types of consumers - households' utility bills will come down, and local businesses' costs of electricity will also decline.

The **Eastern Interconnect project** illustrates the value of such trading opportunities between MISO and PJM. The efficiency of the dispatch decision in both MISO and PJM can be improved by better utilizing existing generation resources in both markets. In LEI's modeling from 2021 to 2026, when MISO is projected to have higher energy prices than PJM, energy in PJM will flow to MISO to take advantage of the higher prices and consumers in MISO can benefit from lower energy costs. Later in the project's life (specifically, 2027-2035 over the modeling timeframe), MISO is forecasted to have lower energy prices than PJM due to changes in market conditions. As a result, MISO will export energy to PJM benefiting consumers in PJM.

Figure 16. Projected electricity market cost savings for the Eastern Interconnect project (nominal, $ million)



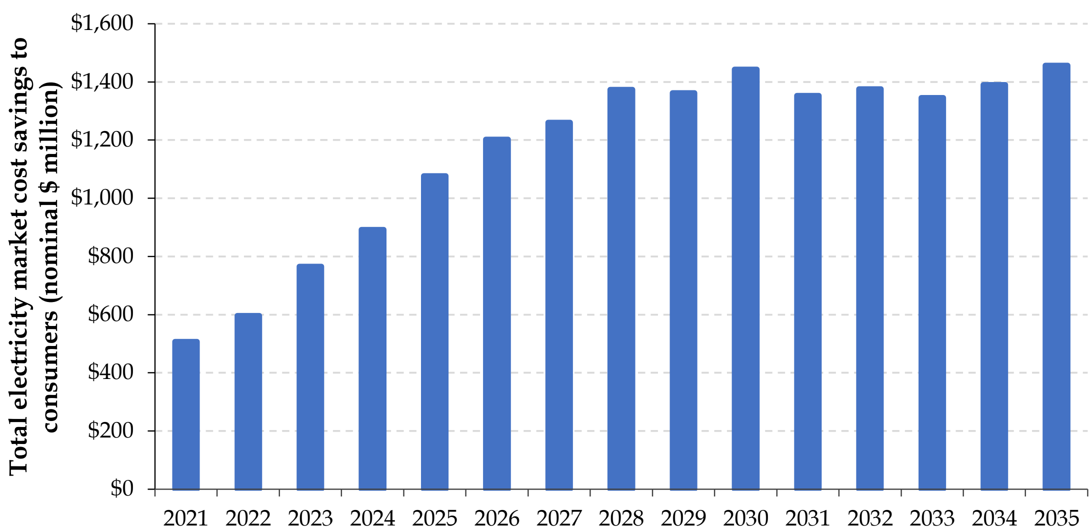
Note: The exporting region incurs negative electricity market cost savings because reduced supply results in higher market clearing price for the exporting region. However, the increase in electricity market cost from the exporting region is outweighed by the electricity market cost savings from the importing region, resulting in a net system-wide electricity market cost savings.

In summary, the beneficiaries and the scale of the benefits change over time as the market conditions and supply-demand balances evolve. Electricity consumers will see reductions on their electricity bill through the energy cost savings brought about by the project (see Figure 16). During the period of 2021-2026, when MISO has higher energy prices than PJM, approximately 200 MWh of energy flows every hour from PJM to MISO on the new transmission line. As a result, the energy price in MISO declines and MISO consumers all together pay approximately $110 million less for electricity on their utility bills every year (net savings), or $2 per year less for each household. During 2027-2035, when PJM is forecasted to have higher energy prices than MISO, 400 MWh of energy flows every hour from MISO to PJM over the new transmission line, driving down the energy prices in PJM and saving PJM consumers almost $400 million on their annual electricity bills, or $5 per year savings for each household. On average, electricity cost savings to consumers in PJM and MISO is forecast to be $275 million per year, which far exceeds the annual levelized cost of the transmission project at $32 million.

The **Eastern Interconnect project** also provides an example of how transmission enhances grid flexibility in the face of future policy changes, and allows for more efficient dispatch decisions to minimize the costs of such policies. When region-specific decarbonization goals are introduced in 2027, the transmission helps PJM to achieve those goals at a lower cost. The impact of the decarbonization policy is an example of a policy change for which system planners may not be able to anticipate the precise timing, but such policies should not be ignored. The region-specific decarbonization goals have profound impacts on energy prices in PJM relative to MISO and therefore change the direction of energy flows on the new transmission line.

With the **Western Interconnect project**, LEI has also modeled the implications of the new trade opportunities for consumers and suppliers. California consumers are assumed to be able to tap into the Rocky Mountain area's abundant wind potential with the new transmission line. The import of wind-generated energy provides California energy consumers with significant savings on their electric utility bills. As seen in Figure 17, total electricity market savings are projected to be $500 million in 2021 and rise to $1.5 billion by 2035, or $1.2 billion per year on average, which far exceeds the annual levelized cost of the transmission line.[14]

Figure 17. Projected total electricity market savings for California electric consumers



4.2.2 Benefits to power generators

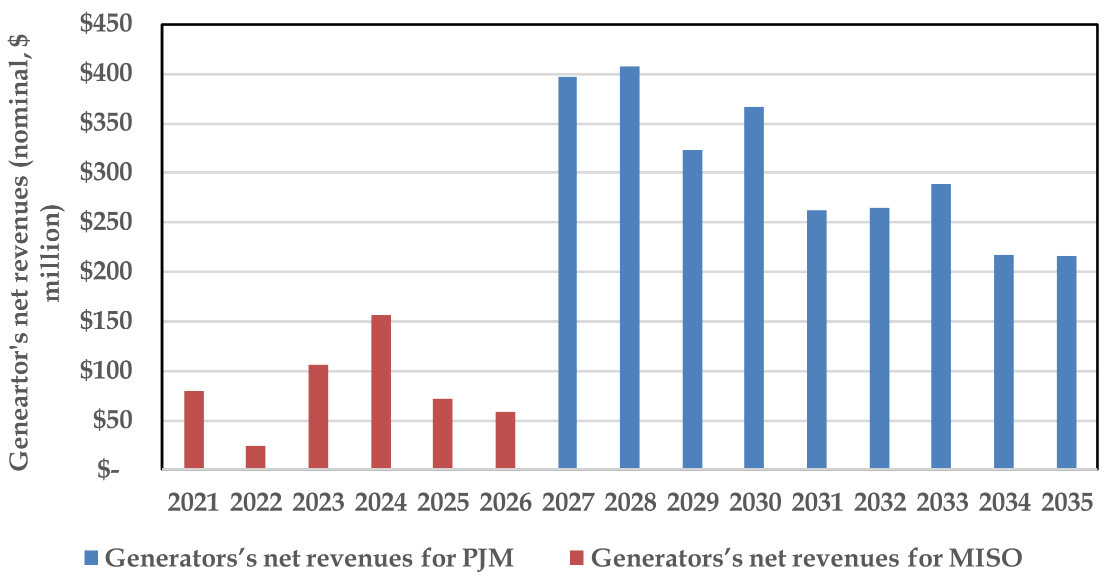
Benefits to power generators arise when a transmission project provides additional revenue streams for generators in the exporting region.

Transmission investment can deliver benefits to many stakeholders, including generators. Generators in the exporting regions can enjoy additional sales that would not have existed if there were no new transmission and no trade opportunities. The market size expands because of transmission investment and some generators can operate more and sell their products at higher market prices than they would have been able to in a world without the transmission investment.

[14] The annual revenue requirement of $480 million is calculated as 16% of the $3 billion transmission line capital cost.

For the **Eastern Interconnect project**, during 2021 to 2026, PJM generators are projected to receive a net revenue[15] increase of more than $80 million per year by exporting energy through the transmission line. This is equal to additional revenues of nearly $380 per MW of installed capacity in the PJM region or a 1% increase in revenues for generators. During 2027 to 2035, net revenues (from both energy and capacity markets) of MISO generators exporting to PJM are projected to increase by more than $300 million per year due to the new transmission project. This is equal to additional revenues of almost $2,000 per MW of installed capacity in MISO or a 3% increase in revenues for generators.

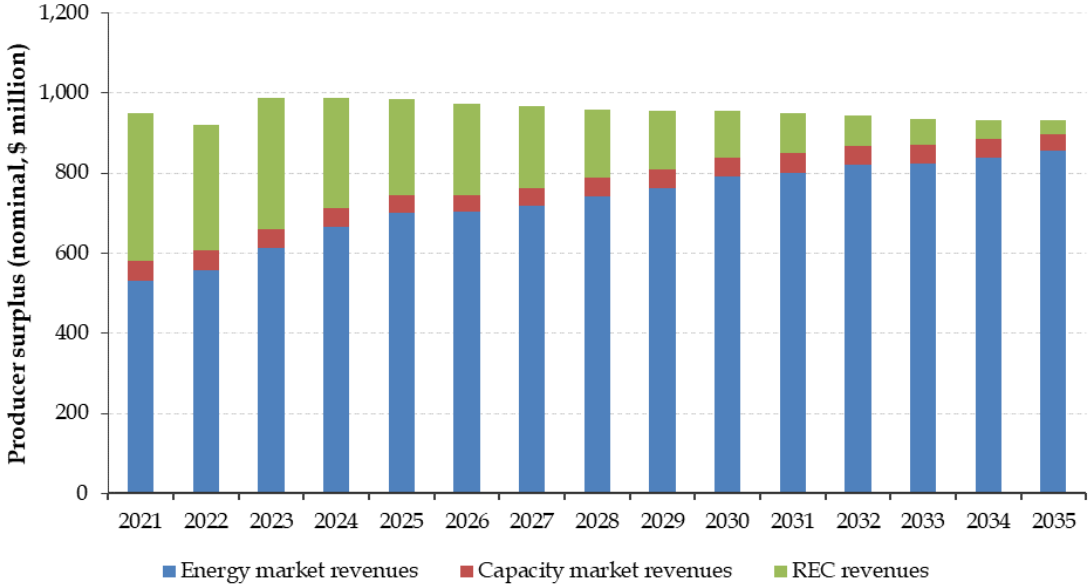
Figure 18. Projected generators' net revenues for the Eastern Interconnect project (nominal, $ millions)



In the **Western Interconnect project**, investment in wind generators in the Rocky Mountain is catalyzed because of the transmission line. These generators are assumed to receive contracted energy, capacity, and renewable energy credit revenues. As shown in Figure 19, the economic value of the revenues earned by the new wind generators in the Rocky Mountain area is projected to be nearly $ 1 billion per year on average over the 2021-2035 period, equivalent to $56/MWh (see Figure 19).

[15] Generators' net revenue refers to total sales less variable operating costs (including fuel and variable O&M costs and emissions costs, if any). LEI focuses on net revenues of generators that are exporting. LEI is not netting out the reduced sales from the generators that get displaced by the increased competition.

Figure 19. Projected revenues received by new wind generators in the Rocky Mountain area for the Western Interconnect project (nominal, $ millions)



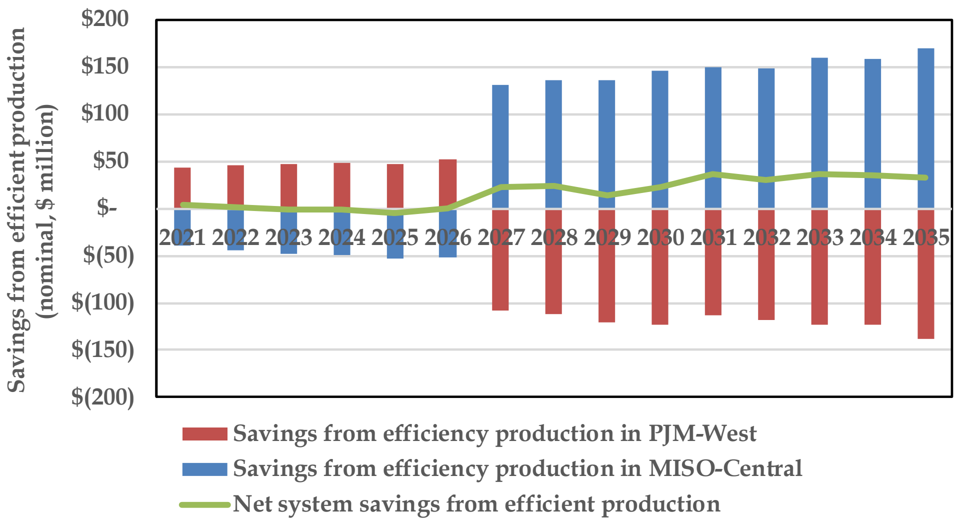
4.2.3 Benefits to regional power systems

> *Benefits to the energy operating system arise when a transmission project brings lower-cost energy from other regions and expands resource that the system operator can dispatch, thereby lowering the short-run marginal costs of production.*

Transmission essentially unlocks efficiency gains and lowers prices to consumers by expanding competition of the market which allows the system operator to optimize dispatch over a larger geographical area. By forming a new "bridge" between two markets, generators compete more aggressively with their peers in the other markets. The efficiency improvement enables access to lower-cost resources, which benefits consumers in the importing region in terms of electricity cost savings. As such savings are achieved through introduction of new energy supply, some generators in the exporting region also benefit.

For the **Eastern Interconnect project**, even as the project size is less than 1% of each regional market's overall capacity, efficiency improvements from more optimized dispatch over a greater market size and reduced incidence of transmission congestion can save the system millions of dollars and will indirectly benefit consumers in the long run, as shown in Figure 20. From 2021 to 2026, there are net projected savings of approximately $1 million per year from realized efficiency improvements in the production of energy (e.g., reduced fuel consumption because the system operators can dispatch more efficient generation to meet consumers' needs). From 2027 to 2035, the net savings are projected to be about $90 million per year from efficiency improvement in the production of energy (reflecting the additional savings from optimizing the costs of carbon emissions between MISO and PJM).

Figure 20. Forecasted savings from efficiency improvement in energy production in MISO and PJM for the Eastern Interconnect project (nominal, $ millions)



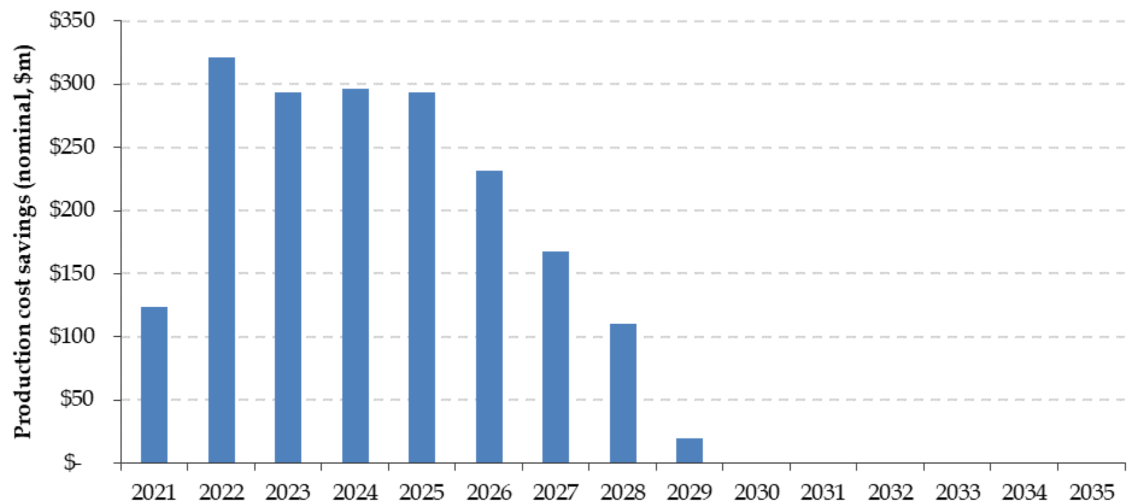
Note: The 2027-2035 period has higher benefits from efficiency production because the energy flows on the transmission line are two times greater than those that are projected during 2021-2026.

The exporting region incurs negative savings from efficiency production because reduced supply results in higher production cost for the exporting region. However, the increase in production cost from the exporting region is outweighed by the production cost savings from the importing region, resulting in a net system savings from efficiency production.

Figure 21 presents the projected savings from efficiency improvements in the production of energy in California wholesale electricity market during 2021 to 2035 because of the **Western Interconnect project**. Over the 15-year period, the projected state-wide savings from efficiency improvements in the production of energy amount to approximately $1.3 billion in Net Present Value ("NPV")[16] terms over the 15-year modeling horizon. Such efficiency gains are generated by the underlying resource mix transformation: wind resources provide energy at zero marginal cost and displace some of the natural gas generation in the market (and defer some of the costlier local renewable investment). Following the anticipated commissioning of the 4,400 MW of wind, efficiency improvements in the production of energy are forecasted to total over $250 million a year but eventually dissipate (declining to zero by 2030). This eventual reduction in the benefits associated with efficiency improvements in the production of energy is driven by the gradual build-out of renewables generation in the world without the transmission project. Once the same levels of in-state renewable generation are achieved in a world without transmission investment as compared to the total renewable generation in a world with transmission investment, there is a convergence of short-run marginal costs of production and therefore there is no further opportunity to achieve incremental efficiency gains by the new transmission project.

[16] The Net Present Value in this report uses 10% discount rate and is discounted to 2021 dollars.

Figure 21. Projected savings from efficiency improvements in energy production in California under the Western Interconnect project (2021-2035)



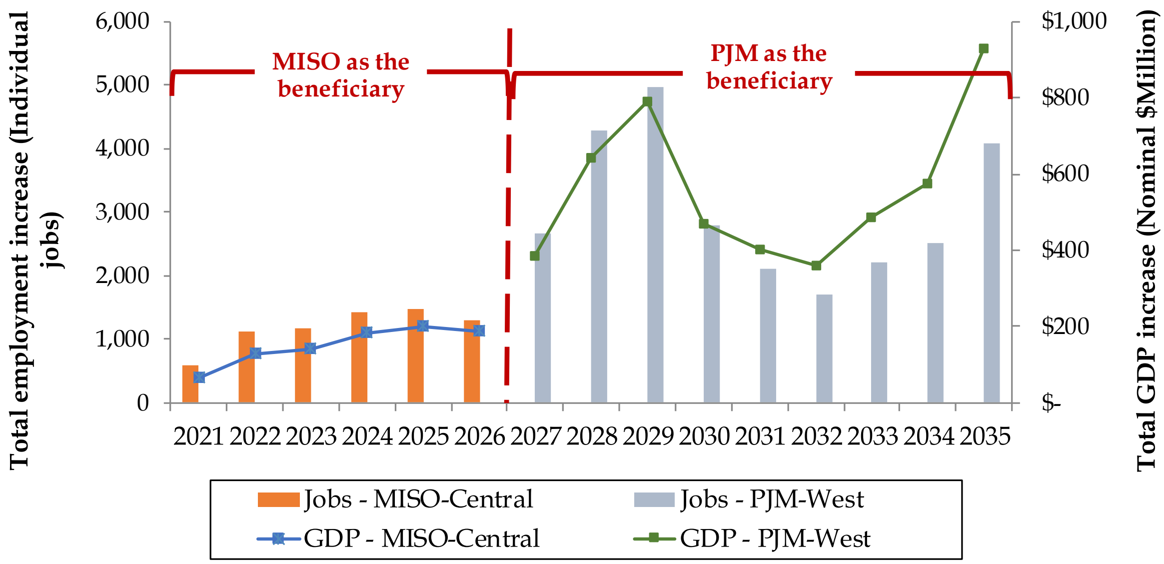
4.2.4 Benefits to local (state) economies

Benefits to the local economies during the medium-term operations period are primarily driven by savings form electricity costs – lower electricity prices support increase consumers' disposable income and reduce costs for local businesses.

The benefits of a transmission project also extend beyond electricity markets. Businesses will be spurred to expand production and hire more workers in lower electricity costs areas. Figure 22 and Figure 23 below show the economic impacts in terms of local economic activity (or state GDP) and new jobs over the first fifteen years of operations for the two hypothetical projects. During this period, economic benefits are primarily driven by lower electricity costs, but there are also some direct benefits from local spending associated with operations and maintenance of the new infrastructure.

For the **Eastern Interconnect project**, total jobs are projected to increase by about 1,200 per year and state GDPs are forecasted to rise by over $150 million per year in MISO during 2021-2026; and over 3,000 new jobs are expected to be created and the local GDP is anticipated to increase by an average of $560 million per year in PJM over the 2027-2035 period.

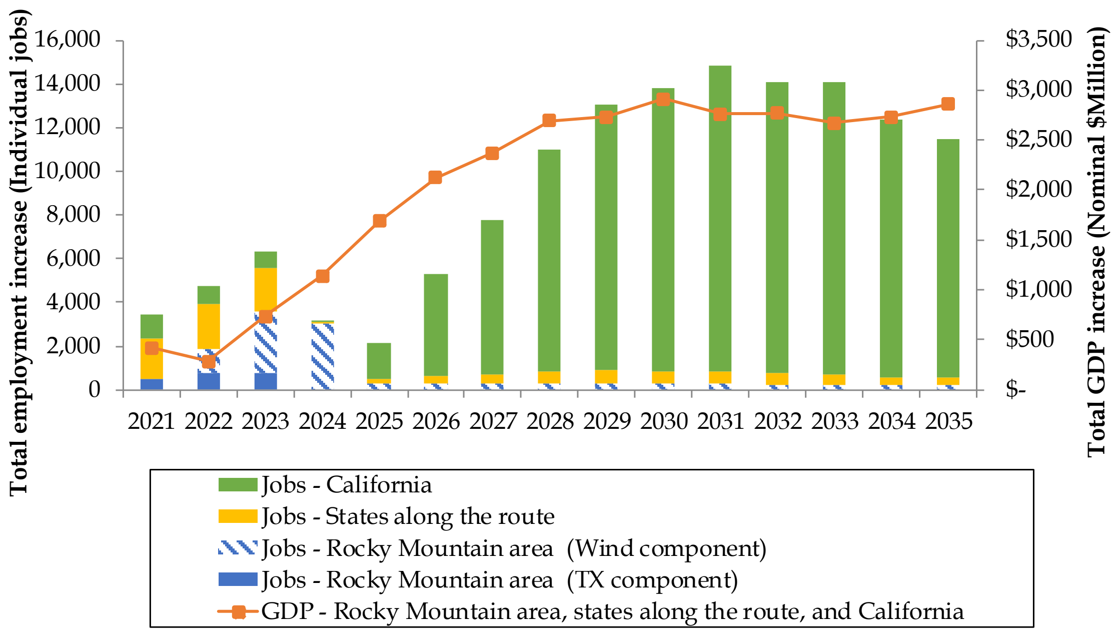
Figure 22. Projected increase in MISO and PJM's local economic activity (GDP) and employment during the first 15 years of operations of the Eastern Interconnect project



For the **Western Interconnect project**, California is expected to enjoy about 9,400 new jobs per year on average and a nearly $2 billion GDP increase per year during the operations period of 2021 to 2035. In the sourcing area of the Rocky Mountains, where the new wind is sited, 250 new jobs are created and the GDP is anticipated to grow by about $90 million per year from the O&M spending on the transmission and new wind generation facilitates. The states along the route of the new transmission line are also expected to experience moderate economic benefits: nearly 400 new jobs and $60 million GDP increase.[17] The overall operations period benefits for this project is greater than those estimated for the **Eastern Interconnect project** because of its larger size and consequently the larger electricity cost savings to California.

[17] There may be additional localized benefits that LEI has not quantified from local property tax payments or payments in lieu of local property tax payments for those localities along the route of the new transmission line.

Figure 23. Projected increase in local economic activity (GDP) and employment during the first 15 years of operations of the Western Interconnect project



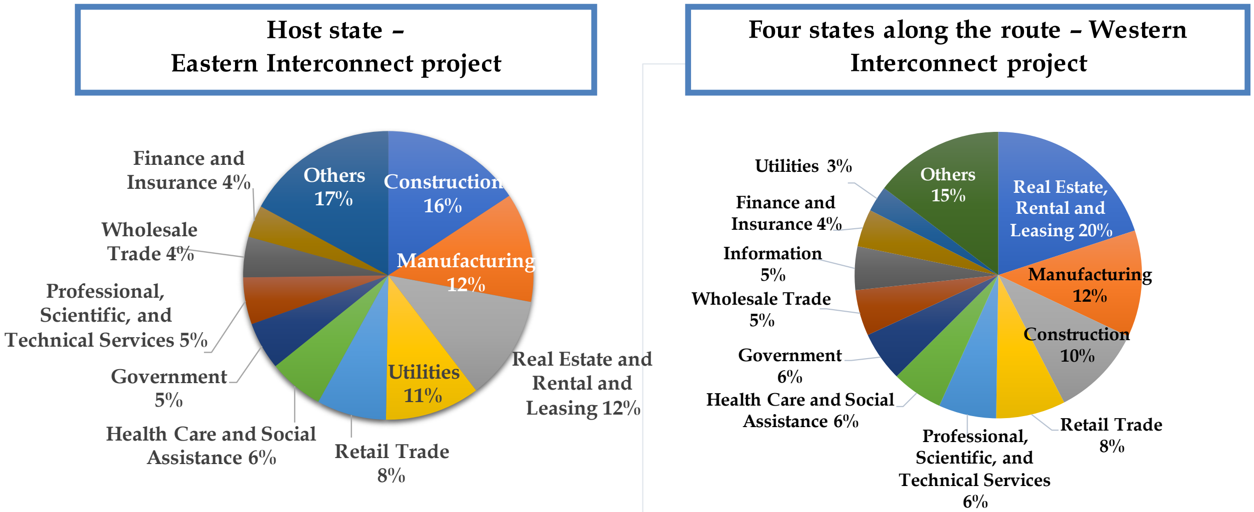
Note: For the **Western Interconnect project**, the projected GDP growth by regions follows a similar pattern as the job increase. Also, the negative local economic impact due to delayed renewable investment in California is netted out from the results.

While construction spending is the primary driver of local economic benefits during the short term (construction phase) of a transmission investment project, it is the lower electricity price that drives the local economic benefits during the medium term.

However, like the construction period, local economic benefits during the operations period can also be categorized as direct, indirect, and induced, as explained below:

- **Direct benefits** - Once the project begins operations, workers and services are needed to operate and maintain ("O&M") the transmission infrastructure (and wind facility in the case of the **Western Interconnect project**). This O&M spending has similar, albeit smaller, benefits to local and regional economies as the initial construction of the transmission project.
- **Indirect benefits** - Lower electric costs will make the local economy more competitive and more attractive to industrial and commercial investments, which will create job opportunities and GDP growth.
- **Induced benefits** - Lower electricity costs allow more disposable income for local residents and therefore prompt those residents to spend more on other goods and services, which will ultimately contribute to the local economy as induced impacts.

Figure 24. Breakdown of local economy boom (GDP increase) by sector during medium-term operations of the transmission project



Electricity cost savings benefit virtually all sectors of the economy proportional to their use of electricity (see Figure 24). The construction, manufacturing, and real estate sectors represent the largest GDP increases – an increase of over 40% are expected in these three sectors for both projects. This is because these sectors account for a relatively large share of the local economy and personal consumption and investment activities, and their output is closely related to the cost of electricity supply.

4.2.5 Impacts on the environment and associated policies

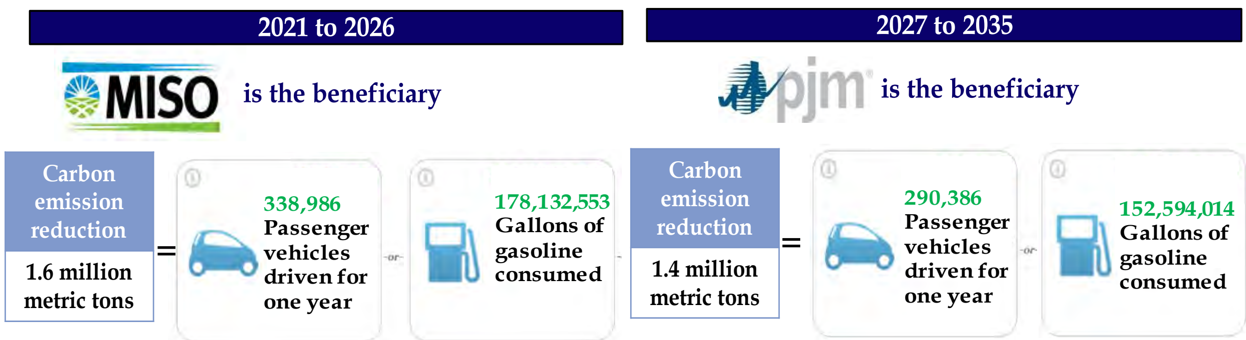
Environmental benefits arise when a transmission project brings lower or zero emissions resources and reduces the aggregated carbon emissions level; this societal benefit (e.g., decarbonization) may further attract more employees and boost the local economy.

New transmission investment designed to facilitate or support non-carbon or lower-carbon electric generation development can help facilitate decarbonization more cost-effectively in the medium to longer term. A new transmission line between two markets will facilitate the dispatch of the lower-cost, more efficient, and cleaner resources. As a result, the generation from more carbon-intensive, less efficient, higher cost resources, like oil and coal, are likely to be curtailed, and the carbon emissions in the region will be reduced.[18] Such environmental benefits brought by transmission investment also provide flexibility for the system to meet policy goals, such as decarbonization targets, especially over the medium and longer term. These developments can be driven by markets and consumer preferences or by public policy or both.

[18] Similarly, a new transmission line can also help reduce the emissions from SO2, NOx, and other pollutants in addition to carbon emissions. However, in this study, we have not reported the effect on these other pollutants.

Carbon emissions reductions are calculated by comparing the system-wide emissions in the affected markets (both export and import regional markets) with and without the transmission line. In the **Eastern Interconnect project**, the new transmission line can help facilitate decarbonization more cost-effectively by reducing carbon emissions of approximately three million metric tons cumulatively over the 2021-2035 period. Importantly, this benefit occurs with no other changes to the overall resource mix.[19] Instead, simply having the transmission available improves the system operator's flexibility and creates efficiencies for both regional markets, resulting in lower overall carbon emissions.

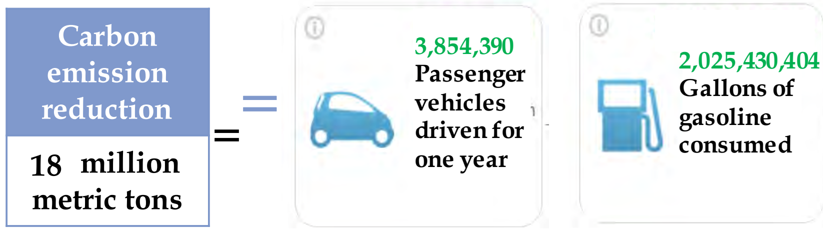
Figure 25. Projected carbon emissions reduction benefits of the Eastern Interconnect project



The **Western Interconnect project** facilitates decarbonization by reducing carbon emissions of approximately 18 million metrics tons cumulatively over the 2021-2035 period, contributing to the state's economy-wide target of 50% below 1990 levels by 2030. Specifically, the **Western Interconnect project** expedites the carbon emissions reductions that may have otherwise occurred in the longer term with local renewable investment. The traditional adage – money in my pocket today is better than money in my pocket tomorrow – also applies to carbon emissions. As seen in Figure 26, avoided carbon emissions because of the **Western Interconnect project** are equivalent to removing 3.8 million cars from the roads or foregoing use of two trillion gallons of gasoline.

[19] To achieve these aggregated emission reduction, more generation occurs in the exporting region, and as such, the exporting regions can see emissions increases. However, the importing regions can see emission decreases by a larger amount. The overall regional carbon emission will be lower.

Figure 26. Projected carbon emissions reduction benefits for the Western Interconnect project



In order to calculate the economic value of these carbon emissions reductions, LEI applies the social cost of carbon ("SCC")[20] to the tons of carbon emissions avoided due to the new transmission. This method allows consideration of the societal value of reduced carbon emissions because it essentially measures the value of damages avoided for the given carbon emissions reduction.[21]

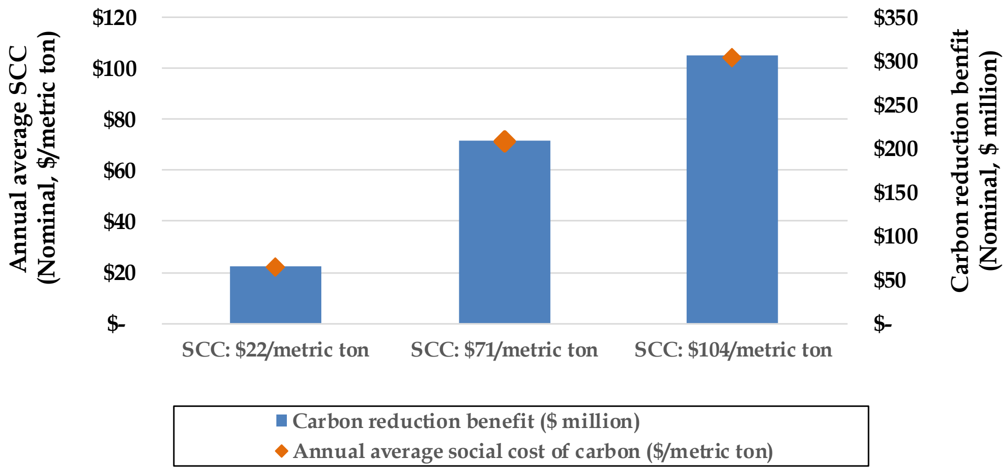
The US Environmental Protection Association ("EPA") has adopted three scenarios with varying values of SCC: the low-end value for SCC is forecast to be $22/metric ton, the median value is $71/metric ton, and the high-end value for SCC is at $104/metric ton.[22] Based on these three scenarios, the resulting societal benefits from carbon emissions reduction over the entire modeled forecast timeframe are estimated to range from $65 million to over $300 million for the **Eastern Interconnect project**, as shown by the bars (and using the right-hand side vertical axis) in Figure 27 below.

[20] SCC is meant to be a comprehensive estimate of climate change damages and includes, among other things: changes in net agricultural productivity; human health; property damages from increased flood risk; and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning.

[21] EPA. *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866.* August 2016. <https://19january2017snapshot.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf>

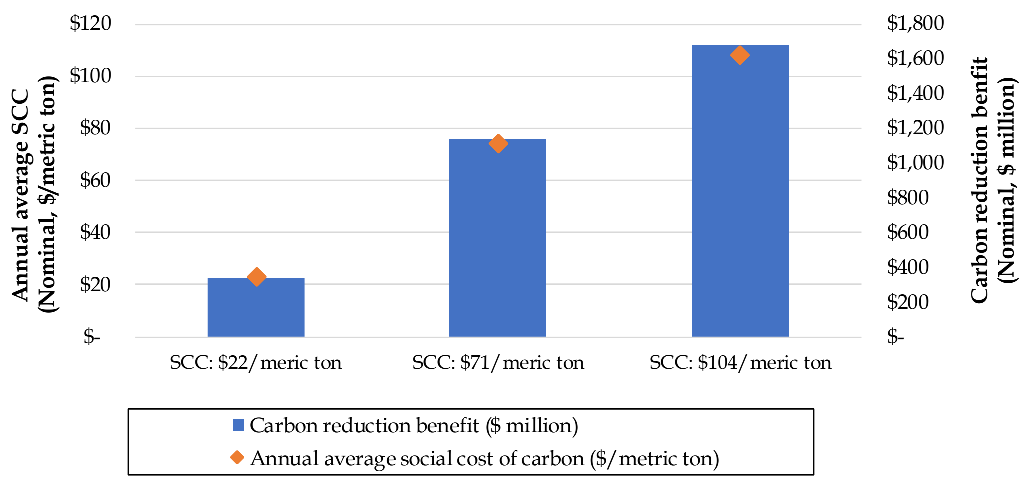
[22] Ibid.

Figure 27. Projected societal value of carbon emissions reductions achieved with the Eastern Interconnect project



Applying the same three SCC values to the **Western Interconnect project** results in societal benefits from cumulative carbon reduction that range from $340 million to $1.7 billion over the 2021 to 2035 timeframe, as shown in the Figure 28.

Figure 28. Projected societal value of carbon emissions reductions achieved with the Western Interconnect project



Furthermore, achievements in reducing carbon emissions can create a "socio-economic" boost to the local economy. Specifically, policies and socially responsible statements that are in favor of reducing carbon emissions have been shown to create the perception of improvements in "quality of life" in the region, which attracts new residents who are often highly educated, appreciate "clean energy goals," and consider states that achieve such goals as a "better place to live."[23] Although the science of such "quality of life" factors is nascent and evolving, the number of studies documenting these effects is growing.[24]

The societal benefits of carbon emissions reductions are projected to translate into a GDP increase of $2 million to $11 million per year in the states showing progress towards carbon emissions reductions under the **Eastern Interconnect project**. For the **Western Interconnect project**, California, the receiving region, is also expected to benefit from the influx of new workers because of the projected decarbonization achievements associated with the new transmission project, increasing the California state's GDP by $180 million to $890 million per year.

[23] The impacts associated with the improvement of "quality of life" due to reduced carbon emissions is modeled with the REMI PI+ model through a consideration of the societal benefits of reduced carbon emissions translated into a monetary value that represents the attractiveness of the specific state to new workers. As new workers relocate to the state, they help expand the local economy. Please see Section 3.6 and Section 4.4 of the Technical Appendices for more detailed explanation.

[24] Some examples of prior studies that involved using REMI PI+ model to estimate "quality of life" through change in amenity value include, but not limited to: (1) Gunther. Peter, "*Driving Smart Growth: Electric Vehicle Adoption and Off-Peak Electricity Rates.*" In this study Dr. Gunther analyzed the environmental amenity benefits due to the adoption of electricity vehicles in Connecticut. (2) Fulton. George A. et, al. "*Evaluating the Economic Benefits to Michigan of Alternative Road-Bridge Investment Mixes.*" Michigan Department of Transportation. March 2008. This paper was conducted the University of Michigan to estimate the monetary value of travel time saved through investment in transportation by using the "quality of life" concept. (3) Southern California Association of Governments. "*Economic and Job Creation Analysis.*" April 2016. This study analyzed how improvements in amenities, e.g. reduced congestion or improved air quality, will draw in-migrants to a region and hence improve competitiveness through labor market pooling effects.

4.3 Longer term impacts – Value of reliability and flexibility for the electric system

Throughout the useful operating life of a project, transmission investment provides insurance value and protects consumers against electric service interruptions and attendant economic losses through enhanced grid reliability.

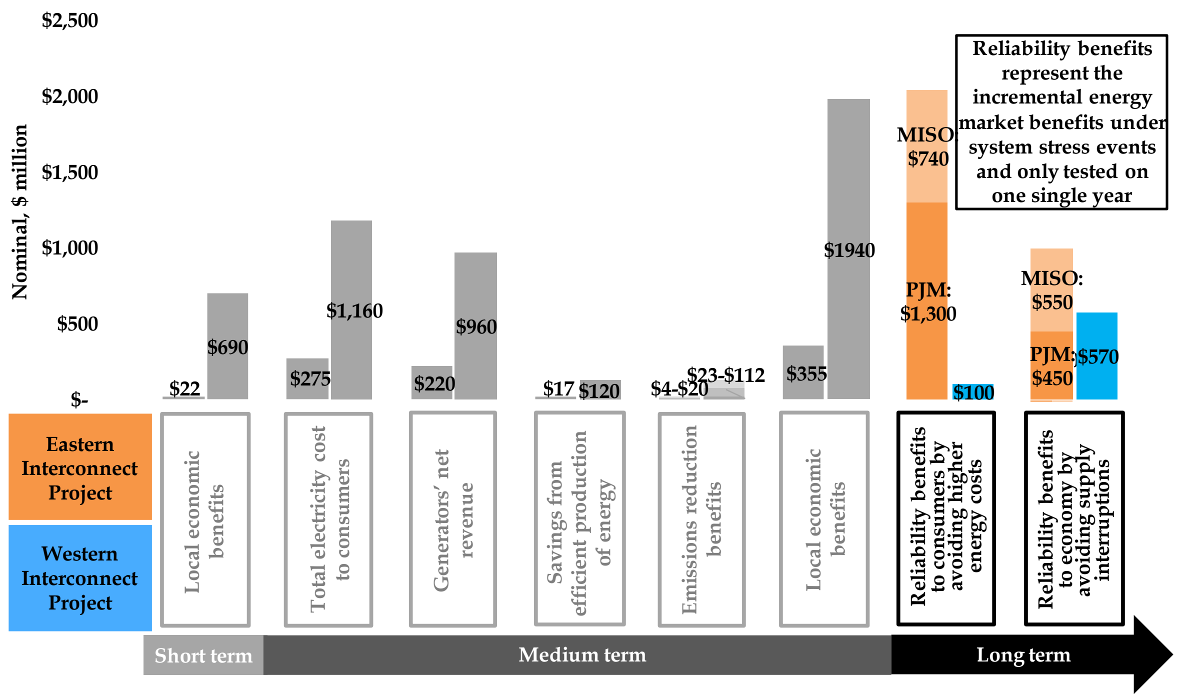
In the longer-term, transmission helps ensure that consumers have access to a reliable and flexible electricity supply, thereby creating reliability benefits, or "insurance" value, that protects consumers against unexpected major generation outages, and even system blackouts.[25]

These benefits are categorized as "long-term" because such events are infrequent. However, they can occur at any time over the life of a transmission project. For example, in California, the Sunrise Powerlink project has often been cited as a value-enhancing addition to the region's transmission infrastructure given the unexpected retirement of the San Onofre Nuclear Generating Station.

LEI quantifies the economic value of the reliability benefits of a new transmission project by modeling the energy system with and without the new transmission investment, as well as by examining the economic value of the outputs (products and services) that are produced by the sectors that rely on electricity, such as the manufacturing and service industries. Results of the analysis are summarized in Figure 29.

[25] Note that the longer-term reliability benefits can be added to the medium-term electricity benefits, because they may occur over the same timeframe and are incremental to the consumer cost savings estimated under normal conditions. However, it is important to understand that the probability of consumer cost savings and reliability benefits is different. This probability must be identified before adding these two benefits together. Although the events that drive reliability benefits are unlikely to happen, they are high impact events. As such, the insurance value of transmission only arises under stressed system conditions in the tail end of the distribution of benefits, probably in the range of 0 to 5%. Assuming the medium-term benefits have a high confidence – such as 95% confidence, and then the "insurance" value of the higher electricity costs (due to annual energy prices avoided under a generation outage or reduced supply scenario) are benefits for the transmission under a more extreme set of conditions, such as a 5% marginal probability. To sum up, we can weigh the "normal weather" benefits by 95% and the insurance value by 5%.

Figure 29. Transmission investment improves the reliability of the system

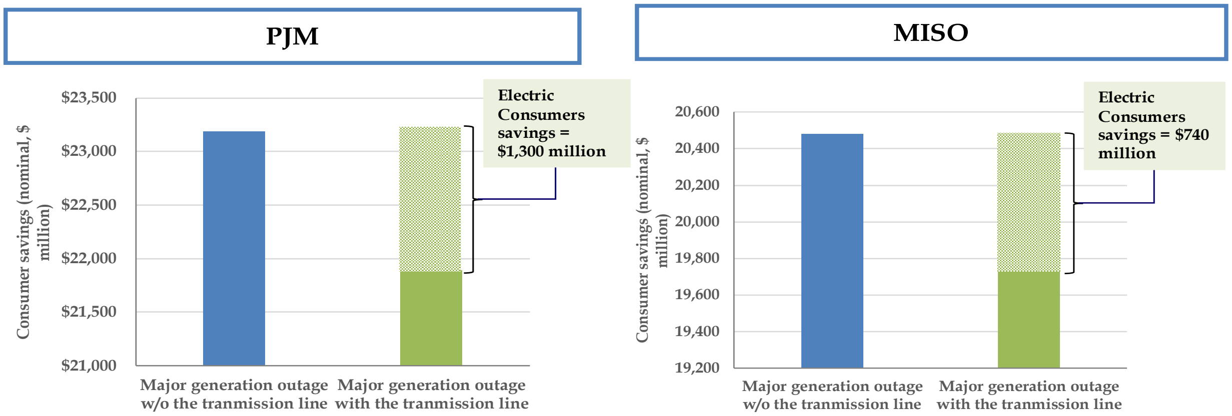


4.3.1 Consumer savings from avoiding higher energy market costs

Unexpected and prolonged shortage in supply can increase electricity costs for consumers. Through targeted scenario analysis, LEI estimates the potential energy costs under supply constrained conditions, with and without the transmission; the difference then represents the indicative ability of the new transmission to reduce such costs and create reliability benefits.[26] Over a single year period, under constrained system operating conditions, electric consumers are projected to save as much as $1.3 billion in PJM and $740 million in MISO with the 1,300 MW **Eastern Interconnect project**. This is equal to savings of about $20 (in MISO) to $40 (PJM) on a typical household's annual electricity utility bill in the affected regions (see Figure 30).

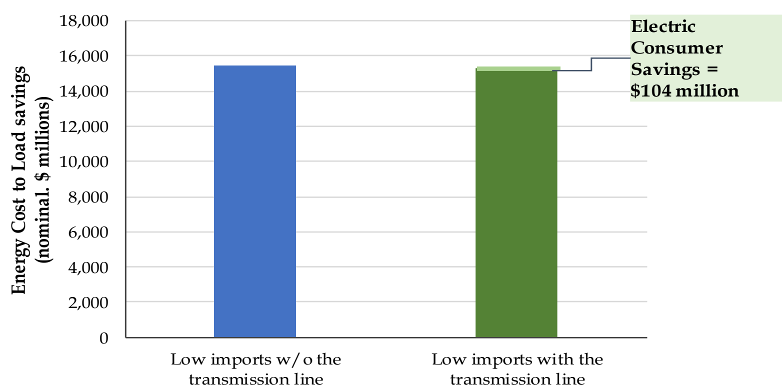
[26] Two shortage scenarios are tested in PJM and MISO by selecting a representative year when there is a nuclear outage. A low import scenario is simulated in the California market to evaluate the long-run system reliability attributes of the new transmission line.

Figure 30. Forecasted electric consumer savings under the Eastern Interconnect project from avoiding higher energy market costs associated with a major generation outage



Electricity consumers are anticipated to save over $100 million, or $8 on a typical household's annual electricity utility bill, over the course of a year with the 3,000 MW **Western Interconnect project** if California experiences materially lower imports from other neighboring markets (see Figure 31).

Figure 31. Forecasted electric consumer savings under the Western Interconnect project from avoiding higher energy market costs associated with a decline in imported supply



4.3.2 Avoided economic losses due to a blackout

Supply interruption or blackout events can be costly, especially for the commercial and industrial ("C&I") sectors whose businesses and manufacturing activities will likely to be unexpectedly interrupted during such events, creating a reduction in sales and profits.

For example, during a blackout, some C&I businesses[27] may be forced to suspend their production processes and therefore forego sales of their goods and services. These economic

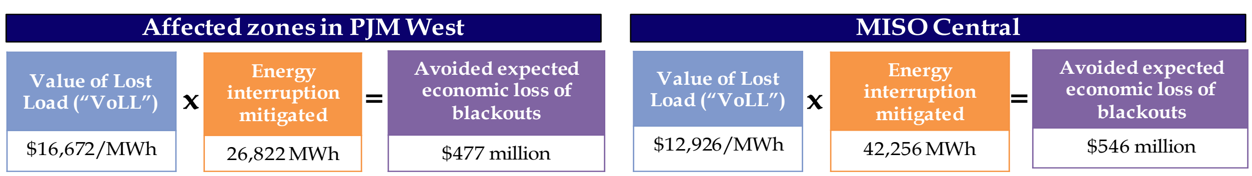
[27] Sectors that are likely to have backup generators (e.g. hospitals/health care and schools/education) and sectors that are primarily dependent on other types of fuels rather than electricity are excluded in the analysis of loss of output due to blackout events.

losses represent the opportunity cost of electricity supply interruptions. Such costs can be estimated through the REMI PI+ model. With these economic costs, LEI then calculates the value of lost load ("VoLL"), or the price of supply interruptions, by dividing the economic losses by the electricity consumption in these C&I sectors.

Next, using its electricity market modeling tools and targeted scenario analysis, LEI estimates the frequency (number of hours) and extent (the amount of load lost, or "megawatts unserved") of possible supply interruptions that could be averted with the new transmission project, which then indicates the scope for reliability improvement that can be achieved with new transmission capacity.

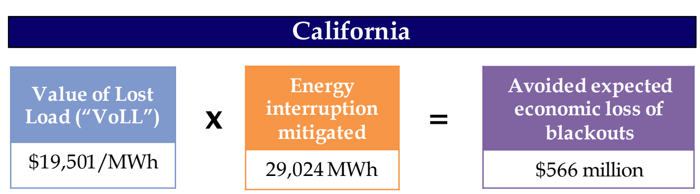
In principle, new transmission capacity helps in system reliability as it allows system operators to change dispatch to accommodate or mitigate contingencies and it can deliver additional generation to a specific location that is supply constrained. Therefore, by multiplying the VoLL and the amount of load that would have otherwise been curtailed due to a supply interruption, LEI derives the indicative economic value of reliability from new transmission. Figure 32 shows the process for estimating the amount of expected economic loss caused by supply interruptions that can be averted through the **Eastern Interconnect project**. The modeling results suggest that as much as $477 million and $546 million of economic losses can be avoided in the local economies in PJM and MISO, respectively, for just one supply interruption event.

Figure 32. Projected economic losses averted because of the reliability improvement associated with the Eastern Interconnect project



Similarly, Figure 33 below illustrates the calculation of savings from avoiding one costly blackout for the **Western Interconnect project**, which can amount to $566 million for the Californian economy for just one supply interruption event.

Figure 33. Economic losses averted because of the reliability improvement associated with the Western Interconnect project



5 Conclusions

LEI's analysis of two hypothetical transmission investment projects, summarized in Section 4, show that the benefits of transmission investment can be quantifiable, substantial, widespread, and long-lasting.

Although benefits of transmission investment are based on a simulation, they are nevertheless **measurable and quantifiable**. Forward-looking simulation analysis is necessary to properly estimate the benefits of a *proposed* transmission project. Once a transmission project is built, impacts of the investment can be observed in the market data (through comparison to historical operations data and/or "back-casting").

Transmission benefits can be **substantial,** even if they result in a relatively small market price reduction. Such reductions spread across many customers add up to a very large societal impact. Even when some customers see increase of cost or some generators see decrease of profits, their economic losses are more than offset by economic gains achieved by other beneficiaries making the society better off (and under some circumstances, those stakeholders facing economic losses could be "compensated" for by the beneficiaries).

Transmission investment typically delivers benefits to **many stakeholders**, including generators, electric consumers, business owners, and governments. Electricity market savings for consumers can lead to extensive and diverse economic benefits – some generators[28] will benefit and almost all other (non-utility) sectors of the local economy are positively affected. In terms of geographic areas, benefits are **widespread** and will accrue beyond just specific locations of transmission investment. Moreover, as shown with the profile of beneficiaries in the **Eastern Interconnection project**, the beneficiaries may change over time – and transmission will be there to support the changing patterns of electricity consumption.

Benefits of well-planned transmission investment are **long-lasting.** Benefits start to accrue even before a transmission project is complete – local spending during the construction period creates local economic benefits. Once the project comes online, electricity markets are positively impacted – electricity customer bill savings translate into positive economic impacts. As many transmission projects have useful lives longer than 50 years, the economic benefits from avoiding situations of limited electricity supply and averting costly supply interruptions (blackouts) in the longer term can be significant.

[28] Transmission investment can deliver benefits to power producers, in addition to consumers, in multiple ways. First, generators in an export-constrained region can makes more sales because of additional transmission capacity. Second, transmission investment can also serve as a catalyst to attract more generation investment to a specific region.

5.1 Implications for real-world transmission investments

In this analysis, LEI studies two inter-regional transmission projects. However, this does not mean that transmission benefits arise only with respect to transmission between regions. Even within a market or region, there will be transmission projects that can improve efficiency, motivate trade, reduce electric consumer costs, and enhance reliability. Essentially, new transmission investment creates benefits by allowing market participants – consumers and suppliers – to use energy more efficiently. Therefore, the methodology for estimating benefits and the general magnitude of the benefits is applicable to many other transmission investments.

A summary of the indicative range of economic benefits of transmission, based on an examination of these two hypothetical projects is presented in Figure 34 below.

Figure 34. Indicative benefits of transmission

Metrics	Results	Drivers
Efficiency improvement in the production of energy	▪ Savings from efficient improvement in the production of energy are in the range of $10 to $40 per MWh of energy that flows on the transmission project	▪ Larger efficiency gains are likely in markets where there are more diversity (steeper supply curve) and vice versa
Electric consumer savings – energy	▪ Typically under $2/MWh in LMP reductions which leads to consumer savings once multiplied by total consumption in the region	▪ Larger reductions for projects with larger energy flows or higher Locational Marginal Prices ("LMPs")
Electric consumer savings - capacity	▪ $100 capacity cost reductions for every kW of qualified capacity	▪ Larger capacity price reductions are likely in markets where the market supply-demand balance is tighter and/ or in smaller size markets with steeper demand curves
Carbon emissions reductions	▪ Approximately 0.7 metric ton reductions per MWh of energy that flows on the transmission project	▪ Greater reduction if a region/market has a higher carbon footprint
GDP increase	▪ For every million dollars spent on construction and installation of a transmission project, the GDP is projected to grow by $1 million or more (short-term) ▪ During operations, for every million dollars of reduction in costs to electric consumers, the GDP is estimated to grow by $1-12 million	▪ Magnitude varies depending on composition of economy and labor productivity rates
Job increase	▪ For every million dollar spent locally on construction and installation of the project, LEI estimates that 10-20 new jobs are created (short-term) ▪ For every million dollar reduction in costs to electric consumers, 10 to 90 new jobs may be created during the operations phase	▪ Magnitude varies depending on composition of economy and labor productivity rates

Efficiency improvements in the production of energy

Projected savings from efficiency improvement in the production of energy are in the range of $10 to $40 per MWh of energy that flows on the transmission project. The level of efficiency gains will vary with the profile of energy flows on the transmission line and the resource mix in the importing and exporting regions. For example, energy flows during peak hours tend to lead to higher efficiency gains for the system than those during off-peak hours. In addition, if the importing market has a mix of local resources (i.e., a steeper supply curve), larger efficiency gains are likely to occur. The cost differential between the imported energy on the new transmission line and the energy that would have been used to meet demand in a world without new transmission project also affects the efficiency improvements: a larger cost differential will lead to a larger efficiency improvement.

Electric consumer savings – Energy

Energy transmitted on a new transmission project will reduce energy prices in wholesale electric markets, consistent with the basic theorem that more supply leads to lower prices. Reductions in hourly energy prices multiplied by the total consumption in the market or region will yield the annual electric consumer savings in the energy market. Typically, for transmission projects that are moving thousands of megawatt hours of energy a year, the energy price impact is forecasted to be between $0.50 and $2 per MWh. For smaller projects, where energy sales are smaller, the impact on energy prices will be less. In addition, the realized energy price reductions will be closely correlated to the price levels for energy. In markets with higher energy prices, the impact of new energy resources accommodated through new transmission tends to be higher than in a market with a relatively lower energy price.

Electric consumer savings – Capacity

There are different wholesale electricity market designs among the two hypothetical projects presented in this paper, with varying capacity market constructs. Nevertheless, the level of capacity-related cost savings for consumers is in a similar range. For every kilowatt of qualified capacity supplied through a new transmission project, LEI observes typically $100 of annual capacity cost reductions. We would expect that if the market is already over supplied - before the new transmission project - the capacity market savings are going to be lower, while a market that is in a need of new capacity (and therefore exhibits relatively high capacity prices before the project comes online) will have bigger capacity market savings. In addition, larger capacity price reductions are expected in smaller size markets with steeper demand curves (if demand curves are used in that region's capacity market price formation process).

Carbon emissions reductions

Approximately 0.7 metric ton reductions are expected per megawatt hour of energy that flows on the transmission project. Intuitively, greater carbon emissions reductions will occur in a region/market with a higher carbon footprint, and vice versa.

Local economic benefits

For every $1 million dollars spent locally on construction and installation of a transmission project, the GDP is projected to grow by $1 million or more. In term of new jobs, for every $1 million dollars spent locally on construction and installation of the project LEI estimates that 10 to 20 new jobs will be created. These local economic benefits will depend on the size of the project (since the local spending is proportional to the capital investment and the capital investment is correlated with project size).

LEI has observed higher multiplier effects for the local economic benefits during the operations period; that is, for every $1 million dollars of reduction in costs to electric consumers, the GDP is estimated to grow by $1 million to over $12 million (the magnitude of the increase is contingent on the economic profile in the locality being targeted for as well). And for every $1 million dollars of reduction in costs to electric consumers, 10 to 90 new jobs may be created during the operations phase.

5.2 Implications for system planning

Benefits of transmission investment are multi-dimensional, arise at different time of a project's life, and affect different stakeholders. In order to properly capture the value of transmission investment, benefits must be comprehensively considered, and only then can these benefits be compared against costs to enable decision-makers to optimize the value of transmission investment.

Benefits should be measured across all identified categories and affected parties – even if that requires taking a very broad perspective and forces system planners to consider affected parties outside their jurisdiction or outside the standard planning time horizon. While LEI has estimated each benefit presented in this study through integrated modeling of electricity markets and local economies, the individual benefit metrics are themselves not universally additive. Some benefits can potentially be aggregated - like electricity cost savings, environmental benefits, and local economic impacts – if they affect the same beneficiaries. However, certain benefit metrics have an inherent level of "overlap" and adding would create double-counting.[29]

Utilizing scenario analysis can help decision makers to better understand and quantify the expected range of benefits over the long term. Scenario analysis can capture the impact of uncertainty or the magnitude and longevity of benefits, and even identify beneficiaries that were not anticipated under a "base case" or most likely forecast. In some cases, scenario analysis can also show that benefits may arise irrespective to future market outcomes.

Once all benefits have been measured, they can then be considered against the costs of investment. Decision-makers for transmission investment, while looking at the cost and benefit of a project from a holistic point of view, should also understand and prioritize the most

[29] Please refer to Section 2.3 in the Technical Appendices.

immediate need that can be met and the major benefits that can be harnessed by such an investment. LEI recognizes that system planners, in some cases, are designing a transmission project that is primarily targeting specific benefits to solve certain problems and may not necessarily be trying to capture the entire spectrum of the benefits, as discussed in the study. However, it is also important for decision-makers to realize that many drivers of benefits will arise as a natural outcome of the investment and these benefits should then be considered in decision-making.

TECHNICAL APPENDICES
FOR
HOW DOES ELECTRIC TRANSMISSION BENEFIT YOU?

IDENTIFYING AND MEASURING THE LIFE-CYCLE BENEFITS OF INFRASTRUCTURE INVESTMENT

Prepared for

WIRES

By

Julia Frayer
Eva Wang
Ruoyun Yang
Jarome Leslie
Jinglin Duan
Tianying Lan

January 8, 2018

LONDON ECONOMICS

www.londoneconomics.com

London Economics International LLC
717 Atlantic Ave, Suite 1A
Boston, MA 02111
www.londoneconomics.com

List of Acronyms

ACR	Avoidable Cost Rate
AEO	Annual Energy Outlook, published by the EIA
AEP	American Electric Power Co
BRA	Base Residual Auction
CAGR	Compound Annual Growth Rate
CAISO	California Independent System Operator
CCGT	Combined Cycle Gas Turbines
ComEd	Commonwealth Edison
CONE	Cost of New Entry
CPM	Capacity Procurement Mechanism
CPUC	California Public Utilities Commission
CT	Combustion Turbine
C&I	Commercial and Industrial
DR	Demand Response
EFORd	Equivalent Demand Forced Outage Rate
EIA	Energy Information Administration
EPA	Environmental Protection Agency
FERC	Federal Energy Regulatory Commission
GDP	Gross Domestic Product
ICAP	Installed Capacity
IGCC	Integrated Gasification Combined Cycle
I/O	Input/Output
kV	kilovolt

LBA	Local Balancing Authorities
LCOP	Levelized Cost of Pipeline
LCR	Local Clearing Requirement
LDA	Locational Deliverability Area
LMP	Locational Marginal Price
MOPR	Minimum Offer Price Rule
OATT	Open Access Transmission Tariff
OTCGH	OTC Global Holdings
O&M	Operations and Maintenance
MISO	Midcontinent Independent System Operator
MRTU	Market Redesign and Technology Upgrade
NRC	Nuclear Regulation Commission
NPV	Net Present Value
NSI	Net Scheduled Interchange
NYISO	New York Independent System Operator
PG&E	Pacific Gas and Electric Company
PPA	Power Purchase Agreement
PRA	MISO's centralized capacity auction, namely Planning Resource Auction
PRMR	Planning Reserve Margin Requirement
RA	Resource Adequacy
REC	Renewable Energy Credits
REMI	Regional Economic Models, Inc.
RECLAIM	Regional Clean Air Incentives Market
RGGI	Regional Greenhouse Gas Initiative
RMR	Reliability-Must-Run Contracts

ROW	Right-of-Way
RPM	PJM's centralized capacity market, known as the Reliability Pricing Model
RPS	Renewable Portfolio Standard
SERC	Southeastern Reliability Corporation
SCC	Social Cost of Carbon
SCE	Southern California Edison
SPP	Southwest Power Pool
SRMC	Short-Run Marginal Costs
TVA	Tennessee Valley Authority
UCAP	Unforced Capacity
VoLL	Value of Lost Load
VRR	Variable Resource Requirement
WECC	Western Electricity Coordinating Council

Technical Appendices

London Economics International LLC
717 Atlantic Ave, Suite 1A
Boston, MA 02111
www.londoneconomics.com

London Economics International LLC
717 Atlantic Ave, Suite 1A
Boston, MA 02111
www.londoneconomics.com

Table of Figures

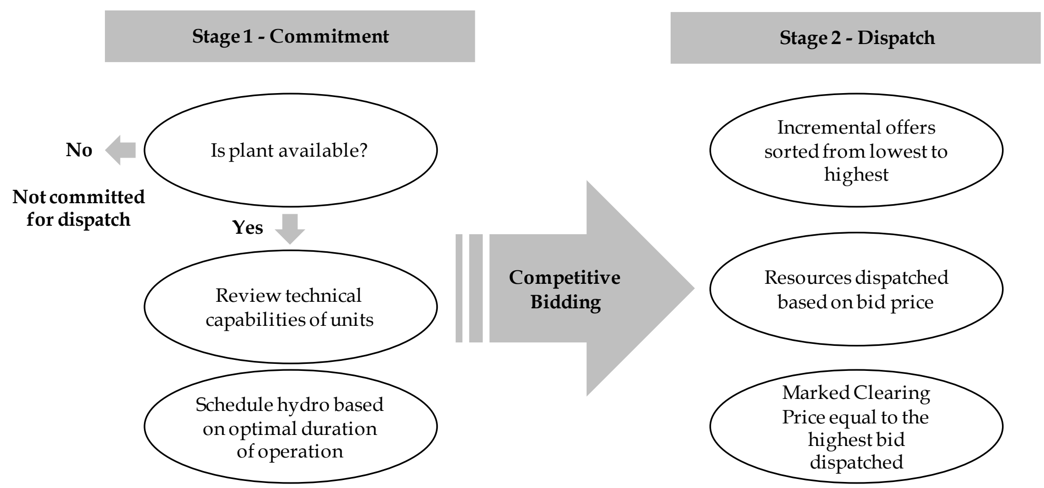
1 Modeling tools and methodology

To quantitatively measure how transmission investment changes electricity market outcomes, reduces the costs of electricity supply and improves reliability, LEI employs its proprietary electricity network simulation model, POOLMod, along with simulators for other wholesale electricity market-related products like capacity and Renewable Energy Credits ("RECs") as needed. LEI customizes the simulation models to fit specific wholesale market designs of each region). The same models are also used to measure impact of transmission investment on carbon emissions. LEI also deploys the Regional Economic Models, Inc. ("REMI")[1] to examine how infrastructure spending and electricity cost savings impact the local economies and employment.

1.1 POOLMod

POOLMod simulates the dispatch of generating resources in the market subject to least cost dispatch principles to meet projected hourly load, and technical assumptions on generation operating capacity and of the transmission system.

Figure 1. POOLMod's two-stage process



POOLMod consists of a number of key algorithms, such as maintenance scheduling, assignment of stochastic forced outages, hydro shadow pricing, commitment, and dispatch. The first stage of analysis requires the development of an availability schedule for system resources. POOLMod determines a 'near optimal' maintenance schedule on an annual basis, accounting for the need to preserve regional reserve margins across the year and a reasonable baseload, mid-merit, and peaking capacity mix. POOLMod also allocates forced (unplanned) outages randomly across the year based on the forced outage rate specified for each resource.

POOLMod next commits and dispatches plants on a daily basis. Commitment is based on the schedule of available plants net of maintenance and takes into consideration the technical

[1] REMI's PI+ model is widely used in both the public and private sectors (including federal and state regulators, utilities, developers, and policy advocate institutions, etc.); it has also been used to consider economic impacts of transmission before state regulators in transmission siting cases.

requirements of the units (such as start/stop capabilities, start costs (if any), and minimum on and off times).[2] In most ISOs/RTOs in the US, generators are required to bid/offer in at or close to their short-run marginal costs. In the dispatch stage, the market clearing price is set based on the projected short run marginal cost of the highest cost resource needed to meet (local) demand.

Since the 1990s, POOLMod has been used to forecast long-term power prices, support market reforms, and finance hundreds of millions of dollars of investment in various regions across North America as well as in other jurisdictions around the world. In the US, POOLMod has been used to help evaluate the initial round of generation divestitures and project pricing after the early market reforms in the 1990s. It supported numerous first-generation asset acquisitions in California, New England, New York, and PJM. Since that time, price forecasts and analysis created using POOLMod has been used in many successful commercial transactions, but also in support of critical policy development, market rules assessments, and general evaluations of market competitiveness. Internationally, POOLMod has been used to evaluate market dynamics and investment opportunities in Australia, Argentina, Brazil, Central American (including Belize, Costa Rica, Guatemala, Honduras, El Salvador, Nicaragua and Panama), Chile, Colombia, Dominican Republic, Italy, Japan, Mexico, Peru, Philippines, Portugal, New Zealand, NordPool, Saudi Arabia, Singapore, South Africa, Southeastern Europe, Spain, and the United Kingdom.

1.2 Capacity model simulator

In addition to the wholesale energy market, LEI also simulates the wholesale capacity market. The capacity market simulator provides a projection of the annual capacity clearing prices and a determination of new entry and retirements that then affects the energy market simulations in POOLMod. LEI has developed proprietary capacity model simulators for both PJM and MISO that represent the key market design and competitive bidding behavior in the capacity markets. Furthermore, LEI's modeling of the wholesale electricity market properly represents the linkages between energy and capacity market designs. Capacity market outcomes from the proprietary capacity model simulator determine the new entry profile and schedule of economic retirements, which are then incorporated in the energy modeling.

1.2.1 MISO's capacity market

Capacity market clearing prices are forecasted using LEI's simulator of MISO's capacity market. The MISO capacity market, known as the Planning Resource Auction ("PRA"), occurs annually for the next period. The MISO uses a quantity-based target (essentially a vertical demand curve) and the PRA is essentially a spot market for capacity. Nevertheless, it can still signal the need for investments. LEI models MISO's ten capacity market zones, using the MISO's auction clearing rules along with a fundamental, bottom-up buildup of demand and supply. The supply curve is made of all plants eligible to sell capacity in MISO. To reflect the true economic value of capacity in MISO, LEI projects bids for each plant based on avoidable costs (for existing generation units) and all-in costs (for new entrants). PRA is a residual market, as many suppliers enter into bilateral contracts for capacity with load serving entities. As such, during periods of over-supply, PRA prices have been very low. By including all resources and demand within its simulations of the

---

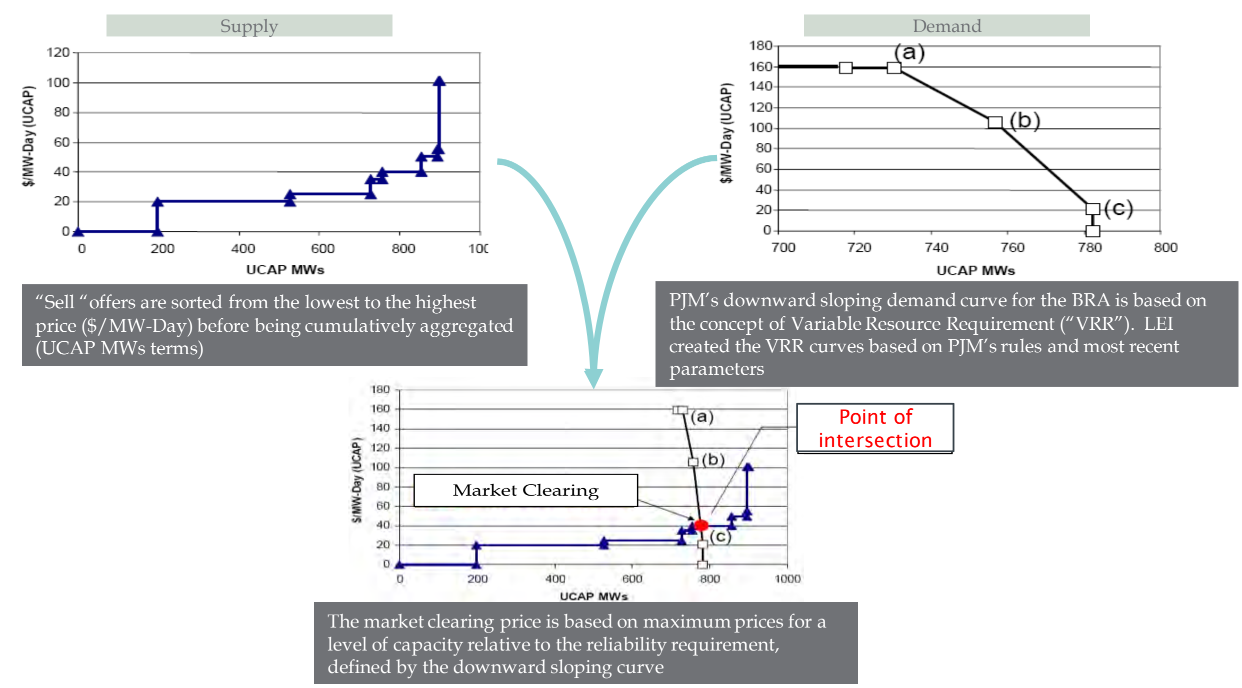
[2] During the commitment procedure, hydro resources are scheduled according to the optimal duration of operation in the scheduled day. They are then given a shadow price just below the commitment price of the resource that would otherwise operate at that same schedule (i.e., the resource they are displacing).

MISO PRA, LEI's capacity price forecast represents a comprehensive value of capacity that aligns with the overall timing and need for new investment and essentially combines the spot market and bilateral contract market.

1.2.2 PJM's capacity market

PJM's Reliability Pricing Model ("RPM") consists of a primary auction, followed by incremental auctions one, two, and three years out. The primary auction uses a single round auction clearing process. Notably, this auction occurs three years in advance of delivery so that new entrants and existing resources can compete on an equal footing. PJM uses a downward sloping demand curve to determine how much capacity to buy and at what price. LEI only models the primary auction which is known as Base Residual Auction ("BRA"), because the incremental auctions are only conducted when there are changes in committed capacity resources or load forecast. LEI assumes competitive bidding behavior except for those with reliability-must-run contracts ("RMRs") and imports which are price takers. Moreover, LEI does not assume bilateral contracts (self-schedule bid at zero) or offer-capping because the model presumes a competitive environment where all resources are already offering at their avoidable costs or the minimum going forward fixed costs. In addition, LEI assumes that all plants will participate in the BRA.

Figure 2. LEI's PJM capacity market simulator



To model the PJM capacity market for the forecasted horizon, LEI has first developed the downward sloping demand curve for the BRA, the Variable Resource Requirement ("VRR") curve. The first step is to determine the price cap, then the installed reserve margin, and finally the Net Cost of New Entry ("CONE"). Consistent with PJM's proposed and recently approved VRR Curve, LEI's VRR Curve is drawn by combining (i) a horizontal line from the y-axis to point (a), (ii) a straight line connecting points (a) and (b), and (iii) a straight line connecting points (b) and (c). Going forward, the VRR curve is projected based on the load forecast which will determine the resource requirement in the capacity market, and an escalation of the Net CONE.

The next step in the simulation of the BRA is to determine the supply stack for capacity. "Sell" offers are estimated for each plant and then sorted from the lowest to the highest price ($/MW-Day). LEI counts the capacity based on its estimates of UCAP.[3] The market clearing price is then determined based on maximum prices for a level of capacity as captured in the intersection of the supply stack and the VRR (see Figure 2).

1.2.3 California's Resource Adequacy market

California does not have a centralized capacity market like MISO or PJM. However, there is a similar bilateral product known as the Resource Adequacy ("RA") product. The California Public Utilities Commission ("CPUC") adopted a RA policy framework (PU Code section 380) in 2004 in order to ensure the reliability of electric service in California. Under the RA framework, California effectively has a bilateral spot market for capacity, where existing generators can sell their capacity on a month-ahead and year-ahead basis to load serving entities that must then show compliance with the RA program to the CPUC.

The system RA requirement uses a 15% planning reserve margin on top of forecast load (there are also additional local RA requirements in transmission constrained areas). On January 1st, 2015, a flexible RA requirement was introduced to maintain grid reliability during significant ramping periods.[4] Resources are assigned system and flexible capacity values which are procured together on a single RA contract. The RA program is not a Federal Energy Regulatory Commission ("FERC")-regulated product market. The RA program is administered by the CPUC, although the California Independent System Operator ("CAISO") complements the CPUC's efforts by providing input on locational constraints through its Interim Reliability Requirements and Market Redesign and Technology Upgrade ("MRTU") initiatives. CAISO also has the tariff authority under its Capacity Procurement Mechanism ("CPM") to procure backstop capacity to address a deficiency or supplement resource adequacy procurement by load-serving entities. Effective November 2016 market-based procurement and pricing replaced the former administrative price for backstop capacity. The new procurement mechanism allows suppliers to offer local, system, and flexible backstop capacity into a competitive solicitation process to meet identified reliability needs.[5,6]

1.3 The REMI PI+ Model

LEI analyzes the local economic benefits of transmission investment using a reginal economic modeling tool – the REMI PI+ model. The REMI PI+ model is developed by the REMI. It is a dynamic economic model that measures the impact on the local economic activity and labor markets due to an infrastructure investment. LEI uses a combination of 70-sector (see Figure 3), state-level and customized regional level REMI PI+ models to analyze economic impacts of the hypothetical transmission and generation investments in this study.

---

[3] Unforced Capacity ("UCAP") refers to the resources installed capacity adjusted for its equivalent demand forced outage rate.

[4] Resources are considered as flexible capacity if they can ramp up or sustain output for 3 hours.

[5] FERC. *Letter Order Accepting Compliance Filings.* August 18, 2016.

[6] FERC. *Order Accepting Tariff Revisions Capacity Procurement Mechanism – ER15-1783.* October 1, 2015.

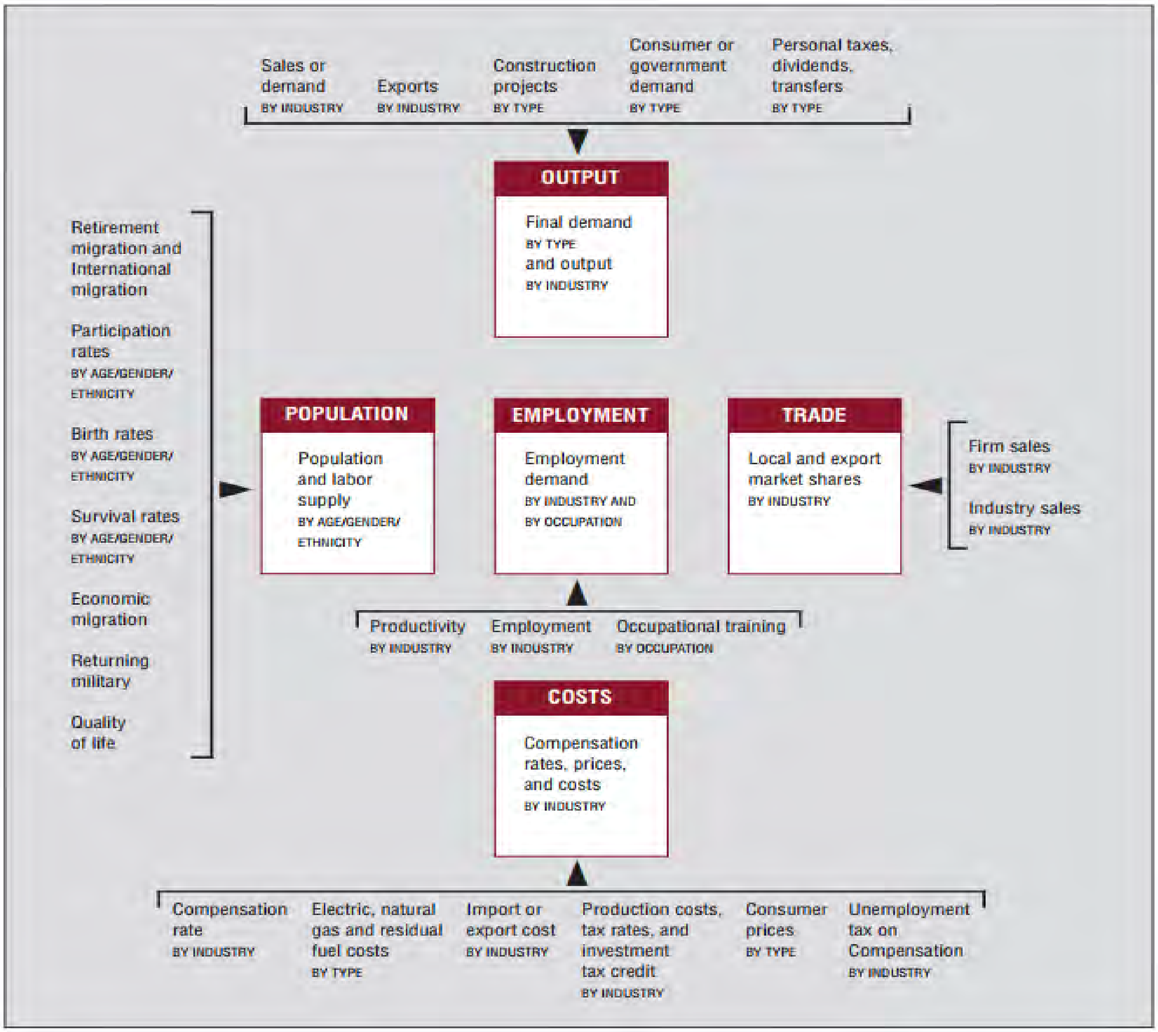
Figure 3. List of the 70 sectors included in the REMI PI+ model used in LEI's study

1. Forestry and logging; Fishing, hunting, and trapping
2. Agriculture and forestry support activities
3. Oil and gas extraction
4. Mining (except oil and gas)
5. Support activities for mining
6. Utilities
7. Construction
8. Wood product manufacturing
9. Nonmetallic mineral product manufacturing
10. Primary metal manufacturing
11. Fabricated metal product manufacturing
12. Machinery manufacturing
13. Computer and electronic product manufacturing
14. Electrical equipment and appliance manufacturing
15. Motor vehicles, bodies and trailers, and parts manufacturing
16. Other transportation equipment manufacturing
17. Furniture and related product manufacturing
18. Miscellaneous manufacturing
19. Food manufacturing
20. Beverage and tobacco product manufacturing
21. Textile mills; Textile products mill
22. Apparel manufacturing; Leather and allied product manufacturing
23. Paper manufacturing
24. Printing and related support activities
25. Petroleum and coal product manufacturing
26. Chemical manufacturing
27. Plastics and rubber products manufacturing
28. Wholesale trade
29. Retail trade
30. Air transportation
31. Rail transportation
32. Water transportation
33. Truck transportation
34. Couriers and messengers
35. Transit and group passenger transportation
36. Pipeline transportation
37. Scenic and sightseeing transportation; Support activities for transportation
38. Warehousing and storage
39. Publishing industries, except Internet
40. Motion picture and sound recording industries
41. Internet publishing and broadcasting, ISPs search portals and data processing
42. Broadcasting, except Internet
43. Telecommunications
44. Monetary authorities – central bank; Credit intermediation and related activities; Funds, trusts, & other financial vehicles
45. Securities, commodity contracts, investments
46. Insurance carriers and related activities
47. Real estate
48. Rental and leasing services; Lessors of nonfinancial intangible assets
49. Processional, scientific, and technical services
50. Management of companies and enterprises
51. Administrative and support services
52. Waste management and remediation services
53. Educational services
54. Ambulatory health care services
55. Hospitals
56. Nursing and residential care facilities
57. Social assistance
58. Performing arts and spectator sports
59. Museums, historical sites, zoos, and parks
60. Amusement, gambling, and recreation
61. Accommodation
62. Food services and drinking places
63. Repair and maintenance
64. Personal and laundry services
65. Membership associations and organizations
66. Private households
67. State and local government
68. Federal civilian
69. Federal military
70. Farm (crop and animal production)

Source: REMI

The REMI PI+ model is a regional economic model that incorporates basic Input/ Output ("I/O") functionality in a Computable General Equilibrium model with advanced Economic Geography and other econometric time-series modeling capabilities, and regression techniques. Economic shocks and policy changes can be captured and simulated in the REMI's PI+ model through adjustment of different categories of policy variables, as shown in Figure 4. These variables are interconnected through geographical linkages and industrial ties, and affect each other through direct and indirect economic impacts. Such dynamic impacts are ultimately reflected in the modeling results, through changes in population, trading activities, economic outputs, employment, product prices and labor compensation rates.

Figure 4. Policy variable modules in the REMI PI+ Model



Source: REMI

Specifically, in this study, LEI models the transmission and generation project investment through policy variables in the "Output" category, which capture the change in industrial sales and demand for goods and services. Changes in electricity price are modeled through electric fuel costs for different types of consumers, which belong to the "Cost" category. Impacts of the carbon emissions reduction are simulated through increases in compensation, under the "Cost" category, which represent improved "quality of life." The analysis of economic impacts related to electric supply shortages are based on changes in "Output" in the affected sectors.

2 LEI's modeling approach and methodology

LEI's analysis of the impacts of transmission investment on wholesale electricity markets and local economies is based on robust modeling, using well accepted methodologies and reasonable assumptions that are derived from various sources (such as ISO studies, primary data filed with FERC and Energy Information Administration ("EIA"), and the professional judgement of LEI to represent the "most likely" set of conditions for the future, based on the information available as of second and third quarter of 2017.

2.1 Developing a world with and without transmission investment

In order to quantify the benefits on transmission investments, we need to be able to measure how the transmission project and the associated energy flows and capacity sales would impact the wholesale electricity market and local economy. The best methodological approach for examining and estimating these impacts involves forward-looking simulation modeling because we cannot otherwise observe such benefits directly from market conditions historically or in the present, since the infrastructure is not currently in place.

The analysis for this study starts with a forecast of a "base case" or "most likely case", spanning a 15-year period of 2021 through 2035. The base case outlook combines the most likely set of market assumptions for key market drivers along with normal system operations and average load conditions, based on "50/50" load forecasts. Rationally, LEI assumes that the modeled wholesale electricity market outcomes converge over time to a supply-demand equilibrium (i.e., that reserve margin requirements are generally met in each year and new investments are made when it is economic to do so, and that stated polices, for example with respect to new renewable investment and carbon emissions reduction goals, are achieved). Therefore, the base case represents a future evolution from the current status quo, based on economically rational investor response to the projected market dynamics and system needs and policy requirements.

Once the base case is set, LEI then considers how market outcomes would change if a transmission project is developed. For example, in the case of the **Western Interconnect project**, moving wind power from the Rocky Mountain area to California will result in deferred development of local renewable generation in California. Such dynamics in wholesale electricity market is taken into consideration in the modeling for the purpose of consistency (See Section and Section 5.2.3.2.

The market impacts – the benefits - of transmission investment are then measured as a function of the difference in costs of production, congestion, emissions, and market prices between a world with and without the transmission investment.

2.2 Integration of a suite of modeling tools

To evaluate the impacts of transmission investment on local economies and on electricity markets, LEI uses several simulation tools/software. Some of these tools are commercially available, such as the REMI PI+ model;[7] while others are proprietary to LEI but very similar to other third-party

[7] For detailed description of the REMI PI+ model, please refer to Section 1.3.

commercially available models, and are used by system operators and policymakers in the energy industry.

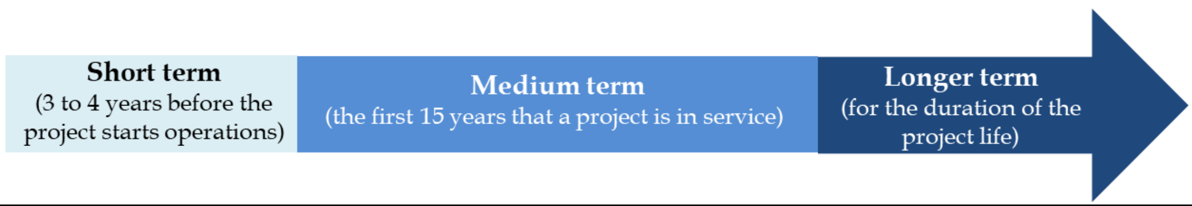
LEI employs its electricity market modeling tools on an integrated basis to represent the linkages between energy and capacity markets, and ensure that state policies are being achieved. For example, LEI simulates the capacity market based on expected performance of the future energy market, using simulation results from POOlMod. The results of the capacity market model, such new entry and retirements, are also essentially "inputs" to the POOLMod simulations.

LEI uses REMI PI+ to examine how local spending for the construction and installation of new power infrastructure and the electricity cost savings from such infrastructure impact the wider economy. Even though the REMI PI+ model is a separate tool/software, the inputs are derived from other LEI's calculations or modeling results around the electricity market. There is a natural integration of the REMI PI+ with other modeling tools in order to ensure consistency.

2.3 Chronology of modeling analysis

This study estimates the benefits of transmission chronologically, starting from the initial days of transmission project development and construction, through the first fifteen years of commercial operations, and into the longer term (see Figure 5).

Figure 5. Timeline of benefits from transmission investments



A 15-year modeling timeframe for modeling medium-term benefits is selected for this study. Although it is common for studies of this nature to look at the first ten to fifteen years of an asset's operating life, this should not imply that the medium-term benefits will last for exactly ten or fifteen years. Some benefits are long-lasting (for example, carbon emissions reductions and local economic benefits during the operations phase can last for many years and reliability benefits can arise at any time over the transmission project's useful life). However, other electricity market-related benefits (for example, savings from efficiency improvements in the production of energy and/or total electricity cost savings to consumers) may dissipate over time because the electric system naturally rebalances itself through new entry and retirements to the same target market price level in the longer term.

2.4 Handling uncertainty in exogenous variables and factors

As described above, LEI focuses the modeling of benefits of transmission under a "base case" or "most likely" future scenario. In addition, LEI captures uncertainty around supply factors in the estimation of the reliability benefits that transmission investment can bring to electric consumers and the economy. Other market drivers – like demand growth, fuel costs, and environmental policies, to name a few – can also be tested and consequences on benefits of transmission can be quantified. Given the overarching goal of this study is to demonstrate the analytical process (rather than to conduct an exhaustive investment appraisal of a specific project), more extensive scenario analysis around other market drivers was not performed.

Nevertheless, LEI recommends that system planners do consider scenario-based analysis as part of their economic assessment. Scenario analysis can provide a more comprehensive assessment of benefits and risks of investment.

How to conduct scenario analysis with simulation-based models?

1. **Identify key drivers** behind market outcomes. These can include any of the major factors affecting the fundamentals of electricity demand or supply (such as gas prices, hourly demand profiles, costs of new supply) and policies and regulations that influence market price outcomes and costs of supply (such as environmental policies, emissions requirements, and market rules).
2. **Build a "scenario space"** that consists of a range of values for each of the key drivers being tested and their correlation and relationship to other drivers. The development of the empirical distribution for each of the identified drivers can be based on historical data, projections, or a combination of both. The potential number of combinations of factor to be tested is likely to be far greater than can be processed by a simulation model within a reasonable amount of time, so it may be important to have objective and robust methods for determining which scenarios will actually be tested in the models. Some extreme conditions, such as blackout events, happen rarely but can have serious impacts to local economies. Such high impact, low probability events should also be included into the scenario analysis.
3. **Conduct simulation modeling.** Simulation modeling tools are used akin to an economically robust "equation" to transform various market drivers into output estimates, and to eliminate the need for estimating joint probabilities of various combinations of input scenarios.
4. **Build the sampling distribution** of market prices (or benefits) as developed through numerous simulations of sampled inputs. Based on the applications of the Central Limit Theorem, this sampling distribution can be used to make an inference regarding the population.

2.5 Resolving market outcome uncertainties relative to endogenous factors

Some uncertainties are not exogenous to the modeled outcomes. Therefore, the modeling tools need to have the capability to factor those uncertainties into the forward outlook. One such uncertainty revolves around the inter-dependence of transmission and other market resource alternatives. For example, will new generation supplant the need for new transmission or vice versa? Or will new transmission expand the need for new generation assets? Well-designed modeling of the electricity sector needs to recognize and allow for rational system investment, where investment in one type of technology can trigger or otherwise affect other investments. The benefits flowing from a transmission investment depends on uncertain future demand for transmission services, and this demand in turn depends on the expected pattern of generation retirements, new generation investment, and where and how electricity consumption is occurring.

In the hypothetical **Western Interconnect project**, the local (i.e., the state of California) wind developers will delay their investments for a few years given a fair amount of renewable energy would be brought through the new transmission investment. However, once the market re-balances and absorbs the renewable flows through the new transmission project, the market will see the need for continued renewable investment. Furthermore, as California becomes more integrated to the rest of WECC due to the Energy Imbalance Market effort, California may use the new transmission line to export the energy from the in-state solar generation during the day time to other part of WECC. In the hypothetical **Eastern Interconnect project,** given its smaller size, it does not trigger any market response from other participants. If a bigger project were modeled, the new transmission investment is likely to trigger response from generators in terms of retirements and new entry; other types of market resource alternatives may also be affected.

3 Description of benefits measured in the study

Transmission investments are complex and multi-faceted, and the benefits of a transmission project can be geographically widespread and take various forms. It is critical to recognize that the benefits of a transmission project can go far beyond meeting regional energy demand alone, they can also provide benefits such as storm hardening, increased competition in wholesale energy markets, congestion relief, deferral of new generation or other upgrades, expanded economic activity, increased income and property tax collections, and numerous other positive impacts to local economies. There are other benefits that are widely recognized and quantifiable. However, as this study is a demonstration, LEI has only quantified a subset of benefits summarized in Figure 6 below.

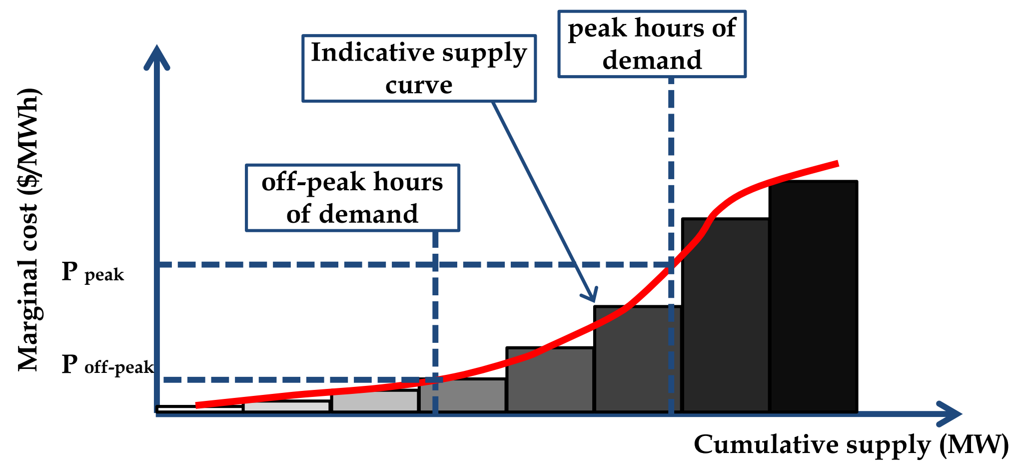
Figure 6. Selected benefit metrics of a transmission project

Total electric consumer savings	▪ arise when a transmission project creates a reduction in the wholesale spot energy and capacity markets clearing prices
Savings from efficient production	▪ arise when a transmission project brings lower-cost resources and lower the system's short run marginal costs of production
Generators' net revenues	▪ arise when a transmission project provide additional revenue streams for generators in the exporting regions
Carbon emissions reduction benefits	▪ arise when a transmission project brings lower or zero emissions resources and lower the system carbon emission level ▪ arise when a transmission project that creates societal benefits (e.g., decarbonization) may further attract more new jobs and boost economy
Insurance value	▪ Insurance value would be looking at one year under system stress condition events, for example, major generation outage
Local economic benefits	▪ Arise when a transmission project directly create new jobs and boost local economy. As a result of indirect and induced effects of the local spending, most sectors of the economy will benefit

3.1 The concept of the market price

The concept of the market price or cost of electricity lies at the heart of the economic benefit calculus for new transmission. The price of electricity is set by the supply and demand in each period, generally each hour. The supply curve is composed of individual available plants and is sorted from the lowest to the highest based on the short-run marginal costs ("SRMCs"), which consists of fuel costs, variable operations and maintenance costs, and emission costs. At the bottom of supply curve, it starts with the zero SRMC resources, like wind, solar, and run-of-river hydroelectric facilities. It is then followed by nuclear units. The mid-metric order plants are coal and efficient gas units. Finally, peaking gas and oil units, together with pumped storage hydro facilities are on the top of the supply curve. During the off-peak hours, varying by the market, efficient gas or coal generally set the hourly price while the high-cost peaking gas and oil set the price during peak hours (illustrated as $P_{\text{off-peak}}$ and P_{peak} in the Figure 7 below).

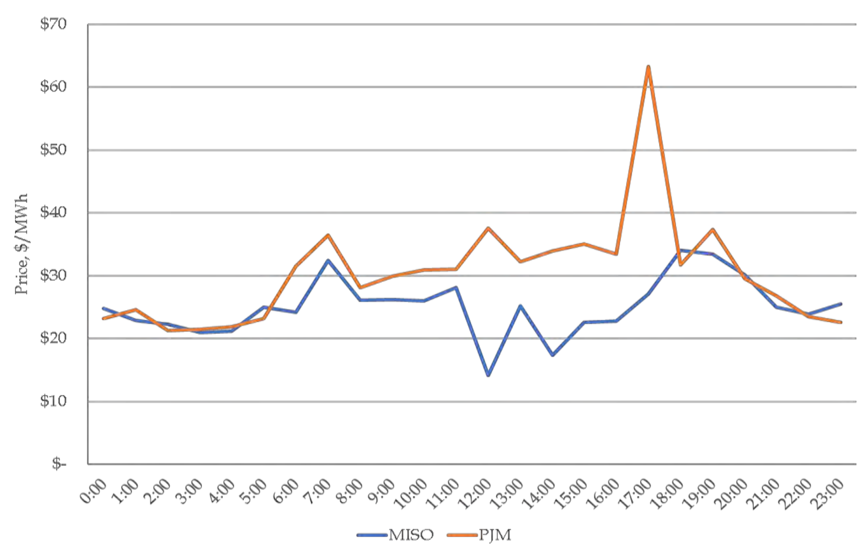
Figure 7. An illustration of price setting during different periods



The hourly price setting process is done in each hour. As shown in Figure 8 and Figure 9, the price of electricity changes continuously throughout the day and the year. In wholesale power markets, the price of electricity for a given hour is referred to as the Locational Marginal Price ("LMP").

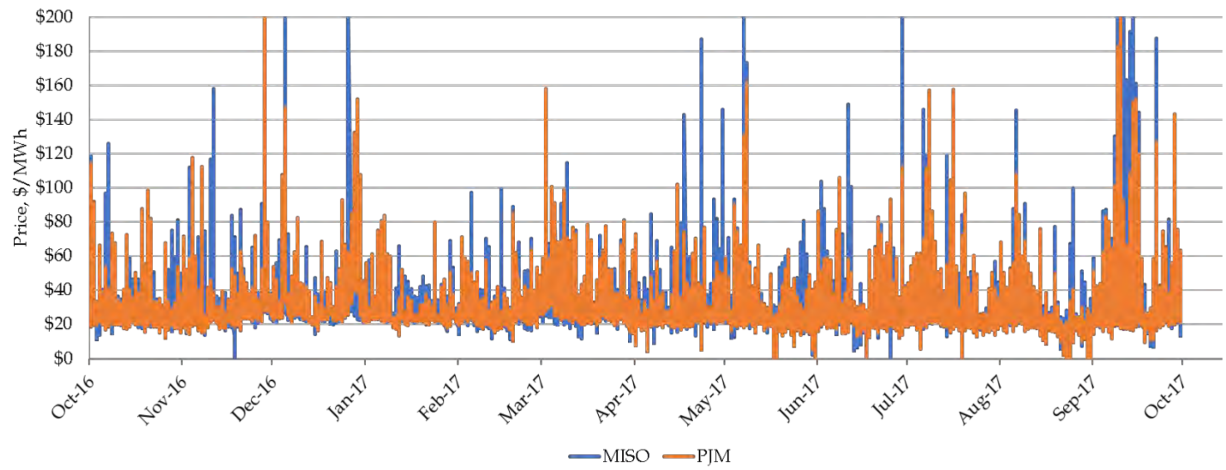
Given the price differences in each hour, trading opportunities exist between markets. LEI takes MISO and PJM historical price as an example, as shown in the Figure 8. PJM has higher prices than MISO in hour 17:00 to 18:00. Under these circumstances, if MISO supplies more energy to PJM, then PJM energy prices will decline, and electric consumers in PJM will benefit from the cost reduction. Figure 9 shows the trading opportunity between two markets over a one-year timeframe.

Figure 8. Real-Time hourly price of electricity: 00:00 am to 23:00 pm October 11, 2017



Source: PJM. "Locational Marginal Pricing." <https://dataviewer.pjm.com/dataviewer/pages/public/lmp.jsf>.

Figure 9. Real-Time hourly price of electricity: October 11, 2016 to October 10, 2017



Source: Third-party commercial database

The energy imports accommodated by the new transmission investment will reduce energy prices as additional lower cost energy will extend the supply curve to the right, indicating that for the same price, there is more supply available. With demand remain at the same level, lower marginal cost unit will be setting system price, as shown in the Figure 10.

Figure 10. Indicative supply curves in a world with and without transmission investment

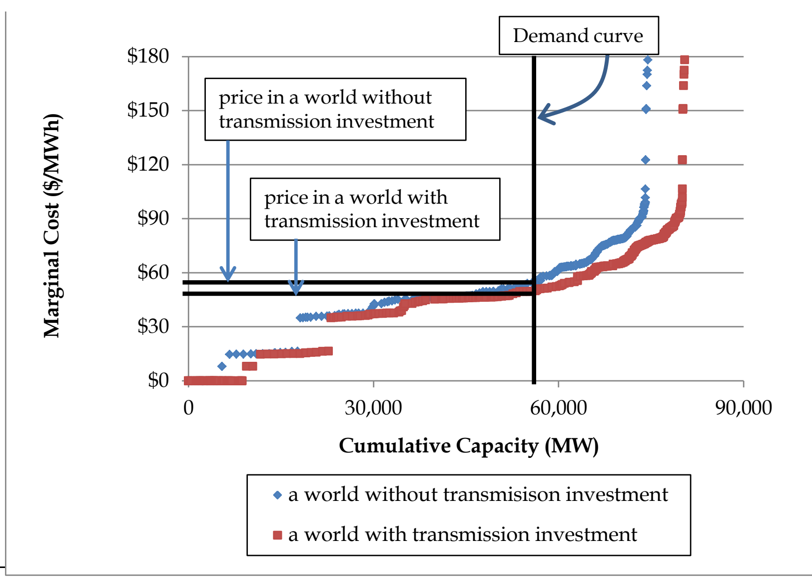
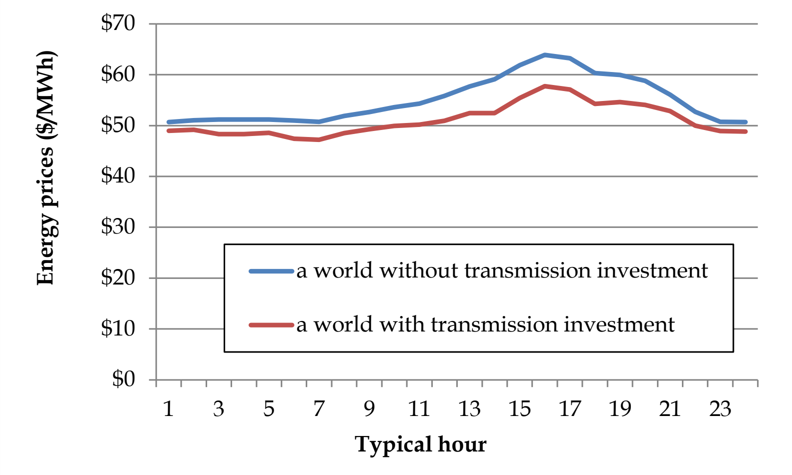


Figure 11 below shows the hourly energy price for a typical day in a world with and without transmission investment. Apparently, transmission investment can effectively reduce the energy price around the clock.

Figure 11. Typical daily price curve in a world with and without transmission investment



3.2 Total electric consumer savings

Total electric cost savings for consumers include both the energy and capacity components. Transmission investments reduce the marginal costs of producing electricity, which will eventually get reflected on consumers' monthly electricity bills.

On the capacity side, a similar dynamic is expected when the additional qualified capacity associated with the transmission investment enters the capacity market. Clearing prices in the capacity market will move down as additional qualified capacity increases the total volume of supply and drives up the system's reserve margin (making the wholesale electricity market more reliable).

3.3 Generators' net revenues

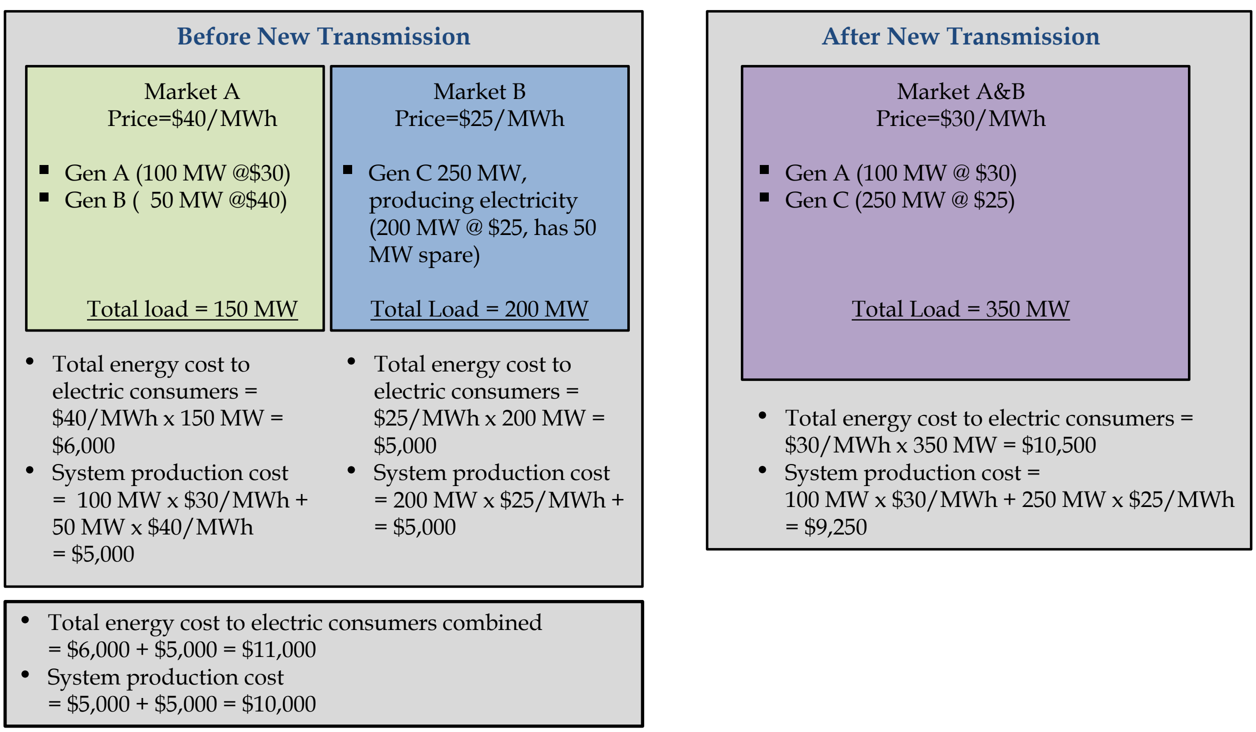
Transmission investment can deliver benefits to many stakeholders, including generators. Generators in the exporting regions can enjoy the additional sales that would not have existed if there were no trading opportunities. The market size expands as a result of transmission investment and the generators run more and even sell into other markets at higher prices. With this higher profit, it is also referred to as "producer surplus" as illustrate in Figure 12 below.

Figure 12. Illustration of generators' net revenues

LEI wants to emphasize that transmission – like other trade-enhancing initiatives in a competitive market – may cause some consumers to face higher market prices (costs) and some suppliers to face lower profits. Transmission connects local markets to form a bigger unified market – some economic losses are a natural outcome of the new competitive forces. Local suppliers that are way more expensive than imported electricity supply will be displaced due to competition and will earn less revenues – they no longer have the barrier-to-entry protection of their "smaller" market. On the other hand, local consumers in the exporting region may pay more for electricity when the transmission limits are lifted, and their local market is encapsulated into a bigger regional market.

In evaluating the benefits of a project, the net effects should be looked at – as long as total benefits (including any dis-benefits) exceed costs, a project is desirable. In the example shown in Figure 13, consumers in Market B see a higher energy price, but the dis-benefit is smaller than the benefits to consumers in Markets A&B after the new transmission (net consumer savings are $500). There are efficiency improvements amount to $750 in Markets A&B with new transmission, although Gen B is no longer able to compete.

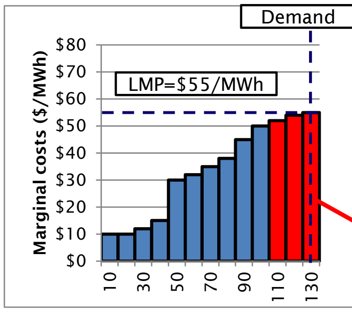
Figure 13. Societal benefits from increased energy market competition as a result of new transmission investment



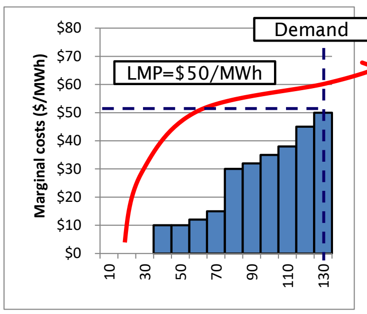
3.4 Savings from efficiency improvements in the production of energy (production cost savings)

As a consequence of the change in the supply stack, transmission investment also provides savings from efficiency improvements in the production of energy, which are sometimes referred to as produce production cost savings for the system.

Figure 14. Illustration of system production cost savings



Marginal Cost ($/MWh)	Capacity (MW)	Cumulative Capacity (MW)	Production Cost ($/h)
$10	10	10	$100
$10	10	20	$100
$12	10	30	$120
$15	10	40	$150
$30	10	50	$300
$32	10	60	$320
$35	10	70	$350
$38	10	80	$380
$45	10	90	$450
$50	10	100	$500
$52	10	110	$520
$54	10	120	$540
$55	10	130	$550
Total system production cost in one hour =>			$4,380



Marginal Cost ($/MWh)	Capacity (MW)	Cumulative Capacity (MW)	Production Cost ($/h)
$0	10	10	$0
$0	10	20	$0
$0	10	30	$0
$10	10	40	$100
$10	10	50	$100
$12	10	60	$120
$15	10	70	$150
$30	10	80	$300
$32	10	90	$320
$35	10	100	$350
$38	10	110	$380
$45	10	120	$450
$50	10	130	$500
Total system production cost in one hour =>			$2,770

For illustrative purposes, LEI has a "market" consisting of 13 plants, each is 10 MW in size, and a total system demand of 130 MW. Additional low-cost resources are introduced into the supply mix as a result of new transmission, displacing the three highest cost existing resources. Efficiency gains are equal to $1,610 in this hour (=$4,380 - $2,770) and electric consumer cost savings in this hour is $650 (= ($55-$50/MWh)*130 MW).

3.5 Carbon emissions reduction benefits

Transmission investment can support the increased use of renewable generation and reduce carbon emissions by connecting cleaner, lower-cost, generation with demand. In addition, a transmission line between two markets can facilitate the dispatch of the lower-cost, more efficient, and cleaner resources. As a result, the generation from more carbon-intensive, less efficient, higher cost resourced, like oil and coal, will be curtailed, and the carbon emissions in region will be reduced. Similarly, a new transmission line can also help reduce the emissions from SO_2, NOx, and other pollutants in addition to carbon emissions. Such environmental benefits created by transmission investment also provide flexibility for the system to meet policy goals, such as decarbonization targets, when the market conditions evolve over the longer term.

In order to calculate the economic value of these carbon emissions reductions, LEI applies the social cost of carbon ("SCC")[8] to the tons of carbon emissions avoided as a consequence of the

[8] SCC is meant to be a comprehensive estimate of climate change damages and includes, among other things: changes in net agricultural productivity; human health; property damages from increased flood risk; and changes in energy system costs, such as reduced costs for heating and increased costs for air conditioning.

new transmission. This method allows us to consider the societal value of reduced emissions, because it essentially measures the value of societal damages avoided for the given carbon emissions reduction. LEI adopts three scenarios with varying values of SCC for studies on socio-economic benefits regarding carbon emissions from US Environmental Protection Agency ("EPA"): the low-end value for SCC is forecast to be $22/metric ton, the median value is $71/metric ton, and the high-end value for SCC is at $104/metric ton for the period between 2021 and 2035.[9]

3.6 Local economic benefits

Local economic benefits arise as early as the planning and construction stages of a transmission plan, when the project spending on labor and materials for designing and building boosts the local economy. Sectors like construction and manufacturing directly benefit from the transmission investment during this period.

Once the transmission line enters commercial operations, electricity market savings become the main driver for local economic benefits. Such savings impact the local economy mainly through indirect and induced effects – lower electricity cost will make the local economy more attractive to industrial and commercial businesses, and boost residents' disposable income and drives consumption for good and services of various sectors in the local and interconnected economies. In addition, operations and maintenance ("O&M") spending of the project also creates job opportunities and boost local economy. Transmission projects can also benefit the local economy through enabling access to cleaner and cheaper renewable energy that are located in remote regions during the operations period. Carbon emissions reduction, as mentioned in Section 2.4, can bring socio-economic benefits by increasing the "quality of life" and therefore attract residents and workers who value environmental performance of a region. These residents and workers, usually highly educated, will then enrich the local labor market and advance the economic development of this region.

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.

3.7 Longer term impacts – "value" of reliability

In the long run, transmission investment can mitigate rising total cost to electric consumers associated with tight supply conditions or other system stresses. Longer term reliability benefits come in two forms: electric consumer savings and avoided economic losses.

To simulate a supply constrained future world, LEI models energy prices under a major power plant outage or lower import level lasting one year. In a world without new transmission investment, energy prices rise due to the system stress conditions. New transmission can alleviate some of that energy cost increase to consumers. The energy price difference (on a demand-weighted basis) multiplied by the load in the affected zones is the savings for electric consumers.

---

[9] EPA. *Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866.* August 2016. <https://19january2017snapshot.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf>

Savings for electric consumers =
energy price difference in a world with and without new transmission investment
x
load in the affected zones

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 quantifies the potential savings of unexpected economic losses through estimating the loss of outputs for the commercial and industrial ("C&I") sectors that are most likely to be affected by an electricity supply interruption. Sectors that are likely to have backup generators (e.g. hospitals/health care and schools/education) and sectors that are primarily dependent on other types of fuels rather than electricity[10] (e.g. construction, transportation, agriculture, forestry, fishing) are assumed not to be impacted seriously by a short-term supply outage, and therefore are excluded from the analysis of output loss due to electricity supply interruption.

LEI uses two models (REMI PI+ model and LEI POOLMod) to estimate the insurance value (or avoided expected economic loss) of the new transmission. The "price" of an unexpected supply interruption (or sometime referred as blackout) is represented as the value of lost load ("VoLL"), which is obtained through the following steps:

- step (a): In a given region, identify the 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 the economic output of that industry
- step (b): identify the expected GDP contribution of these C&I sectors for a typical year in the REMI PI+ baseline
- step (c): identifying the C&I sector's consumption of electricity over a typical year for the region
- VoLL is calculated by dividing the values from step (b) by the values extracted from step (c).

Then using LEI's proprietary electricity market simulation model, POOLMod, LEI estimates the frequency (number of hours) and magnitude of unserved load (in terms of energy not consumed and the amount of loss of load), as well as how many of those service interruptions can be "eliminated" by the transmission project. Therefore, the expected avoided economic losses due to the transmission project are calculated as:

VoLL (using REMI PI+) x Mitigated load loss (from POOLMod)

3.8 Should all these benefits be added up?

LEI has estimated each of the benefits individually, but some benefit metrics are inter-related. It may be possible to add or aggregate some benefits (for example, electricity cost savings, environmental benefits, and local economic impacts) so long as the distinct categories of

---

[10] These sectors have low coefficient between electricity supply and their output in the REMI Input/Output linkage

beneficiaries are tracked properly. Some benefits are more appropriately considered on a "side by side" basis as part of the lifecycle analysis of a particular project. Here are other reasons and conditions that some of these benefits cannot be added up directly.

- Some benefits should not be aggregated as there is a level of "**overlap**" inherent in the metrics. For example, efficiency improvements in the production of energy are indirectly reflected in the electric cost savings for consumers and in increased generation revenues for some generators, as all these metrics are evaluating what happens in the energy market.
- Benefits accrue to **different stakeholders** over varying time periods. For example, the benefit analysis would create a false impression if we add up benefits to consumers with benefits to generators.
- Benefits arise at **different points in time**. Some benefits last for a long period of time, while others are temporary. LEI recommends considering the chronology of benefits for each beneficiary using net present value techniques.
- The benefits from the electricity market are essentially the catalyst for the jobs and GDP benefits measured for the local economy over the medium term. It is important to recognize this **"causal" relationship** between some benefits (e.g., improved efficiency, cost savings, and increased GDP).

Given this complex nature, planners and policymakers should consider the full range of benefits in order to make the best decisions about investment opportunities. As such, LEI recommends that evaluating benefits should take into consideration the beneficiaries and the linkages between different benefit metrics.

4 Modeling assumptions and results for the hypothetical Eastern Interconnect project

The hypothetical Trade-enhancing Transmission Project in the Eastern Interconnect (referred to as the "**Eastern Interconnect project**") represents a transmission investment that is primarily intended to expand market access to lower-cost generation, by increasing trade of electricity and introducing additional supply resources into higher-energy-cost regions.

The **Eastern Interconnect project** would enhance electricity trading between PJM and MISO regions, which leads to efficiency improvements in the production of energy. The direction of energy flows on the new transmission line is not static – the flows will change to reflect evolving market conditions and supply-demand balances within and between the two regions. By harnessing trade opportunities between PJM and MISO, buyers and sellers on both sides of the new transmission line receive benefits, although not at the same exact time. The enhancement of trade between PJM and MISO creates savings to customers on their electric utility bills, as well as other benefits. For example, this new transmission project is projected to help achieve decarbonization goals in PJM more cost-effectively. By leveraging spare capacity with a lower carbon footprint in MISO, the combined systems' carbon emission level is reduced without additional investment in low or zero-cost generation resources.

4.1 Assumptions for the PJM wholesale electricity modeling of the Eastern Interconnect project

Figure 15. Summary of modeling assumptions for PJM wholesale electricity modeling

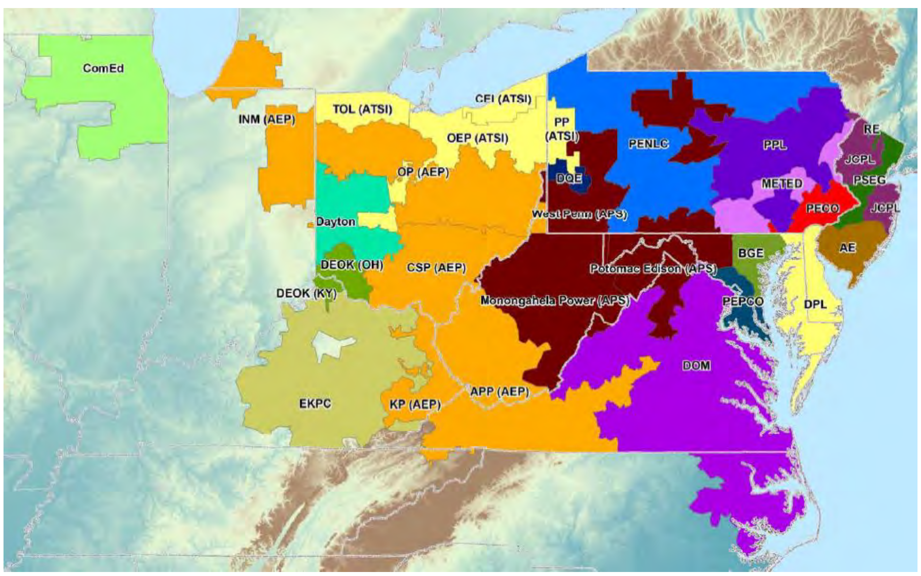
Assumptions	Descriptions
Topology	PJM is modeled into 10 zones based on historical transmission constraints.
Gas prices	LEI employs its proprietary gas forecast model, Levelized Cost of Pipeline ("LCOP") to forecast longer term trends in the transportation adder element. The LCOP Model evaluates 30 gas pricing hubs in North America, by tracking forward basis differentials with reference hubs and the levelized cost of building new pipeline(s) between each hub. The cost of pipeline capacity in the model relies on data collected from FERC on actual and proposed pipeline projects. In the long run, price spreads between two gas pricing hubs is assumed not to exceed the levelized cost of building a new pipeline between the two hubs. This levelized cost therefore effectively sets a long-term price cap on the transportation cost adder or basis differential between two pricing hubs.
Coal prices	Projected coal prices are unit-specific. Projected coal prices start at the actual 2016 delivered coal price then inflated by the growth rate of the coal plant supply region from the EIA 2017 AEO Report.
Oil prices	Projected distillate oil prices are based on NYMEX forward prices in the short term and are extrapolated based on the growth rate of EIA AEO 2017's oil price forecast. The residual oil prices are based on a multi-year average of the ratio of residual and distillate oil prices.
NOx and SO2 prices	The projected SO2 and NOx allowance prices are based on Bloomberg data for the short term and escalated over the long term at the assumed 2% rate of inflation.
CO2 prices	LEI assumes that the RGGI program will continue throughout the forecasted horizon in Maryland and Delaware. LEI assumes that a national carbon cap and trade program will be implemented starting in 2027. LEI uses an iterative approach to identify the "optimal" local carbon allowance price that allows a region to achieve EPA's emissions reduction target (to reduce CO2 emissions from existing fossil fuel-fired power plants in the US by 32% from 2005 levels by 2030) on a least cost basis.

4.1.1 Market topology

Presently, PJM is divided into 20 load/transmission zones in its market configuration (Figure 16). These zones consist of Allegheny Power Company, American Electric Power Co, Inc. ("AEP"), American Transmission System Inc., Atlantic Electric Company, Baltimore Gas and Electric Company, Commonwealth Edison ("ComEd"), Dayton Power and Light Company, Delmarva Power and Light, Dominion, Duke Energy Ohio and Kentucky, Duquesne Light, East Kentucky Public Cooperative, Jersey Central Power and Light Company, Metropolitan Edison Company, PECO Energy, Pennsylvania Electric Company, Potomac Electric Power, PPL Electric Utilities, Public Service Electric and Gas Company, and Rockland Electric Company.

PJM's energy market uses a nodal or LMP framework, where generators are paid based on their location, taking into account the marginal cost of energy, marginal cost of transmission congestion, and the value of marginal transmission losses. There are currently 11,464 nodes in the PJM energy market, related to over 3,000 operating power plant units. Wholesale energy prices are also reported on the basis of 20 separate load zones, which are used to settle wholesale load costs.

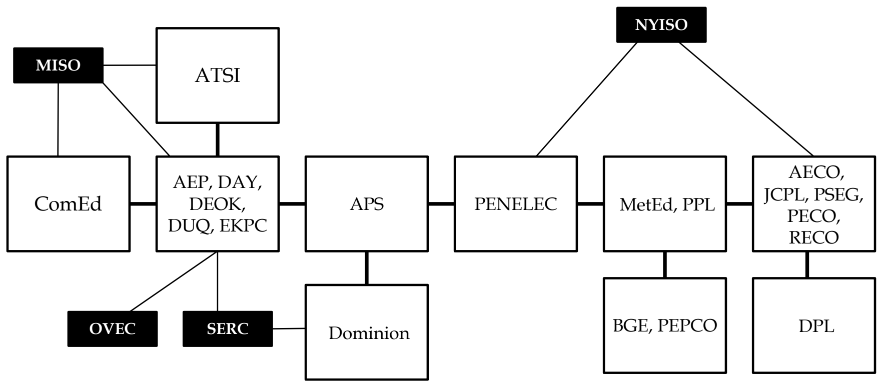
Figure 16. PJM footprint



Source: PJM 2017 Load Forecast Report

PJM is modeled as a ten-region market in POOLMod based on the historical transmission constraints and the level of congestion actually observed through historical market prices. These zones are grouped as shown in Figure 17 below.

Figure 17. Market topology



Source: Groupings of zones based on LEI analysis

4.1.2 Fuel price projections

In the near term, LEI has relied on the forwards for projecting delivered gas prices. LEI uses forward price data, only to the extent the forward hubs are liquid. For the first two years of the forecast period (2018 and 2019), LEI uses the 84-day[11] average forwards, as reported by OTC Global Holdings ("OTCGH"). From 2020 and onward, the delivered gas prices are based on fundamental analysis, using a reference point plus a transportation adder and local distribution charges.

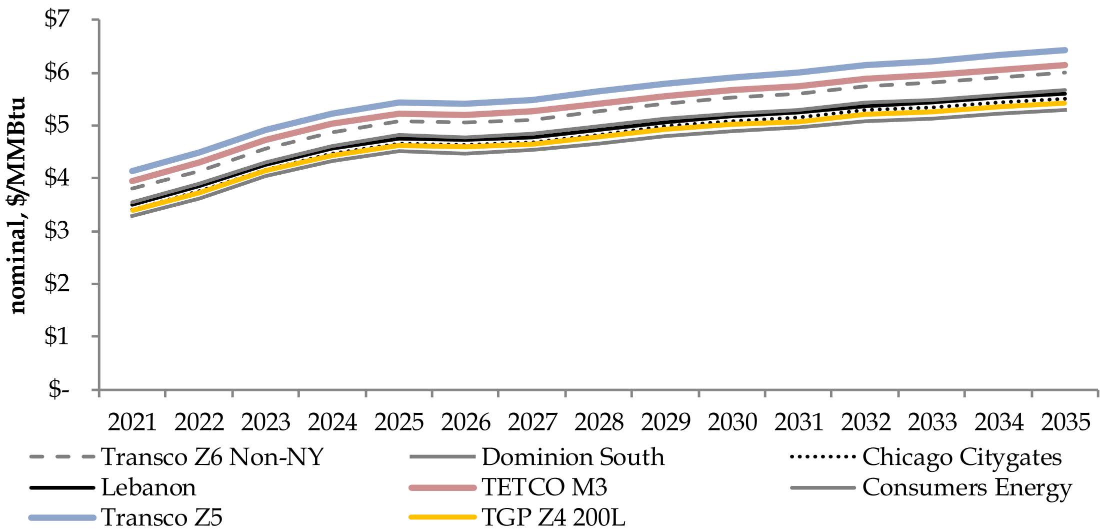
Traditionally, Henry Hub has been the reference point for the North American gas market. However, due to the relatively low-cost shale gas production from Marcellus and Utica, Dominion South is becoming an important source of supply to eastern hubs. LEI therefore chooses Dominion South as the reference point for PJM gas hubs. LEI expects the Dominion South price will increase and converge with Dawn Ontario as pipelines are built out of the Marcellus in 2018. Furthermore, Dawn Ontario and Henry Hub prices are not expected to diverge widely from one another; therefore, LEI increases the Dawn Ontario gas prices at the same rate as Henry Hub's, based on the 2017 U.S. Energy Information Administration Annual Energy Outlook ("EIA AEO"). The transportation adders are based on the differentials from the 2019 forwards between Dawn Ontario and relevant PJM gas hubs - until new pipelines are triggered.

LEI employs its proprietary gas forecast model, Levelized Cost of Pipeline ("LCOP") to forecast longer term trends in the transportation adder element. The LCOP Model evaluates 30 gas pricing hubs in North America, by tracking forward basis differentials with reference hubs and the levelized cost of building new pipeline(s) between each hub. The cost of pipeline capacity in the model relies on data collected from FERC on actual and proposed pipeline projects. In the long run, price spreads between two gas pricing hubs is assumed not to exceed the levelized cost of building a new pipeline between the two hubs. This levelized cost therefore effectively sets a long-term price cap on the transportation cost adder or basis differential between two pricing hubs.

[11] 84-day average forward prices as of April 1 to June 23, 2017.

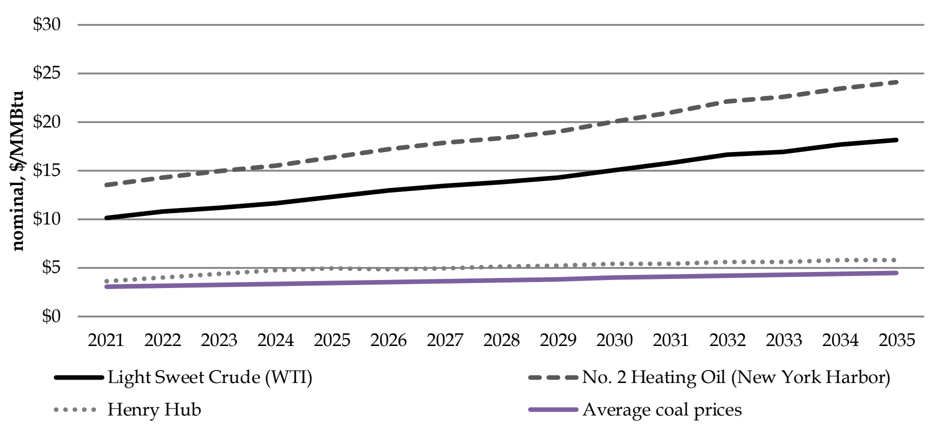
LEI uses eight (8) natural gas pricing points for PJM: (i) Chicago Citygates; (ii) Consumers Energy; (iii) Dominion South; (iv) Lebanon; (v) Tennessee Gas Pipeline Zone 4 200L; (vi) TETCO M3; (vii) Transco Z5; and (viii) Transco Z6 non-NY. The average delivered gas price in PJM is trading at more than a 9% premium to Dominion South from 2021 to 2035. Gas prices have also exhibited strong seasonal variations. Therefore, the historical five-year (2011-2015) seasonality of these gas pricing points is also taken into consideration in the forecasts.

Figure 18. Projected natural gas prices for delivery in PJM (nominal $/MMBtu)



Sources: OTCGH and 2017 EIA AEO

Figure 19. Fossil fuel price projections (nominal $/MMBtu)



Sources: OTCGH, Bloomberg, 2017 EIA AEO, third-party database provider (for coal)

Projected coal prices are unit-specific. Projected coal prices start at the actual 2016 delivered coal price then inflated by the growth rate of the coal plant supply region from the 2017 EIA AEO Report.

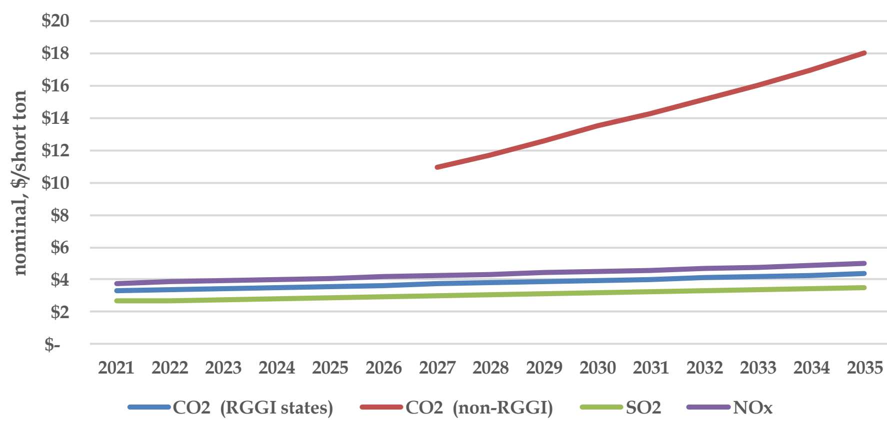
Projected distillate oil prices are based on NYMEX forward prices in the short term and are extrapolated based on the growth rate of 2017 EIA AEO's oil price forecast. The residual oil prices are based on a multi-year average of the ratio of residual and distillate oil prices.

4.1.3 Emission costs

The projected SO_2 and NO_x allowance prices are based on Bloomberg data for the short term and escalated over the long term at the assumed 2% rate of inflation. LEI assumes that the Regional

Greenhouse Gas Initiative ("RGGI") program will continue throughout the forecasted horizon in Maryland and Delaware. LEI further assumes that a regional carbon cap and trade program will be implemented starting in 2027.[12]

Figure 20. Emissions cost projections (nominal, $/short ton)



Sources: Bloomberg and LEI

LEI has adopted an iterative approach to identify the "optimal" local carbon allowance price that allows a region to achieve its emissions reduction targets on a least cost basis. LEI uses its proprietary network simulation model, POOLMod, to forecast future market outcomes under a "business as usual" scenario (i.e., no carbon). Next, LEI uses the simulation model with an assumed market-based allocation of carbon allowances to determine the "optimal" local carbon allowance price for each region. In LEI's analysis, carbon allowances are bought by resources that will value them the most (and need them the most).

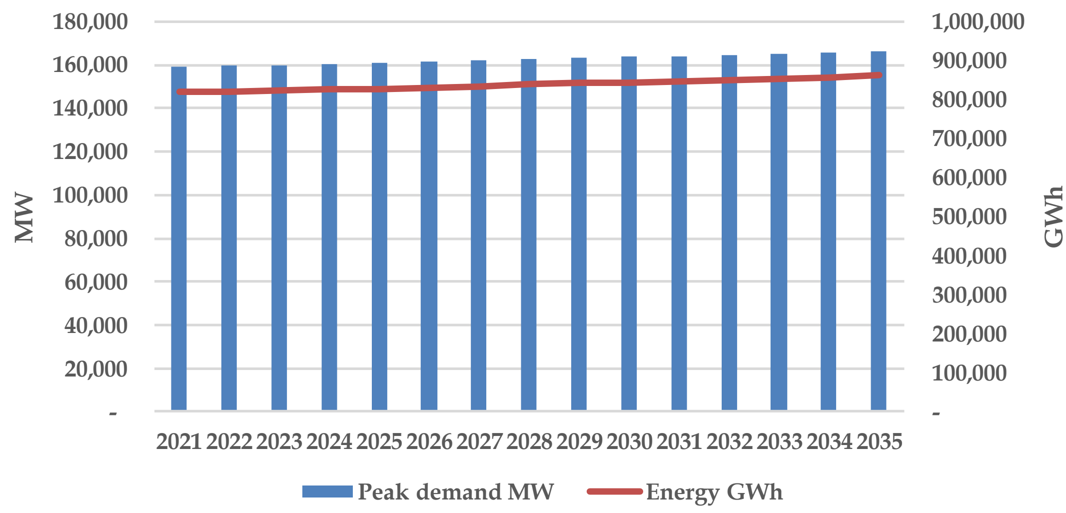
4.1.4 Demand

Historical hourly load data and projected load data for each zone by PJM are used to develop the load forecast for the modeling. The forecasted zonal load is directly taken from the 2017 PJM Load Forecast Report.[13] The summer peak load growth for the modeled PJM region is projected to average 0.2% per annum over the next fifteen years.

[12] Assumptions on carbon emissions price forecasts, implementation timing, as well as the compliance mechanism analyzed in this report, should be considered illustrative. No assumption provided by LEI on a potential carbon regulatory framework (regional) should be taken as a promise or guarantee of any such occurrence in the future. Moreover, LEI does not make any recommendations as to the timing and/or mechanism of the program or the expected carbon emissions prices.

[13] PJM. 2016 PJM Load Forecast Report. January 2016.

Figure 21. Forecasted peak demand in MW (2021-2035)



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Peak demand (MW)	159,509	159,570	159,647	160,220	160,836	161,555	162,006	162,577	163,285	163,729	164,257	164,749	165,242	165,752	166,255
Energy (GWh)	820,415	821,341	822,626	827,522	827,944	831,502	835,137	841,099	842,931	843,429	845,602	851,227	854,029	857,609	861,664

Source: 2017 PJM Load Forecast Report

4.1.5 Supply

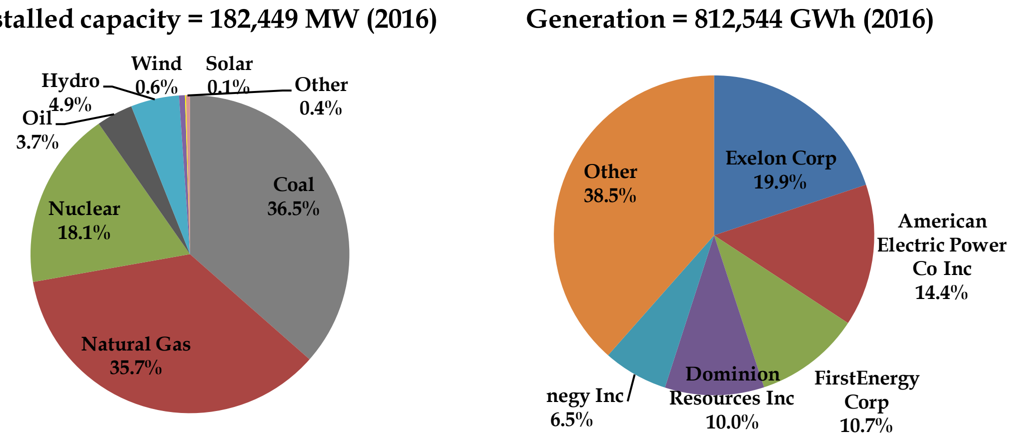
Existing supply

As of December 31, 2016, PJM had an installed generating capacity base of 182,449 MW.[14] PJM is dominated by baseload resources for generation with more than 70% and 60% of energy and capacity coming from coal and nuclear plants, respectively (Figure 22). Most of these coal-fired plants are located in the PJM Western region. Natural gas is the second most prevalent fuel - comprising 36% of the total installed capacity. LEI anticipates that the share of natural gas will increase in the next few years as a result of the increased availability of gas from Marcellus and Utica shale reserves and the retirement of coal plants (or conversion of coal plants to gas) due to changing economics of gas and coal generation and tighter environmental rules. The other fuels consist of oil (3.7%) and renewables (6.0%), which include wind, solar, biomass, and hydro plants.

The five biggest individual players in PJM in terms of capacity are Exelon Corporation, Dominion Resources Inc., American Electric Power AEP Company, NRG Energy Inc., and FirstEnergy Corporation as shown in Figure 23 below.

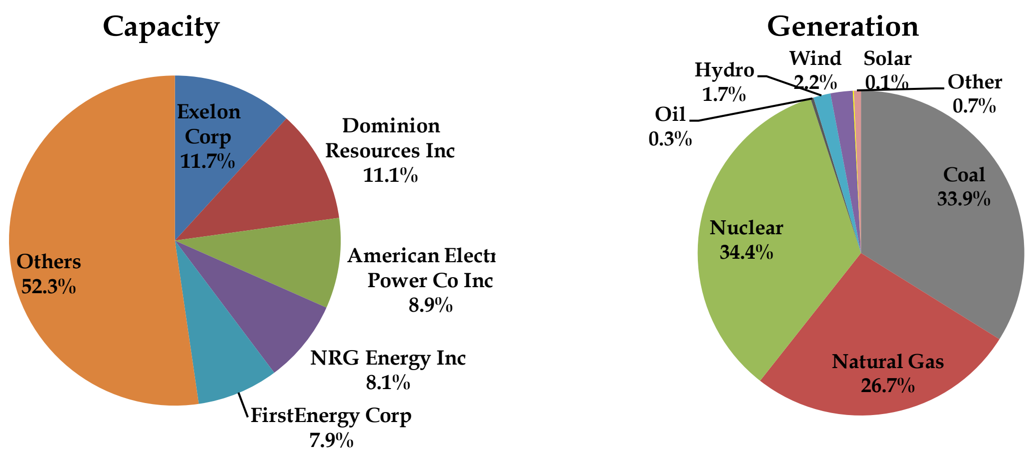
[14] Monitoring Analytics. State of the Market Report for PJM 2016. p. 3.

Figure 22. Installed capacity and generation by technology type



* Renewables include wind, solar, and biomass while other resources include batteries, hydrogen, etc.; wind and solar are not derated; installed capacity includes plants that are operating, standby, and restarted.
Source: State of the Market Report for PJM 2016

Figure 23. Installed capacity and generation by market player

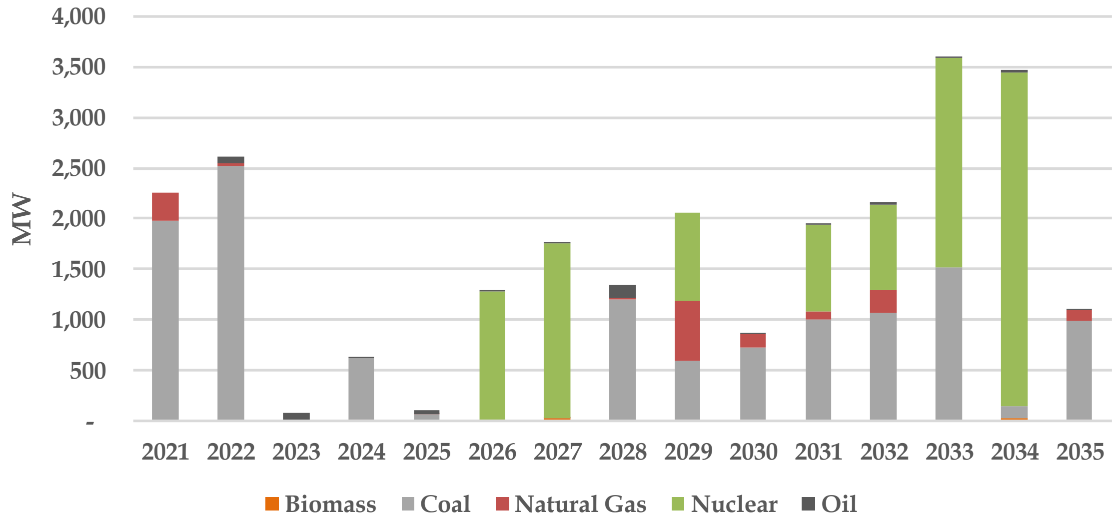


Source: Third party database provider (Accessed on March 2017)

Retirements

There will be over 25.3 GW of retirements between 2021 and 2035, including announced retirement included in PJM's deactivation list as of May 2017 and economic retirements. Over the modeling timeframe, LEI examines candidates for further retirement based on expected minimum going forward fixed costs of operation and projected market revenues. LEI uses a rational investor rule – if a plant cannot cover its minimum going forward fixed cost for more than three consecutive years, it is subject to retirement.

Figure 24. LEI modeled retirement (2021-2035)

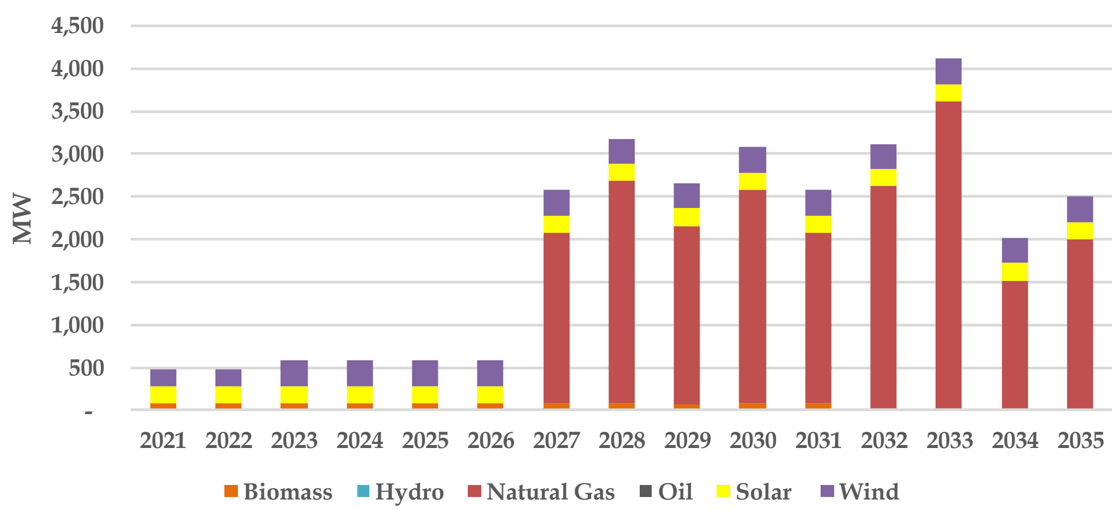


Sources: Third party database provider and independent LEI research

New entry

As a consequence of announced retirements and demand growth, LEI has added nearly 20.9 GW of new gas entry over modeling timeframe. In the short term, plants that are under construction or have received financing are included. In the long term, new entry is generally introduced based on economics (energy revenues and capacity payments needed to fully remunerate new generic Combined Cycle Gas Turbines ("CCGTs") consistent with the net CONE in the capacity market). In addition to the gas, approximately 8.2 GW of generic new renewables are added to the supply mix to meet state Renewable Portfolio Standard ("RPS") target.

Figure 25. LEI modeled new entry (2021-2035)



Note: Wind and solar are not derated in the chart above.

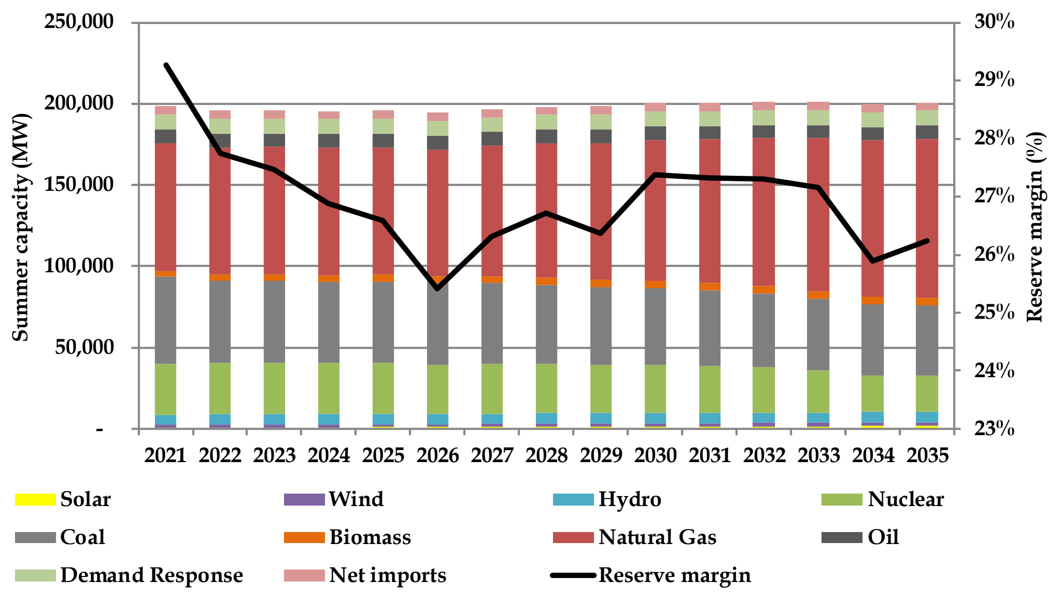
Sources: Third party database provider and independent LEI research

London Economics International LLC
717 Atlantic Ave, Suite 1A
Boston, MA 02111
www.londoneconomics.com

Supply-Demand balance

The capacity-based reserve margin is forecast to decline in the long term to 26% due to economic retirements. The calculation of the reserve margin includes Demand Responses ("DRs") and imports, as shown in Figure 26.

Figure 26. Region-wide forecasted capacity and reserve margins for PJM (MW)



Note: Wind is derated by 13% and solar is derated by 38% based on PJM Manual 21.

Source: LEI analysis and PJM 2017 Load Forecast Report

4.1.6 Interchange

PJM is interconnected with New York ("NY Independent System Operator or NYISO"), MISO, and the Southeastern Reliability Corporation ("SERC") and has been a net exporter of energy to its neighboring control areas. In our modeling, we evaluate each intertie, looking at historical patterns of import (export) and then consider how the market conditions in those neighboring markets will evolve.

PJM has been a net exporter to Upstate New York historically and we expect that this will continue into the future. PJM is also connected to New York Control Area (and specifically in the downstate New York City and Long Island zones) through the Neptune Underwater Transmission Line, Linden VFT line, and Hudson Transmission Partners. The Linden VFT facility is a bi-directional facility but power flows are anticipated to be only from PJM to New York per Schedule 16 of the PJM Open Access Transmission Tariff.[15]

---

[15] PJM. PJM Open Access Transmission Tariff. October 15, 2009.

<http://www.pjm.com/documents/~/media/documents/agreements/tariff.ashx>

PJM has also been a net energy exporter to MISO.[16] Energy flows on other existing interties between PJM and MISO would continue throughout the modeling timeframe. These energy flows are based on historical levels of hourly interchange, as metered and reported by the ISOs/RTOs. PJM is connected to MISO through ComEd and AEP and to SERC through AEP.

PJM is a net importer from SERC, which includes Louisville Gas and Electric Company, Tennessee Valley Authority ("TVA"), and Ohio Valley Electric Corporation.

LEI has modeled the imports and exports based on the review of the historical PJM Schedule Interchange Summary Report[17] as well as future market events. Figure 27 provides the net annual import or export used in the modeling throughout the forecast horizon.

Figure 27. Annual import and export targets (GWh)

Year	MISO Net Exports	SERC Net Imports	NYISO Net Exports	OVEC Net Exports
2018-2027	(8,659)	8,334	(8,244)	6,546

Sources: PJM Interchange Summary Report and LEI

4.1.7 Capacity market demand curve

PJM has had a centralized capacity market called the RPM since June 1, 2007. RPM involves a forward commitment (three years ahead) of supply which allows existing resources to participate and for new resources to plan for capital investment in advance. PJM has Locational Deliverability Areas ("LDAs") as well as locational capacity prices that are able to reflect the need for capacity in import constrained areas. RPM uses a downward sloping demand curve called the VRR curve that is anchored at the PJM-determined value of the Net CONE and that determines required reserve margins as a function of capacity prices.

Generally, existing generators submit offers in the RPM based on their Avoidable Cost Rate ("ACR") less historical energy and ancillary services revenues. The minimum going forward fixed costs used in the model are based on the latest ACR published by PJM. LEI assumes an inflation rate for the ACR based on the assumed inflation for each case. PJM has a Minimum Offer Price Rule ("MOPR") for new entrants (CCGT, combustion turbine ("CT"), and integrated gasification combined cycle ("IGCC") plants) where the MOPR floor is 100% of net CONE for the technology. Intermittent resources such as wind are usually price takers and are not subject to MOPR.[18]

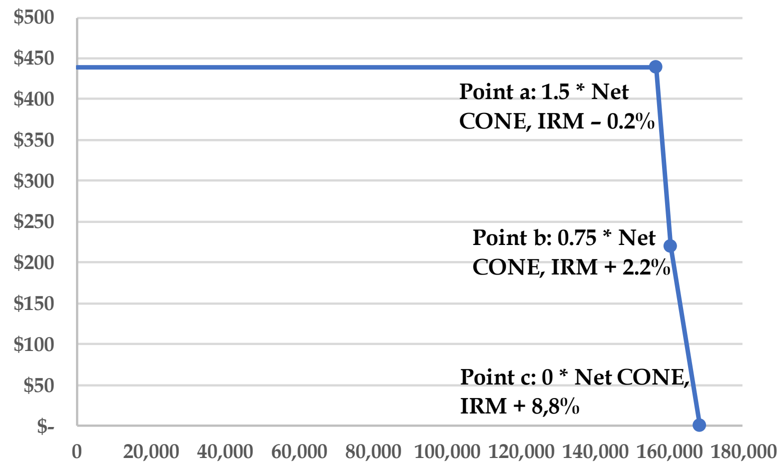
---

[16] The MISO control areas that import and export to the modeled PJM region include Alliant Energy East, Alliant Energy West, Ameren Illinois, Cinergy Corporation, Duke Energy, Indianapolis Power & Light, Michigan Electric Coordinated System, Northern Indiana Public Service, and Wisconsin Energy Corporation.

[17] PJM. *PJM Operational Analysis – Interchange*. <http://www.pjm.com/markets-and-operations/ops-analysis.aspx>

[18] PJM and its Independent Market Monitor have put forward proposals to extend MOPR to existing resources. However, the proposal is still under the review of PJM's stakeholders and has not filed with FERC. Therefore, LEI models capacity market based on the current market design.

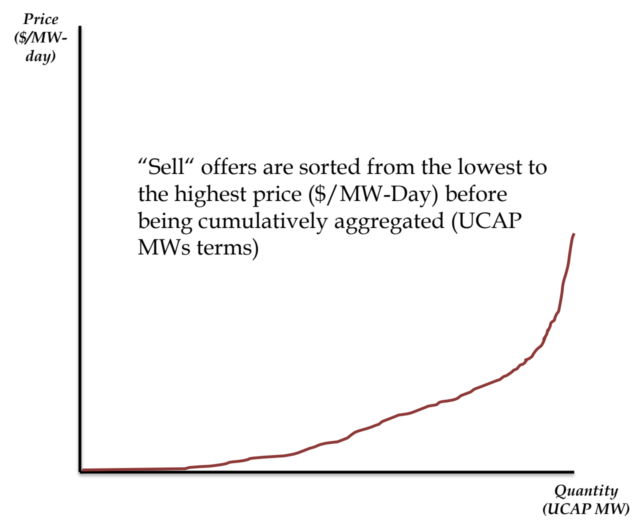
Figure 28. PJM's VRR for 2020/2021 Delivery Year



Sources: PJM 2020/2021 planning period parameters for Base Residual Auction

LEI then develops the supply stack. Capacity in the RPM is supplied on a UCAP basis, where the UCAP of a resource is defined as the resources installed capacity ("ICAP") adjusted for its equivalent demand forced outage rate ("EFORd"). In other words, UCAP equals the ICAP times (1-EFORd).[19] EFORd is a measurement of the probability that a particular unit will not be available for generation due to forced outages or derates when called upon to do so. LEI uses the five-year class average EFORd by fuel type issued by PJM. UCAP is set individually for each plant. Figure 29 provides a sample of the supply stack.

Figure 29. Supply stack



[19]PJM. "RPM for LSEs. "*PJM Website*." November 8, 2012. Available at http://www.pjm.com/~/media/training/core-curriculum/ip-lse-202/reliability-pricing-model.ashx

The capacity market bid price for new resources is based on Net CONE. Gross CONE is based on LEI's levelized CONE model, while energy revenues are based on the three-year average of the energy revenues prior to the auction. Energy revenues are plant-specific and come from the POOLMod run. Ancillary revenues are fixed at $2,199/MW-year and $3,198/MW-year for CTs and CCGTs, respectively, based on the PJM's Open Access Transmission Tariff ("OATT").

Bidding in the capacity market is based on the general principles of competition and economically rational behavior. Recognizing that LEI models a competitive market dynamic, the capacity market bid price is essentially truing up existing generators' profits so that they remain economically viable and avoid retirement.

4.2 Assumptions for the MISO wholesale electricity modeling

Figure 30. Summary of modeling assumptions for MISO wholesale electricity modeling

Assumption	Approach
Network Topology	MISO is modeled as 3 sub-regions (MISO North, MISO Central, and MISO South) based on MISO's topology
Load Growth	*2016 MISO Independent Load Forecast* results are used to project load till 2026. The average annual growth rate of 2023-2026 is applied to the demand from 2027 to 2035
Load Shape	Coincident hourly load profiles for each region are developed based on the 2011 load shape (a year with normal weather)
Existing Resources	Existing supply in MISO is based on a third-party commercial database and also with reference to utilities' news release for cross-checking
New Entry	First, plants that are under construction are included. Second, more renewable new entry is added to meet renewable portfolio standards set by state regulators. Third, generic gas units are added to meet MISO's reserve margin requirements in regions where they are economic
Retirements	LEI considers announced retirements in MISO as well as economic/ age retirements in the long run (fossil fuel plants that are more than 60 years are considered as aging plants; Economic retirements are applied to these aging plants, which checks whether they have enough market revenues to cover minimum going forward fixed costs)
Fuel Prices	Projected gas prices are based on LEI's proprietary Levelized Cost of Pipeline ("LCOP") model; Projected coal prices are unit-specific and are modeled based on the growth rate of the coal plant supply region from the *EIA 2017 AEO Report*; Distillate oil price forecasts are based on the NYMEX heating oil price forwards in the short run (years 2018 and 2019). In the mid to long term (beyond the horizon of NYMEX forwards), oil commodity index prices are escalated based on implied projected growth rates for crude oil from
Carbon Assumptions	LEI assumes that a regional carbon cap and trade program will be implemented starting in 2027. LEI uses an iterative approach to identify the "optimal" local carbon allowance price that allows a region to achieve emissions reduction target on a least cost basis
Interchange	Imports and exports between MISO and external regions are modeled based on historical hourly interchange data and adjusted according to season and hour

4.2.1 Market topology

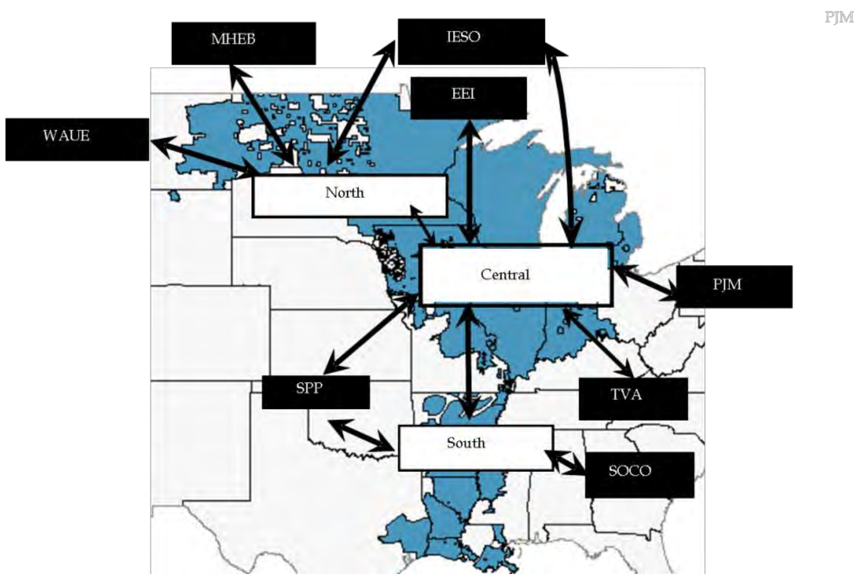
The Midcontinent ISO's footprint covers 36 Local Balancing Authorities ("LBAs") that are grouped within three zones or regions (North, Central, and South).[20] MISO is interconnected with eight reliability bodies: PJM Interconnection, Electric Energy Inc., the Independent Electricity

[20] MISO. "BA to Region Mapping."

System Operator of Ontario, the Southwest Power Pool ("SPP"), TVA, Western Area Power Administration Upper Great Plains East, Southern Company, and Manitoba Hydroelectric Board).

MISO's energy market uses a nodal (or LMP) framework, where generators are paid based on their location, taking into account the marginal cost of energy, marginal cost of transmission congestion, and the value of marginal transmission losses. There are currently about 380 pricing nodes in the MISO energy market, related to about 4,000 operating power plant units. Wholesale prices resulting from transactions at the seven hubs[21] are routinely reported by MISO.

Figure 31. Market topology



Sources: MISO BAs mapping and MISO Scheduled Interchanges Flows Summary reports.

The Midcontinent ISO is, overall, a net importer of energy from its neighboring markets. Figure 31 shows a simplified chart of MISO regions and their external interconnections.

4.2.2 Fuel price projections

The method to develop projections for fuel price is the same as PJM market. There are four (4) main natural gas pricing points considered in our modeling of the MISO region: (i) Northern Ventura; (ii) Chicago Citygates; (iii) Michigan Consolidated Citygates; and (iv) Carthage.[22] Gas prices have also exhibited strong seasonal variations. Hence, the historical five-year (2011-2015) seasonality of these gas pricing points is also taken into consideration in the forecasts. Projected

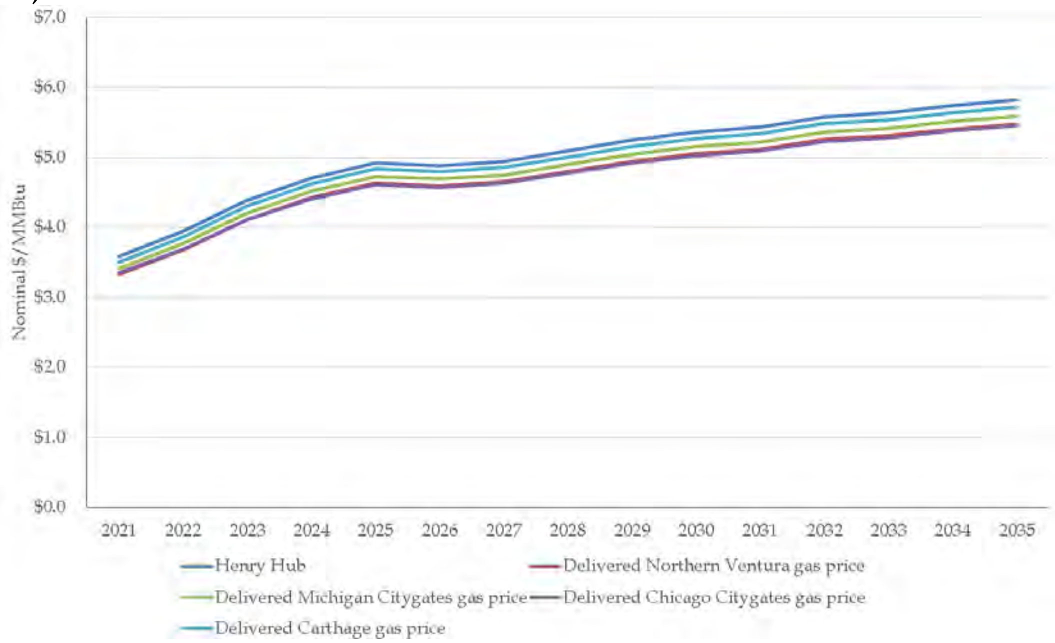
---

[21] Seven hubs include Minnesota Hub, Illinois Hub, Michigan Hub, Indiana Hub, Arkansas Hub, Louisiana Hub, and Texas Hub. Source: MISO Energy. LMP Contour Map and Table. Web. https://www.misoenergy.org/LMPContourMap/MISO_All.html

[22] According to the analysis, the gas pricing points serve the plants in the following zones: Northern Ventura – MISO North, Chicago Citygates - MISO Central, Michigan Consolidated Citygates – MISO Central (Michigan and Wisconsin), and Carthage – MISO South.

gas prices for the four relevant hubs are summarized in Figure 32. All of the four hubs are expected to trade on average at a discount to Henry Hub.

Figure 32. Projected delivered natural gas price at MISO's relevant four gas hubs (nominal $/MMBtu)



Sources: NYMEX; EIA AEO 2017.

Same as the modeling approach for the PJM market, oil prices are based on the *EIA's Annual Energy Outlook 2017* in the long-term, and plant specific coal price outlooks are used given the diversity in sourcing, quality, and sulphur content levels, etc.

4.2.3 Emission costs

Same as PJM, LEI assumes that a regional carbon cap and trade program will be implemented starting in 2027.[23] LEI has used an iterative approach to identify the "optimal" local carbon allowance price that allows a region to achieve its emissions reduction targets on a least cost basis. LEI uses its proprietary network simulation model, POOLMod, to forecast future market outcomes under a "business as usual" scenario (i.e., no carbon). Next, LEI uses the simulation model with an assumed market-based allocation of carbon allowances to determine the "optimal" local carbon allowance price for each region. In LEI's analysis, carbon allowances are bought by resources that will value them the most (and need them the most). Projected carbon allowance prices in MISO to achieve the regional carbon goal range from $1/ton to $3/ton from 2027 to 2033, and decrease to zero by 2034. Sustained coal retirement before the implementation of the

[23] Assumptions on carbon emissions price forecasts, implementation timing, as well as the compliance mechanism analyzed in this report, should be considered illustrative. No assumption provided by LEI on a potential carbon regulatory framework (regional) should be taken as a promise or guarantee of any such occurrence in the future. Moreover, in this report LEI does not make any recommendations as to the timing and/or mechanism of the program or the expected carbon emissions prices.

regional carbon cap and trade program is a major contributor to MISO's ability to comply with the regional carbon goal with low carbon prices.

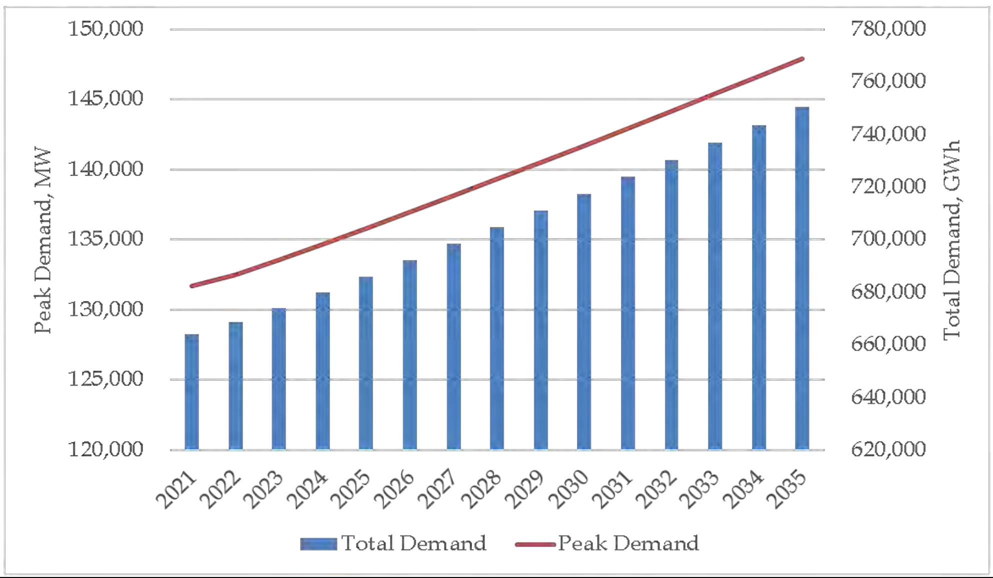
Figure 33. Carbon allowance prices forecast (nominal $/ton)

[$/ton]	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
Implicit carbon price	$2.00	$2.29	$2.62	$3.00	$3.00	$2.00	$1.00	$0.00	$0.00	$0.00	$0.00

4.2.4 Demand

LEI uses MISO's load forecast results for near term (until 2026) and takes the average annual growth rate of 2023-2026 to forecast the demand from 2027 to 2035. Coincident hourly load profiles for each region are developed based on the 2011 load shape (a year with normal weather), to which LEI applies regional forecasts of total energy usage and peak demand. Peak demand and consumption in MISO are both expected to increase at Compound Annual Growth Rate ("CAGR") of 0.9%.

Figure 34. Peak demand and total consumption forecast for MISO



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Peak Demand (MW)	128,264	129,099	130,125	131,264	132,359	133,548	134,712	135,887	137,073	138,271	139,480	140,702	141,935	143,180	144,438
Energy (GWh)	682,405	686,887	692,407	698,484	704,328	710,692	716,906	723,180	729,516	735,913	742,372	748,894	755,480	762,130	768,844

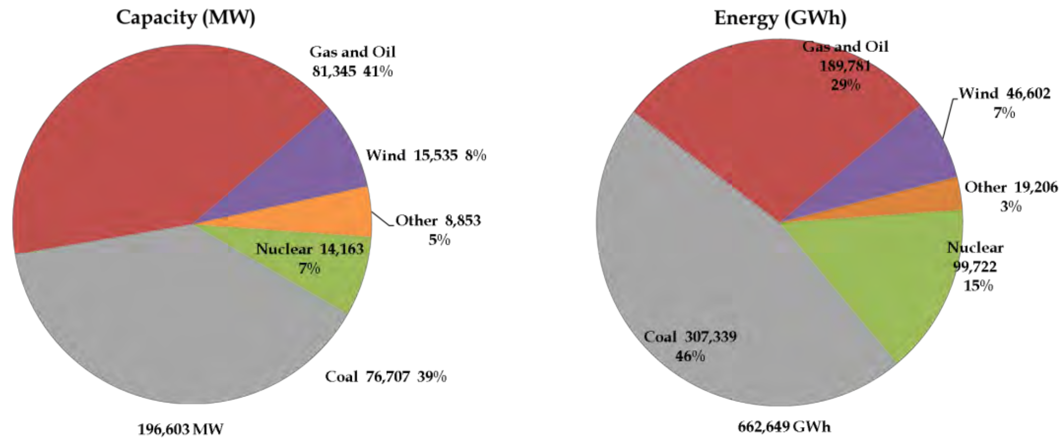
Source: MISO. 2016 Independent Load Forecast Results. LEI analysis.

4.2.5 Supply

Existing supply

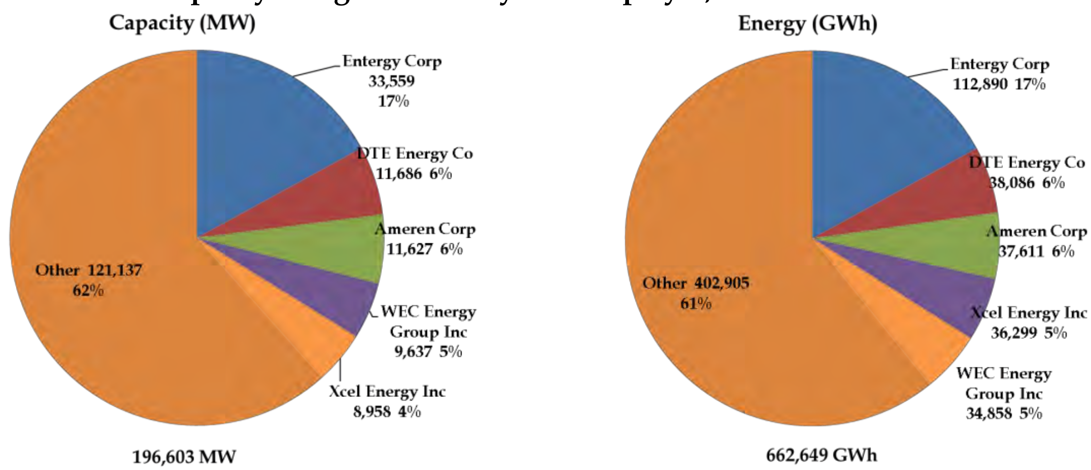
As of December 2016, MISO's fuel mix is dominated by coal and natural gas, each of the two fuel types making up about 40% of the installed capacity. The remainder of the fleet is split between nuclear, wind, and hydropower technologies. However, compared to the previous year, the share of coal in terms of both capacity and energy has declined. Gas is playing an increasingly important role in MISO, representing 40% of total installed capacity in MISO in 2016. Figure 35 and Figure 36 depict MISO's installed capacity and energy output by fuel types and major palyers, respectively.

Figure 35. Installed capacity and generation by technology type, 2016



Note: i) "Other" includes oil, hydro, biomass, and wood waste solids; ii) total generation only considers generation reported by operating plants. Small facilities do not fall under FERC reporting requirements; iii) installed capacity is composed of aggregate name plate capacity of all plants located within MISO's local balancing authorities.

Figure 36. Installed capacity and generation by market player, 2016



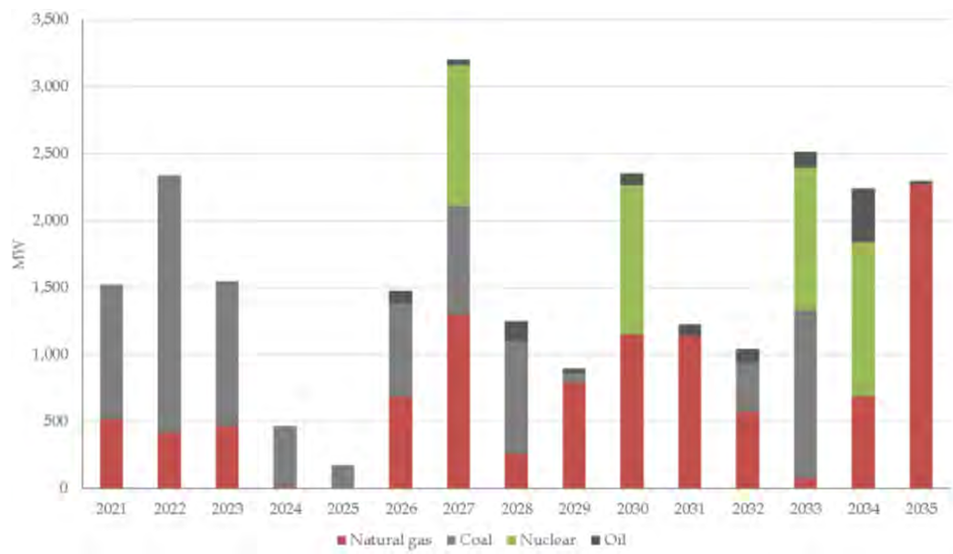
Note: Market players refer to plant operator's holding companies.
Sources: Third party database provider, EIA 860M, and EIA 923 (former EIA 906 and EIA 423)

The market shares by the five biggest market players in terms of installed capacity in MISO are relatively small; a handful of companies (including DTE Energy, Ameren, WEC Energy, and Xcel Energy) have market shares exceeding 4%. Entergy Corp has the highest share at 17%. Similarly, Entergy tops among utility holding companies in net generation in 2016, with other players each accounting for 5%-6% of total generation. LEI expects Entergy's share to decline as it plans to close the Palisades nuclear plant in Michigan in 2022.

Retirements

In addition to incorporating announced retirements, LEI has performed an economic analysis to consider retirements of fossil-fuel plants based on projected market economics. In LEI's analysis, there is over 24.5 GW of retirements between 2021 and 2035. Over the modeling timeframe, LEI examines candidates for retirement based on expected minimum going forward fixed costs of operation and projected market revenues, further supplemented with age analysis. First, LEI filters fossil-fuel plants that are over 60 years old, but still operating between 2021 and 2035. Second, LEI uses a rational investor rule – comparing the total revenue with minimum going forward fixed costs of these aging plants. Third, if the aging plant cannot cover its minimum going forward fixed cost for more than three consecutive years, it is subject to retirement. As a result, about 20 GW of coal, oil or gas plants have been retired due to uneconomic aging facilities. About 4.5 GW of nuclear units have been retired due to license expiration. Figure 36 below shows modeled retirements from 2021 to 2035.

Figure 37. Modeled retirements, MW



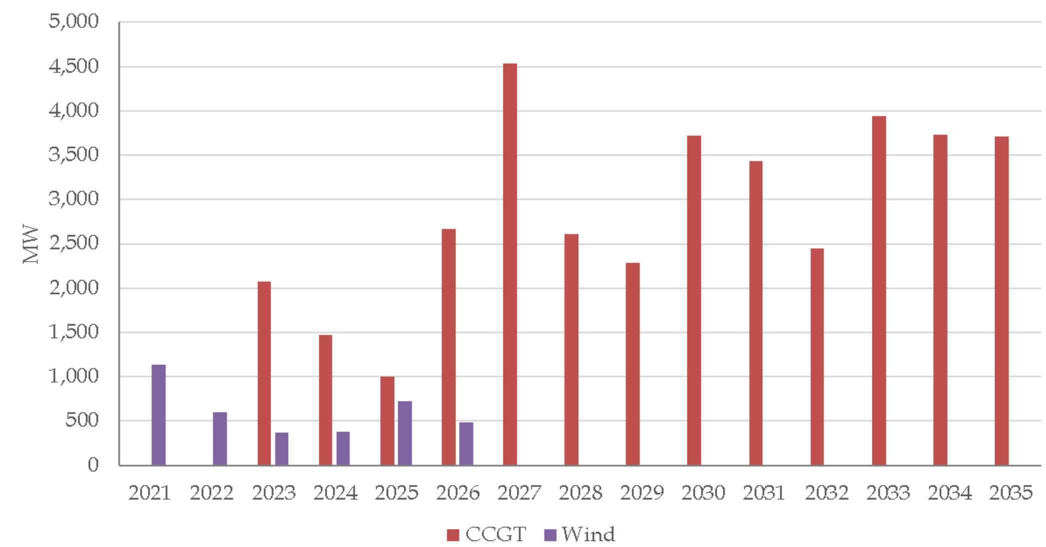
New Entry

As a consequence of announced retirements and demand growth, LEI has added nearly 37 GW of new CCGTs over modeling timeframe. New entry is generally introduced based on economics (energy revenues and capacity payments needed to fully remunerate new generic CCGTs consistent with the net CONE). New CCGTs are added to meet the local clearing requirement ("LCR") at zonal level. Additional CCGTs are added to meet the MISO system-level Planning Reserve Margin Requirement ("PRMR") and these CCGTs are located to zones where they are economic. In addition to the above entry, approximately 3.7 GW of generic new renewables[24] are introduced to meet the renewable portfolio standards set by state regulators. Modeled new entrants from 2021 to 2035 are summarized in the figure below.[25]

[24] Wind plants are added as opposed to solar because MISO region has some of the strongest, most consistent wind characteristics in the nation. *Source: MISO. Wind Integration. Web.* < *https://www.misoenergy.org/WhatWeDo/StrategicInitiatives/Pages/WindIntegration.aspx*>.

[25] There is no new wind added post-2027 because the existing renewable resources by 2027 are sufficient to meet renewable portfolio standards in each state, and CCGTs are more economic to meet reserve margins.

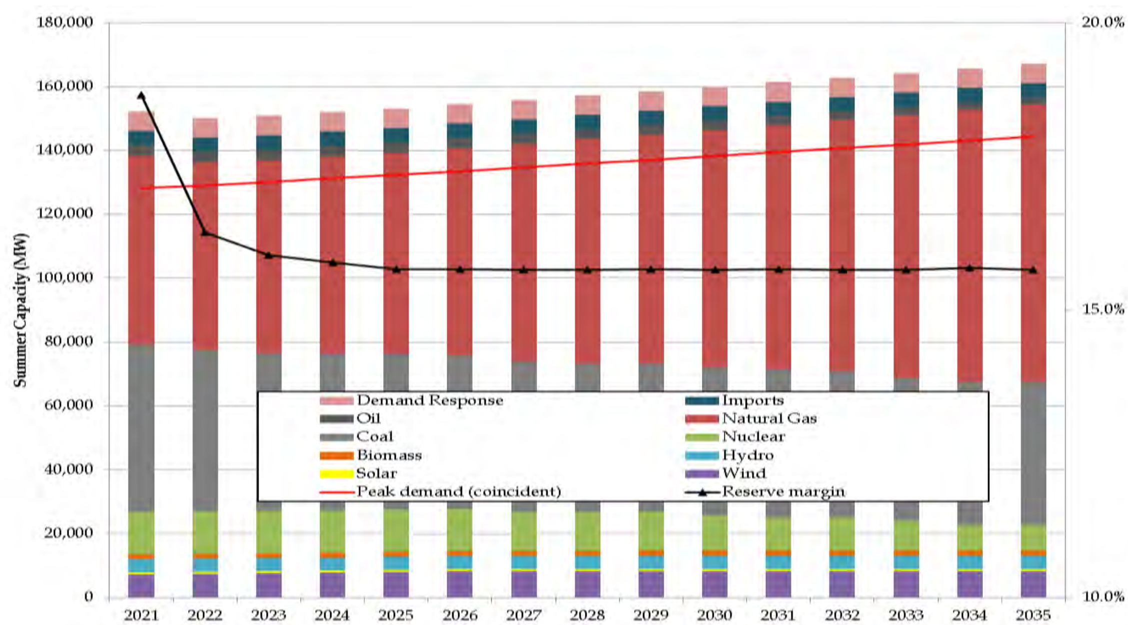
Figure 38. Modeled new entry, MW



Supply-Demand Balance

As a result of the modeled supply and demand, more gas-fired plants together with renewables will replace aging uneconomic coal plants to meet peak demand and reserve margin in the future.

Figure 39. Projected supply demand balance in MISO



4.2.6 Interchange

MISO has mainly been a net importer of energy from its neighboring markets in recent years. In LEI's modeling, net imports are modeled based on MISO's historical Net Scheduled Interchange

("NSI") for the most recent years available (2014-2016) for all interties, with the exception of flows between MISO and Ontario, and flows between MISO and PJM.

Figure 40. Modeled net imports, GWh

[GWh]	Net Import (GWh)							
	EEI	TVA	SWPP	SOCO	WAUE	MHEB	IESO	PJM
2014 - 2016 average	4,844	2,004	1,715	1,248	1,703	9,834	9,614	8,663

Note: Net imports were modeled in a static fashion for all regions except Ontario.

Net Imports from Ontario (GWh)										
Net Imports (GWh)	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
MISO	8,200	8,200	7,400	6,900	6,900	5,400	5,900	4,000	4,200	4,200

Sources: MISO 2014-2016 NSI, LEI, PJM Interchange Summary Report and Independent Electricity System Operator.

Assumptions on interchange flows between MISO and PJM are based on PJM's Interchange Summary Report,[26] while LEI relies on the Ontario Independent Electric System Operator's data for defining energy flows between MISO and Ontario.

Interchange flows are then refined for the rest of the modeling horizon based on the expected evolution of supply resources (in terms of quantity and fuel mix) in the MISO system and in neighboring regions. The decrease in Ontario's imports, highlighted in Figure 40, is largely driven by the retirement of nuclear units in the province.

4.2.7 Capacity market demand curve

As mentioned in Section 1.2, MISO's capacity market modeling is designed to operate according to the MISO PRA's existing rules (including a vertical demand curve), under the assumption that competitive bilateral markets converge to the outcomes that would result from a centralized auction market, and the impetus for participation is the recovery of investment costs.

4.3 Assumptions for local economic modeling

This section discusses in detail how the local economic benefits from the **Eastern Interconnect project** are captured and modeled through the REMI PI+ model, and what these benefits mean to local economies.

4.3.1 Topology

Construction period and operations period are studied separately because economic activities associated with these two periods are different in nature (See Figure 41). Specifically, during the construction period, construction activities and the related material and supporting services demand are the main driving force for local economic growth in the host state where the line is built. LEI models the construction period impacts in the host state, who directly benefits from the construction spending. During the operations period, electricity market savings and local spending due to increased income of workers and local residents are the dominating factors for local economic benefits in regions where electricity market benefits are observed. The benefits from electricity market savings are more wide-spread, and are captured through the PJM-MISO

[26] PJM. *PJM Operational Analysis – Interchange.* <http://www.pjm.com/markets-and-operations/ops-analysis.aspx>

regional model. Along with electricity cost savings comes also the socio-economic benefits of reduced carbon emissions. In the longer term, the study focuses on the reliability benefits brought by the transmission line.

Figure 41. Summary of modeled period, economic impact items, and affected regions for the Eastern Interconnect project

Modeling Period	Economic impact items	Modeled regions
Construction Period (2018 – 2020)	Construction spending	Host state of the transmission line
Medium-term Operations Period (2021 – 2035)	Electricity market cost savings, O&M spending, carbon emissions	MISO-Central region and the affected regions in PJM-West
Longer-term Operations Period	Reliability benefits	MISO-Central region and the affected regions in PJM-West

4.3.2 Assumptions for planning and constructions period

4.3.2.1 Project configuration

The **Eastern Interconnect project** is a bidirectional 345kv transmission line linking PJM's West zone to MISO's Central zone, aiming to relieve the congestions between the two zones. The transmission line has a maximum capacity of 1300 MW and is expected to be online in 2021. The project contains a double-circuit transmission line located in Indiana, two transformers at the PJM ends, and two substations at the MISO end.

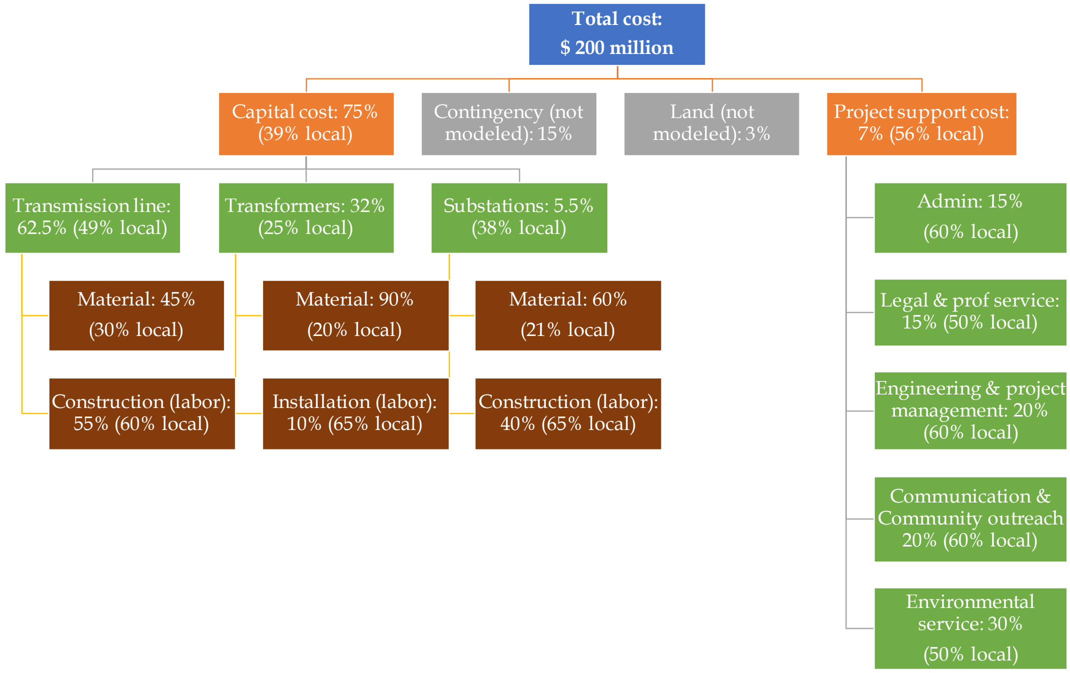
Figure 42. Configuration of the Eastern Interconnect project

Capital cost components	Trade-Enhancing Transmission Project
Total project cost	$200 million
Length of line (miles)	45
Number of transformers (765/345)	2
Number of substations (500kv)	2
Unit Capital cost - Transmission line	$2.1million/mile
Unit Capital cost - Transformers	$24 million/station
Unit Capital cost - Substation upgrades	$4.2 million/station
Construction period	2018 - 2020
Operations perid	2021- 2035

4.3.2.2 Project costs during construction period

The itemized cost allocation and local share assumptions are based on publicly-available studies along with LEI's professional judgement. Figure 43 below shows a high-level summary of the assumption for construction cost for the **Eastern Interconnect project**.

Figure 43. Cost allocation for the Eastern Interconnect project, construction period



- The total cost for the construction period related to the transmission infrastructure is $200 million, of which 75% is capital cost related (including construction material and labor costs), and 7% is spent on project support services (including costs related to administrative services, legal & professional services, engineering & project management, environmental services, communications support, etc.)
- 15% of the total cost is allocated to contingency, another 3% is allocated to land costs as a common industry practice (usually 5%-10% of total cost is related to land acquisition or lease, depending on the configuration and location of the project). LEI assumes that the majority of the project will use existing right-of-way ("ROW") in PJM and MISO, therefore the cost on land is relatively low. These costs are not included in REMI modeling for the sake of conservativeness. [27]
- Total costs are expected to be spread across three years of the construction period of 2018-2020, with capital costs allocated as 20%, 40%, and 40%, from Year 1 to Year 3 respectively. Project support services generally start from the planning period – three to four years earlier than the construction period. For the purpose of simplicity, LEI has rolled over the project support costs during the planning period to Year 1 of the construction period. Thereby, LEI assumes the project support costs to be allocated as 60%, 20%, and 20%, from Year 1 to Year 3.

[27] This is a routine approach, as the effect of such spending on land and contingency is not certain

- Transmission infrastructure related capital cost is further broken down for costs related to the construction of the transmission line (62.5%), the two transformers (32%) in MISO, and the upgrades of two substations (5.5%) in PJM.
- For the transmission line, the capital costs are broken down into material costs (45%) and construction costs/labor costs (55%). For the transformers, the capital costs are broken down into material costs (90%) and installation costs/labor costs (10%). For the substations, the capital costs are broken down into material costs (60%) and installation costs/labor costs (40%).
- 7% of the total project costs is allocated to project support costs, which includes administration, legal support, environmental study & compliance, engineering & project management etc.
- 39% of the total capital costs and 56% project support costs are expected to be spent in the modeled region (i.e. Indiana), which have direct impacts in the local economy and are used as the REMI model inputs. The rest of the capital cost and project support costs are spent in the rest of the country or rest of the world, due to imported materials and labor sourced from outside the modeled region, may also have spillover effects on the modeled region, but they are not included in the modeling as a conservative approach. Specifically, most of the construction and supporting labors (~65%) are assumed to be sourced from within the modeled regions, while LEI assumes only about 28% of the material costs to be sourced locally.

4.3.3 Assumptions for operations period

Local economic benefits during the medium-term operations period is primarily driven by electricity cost savings in the beneficiary regions. The electricity cost savings for residential, commercial, and industrial customers are estimated through the wholesale electricity modeling. The cost savings are modeled in the REMI PI+ model as electricity fuel cost reduction for the commercial and industrial sector consumers, and reduction in consumer price for electricity for residential consumers.

The project spending during the operations period is relatively small and simple comparing to the construction period. The total O&M costs for the first year is assumed to be 2.5% of the total capital cost for the construction of the project, and inflated by 2% for each year during the operations period. Major components of project operations spending include O&M labor spending (80%), of which 80% is spent locally, and O&M material and equipment spending (20%), of which 45% is spent locally.

4.3.4 Assumptions for measuring carbon emissions reduction impacts

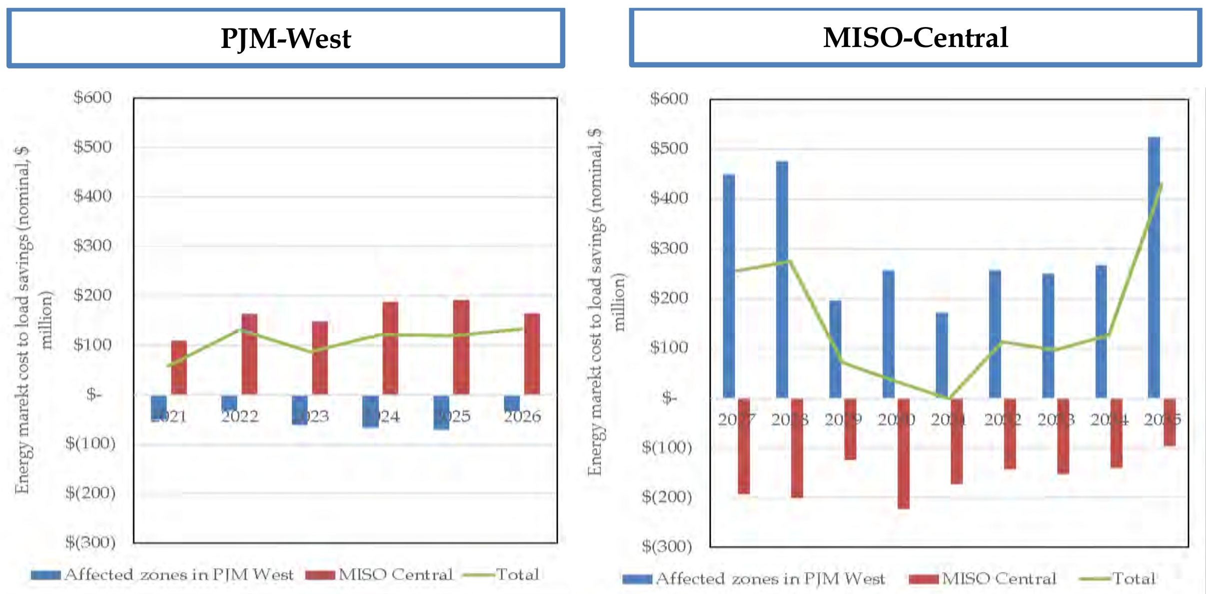
Achievements in reducing carbon emissions provide for a perception of an improved “quality of life” in the beneficiary regions, which attracts new workers and creates yet another boost to the local economy. Savings from avoided carbon emissions are monetized using the SCC concept (as described in Section 3.5), and are reflected in the REMI PI+ model through increased compensation for workers, which attracts new residents. These new residents will enrich the local labor pool and their work and consumption will then contribute to the local economy. Three scenarios with varying SCC values adopted by EPA are used in this analysis.

4.4 Modeling results for wholesale electricity market

4.4.1 Benefits to electric consumers

In early years, MISO consumers are projected to save $460 million in Net Present Value ("NPV") terms (in 2021) in the energy market, while in later years PJM consumers save $503 million in NPV (in 2021) terms in the energy market. From 2021 to 2026, affected zones in PJM West have a negative $52 million in energy cost to load savings on an annual average, but this can be offset by $161 million positive savings in MISO Central. Conversely, from 2027 to 2035, about $161 million per year energy dissaving in the MISO Central can be covered by the energy benefits of $316 million per year in affected zones in PJM West.

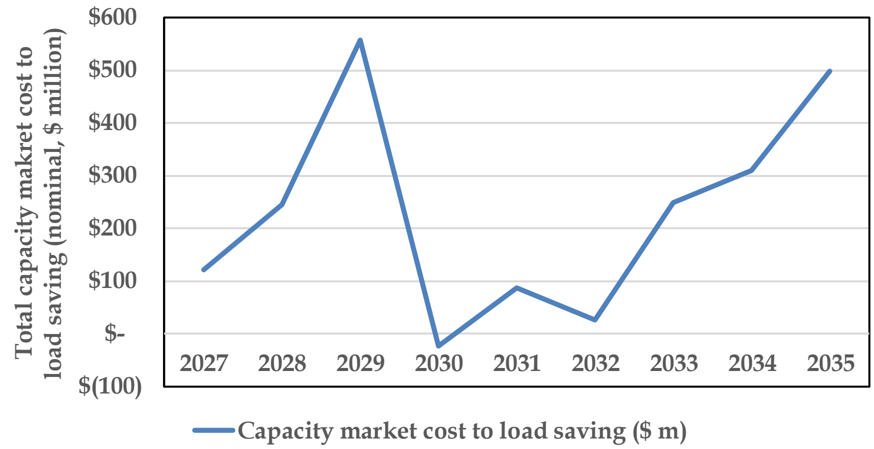
Figure 44. Energy market cost to load savings, 2021-2026 and 2027-2035



Note: Net present value is calculated assuming a 10% discount rate.

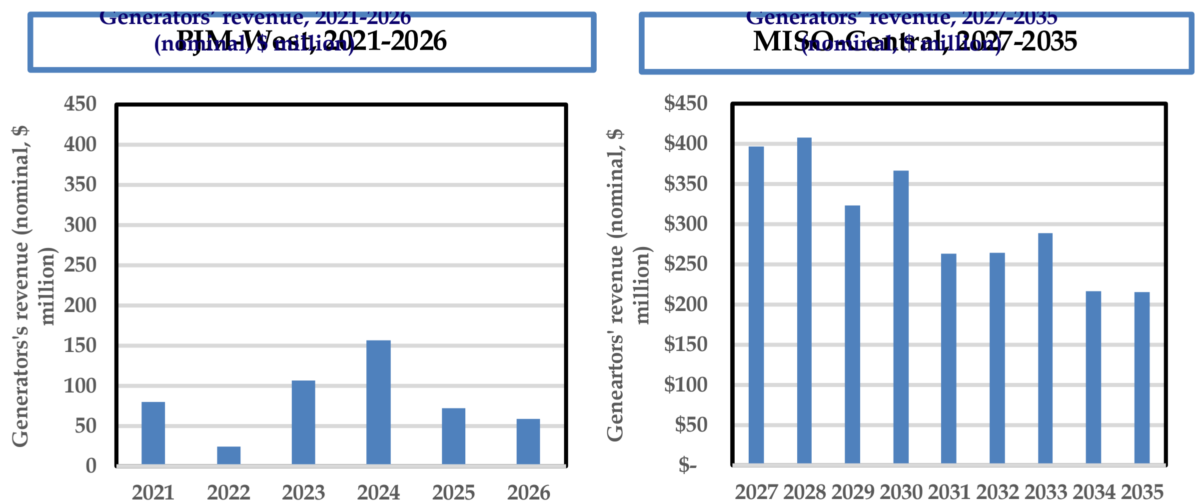
To complement to the energy flows, there is an opportunity for additional cost to load savings from capacity market sales on the new transmission line into the PJM market for the period between 2027 and 2035. Given the capacity prices in MISO and PJM in these years, there is a natural capacity market arbitrage opportunity to export capacity from MISO to PJM. LEI has simulated the impact of 1,200 MW imports into PJM's capacity market from 2027 to 2035. Relevant capacity market zones in MISO have surplus capacity relative to their requirements, so MISO does not see any material increase in capacity market prices from these exports. BRA prices in PJM RTO decline in 8 of the 9 years - in some years, by as much as $0.3/kW-month ($8.7/MW-day).

Figure 45. Capacity market cost to load savings, 2027-2035



4.4.2 Benefits to power generators

Figure 46. Generators' net revenues for the Regional Eastern Interconnect project

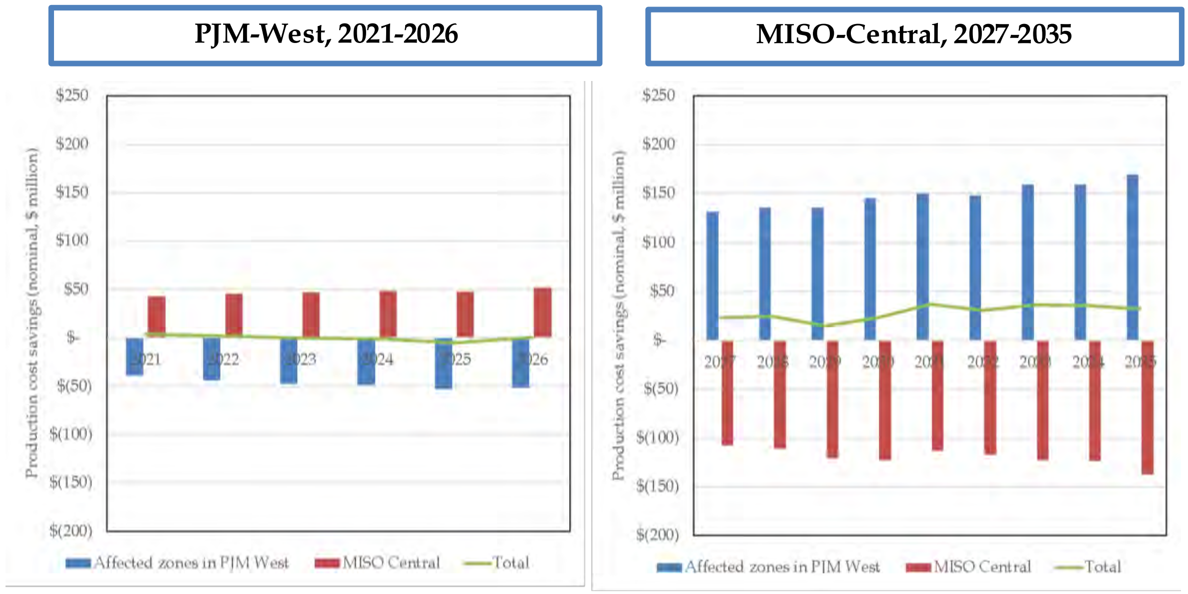


For the **Eastern Interconnect project**, during 2021 to 2026, PJM generators will see net revenues increase of $83 million (annual average) by exporting energy through the transmission line. That is equal to additional revenues of $376 per MW of installed capacity in the region or a 1% increase in revenues for generators in PJM. During 2027 to 2035, MISO generators exporting to PJM-West will see their net revenues increase by $305 million (annual average in both energy and capacity market) due to the new transmission project. That is equal to additional revenues of $1,954 per MW of installed capacity in the region or a 3% increase in revenues for generators in MISO.

4.4.3 Efficiency improvements in production of energy (or production cost savings)

In terms of production cost savings, the net benefits in the early years average $1 million (2021-2026) in NPV terms and as much as $89 million in the later years (2027-2035) in NPV terms. From 2021 to 2026, the production cost savings in MISO Central are very close to dissaving in affected zones in PJM West on annual average. However, after 2027, production cost savings in affected zones in PJM West are significant – about a net saving of $29 million on average every year.

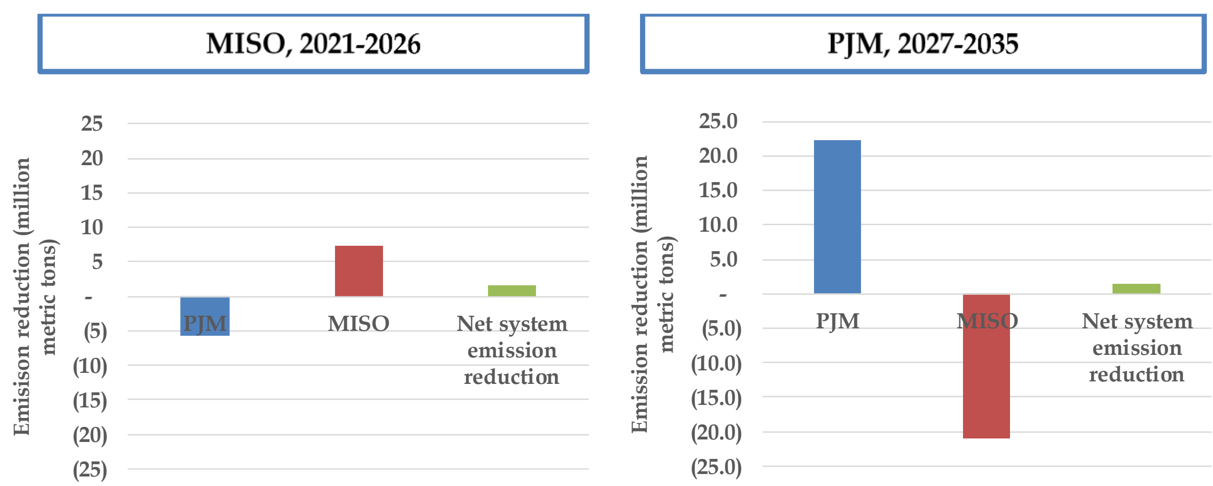
Figure 47. Production cost savings, 2021-2026 and 2027-2035



4.4.4 Benefits on the environment

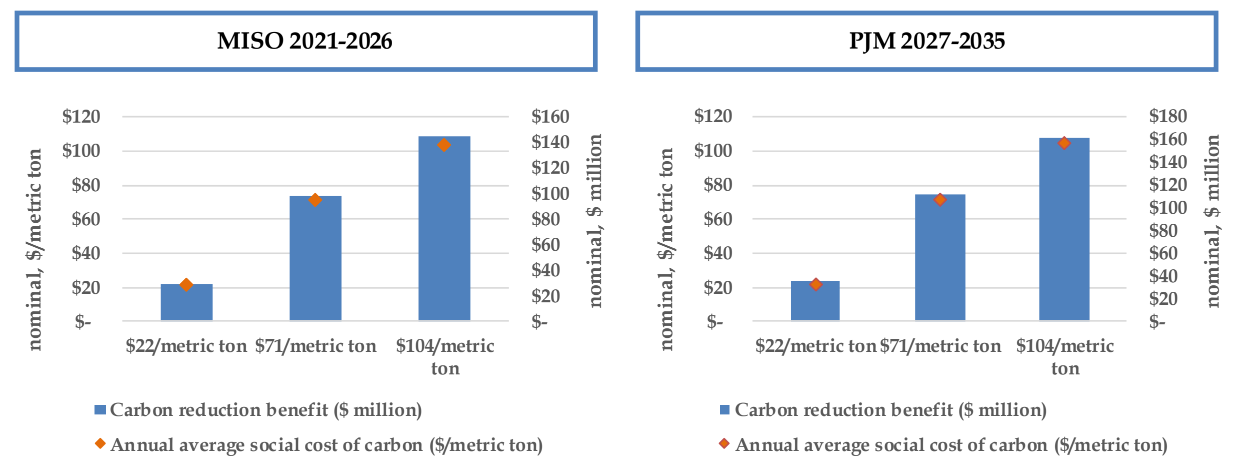
The new transmission line reduces carbon emissions (across PJM and MISO) by about 3.2 million metric tons cumulatively over the 2021-2035 period. From 2021 to 2026, MISO will see more than 8 million metric tons of carbon emission reduction, but about 6 million will be offset by carbon emission increase in PJM. Thus, this will result in about 1.7 million metric tons of total carbon emission reduction in early years. While from 2027 to 2035, more than 24 metric tons of carbon emission reduction cumulatively in PJM West can cover increased emission of 23 million metric tons in MISO. As a result, there will be about 1.5 million metric tons of carbon emission reduction in later years.

Figure 48. Carbon emission reduction, 2021-2026 and 2027-2035



Moreover, the reduction in carbon emissions can be translated into carbon reduction benefit[28] in dollars when social cost of carbon is applied. 1.7 million metric tons of CO_2 emissions reductions between 2021 and 2026 can save the affected MISO regions $30 million to $150 million by avoiding damages from climate change while 1.5 million metric tons of CO_2 emissions reductions between 2027 and 2035 can also save the affected PJM regions $32 million to $150 million by avoiding damages from climate change, depends on the levels of estimated social cost of carbon are applied.

Figure 49. Carbon reduction benefit, 2021-2026



4.4.5 Reliability benefits

LEI simulates system conditions in each market from a major power plant outage in order to evaluate the long run system reliability attributes of the new transmission line. LEI compares the savings from a blackout and energy cost to load of the case with nuclear outage both with and without the transmission line and assumes 1,300 MW maximum flow in PJM/MISO in the year of the nuclear outage. For PJM, LEI models a representative year 2027. The one-year energy cost to load savings for the affected zones in PJM West is $1,300 million in 2027. The annual average energy cost-to-load savings are calculated by multiplying the reduction in energy prices of $3.3/MWh from the world with transmission investment with the annual consumption of 394,634 GWh of the affected zones in PJM West. The savings for eliminating an unexpected costly blackout is $477 million. It is calculated using the estimated magnitude of unserved load (26,822 MWh) and multiplied by the Value of Lost Load ($16,672/MWh).

Similarly, MISO also sees significant reliability benefits and energy cost-to-load savings associated with a major outage event. LEI has modeled 2030 as a representative year. The one-year energy cost to load savings for MISO Central is $740 million in 2030. It is calculated by multiplying the reduction in energy prices of $2/MWh from the world with transmission investment with the annual generation of 393,005 GWh of affected zones in MISO-Central. The savings for eliminating the economic loss of an unexpected blackout is $546 million. It is

[28] 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.

calculated using the estimated magnitude of unserved load (42,256 MWh) and multiplied by the Value of Lost Load ($12,926/MWh).

Figure 50. Consumer savings from major generation outage of the Eastern Interconnect project

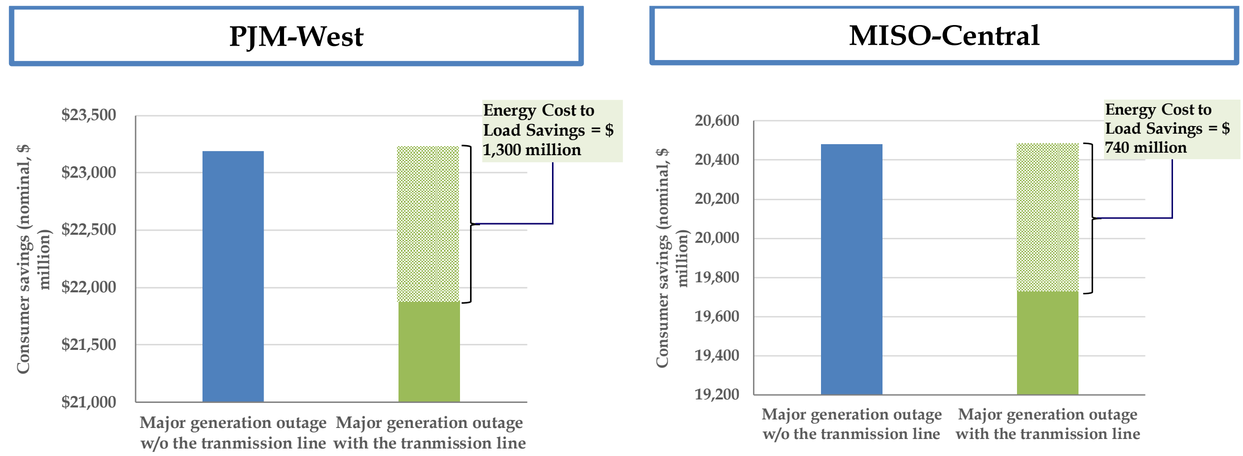


Figure 51. Savings from costly blackouts of the Eastern Interconnect project

Region	Value of Lost Load (VoLL) =	x	Energy Unserved	=	Avoided expected economic loss
Affected zones in PJM West	$16,672/MWh	x	26,822 MWh	=	$477 million
MISO Central	$12,926/MWh	x	42,256 MWh	=	$546 million

4.5 Modeling results for local economic modeling

The **Eastern Interconnect project** will impact the local economy in the host state (LEI assumes, for the purposes of the modeling, that the host state is Indiana, which lies in both PJM and MISO) through direct construction spending in the short term. During the medium-term operations period, the project will boost the local economies in the affected areas in the MISO Central region and PJM West region through electricity cost savings. Over the longer-term, the project will also benefit the PJM and MISO regions through enhanced reliability on the grid. Figure 52 and Figure 53 provide a summary for the short-term and medium-term local economic benefits brought about by the **Eastern Interconnect project**. Long-term reliability benefits are discussed in Section 4.4.5

Figure 52. New jobs created by the Eastern Interconnect project, construction and medium-term operations periods

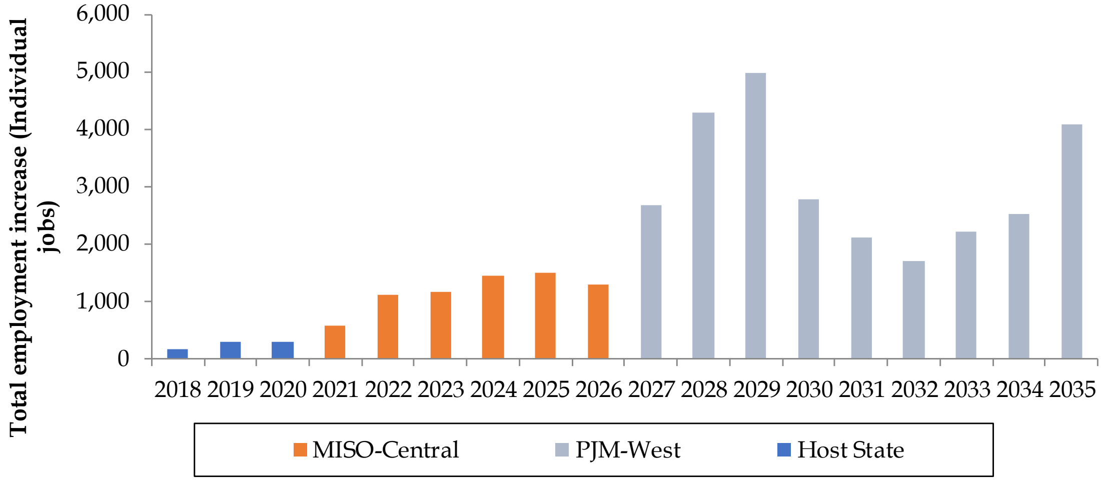
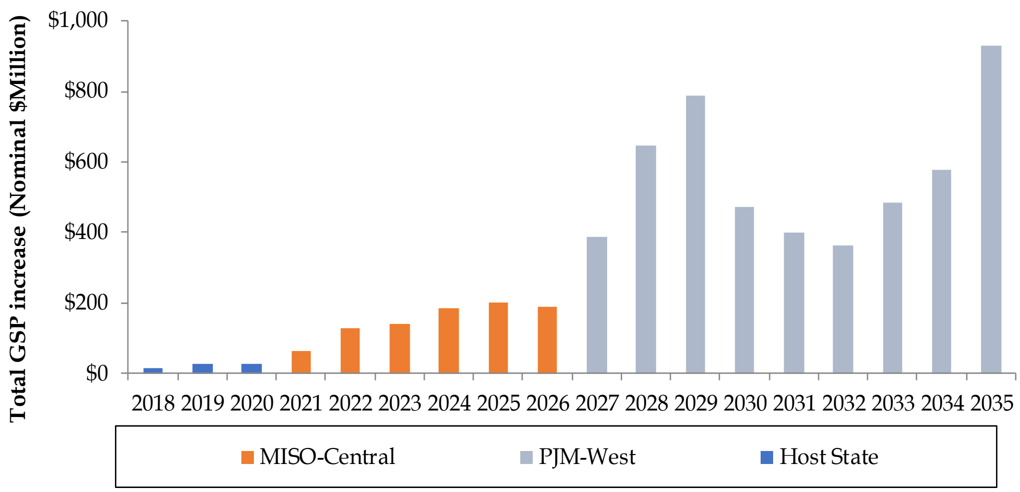


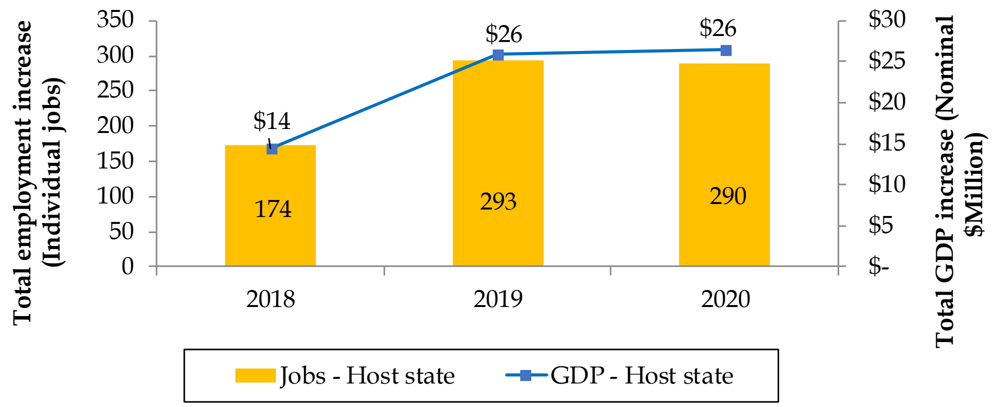
Figure 53. GDP increase due to the Eastern Interconnect project, construction and medium-term operations periods



4.5.1 Short-term impacts

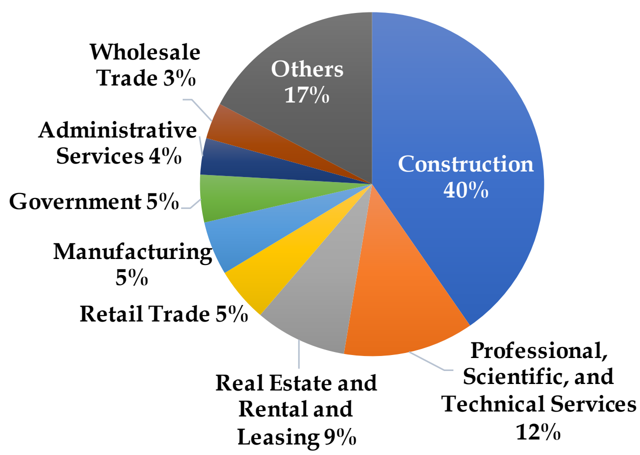
The **Eastern Interconnect project**, although a smaller scale investment and situated in a smaller geographic footprint, also generates notable economic benefits to the host state. During the peak years for construction activities, the local GDP increased by an average of $26 million and local jobs increased by nearly 300 per year in the host state for the $200 million **Eastern Interconnect project** (see Figure 54).

Figure 54. Increase in host state's local economy and employment during construction of the Eastern Interconnect project



The construction sector, and the professional, scientific, and technical services sectors benefit the most from the transmission investment during this period, as they provide the materials and laborers needed for the various construction activities (see Figure 55).[29] Other sectors will also see economic benefits by supplying supporting goods and services to the construction activities, or as a result of increased local spending from workers who are hired to construct the project.

Figure 55. Local economy boost (GDP increase) by sector during construction of the Eastern Interconnect projects in the host state



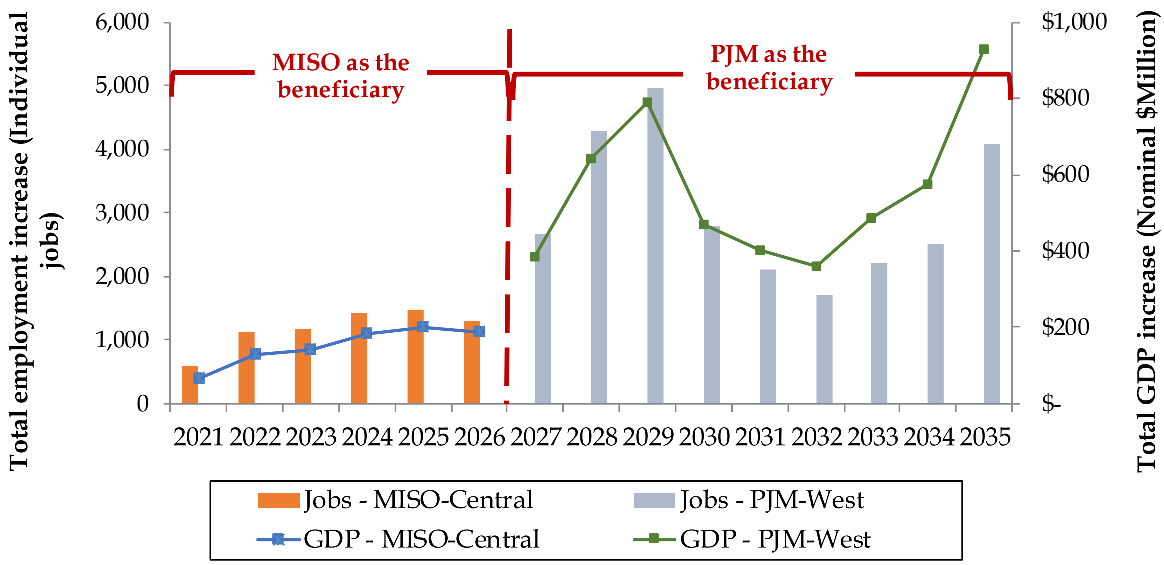
[29] The magnitude of changes in economic output (and GDP) of each sector is primarily determined by the relative size of that sector to the entire (local) economy, as well as personal consumption and investment activities.

4.5.2 Medium-term impacts

4.5.2.1 Impacts from electricity cost savings and O&M spending

During the medium-term operations period, local economic benefits are primarily driven by electricity cost savings. O&M spending on labor and materials also contribute to a small portion of the total benefits. During 2021-2026, the MISO-Central region is the beneficiary of the electricity cost savings from the inter-regional trade. PJM becomes the beneficiary during 2027-2035.

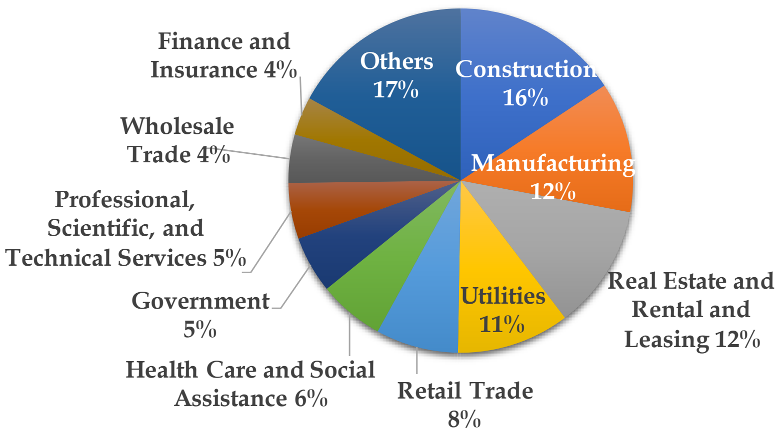
Figure 56. Increase in MISO and PJM's local economy and employment during the first 15 years of operations of the Eastern Interconnect project



The **Eastern Interconnect project** is expected to bring job increases of 1,184 per year and a GDP increase by $152 million per year in the MISO-Central region during 2021-2026. During 2027- 2035, 3,036 new jobs are created, and the GDP increases by an average of $561 million per year in the PJM West region. The economic benefits in each year are primarily determined by the magnitude of electricity market benefits in that region for that year. The PJM-West region overall sees higher GDP increases and job creation relative to the MISO-Central region, because it receives more substantive electricity market savings. The temporary drop in economic benefit increase during 2030 and 2034 is also caused by decrease in electricity market savings in these years (see Figure 56)

Electricity cost savings cover virtually all sectors of the economy proportional to their use of electricity (see Figure 57). The construction, manufacturing, and real estate sectors represent the biggest GDP increases – over 40% increase are seen in these three sectors for both projects. This is because these sectors are accountable for a relative large share of the local economy and personal consumption and investment activities, and their output depends relatively heavily on the electricity supply.

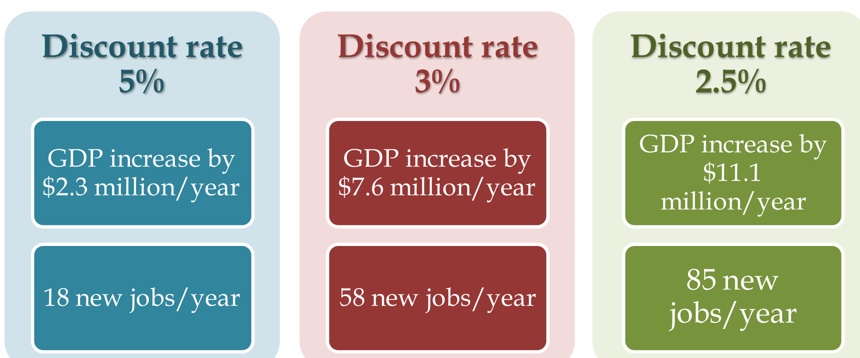
Figure 57. Local economy boost (GDP increase) by sector during medium-term operations of the Eastern Interconnect project in the host state



4.5.2.2 Impacts from carbon emissions reduction

The affected regions in MISO-Central and PJM-West are expected to see the influx of new workers because of the projected decarbonization achievements associated with the new transmission project. The societal benefits of carbon emissions reductions will translate into $2.3 million to as much as $11.1 million increase in GDP per year in affected regions, based on the three SCC scenarios used in estimating the avoided social cost (see Figure 58).

Figure 58. Socio-economic boost by reducing carbon emissions in the affected PJM-West and MISO-Central regions



5 Modeling assumptions and results for the hypothetical Western Interconnect project

The Resource Delivery Transmission Project in the Western Interconnect (referred to as the "**Western Interconnect project**") represents a transmission investment that brings energy from remotely-located resources to load centers. Such a transmission project would be another example of "trade" because it creates a bridge between suppliers and consumers, culminating in a mutually beneficial outcome.[30]

The **Western Interconnect project** is assumed to deliver wind-based energy from the Rocky Mountain area of the Western Electricity Coordinating Council ("WECC") to load centers of southern California, using an approximately 700-mile new transmission line passing through multiple states. In contrast to the **Eastern Interconnect project**, this project includes the development of new generation in conjunction with the new transmission line. The electric consumers in southern California would benefit from lower electricity costs, while the generators and residents in or near the remote resource location can also benefit from higher revenues (for those new wind generators) and more job opportunities (for residents in the states along the Rocky Mountain area).

[30] LEI's analysis considers economic impacts on both the delivery side and the receiving side. Specifically, the local generation investment displacement in the receiving state, i.e., California, due to new imports from the Rocky Mountain area is included.

5.1 Assumptions for the California wholesale electricity modeling for the Western Interconnect project

Figure 59. Summary of modeling assumptions for California wholesale electricity modeling

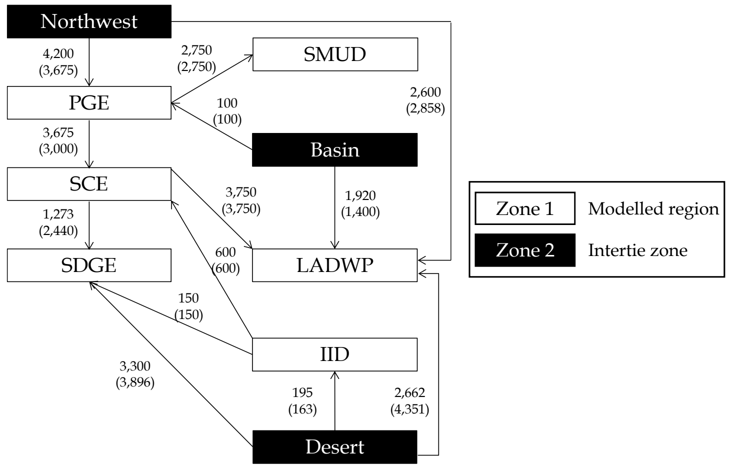
Assumption	Approach
Topology	California is modeled into 6 zones based on historical transmission constraints
Load Growth	Consists of hourly load data for each zone for the duration of the analysis period based on 2016-2026 California Energy Commission Revised Electricity Demand Forecast (issued in January 2016). Post 2026, it is modelled to grow at the previous three year's rolling average rate
Load Shape	Coincident hourly load profiles for each region are based on CAISO's 2016 load shape
Esisting Resources	Existing supply in California is based on a third-party commercial database provider and also reference to the CEC supply data. Hydroelectric generation is based on 10-year average historical hydrology levels
New Entry	First, plants that are under construction or have been awarded PPAs (through RFOs) are included; second, more capacity is added, if necessary to meet certain state policies, specifically, generic renewables are also added to achieve California's renewable portfolio standards ("RPS") target of 50% by 2030. Generic energy storage is also added to reflect the achievement of the 1.3 GW target by 2020.
Retirements	LEI considers announced retirements in California as well as economic retirements in the long run (economic retirements will be driven by competition from new resources and viability of market revenues to cover minimum going forward fixed costs as most resources, once they come off PPA, will have to rely on market revenues alone)
Fuel Prices	Gas prices for PG&E City Gate and SoCal Border are calculated using LEI's LCOP gas model
Carbon Assumptions	The starting carbon emissions price projection is based on the California carbon allowance auction reserve floor price escalated at 5% plus inflation in line with the program-defined rules
Interchange	Imports and exports between the California and other WECC states are modeled based on historical hourly interchange data. Going forward, some of the resources supporting imports may retire and therefore LEI made adjustments over time to the interchange assumptions to accommodate such changes. LEI is also expecting that imports from other resources type will increase to meet CA's 50% RPS target by 2030, subject to transmission capacity availability

5.1.1 Market topology

The California electricity market is modeled as six zones with current interties to the Northwest, the Basin states, and the Desert region of WECC, as shown in Figure 60.[31] The primary transmission constraint is between Pacific Gas and Electric Company ("PG&E") and Southern California Edison ("SCE"), with very little west-east congestion.

[31] The Northwest states include Oregon, Washington and Montana. The Basin states refer to Idaho, Utah and Northern Nevada. The Desert states refer to Arizona, New Mexico and Southern Nevada.

Figure 60. Regional transmission interface limits (MW)



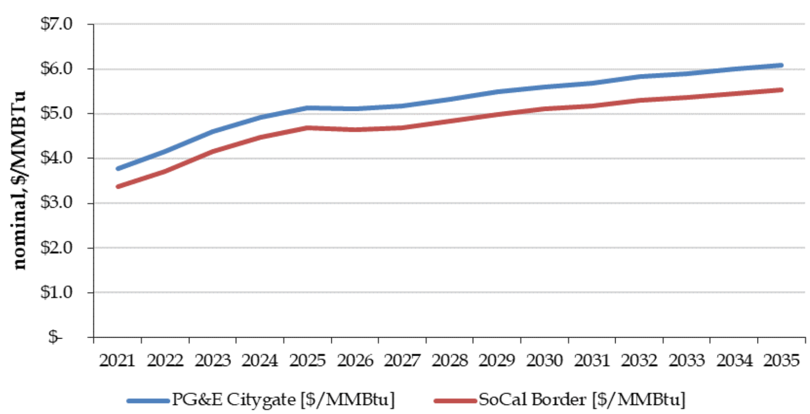
Source: LEI Analysis based on WECC 2015 Power Supply Assessment, page 20. Number on top shows the limit in the direction of the arrow, while those in parentheses on the bottom show the limit in the reverse direction.

California relies heavily on out-of-state generation. LEI models in excess of 11,000 MW of intertie capacity. Although an interconnection between California and Mexico exists, it has historically been used only in emergency situations and is thus not incorporated into the model.

5.1.2 Fuel price projections

The method to develop modeled fuel price is the same as MISO and PJM markets. For the California market, the primary gas pricing points include: (1) PG&E ("North"): PG&E Citygate; and (2) SCE, SDGE ("South"): SoCal Border.

Figure 61. Natural gas price projections (nominal $/MMBtu)



Source: 2017 EIA AEO

As shown in Figure 61, the modeled gas prices remain roughly below $6/MMBtu through the next decade. Further, as gas prices also exhibit strong seasonal variations we examine the historical seasonality profiles for all gas pricing points and use the five-year average (2011- 2015) seasonality index in our modeling.

The distillate oil price is based on heating oil forwards in the short-term and the EIA crude oil growth rate forecast in the long-term. The residual oil price is developed based on a multi-year average of the ratio of residual and distillate oil prices.

5.1.3 Emission costs

Carbon dioxide emission costs are modeled in accordance with the California carbon allowance futures price and guided by the anticipated costs of carbon allowances under California's cap-and-trade program. The first compliance period for the cap-and-trade program began in 2013. This program, covering 350 businesses and 600 facilities, is divided into three compliance periods: 2013-2014, 2015-2017, and 2018-2020. The first compliance period involved the participation of electric utilities and large industrial facilities. The second compliance period, commenced in January 2015, has doubled the size of the two-year-old market through the inclusion of distributors of transportation fuel, natural gas and other fuels. Each market participant has a three-year window to "cover" its cap with allowances and offsets, though within each year it must cover at least 30% of the cap.[32]

SO_2 and NO_X emission allowances are applicable to Southern California facilities that fall under the Regional Clean Air Incentives Market ("RECLAIM") administered by the South Coast Air Quality Management District. However, since baseline SO_2 and NO_X emissions are based on emissions prior to the installation of scrubbers and "best-available control technologies," facilities in the RECLAIM jurisdiction are not expected to purchase additional allowances to offset emissions since most facilities have already installed the equipment. Thus, their incremental NO_X and SO_2 costs during the forecast period are zero. The remaining facilities generally satisfy SO_2 and NO_X emission requirements in California through fixed costs associated with air permits and emission reduction credits.

With respect to carbon emissions, LEI believes that California's long-standing initiatives to curb greenhouse gas emissions from electricity generation imply that it is likely to be already in compliance with the EPA rule proposed on June 2, 2014 under Section 111(d) of the Clean Air Act. The rule calls for a 30% reduction in greenhouse gas emissions from existing power plants from 2005 levels by 2030, with interim goals beginning in 2020.[33] Given California's RPS targets of achieving 33% renewables-based generation by 2020, and 50% renewables-based generation by 2030, and virtually no reliance on heavy emitters like coal and oil, the state is likely to remain in compliance of proposed EPA carbon targets in future years.

---

32 CARB. *Overview of ARB Emissions Trading Program.* October 20, 2011. <http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm>

33 Total carbon emissions in California for the electricity sector in 2011 were approximately 36 million metric tons for 201 TWh of in-state generation and have since increased to approximately 50 million metric tons for 199 TWh of instate generation in 2014. This translates into aggregate emission rates of 399 lbs./MWh and 550 lbs./MWh respectively. The lowest target emission rate identified by the EPA legislation for California is 537 lbs./MWh. This opinion is further supported by a recent report from Morgan Stanley titled, "EPA CO2: Costs and Opportunities," which claims that California may in fact be over-compliant under the recent EPA regulation. See: Amanda Luhavalja. "Report: RGGI, California will be 'over-compliant' under EPA's Clean Power Plan." *SNL Financial*. July 8, 2014.

LEI assumes 2018 carbon costs of $14.53 in line with the floor price.[34] Over the 2021 to 2030 period, carbon costs are assumed to increase at a rate (5% plus inflation) consistent with the indexed growth rate of the auction floor price and such that by 2030 California would still remain in compliance with the target EPA emission rate of 537 lbs./MWh. Given that the cap and trade program is legislated to operate until 2030, LEI assumes that carbon costs post 2030 remain flat. This assumption balances the policy uncertainty of whether the program will be further extended or terminated.

Figure 62. Emissions cost projections

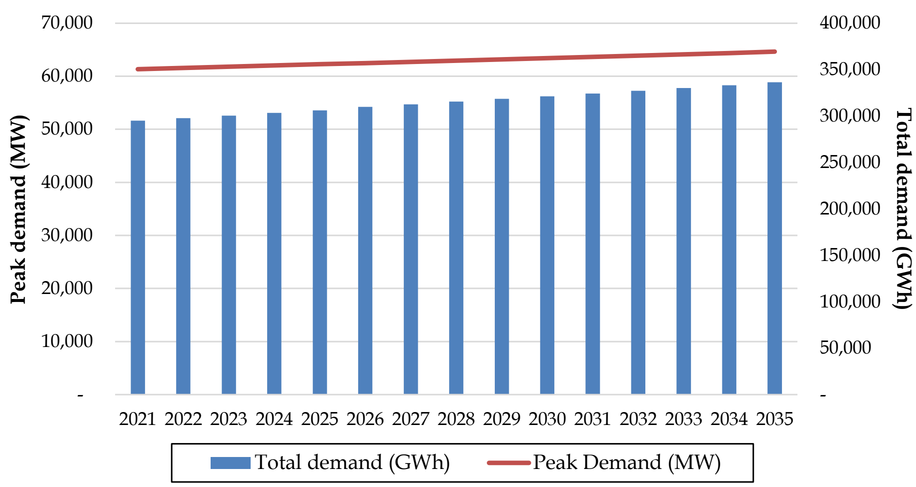
	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Carbon allowance price [$/metric ton]	$17.8	$19.0	$20.4	$21.8	$23.3	$24.9	$26.7	$28.6	$30.6	$32.7	$32.7	$32.7	$32.7	$32.7	$32.7

Source: Bloomberg; CARB

5.1.4 Demand

LEI uses California Energy Commission's load forecast results for near term (until 2026) and used the average annual growth rate of 2017-2026 to forecast the demand from 2027 to 2035. Coincident hourly load profiles for each region are developed based on CAISO's 2016 load shape, to which we applied regional forecasts of total energy usage and peak demand. Peak demand and consumption in California are expected to increase at CAGRs of 0.4 and 0.9% respectively.

Figure 63. Forecast demand



	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
Peak Demand (MW)	61,304	61,552	61,807	62,036	62,268	62,473	62,706	62,941	63,176	63,413	63,652	63,891	64,132	64,374	64,617
Energy (Gwh)	295,071	297,765	300,525	303,264	306,027	309,870	312,694	315,547	318,426	321,333	324,267	327,229	330,219	333,236	336,284

Source: California Energy Commission

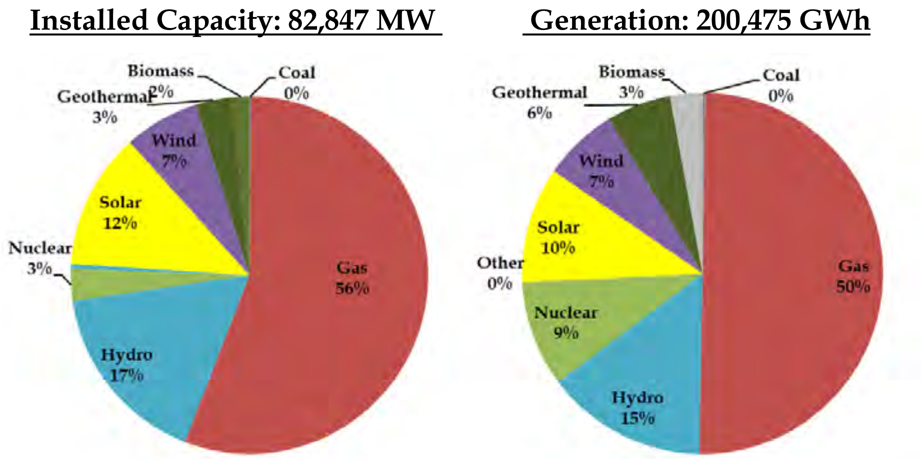
[34] California Air Resources Board. *2018 Annual Auction Reserve Price Notice.* December 1, 2017.

5.1.5 Supply

Existing supply

As of December2016 and shown in Figure 64 (which excludes out-of-state capacity and generation), California is dominated by natural gas fired facilities, representing 56% of installed capacity. Hydroelectric generation capacity represents 17%, nuclear represents 3%, and renewables (including wind, geothermal, solar and biomass) represent around 24% of capacity on a nameplate basis.

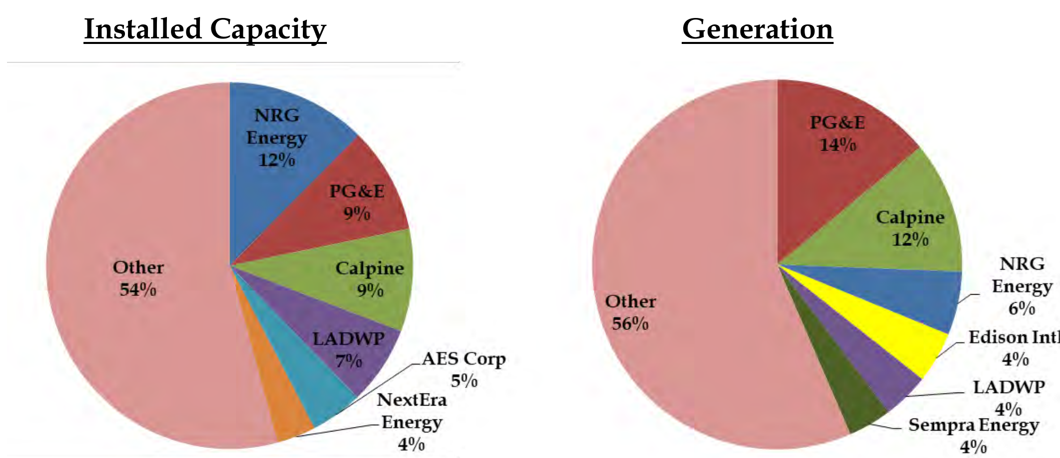
Figure 64. Installed capacity and generation by technology type, 2016



Source: California Energy Commission

California is highly reliant on imported capacity, especially nuclear from Arizona and hydroelectric generation from the Pacific Northwest. Top holding companies, in terms of capacity owned and in terms of actual electricity production, include NRG Energy Inc., PG&E, and Calpine Inc. (See Figure 65).

Figure 65. Installed capacity and generation by holding company, 2016

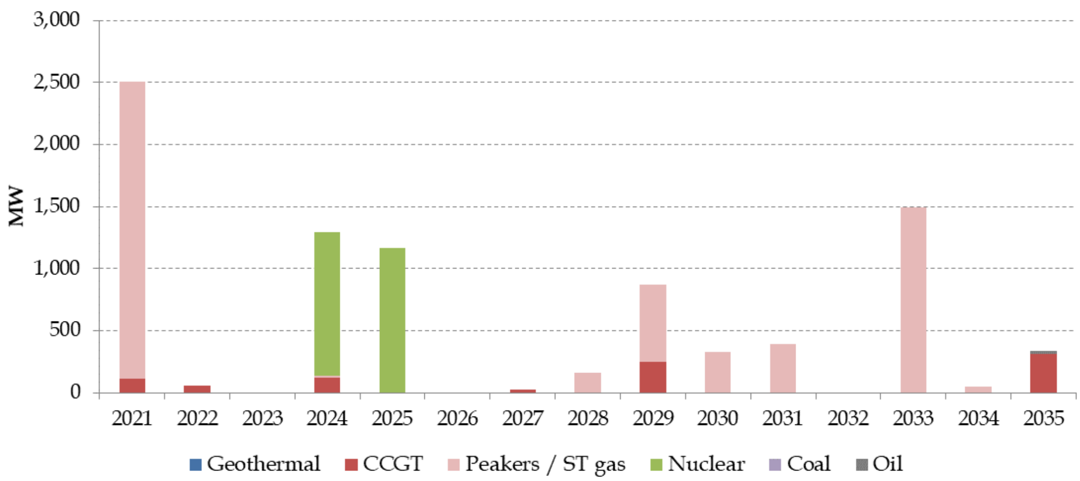


Source: Third party database provider

Retirements

During the 2021 to 2035 modeling timeframe, over 8 GW of capacity is retired in the state of California. Gas generators (peakers and CCGT) account for the majority of retirements, followed by nuclear. Assumed retirements take into account announced retirements, which are primarily due to once-through-cooling rules; other facilities that have outlived their expected useful life. PG&E's Diablo Canyon nuclear plant is expected to retire its two units in 2024 and 2025 following the expiry of its US Nuclear Regulation Commission ("NRC") operating licenses.[35] Beyond announced retirements, LEI examines candidates for further retirement based on expected minimum going forward fixed costs of operations and projected market revenues.

Figure 66. Modelled retirements across the modeled California region, 2021-2035



Source: Third Party Commercial Database

__New entry__

Short-term new entry is based on proposed projects that have received long-term contracts and/or plants that are already under construction or in the site-testing and site-preparation stages of development.

In the medium term, generic renewable (e.g. wind, solar, biomass, etc.) and natural gas fired resources are also included as supply resources in the longer term. California has aggressive RPS targets of 33% by 2020 and 50% by 2030. We currently model the state achieving the 2020 and 2030 RPS targets, based on the pace of renewable procurement and 29% progress achieved as of August 2017.[36]

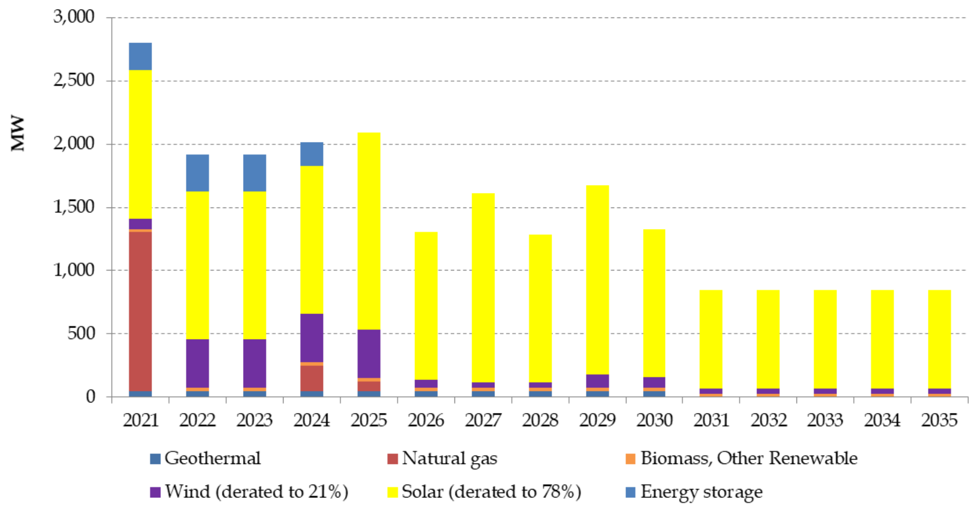
Over the 2021 to 2035 modelling horizon, new generation additions in California have been predominantly solar, representing 85% of total new generation derated capacity additions,

[35] Pacific Gas and Electric Company. *Application for Approval of the Retirement of Diablo Canyon Power Plant, Implementation of the Joint Proposal, And Recovery of Associated Costs Through Proposed Ratemaking Mechanisms.* August 11, 2016.

[36] CEC. Tracking Renewables Progress. August 2017.

followed by natural gas (7%), and energy storage (4%).[37] Figure 67 presents the cumulative additions (more than 22 GW of derated capacity) added in the energy model over the modeling timeframe. As a result of the modeled supply and demand, nuclear capacity will be replaced by renewables and gas-fired generation.

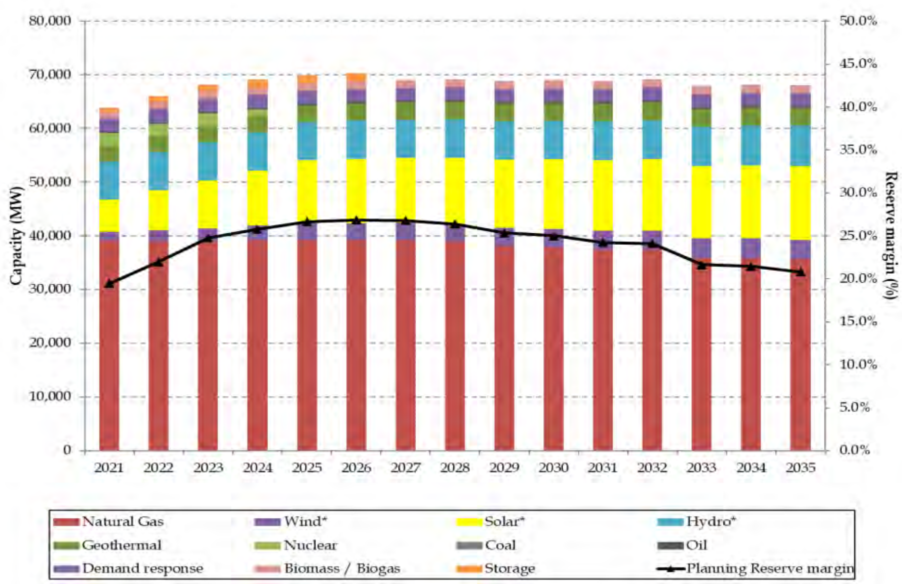
Figure 67. Cumulative additions across the modeled California region, 2021-2035



Source: Third Party Commercial Database

Supply-demand balance

Figure 68. Projected supply demand balance in California



[37] Based on LEI analysis using third party commercial database.

5.1.6 Interchange

California is a net importer of electricity from Arizona, Nevada, Utah and the Pacific Northwest. Between 2007 and 2016, exports have averaged 11,306 GWh per year while imports have averaged 84,958 GWh per year. LEI has modeled imports and exports based on the historical ten-year average (see Figure 69 below).

Figure 69. Average imports and exports to and from California

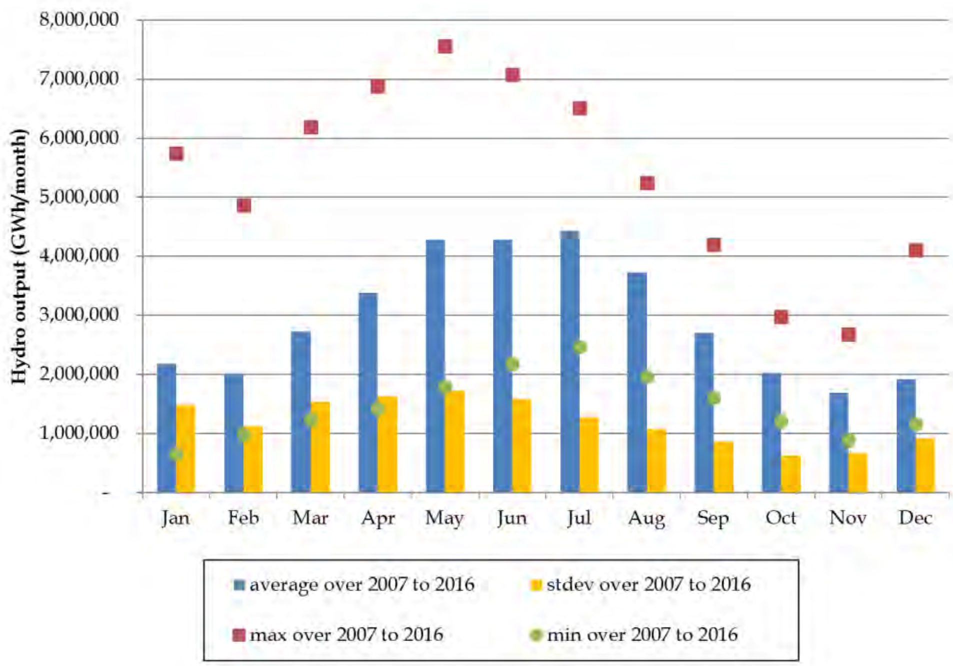
Year	Import from rest of WECC to CA (GWh)	Export from CA to rest of WECC (GWh)
2007	79,638	5,561
2008	81,958	5,062
2009	75,279	4,564
2010	71,770	4,630
2011	82,208	5,090
2012	88,721	5,541
2013	91,425	9,339
2014	109,011	11,368
2015	85,222	10,737
2016	84,349	11,812
2007 to 2016 avg	84,958	7,572

Source: Third-party commercial database

California is a net importer of electricity in both the off-peak and on-peak periods. Nuclear, coal and, to a lesser extent, wind generation is supplied off-peak, while hydro resources with storage are added to the resource mix during peak periods. More imports are typically required to meet demand when California hydrological conditions limit hydroelectric production in the state.

Given the large variation in California's hydrology conditions, modeled import and export flows are aligned with historical levels and where appropriate are "normalized" for average conditions to align the assumptions with the intent of the baseline forecast to capture long run average conditions.

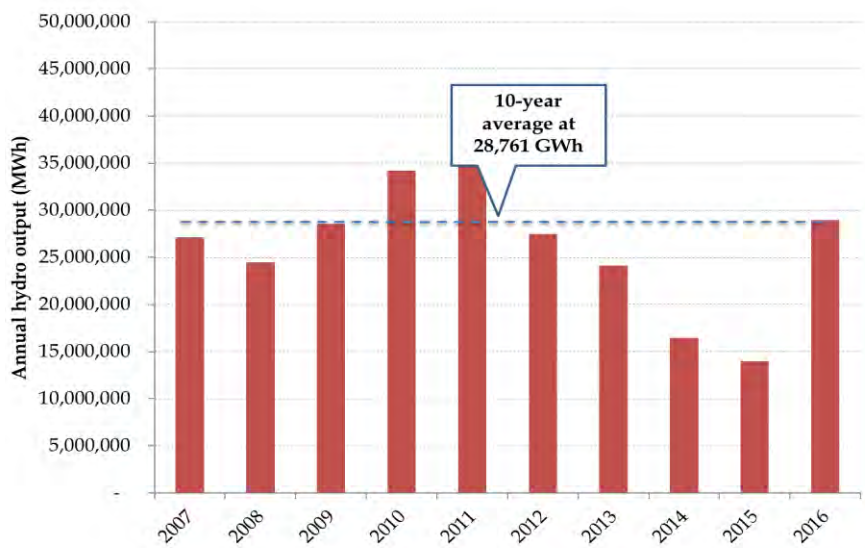
Figure 70. Monthly hydroelectric production in California (2007-2016)



Source: Third-party commercial database

Imports into California are dependent on hydrology, both in-state and out-of-state. Increased internal hydroelectric generation reduces import requirements, while at the same time, an increase of hydroelectric import availability from the Pacific Northwest can decrease import prices. The above two figures characterize internal hydroelectric production, including the seasonal profile for hydroelectric resources assumed in the modeling (Figure 70) and the historical year-on-year correlation in overall production. In our baseline modeling, we targeted net annual hydroelectric production of 28.76 TWh per year (a little below the ten-year average shown in Figure 71 below) across non-pumped storage hydroelectric resources within California.

Figure 71. Average yearly hydroelectric production (2007-2016)



Source: California Energy Commission, < http://energyalmanac.ca.gov/electricity/electricity_generation.html>

5.2 Assumptions for local economic modeling

5.2.1 Topology

Similar to the **Eastern Interconnect project,** construction period and operations period are studied separately for this project under different geographic configuration. The different economic impact items and regions impacted are presented in Figure 72 below.

Figure 72. Summary of modeled period, economic impact items, and affected regions for the Western Interconnect project

Modeling Period	Economic impact items	Modeled regions
Construction Period (Transmission 2018 – 2020; Wind generation 2019-2021)	Construction spending	Transmission: host states along of the line; Wind generation: the Rocky Mountain area
Medium-term Operations Period (2021 – 2035)	Electricity market cost savings, O&M spending, carbon emissions	Transmission: host states along of the line; Wind generation: the Rocky Mountain area
Longer-term Operations Period	Reliability benefits	California

5.2.2 Assumptions for planning and constructions period

5.2.2.1 Project configuration

The **Western Interconnect project** contains two major components: **a 3,000 MW transmission line (with converters)** going from the Rocky Mountain area to California, and **4,400 MW of new**

wind generation in the Rocky Mountain area. Assumptions for the configuration of the transmission and wind generation components for this project are presented in Figure 73 and Figure 74 below.

Figure 73. Configuration of the transmission component of the Western Interconnect project

Capital cost components	New Resouerce Delivery Transmission Project - Transmission
Total project cost	$3 billion
Length of line	700 miles
Number of converter stations (500kv)	2
Unit Capital cost - Transmission line	$1.75 million/mile
Unit Capital cost - Converter stations	$375 million/station
Construction period	2018-2021
Operations perid	2022- 2035

Figure 74. Configuration of the wind component of the Western Interconnect project

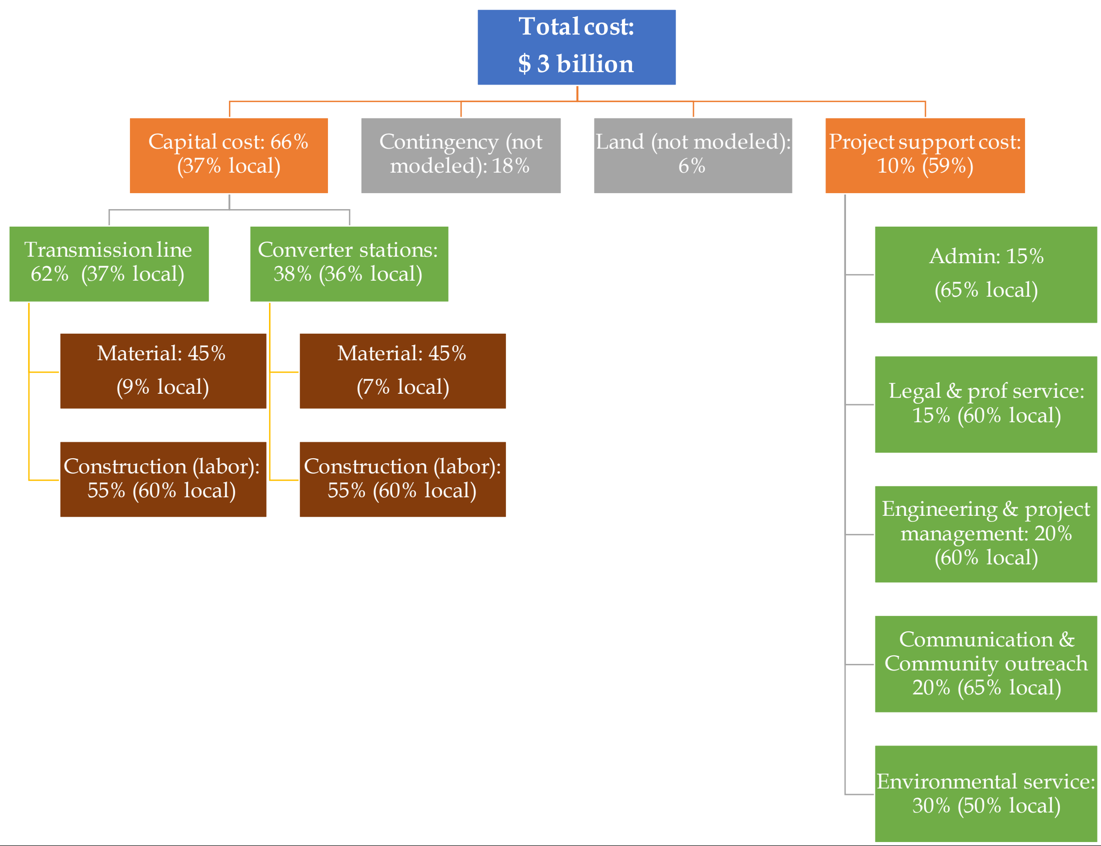
Capital cost components	New Resouerce Delivery Transmission Project - Wind Generation
Capacity (MW)	4,400
Unit capital cost - RMPA (WY)	$1,477/kW
Load factor	49.7%
Construction period	2020-2021
Commercial online date (COD)	2,200MW in 2021; 2,200MW in 2022
Operations perid	2021- 2035

5.2.2.2 Project costs of the transmission component during construction period

The itemized cost allocation and local share assumptions are based on publicly-available studies along with LEI's project experience professional judgement. Figure 75 below shows a high-level summary of the assumption for construction cost for the transmission component of the **Western Interconnect project**.

- The total cost for the construction period related to the transmission infrastructure is $3 billion, of which 66% is capital cost related (including construction material and labor costs), and 10% is spent on project support services (including costs related to administrative services, legal & professional services, engineering & project management, environmental services, communications support, etc.)
- 18% of the total cost is allocated to contingency, another 6% is allocated to land costs as a common industry practice (usually 5%-10% of total cost is related to land acquisition, depending on the configuration and location of the project). These costs are not included in the REMI PI+ model for the sake of conservativeness (this is a routine approach, as the effect of such spending on land and contingency is not certain).

Figure 75. Cost allocation for the transmission component of the Western Interconnect project, Construction period



- Total costs will be spread across three years of the construction period of 2018 to 2020, with capital costs allocated as 16%, 42%, and 42%, from Year 1 to Year 3 respectively. Project support services generally start from the planning period – 3 to 4 years earlier than the construction period. For the purpose of simplicity, we rollover the project support costs during the planning period to Year 1 of the construction period. Thereby, LEI assumes the project support costs to be allocated as 60%, 20%, and 20%, from Year 1 to Year 3.
- Transmission infrastructure related capital cost is further broken down for costs related to the construction of the transmission line (62%) and the two converter stations (38%) – one in the originate state and another one in the receiving state
- For both transmission line and converter stations, the capital costs are broken down into material costs (45%) and construction labor costs (55%)
- 10% of the total project costs is allocated to project support costs, which includes administration, legal support, environmental study & compliance, engineering & project management etc.
- 40% of the total costs is expected to be spent in states along the route, which will have direct impacts in the local economy and will be used as REMI model inputs. The 60% of

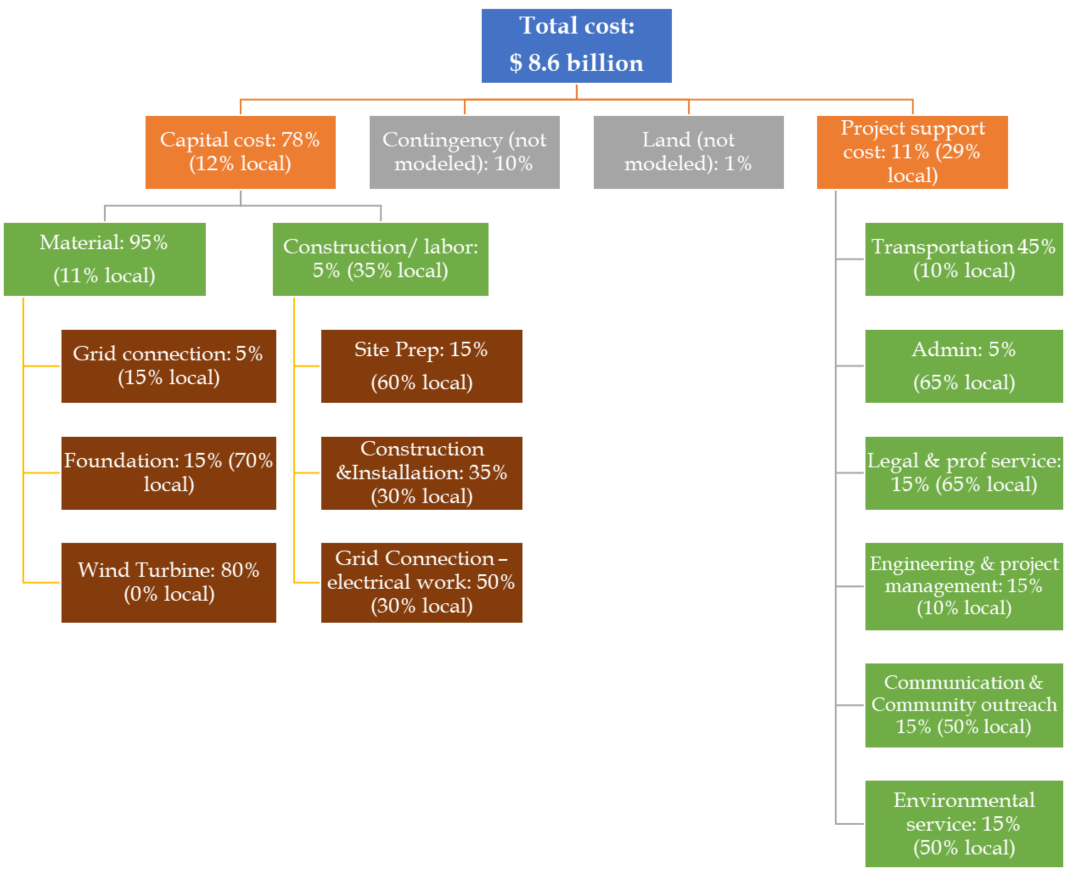
total cost that is expected to be spent in the rest of the country or rest of the world, due to imported materials and labor sourced from outside the modeled region, may also have spillover effects on the modeled region, but they are not included in the modeling as a conservative approach. Specifically, most of the construction and supporting labors (about 60%) are assumed to be sourced from within the modeled regions, while LEI assumes only about 8% of the total material costs is spent locally.

- The local spending related to the transmission line itself will be allocated across the regions according to line miles that fall within that region (20% is in the originate state, 62% is in other states along the route, 18% is in the receiving state), and the local spending related to the converter stations will be allocated to the originate and receiving states – where the stations are allocated.

5.2.2.3 Project costs of the wind generation component during construction period

Figure 76 below shows a high-level summary of the assumption for construction period project cost for the 4,400 MW wind generation in the Rocky Mountain area for the **Western Interconnect project**.

Figure 76. Cost allocation for the wind component of the Western Interconnect project, Construction period



- The total cost for the construction period related to the wind generation facility is $8.6 billion, of which 78% is capital cost related (including construction material and labor costs), and 11% is spent on project support services (including costs related to transportation, administrative services, legal & professional services, engineering & project management, environmental services, communications support, etc.)

- 10% of the total cost is allocated to contingency, another 1% is allocated to land costs as a common industry practice. These costs are not included in REMI model for the sake of conservativeness (this is a routine approach, as the effect of such spending on land and contingency is not certain).
- Based on the expected commercial online date of the wind generation facilities, i.e. 2,200 MW in 2021 and another 2,200 MW in 2022, the capital cost will be spent evenly across two years of the construction period of 2021-2022. 40% of the project support cost is allocated in 2020 (taking into consideration of the project support cost rolled over from the project plan and development period), and 30% for each of 2021 and 2020.

5.2.3 Assumptions for Operations Period

5.2.3.1 Impacts of electricity cost savings and O&M investment

Local economic benefits during the medium-term operations period is primarily driven by electricity cost savings in the beneficiary regions. Similar to the **Eastern Interconnect project**, the electricity cost savings for residential, commercial, and industrial customers are estimated through the wholesale electricity modeling, and then modeled in the REMI PI+ model as electricity fuel cost reduction for the commercial and industrial sector consumers, and reduction in consumer price for electricity for residential consumers.

The first-year O&M costs for the transmission component of the **Western Interconnect project** are assumed to be 2.5% of the total construction capital cost of the line. Major components of project operations spending included O&M labor spending (80%), of which 60% is spent locally, and O&M material and equipment spending (20%), of which 10% is spent locally. For the wind generation component, the first-year O&M spending is assumed to be $25/kW, which is 1.7% of the construction capital cost of the wind generation facilities. 15% of such costs are allocated to field O&M activities, 55% are allocated to material spending, 20% are allocated to insurance and other fees, the rest goes to sectors project management, utilities, and transportation. The O&M costs for both the transmission and wind generation components are both inflated by 2% for each year during the operations period.

5.2.3.2 Impacts from deferred renewable investment in California

In the world without the **Western Interconnect project**, California would have seen more local investments in solar and wind. The construction of those local power plants would have created temporary boost in local labor market and GDP. However, due to the **Western Interconnect project** delivering wind-generated power from the Rocky Mountain area, the need for local investments in wind and solar in California will be deferred. Therefore, there will be a lost opportunity for California's local economy.

LEI assumes that certain local generation investments - 1,500 MW of wind (total project cost of $3.5 billion) and 6,000 MW of solar (total project cost of $16.7 billion) in California would be deferred between 2019- 2030. In order to comprehensively measure the net impact to the local economy, the implications from these deferred investments are considered in the local economic modeling.

Cost composition and local spending allocation are presented in Figure 77 and Figure 78 below. The California economy would forgo seeing the local labor and local material spending due to the delayed 1,500 MW wind and 6,000NW solar investment, on average $33 million and $7 million per year respectively. The reduced levels of spending in the labor market are modeled as a reduced compensation, given that the labor markets for construction and installation of such infrastructure are expected to be robust. Therefore, the workers that would have done the construction and installation work related to these projects are assumed to find opportunities to work on other projects, but at a lower compensation.

Figure 77. Cost allocation for the 1,500 MW deferred wind construction in California due to the Western Interconnect project

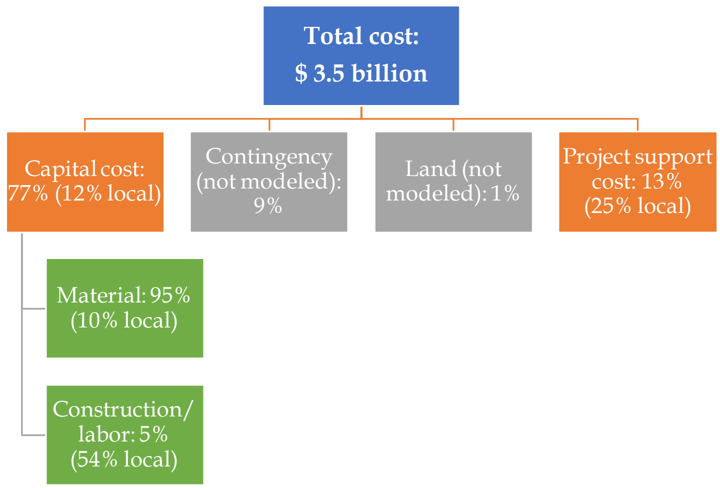
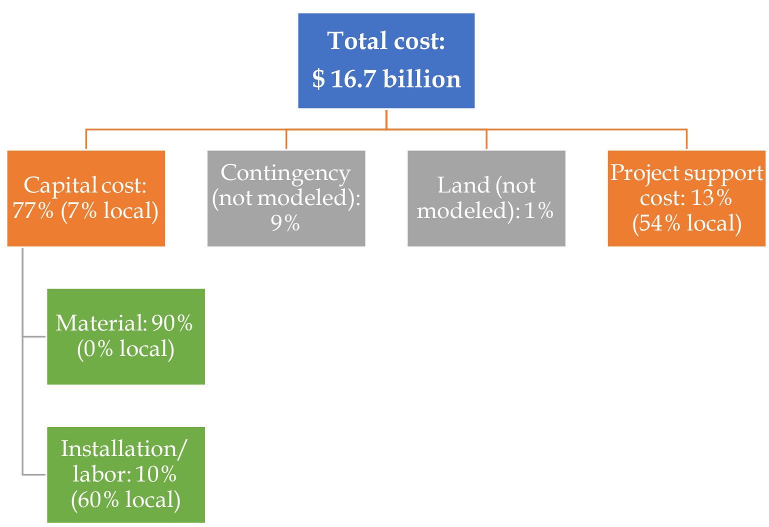


Figure 78. Cost allocation for the 6,000 MW deferred solar construction in California due to the Western Interconnect project



5.2.3.3 Impacts of reduced carbon emissions

The **Western Interconnect project** facilitates decarbonization by reducing carbon emissions of approximately 18 million metrics tons cumulatively over the 2021-2035 period, or $341 million to $1,680 million in terms of avoided social costs under the three SCC scenarios. These SCC values are then modeled as increased "quality of life" approach in California through the REMI PI+ model, as explained in Section 4.3.4.

5.2.4 Assumptions for longer term Operations

Please refer to Section 3.7.

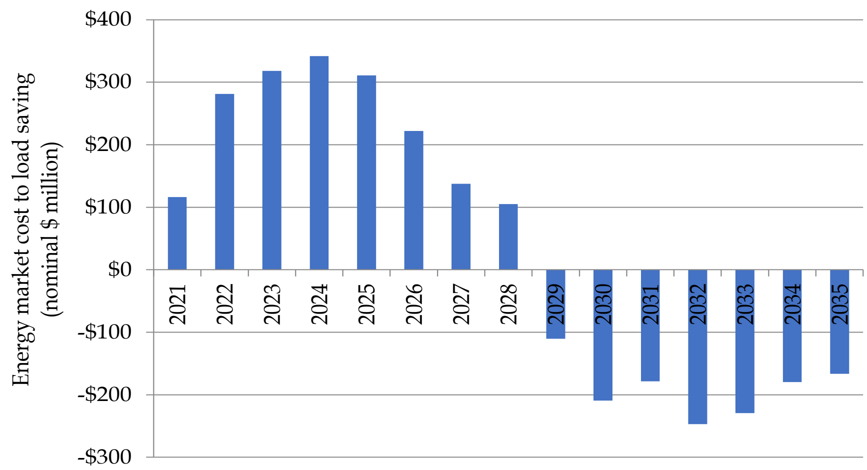
5.3 Modeling results for whole electricity market

5.3.1 Benefits to electric customers

In California, the energy cost for ratepayers consists of three main components: wholesale energy market costs, resource adequacy ("RA") costs, and the cost of power purchase agreements ("PPAs").[38] Wholesale energy market costs refer to the amounts paid to the California ISO for the volume of energy consumed. RA costs refer to bilateral contracted capacity payments made to generators needed for resource adequacy. In addition, many resources in California, including the new wind generators that are using the transmission line, will have longer term PPAs, which will be settled against the wholesale energy market costs. Given the renewables portfolio standard ("RPS") target of 50% generation share of renewables by 2030, a large share of the PPAs will be associated with renewables generation investment over the modeling timeframe.

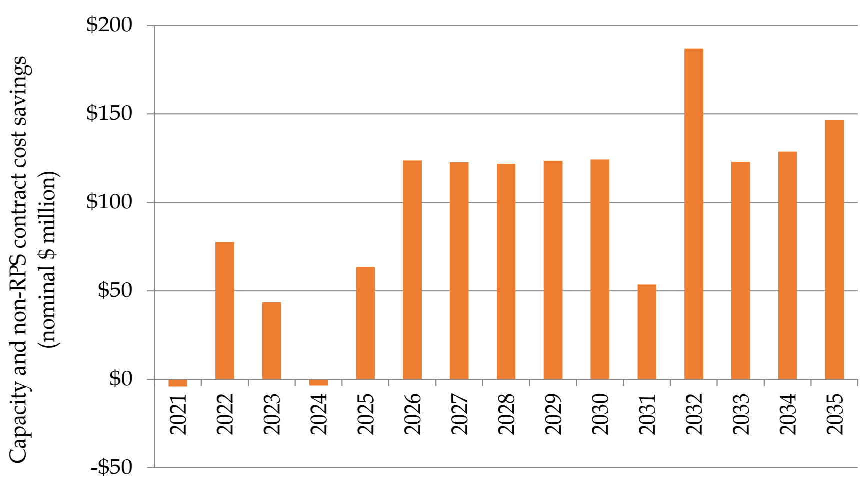
The introduction of wind in Rocky Mountain area in 2021 and 2022 has resulted in lower wholesale energy prices by $0.80/MWh between 2021 and 2030, stemming from the surplus generation in the market. While the total generation from renewables is equal by 2030, both with and without transmission investment, wholesale energy market cost to load savings decrease, as renewable generation in a world with transmission investment is more concentrated toward off peak hours compared to a world without transmission investment. Post 2029, even though spot energy market costs are higher in a world with transmission investment creating dis-savings, there are other offsetting benefits to consumers and the total cost to load impact is positive. With the **Western Interconnect project**, California electric consumers can save $826 million in spot energy market cost to load in 2021 NPV terms over the 15-year modeling horizon, with year-on-year data shown in the Figure 79.

Figure 79. Wholesale energy market benefit of the Western Interconnect project (nominal $ million)



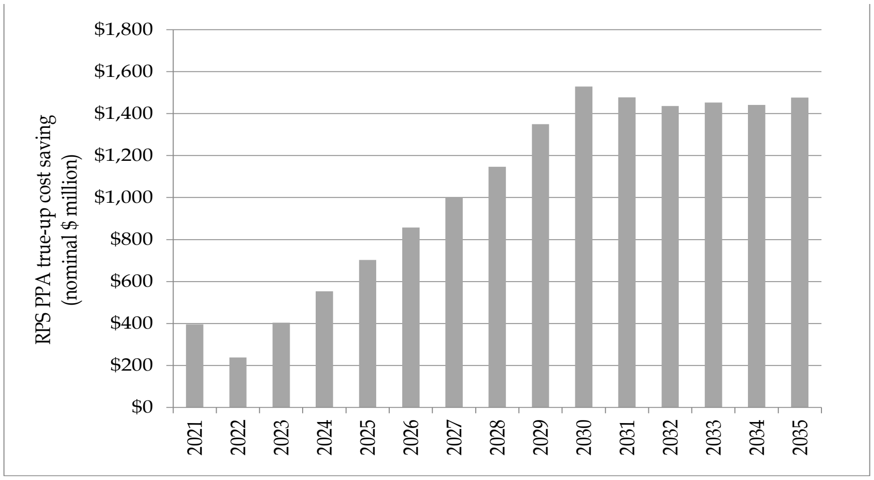
Capacity-related cost savings consist of RA market cost savings and reduction in the settlement costs of long term PPAs. There are also associated capacity-related cost savings for electric consumers of $603 over the 15-year period in 2021 NPV terms, assuming a 10% discount rate. Capacity-related benefits accrue over the longer term as higher energy market costs result in lower RA capacity prices and lower non-RPS PPA costs.

Figure 80. Capacity-related cost savings (RA costs and non-RPS PPA true-up) of the Western Interconnect project (nominal $ million)



Lastly, import of wind-resources from Rocky Mountain area through this new transmission line allows for the deferral of 1,500 MW of California in-state wind and 6,000 MW of California in-state solar. Avoided capital costs from deferred in-state renewable investment increase up until 2030, plateauing thereafter and enabling renewable contract cost savings of $6.5 billion over the 15-year period in 2021 NPV terms, assuming a 10% discount rate for California ratepayers. This also demonstrates transmission investment can allow California to achieve its 50% renewables by 2030 target more cost effectively.

Figure 81. RPS PPA true-up cost savings of the Western Interconnect project



Note: Rocky Mountain wind PPA costs are included in the RPS PPA true-up cost calculations

Figure 82. Total electricity market savings for California electric consumers of the Western Interconnect project

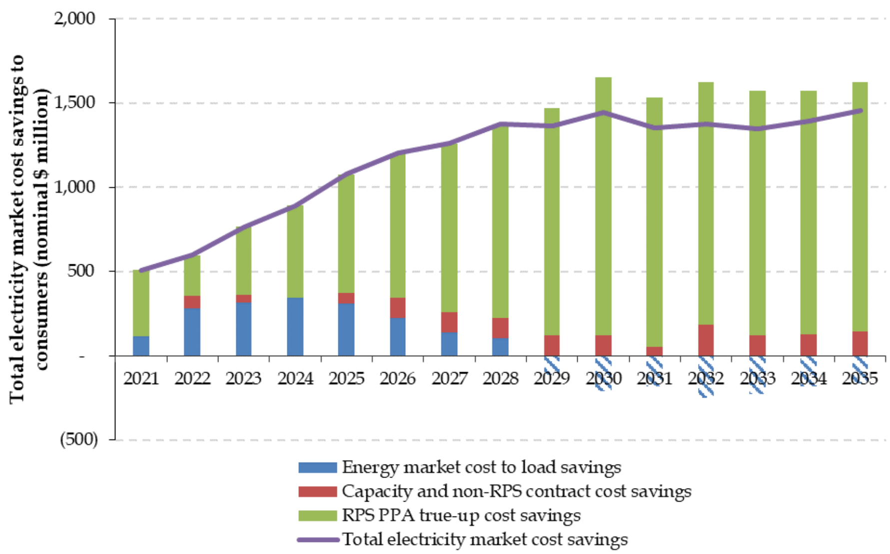


Figure 82 presents the projected total electricity cost savings and each component discussed above. The total electricity market benefit of the project is estimated to be over $7.9 billion over the 15-year period in 2021 NPV terms assuming 10% discount rate. Total electricity market savings are projected to be equal to $508 million in 2021 rising to $1,457 million by 2035, or $1,160 million per year on average, which far exceed the annual levelized cost of the transmission line. With the **Western Interconnect project**, California is assumed to be able to tap into Rocky Mountain area's abundant wind potential with the new transmission line. The import of wind-generated energy provides California electric consumers with a significant savings on their electric utility bills.

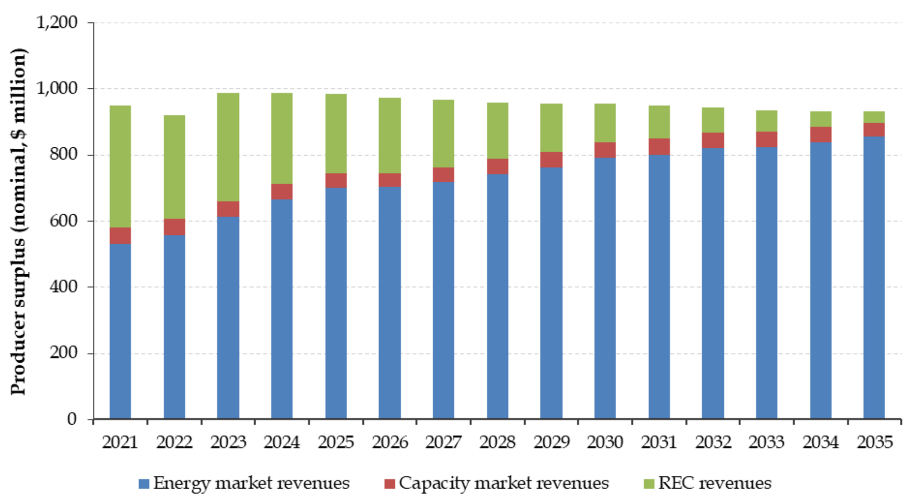
5.3.2 Benefits to power generators

In the **Western Interconnect project**, wind generators in the Rocky Mountain area are motivated to get built as a result of the transmission line, and they will receive contracted energy, capacity and REC revenues. If there were no new transmission line, new wind generation won't get built and the producers earn zero. With the construction of 4,400 MW of new wind:

- The wind generators' energy market profits (net of transmission losses) grow from $530 million in 2021 to $855 million in 2035 at a CAGR of 3.5%
- Wyoming wind's capacity market profits increase from $49 million in 2021 to $44 million in 2035 at a CAGR of -0.9%
- Renewable energy credit ("REC") profits decreases from $369 million in 2021 to $34 million in 2035. LEI models REC prices in $/MWh as the residual revenue shortfall needed to cover the levelized cost of new renewable generation.

As shown in Figure 83, the economic value of the revenues earned by the new wind generators in Rocky Mountain area amounts to $7.3 billion over the 15-year period in 2021 NPV terms assuming 10% discount rate, or $956 million per year. This is equivalent to average earnings of $55.48/MWh.

Figure 83. Revenues received by new wind generators in the Rocky Mountain area (2021-2035) of the Western Interconnect project

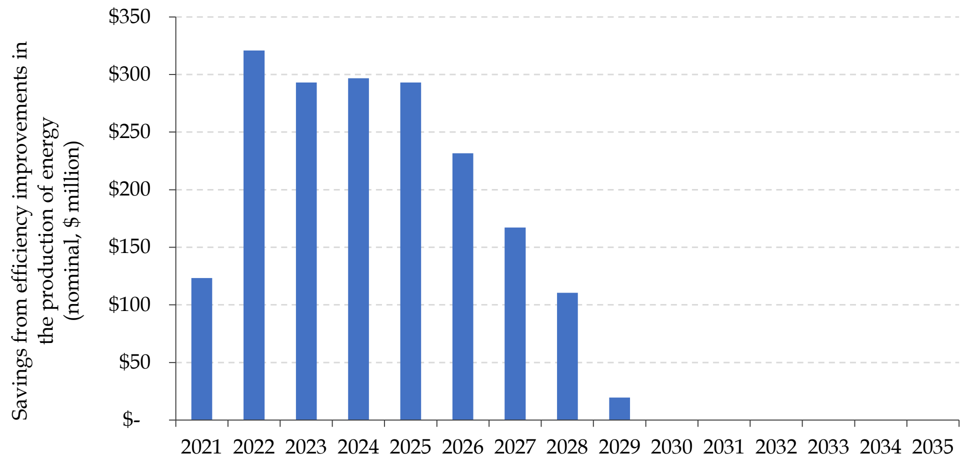


5.3.3 Efficiency improvements in production of energy (or production cost savings)

The introduction of zero-cost Rocky Mountain wind generation reduces the amount of thermal generation needed to meet demand, lowering production costs of the system. Production costs include the sum of fuel costs, variable O&M costs and emissions costs. The production cost savings are about $0.90/MWh between 2021 and 2029 or $1.25 billion over the 15-year period in 2021 NPV terms, assuming 10% discount rate.

Efficiencies in energy production declines over time as the Rocky Mountain wind generation in a world with transmission investment starts to converge to the generation of local renewables in the world without transmission investment. By 2030, while the renewable generation in both worlds with and without transmission investment is essentially equal, project cost savings dissipate.

Figure 84. Savings from efficiency improvements in the production of energy (nominal, $ million) of the Western Interconnect project

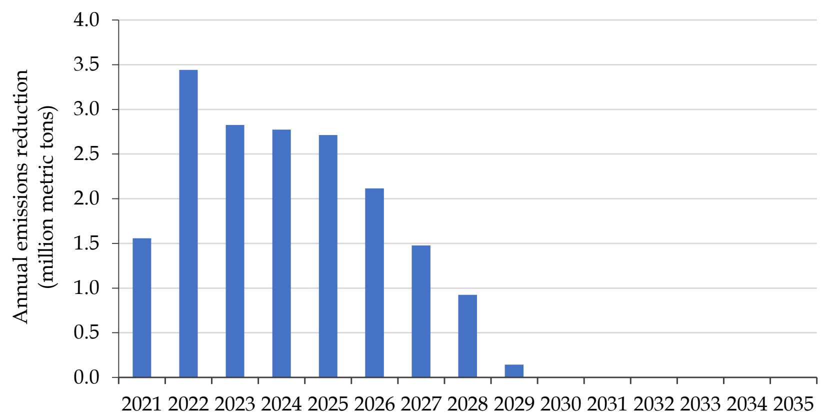


5.3.4 Benefits on the environment

This project allows for significant carbon emissions reductions in the 2020s in the State of California. As the wind resources are incremental, the Rocky Mountain area does not see any increase in offsetting local carbon emissions. Cumulative carbon emission reductions in California reach 18 million metric tons by 2030, contributing towards the state's economy-wide target of 50% below 1990 levels by 2030 (or 256.3 million metric tons).

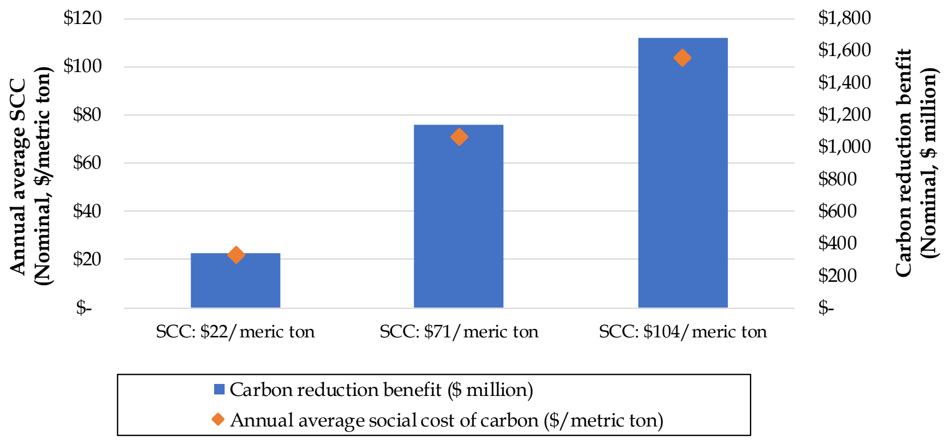
Similar to production cost saving, emission reduction benefits decline over time as the Wyoming wind generation in a world with transmission investment starts to converge to the generation of local renewables in a world without transmission investment. By 2030, when the renewable generation between a world with and without transmission investment is essentially equal, emission reduction benefits dissipate.

Figure 85. Carbon Emissions Reduction (million metric tons) of the Western Interconnect project



Moreover, the reduction in carbon emissions can be translated to carbon reduction benefit[39] in dollars when social cost of carbon is applied. 18 million metric tons of emission reductions are equal to $300 million to $1.7 billion in avoided damages from carbon emissions.

Figure 86. Carbon reduction benefit of the Western Interconnect project

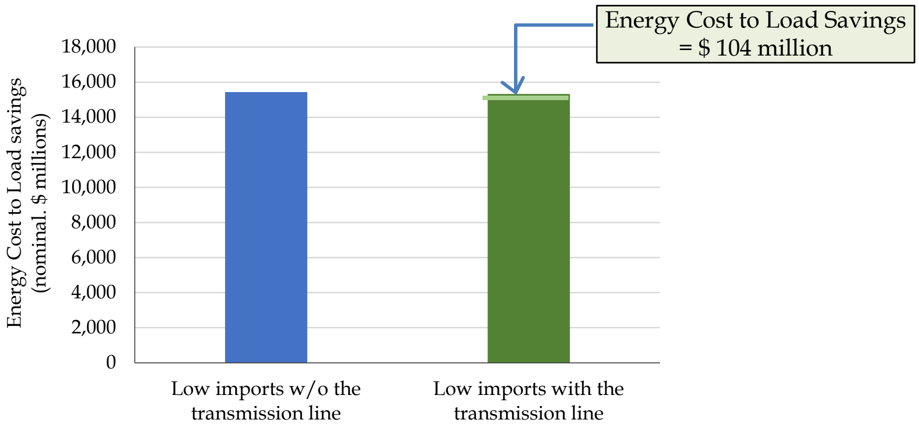


5.3.5 Reliability benefits

The new transmission will diversify California's supply mix and reduce the energy cost to consumers associated with possibility of limited imports from other regions. It could also eliminate the possibility of a costly blackout. Imports account for an important part of California supply. On average, imports accounted for approximately 33% of in-state consumption for the past 5 years. LEI simulates a low import scenario in California market in order to evaluate the long run system reliability attributes of the new transmission line. 2026 is chosen to reflect system conditions after the retirement of the Diablo Canyon nuclear station. The one-year energy cost to load savings for California electric consumers is $104 million in 2026.

[39] 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.

Figure 87. Consumer savings from major generation outage of the Western Interconnect project



The savings for eliminating an unexpected blackout is $566 million. It is calculated using the estimated magnitude of unserved load (29,024 MWh) and multiplied by the Value of Lost Load ($19,501/MWh).

Figure 88. Savings from costly blackouts of the Western Interconnect project

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

5.4 Modeling results for local economic modeling

Both the construction of the 3,000 MW **Western Interconnect project** line and the 4,400 MW of new wind generation in the Rocky Mountain area will benefit the host states' economy significantly. Figure 89 and Figure 90 illustrate the impacts of this project on local economies in terms of GDP increase and jobs created, which will be explained in more detail later in this section. The negative impacts from the loss of opportunities in renewable development in California are netted out from the results. Long-term reliability benefits are discussed in Section 5.3.5.

Figure 89. New jobs created by the Western Interconnect project, construction and medium-term operations periods

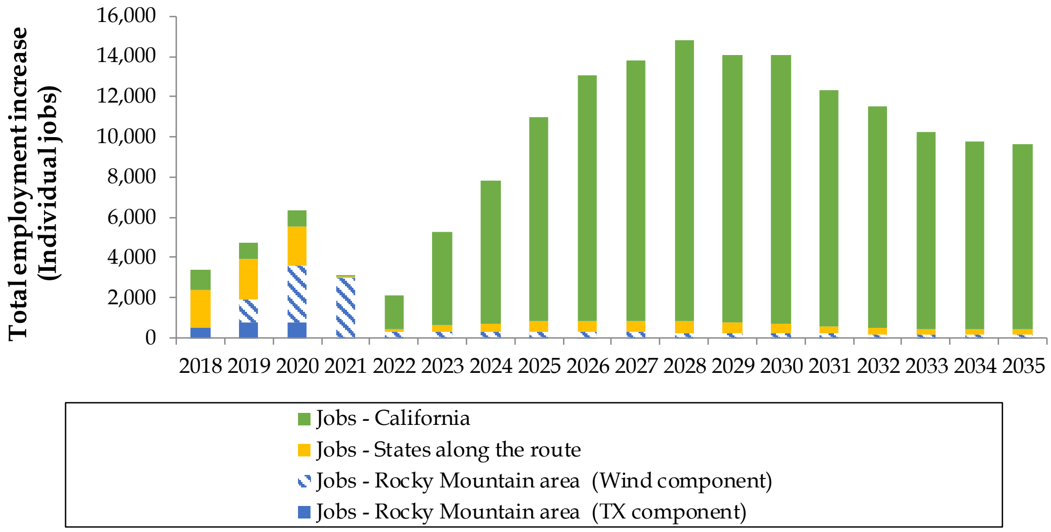
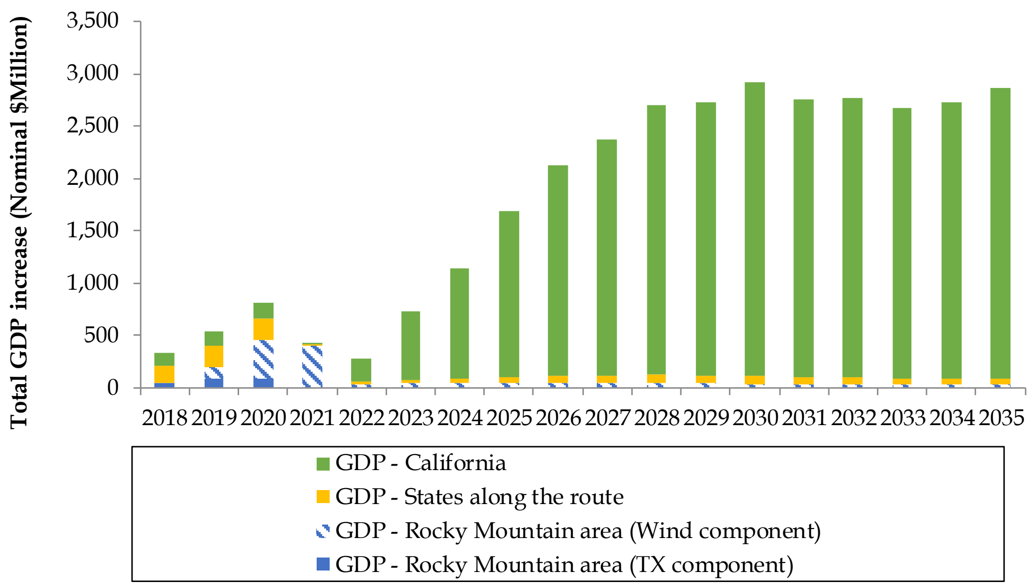


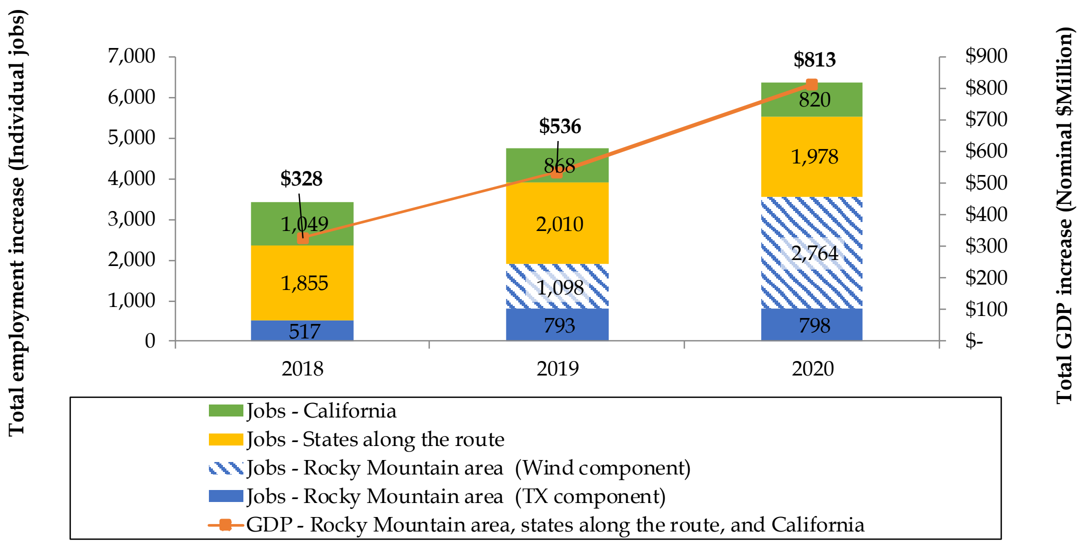
Figure 90. GDP increase due to the Western Interconnect project, construction and medium-term operations periods



5.4.1 Short-term impacts

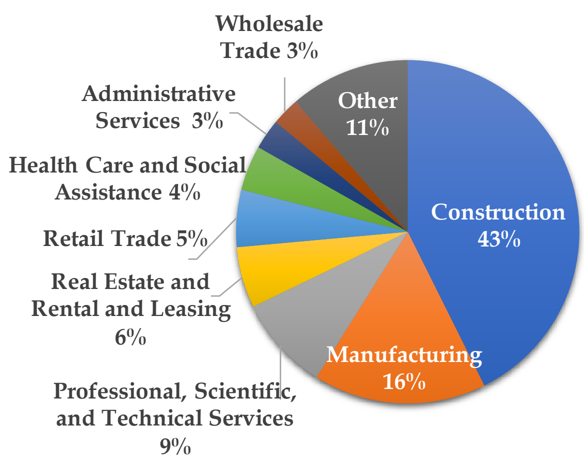
During the construction of the transmission part for the **Western Interconnect project**, all the states that hosting the line are expected to see an increase of GDP by $398 million and jobs increase by 3,562 per year on average during 2018 to 2020. Separately, construction of the wind generation facilities in the Rocky Mountain area will benefit the local economy by increasing the local GDP by an average of $293 million per year and creating 2,283 new jobs per year during 2019 to 2021 (See Figure 91).[40]

Figure 91. Increase in four states' local economy and employment during construction of the Western Interconnect project



Note: The GDP increase by regions follows a similar pattern as the job increase in each host state

Figure 92. Local economy boost (GDP increase) by sector during construction of the Western Interconnect project, all states along the route



The construction sector, manufacturing sector, and professional, scientific and technical services sector benefit the most from the transmission investment during this period as they provide the materials and laborers needed for the construction activities (see Figure 92).

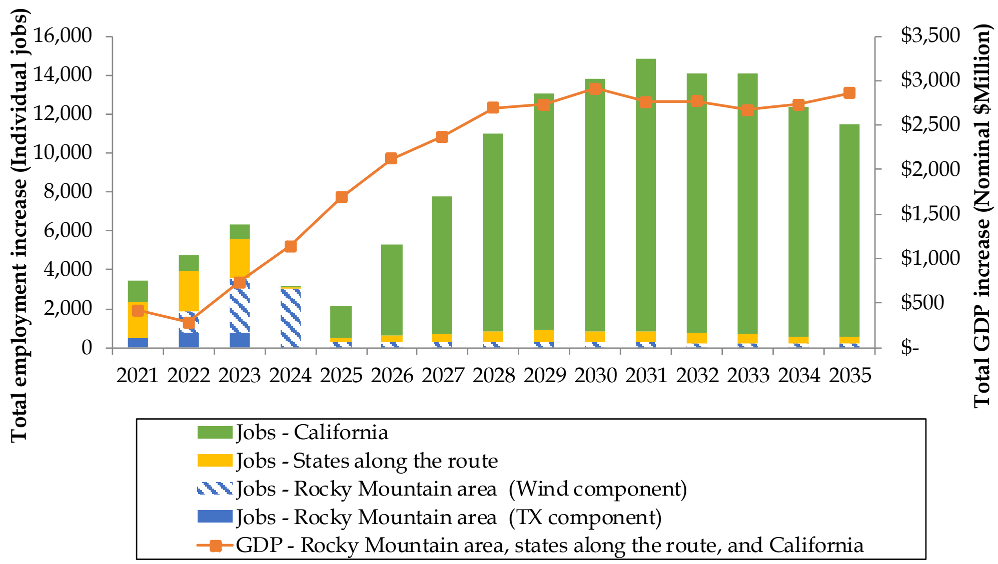
[40] The construction of the wind generation facilities for the **Western Interconnect project** is from 2019 to 2021. Figure 91 here shows the construction period of the transmission component of the project.

5.4.2 Medium-term impacts

5.4.2.1 Impacts from electricity cost savings and O&M spending

Similar to the **Eastern Interconnect project**, economic benefits from this project over medium-term operations period is driven by electricity market savings to consumers. California, as the state receiving the electricity cost savings, receives the majority (95%) of economic benefits. Other states also see economic benefits from O&M investment on the transmission project and the wind generation facilities.

Figure 93. Increase in local economy and employment during first 15 years of operations of the Western Interconnect project

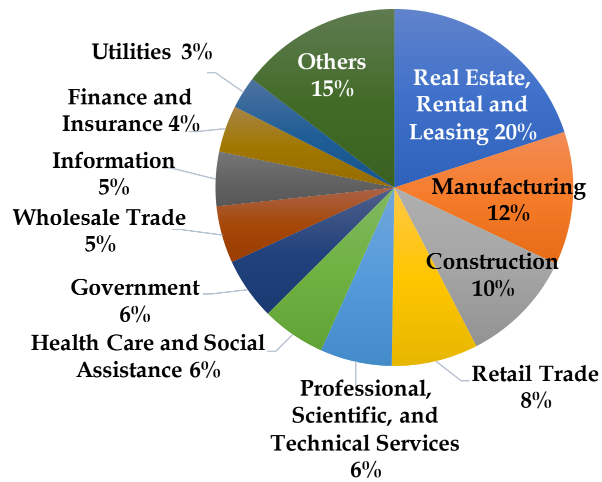


Note: For the **Western Interconnect project**, the GDP increase by regions follows a similar pattern as the job increase. Also, the negative local economic impacts due to delayed renewable investment in California are netted out from the results.

Specifically, California is expected to enjoy about 9,400 new jobs per year on average and a nearly $2 billion GDP increase per year during the operations period of 2021 to 2035. The Rocky Mountain area will see jobs increase by 250 per year and the GDP increase by $89 million per year from the O&M spending on the transmission and wind generation facilitates. The other states along the route also see moderate economic benefits, 379 new jobs $56 million GDP increase every year. The overall operations period benefits for this project is larger than the **Eastern Interconnect project**, partly because of its larger project and investment amount scale, also owing to the more substantive electricity cost savings it brings to California. The GDP is expected to increase, and new jobs are expected to increase during 2021 to 2035, as the electricity market benefits ramp up. During 2031-2035, a slight drop in economic benefits is observed, due to the less significant electricity market savings and the adverse impacts from the lost opportunity for the deferred renewable investment.

Nearly all industries are affected by electricity cost savings through the direct, indirect, and induced impacts, as shown in Figure 94. The magnitude of impacts for each sector is determined primarily by the share of outputs in each sector and their relative dependence on electricity supply, as well as direct O&M spending.

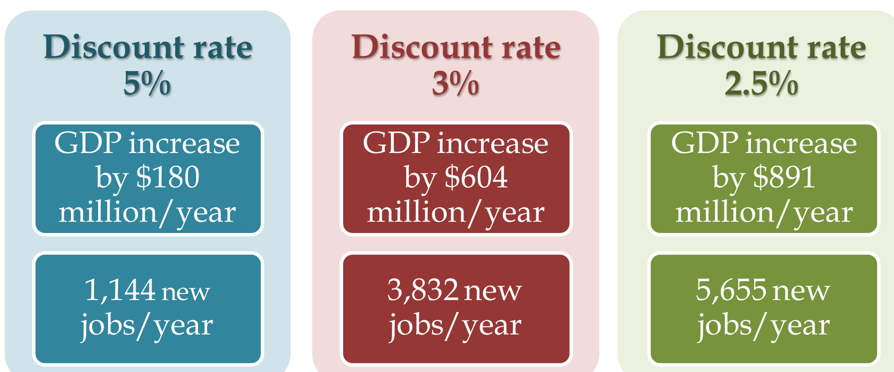
Figure 94. Local economy boost (GDP increase) by sector during construction of the Western Interconnect project, all states along the route



5.4.2.2 Impacts from carbon emissions reduction

Due to the **Western Interconnect project**, California is expected to see an influx of new workers because of the projected decarbonization achievements associated with the new transmission project, creating an additional $180 to $890 million per year boost to the state's $2,400 billion economy during the operations period of 2021 to 2035 (See Figure 95).

Figure 95. Socio-economic boost by reducing carbon emissions in California



6 Indicative of the benefits of transmission

In Section 5 of the main report, LEI demonstrates that the methodology for estimating benefits and the general magnitude of the benefits is generally indicative of all transmission investments. The indicative range of economic benefits of transmission as a result of these two projects is presented in Figure 96 below.

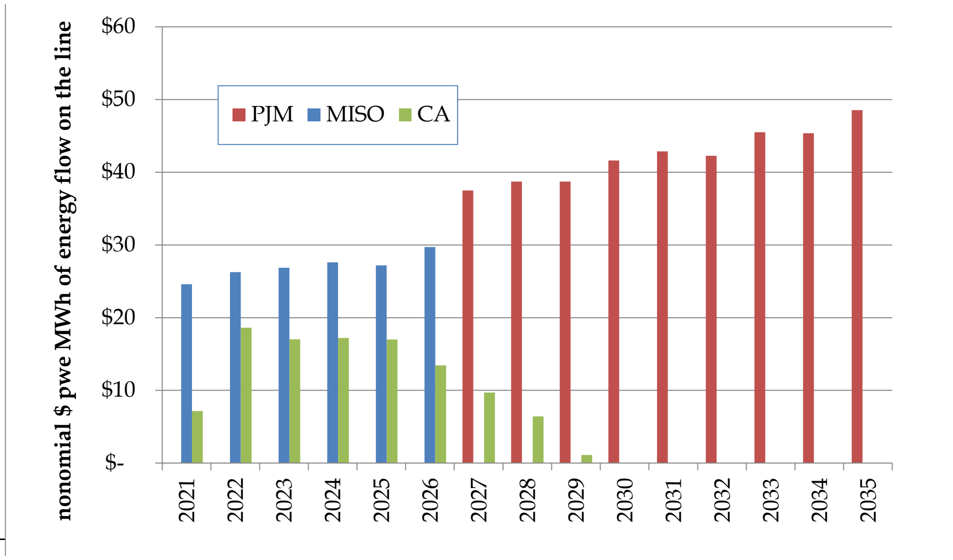
Figure 96. Indicative of the benefits of transmission

Metrics	Results	Drivers
Efficiency improvement in the production of energy	▪ Savings from efficient improvement in the production of energy are in the range of $10 to $40 per MWh of energy that flows on the transmission project	▪ Larger efficiency gains are likely in markets where there are more diversity (steeper supply curve) and vice versa
Electric consumer savings – energy	▪ Typically under $2/MWh in LMP reductions which leads to consumer savings once multiplied by total consumption in the region	▪ Larger reductions for projects with larger energy flows or higher Locational Marginal Prices ("LMPs")
Electric consumer savings - capacity	▪ $100 capacity cost reductions for every kW of qualified capacity	▪ Larger capacity price reductions are likely in markets where the market supply-demand balance is tighter and/ or in smaller size markets with steeper demand curves
Carbon emissions reductions	▪ Approximately 0.7 metric ton reductions per MWh of energy that flows on the transmission project	▪ Greater reduction if a region/market has a higher carbon footprint
GDP increase	▪ For every million dollars spent on construction and installation of a transmission project, the GDP is projected to grow by $1 million or more (short-term) ▪ During operations, for every million dollars of reduction in costs to electric consumers, the GDP is estimated to grow by $1-12 million	▪ Magnitude varies depending on composition of economy and labor productivity rates
Job increase	▪ for every million dollar spent locally on construction and installation of the project, LEI estimates that 10-20 new jobs are created (short-term) ▪ for every million dollar reduction in costs to electric consumers, 10 to 90 new jobs may be created during the operations phase	▪ Magnitude varies depending on composition of economy and labor productivity rates

In this sub-section, LEI will show the detailed year-on-year results in various figures (please refer to Section 5 of the main report for detailed discussion).

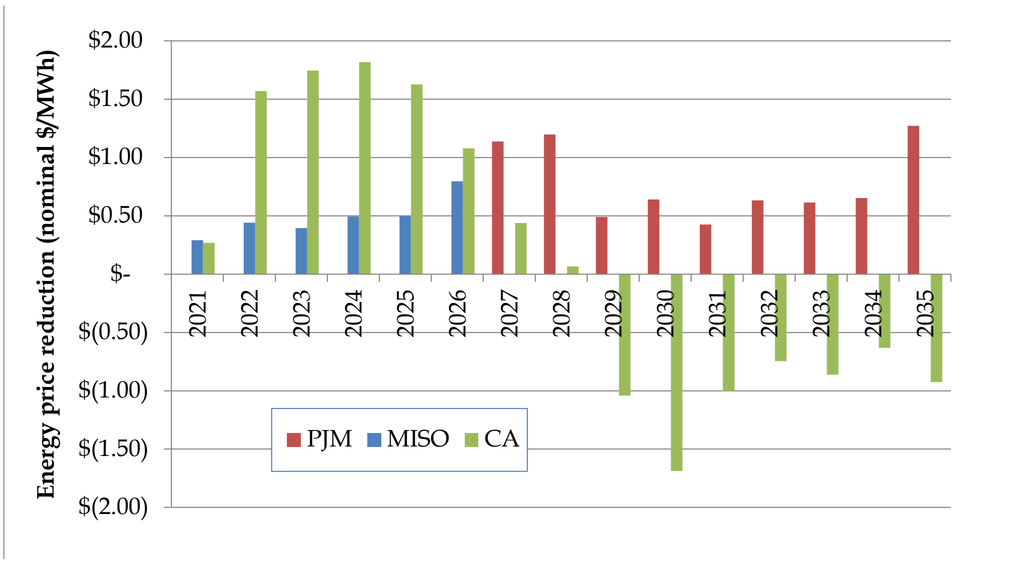
6.1 Efficiency improvement in the production of energy

Figure 97. Generalized savings from efficiency improvement in the production of energy (nominal $/ MWh of energy flows on the new transmission project)



6.2 Electricity market cost savings – Energy

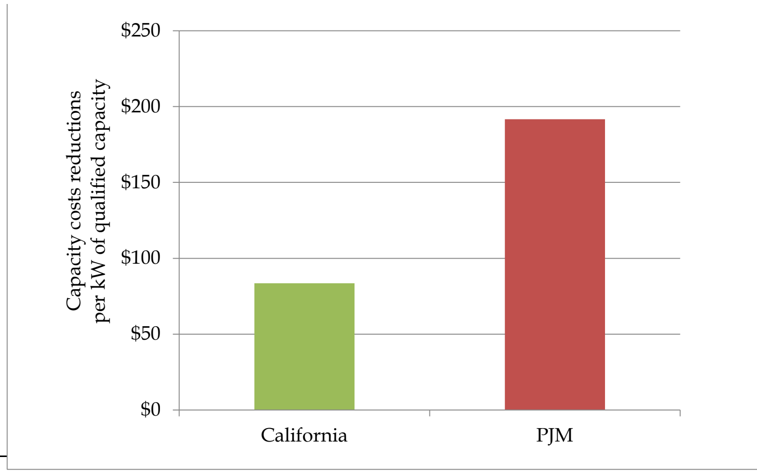
Figure 98. Energy price reductions (nominal $/MWh)



Note: Even though spot energy market costs are higher in a future world with a hypothetical transmission project under the **Western Interconnect project**, creating dis-savings, there are other offsetting benefits to consumers and the total cost to load impact is positive.

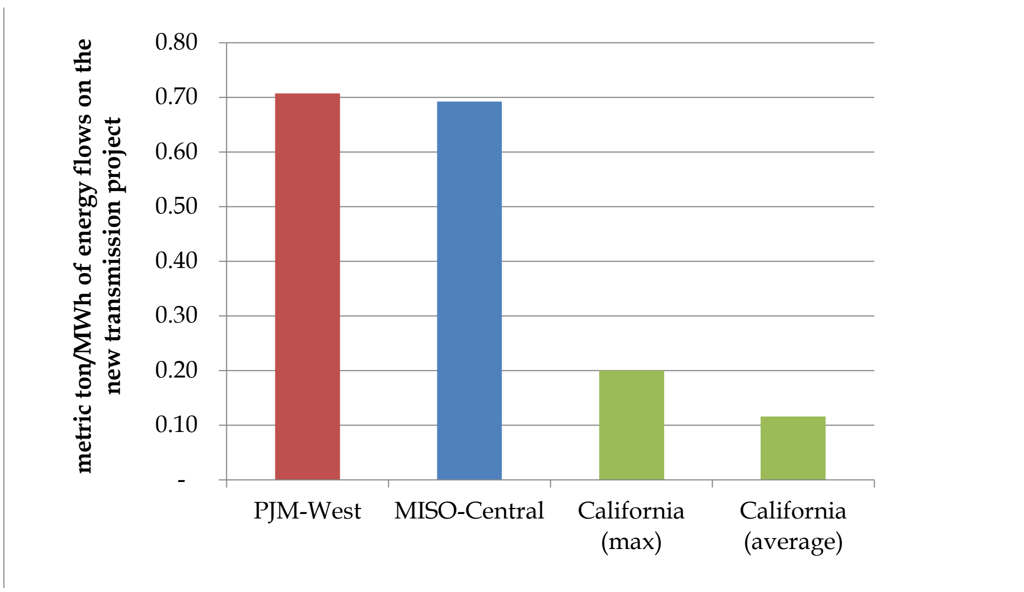
6.3 Electricity market cost savings – Capacity

Figure 99. Illustration of an indicative downward sloping demand curve for PJM capacity market



6.4 Carbon Emissions Reduction Benefits

Figure 100. Carbon emissions reduction (metric ton/MWh of energy flows on the new transmission project)



Note: California average represents average between 2021 and 2029 only

6.5 Local Economic Benefits

Figure 101. GDP increase per local spending (construction period) and GDP increase per local spending plus retail savings (operations period)

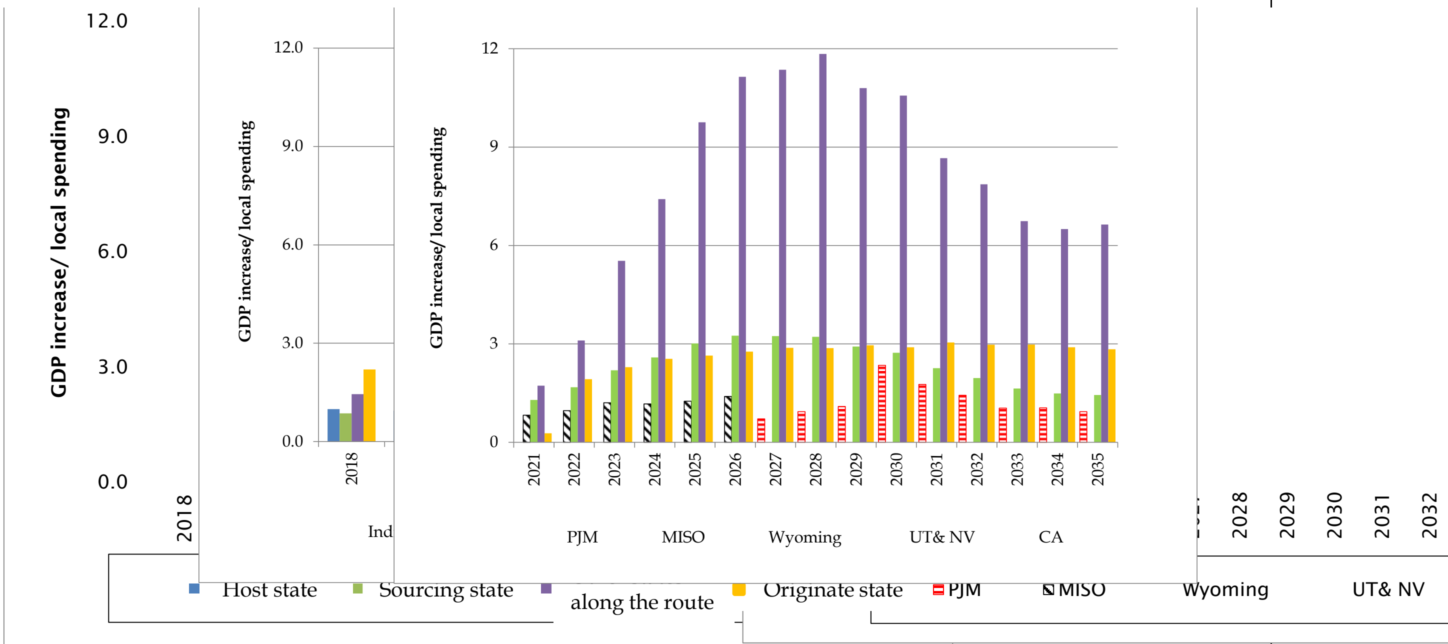


Figure 102. Job increase per local spending (construction period) and job increase per local spending plus retail savings (operations period)