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Addendum StartPage: 0

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**PROJECT NO. 48539**

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| **REVIEW OF THE INCLUSION OF MARGINAL LOSSES IN SECURITY CONSTRAINED ECONOMIC DISPATCH** | § § § § § § | **PUBLIC UTILITY COMMISSION OF TEXAS** |

FILING CLERK

## COMMENTS OF INVENERGY LLC

Invenergy LLC ("Invenergy" or "Company") submits the following responses to the request for comments issued by the Public Utility Commission of Texas ("Commission") on August 9, 2018.

## I. INTRODUCTION

Since Invenergy was founded in 2001, it has developed over 20,400 MW of generation capacity using natural gas, wind, solar, and energy storage. The Company currently has 10,900 MW of operational generation capacity, with 2,040 MW across 11 operational projects in Texas alone. In 2017, these Texas projects generated over $34 million in economic development benefits for the state. Invenergy's investments in the ERCOT market have been facilitated by, and have relied on, ERCOT's unique energy-only market design with "postage stamp" transmission pricing.

In ERCOT, the cost of transmission construction and upgrades is rolled into costs that all ratepayers pay. This is known as the postage stamp transmission rate because it is the same access fee regardless of location within the ERCOT grid. Legislators and regulators in Texas intentionally designed the ERCOT competitive retail market to eliminate distance sensitive transmission pricing to ensure that the power system provides cost-effective service to, and in turn maximizes economic benefits for, electric retail customers.[1] The decision to exclude marginal losses at the outset of the competitive retail market created a competitively neutral pricing system for customers, no matter where generation that serves them is located. The deliberate exclusion of marginal losses from transmission pricing in ERCOT has indeed led to vigorous competition between producers on the basis of the cost to produce power, and ultimately translated to lower prices for customers in Texas.

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[1] *See* Public Utility Regulatory Act ("PURA") § 39.004(d) (requiring the Public Utility Commission of Texas ("Commission") to price wholesale transmission services within ERCOT based on the postage stamp method); *see also* Order Adopting Amendments to 16 TAC § 25.192, et al, Project No. 21080 (Dec. 9, 1999) (In adopting its rules to implement postage stamp pricing, the Commission noted that "the ERCOT transmission system acts as a single network that all of the customers use...Where transmission customers use the entire network, they should share in the costs of use and expansion of facilities throughout the network.").



30

Implementing marginal losses into locational marginal pricing ("LMP") would be a dramatic reversal of a fundamental market design element in the ERCOT market that currently recognizes that all customers benefit from an interconnected transmission grid. Therefore, the Company respectfully urges the Commission to maintain the long-standing state policy of broadly sharing transmission costs, which provides greater economic output for the State of Texas, provides customers with material energy cost savings, increases the number of jobs in Texas, and equates to lower production costs.

## II. COMMENTS

1. **What are the benefits of implementing the use of marginal transmission losses rather than average transmission losses in the Electric Reliability Council of Texas' (ERCOT) Security-Constrained Economic Dispatch (SCED) over the long-term?**

Implementation of the use of marginal transmission losses rather than average transmission losses in ERCOT's SCED would not have benefits to Texans. In fact, it would have long-term material costs to Texans.

Invenergy LLC and Pattern Development, in 2017, engaged PA Consulting Group, Inc. ("PA Consulting") to conduct a forward-looking analysis of the economic impacts associated with incorporating marginal losses into ERCOT's energy-only wholesale market. A copy of PA Consulting's report: "*The Long-term Impacts of Marginal Losses on Texas Electric Retail Customers (April 2018)*" is provided hereto as Attachment 1 to this response.[2] This forward-looking analysis compares two scenarios: implementing marginal losses or continuing to use average losses, and finds that implementing marginal losses would result in materially lower economic output than continuing ERCOT's current market design.

The logic supporting this finding is straightforward: implementing marginal losses penalizes zero-marginal cost renewable resources, which in Texas, are located farther from load. Imposing this penalty reduces future investment in renewable resources, which in turn increases reliance on more expensive thermal generation located closer to load. This would increase system production and energy costs for customers in ERCOT. Specifically, PA Consulting's analysis demonstrates that the current market structure provides greater economic output for the State of Texas, provides customers with material energy cost savings, increases the number of jobs in Texas. PA Consulting found that "induced economic output and the number of induced jobs attributable to energy cost savings would be higher under the current market structure than under a market where marginal losses are included in

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[2] Invenergy also filed a copy of the report in Project 47199, Item No. 93, Project to Assess Price-Formation Rules in ERCOT's Energy-Only Market (April 20, 2018).

LMP formation...nearly 26,600 additional FTEs and an additional $5.8 billion in economic output would be generated by induced economic activity under the current market structure compared with a market where marginal losses are included in LMP formation."[3]

In theory, marginal losses are supposed to incentivize the siting of generation closer to load centers. This would increase *physical* efficiency by reducing physical losses over transmission lines. In a traditional power system based exclusively on thermal generation resources, this increase in *physical* efficiency is expected to improve *economic* efficiency by reducing the overall system cost to produce electricity, since less electricity needs to be produced to meet demand and the marginal cost of thermal generation is well above zero due to fuel and operating costs. However, such conditions do not exist in the reality of Texas, for a host of reasons. Therefore, implementing marginal losses will likely lead to higher costs for customers in Texas.

Renewable resource potential in Texas is often highest in areas far from load, which means that there are inherent limits to how close renewable generation can be located to load. This also implies that moving closer to load requires accepting lower renewable resource potential sites, further reducing renewable energy generation. If marginal losses decrease investment in renewable energy generation and output, the corresponding increase in production costs can far outweigh any benefits from physical efficiency gains.

PA Consulting's findings demonstrate that in ERCOT, focusing on optimizing the physical efficiency of system dispatch will not optimize economic efficiency for Texas customers in the long-run. The ERCOT market is unique—among several reasons—in the physical realities of resources that support generation in Texas. The best renewable generation potential is located within the western and northern portions of Texas, far from most electricity demand, which is concentrated in regions farther east and south. Wind and solar resources are different from thermal generation in that the marginal cost of producing electricity from wind and solar is close to zero, whereas the marginal costs of thermal resources are much higher due to fuel and other operating costs. However, wind and solar resources are constrained by natural resources in their ability to physically locate by proximity to load. Fundamentally changing the market to include marginal transmission losses would decrease the development of renewable generation and, in turn, overall electricity production of zero marginal cost renewable resources on the ERCOT system. More thermal generation with higher marginal costs then would be needed on the system to meet future customer demand, thus increasing system production

[3] *See* Attachment 1, *The Long-term Impacts of Marginal Losses on Texas Electric Retail Customers*, at 20 (April 2018).

and energy costs for customers. If thermal generation was unable to be built near load centers, like Houston, because of economic or environmental restrictions, costs of existing thermal generation would increase even higher to the detriment of customers.

2. **Are the benefits identified in response to Question 1 sufficient to justify the near-term costs to the market as a whole? Please consider individual stakeholder implementation costs as well as the costs to ERCOT identified in its study.**

As described in the response to Question 1, the implementation on marginal losses would not benefit the market as a whole over the long-term, and would result in not only near-term costs but long-term costs due to losing the economic benefits that are provided by the current market structure. PA Consulting's analysis finds that the current ERCOT market structure is highly beneficial and cost-effective for customers in Texas compared to a market structure that includes the implementation of marginal losses. Specifically, PA's analysis demonstrates that the current market structure provides greater economic output, provides customers with material energy cost savings, increases the number of jobs in Texas, reduces production costs relative to a market with marginal losses, and provides material emissions savings.

Moreover, while the implementation costs estimated by ERCOT[4] may be relatively modest, the impacts on selected stakeholder groups are likely to be orders of magnitude larger– particularly over the longer term. The implementation of marginal losses would amount to a reallocation of wealth to particular stakeholder groups. As Dr. Hogan has noted in an April 7, 2014, paper entitled "Refunds of Refunds":

> A central role of a well-designed market is to allow parties to operate more efficiently by unbundling generation, transmission, distribution, and all the related supply activities needed to serves load. However, if the rules of the market increase the chances that costs and benefits of one segment or participant will be reallocated to others, there is a reduced incentive to unbundle and trade, and an increased incentive to reintegrate to internalize the uncertain transfer payments.[5]

3. **What are the effects on retail customers and the retail market from the implementation of marginal transmission losses?**

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[4] *See* ERCOT's Report in Response to Commission Staff's Request, Project No. 47199, Item No. 12 (Jul. 14, 2017).

[5] Hogan, William W. "Refunds on Refunds" (Apr. 7, 2014), available at: https://sites.hks.harvard.edu/fs/whogan/Hogan_Refunds_040714.pdf at 6.

Implementing marginal transmission loss pricing will increase costs for retail customers, over the long-term, and fundamentally change a core design element of the competitive ERCOT market that has led to vigorous competition between producers on the basis of the cost to produce power, and ultimately translated to lower prices for customers in Texas. ERCOT's historical method of allocating transmission losses ensures that generation resources compete on a level playing field to provide cost-effective service to retail customers. PA Consulting's study found that the current market structure will provide significantly greater energy cost savings over the next 20 years compared to a market where marginal losses are included in LMP formation due to higher levels of low variable cost power generation in ERCOT under the current market structure. Furthermore, generation resources cannot be located anywhere on the system at the same cost. Therefore, the costs to customers are greater if the Commission decides to implement marginal losses.

4. **The ERCOT study of using marginal transmission losses instead of average transmission losses in SCED simulated one year. How would cumulative, multi-year impacts of using marginal transmission losses be different, if at all?**

As described in the answer to Question 1, PA Consulting conducted a 20-year study on the impact of marginal losses on the ERCOT market. While both the ERCOT study and PA Consulting's study indicates that the implementation of marginal losses would lead to modest near-term benefits in production cost savings, over the long-term, PA Consulting found that the implementation of marginal losses would increase system energy costs by $4.6 billion and decrease economic output within the state of Texas by $7.1 billion over the 20-year study period. Moreover, PA Consulting's study found that the implementation of marginal losses would lead to 29,500 fewer full-time employees ("FTE") in Texas, or approximately 1,500 fewer FTEs per year on average, with the implementation of marginal losses.[6]

The primary reason for these production and energy costs savings under the current average cost structure is that higher levels of low-cost marginal renewable generation would occur under the current market structure, as compared to a market where marginal losses are included in LMP formation. These higher levels of low-marginal cost generation reduce ERCOT's reliance on more expensive thermal generators in most years of the study period, which significantly decreases total system production costs by decreasing fuel and variable operations and maintenance costs of generators on the ERCOT system. This same dynamic also leads to lower all-hours power prices in

[6] *See* Attachment 1 at 5.

ERCOT under the current market structure of average losses, which leads to lower total energy costs in ERCOT. Energy costs represent the total cost of electricity consumed on the ERCOT system, inclusive of transmission losses.

5. **What costs would be incurred by market participants if marginal losses were implemented in the ERCOT market? Please provide an estimate of the costs that would be incurred by your company or companies or customers represented by your organization. Please describe the elements of those costs.**

Invenergy operates approximately 2,040 MW of both renewable and thermal generation resources in Texas, predominantly in West Texas. The Company has made prudent business decisions regarding the long-term viability of its generation portfolio in ERCOT, and has put in place appropriate contract structures based on the historical market rules. Invenergy estimates significant financial damages if marginal losses are implemented in the ERCOT market. Financial damages would be derived from lower LMPs at Invenergy's generator buses because of the inclusion of marginal losses. Incorporation of marginal losses would change a fundamental market structure premise upon which Invenergy and many other generators took judicious economic actions.

In general, ERCOT's marginal loss study showed the annual generator revenue changes for renewable generators is provided below:[7]

**Change in Annual Generator Revenue (Renewable, in $M)**

| | Low Gas Price Case | Base Case | High Gas Price Case |
|---|---|---|---|
| North Zone | -4.2 | -4.7 | -4.2 |
| South Zone | -14.2 | -13.5 | -16.0 |
| West Zone | -115.2 | -131.8 | -132.5 |

ERCOT's marginal loss study also showed the following results for energy production from wind generation units in West Texas:[8]

[7] *See* Attachment 2, excerpt from ERCOT Marginal Losses Study Q&A (Sept. 5, 2018), available at: http://www.ercot.com/mktinfo/rtm/marginallosses.

[8] *See id.*

**Wind Generation in West Texas**

| | Low Gas Price Case | Base Case | High Gas Price Case |
|---|---|---|---|
| Average Losses (GWh) | 59,519.8 | 59,524.7 | 59,514.8 |
| Marginal Losses (GWh) | 59,536.1 | 59,548.3 | 59,551.0 |

6. **How would a decision to use marginal transmission losses affect your company's market systems?**

See response to Question 7.

7. **How would a decision to use marginal transmission losses affect your company's internal operations?**

Adding Marginal Losses to the LMP prices would require several changes to Invenergy's market systems and internal operations. Changes would include the programming of Invenergy's Energy Trading and Risk Management system and its RTO Bid to Bill system that connects to ERCOT for market bids and offers and for Settlements. Both systems currently handle both the energy prices and congestion prices in ERCOT, and would need to be modified to include the third element of marginal losses. This would make Shadow Settlements more complicated and would require additional processes to verify the loss charges faced by each generator. In other RTOs that include losses in the calculation of LMP, Invenergy has experienced much more frequent corrections of market prices, than currently in ERCOT. Each time those market price corrections occur, the settlements processes must be re-run to check the new values.

8. **What are the effects on reliability on the ERCOT grid of using marginal transmission losses instead of average transmission losses in SCED?**

According to the PA Consulting study, the current market construct results in more wind and solar capacity installed in the West Zone.[9] In Texas, this is where much of the oil and gas production is

[9] Attachment 1. *The Long-term Impacts of Marginal Losses on Texas Electric Retail Customers*, at p. 15

currently located. Marginal losses would discourage new projects near oil and gas production areas, which could lead to reliability problems on a on localized basis and impair the economic extraction of fossil fuels.

9. **What effects, if any, would marginal transmission losses have on grid hardening and resilience?**

Invenergy has no comments in response to this question at this time.

10. **What effects would the use of marginal transmission losses in SCED have on grid reliability in regions of the ERCOT grid where non-synchronous generation is more prevalent?**

Implementation of marginal losses is likely to decrease reliability in regions of ERCOT where non-synchronous, inverter-based generation is most prevalent. As noted in ERCOT's whitepaper "Inertia: Basic Concepts and Impacts on the ERCOT Grid" (April 4, 2018):[10]

> "Synchronous generation commitment patterns are strongly affected by both system load and by the amount of non-synchronous (wind and solar) generation on the system. Consequently, system inertia is correlated with net load, which is load minus the aggregated wind and solar generation. If there is an abundant amount of wind or solar generation at times of low load conditions, wholesale energy market prices may be low or even negative. During these conditions, synchronous generators may choose to remain offline for economic reasons, which reduces system inertia."

Implementation of marginal losses will lower prices in those areas where non-synchronous generation is prevalent. This increases the incentive for existing synchronous generators to remain offline and decreases the incentives for new synchronous to be built. Hence, implementation of marginal losses, everything else held equal, will tend to reduce reliability and/or increase the costs of maintaining a given level of reliability in those regions where non-synchronous generation is prevalent.

11. **How would a decision to implement marginal transmission losses affect investment in new generation resources in ERCOT over the next five years, the next 10 years, and in the years beyond 10 years?**

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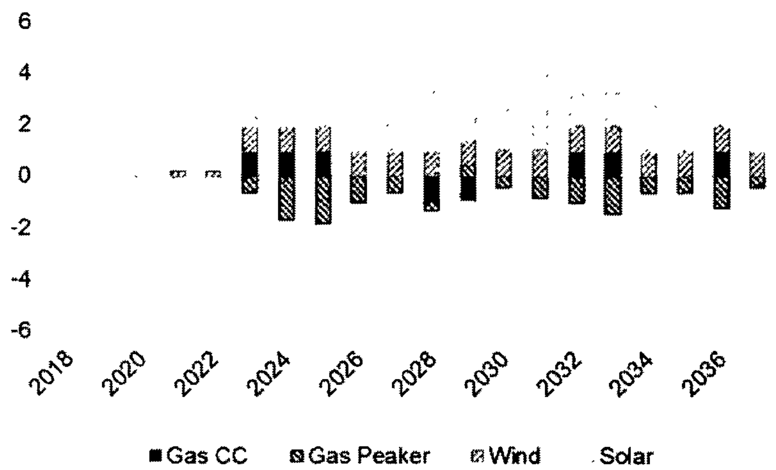
[10] Available at: http://www.ercot.com/content/wcm/lists/144927/Inertia_Basic_Concepts_Impacts_On_ERCOT_v0.pdf

Implementing marginal loss transmission pricing will reduce nodal prices in the ERCOT West zone,[11] thereby affecting the economic viability of renewable generation in ERCOT. PA Consulting's analysis demonstrates that the integration of marginal losses into LMP formation would change the generation mix, reducing investment in new renewable generation resources in ERCOT. Over the next five years, PA Consulting's analysis demonstrates limited impact on investment decisions. However, over the subsequent 15 years, the implementation of marginal losses will significantly reduce installed wind and solar capacity on the ERCOT system as compared with continuing the current ERCOT market structure.

**Difference in Total Installed Capacity Between PA's Average Losses vs. Marginal Losses Cases (GW)**




The majority of the difference in wind capacity additions takes place in the West Zone, with more wind capacity installed in the West Zone under the current market structure. Similarly, the differences in installed solar capacity by zone reflect the economic favorability of solar development in the West Zone under the current market structure. Conversely, including marginal losses in LMP formation results in reduced solar development in the West Zone by roughly 800 MW by 2037, compared to the current market structure of average losses.

The higher levels of wind and solar capacity under the current market structure are partially offset by slightly lower levels of natural gas-fired peaking capacity than would otherwise be expected with marginal losses included in LMP formation. The locations of combined cycle and peaking capacity additions are also different under the current market structure compared to a market where

[11] *See* Attachment 2, excerpt from ERCOT Marginal Losses Study Q&A (Sept. 5, 2018).

marginal losses are included in LMP formation. Specifically, with marginal losses included in LMP formation, more capacity is built in the Houston and South Zones near population centers, reflecting increased power pricing closer to load in those Zones.

12. **How would the implementation of marginal transmission losses affect the composition of the generation fleet in ERCOT?**

PA Consulting's long-term study found that the implementation of marginal losses would materially reduce the amount of wind and solar capacity in ERCOT over the next 20 years. As shown in response to Question 11, by 2037, under the current market structure, installed wind and solar capacity in ERCOT would be higher, respectively, than under a market where marginal losses are incorporated into LMP formation. PA Consulting projects no net difference in combined cycle development over the full study period. That is likely because changing the methodology for calculating transmission losses from an average to marginal basis would not actually result in new generation capacity sited closer to load centers.

The changes in annual generator revenue and annual generation by zone and technology shown by ERCOT's model for the base case and two sensitivities are provided in Attachment 2.

13. **Assuming the Commission decided to go forward with implementation of marginal transmission losses, what are the key issues related to determining the appropriate treatment and allocation of the marginal transmission loss surplus revenues?**

Implementing marginal loss pricing in ERCOT will result in over-collection of $205 million of loss revenues.[12] If the Commission decides to implement marginal loss pricing, then it also must answer the question of how to handle over-collection and reallocation of those surplus dollars ***before*** deciding to change the market pricing. Determining the methodology for allocating over-collected marginal loss payments among loads and generators should not be subject to a separate policy discussion. The Commission should determine the allocation methodology as part of its consideration of whether to change the market to include marginal transmission losses.

ERCOT's September 29, 2017, in response to Commission Staff's request on an estimated cost and implementation time of the inclusion of marginal losses mentions that "a mechanism would need to be developed to distribute these excess revenues" but does not specify the time and money that

[12] Brattle Group. "Impact of Marginal Loss Implementation in ERCOT." October 11, 2017.

would be attributed to that aspect.[13] As other RTOs have experienced, management of the overcollection of losses is not a trivial matter and creates a significant amount of new work for staff. As well as having to determine the methodology, ERCOT would have to incur costs and time in the actual management of the reallocation of the surplus.

14. **Does the ERCOT analysis of the benefits of including marginal transmission losses in SCED accurately measure such benefits? Are potential costs to the market or to market participants adequately accounted for?**

ERCOT's analysis of the benefits of including marginal transmission losses in SCED is a reasonable estimation of the benefits of marginal transmission losses over the single simulated year. However, we believe that analyzing a single year is an insufficient timeframe to appropriately capture the impacts of such an important market structure change.

PA Consulting's long-term study demonstrates that while there may be some near-term benefits, implementing marginal losses creates material long-term negative consequences. In particular, it would lead to higher long-term energy costs for customers, lower economic output in Texas, and fewer jobs.

15. **What ERCOT operational changes would need to be made that are not considered in ERCOT's studies?**

Invenergy has no comments in response to this question at this time.

16. **Would the use of marginal transmission losses in SCED change the ERCOT transmission planning process and transmission build-out?**

The implementation of marginal losses should not change the ERCOT planning process, but would, of course change the factors considered in transmission build-out decisions and have an impact on the projects selected for build-out as a result of the planning process and the Commission's approval process.

17. **Assuming that the implementation of marginal transmission losses results in the location of generation closer to load, what advantages and disadvantages would there be during an emergency event or a market restart to having generation located closer to load?**

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[13] *See* ERCOT's Second Report in Response to Commission Staff's Request. Project No. 47199. Item No. 22. at 6 (Sep. 29. 2017).

Implementing marginal losses would in theory provide economic incentives to add generation resources in Houston. Notwithstanding the barriers to constructing utility-scale generation sources near load, the Houston area is also at risk of hurricanes and flooding, making a market restart during an emergency event more difficult in the event even more generation is located there.

Additionally, over-reliance or concentration of generation on the same natural gas pipelines could have systemic implications in the case of a targeted attack on natural gas pipeline infrastructure or flooding event that forces pump stations to shut-down.

Under any emergency condition, geographic diversity of resources is likely to be more beneficial. Rather than encouraging all generation in the same location, the current geographic diversity should continue to be encouraged, as a geographically diverse portfolio enhance overall reliability.

18. **What effects, if any, would the implementation of marginal transmission losses have on the Congestion Revenue Rights (CRR) market?**

Since the implementation of marginal losses will increase "transmission" costs from generation-rich, low cost portions of ERCOT to those portions of ERCOT that are load dominant and higher cost, it will result in less transmission use and less congestion, on the margin. Hence, this can be expected to reduce the relative value of CRRs and overall CRR market liquidity.

19. **How should the commission direct ERCOT to implement marginal transmission losses in a way that mitigates any deleterious effects on the CRR market?**

Any impacts on the CRR market result from the basic economic impacts of implementing marginal losses, rather than any specific implementation path. Therefore, the Commission cannot lessen the impact of implementing marginal transmission losses on the CRR market.

20. **Does your assessment of the incorporation of marginal transmission losses change based on the timeline of implementation?**

No. Regardless of any particular timeline of implementation, marginal transmission losses will not benefit Texas customers in the long-run, for reasons explained in Invenergy's responses herein.

21. **What are the effects of implementing both Real Time Co-optimization (RTC) and marginal transmission losses on reliability and price formation?**

See response to Question 23.

22. **Are there any synergies that may result from contemporaneous adoption of both RTC and marginal transmission losses?**

See response to Question 23.

23. **What are the effects on retail customers and the retail market from the implementation of both RTC and marginal transmission losses?**

Implementing the use of marginal transmission losses would decrease the development and overall electricity production of zero marginal cost renewable resources on the ERCOT system. To meet future customer demand, more thermal generation with higher marginal costs then would be needed on the system, thus increasing system production and energy costs for customers. If thermal generation was unable to be built near load centers, like Houston, because of economic or environmental restrictions, costs of existing thermal generation would increase even higher to the detriment of customers.

## III. CONCLUSION

Invenergy appreciates the opportunity to provide comments in this Project and looks forward to further discussing these issues with the Commission.

Respectfully submitted,


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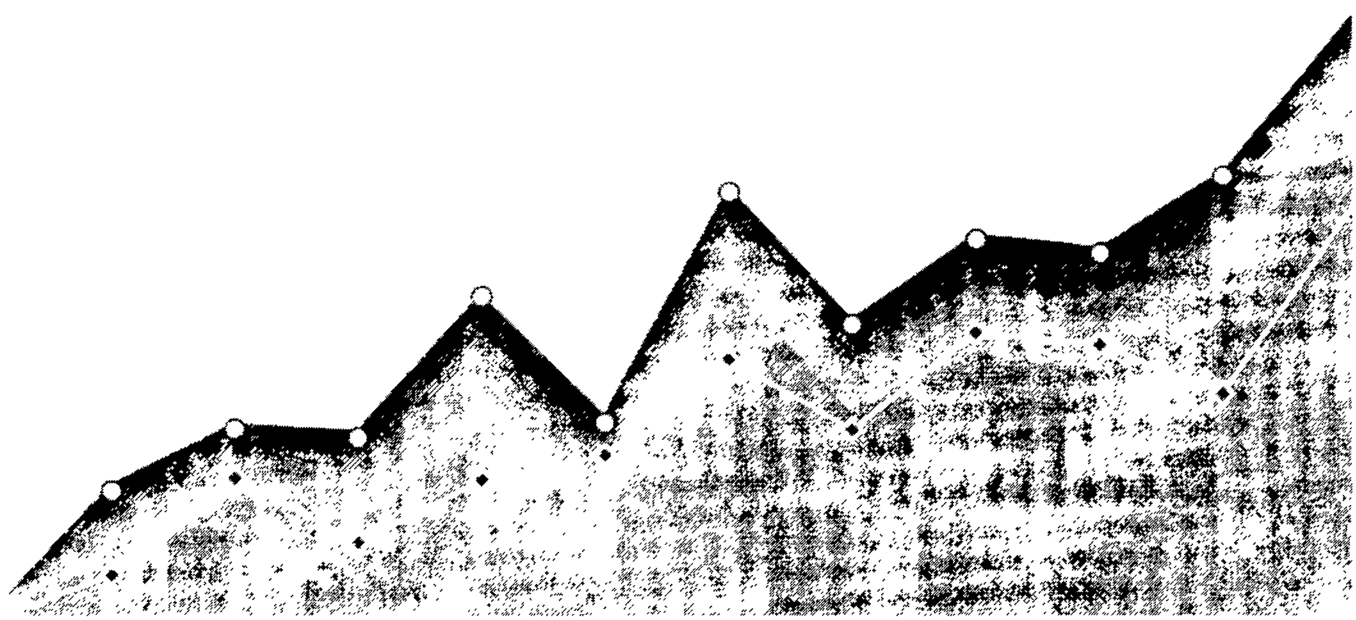
Attachment 1
Project 48539

# THE LONG-TERM IMPACT OF MARGINAL LOSSES ON TEXAS ELECTRIC RETAIL CUSTOMERS

April 2018



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# DISCLOSURES AND DISCLAIMERS

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The methodology, analysis, and findings expressed in this report are current as of April 2018 and, where applicable, incorporate underlying market data as of November 30, 2017 They were prepared by PA Consulting Group, Inc. ("PA") at the request of Invenergy LLC and Pattern Development. PA is not responsible for any loss or damage to any third party as a result of their use or reliance (direct or otherwise) on PA's analysis and this report.

# CONTENTS

# FIGURES AND TABLES

## FIGURES

## TABLES

# EXECUTIVE SUMMARY

Historically, power generation owners within the Electric Reliability Council of Texas ("ERCOT") power market have made investment decisions based on the expectation of energy price formation that excludes marginal losses. However, recently, some power generation owners have voiced concerns that the ERCOT market is not providing high enough power pricing to justify past and future investment decisions.[1] These generation owners have advocated for several proposed market design changes, including the addition of marginal losses to locational marginal price ("LMP") formation.

To help better understand how the inclusion of marginal losses in LMP formation will impact electricity customers within the State of Texas, Invenergy LLC and Pattern Development engaged PA Consulting Group, Inc. ("PA") to conduct an independent long-term economic study. Specifically, PA's study is designed to answer the following question:[2]

> ***How will the inclusion of marginal losses in ERCOT's market structure impact electricity customers in the State of Texas over the long-term?***

To evaluate this question, PA conducted a forward-looking, long-term analysis (years 2018-2037) that assessed the economic and environmental impacts of integrating marginal losses into LMP formation. For this analysis, PA modeled the ERCOT market under two Cases: (i) a "Base Case" that reflects the current market structure and (ii) a "Forward Marginal Losses Case" that includes marginal losses in LMP formation.

PA's results demonstrate that **customers in Texas would be much better off under the current market structure without the integration of marginal losses**. Table 1 summarizes the results of PA's analysis.

**Table 1: Benefits of Current Market Structure versus Integration of Marginal Losses[3]**

| Timeframe: 2018-2037 | *Foregone Benefits to Texas if Marginal Losses are Implemented* |
|---|---|
| Economic Output in Texas | [redacted] |
| Energy Cost Savings | $4.6 Billion |
| Production Cost Savings | [redacted] |
| Additional Jobs in Texas | 29,500 FTEs |
| $CO_2$ Emissions Savings | [redacted] |
| NOx Emissions Savings | 13.8 Thousand Tons |
| $SO_2$ Emissions Savings | [redacted] |

From a theoretical perspective, marginal losses are intended to improve the economic efficiency of a wholesale power market by increasing the dispatch of generators located closer to load centers, which improves the physical efficiency of the system by reducing transmission line losses. This is essentially achieved by financially penalizing electricity based on how far away from load centers it is produced. In a traditional power system based exclusively on thermal generation resources, this improvement in *physical*

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[1] Hogan, William and Pope, Susan "Priorities for the Evolution of an Energy-Only Market in ERCOT " PUCT Project Nos 40000, 41837, 45572. Informational Filing by Calpine Corporation and NRG Energy Inc 10 May 2017 <http //interchange puc state tx us/WebApp/Interchange/Documents/40000 669 939373 PDF>

[2] PA's modeling process is described in detail in Section 3, titled "Methodological Overview "

[3] Unless otherwise stated, all financial figures are in nominal dollars assuming a 2 2 percent per annum average inflation rate, FTE· Full Time Equivalent; all emissions are quoted in short tons.

efficiency can improve *economic* efficiency by reducing the overall system cost to produce electricity, since less electricity needs to be produced to meet demand. However, PA's findings demonstrate that in a unique market like ERCOT, focusing on optimizing physical efficiency of system dispatch misses the forest for the trees, as **optimizing physical efficiency does not necessarily optimize economic efficiency for Texas customers in the long-run**.

The ERCOT market is unique—among several reasons—in that the best renewable generation potential is located within the western and northern portions of the State, whereas the majority of electricity demand is concentrated in regions farther east and south. Wind and solar resources are different from thermal generation in that the marginal cost of producing electricity from wind and solar is close to zero, whereas the marginal costs of thermal resources are much higher due to fuel and other operating costs.

PA finds that the implementation of marginal losses would alter future power generation investment decisions Since implementation of marginal losses would financially penalize resources farther from load, it would decrease the development and, in turn, overall electricity production of zero marginal cost renewable resources on the system. In turn, higher levels of thermal generation would be needed on the system, which have higher marginal costs than renewable generation, thus increasing system production and energy costs in a system with marginal losses implemented. This indicates a less optimal economic outcome for consumers.

The decision not to implement marginal losses is just one example of how of market structure decisions that take into account ERCOT's unique system attributes can drive significant long-term benefits to the customer. To further demonstrate this dynamic, PA also evaluated the economic and environmental impacts of the generation development enabled by construction of the Competitive Renewable Energy Zones ("CREZ") transmission projects, which facilitated renewable energy development in ERCOT by removing transmission constraints between wind- and solar-rich regions and load centers.

PA conducted a historical analysis (years 2010-2017) and forward looking analysis (years 2018-2037) that evaluated the economic impacts of CREZ and associated renewable energy development. For these analyses, PA modeled the ERCOT power market under two Cases: (i) a "Base Case" that reflects the current market structure and (ii) an "Elimination of CREZ Case" that assumes the CREZ projects did not enter service, which leads to less renewable generation being constructed in ERCOT. PA's analysis demonstrates that **customers in Texas have been (and will be) materially better off with CREZ and associated renewable development**. The results of this analysis are shown in Table 2:

**Table 2: Benefits of Current Market Structure versus the Exclusion of CREZ**

| | *Historical benefits to Texas driven by CREZ (2010-2017)* | *Future benefits to Texas driven by CREZ (2018-2037)* | *Total benefits to Texas driven by CREZ (2010-2037)* |
|---|---|---|---|
| **Economic Output in Texas** | [redacted] | [redacted] | [redacted] |
| **Energy Cost Savings** | $2.8 Billion | $33.9 Billion | $36.7 Billion |
| **Production Cost Savings** | [redacted] | [redacted] | [redacted] |
| **Additional Jobs in Texas** | 46,400 FTEs | 238,600 FTEs | 285,000 FTEs |
| **$CO_2$ Emissions Savings** | [redacted] | [redacted] | [redacted] |
| **NOx Emissions Savings** | 42.2 Thousand Tons | 175.4 Thousand Tons | 217.8 Thousand Tons |
| **$SO_2$ Emissions Savings** | [redacted] | [redacted] | [redacted] |

ERCOT's unique energy-only market design is intended to allow competitive market forces to drive power generation investment in a manner that is most efficient for the consumer. This intent is reflected in historical approaches to transmission pricing and cost allocation within the State of Texas and ERCOT, which represent deliberate efforts by legislators and regulators to ensure that the power system provides cost-effective service to, and in turn maximizes economic benefits for, electric retail customers across the

State. PA's analysis demonstrates that the current ERCOT market structure has facilitated these goals, and will continue to facilitate these goals, with the exclusion of marginal losses from LMP formation.

# INTRODUCTION

Historically, power generation owners within the ERCOT power market have made investment decisions based on the expectation of energy price formation that excludes marginal losses. However, some power generation owners have recently voiced concerns that the ERCOT market is not providing high enough power pricing to justify past and future investment decisions. These generation owners have advocated for several proposed market design changes, including the integration of marginal losses in LMP formation.

To help better understand how the inclusion of marginal losses in LMP formation would impact electricity customers within the State of Texas, Invenergy LLC and Pattern Development engaged PA Consulting Group, Inc. to conduct an independent long-term economic study Specifically, PA's study is designed to answer the following question:[4]

> ***How will the inclusion of marginal losses in ERCOT's market structure impact electricity customers in the State of Texas over the long-term?***

PA's analysis finds that the current ERCOT market structure is highly beneficial and cost-effective for customers within the State of Texas compared with the implementation of marginal losses. Specifically, PA's analysis demonstrates that the current market structure provides greater economic output for the State of Texas, provides customers with material energy cost savings, increases the number of jobs in Texas, has lower production costs, and provides material emissions savings.

## Background

The ERCOT power market is unique among North American electric regions in that it relies on an energy-only market design to ensure reliability. In an energy-only market, a generator must seek to recover fixed costs when energy prices rise above that generator's short-run marginal costs. This is in contrast to most other competitive wholesale markets in North America, in which generators are able to recover fixed costs through capacity markets or bilateral capacity contracts with incumbent utilities The intent of an energy-only market design is to allow competitive market forces to drive power generation investment in a manner that is most efficient for the consumer.

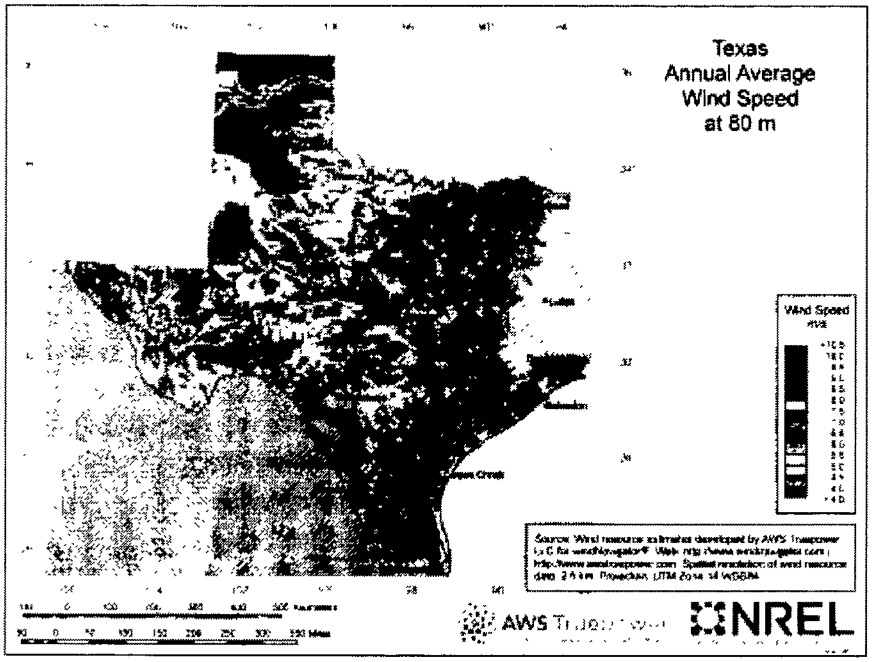
The ERCOT market is also unique in that the best renewable generation potential is located within the western and northern portions of the State (see Figure 1 and Figure 2 below), whereas the majority of electricity demand is concentrated in regions farther east and south. In other words, within Texas, renewable capacity cannot simply be sited closer to load and achieve the same generation outcome, so the economic case for renewable capacity sited closer to load is worse, all else equal.[5] Wind and solar resources are different from thermal generation in that the marginal cost of producing electricity from wind

[4] PA's modeling process is described in detail in Section 3, titled "Methodological Overview"

[5] In addition, land acquisition costs closer to load centers are likely materially higher than locations in the West and North Zones of ERCOT Furthermore, sufficient land may be physically unavailable closer to load centers given the required land parcel size to site cost-effective, large-scale renewable resources

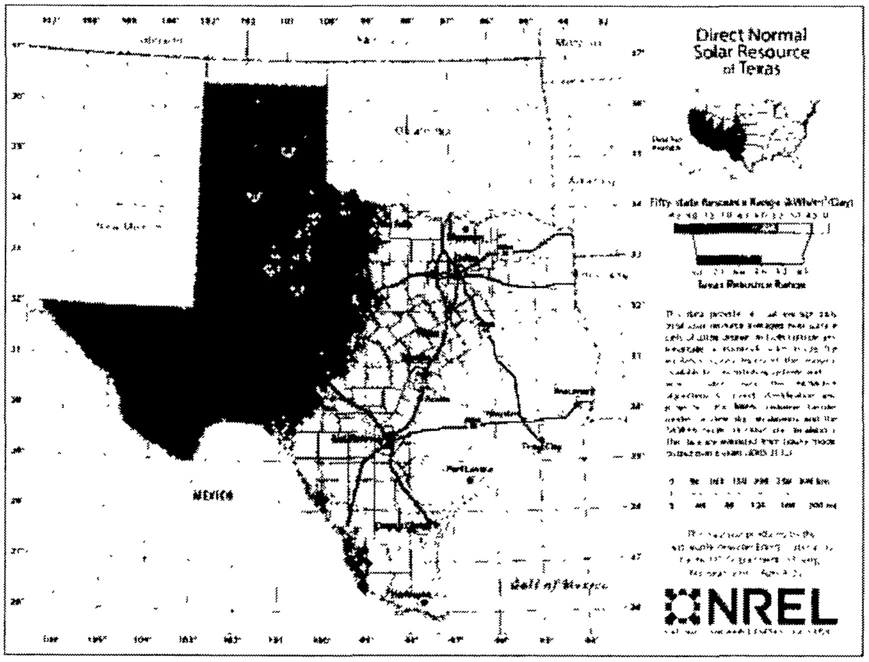
and solar is essentially zero, whereas the marginal costs of thermal resources are much higher due to fuel and other operating costs.

**Figure 1: Texas 80-Meter Wind Speed Map**[6]




[6] Source AWS Truepower, LLC, NREL

**Figure 2: Texas Solar Resource Map[7]**




Consistent with this purpose, Texas' historical approach to transmission planning and cost allocation within ERCOT represents a deliberate effort to ensure that generation resources compete on a level playing field to provide cost-effective service to retail customers. In its 1999 Report to the 76th Texas Legislature, "*The Scope of Competition in the Electric Industry of Texas*", the Public Utility Commission of Texas ("PUCT" or "Commission") stated that it "*adopted a uniform transmission pricing system for ERCOT*" to promote "*vigorous competition between producers on the basis of the price of power, and ultimately to lower prices for customers in Texas*"[8] A uniform transmission pricing system is one that excludes marginal losses from LMP formation In other words, the Commission has historically viewed the transmission system as a vehicle to promote competition among generators across the State so that the electricity system provides low-cost electric service to customers, in turn creating economic benefits across the state

With this view of the transmission system in mind, in 2005, the 79th Texas Legislature amended PURA §39 904 to direct the Commission to develop "*a plan to construct transmission capacity necessary to deliver to electric customers, in a manner that is most beneficial and cost-effective to the customers, the electric output from renewable energy technologies in the competitive renewable energy zones.*"[9] In October 2008, the Commission released its first major Order regarding CREZ, which determined the most beneficial and cost-effective level of transmission capacity for the CREZ projects. Between 2009 and 2014, the majority of CREZ-related transmission projects were built and energized, allowing for greater

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[7] Source NREL

[8] Page 36

[9] Within its first major order approving CREZ, the PUCT found within its finding of fact that "the intent of the Legislature in passing the amendments to PURA §§ 36 053, 39 203, and 39 904 in 2005 was to further encourage the development of renewable-energy resources by establishing a process to provide reliable and economical transmission resources ahead of renewable generation " (PUC Order, Project No 33672, 7 October 2008, Page 46) "

transfer capability of new renewable generation in the West and North Zones to load farther to the east within Texas.

For many years, power generation owners within the ERCOT power market have made investment decisions based on this expectation of uniform transmission pricing (i.e., no marginal losses) and the inclusion of the CREZ transmission projects. These investment decisions—especially those related to renewable generation—were incentivized via these deliberate market design choices by the State of Texas and occurred through the competitive forces unleashed by these market design choices.

However, some owners of generation resources have recently voiced concerns that the ERCOT market is not providing high enough power pricing to justify past and future investment decisions; these generators have argued that market design components such as the lack of marginal losses within LMP formation are negatively impacting the ERCOT power market via inefficient pricing signals.

On May 10, 2017, Calpine Corporation and NRG Energy, Inc. filed a paper titled "*Priorities for the Evolution of an Energy-Only Electricity Market Design in ERCOT*" under three separate PUCT Project Dockets (Nos. 40000, 45572, and 41837) [10] At the direction of the Commission, PUCT Staff opened a new Project on May 22, 2017, called the "*Project to Assess Price-Formation Rules in ERCOT's Energy-Only Market,*" under Project No. 47199. In this Project, Staff requested comment on the paper's "*price-formation concerns and proposed solutions.*"[11]

Seeking to add rigor to the assessment of potential impacts of some of these proposed market design changes within ERCOT, on October 12, 2017, a group comprised of First Solar, Inc., Vistra Energy Corp., and the Wind Coalition jointly filed an independent study titled "*Impacts of Marginal Loss Implementation in ERCOT: 2018 Reference Scenario Results.*"[12] This study found that production cost savings from the incorporation of marginal losses would be immaterial, while reductions to generator net revenues would be substantial. Further, on December 7, 2017, ERCOT and the Independent Market Monitor ("IMM") announced a plan to "*assess the benefits of the potential implementation of Real-Time Co-optimization ("RTC") and/or Marginal Losses in the ERCOT wholesale electricity market.*"[13]

PA's study complements these two quantitative studies by examining the comparative long-term economic and environmental benefits and costs associated with the current ERCOT market structure versus the implementation of marginal losses PA's findings indicate that the long-term economic and environmental benefits are materially higher under the current market structure versus with the implementation of marginal losses.

The decision not to implement marginal losses is just one example of how market structure decisions that appropriately take into about ERCOT's unique physical realities can drive significant long-term benefits to the customer through competitive market forces. To further demonstrate this dynamic, PA also evaluated the economic and environmental impacts of the generation development enabled by the CREZ transmission projects, which facilitated renewable energy development in ERCOT by removing transmission constraints between wind- and solar-rich regions (i.e., western and northern Texas) and load centers in eastern and southern Texas. Specifically, PA sought to answer the following questions:

- ***How have the CREZ transmission projects and associated generation development enabled by CREZ impacted electricity customers in the State of Texas to date?***

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[10] Ibid

[11] PUCT, "Memorandum Re Project No 47199 – Project to Assess Price-Formation Rules in ERCOT's Energy-Only Market – Agenda Item No. 9 "

[12] Performed by The Brattle Group.

[13] ERCOT, "Proposed Plan for Conducting Benefits Analyses," Project No 47199 7 December 2017, Page 1

- ***How will the CREZ transmission projects and associated generation development enabled by CREZ impact electricity customers in the State of Texas over the long-term on a going forward basis?***

While PA shows that the historical benefits resulting from the generation development enabled by the CREZ transmission projects are already significant, this development is projected to provide materially greater economic output for the State of Texas over the long-term, provide customers with significant energy cost savings, increase the number of jobs in Texas, lower production costs, and provide material emissions savings.

The remainder of this white paper is divided into three primary sections that describe (i) PA's methodology; (ii) the results of the study; and (iii) a discussion of the results

# METHODOLOGICAL OVERVIEW

To evaluate the long-term benefits and cost-effectiveness of the current market structure versus proposed alternatives, PA used its proprietary electricity market modeling process. The core of PA's modeling process uses an industry standard chronological dispatch simulation model (AURORA$^{xmp}$) to simulate the hourly operations of ERCOT.[14] The AURORA$^{xmp}$ model is widely used by electric utilities, power market regulators, independent system operators, and other market consultants. This model enables PA to project hourly power prices, energy flows, the development of new power plants, and the operating profiles of the power plants and transmission lines within a given system, in this case ERCOT.

To forecast the long-term wholesale natural gas prices that are used in AURORA$^{xmp}$, PA uses the GPCM® Natural Gas Market Forecasting System™ ("GPCM"). GPCM models natural gas production, existing pipeline flows and constraints, new pipeline construction, and natural gas demand from the power sector and residential, commercial, and industrial sectors for the entire United States PA used GPCM to develop a long-term forecast of both Henry Hub natural gas prices and the prices of regional natural gas pricing hubs applicable to the ERCOT region. GPCM is used across the energy industry, including by government agencies such as the U.S. Federal Energy Regulatory Commission ("FERC") and Canadian National Energy Board ("NEB"), as well as independent system operators such as the Midcontinent Independent System Operator ("MISO").

To estimate economic impacts, PA employed two widely utilized tools for Input-Output ("I-O") analysis: the Impact Analysis for Planning ("IMPLAN") model and the Jobs and Economic Development Impact ("JEDI") model. IMPLAN and JEDI both use data from multiple U.S. government sources and employ estimation methods based on industry accounts to project how changes in demand for specific types of goods and services are likely to affect a specific geographic region. Both models estimate economic impacts by relating projected expenditures specified by the user (e.g., the various costs of constructing a large industrial structure) with economic multipliers specific to Texas provided to PA by IMPLAN.[15]

PA modeled the ERCOT market under three primary Cases. These Cases include a Base Case that represents ERCOT's current market structure, as well as two other Cases to compare against the Base Case.

Aside from the assumption differences noted below, PA has kept assumptions consistent across the Cases (e.g., natural gas prices, new build construction costs, etc.) to facilitate comparisons. Importantly, PA's analysis does not alter construction costs for resources (thermal and renewable) built closer to load centers, although these costs (such as land acquisition) could be higher closer to load centers. PA's analysis also does not limit the amount of renewables that can be sited closer to load centers, even though acquiring the necessary land to site renewables near load centers could prove more difficult.[16] In addition, PA's analysis does not account for potential changes in transmission feeder and/or ancillary

[14] AURORA$^{xmp}$ is a product of EPIS, LLC

[15] PA acquired the necessary data concerning inter-industry accounts for Texas from IMPLAN

[16] PA allowed for the economic build out of renewable generation (both wind and solar) subject to the current backbone transmission system and did not assume any new backbone transmission projects

costs between the Cases, but PA notes that these costs are expected to be immaterial relative to the other analyzed impacts.

**Base Case (2010-2037):**

The Base Case represents the status quo environment within ERCOT. Marginal losses *are not* incorporated into LMP formation, and the CREZ transmission projects and associated generation projects built because of CREZ (e.g., western ERCOT wind projects) enter service at their historical and projected commercial online dates. Note that in projecting the development of new renewable energy plants, PA limited development according to the expected transmission limitations of the CREZ transmission upgrades – in other words, projected renewable additions do not require any new large-scale transmission development (and associated costs) in the state [17] Future investment decisions in ERCOT are impacted by the presence of CREZ and the exclusion of marginal losses from LMP formation.

**Forward Marginal Losses Case (2018-2037):**

This Case is designed to determine the long-term economic impacts associated with the integration of marginal losses in LMP formation The Forward Marginal Losses Case represents the Base Case world, but marginal losses *are* incorporated into LMP formation on a go-forward basis starting in 2018. Comparing this Case against the Base Case provides a basis for understanding whether the inclusion of marginal losses in LMP formation in ERCOT would be beneficial and cost-effective for customers in the State of Texas

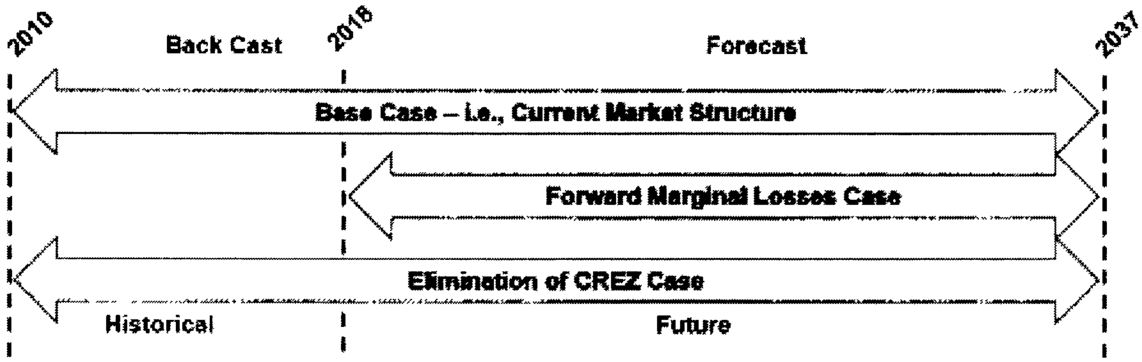
**Elimination of CREZ Case (2010-2017):**

This Case is designed to determine the economic impacts associated with the elimination of the CREZ transmission projects and associated renewable energy development made possible by the increased transmission capability due to CREZ. Comparing this Case against the Base Case provides an assessment of long-term economic and environmental impacts. Specifically, comparing this Case against the Base Case provides a basis for understanding whether CREZ was beneficial and cost-effective for customers in the State of Texas.

PA references this case using two names: (i) **Historical Elimination of CREZ Case** (2010-2017), and (ii) **Forward Elimination of CREZ Case** (2018-2037). The purpose in making this distinction is to separate historic from future benefits.

[17] Similarly, the Forward Marginal Losses Case incorporates these same limitations.

**Figure 3: Overview of Modeled Cases**



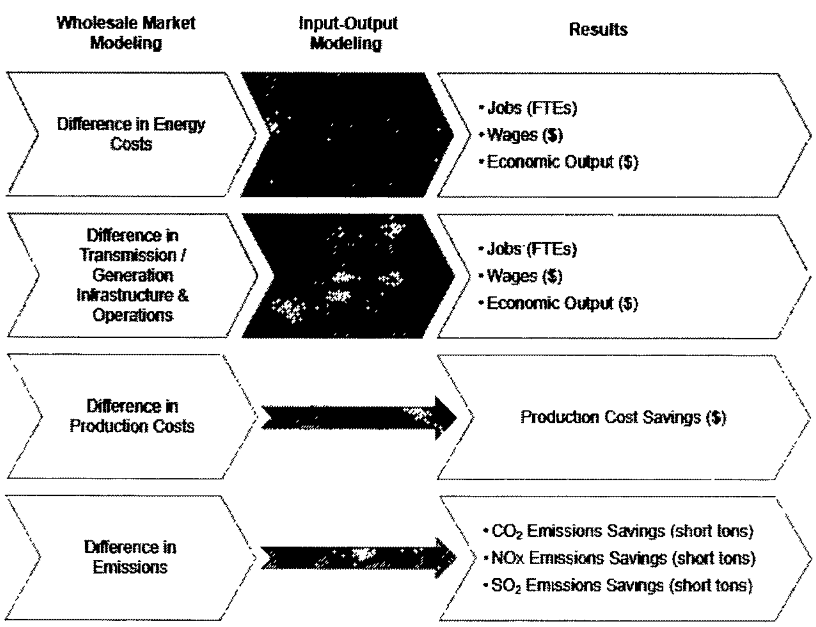
# RESULTS

PA's analysis demonstrates that the current market structure in ERCOT has been, and will continue to be, highly beneficial and cost-effective for electricity customers in the State of Texas.

The results of PA's analysis can be divided into two categories: (i) the results of the wholesale market analysis; and (ii) the results of the I-O analysis. The wholesale market results include differences in production costs, energy costs, generator investment decisions (e.g., differences in installed wind, solar, and natural gas-fired generation builds), and generator operations across the different Cases.

The I-O analysis results include direct, indirect, and induced economic benefits driven by the construction and operation of transmission and power generation infrastructure, as well as induced economic benefits due to energy cost savings.[18]

**Figure 4: Overview of Modeling Process and Results**




While reported within this results section of the study, we note that generator investment decisions (i e., capacity built and generation by fuel type) are not considered benefits in and of themselves. Rather, these investment decisions contribute to differences in construction, operation, production, and energy costs that drive differences in economic impacts for the State of Texas, and understanding these differing investment decisions between the Cases is crucial to understanding the economic and emissions results.

[18] Energy cost savings only provide induced economic benefits and do not provide direct or indirect economic benefits

Similarly, historical and projected production and energy cost savings are driven by a multitude of factors, some of which are unrelated to ERCOT's market structure. For example, renewable energy investment decisions and related changes to production and energy costs depend partly on federal subsidies for renewable generation (specifically the Production Tax Credit for wind and the Investment Tax Credit for solar). It is important to note that these subsidies will step down or expire completely in the near future. Additionally, low natural gas prices have contributed and will continue to contribute to lower production and energy costs since natural gas-fired generation is the predominant generation source on the ERCOT system and sets the price of power in a majority of hours. However, by keeping these external factors constant across Cases (as we have done in our analyses), it is possible to assess the incremental impacts of proposed changes to ERCOT's market structure to the economic benefits experienced by Texas electric retail customers.

# Forward Marginal Losses Results

To answer the question, "***How will the inclusion of marginal losses in ERCOT's market structure impact electricity customers in the State of Texas over the long-term?***", PA compared the results of the Base Case with the Forward Marginal Losses Case. The Forward Marginal Losses Case represents the Base Case world, but where marginal losses _are_ incorporated into LMP formation on a go-forward basis starting in 2018.

The results of this comparison demonstrate that the current market structure provides significantly greater benefits to customers going forward compared to including marginal losses in LMP formation.

Over the 2018-2037 timeframe:

- Total economic output would be $7 1 billion higher under the current market structure, with $5.8 billion of the additional economic output attributable to energy cost savings and $1.3 billion attributable to higher construction and operations expenditures.
- Under the current market structure, the ERCOT system would experience $5.1 billion of total future production cost savings and nearly $4.6 billion of total future energy cost savings over the next 20 years due to higher levels of low variable cost power generation.
- Under the current market structure, total future jobs in Texas over the next 20 years would higher by over 29,500 FTEs, with a 26,600 FTE increase attributable to energy cost savings and a 3,000 FTE increase attributable to higher construction and operations expenditures [19]
- Under the current market structure, total future $CO_2$ emissions over the next 20 years would be lower by 66.8 million tons, NOx emissions would be lower by 13,800 tons, and $SO_2$ emissions would be lower by 53,900 tons

**Wholesale Market Impacts**

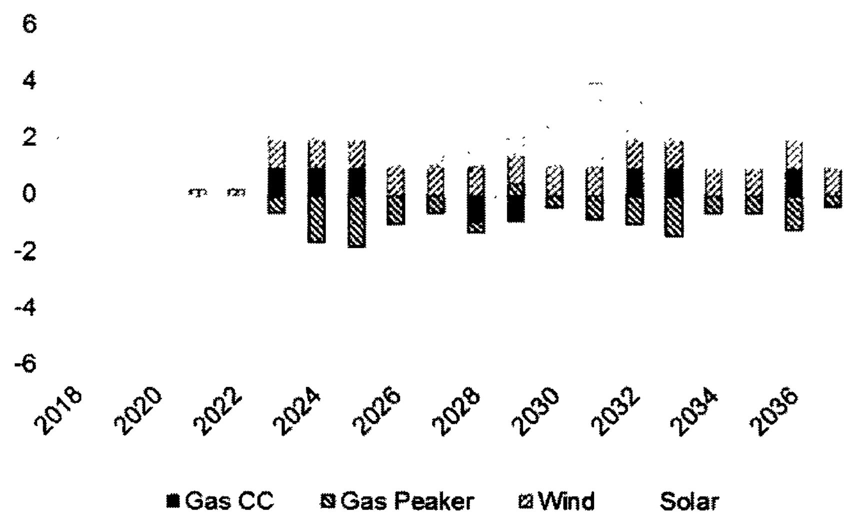
_Comparison of Capacity Built by Fuel Type_

PA's analysis demonstrates that the integration of marginal losses into LMP formation would lead to material changes in future power generation investment. In particular, PA's analysis projects a meaningful impact on the amount of new wind and solar development in ERCOT compared with continuing the current market structure Across the study period, the current market structure will lead to higher levels of installed wind and solar capacity on the ERCOT system as compared with a market where marginal

[19] When we refer to FTEs throughout this report, we are referring to full time equivalent jobs over a 12 month time frame So, two FTEs can be thought of a two jobs for one year or one job for two years. Additionally, numbers may not sum perfectly due to rounding

losses are included in LMP formation. See Figure 5. By 2037, under the current market structure, installed wind and solar capacity in ERCOT would be 3 percent and 4 percent higher, respectively, than under a market where marginal losses are incorporated into LMP formation, although gas peaker capacity would be 2 percent lower under the current market structure. There is no projected difference in combined cycle ("CC") development.

**Figure 5: Difference in Installed Capacity – Base Case vs. Forward Marginal Losses Case (GW)**




The majority of the difference in wind capacity additions under the current market structure takes place in the West Zone, with more wind capacity installed in the West Zone under the current market structure. Similarly, the differences in installed solar capacity by zone reflect the economic favorability of solar development in the West Zone under the current market structure. Conversely, including marginal losses in LMP formation results in reduced solar development in the West Zone by roughly 800 MW by 2037 compared to the current market structure.

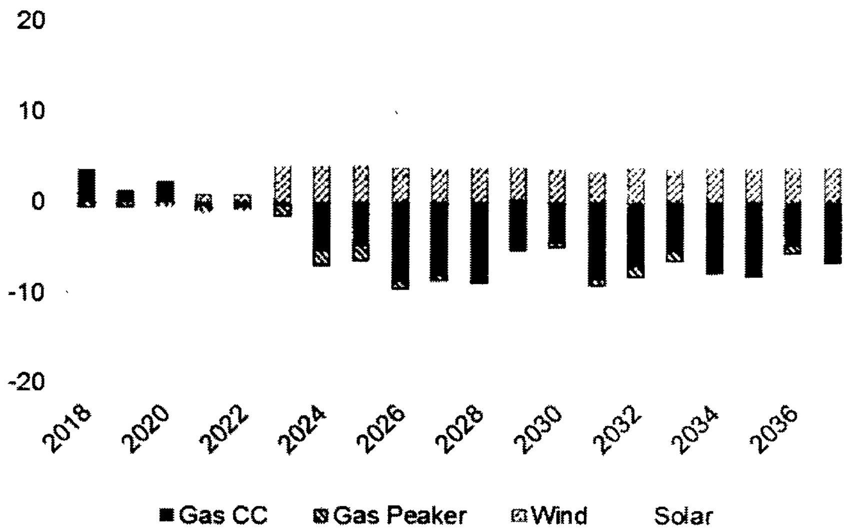
The higher levels of wind and solar capacity under the current market structure are partially offset by slightly lower levels of natural gas-fired peaking capacity than would otherwise be expected with marginal losses included in LMP formation. The locations of combined cycle and peaking capacity additions are also different under the current market structure compared to a market where marginal losses are included in LMP formation Specifically, with marginal losses included in LMP formation, more capacity is built in the Houston and South Zones near population centers, reflecting increased power pricing closer to load in those Zones.

It is important to note that by the end of the study period, there is less than a ~2 GW difference in total installed capacity between the two cases. While PA's analysis does not incorporate interconnection costs from the point of interconnect to the current transmission system (as such costs are highly site specific), the limited difference in installed capacity between the two cases suggest that any such feeder costs would be similar between the two cases. However, as described in the next section, while there are minimal differences in overall capacity, the amount of generation by fuel type varies materially between the two cases on a MWh basis.

<u>Comparison of Generation by Fuel Type</u>

Reflecting projected impacts on installed capacity by fuel type (see previous section), PA's analysis also projects a meaningful impact on the amount of solar and wind generation in ERCOT if marginal losses are incorporated into LMP formation. Figure 6 illustrates the differences in generation by fuel type between the Base Case and the Forward Marginal Losses Case.

**Figure 6: Difference in Generation – Base Case vs. Forward Marginal Losses Case (TWh)**

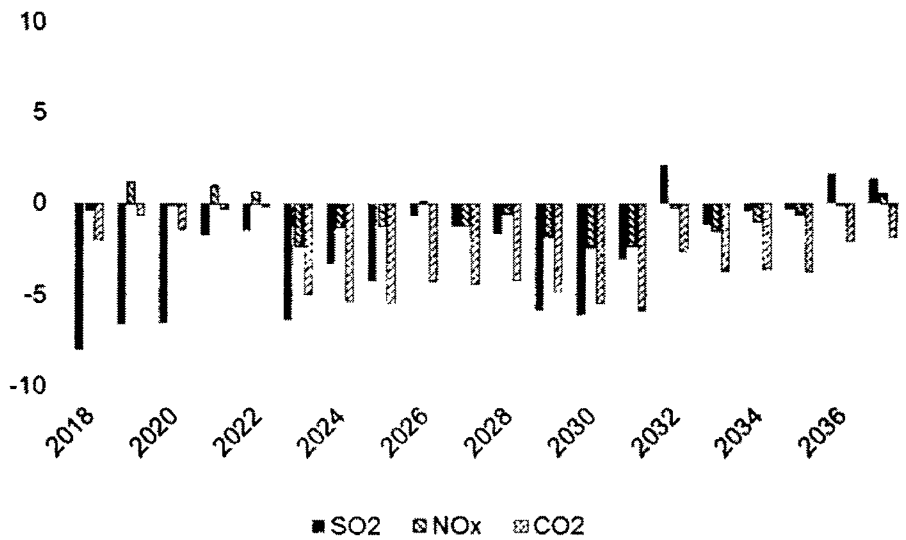



Specifically, under the current market structure, by 2037, wind and solar generation would be 3 percent and 4 percent higher, respectively, compared to a market where marginal losses are incorporated into LMP formation. Meanwhile, natural gas combined cycle and peaker generation, by 2037, would each be approximately 3 percent lower, respectively. These higher levels of lower marginal cost generation under the current market structure (driven by more wind and solar development in the West Zone of ERCOT across the study period) lead to lower overall production and energy costs

*Comparison of Emissions*

Incorporating marginal losses in LMP formation leads to higher levels of thermal generation dispatch, with a corresponding decrease in the amount of emission-free wind and solar generation. PA's analysis projects that $CO_2$, $SO_2$, and NOx emissions will be higher with marginal losses included in LMP formation than under the existing market structure. Figure 7 illustrates the differences in power sector emissions between the Base Case and the Forward Marginal Losses Case.

**Figure 7: Difference in Emissions – Base Case vs. Forward Marginal Losses Case (Million tons for $CO_2$ and thousand tons for $SO_2$ and NOx)**




Although annual emissions impacts vary across the study period, with some years seeing higher emissions of certain gases under the current market structure compared with a market where marginal losses are included in LMP formation, PA's analysis projects that by 2037, total $SO_2$, NOx, and $CO_2$ emissions will each be approximately 1 percent lower, respectively, under the current market structure. While appearing small on a percentage basis, these differences in emissions are noteworthy on an absolute basis. For example, total $CO_2$ emissions over the study period are nearly 67 million tons lower under the current market structure than a market where marginal losses are included in LMP formation. This equates to taking over 450,000 passenger vehicles off the road each year over the study period.[20]

*Comparison of Production Costs and Energy Costs*

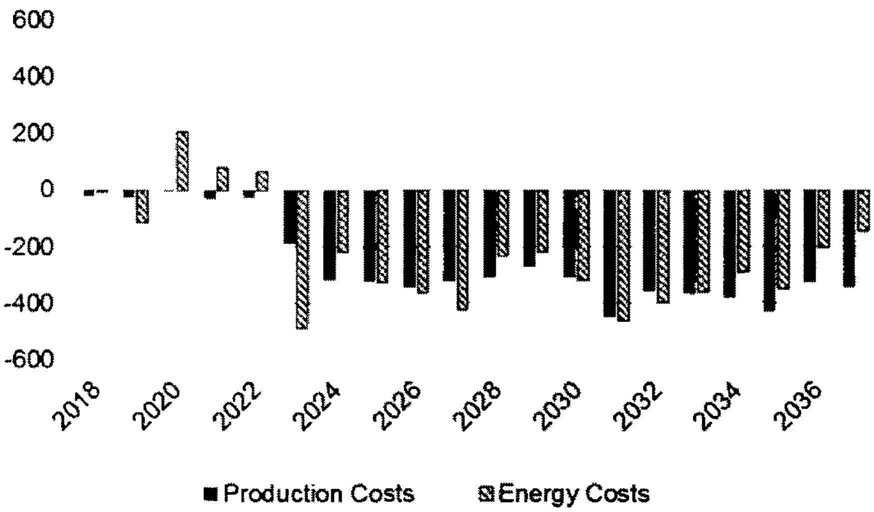
The higher levels of low-cost renewable generation under the current market structure compared to a market where marginal losses are included in LMP formation reduce ERCOT's reliance on more expensive thermal generators in most years of the study period. This decreased reliance on thermal generation significantly decreases total system production costs, which include the cost of fuel and variable operations and maintenance ("O&M") of generators on the ERCOT system.

This same dynamic also leads to lower all-hours power prices in ERCOT under the current market structure, which leads to lower total energy costs in ERCOT. Energy costs represent the total cost of electricity consumed on the ERCOT system, inclusive of transmission losses. Energy costs differ from production costs because energy prices are based on the cost of the marginal generator at that time rather than the summation of the individual production costs of all resources that are generating at that time.

Under the current market structure, PA's analysis projects $5.1 billion lower production costs and $4.6 billion in energy cost savings over the study period compared with the inclusion of marginal losses in LMP formation. Figure 8 illustrates the differences in production costs and energy costs between the Base Case and the Forward Marginal Losses Case

[20] Source U.S Environmental Protection Agency Greenhouse Gas Equivalencies Calculator. One passenger vehicle emits 4 67 metric tons, or 5 15 short tons, per year, on average

**Figure 8: Difference in Production and Energy Costs – Base Case vs. Forward Marginal Losses Case ($ Millions)**




## Economic Impacts

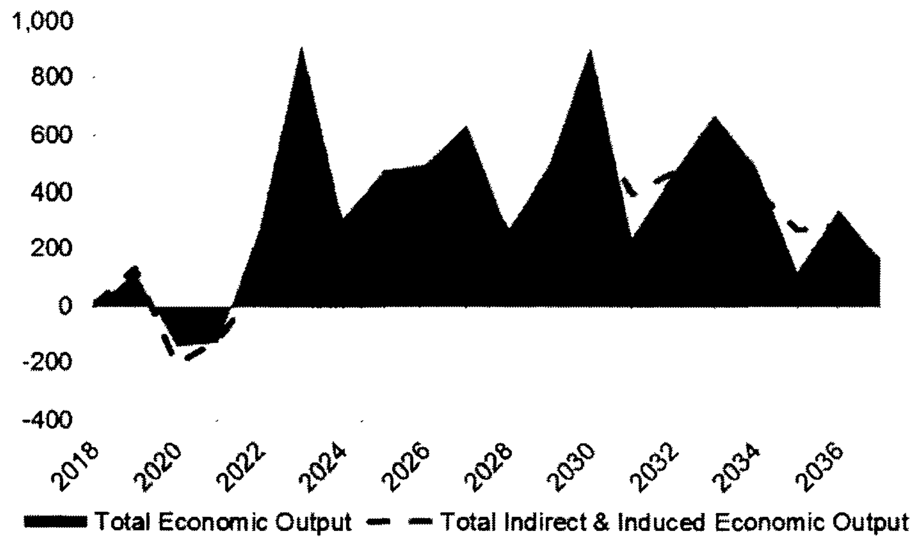
*Total Economic Impacts*

Across the study period, the current market structure leads to significant benefits for the Texas economy compared to a market where marginal losses are included in LMP formation, with total economic output across the study period projected to be over $7.1 billion higher under the current market structure. This difference is driven by direct, indirect, and induced contributions from construction and operation jobs and wages that would otherwise not have materialized, as well as from the induced jobs and wages spurred by energy cost savings experienced by Texas' electric retail customers.

Over the study period, indirect and induced economic output provides approximately 86 percent of the total incremental economic output created under the current market structure compared to a market where marginal losses are incorporated in LMP formation. This figure accounts for the value provided throughout the Texas economy resulting from the indirect benefits of the direct spending as well as the increased household spending spurred by direct and indirect wages as well as the energy cost savings.

Although total economic output is projected to be higher in some years with incorporation of marginal losses into LMP formation when compared to the current market structure, as shown by the slightly negative values in Figure 9 (largely driven by differences in the timing of generator additions), the benefits of the current market structure are clear over the study period. If marginal losses are incorporated into LMP formation on a go-forward basis, PA's analysis expects direct economic output to be materially lower over the course of the study period

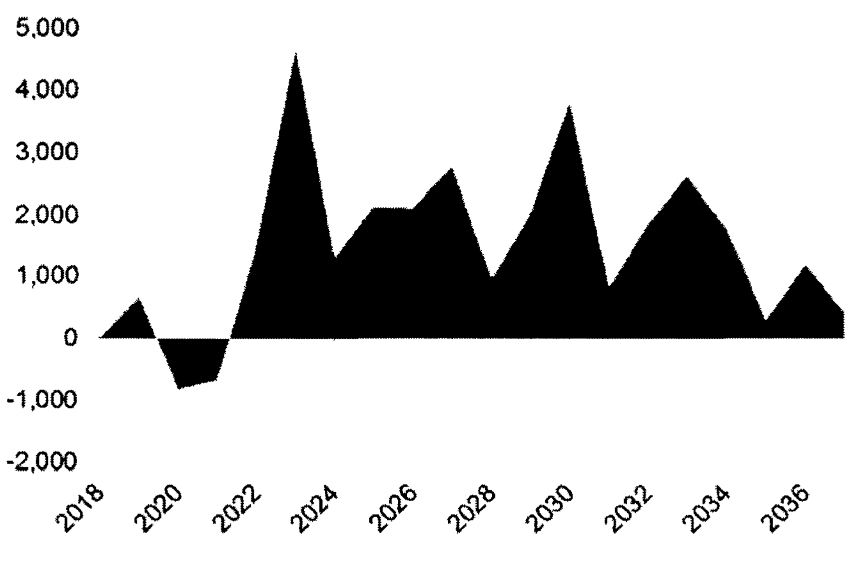
**Figure 9: Difference in Total Economic Output – Base Case vs. Forward Marginal Losses Case ($ Millions)**




*Total Jobs Created*

PA's analysis expects 29,500 higher FTEs, or approximately 1,500 higher FTEs per year on average, under the current market structure compared with a market where marginal losses are incorporated in LMP formation. This includes direct, indirect, and induced jobs. Projected job creation impacts follow similar patterns to those observed in total economic impacts. Figure 10 illustrates the differences in total jobs created between the Base Case and the Forward Marginal Losses Case.

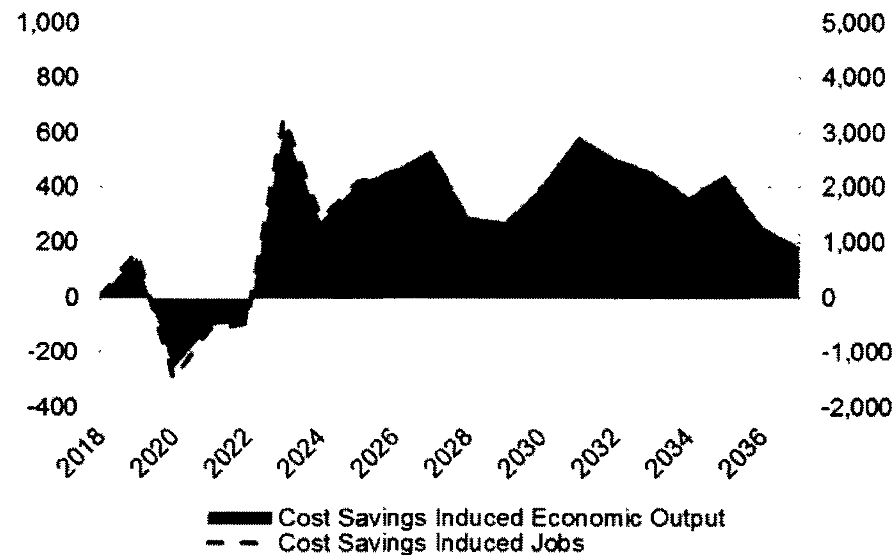
**Figure 10: Difference in Total Jobs – Base Case vs. Forward Marginal Losses Case (FTE)**



*Induced Economic Impacts from Retail Customer Cost Savings*

Induced economic output and the number of induced jobs attributable to energy cost savings would be higher under the current market structure than under a market where marginal losses are included in LMP formation. The economic benefits spurred by energy cost savings are expected to drive the majority of additional economic benefits over the study period. Nearly 26,600 additional FTEs and an additional $5.8 billion in economic output would be generated by induced economic activity under the current market structure compared with a market where marginal losses are included in LMP formation. Figure 11 illustrates the differences in economic output and job creation driven by energy cost savings between the Base Case and the Forward Marginal Losses Case.

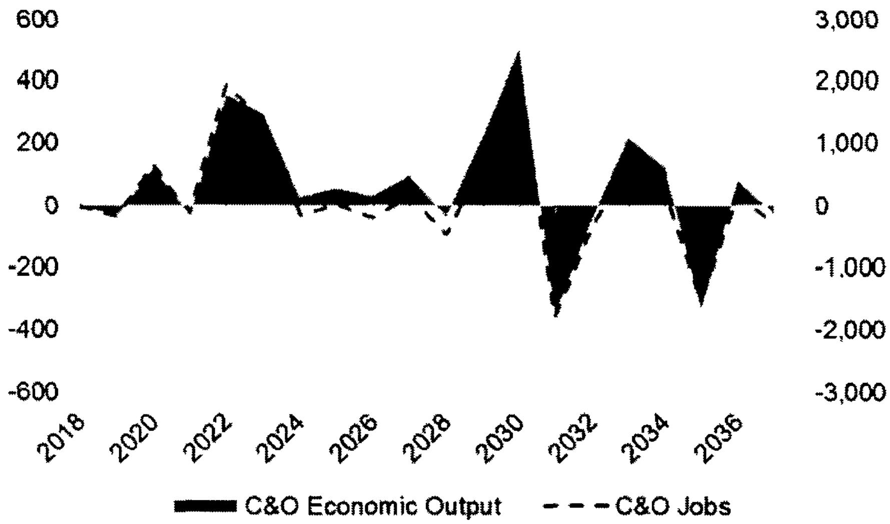
**Figure 11: Difference in Cost Savings-Induced Economic Output ($ Millions, left) and Jobs (FTE, right) Base Case vs. Forward Marginal Losses Case**




*Construction & Operations Economic Output*

While the majority of economic impact differences between the two Cases would be driven by differences in energy costs, the economic impacts stemming from construction and operation of generation infrastructure are still material. Under the current market structure, increased construction and operations activity would result in an additional 3,000 FTEs and nearly $1.3 billion in incremental economic output over the study period compared with a market where marginal losses are included in LMP formation. Figure 12 illustrates the differences in economic output and job creation driven by construction and operations between the Base Case and the Forward Marginal Losses Case.

**Figure 12: Difference in Construction & Operations Economic Output ($ Millions, left) and Jobs (FTE, right) Base Case vs. Forward Marginal Losses Case**




# Historical Elimination of CREZ Results

To answer the question, *"**How have the CREZ transmission projects and associated generation development enabled by CREZ impacted electricity customers in the State of Texas to date?**"*, PA compared the results of the Base Case with the Historical Elimination of CREZ Case. The Historical Elimination of CREZ Case represents a world where the CREZ transmission system was not built. Comparing this Case against the Base Case provides a basis for understanding whether the generation development enabled by the CREZ transmission projects has been beneficial and cost-effective for customers in the State of Texas.

The results of this comparison demonstrate that the current market structure has provided significantly greater benefits to customers than eliminating CREZ and its associated renewable energy development.

Over the 2010-2017 timeframe.

- Total economic output was $8 0 billion higher under the current market structure, with $3.6 billion of the additional economic output attributable to energy cost savings and $4.4 billion attributable to higher construction and operations expenditures
  - This $8 0 billion in additional economic output is already higher than the $6.9 billion published cost of CREZ,[21] which indicates that the CREZ projects will be of material benefit to customers over the long-term.
- Under the current market structure, the ERCOT system has experienced $3.0 billion in past production cost savings and nearly $2.8 billion in past energy cost savings due to higher levels of low variable cost power generation.

[21] Public Utility Commission of Texas. "Comments by the Public Utility Commission of Texas Regarding the Carbon Pollution Emission Guidelines for Existing Stationary Sources Emissions from Existing Stationary Sources Electric Utility Generating Units, Proposed Rule, EPA Docket ID No EPA-HQ-OAR-2013-0602 " June 18, 2014, <http //www puc texas gov/agency/topic_files/PUCT_Comments.pdf>

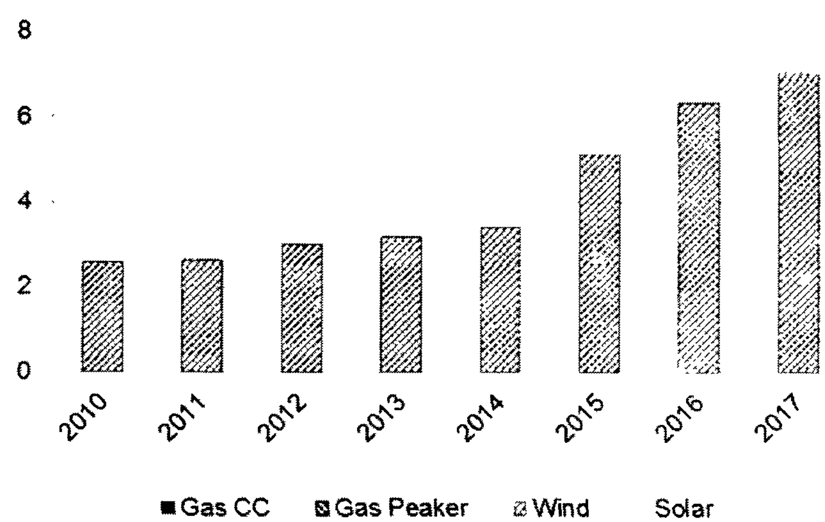
- Under the current market structure, total jobs over the 8-year study period were higher by 46,400 FTEs, with a 22,700 FTE increase attributable to energy cost savings and a 23,700 FTE increase attributable to increased construction and operations expenditures.
- Under the current market structure, total $CO_2$ emissions over 8 years were lower by nearly 79.8 million tons, NOx emissions were lower by 42,200 tons, and $SO_2$ emissions were lower by 89,400 tons.

**Wholesale Market Impacts**

*Comparison of Capacity Built by Fuel Type*

PA's analysis estimates that the CREZ transmission projects had a significant impact on the amount of wind development in ERCOT compared with a market where CREZ was excluded Nearly all of the difference in wind capacity additions under the current market structure takes place in the West Zone, with significantly more wind capacity installed in the West Zone under the current market structure However, the exclusion of CREZ had no impact on the overall levels of installed natural gas-fired generation. These results indicate that the current market structure has indeed helped encourage renewable development within the CREZ regions, which was the explicit goal of the Texas Legislature when it originally promoted CREZ. Figure 13 illustrates the differences in installed capacity by fuel type between the Base Case and the Historical Elimination of CREZ Case

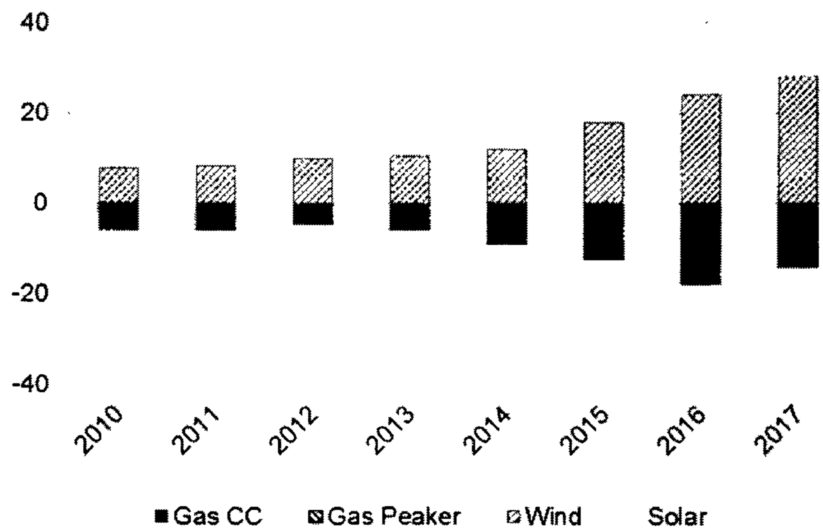
**Figure 13: Difference in Installed Capacity – Base Case vs. Historical Elimination of CREZ Case (GW)**




*Comparison of Generation by Fuel Type*

PA's analysis also projects that the CREZ transmission projects had a meaningful impact on the amount of wind and natural gas-fired generation in ERCOT. The increase in wind capacity compared to excluding CREZ materially increases total expected wind generation in ERCOT, with commensurate decreases in thermal generation. With CREZ included, wind generation was 63 percent higher compared to a market where CREZ was not built. Meanwhile, natural gas combined cycle and peaker generation were 6 percent and 4 percent lower, respectively, with CREZ included. Figure 14 illustrates the differences in generation by fuel type between the Base Case and the Historical Elimination of CREZ Case.

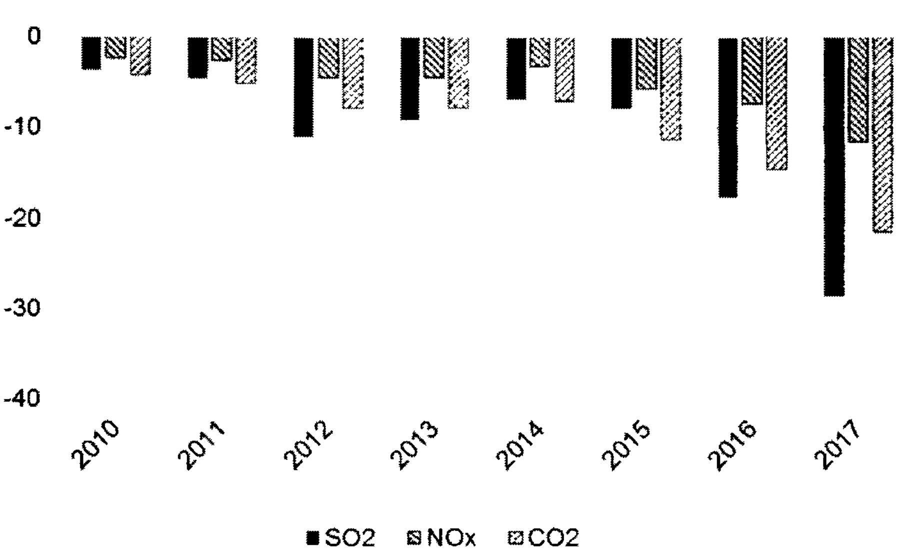
**Figure 14: Difference in Generation – Base Case vs. Historical Elimination of CREZ Case (TWh)**




*Comparison of Emissions*

Including the CREZ transmission projects increased the amount of emission-free wind generation in ERCOT, with a corresponding decrease in the amount of emitting thermal generation. PA's analysis projects that $CO_2$, $SO_2$, and NOx emissions were substantially lower with CREZ than under a market where CREZ was excluded. Figure 15 illustrates the differences in power sector emissions between the Base Case and the Historical Elimination of CREZ Case

**Figure 15: Difference in Emissions – Base Case vs. Historical Elimination of CREZ Case (Million tons for $CO_2$, thousand tons for $SO_2$ and NOx)**



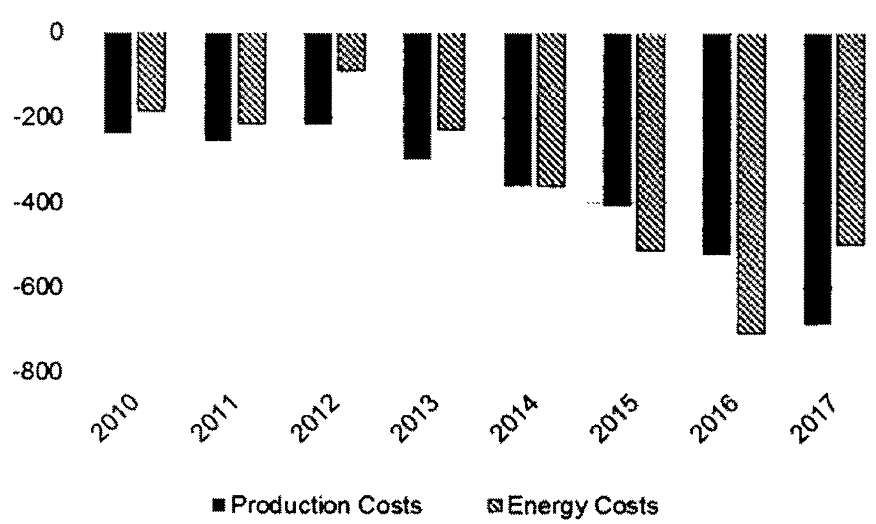

PA's analysis projects that from 2010 to 2017, $CO_2$, $SO_2$, and NOx emissions were approximately 5 to 6 percent lower under the current market structure than they would have been without CREZ. In absolute terms, $SO_2$ emissions were 89,000 tons lower, NOx emissions were 42,000 tons lower, and $CO_2$ emissions were 80 million tons lower under the current market structure. The reduction in $CO_2$ emissions equates to having taken over 1.9 million passenger vehicles off the road each year

*Comparison of Production Costs and Energy Costs*

Increased reliance on wind generation and decreased reliance on more expensive thermal generators under the current market structure significantly decreased total system production costs in ERCOT compared to a market where the CREZ transmission projects were not built. Similarly, increased reliance on wind generation decreased all-hours power prices in ERCOT, which decreased the total energy costs paid by customers in ERCOT

PA's analysis projects that the construction of CREZ led to production costs that were $370 million lower per year, on average, from 2010-2017 compared to a market where CREZ was not built PA's analysis also projects that energy costs would have been $350 million lower per year, on average, over the same timeframe compared to a market where CREZ was not built. Figure 16 illustrates the differences in production costs and energy costs between the Base Case and the Historical Elimination of CREZ Case.

**Figure 16: Difference in Production and Energy Costs – Base Case vs. Historical Elimination of CREZ Case ($ Millions)**




## Economic Impacts

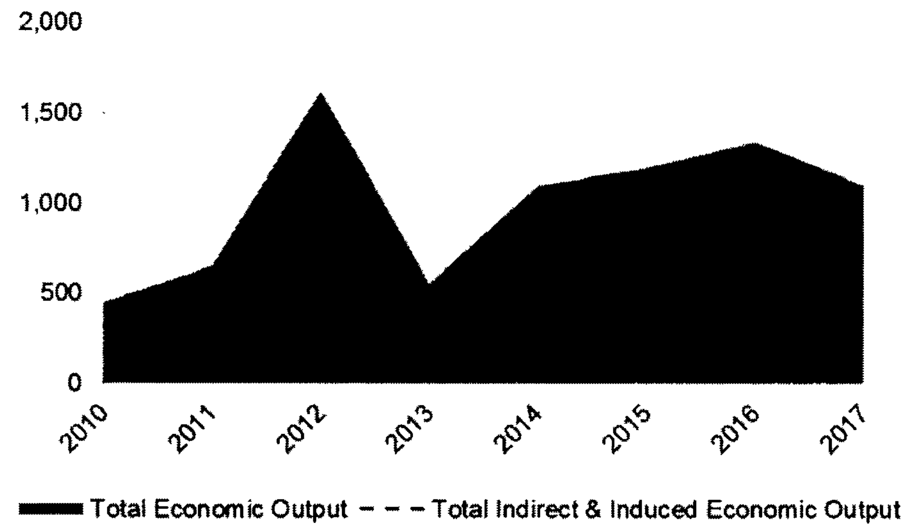
*Total Economic Impacts*

Across the study period, the current market structure led to significant benefits for the Texas economy compared to a market where CREZ and associated renewable energy capacity was not built, with total economic output across the study period projected to be over $8.0 billion higher under the current market structure due to the integration of CREZ. This difference is driven by direct, indirect, and induced contributions from construction and operation jobs and wages that would have otherwise not materialized, as well as from the induced jobs and wages spurred by energy cost savings experienced by Texas' electric retail customers.

Over the study period, indirect and induced economic output provided approximately 69 percent of the total incremental economic value created under the current market structure compared to a system without CREZ. This figure accounts for the value provided throughout the Texas economy resulting from the indirect benefits of the direct spending as well as the increased household spending spurred by the direct and indirect wages as well as the energy cost savings.

Total economic output is calculated to have been higher in all years under the current market structure than would have occurred without CREZ. See Figure 17.

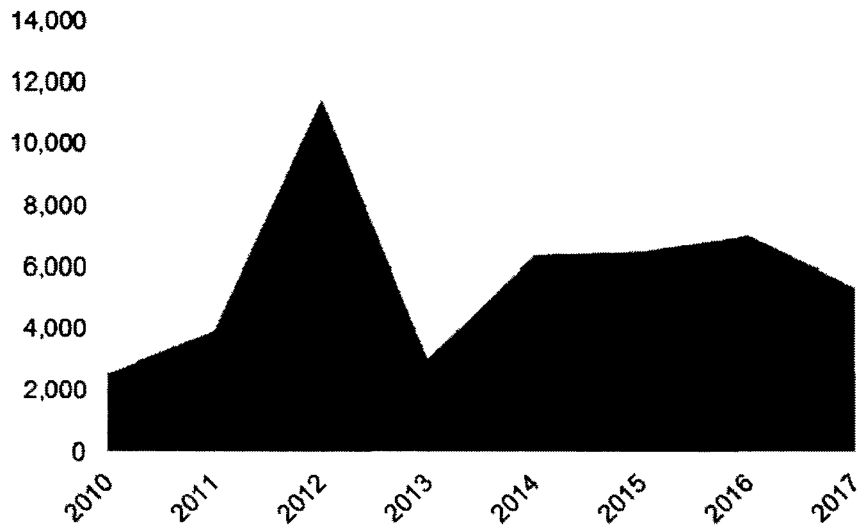
**Figure 17: Difference in Total Economic Output – Base Case vs. Historical Elimination of CREZ Case ($ Millions)**




*Total Jobs Created*

PA's analysis estimates that 46,400 total incremental FTEs, or approximately 5,800 incremental FTEs per year on average, were created throughout the Texas economy under the current market structure compared with a market where CREZ and its associated renewable energy development were excluded. This includes direct, indirect, and induced jobs. Job creation impacts follow similar patterns to those observed in total economic impacts. Figure 18 illustrates the differences in total jobs created between the Base Case and the Historical Elimination of CREZ Case.

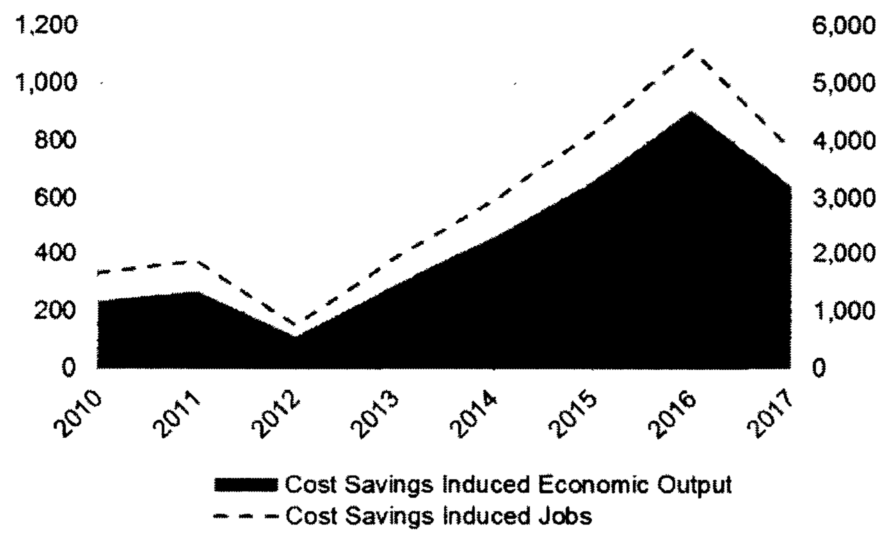
**Figure 18: Difference in Total Jobs – Base Case vs. Historical Elimination of CREZ Case (FTE)**




*Induced Economic Impacts from Retail Customer Cost Savings*

Induced economic output and the number of induced jobs attributable to energy cost savings are higher under the current market structure than under a market where CREZ and its associated renewable energy development was not built. The economic benefits spurred by energy cost savings drove a substantial share of additional economic benefits over the study period. The buildout following CREZ generated 22,700 FTEs and $3.6 billion of induced economic activity that would not have been realized otherwise. Figure 19 illustrates the differences in induced economic output and job creation driven by energy cost savings between the Base Case and the Historical Elimination of CREZ Case.

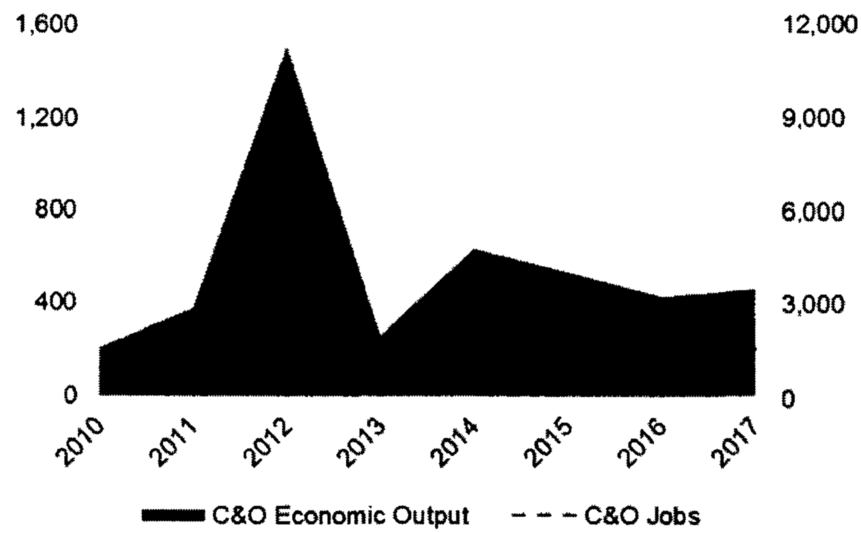
**Figure 19: Difference in Cost Savings-Induced Economic Output ($ Millions, left) and Jobs (FTE, right) Base Case vs. Historical Elimination of CREZ Case**



*Construction & Operations Economic Output*

The economic impacts stemming from construction and operations are materially higher under the current market structure than under a market where CREZ and its associated renewable energy development was not built. The increased construction and operations activity associated with the CREZ projects and associated renewable development resulted in an additional 23,700 FTEs and nearly $4 4 billion in incremental economic output from 2010-2017. Figure 20 illustrates the differences in economic output and job creation driven by construction and operations between the Base Case and the Historical Elimination of CREZ Case.

**Figure 20: Difference in Construction & Operations Economic Output ($ Millions, left) and Jobs (FTE, right)**
**Base Case vs. Historical Elimination of CREZ Case**




# Future Elimination of CREZ Results

To answer the question, "***How will the CREZ transmission projects and associated generation development enabled by CREZ impact electricity customers in the State of Texas over the long-term on a going forward basis?***", PA compared the results of the Base Case with the Future Elimination of CREZ Case. This Case relies on the same assumptions as the Historical Elimination of CREZ Case, but considers impacts from these assumptions on a go-forward basis starting in 2018.

The results of this comparison demonstrate that the current market structure will provide significantly greater benefits to customers than the absence of CREZ and its associated renewable energy development.

Over the 2018-2037 timeframe:

- Total economic output is projected to be nearly $56.8 billion higher under the current market structure, with $43.4 billion of the economic output attributable to energy cost savings and $13.3 billion attributable to higher construction and operations expenditures.
  - This nearly $57 billion of additional economic output, plus the $8 0 billion in economic output already achieved (as described in Section 4.2), is significantly higher than the $6.9 billion published cost of CREZ.

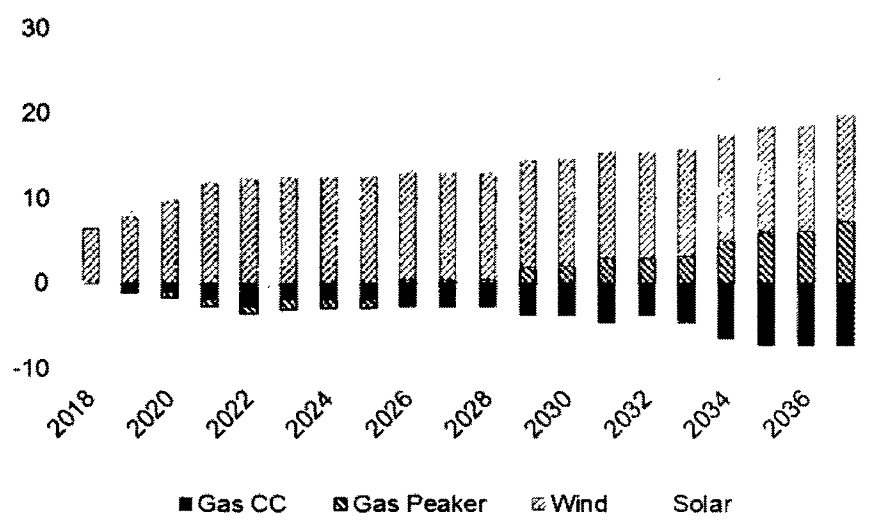
- Under the current market structure, the ERCOT system is projected to experience $44 5 billion of total future production cost savings and $33.9 billion of total future energy cost savings over the next 20 years due to higher levels of low variable cost power generation.
- Under the current market structure, total future jobs over the next 20 years are projected to be higher by 238,600 FTEs, with a 214,800 FTE increase attributable to energy cost savings and a 23,800 FTE increase attributable to higher construction and operations expenditures.
- Under the current market structure, total future $CO_2$ emissions over the next 20 years are projected to be lower by 585 million tons, NOx emissions lower by 175,000 tons, and $SO_2$ emissions lower by 245,000 tons.

**Wholesale Market Impacts**

*Comparison of Capacity Built by Fuel Type*

PA's analysis demonstrates that the absence of CREZ would result in material changes in future power generation investment on a going-forward basis. In particular, PA projects higher levels of wind and solar capacity under the current market structure, mostly located in the West Zone, partially offset by slightly lower levels of natural gas-fired combined cycle capacity than would otherwise be expected without CREZ. By 2037, the current market structure yields 12 percent less combined cycle capacity compared to a market where CREZ is absent. Conversely, gas-fired peaking capacity is ultimately 41 percent higher under the current market structure. Figure 21 illustrates the differences in installed capacity by fuel type between the Base Case and the Future Elimination of CREZ Case.

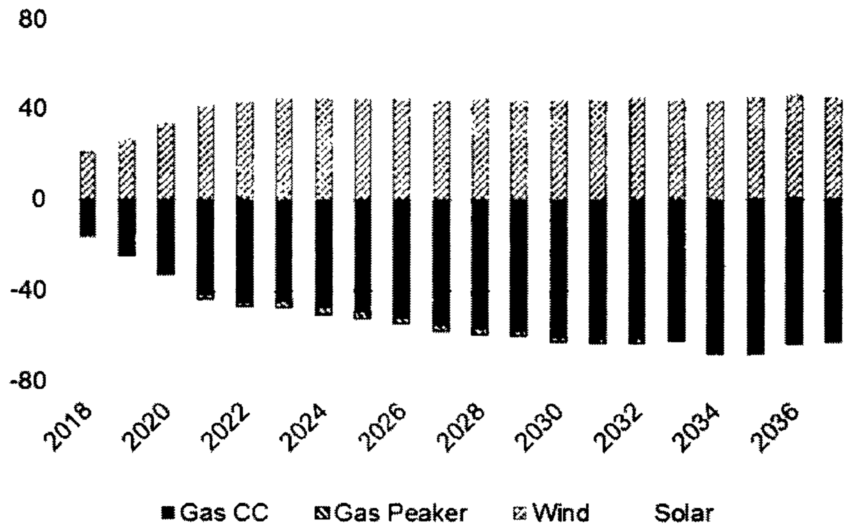
**Figure 21: Difference in Installed Capacity – Base Case vs. Future Elimination of CREZ Case (GW)**




*Comparison of Generation by Fuel Type*

Reflecting projected impacts on installed capacity by fuel type (see previous section), PA's analysis also projects a meaningful impact on the amount of solar and wind generation between the two Cases. Figure 22 illustrates the differences in generation by fuel type between the Base Case and the Future Elimination of CREZ Case.

**Figure 22: Difference in Generation – Base Case vs. Future Elimination of CREZ Case (TWh)**

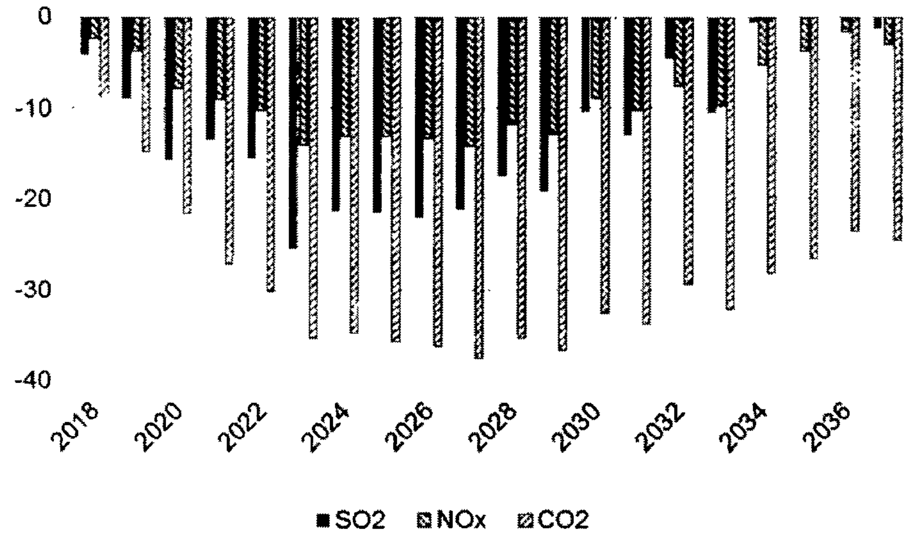



Specifically, under the current market structure, total wind and solar generation are 59 percent higher and 82 percent higher, respectively, over the course of the study period compared to a market where CREZ is excluded. Meanwhile, natural gas combined cycle and peaker generation are projected to be 23 percent lower and 12 percent lower, respectively, under the current market structure.

*Comparison of Emissions*

Driven by higher levels of emission-free wind and solar generation, with a corresponding decrease in the amount of thermal generation dispatch, PA's analysis projects that $CO_2$, $SO_2$, and NOx emissions will be lower under the current market structure compared to a market where CREZ is excluded. Figure 23 illustrates the differences in power sector emissions between the Base Case and the Future Elimination of CREZ Case.

**Figure 23: Difference in Emissions - Base Case vs. Future Elimination of CREZ Case (Million tons for $CO_2$, thousand tons for $SO_2$ and NOx)**



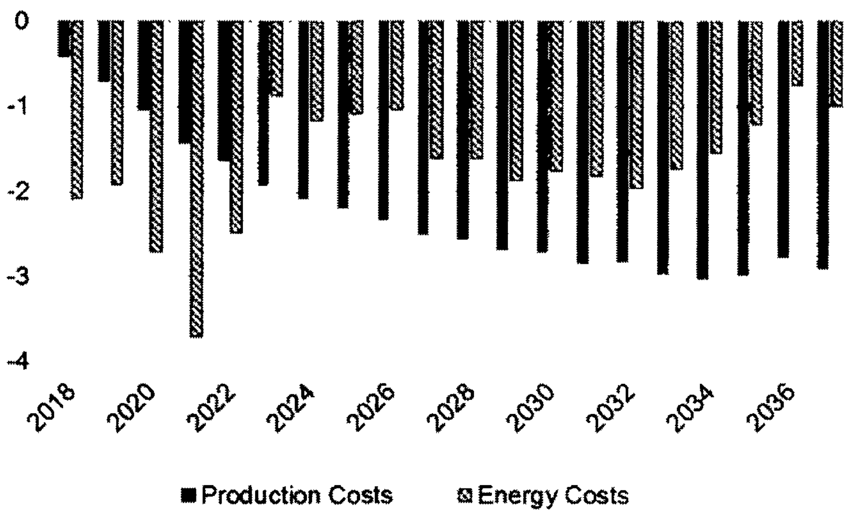

PA's analysis projects that over the 2018-2037 study period, $SO_2$, NOx, and $CO_2$ emissions are projected to be 10 percent lower, 12 percent lower, and 14 percent lower, respectively, under the current market structure In absolute terms, this means that the presence of CREZ and its associated renewable energy development will avoid 245,000 tons of $SO_2$ emissions, 175,000 tons of NOx emissions, and 585 million tons of $CO_2$ emissions over the study period. To put these $CO_2$ emissions reductions in context, avoiding 585 million tons of $CO_2$ emissions is the rough equivalent of taking 5.7 million passenger vehicles off the road each year over the study period.

_Comparison of Production Costs and Energy Costs_

The higher levels of low variable cost renewable generation under the current market structure compared to a market where CREZ is excluded reduces ERCOT's reliance on more expensive thermal generators in most years of the study period This decreased reliance on thermal generators significantly decreases both total system production costs and total energy costs.

Under the current market structure, PA's analysis projects $44.5 billion lower production costs and $33 9 billion in energy cost savings over the study period compared with a market where CREZ and its associated renewable development are excluded. Figure 24 illustrates the differences in production costs and energy costs between the Base Case and the Future Elimination of CREZ Case

**Figure 24: Difference in Production and Energy Costs - Base Case vs. Future Elimination of CREZ Case ($ Billions)**




## Economic Impacts

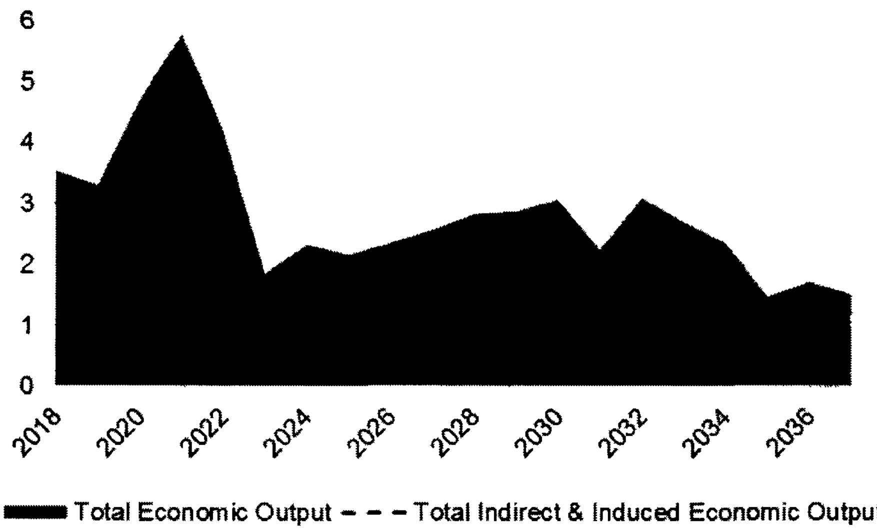
*Total Economic Impacts*

Across the study period, the current market structure leads to significant benefits for the Texas economy compared to a market where CREZ and its associated renewable energy development are excluded, with total economic output across the study period projected to be $56.8 billion higher under the current market structure. This difference is driven by direct, indirect, and induced contributions from construction and operation jobs and wages that would have otherwise not materialized, as well as from the induced jobs and wages spurred by energy cost savings delivered to Texas' electric retail customers.

Over the study period, indirect and induced economic output provides approximately 82 percent of the total incremental economic value created under the current market structure compared to a market where CREZ and its associated renewable energy development are excluded. This figure accounts for the value provided throughout the Texas economy resulting from the indirect benefits of the direct spending as well as the increased household spending spurred by the direct and indirect wages as well as the energy cost savings

Total economic output is projected to be higher in all years under the current market structure compared to the Future Elimination of CREZ Case, as shown in Figure 25.

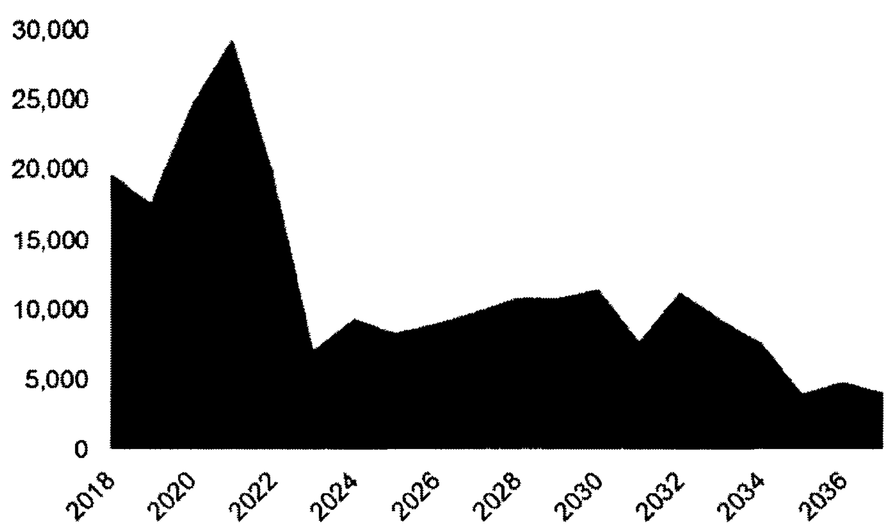
**Figure 25: Difference in Total Economic Output - Base Case vs. Future Elimination of CREZ Case ($ Billions)**




*Total Jobs Created*

PA's analysis expects 238,600 more FTEs, or approximately 11,900 more FTEs per year on average, under the current market structure compared with a market where CREZ and its associated renewable energy development are excluded This includes direct, indirect, and induced jobs. Projected job creation impacts follow similar patterns to those observed in total economic impacts. Figure 26 illustrates the differences in total jobs created between the Base Case and the Future Elimination of CREZ Case.

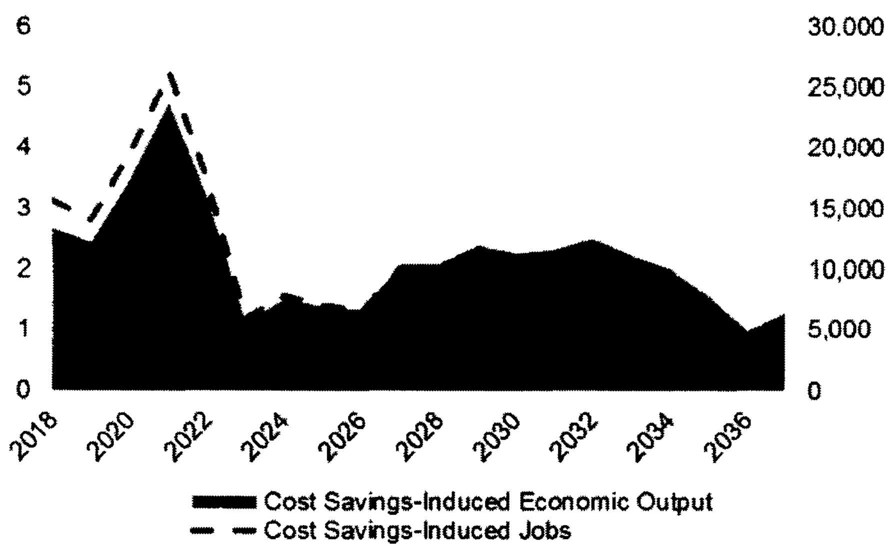
**Figure 26: Difference in Total Jobs - Base Case vs. Future Elimination of CREZ Case (FTE)**



*Induced Economic Impacts from Retail Customer Cost Savings*

Induced economic output and the number of induced jobs attributable to energy cost savings would be higher under the current market structure than under a market where CREZ and its associated renewable energy development are excluded. The economic benefits spurred by energy cost savings are expected to drive the majority of additional economic benefits over the study period. Energy cost savings under the current market structure compared to the alternative would create an incremental 214,800 FTEs and generate an additional $43.4 billion in economic output. Figure 27 illustrates the differences in economic output and job creation driven by energy cost savings between the Base Case and the Future Elimination of CREZ Case

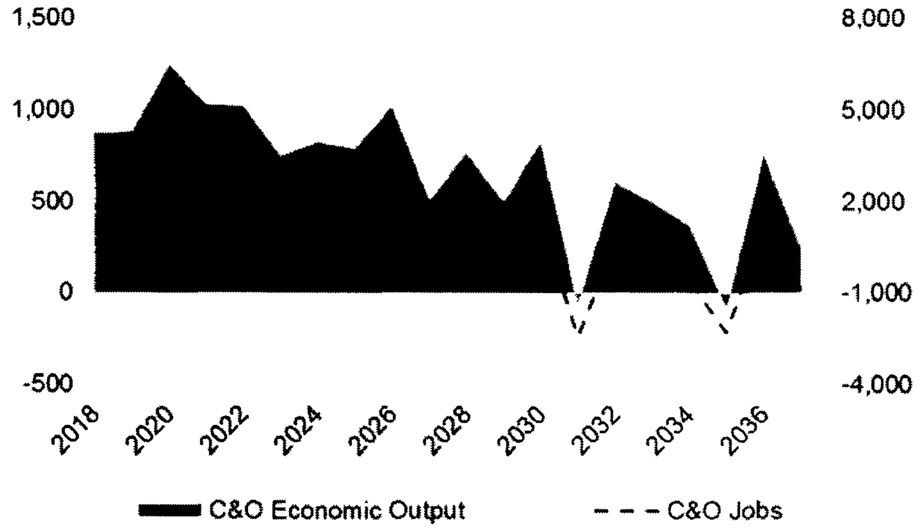
**Figure 27: Difference in Cost Savings-Induced Economic Output ($ Billions, left) and Jobs (FTE, right) Base Case vs. Future Elimination of CREZ Case**




*Construction & Operations Economic Output*

While the majority of differences in economic impacts between the current market structure and the alternative would be driven by energy cost savings, the economic impacts stemming from the operation of CREZ and construction and operation of generation infrastructure are still material. Under the current market structure, increases in construction and operations activity are projected to result in an incremental 23,800 FTEs and $13 3 billion in additional economic output over the course of the study period. Figure 28 illustrates the differences in economic output and job creation driven by construction and operations between the Base Case and the Future Elimination of CREZ Case.

**Figure 28: Difference in Construction & Operations Economic Output ($ Millions, left) and Jobs (FTE, right) Base Case vs. Future Elimination of CREZ Case**



# DISCUSSION

ERCOT's unique energy-only market design is intended to allow competitive market forces to drive power generation investment in a manner that is most efficient for the consumer. This intent is reflected in historical approaches to transmission pricing and cost allocation within the State of Texas and ERCOT, which represent deliberate efforts by legislators and regulators to ensure that the power system provides cost-effective service to, and in turn maximizes economic benefits for, electric retail customers across the State. As PA's analysis shows, two specific features of the current ERCOT market that have facilitated these goals are the exclusion of marginal losses from LMP formation and the addition of the CREZ transmission upgrades.

In recent months, some power generation owners have voiced concerns that the ERCOT market is not providing high enough power pricing to justify past and future investment decisions. These generation owners have advocated for several proposed market design changes, including the addition of marginal losses to LMP formation It is certainly true that excluding marginal losses from LMP formation alters system dispatch patterns. Furthermore, incorporating marginal losses into LMP formation may increase the physical efficiency of ERCOT system dispatch by increasing the dispatch of generators located closer to load centers, ultimately reducing transmission line losses on the system.

However, the singular focus on optimizing the physical efficiency of system dispatch misses the forest for the trees, as optimizing physical efficiency is not projected to be economically beneficial for Texas electricity customers in the long-run. Rather than a narrow focus on physical efficiency, the Commission is tasked with ensuring the availability of safe, reliable, high quality services that meet the needs of all Texans at just and reasonable rates Rates are made more reasonable for consumers by creating a market structure within ERCOT that achieves long-term production and energy cost savings by maintaining the current competitive market environment.

PA's study shows that the implementation of marginal losses would alter future power generation investment decisions, decreasing the development and, in turn, overall electricity production of zero marginal cost renewable resources on the system. These changes to long-term investment in new power generation facilities and associated lower levels of zero marginal cost generation would ultimately lead to higher electricity costs for customers, less economic output for the State of Texas, higher production costs, and increased emissions. In other words, incorporating marginal losses in LMP formation would forego billions of dollars in production cost savings and economic output, create fewer jobs in Texas, and lead to higher air pollution, all to the detriment of Texas residents.

PA's study also shows the impacts of the absence of CREZ, providing an additional example of how market structure decisions that take into account ERCOT's unique physical attributes can have significant long-term economic and environmental impacts in Texas. The absence of CREZ would have led to even more substantial foregone benefits than the implementation of marginal losses, both historically and into the future.

These examples demonstrate that any analysis of potential changes to the current market structure should carefully consider the ramifications of such changes to the competitive market forces in the unique ERCOT system that have created, and will continue to create, sizeable benefits for Texas electricity customers. Furthermore, this study demonstrates the critical importance of considering the impacts to benefits of market structure changes over the long-term

# GLOSSARY

## Locations and Organizations

- **Electric Reliability Council of Texas ("ERCOT")**: Transmission operator that coordinates the movement of wholesale electricity generation and transmission of power throughout most of Texas.
- **Houston Zone**. A distinct ERCOT electric market zone covering the Houston area in Southeastern Texas
- **North Zone**· A distinct ERCOT electric market zone covering the majority of Northeastern and North-central Texas.
- **South Zone** A distinct ERCOT electric market zone covering southern Texas.
- **West Zone**: A distinct ERCOT electric market zone covering much of western Texas

## Market Features

- **Bilateral capacity contract**: Allows a buyer and seller to exchange rights to generating capacity under mutually agreeable terms for a specified amount of time.
- **Capacity**. The physical amount of power the electric system has available to serve load in megawatts (MW); it represents generators' potential to generate electricity.
- **Capacity market**· A competitive market that is designed to ensure that a power system has the adequate resources to meet current and future demand for electricity by providing monetary rewards to power suppliers for their generating capacity.
- **Combined cycle ("CC")**. A power plant that uses both a gas and a steam turbine to produce electricity
- **Carbon dioxide ("$CO_2$")**· The primary greenhouse gas emitted through burning fossil fuels (such as coal and natural gas) to generate electricity.
- **Competitive Renewable Energy Zones ("CREZ")**: Identified geographic areas located in West Texas and the Texas panhandle with favorable (i.e., wind- and solar-rich) conditions for wind and solar generation development.
- **Construction and operations expenditures**. The cost incurred by a business or firm for the construction and operating of a project.
- **Direct economic impact**: A measure of the total amount of additional expenditure within a defined geographical region that is directly attributed to an event.
- **Economic output**: The value of all goods and services (output) produced by an economy
- **Energy cost**· The marginal cost of electricity multiplied by energy demand in any given hour.
- **Energy-only market**. A market where electric generators are compensated only for the physical power that they supply to the grid, as compared to capacity markets where electric generators are paid for the capability to generate a certain amount of power when needed to maintain electric system reliability
- **Fixed cost**: A cost that does not change over time and is independent of the number of goods or services (such as electricity) produced.

- **Full time equivalent ("FTE")**: When used in this report, FTEs refer to full time equivalent jobs over a 12 month time frame. For example, two FTEs can be thought of a two jobs for one year or one job for two years.
- **Indirect economic impact**: A measure of the secondary effects resulting from a direct economic stimulus, such as the number of FTEs created or eliminated.
- **Induced economic impact**: A measure of the results of increased personal income due to the direct and indirect economic impacts.
- **Locational marginal price ("LMP")**: LMP, measured in $/MWh, gives market participants a signal of the price of energy at every location on the electric system. LMP represents the cost of serving the next MW of load at a specific location on the transmission system at a certain point in time. LMP in ERCOT reflects the costs of both energy and transmission congestion.
- **Nitrous oxide ("NOx")**: Nitrous oxide, an air pollutant emitted through burning fossil fuels such as coal and natural gas to generate power.
- **Peaker**: Power plants that generally run only when there is a high demand for electricity Peakers are typically simple-cycle gas turbines
- **Production cost**: The cost of generating electricity for each electric generator, which includes the cost of fuel as well as variables operations and maintenance expenditures
- **Regional Transmission Organization:** An independent, non-profit organization of members responsible for managing bulk power flows over a designated transmission system via wholesale electricity markets and ensuring electric system reliability.
- **Short-run marginal cost**: The variable cost incurred by a supplier to produce one unit of electricity. Short-run marginal cost includes the cost of fuel and variable operations and maintenance.
- **Sulfur dioxide ("$SO_2$")**: An air pollutant emitted through the combustion of sulfur in fuel (primarily coal) used by electric generators and industrial facilities.
- **Variable cost**. A cost that varies with the amount of goods and services (e.g , electricity) produced.

# Methodology

- **AURORA$^{xmp}$**: Computer-based chronological dispatch simulation model used to project wholesale power prices.
- **Chronological dispatch simulation model**: A computerized model that simulates the dispatch of power generation units in (a) given market(s) while minimizing total system cost, taking into account both fixed and future capital costs required to meet electric demand and ensure system reliability
- **GPCM (Natural Gas Market Forecasting System)**: Computer-based natural gas price forecasting system that models natural gas production, existing pipeline flows and constraints, new pipeline construction, and natural gas demand from the power sector and residential, commercial, and industrial sectors for the entire United States
- **Impact Analysis for Planning ("IMPLAN")** Computer-based software used in Input-Output ("I-O" analysis) to project how changes in demand for specific types of goods and services are likely to affect a specific geographic region.
- **Input-Output ("I-O") analysis**: A form of economic analysis that models the interdependencies between economic sectors or industries.

- **Jobs and Economic Development Impact ("JEDI")**: Computer-based model used in Input-Output ("I-O" analysis) to estimate the economic impacts of constructing and operating power generation and biofuel plants at the local and state levels.

Attachment 1
Project 48539

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**Change in Annual Generator Revenue (Low Gas Price Case, in $M)**

| | Houston Zone | North Zone | South Zone | West Zone |
|---|---|---|---|---|
| Combined-cycle greater than 90 MW | 88.2 | -120.1 | -2.9 | -21.7 |
| Combined-cycle less than or equal to 90 MW | 19.1 | - | 8.6 | -6.0 |
| Coal and lignite | 12.3 | -58.5 | -0.5 | -2.7 |
| Reciprocating engines | - | -1.5 | -2.3 | - |
| Gas steam non-reheat or boiler without air-preheater | 0.5 | -0.1 | - | -0.1 |
| Gas steam reheat boiler | 10.3 | -16.9 | 12.0 | -4.4 |
| Gas steam supercritical boiler | 28.9 | - | - | - |
| Hydro | - | -0.2 | -0.0 | - |
| Nuclear | - | -13.5 | 28.6 | - |
| Simple-cycle greater than 90 MW | 7.1 | -8.3 | 9.4 | -1.0 |
| Simple-cycle less than or equal to 90 MW | 5.5 | -0.1 | -0.5 | -0.9 |
| PhotoVoltaic Generation Resources | - | -0.9 | -0.0 | -11.8 |
| Wind generation Resources | - | -2.7 | -14.1 | -103.4 |
| Other | - | -0.3 | - | 0.1 |

**Change in Annual Generation (Low Gas Price Case, in GWh)**

| | Houston Zone | North Zone | South Zone | West Zone |
|---|---|---|---|---|
| Combined-cycle greater than 90 MW | 2,657 | -3,494 | 74 | -878 |
| Combined-cycle less than or equal to 90 MW | 636 | - | 256 | -252 |
| Coal and lignite | 363 | -1,612 | -15 | -83 |
| Reciprocating engines | - | -51 | -67 | - |
| Gas steam non-reheat or boiler without air-preheater | 0 | 1 | - | - |
| Gas steam reheat boiler | 334 | -561 | 426 | -149 |
| Gas steam supercritical boiler | 1,014 | - | - | - |
| Hydro | - | - | 1 | - |
| Nuclear | - | -1 | 265 | - |
| Simple-cycle greater than 90 MW | 142 | -348 | 345 | -28 |
| Simple-cycle less than or equal to 90 MW | 80 | -2 | -29 | -1 |
| PhotoVoltaic Generation Resources | - | - | 0 | 7 |
| Wind generation Resources | - | 3 | 209 | 16 |
| Other | - | -11 | - | 3 |

**Change in Annual Generator Revenue (Base Case, in $M)**

| | Houston Zone | North Zone | South Zone | West Zone |
|---|---|---|---|---|
| Combined-cycle greater than 90 MW | 125.6 | -234.3 | 5.5 | -26.5 |
| Combined-cycle less than or equal to 90 MW | 18.1 | - | 24.7 | -5.4 |
| Coal and lignite | 55.9 | -55.0 | 8.4 | -12.3 |
| Reciprocating engines | - | -0.6 | -1.3 | - |
| Gas steam non-reheat or boiler without air-preheater | -1.6 | 2.9 | - | -0.2 |
| Gas steam reheat boiler | 4.6 | -13.3 | 4.7 | -1.6 |
| Gas steam supercritical boiler | 15.8 | - | - | - |
| Hydro | - | -0.2 | -0.1 | - |
| Nuclear | - | -14.4 | 42.4 | - |
| Simple-cycle greater than 90 MW | -0.9 | -13.8 | 15.9 | -0.9 |
| Simple-cycle less than or equal to 90 MW | -1.3 | 0.2 | -0.0 | -1.0 |
| PhotoVoltaic Generation Resources | - | -1.1 | -0.0 | -14.0 |
| Wind generation Resources | - | -2.6 | -13.4 | -117.8 |
| Other | - | -0.8 | - | 0.1 |

**Change in Annual Generation (Base Case, in GWh)**

| | Houston Zone | North Zone | South Zone | West Zone |
|---|---|---|---|---|
| Combined-cycle greater than 90 MW | 3,359 | -6,790 | 444 | -949 |
| Combined-cycle less than or equal to 90 MW | 496 | - | 753 | -190 |
| Coal and lignite | 1,641 | -496 | 335 | -374 |
| Reciprocating engines | - | -16 | -31 | - |
| Gas steam non-reheat or boiler without air-preheater | -28 | 79 | - | - |
| Gas steam reheat boiler | 109 | -343 | 122 | -43 |
| Gas steam supercritical boiler | 436 | - | - | - |
| Hydro | - | - | 1 | - |
| Nuclear | - | 1 | 252 | - |
| Simple-cycle greater than 90 MW | -30 | -460 | 480 | -19 |
| Simple-cycle less than or equal to 90 MW | -49 | 4 | -12 | -0 |
| PhotoVoltaic Generation Resources | - | - | 0 | 5 |
| Wind generation Resources | - | 4 | 279 | 24 |
| Other | - | -10 | - | 4 |

**Change in Annual Generator Revenue (High Gas Price Case, in $M)**

| | Houston Zone | North Zone | South Zone | West Zone |
|---|---|---|---|---|
| Combined-cycle greater than 90 MW | 137.1 | -307.4 | 25.2 | -24.0 |
| Combined-cycle less than or equal to 90 MW | 17.3 | - | 31.6 | -1.6 |
| Coal and lignite | 99.9 | -61.4 | 18.8 | -27.8 |
| Reciprocating engines | - | -0.3 | -0.9 | - |
| Gas steam non-reheat or boiler without air-preheater | -2.2 | 0.5 | - | -0.2 |
| Gas steam reheat boiler | 3.9 | -11.8 | 4.6 | -0.9 |
| Gas steam supercritical boiler | 11.9 | - | - | - |
| Hydro | - | -0.3 | -0.1 | - |
| Nuclear | - | -14.0 | 43.9 | - |
| Simple-cycle greater than 90 MW | -5.0 | -18.0 | 18.8 | -1.2 |
| Simple-cycle less than or equal to 90 MW | -5.2 | 0.0 | -0.0 | -1.0 |
| PhotoVoltaic Generation Resources | - | -1.1 | -0.0 | -14.5 |
| Wind generation Resources | - | -2.0 | -15.9 | -118.0 |
| Other | - | -0.7 | - | 0.0 |

**Change in Annual Generation (High Gas Price Case, in GWh)**

| | Houston Zone | North Zone | South Zone | West Zone |
|---|---|---|---|---|
| Combined-cycle greater than 90 MW | 3,655 | -8,910 | 1,016 | -773 |
| Combined-cycle less than or equal to 90 MW | 465 | - | 911 | -47 |
| Coal and lignite | 2,866 | -490 | 629 | -863 |
| Reciprocating engines | - | -8 | -17 | - |
| Gas steam non-reheat or boiler without air-preheater | -23 | 13 | - | - |
| Gas steam reheat boiler | 82 | -274 | 110 | -20 |
| Gas steam supercritical boiler | 290 | - | - | - |
| Hydro | - | - | 0 | - |
| Nuclear | - | 1 | 40 | - |
| Simple-cycle greater than 90 MW | -75 | -582 | 559 | -22 |
| Simple-cycle less than or equal to 90 MW | -89 | 0 | -16 | -0 |
| PhotoVoltaic Generation Resources | - | - | 1 | 5 |
| Wind generation Resources | - | 7 | 318 | 36 |
| Other | - | -5 | - | 1 |