Siemens PTI

Cost Benefit Analysis of 765-kV Transmission Facilities in ERCOT

Prepared for: Google & TEBA

Date:June 2025

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Executive Summary

Siemens PTI Analysis Shows Various Benefits in 765 kV System Over 345 kV

The 765-kV transmission option delivers up to five times greater benefits per dollar spent compared to the 345-kV alternative, highlighting strong economic and system value based on the benefit-cost ratio analysis.

West-to-East transfer capability improves by 1.46 GW under the 765-kV design, significantly enhancing regional system deliverability and operational flexibility.

Renewable energy curtailment is reduced by nearly 50% with the 765-kV design compared to the 345-kV alternative, leading to lower production costs, reduced congestion, and improved grid efficiency—all of which support more stable customer costs.

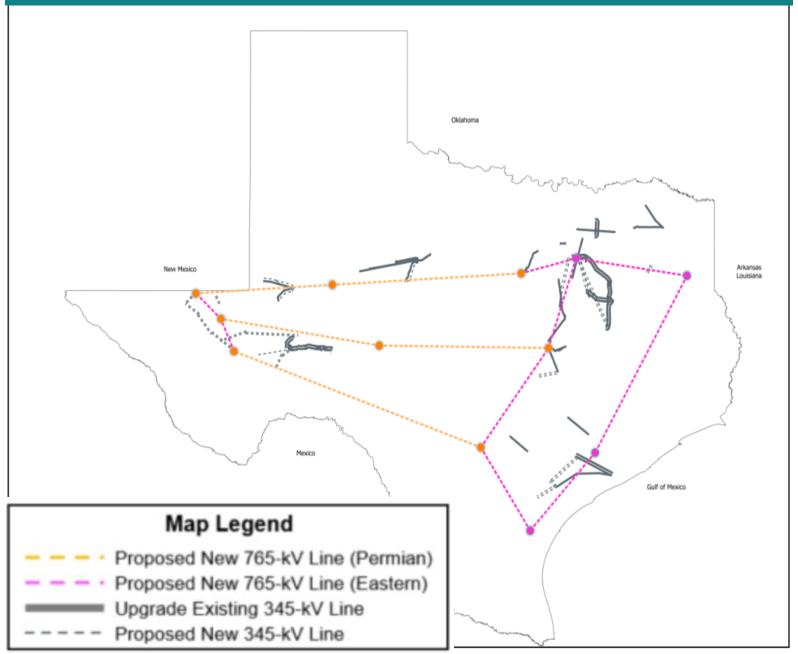
Net benefits remain positive even under high discount rates, indicating that the 765-kV project's internal rate of return exceeds the cost of capital and outperforms the 345-kV alternative.

During major system maintenance periods, the 765-kV configuration maintains transmission capacity more than twice as effectively as the 345-kV design, offering critical reliability and resilience benefits.

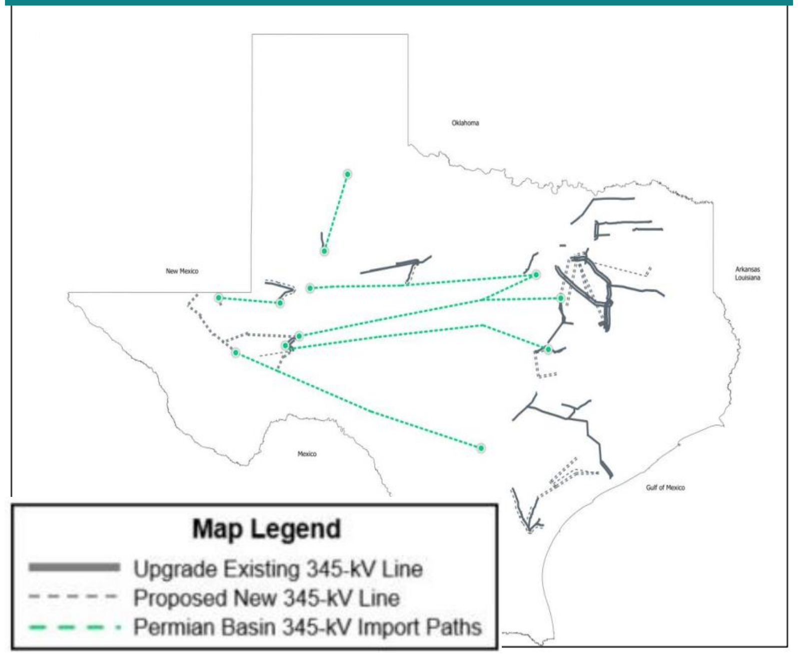
Background: Strategic Planning for a High-Growth Grid

- ERCOT is experiencing unprecedented load growth, with the 2030 summer peak demand projected to exceed 150 GW—driven by approximately 50 GW of large new loads, including:
  - Oil and gas electrification (especially in the Permian Basin)
  - Data centers, AI applications, and Crypto mining,
  - Hydrogen production and related industrial processes.
- In response, Google and the Texas Energy Buyers Alliance (TEBA) have engaged Siemens PTI to conduct a **cost-benefit analysis (CBA) of the potential 765-kV transmission buildout in ERCOT.**

765-kV Core Plan



345-kV Plan



Source: 2024 Regional Transmission Plan (RTP) 345-kV Plan and Texas 765-kV Strategic Transmission Expansion Plan Comparison.pdf

- As part of this study, Siemens PTI is evaluating the benefits of the **765-kV Core Plan**, designed to enhance long-distance power delivery from generation-rich western regions.
- A 345-kV alternative scenario is used as the counterfactual, leveraging the 2024 ERCOT Regional Transmission Plan (RTP) as the basis for comparison.

Study Assumptions

- This study aligns with ERCOT's 2024 Long-Term System Assessment (LTSA) and reflects the following planning scenarios:
- **Current Trends Scenario:** Reflects ERCOT's baseline outlook with moderate economic and demand growth, reflecting historical trends and expected economic expansion.
- **High Large Load Adoption Scenario:** Includes over 70 GW of new load from TSP forecasts, driven by cryptomining, hydrogen, and data centers.

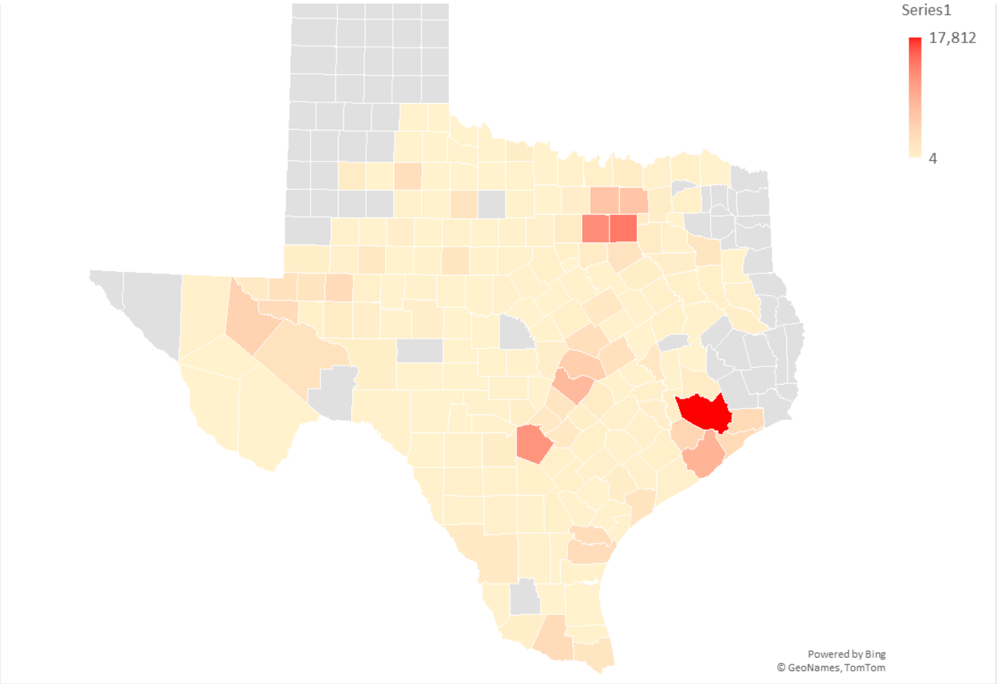
For reference, ERCOT's latest load forecast (ERCOT 2025 HB5066) projects peak demand reaching 218 GW by 2031—a projection not included in this study's analysis.

Input	Scenario	Source	2034	2039
Load	Current Trends	LTSA	109-GW	115-GW
	High Large Load Adoption	LTSA Mapping: RPG (155-GW modeled)	144-GW	186-GW (31-GW unmapped: allocate ¼ to CNP, ¾ Oncor/AEP)
Capacity Additions	Current Trends	LTSA	57.9-GW	87.7-GW
	High Large Load Adoption	LTSA Mapping: RPG (246-GW modeled)	197-GW	285-GW (39-GW unmapped: allocate to strong 345-kV buses)
Natural Gas Price	All Scenarios	HH: EIA 2023 AEO Basis: Siemens PTI	$3.67/MMBTU (2024)	$4.15/MMBTU (2024)
Transmission Topology	All Scenarios	RTP Cases	345-kV RTP (2038) 765-kV RTP STEP Case (2030)	345-kV RTP (2038) 765-kV RTP STEP Case (2030)

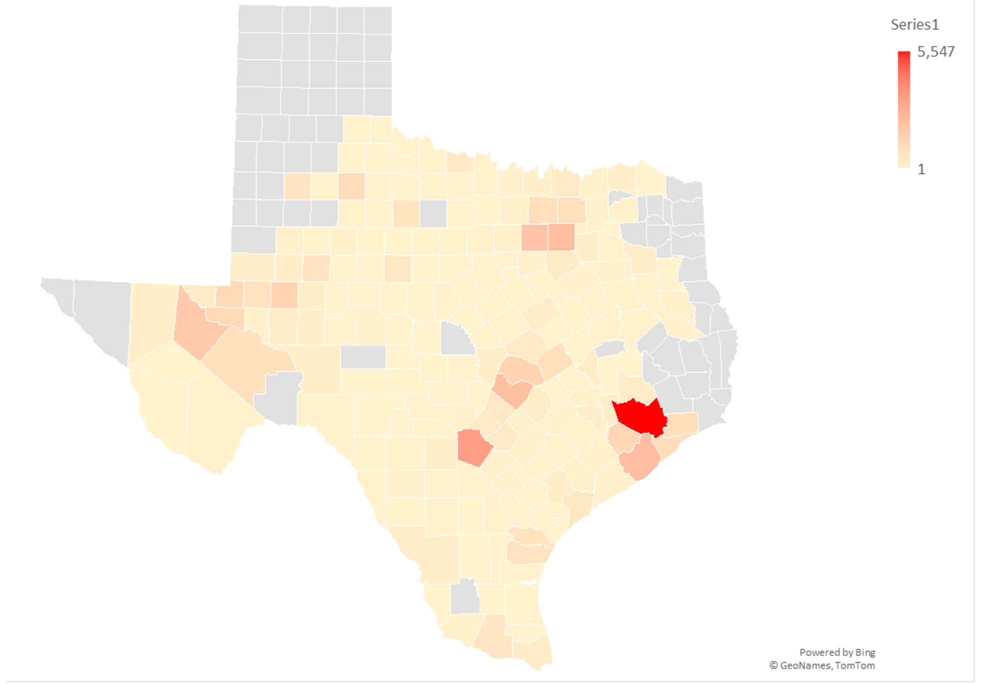
LTSA – Long-Term System Assessment (2024)
RTP – Regional Transmission Plan (2024)
RPG – Regional Planning Group

Regional Concentration of ERCOT Load and Growth

Peak Load by County – Current Trends 2039 (MW)



Peak Load Growth 2026-2039 – Current Trends (MW)

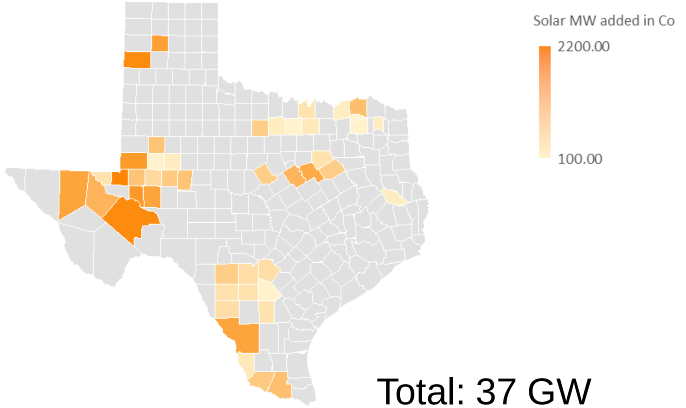


Key Insights:

- By 2039, ONCOR, CNP, and AEP collectively account for 67% of ERCOT's peak load.
- North Central (Dallas), South Central (Austin/San Antonio), and Coast (Houston) regions contribute **52% of the total peak load** in 2039.
- Between 2026 and 2034, **63% of peak load growth** occurs in these three regions, while the **Permian Basin (Far West/West) accounts for approximately 13%.**

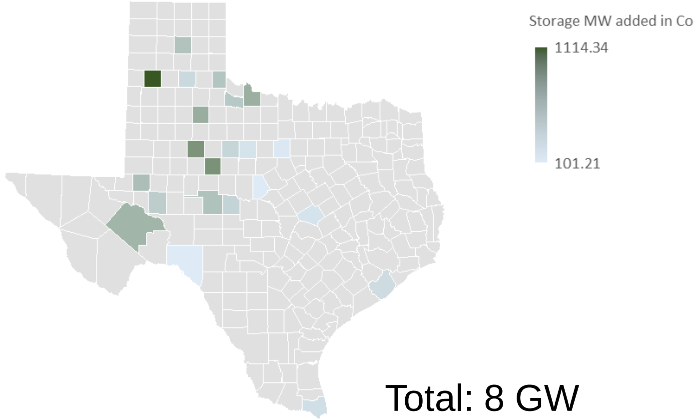
Current Trends Capacity Additions by 2039 – Key Trends

Solar Additions by 2039 (MW)



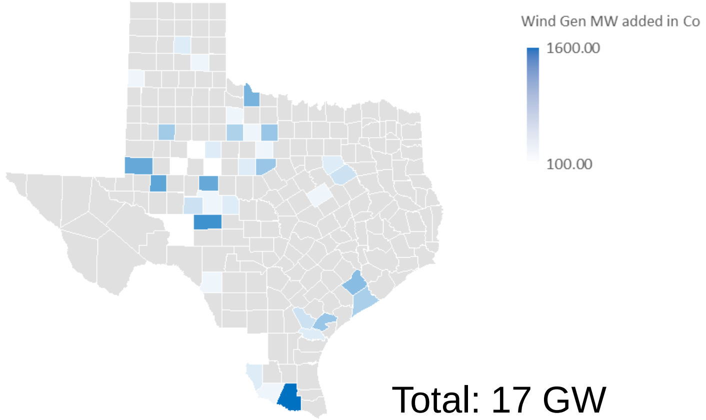
Total: 37 GW

Storage Additions by 2039 (MW)



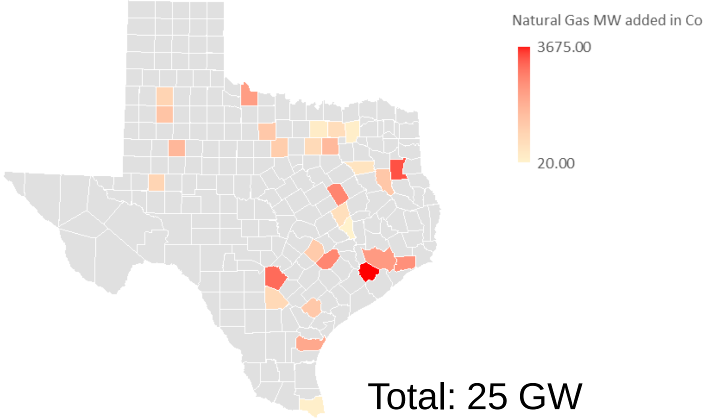
Total: 8 GW

Wind Additions by 2039 (MW)



Total: 17 GW

NG Additions by 2039 (MW)



Total: 25 GW

Key Insights:

- Over 70% of new capacity by 2039 will come from renewables, with solar leading the growth.
- Solar and wind are being developed where resource conditions are strongest — primarily in West and North Texas.
- Major load growth is occurring in the North Central (Dallas), South Central (Austin/San Antonio), and Coast (Houston) regions (63% of peak load growth).
- **This geographic disconnect between generation and demand underscores the urgent need for new transmission infrastructure.**

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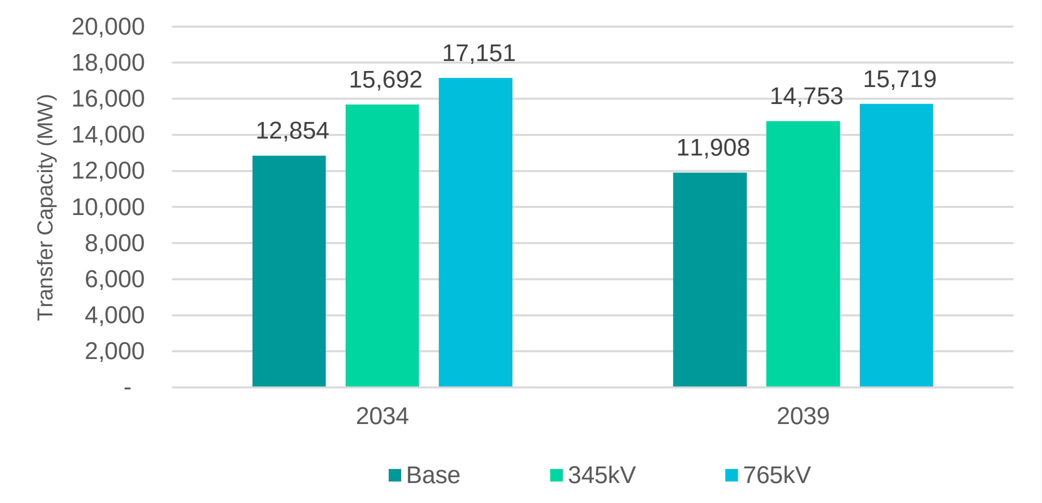
Steady-State Voltage Stability (PV Analysis): Enabling Low-Cost Power Transfer from West to East

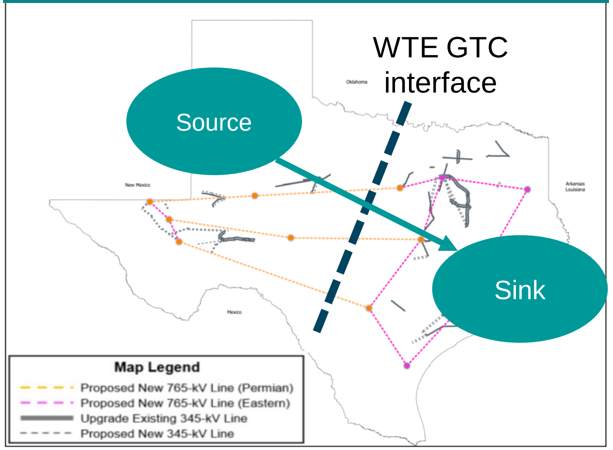
- A Steady State Voltage Stability Analysis (PV analysis) was performed to analyze the WTE transfer capacity for all cases.
- For the study year 2034, results show an improvement of 2.8 GW (**22.1%**) in WTE GTC transfer capacity for 345-kV option and 4.3 GW (**33.4%**) for 765-kV core plan.
- The 765-kV option demonstrates substantially greater improvement in transfer capability compared to the 345-kV option **(~1.46 GW** higher).
- The results of year 2039 shows similar trends when using same topology but with higher load level modeled.

WTE GTC (West to East) Transfer Capacity



Study Year	Transfer Capacity (MW)			Delta (%) Compared to Base		Delta (MW) Compared to Base	
	Base	345kV	765kV	345kV	765kV	345kV	765kV
2034	12,854	15,692	17,151	22.1%	33.4%	2,838	4,297
2039	11,908	14,753	15,719	23.9%	32.0%	2,845	3,810

765-kV Core Plan



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765-kV Transmission Reduces ERCOT's Wind Curtailment from 7.4% to 3.1% in 2039 and Solar Curtailment from 6.2% to 4.2%

- Total energy curtailment (Solar + Wind) drops to about half with 765-kV compared to 345-kV (from 2,990 MWh to 1,568 MWh).
- ERCOT South sees the most important improvement, followed by North, but benefits extend across all zones.
- Wind curtailment alone decreases by 63%, contributing to lower production and congestion costs.
- Reduced curtailment enhances grid efficiency, supports renewables integration, and helps stabilize customer costs.
- The 2034 results show identical trend.

Current Trends - 2039		Wind		Solar	
Region	Metric	765-kV	345-kV	765-kV	345-kV
ERCOT-Houston	Curtailment (%)	1.0%	0.0%	0.2%	0.1%
ERCOT-North	Curtailment (%)	1.4%	1.9%	1.1%	**3.7%**
ERCOT-South	Curtailment (%)	4.8%	**14.8%**	**4.1%**	**6.6%**
ERCOT-West	Curtailment (%)	3.0%	**6.0%**	**8.2%**	**9.2%**
Total	**Curtailment (%)**	**3.1%**	**7.4%**	**4.2%**	**6.2%**
	Curtailed Energy (MWh)	**752**	**1,779**	**817**	**1,211**

Current Trends - 2034		Wind		Solar	
Region	Metric	765-kV	345-kV	765-kV	345-kV
ERCOT-Houston	Curtailment (%)	1.9%	0%	0.8%	0.1%
ERCOT-North	Curtailment (%)	1.4%	0.8%	0.7%	**2.5%**
ERCOT-South	Curtailment (%)	3.9%	**13.7%**	**4.00%**	**6.9%**
ERCOT-West	Curtailment (%)	2.6%	**5.6%**	**7.9%**	**7.1%**
Total	**Curtailment (%)**	**2.6%**	**7.1%**	**3.9%**	**5.3%**
	Curtailed Energy (MWh)	**579**	**1,552**	**665**	**901**

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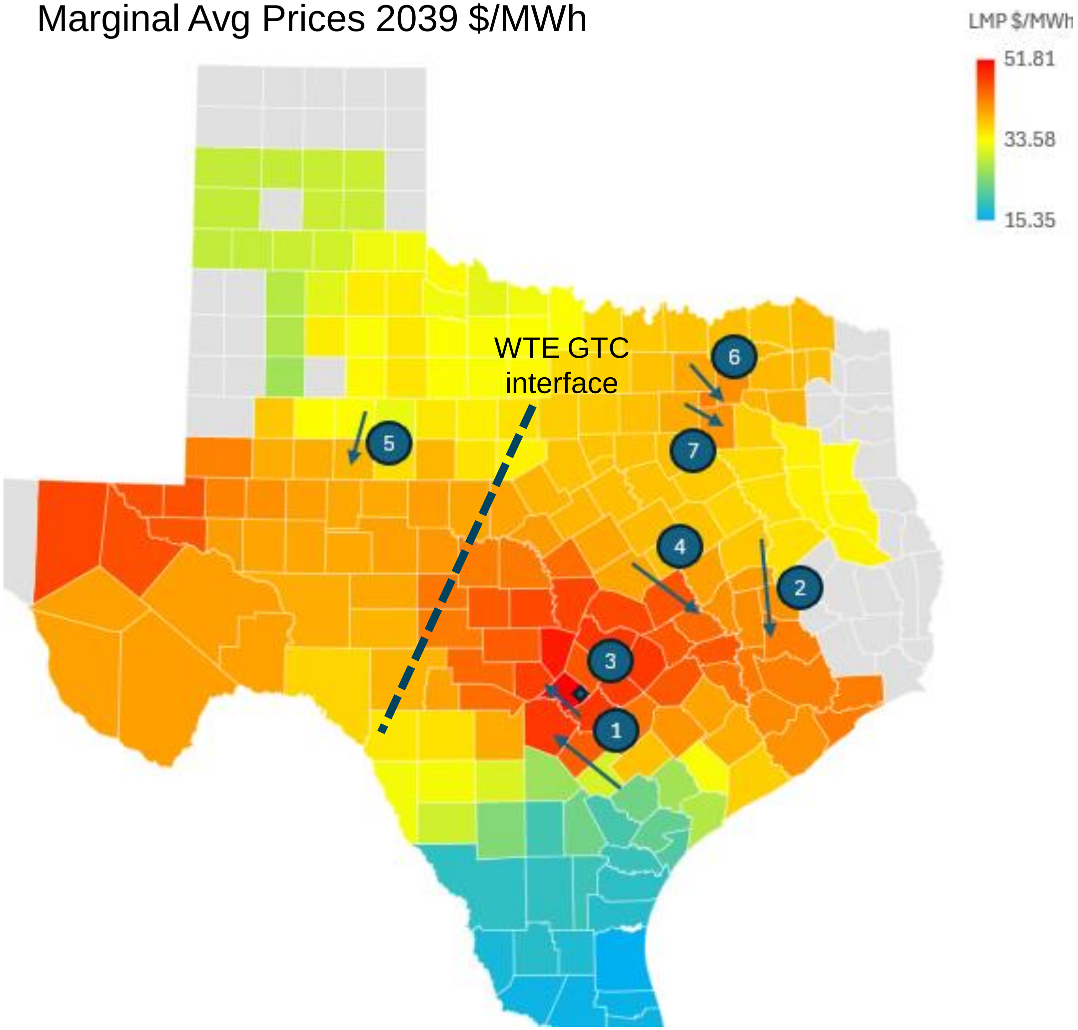
The 345 kV Transmission Scenario shows important Congestion particularly affecting the South-Central Region (2039 results)

Marginal Avg Prices 2039 $/MWh



- **South Central emerges as the congestion hotspot:** 4 of the 6 most congested lines in the 345-kV scenario affect this region.
- **The average LMPs also reflect this**. The lowest LMPs are in the south zone and facility #1 in the list (the most congested) and facility #3 constrain the transfer.
- The lower LMPs and associated generation the north and panhandle also limited to reach the load due to transmission constraints.
- The WT-GTC appears also to be binding

	345-kV Top Congested Branches - Current Trends 2039				
	From Bus	To Bus	From Zone	To Zone	Congestion
1	5400 [SPRUCE] 345kV	5725 [PAWNEESW5] 345kV	SOUTH_CE	SOUTH_CE	$ 546.28
2	3390 [JEWETT_S5] 345kV	44645 [SNGLTN__B345] 345kV	EAST	EAST	$ 171.27
3	7770 [L_BERGHE5] 345kV	345/138 kV transformer	SOUTH_CE	SOUTH_CE	$ 167.62
4	3687 [BELL_E_5] 345kV	13429 [SAND_TXU_5] 345kV	NORTH_CE	SOUTH_CE	$ 163.35
5	10049 [RANGER_5] 345kV	11048 [TONKAWAW_5] 345kV	NORTH_CE	WEST	$ 153.66
6	1685 [FARMVLSW_5] 345kV	2461 [ROYSE_N5] 345kV	NORTH_CE	NORTH_CE	$ 118.31
7	2432 [TRICRN1_5] 345kV	2437 [FRNY1_5] 345kV	NORTH_CE	NORTH_CE	$ 114.48
	Total Congestion top 20 facilities 345 kV Case				**$ 2,142.89**

To and From buses do not indicate flow direction

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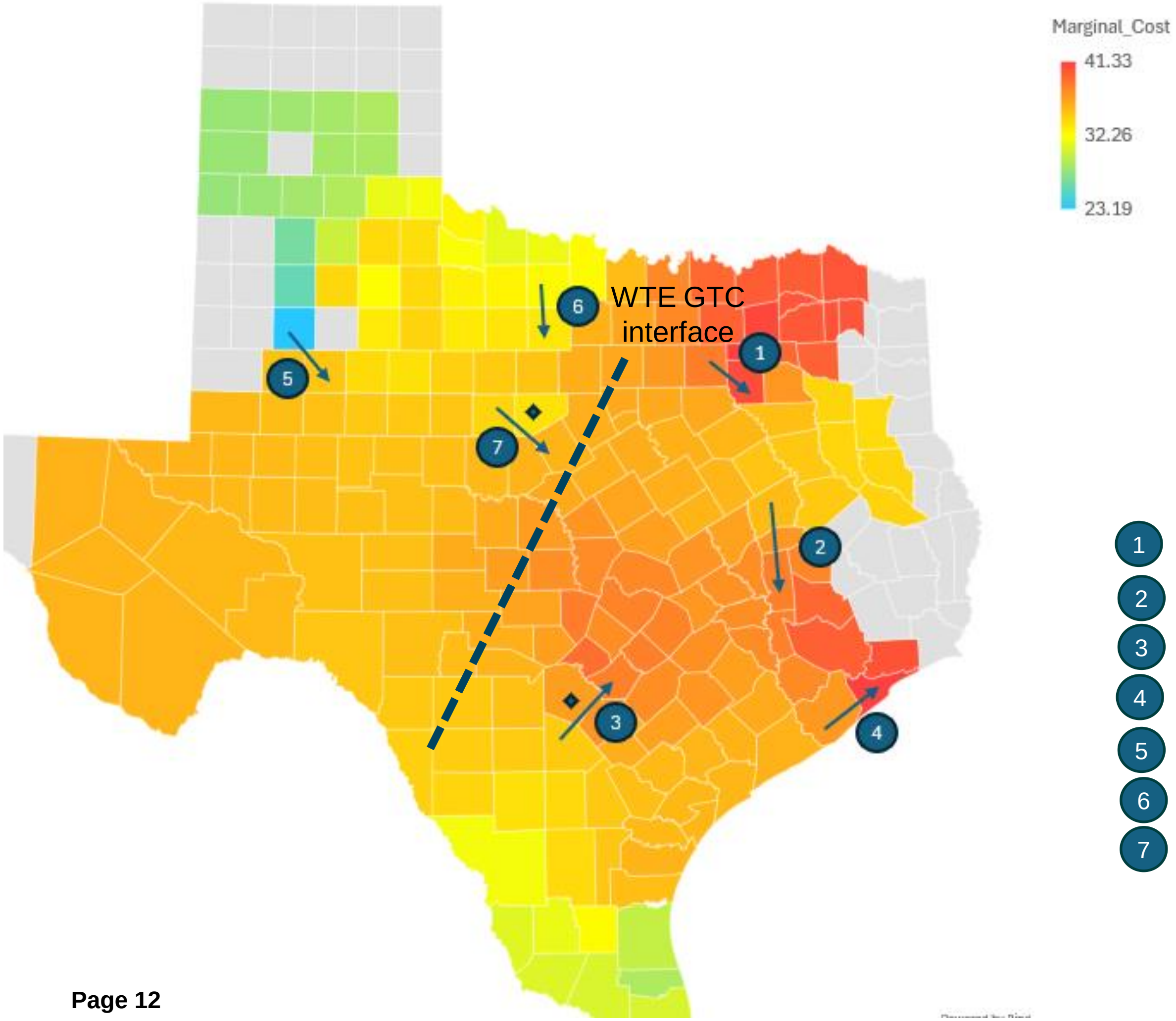
The 765 kV Transmission Scenario largely addresses the congestion affecting the South-Central Region (2039 results)

Marginal Avg Prices 2039 $/MWh



- The 765 kV option, diminishes system-wide congestion, especially in the South-Central Zone, mitigating the major transmission bottlenecks.
- **Again, the average LMPs also reflect this**. The LMPs are in a narrower range reflecting lower congestion.
- With 765 kV Option the Texas Panhandle shows similar levels of constraint as the south zone and the identified constraints reflect this.
- The WT-GTC appears be only weakly binding
- The 2034 results show the same trend

	765 kV Top Congested Branches - Current Trends 2039				
	From Bus	to Bus	From Zone	To Zone	Congestion
1	2432 [TRICRN1_5] 345kV	2437 [FRNY1_5] 345kV	NORTH_CE	NORTH_CE	$ 146.02
2	3390 [JEWETT_S5] 345kV	44645 [SNGLTN__B345] 345kV	EAST	EAST	$ 120.47
3	5056 [CAGNON_5] 345kV	5211 [HILLCTY_5] 345kV	SOUTH_CE	SOUTH_CE	$ 117.88
4	42000 [P_H_R__B345] 345kV	43030 [MEADOW_B345] 345kV	COAST	COAST	$ 114.40
5	23924 [FARMLAND_5] 345kV	888856 [HOLLY_POI] 345kV	FAR_WEST	SOUTH_CE	$ 110.98
6	1430 [GRHAMSES1_] 345kV	17002 [GARVEYRD_5] 345kV	NORTH_CE	NORTH	$ 64.12
7	68010 [ROMNEY1_W] 345kV	68020 [ROMNEY1_E] 345kV	NORTH_CE	NORTH_CE	$ 57.73
	Total Congestion top 20 facilities 345 kV Case				**$ 926.82**

To and From buses do not indicate flow direction

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CBA Highlights Strong Economic and System Value of 765-kV Transmission System

- **Affordability:** 765-kV infrastructure delivers lower production costs, lower consumer energy costs, and dramatically reduced congestion rents driven by the ability of 765 kV lines to deliver more low-cost energy into high-demand areas.
- **Sustainability:** Greater access to renewable energy under 765-kV reduces reliance on fossil fuels and curtailment, with potential for meaningful emissions reductions.
- **Reliability:** Results show 765 kV design is over 2x more effective in providing resiliency when extreme events happened during maintenance outages period (N-1-1), and approximately 4x more effective in reducing thermal overloads under N-1 extreme events vs 345 kV design.

			Current Trends		
	Attributes	**Metric**	**765-kV**	**345-kV**	**CBA (Δ/ΔARR)***
Affordability	Production Cost	2034 (M$)	15,137	15,508	2.1
		2039 (M$)	15,982	16,471	2.8
	Consumer Energy Cost	2034 (M$)	13,518	14,323	4.6
		2039 (M$)	15,434	16,375	5.4
	Congestion Rent	2034 (M$)	469	1,386	5.0
		2039 (M$)	972	2,318	7.7
	Generator Revenue	2034 (M$)	22,486	23,353	5.3
		2039 (M$)	25,251	26,280	5.9
Sustainability	Emissions	Total from 2034-2039 (millions tCO_2)	774	801	NA
Reliability	Resilience (Transmission Impact Event)	N-1 Vulnerability Index (MVA)	148	737	NA
		N-1-1 Vulnerability Index (MVA)	99,915	249,426	NA

*ARR: Annual Revenue Requirements or annualized cost for capital investments. More detail in Appendix C.

$$\mathrm{CBA}_{\mathrm{metric}} = \frac{\mathrm{Value}_{345} - \mathrm{Value}_{765}}{\mathrm{ARR}_{765} - \mathrm{ARR}_{345}}$$

765-kV Outperforms 345-kV Across Key Metrics in Both ERCOT and Siemens PTI's Analyses

- Both ERCOT and Siemens PTI analyses confirm that a 765-kV system outperforms the 345-kV option even under the Current Trends Scenario, which represents a conservative load forecast.
- Siemens PTI's analysis shows even greater cost savings across all categories, further strengthening the case for 765-kV development.

		ERCOT RTP Analysis			Siemens PTI Analysis		
Attributes	**Metric**	**765-kV**	**345-kV**	**Difference**	**765-kV**	**345-kV**	**Difference**
Production Cost	2034 (M$)	16,836	16,969	133	15,137	15,508	370
	2039 (M$)	19,059	19,088	28	15,982	16,471	489
Consumer Energy Cost	2034 (M$)	18,279	18,143	-136	13,518	14,323	805
	2039 (M$)	21,914	22,143	229	15,434	16,375	941
Congestion Rent	2034 (M$)	1,444	1,539	94	469	1,386	917
	2039 (M$)	2,089	2,261	172	972	2,318	1,345

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765-kV Outperforms 345-kV Across Key Metrics in Both Current Trends and High Large Load

- Both ERCOT and Siemens PTI analyses confirm that a 765-kV system outperforms the 345-kV further under the High Large Load Scenario, which is more reflective of the latest release of ERCOT's long-term load forecast as of April 2025.
- Siemens PTI's analysis shows even greater cost savings across all categories, further strengthening the case for 765-kV development.

		Siemens PTI Current Trends			Siemens PTI High Large Load		
Attributes	**Metric**	**765-kV**	**345-kV**	**Difference**	**765-kV**	**345-kV**	**Difference**
Production Cost	2034 (M$)	15,137	15,508	370	20,465	20,572	107
	2039 (M$)	15,982	16,471	489	29,984	30,070	86
Consumer Energy Cost	2034 (M$)	13,518	14,323	805	30,128	32,613	2,485
	2039 (M$)	15,434	16,375	941	102,011	103,508	1,496
Congestion Rent	2034 (M$)	469	1,386	917	6,646	7,008	362
	2039 (M$)	972	2,318	1,345	28,581	34,314	5,733

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Discounted Future Benefits of Transmission Projects

- Purpose: To evaluate long-term transmission benefits by applying discount rates that reflect the time value of money and uncertainties in realizing future benefits. The left table presents Net Present Value (NPV) of 765 kV benefits and capital cost differences under varying discount rates and rate escalation scenarios.
- The right table shows Net Benefits (Benefits minus CapEx) for the same conditions.
- Net Benefits remain positive even under high discount rates, indicating the Internal Rate of Return (IRR) for the 765 kV option exceeds those rates.
- A discount rate of 21% would be required for Net Benefits to fall to zero, demonstrating strong economic resilience.
- Results consistently support the 765 kV option as economically superior to the 345 kV alternative across a wide range of assumptions.

765 vs 345 Benefits & Delta CapEx ($M)				
Discount	Production	Consumer	Congestion	CapEx
2%	$3,925	$7,726	$8,428	-$1,130
4%	$2,640	$5,221	$5,691	-$948
6%	$1,854	$3,683	$4,012	-$799
8%	$1,344	$2,682	$2,920	-$675
10%	$999	$2,000	$2,176	-$573
12%	$756	$1,519	$1,652	-$487
14%	$581	$1,172	$1,274	-$415

765 vs 345 Net Benefits after CapEx ($M)			
Discount	Production	Consumer	Congestion
2%	$2,795	$6,596	$7,298
4%	$1,691	$4,272	$4,742
6%	$1,055	$2,884	$3,213
8%	$669	$2,006	$2,244
10%	$426	$1,427	$1,603
12%	$270	$1,032	$1,166
14%	$166	$757	$859

Based on Current Trends

765 kV Transmission Provides Stronger Resilience under Extreme Weather Events Tested

Resilience Assessment:

Siemens PTI evaluated system resilience under two low-probability, high-impact events:

- **Generation Impact Event (e.g. Winter Storm URI):** No significant difference observed between 345 kV and 765 kV designs.
- **Transmission Impact Event (e.g. major hurricane):** Results show two designs perform similarly under the loss of a whole substation, however 765 kV design is over 2 times more effective/flexible in accommodating required transmission maintenance.

Resource Adequacy Assessment:

- Monte Carlo simulations were used to assess the 2034 system.
- 765 kV topology results in minimal unserved energy reduction. Most shortages were due to system-wide energy limitations, not transmission constraints.

Scenario (events)	Metric	345 kV Design	765 kV Design	Key Finding
2034_Current Trend (loss of a sub)	Vulnerability Index (MVA)	216	148	Two designs perform similarly
2034_High Renewable (P7 during maintenance)	Vulnerability Index (MVA)	249,426	99,915	765 kV design is >**2x more effective** in accommodating required maintenance

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Import Path 1 is the most critical path foundational to the 765-kV system's value

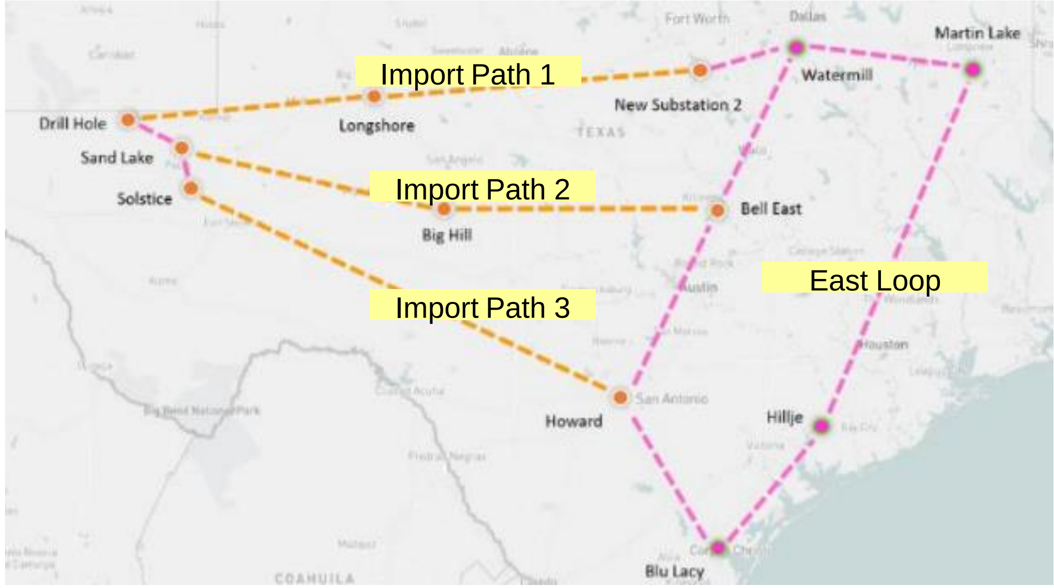
- Siemens PTI evaluated multiple import path combinations to determine which lines deliver the greatest impact on GTC relief and production cost savings, guiding prioritization for ERCOT's 765-kV development.

- **Import Paths 1 & 2 + Watermill–Bell East** delivers the best GTC improvement per ARR, making it the most cost-effective configuration for improving system transfer capability.

- **Import Path 1 alone** provides the highest production cost savings per dollar of ARR added, making it the most cost-efficient building block of the 765-kV plan.

- **Prioritizing Import Path 1 provides the most efficient return on investment and serves as the anchor investment for unlocking full 765-kV system benefits.**

Transmission Configuration	GTC Limit (MW)	GTC improvement (MW)	Tlines (Miles)	ARR (B$/yr)	GTC/ARR Ratio	2034 Production Cost (B$)	Net Benefit vs 345-kV (B$)	Contribution to the Production Cost Benefit
Base Case (Do Nothing)	11908							
Import 1	12916	1008	519	1.027	0.982	15.227	0.281	76%
Import 1 & 2	13297	1389	963	1.417	0.980	15.191	0.317	85%
Import 1 & 3	13248	1340	889	1.349	0.994			
Import 1 + East Loop	14373	2465	1654	3.564	0.692			
import 2 + East Loop	14252	2344	1579	3.505	0.669			
Import 1 & 2 with Watermill – Bell East	14764	2856	1096	1.714	1.666	15.187	0.321	87%
Import 1 & 3 with Watermill – Bell East - Howard	14772	2864	1192	2.026	1.414			
import 3 + East Loop	14219	2311	1505	3.436	0.673			
Import 1 & 2 + East Loop	15425	3517	2098	3.954	0.889			
Import 1 & 3 + East Loop	15344	3436	2024	3.885	0.884			
Import 2 & 3 + East Loop	14612	2704	1948	3.826	0.707			
765-kV	15779	3871	2468	4.272	0.906	15.137	0.371	
345-kV	12664	756		4.102	0.184	15.508		



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Appendix A - Assumptions

Assumptions Summary

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Transmission Topology	All Scenarios	RTP Cases	345-kV RTP (2030) 765-kV RTP STEP Case (2030)	345-kV RTP (2038) 765-kV RTP STEP Case (2030)

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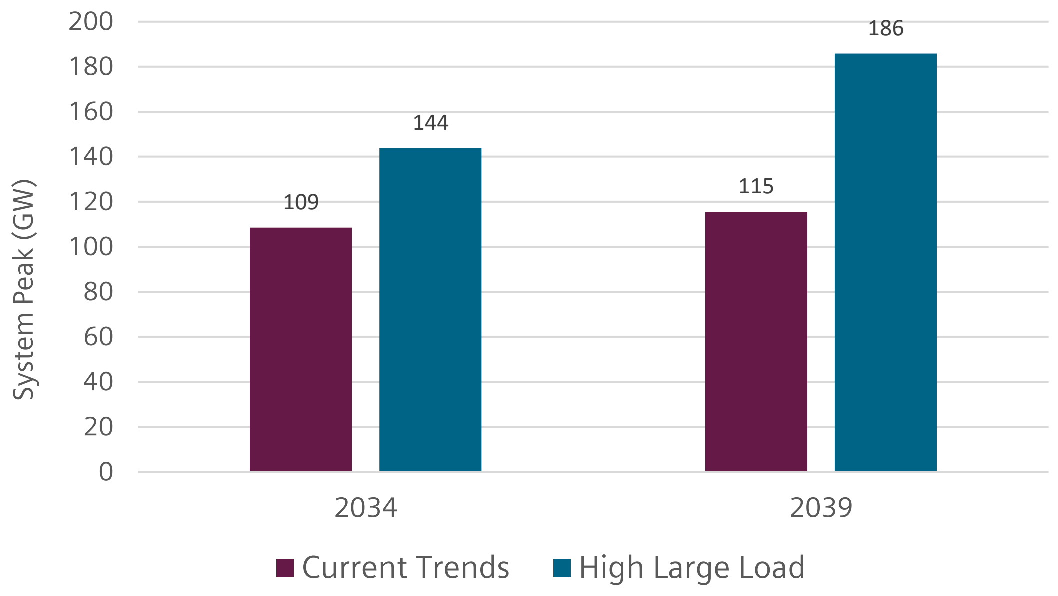
Load Scenarios & Load Distribution

- **Load Scenarios:**
  - **Current Trends:** Represents ERCOT’s moderate growth scenario from the LTSA, reflecting historical trends and expected economic expansion.
  - **High Large Load Adoption:** Assumes significant load growth beyond historical trends, incorporating TSP-submitted forecasts based on interconnection requests, industrial expansion, and economic growth. This scenario includes large flat demand (66 GW) and price-responsive load (4 GW LFL).
- **Load Distribution to Nodal Level:**
  - **Current Trends:** Detailed data at an hourly and nodal level allocations for 2034 and 2039 based on ERCOT’s LTSA projections.
  - **High Large Load Adoption:** Includes no detailed nodal allocation data, therefore we will use the RPG case to allocate to the nodal level, up to 155 GW. Since CNP shows no growth in the Current Trends scenario, the necessary unmapped additional load in 2039 will be allocated as follows: CNP: ¼ of the additional load & Oncor/AEP: ¾ of the additional load

Load Scenarios (GW)



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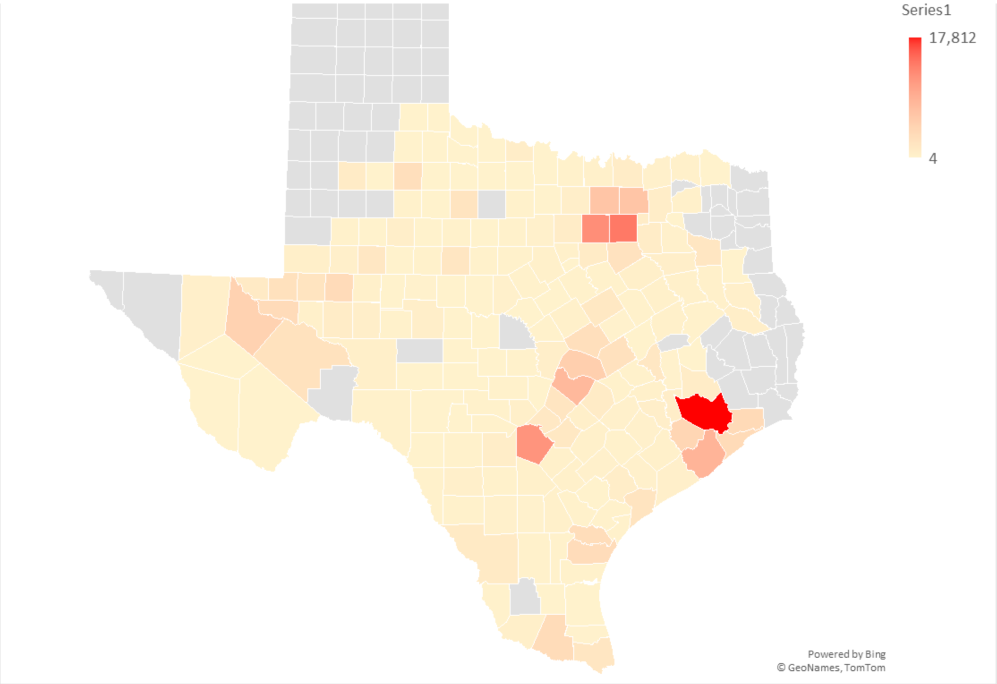
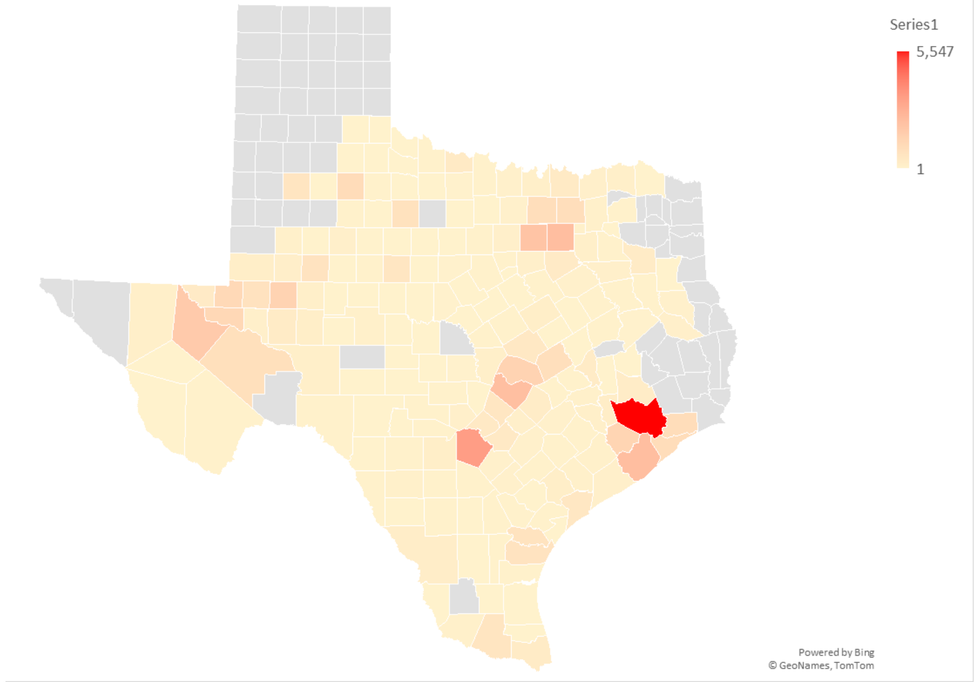
Regional Concentration of ERCOT Load and Growth

Peak Load by County – Current Trends 2039 (MW)



Peak Load Growth 2026-2039 – Current Trends (MW)



Key Insights:

- By 2039, ONCOR, CNP, and AEP collectively account for 67% of ERCOT's peak load.
- North Central (Dallas), South Central (Austin/San Antonio), and Coast (Houston) regions contribute **52% of the total peak load** in 2039.
- Between 2026 and 2034, **63% of peak load growth** occurs in these three regions, while the **Permian Basin (Far West/West) accounts for approximately 13%.**

New Capacity Additions

- **Capacity Additions:**
  - New large load additions in the High Large Load Adoption scenario are expected to be primarily supplied by wind and solar, with solar additions projected to be 4x higher than in the Current Trends outlook.
  - The largest capacity increase is expected from combustion turbines (CTs) to mitigate intermittency and support the 24/7 energy demands of large loads
- **Mapping:**
  - **Current Trends:** ERCOT provides capacity additions and mapping for Current Trends (2034 and 2039).
  - **High Large Load Adoption:** ERCOT's LTSA outlines total capacity additions, but Siemens PTI must perform mapping. As a starting point, Siemens will use the RPG case mappings (246 GW), which allocate capacity to strong 345-kV buses.

New Capacity by 2034 (MW)		
Technology	**Current Trends**	**High Large Load**
Battery	9,748	23,095
Combined Cycle	9,747	17,328
CT & IC	6,162	52,140
Solar	19,951	84,056
Wind	12,300	20,400
Total	**57,908**	**197,019**

New Capacity by 2039 (MW)		
Technology	**Current Trends**	**High Large Load**
Battery	17,514	26,911
Combined Cycle	15,162	28,158
CT & IC	9,951	83,187
Solar	28,800	125,368
Wind	16,300	22,200
Total	**87,727**	**285,824**

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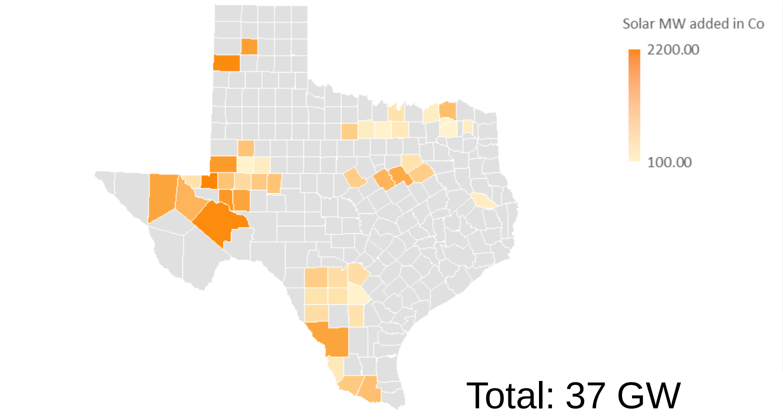
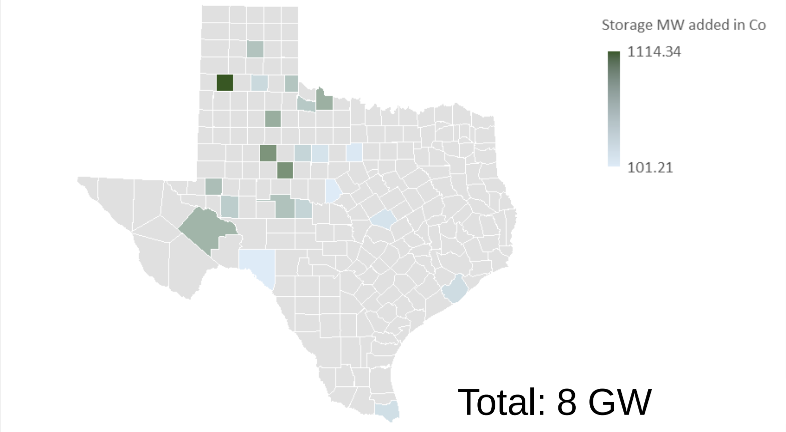
Current Trends Capacity Additions by 2039 – Key Trends

Solar Additions by 2039 (MW)



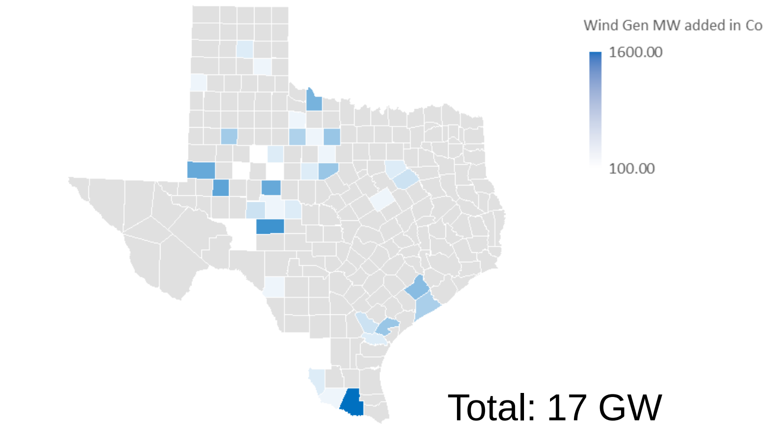
Total: 37 GW

Storage Additions by 2039 (MW)



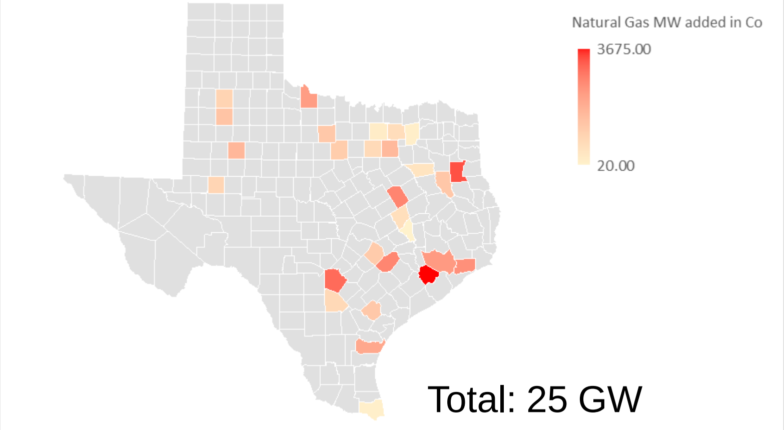
Total: 8 GW

Wind Additions by 2039 (MW)



Total: 17 GW

NG Additions by 2039 (MW)



Total: 25 GW

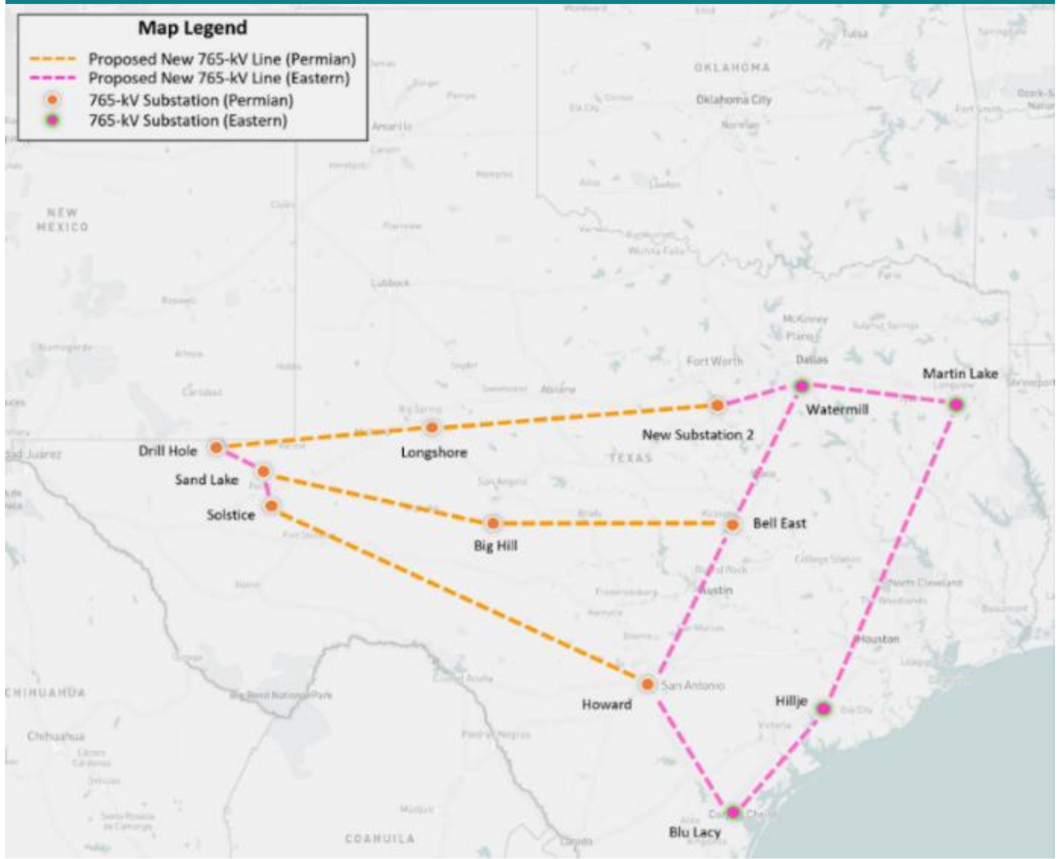
Key Insights:

- Over 70% of new capacity by 2039 will come from renewables, with solar leading the growth.
- Solar and wind are being developed where resource conditions are strongest — primarily in West and North Texas.
- Major load growth is occurring in the Central and Coast.
- This geographic disconnect between generation and demand underscores the urgent need for new transmission infrastructure.

765-kV Topology

- Siemens PTI will use the 765-kV Core Plan based on 2030 Case as depicted in ERCOT's 2024 RTP.

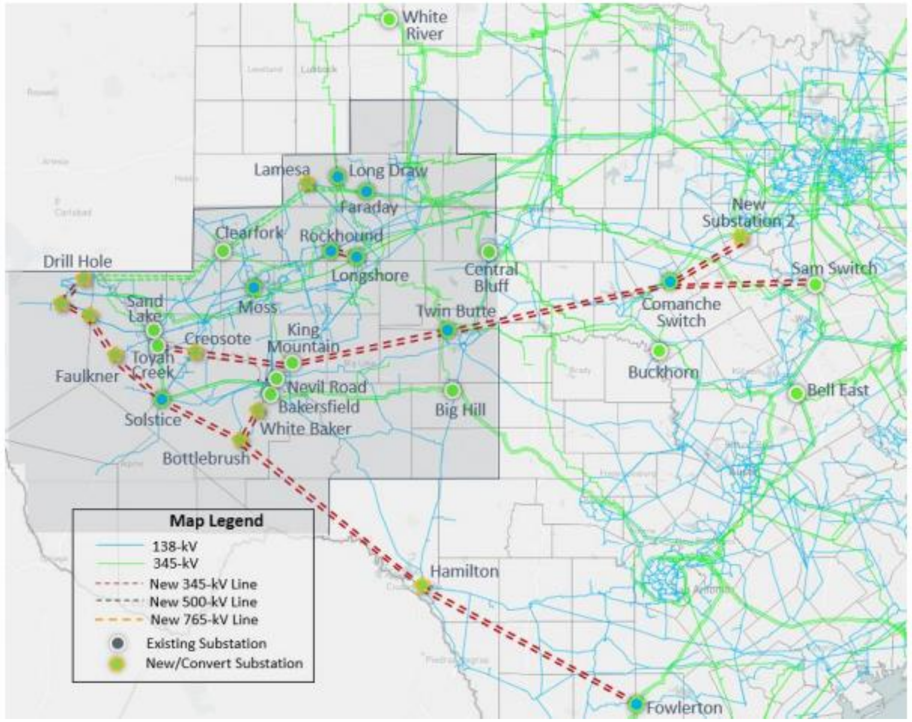
765-kV Core Plan Transmission System



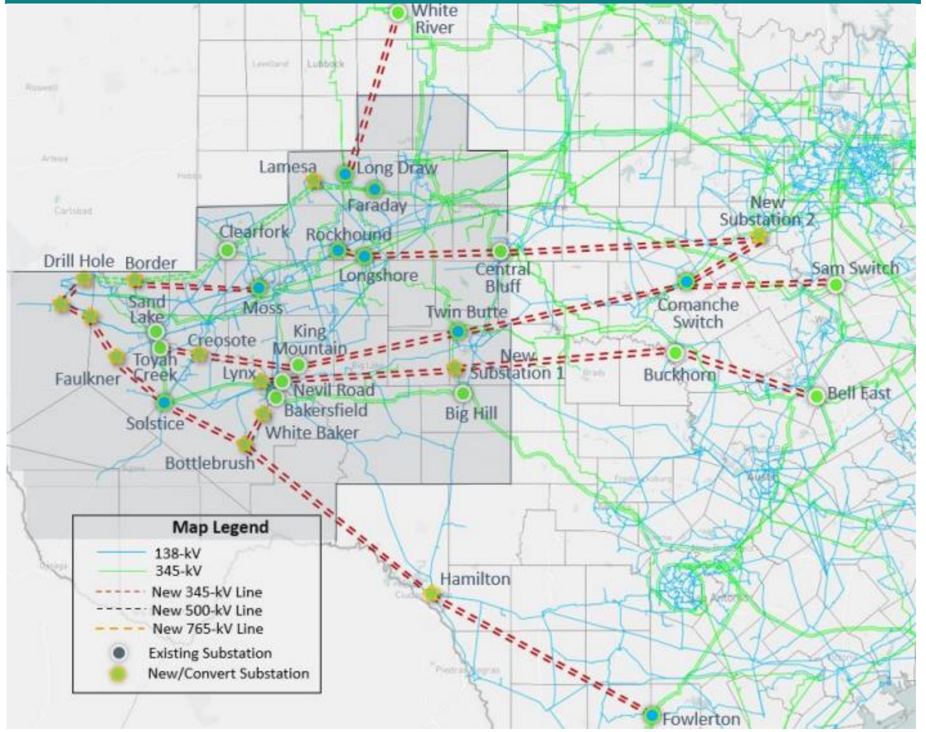
345-kV Topology

- Alternative Solution: 345-kV transmission reinforcements depicted below and obtained from recent ERCOT analyses (Permian Basin Reliability Plan Study, from Jul 2024, and the 2024 Regional Transmission Plan, from Dec 2024).
- The 2034 Case will be based on RTP plan for 2030 and 2039 will be based on 2038 Case.

345-kV Permian Basin Upgrades 2034

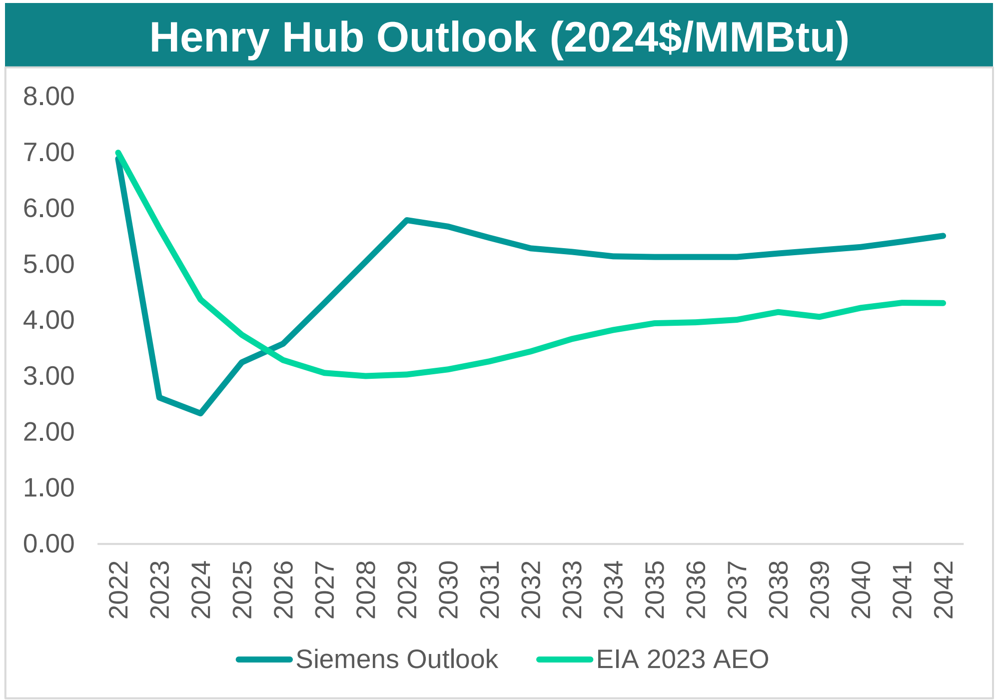


345-kV Permian Basin Upgrades 2039



Natural Gas Forecast

- As reported in their 2024 LTSA, ERCOT utilized the gas price outlook from the latest EIA Annual Energy Outlook (AEO)*
- Due to the fast-changing nature of the electric industry right now, EIA has decided to skip the 2024 AEO to focus on incorporating large changes within their modeling (such as new emerging technologies, etc.)
- Due to this, the latest available AEO was released in March 2023.
- Siemens PTI produces and regularly updates our gas outlooks via a fundamentals-based industry standard model, GPCM. which also incorporates recent forwards as of October 2024.
- **After careful consideration, we have collectively decided to use the EIA 2023 AEO, despite its outdated nature, as it remains more conservative and aligns with ERCOT's RTP study.**



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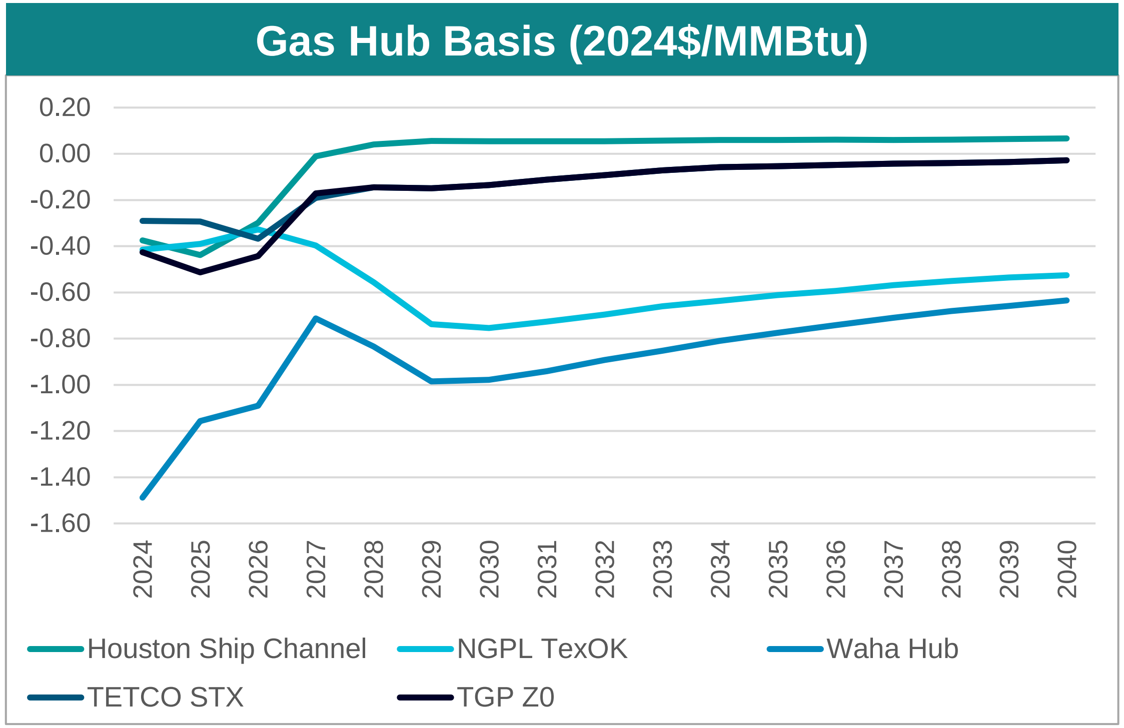
Natural Gas Basis

WAHA Hub Basis Insights

- WAHA hub often shows more volatility due to infrastructure constraints and pipeline bottlenecks in West Texas
- WAHA prices historically trade at a discount to Henry Hub due to transportation costs and regional supply imbalances.

Waha Future Expectations

- Anticipated to benefit from infrastructure upgrades, which are expected to reduce the differential with Henry Hub
- Various projects are expected to alleviate bottlenecks including:
  - Matternhorn Express Pipeline (operational as of late 2024)
  - Blackcomb Pipeline (expected 2026)
  - Hugh Brinson Pipeline (approved Q4 2024, operations expected 2026)



Note: Historical prices from Jan 2019 to September 2024. Reference case prices were developed using NYMEX forwards (Forwards are an average of 10/2/2024, 10/9/2024, and 10/16/2024). Forwards were used until March 2026 with hybrid of forwards and fundamentals until September 2027 and pure fundamentals thereafter.

Currently, less than 10% of the total gas capacity in ERCOT is utilizing the WAHA price point.

Discounted Future Benefits of Transmission Projects Methodology

- **Purpose:** To evaluate long-term transmission benefits using discount rates to reflect the time value of money and uncertainties on the realization future benefits .

- **Method:** Analyze projected benefits for the life of the projects
  - Transmission projects were assumed to have an economic life of 60 years
  - For the 345 kV and 765 kV project a discount model was created with Production Costs, Consumer Costs, Generator Revenue, Congestion Costs from 2034 to 2094 (60 years).
  - For 2034 and 2039 the results of the AURORA runs were used, for 2035 to 2038 interpolation was used and values for 2040 onwards were maintained equal to 2039.
  - The discount model was extended to 2025 (zero costs before 2034) and the projects total CapEx was modeled as an overnight amount in 2033.
  - The benefit and CapEx differential was determined subtracting 345 kV yearly results from 765 kV results. Benefits were positive, CapEx differential negative as 765 kV has greater capital requirements.
  - The 2025 NPV was determined using base discounts rates of 2% to 14%, which were increased by adding 2.5% for the period 2035 to 2039 and 5% for 2039 onwards. This increase in the discount rate reduces the NPV’s impact of future benefits, which are uncertain.

- **Goal:** Provide deeper insight into the economic and reliability value of the 765-kV transmission investment compared to 345-kV.

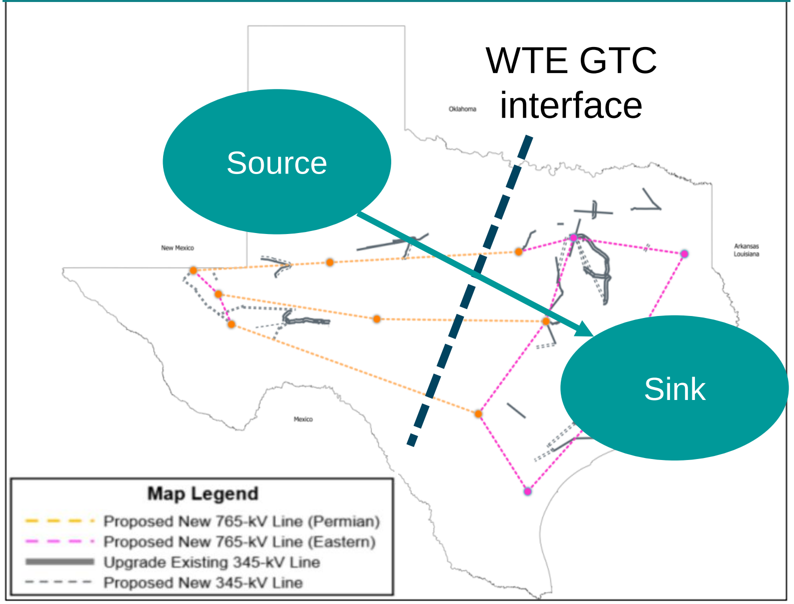
Appendix B – PV Analysis

PV Analysis Conclusions

Methodology:

- Cases were adjusted based on ERCOT 2030 RTP cases to have a reasonable west to east flow in the WTE GTC interface:
  - ALL ERCOT coal and CT units were turned off
  - Partial East/Coastal CC units were turned off/ dispatched down
  - ERCOT loads were scaled down from 155 GW (in RTP cases) to 115 GW which aligns with 2039 current trend

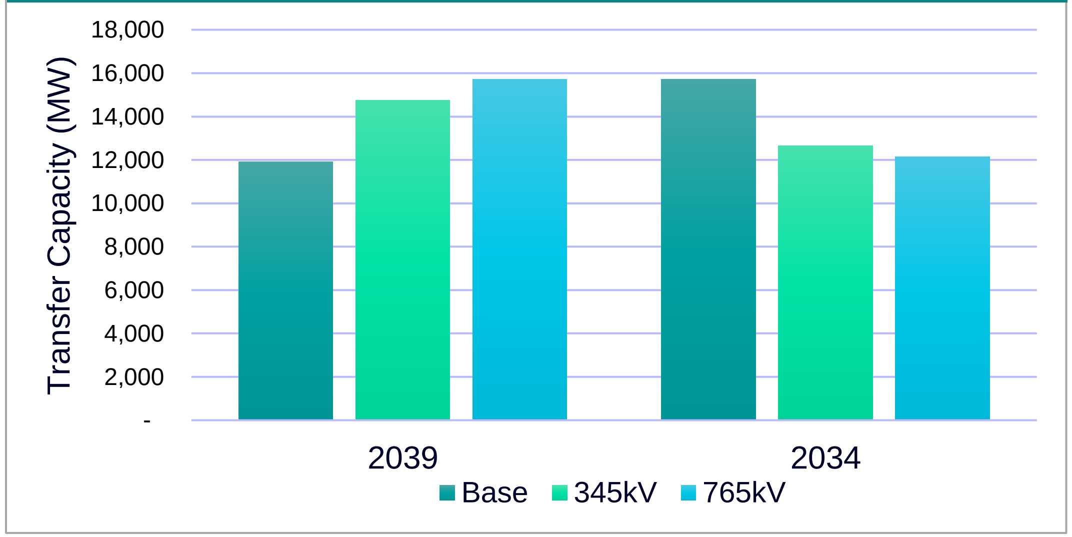
765-kV Core Plan



Key Insights:

- For the study year 2039, results show an improvement of 2.8 GW (***23.9%)*** in WTE GTC transfer capacity for 345-kV option and 3.8 GW (***32%***) for 765-kV core plan.
- The 765-kV option demonstrates substantially greater improvement in transfer capability compared to the 345-kV option (***~1GW*** higher).
- The results of year 2034 shows similar trends when using same topology but with lower load level modeled.

WTE GTC (West to East) Transfer Capacity



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Appendix C - Economic Results

Annual Revenue Requirements

- To evaluate the CBA of each transmission system (765-kV and 345-kV), we calculated the Annual Revenue Requirement (ARR) associated with each buildout.
- ARR provides a standardized annualized cost for capital investments,.
- We used the Capital Charge Rate (CCR) approach to annualize total capital costs.
- The CCR converts up-front capital costs into an equivalent annual cost.
- The total ARR includes:
  - Cost of capital (debt & equity)
  - Asset life (amortization schedule)
  - Depreciation schedule
  - Income taxes (federal & state)
  - Property taxes
  - Insurance
  - Fixed O&M

Annual Revenue Requirement	
765-kV ARR	4.278 B/year
365-kV ARR	4.102 B/year

Financial Assumptions		
Useful Life	40	years
Cost of Equity	13.0	%
Cost of Debt	7.3	%
Equity	40	%
Debt	60	%
Depreciation Annual Rate	2.50	%
WACC (Nominal After Tax)	8.66	%
Insurance and Admin	0.70	%
Tax Rate	21.0	%
Property Taxes	0.7	%
Capital Charge Rate (CCR)	12.6	%

Economic Assumptions		
CAPEX 765-kV	33.9	Billion
CAPEX 345-kV	32.55	Billion
765-kV Miles	2468	Miles
345-kV Miles	2673	Miles
Annual FOM (765-kV)	$8,000	Mile-year
Annual FOM (345-kV)	$5,000	Mile-year

Appendix D – Reliability Study

Resiliency Scenarios

Historical Low Probability High Impact Events in ERCOT

- Siemens PTI will assess the resilience of the system by testing its response to two low-probability, high-impact events.
- The analysis will evaluate the system's resilience using EUE and LOLE metrics under these extreme conditions, providing insights into how the systems perform during rare but critical events.
- ERCOT has historically experienced three types of events that result in unserved electricity: heat waves, winter storms, and hurricanes.
- We will be simulating one Generation Impact event (e.g., a severe winter storm or heat wave with generation derates) and one Transmission Impact event (e.g., a major hurricane causing significant transmission outages).

Events	Years	Load Impact	Generation Impact	Transmission Impact
Heat Waves	2006, 2011, 2019, 2022, 2023	High Electric Demand	Reduced wind generation during peak hours due to still air conditions	None
Winter Storms	2008, 2011, 2014, 2021, 2022	High Electric and Gas Demand	Significant thermal unit outages; e.g., over 26,000 MW offline during Winter Storm Uri in 2021	Minimal
Hurricanes	2008, 2017	High Electric and Gas Demand	Minimal	Extensive transmission outages; e.g., Hurricane Harvey caused over 100 circuits out of service

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Resilience Scenarios – Low Probability High Impact Events

Events	Description	Generation Forced Outage	Transmission Loss	Load
Transmission to Extreme Weather Event (Hurricane)	Transmission Outage	NA	Run an extreme contingency system analysis (PSS/E), including ERCOT 1 (common tower outage) during the maintenance period and loss of a whole substation (>= two lines at the time). Assess Vulnerability Index to quantify the impact.	NA
Generation to Extreme Event (Winter Storm)	Generator Outage	1st Week: 30% thermal units offline 2nd Week: 15% thermal units offline	No-Prexisting, system to be secure for next contingency, using ERCOT's contingency set.Use AURORA to estimate energy not served. ***Note URI affected largely 138 kV and below due to ice accumulation.*	Duplicate load level % leading up to Uri outages based on new forecasted annual average

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Transmission to Extreme Weather Event Results

To quantify impact of transmission extreme weather event on the system, below vulnerability index is defined.

- Vulnerability Index = Sum of all thermal overloads (345 kV and above) in MVA
    - For example: if a line is rated 2,000 MVA and is overloaded by 4%, then it contributed 80 MVA to the index.

- ***Loss a whole substation***
    - Extreme events of losing a whole substation (345kV and above) were tested in the 2034 Current Trend case. *Vulnerability index shows small difference between the two designs.*

Year_Scenario	Design	Vulnerability Index (MVA)
2034_Current Trend	345 kV	216
	765 kV	148

- ***Loss of common tower double circuits during maintenance period***
    - Assuming one transmission line (s) (345kV and above) under maintenance (modeled as P1), followed by the loss of another common tower double circuits (P7).
    - Tested under a high renewable low load scenario since maintenances are usually scheduled during off-peak seasons.
    - *Vulnerability index shows the 765kV core design is more than 2 times effective/flexible in accommodating required transmission maintenance.*

Year_Scenario	Design	Vulnerability Index (MVA)
2034_High Renewable	345 kV	249,426
	765 kV	99,915

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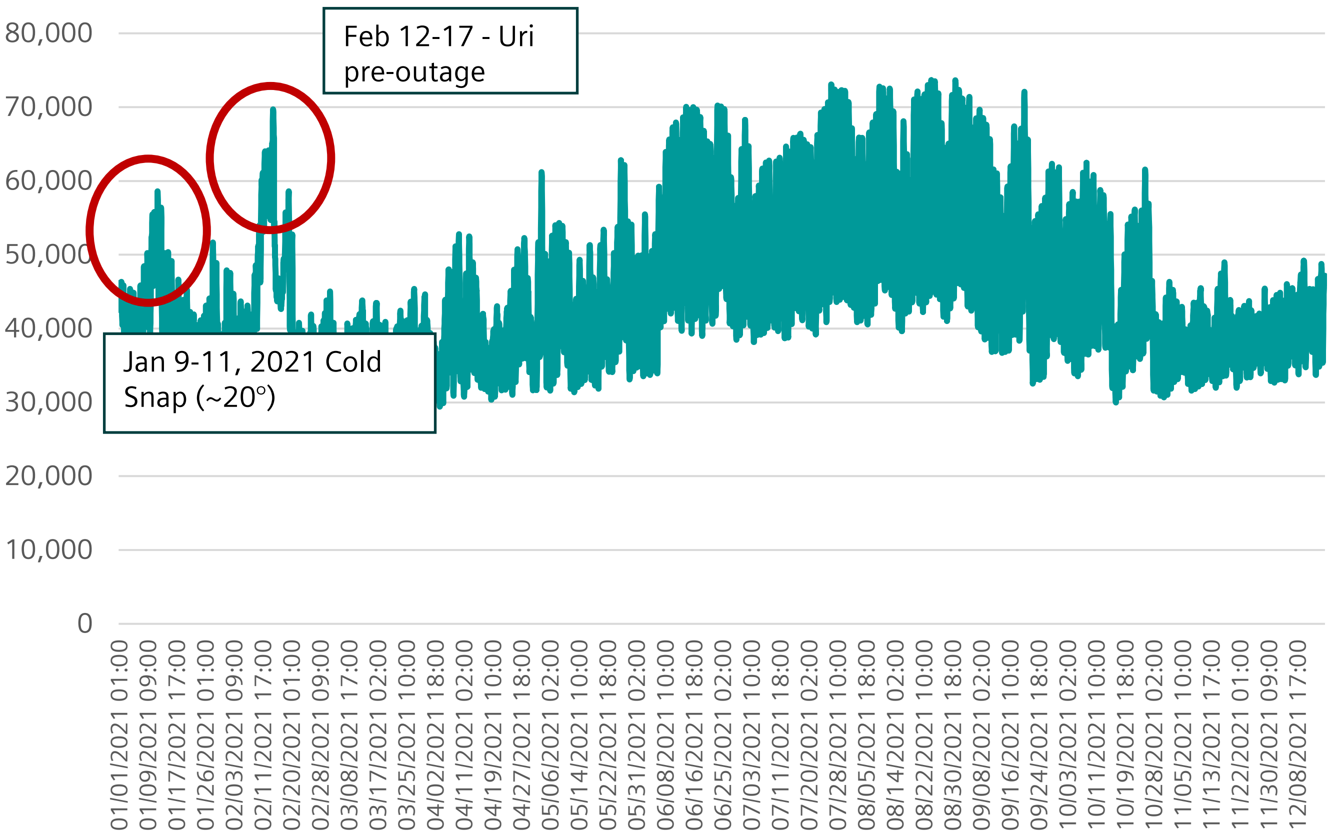
Analyzing URI Winter Storm: ERCOT Reacts to Cold Weather, Despite Assumption Around Gas Heating Usage

- **Cause:** Generator outages - poor generation weatherization and procedures to maintain the electricity generation availability under extreme weather conditions
- **Highest Forced Outage Amount:** 52-GW or 45% of the total capacity (Expected was only 10% based on 2011, 2014 and 2022 weather events)
- **Highest Forced Outage Amount taking into account wind and solar estimated lost output:** ~39-GW
  - Thermal Outage: 32-GW or 82%
  - Wind Outage: 7-GW or 18%
- **Generation Loss Driven by Transmission Loss:** Only 1.5-GW

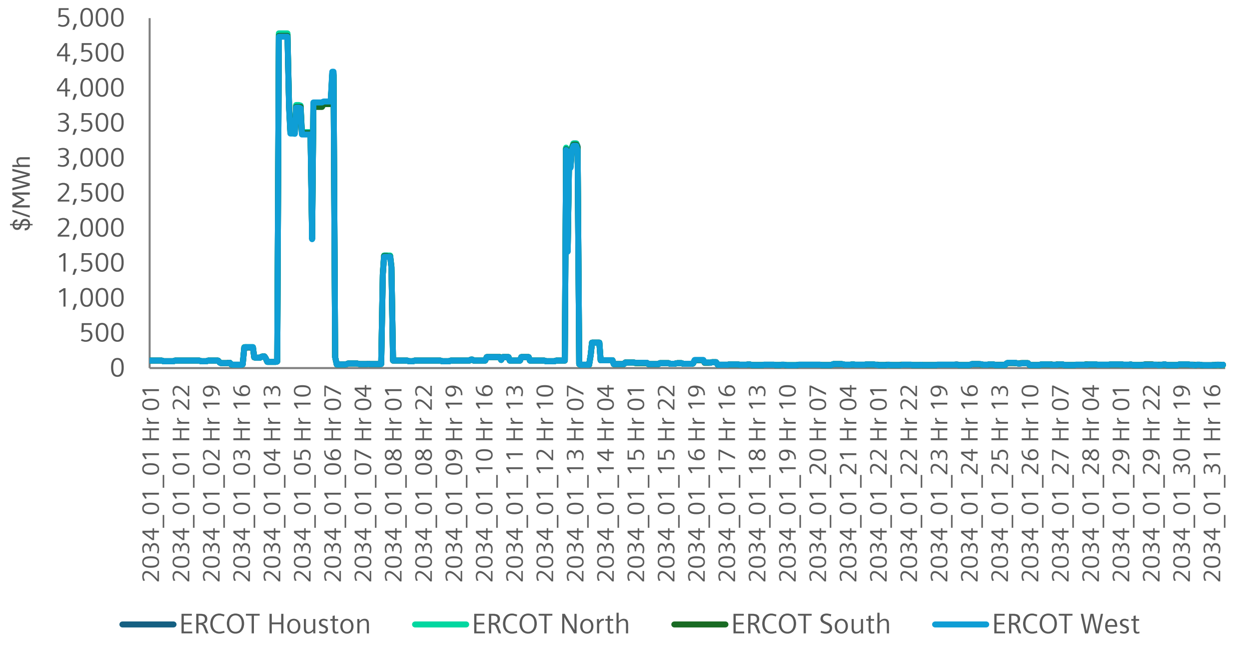
Uri Storm Load Impact (MW)



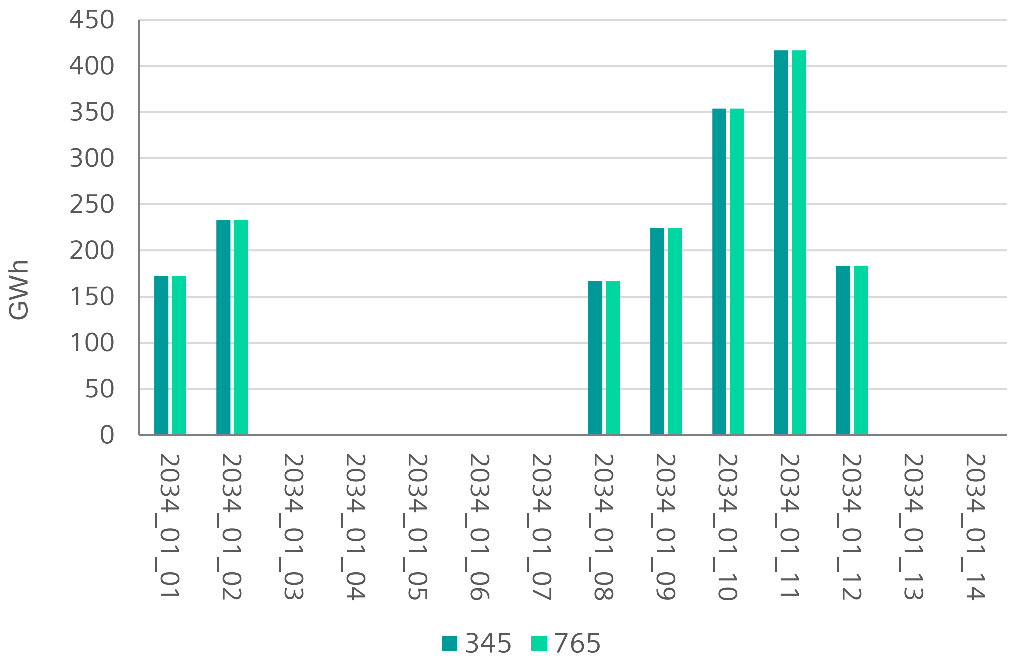
Generation to Extreme Weather Events Results

- **Load Surge During Winter Storm Uri:** Historical load increased by approximately 47% compared to typical winter demand. This uplift was applied to the current trends baseline scenario.[1]
- **Transmission Resilience and Unserved Energy:** While 765 kV upgrades offered limited additional resilience due to the severity of the event, they resulted in lower unserved energy on key days compared to 345 kV.
- **Power Price Impact:** Despite extreme conditions, power prices remained similar between 345 kV and 765 kV configurations, with minimal differences in total value.

2034 Power Prices (765-kV System)



Unserved Energy

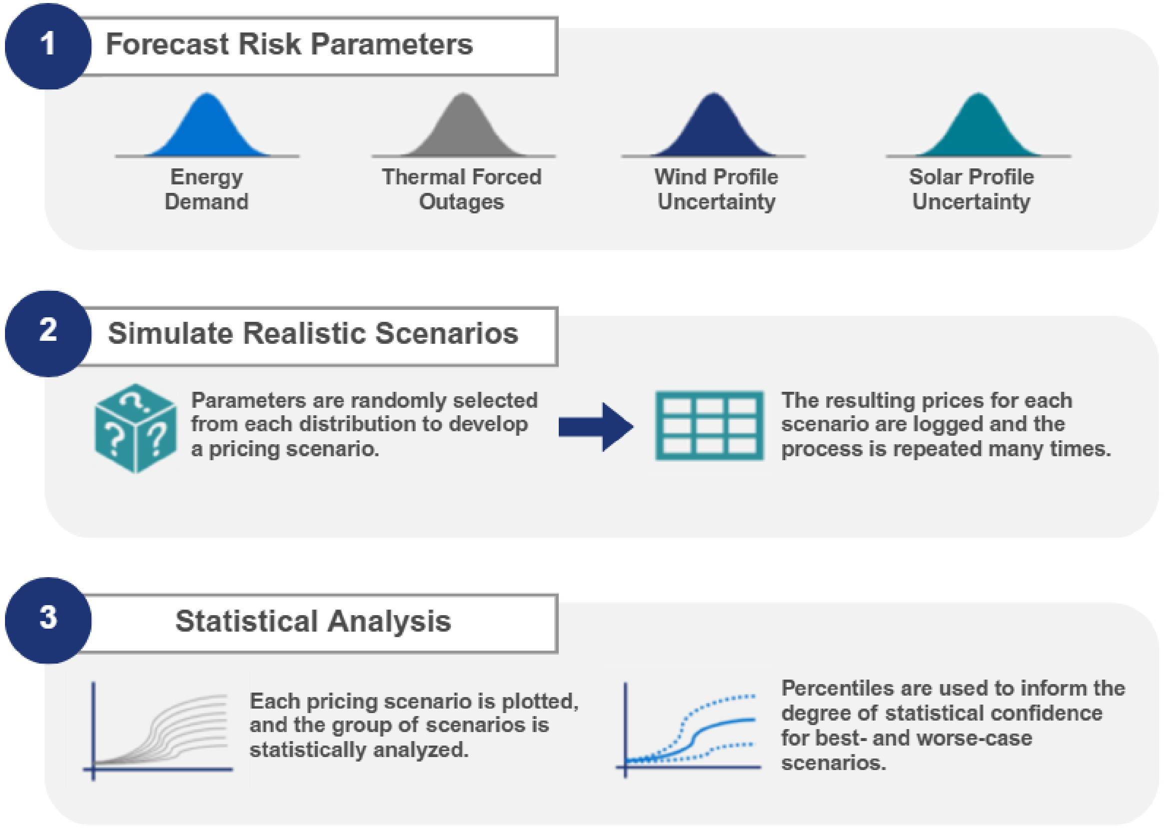


[1] *Large Flat Loads were not assumed to be affected at the 47% increase*

Resource Adequacy

Siemens PTI has taken a stochastic approach to quantify market resource adequacy

- Siemens PTI will assess the resource adequacy of the 765-kV and 345-kV systems for 2034 using Monte Carlo simulations.
- Siemens PTI treat the following drivers as stochastic inputs into the Monte Carlo approach:
  - Hourly energy demand
  - Solar and wind generation
  - Fossil generation forced outages
- **Methodology Highlights:**
  - 200 simulation iterations for each year, covering all hours
  - Inputs reflect historical variability
  - Random sampling with boosting to capture uncertainties in demand, renewable output, and outages
  - Energy market value is derived from commitment and dispatch into the ERCOT.
  - Reliability Metrics: Expected Unserved Energy (EUE) & Loss of Load Expectation (LOLE)



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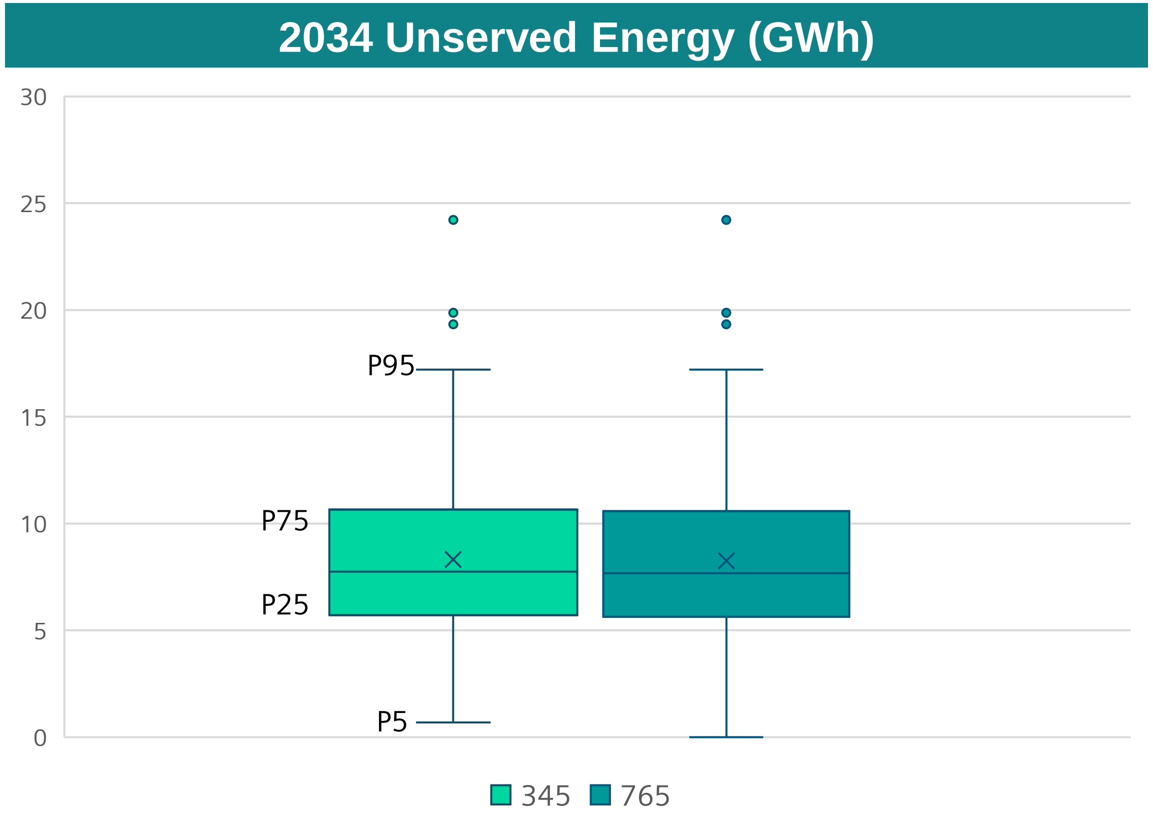
Resource Adequacy Stochastic Results

- **Comparable Adequacy Outcomes:** Both 345 kV and 765 kV systems yield similar resource adequacy results. Energy shortages are primarily system-wide and driven by scarcity during specific hours, not transmission constraints.
- **Scalability Advantage:** The 765 kV topology enables greater future flexibility, supporting additional generation without worsening congestion—unlike the more constrained 345 kV system.
- **Average Impact:** Across all simulations, both topologies showed ~10 hours/year of unserved energy on average.



Appendix E – Redefining the 765-kV Solution

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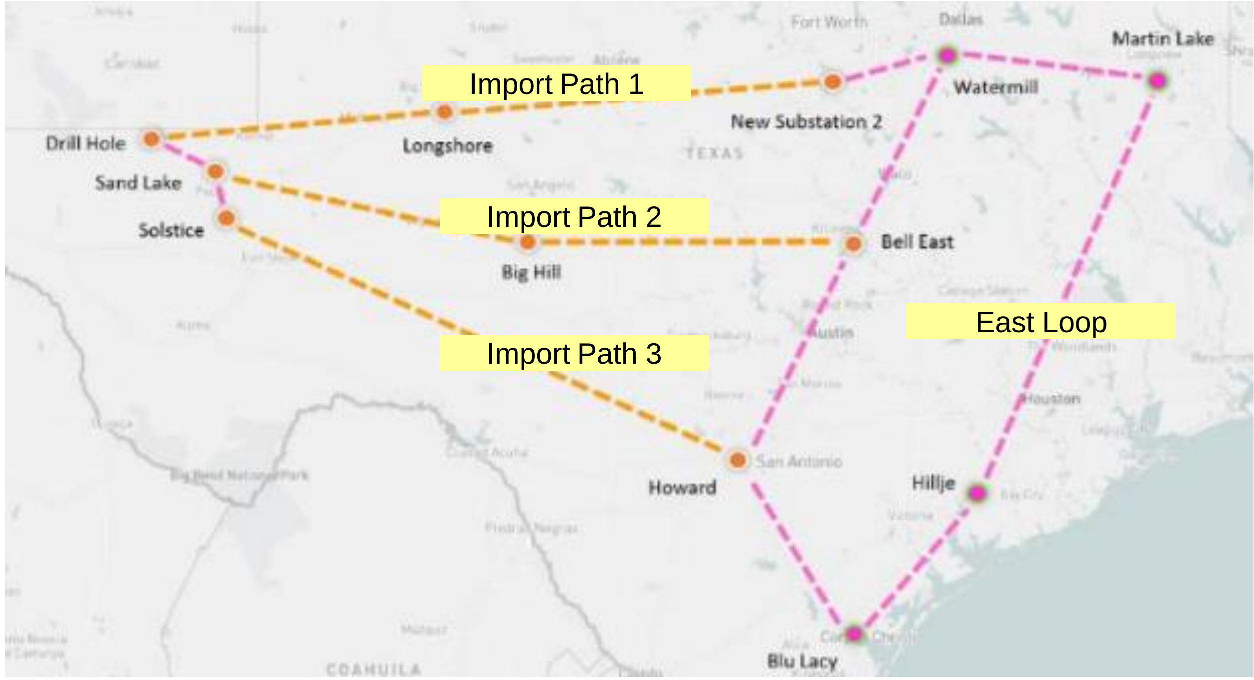
Redefining the 765-kV Solution

Background:

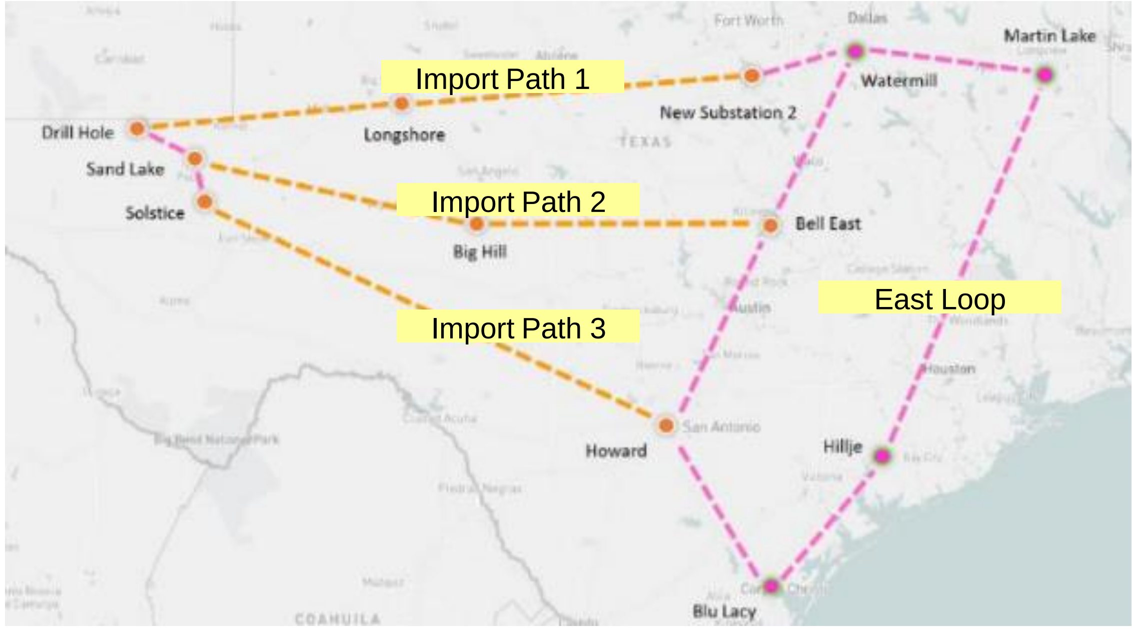
- For the target 765-kV solution, not all investments in the 765 kV system have the same required in service date.
- Siemens PTI will evaluate the contribution of each line or group of lines investment in alleviating binding constraints to **estimate the optimal in-service dates.**
- The purpose of this task was to determine the in-service dates based on economic and technical factors, prioritizing the lines that most effectively improve GTC limits and are urgently needed by the ERCOT system.



WTE GTC Transfer – New Capability with different Combinations

- The improvement in GTC limits—defined as the delta between scenarios with and without specific upgrades—was evaluated for each individual 765-kV line or group of lines in the portfolio.
- Among the configurations analyzed, **Import Paths 1 & 2 combined with the Watermill – Bell East** segment yielded the most cost-effective solution. This determination was based on the ratio of GTC improvement to ARR, indicating the highest economic efficiency.
- The CBA was recalculated using the production cost model for this configuration to assess whether its benefits—specifically in terms of consumer energy cost reductions and production cost savings—outperform the full TX 765-kV Transmission System for 2034. (See slide 18 for results detail)

Transmission Configuration	GTC Limit (MW)	GTC improvement	Tlines Miles Total	CAPEX (Billion)	ARR (Billion/yr)	Ratio (GTC Improvement /ARR)
No 765	11908					
Import 1	12916	1008	519	$8.1	1.027	0.982
Import 1 & 2	13297	1389	963	$11.2	1.417	0.980
Import 1 & 3	13248	1340	889	$10.7	1.349	0.994
Import 1 + East Loop	14373	2465	1654	$28.3	3.564	0.692
import 2 + East Loop	14252	2344	1579	$27.8	3.505	0.669
Import 1 & 2 with Watermill – Bell East	14764	2856	1096	$13.6	1.714	1.666
Import 1 & 3 with Watermill – Bell East - Howard	14772	2864	1192	$16.1	2.026	1.414
import 3 + East Loop	14219	2311	1505	$27.3	3.436	0.673
Import 1 & 2 + East Loop	15425	3517	2098	$31.3	3.954	0.889
Import 1 & 3 + East Loop	15344	3436	2024	$30.8	3.885	0.884
Import 2 & 3 + East Loop	14612	2704	1948	$30.3	3.826	0.707
all 765	15779	3871	2468	$33.9	4.272	0.906



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