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

ERCOT Grid Planning

ERCOT EHV Workshop
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Introduction

ERCOT System and Growth

- 2024 Regional Transmission Plan (RTP), which identified the ERCOT near-term (2026-2030) transmission need, included an unprecedented amount of economic growth led by large load interconnections;
  - oil and natural gas electrification
  - data centers, AI, crypto mining
  - hydrogen and hydrogen-related manufacturing,
- The forecasted summer peak demand for 2030 exceeded 150 GW, of which approximately 50 GW is large load growth.
  - 2030 demand includes ~24 GW of oil and gas loads in the Permian Basin region
- This unprecedented load growth coupled with the growing amount of congestion already present in today's system prompted discussions about introducing 765-kV infrastructure to the ERCOT Transmission Grid.
- 765-kV transmission addition would enable power to flow more efficiently through long-distance transmission from resource-rich regions to load centers.

Permian Basin Reliability Plan and 2024 RTP

- In July 2024, ERCOT completed the Permian Basin Reliability Plan identifying the transmission facilities including local projects and import paths needed to serve existing and future demand in the Permian Basin region
  - Import paths included options for 345-kV and 765-kV
  - The PUCT approved the Permian Basin Reliability Plan in October 2024, but deferred a decision on the voltage level of the import paths.
  - The PUCT is anticipated to make a determination on the voltage level by May 1, 2025
- The 2024 RTP continued to build on the Permian Basin Reliability Plan to address statewide reliability needs
  - developed two transmission plans (345-kV and 765-kV), to address the 2030 projected demand of ~150 GWs
- This presentation provides additional analysis (including cost estimates, ROW impact) to compare the benefits of the 2024 RTP 345-kV plan and the Texas 765-kV Strategic Transmission Expansion Plan (TX 765-kV STEP)

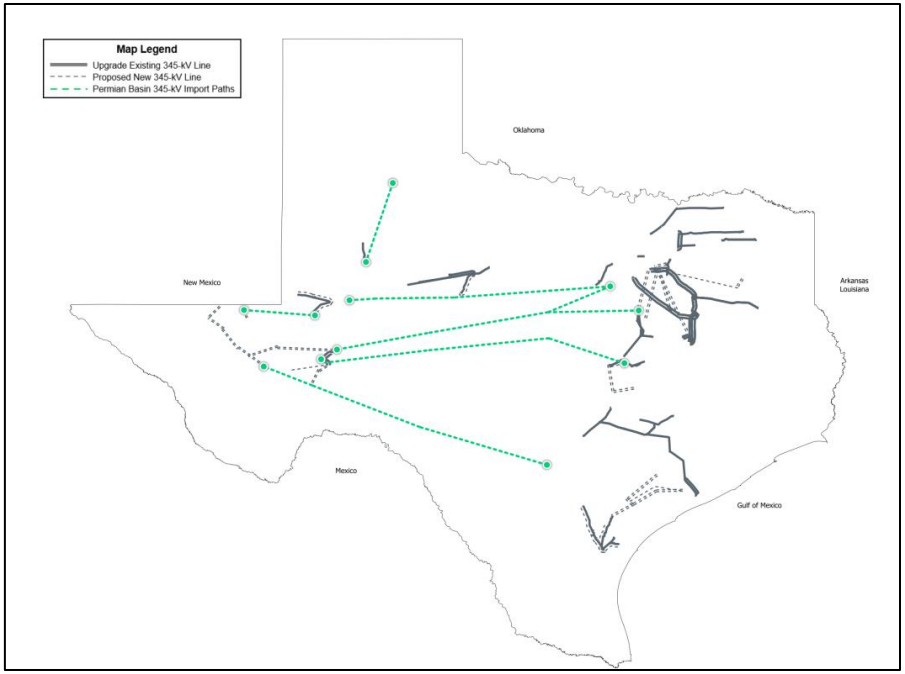
Steady-State Analysis
2024 Regional Transmission Plan (RTP)

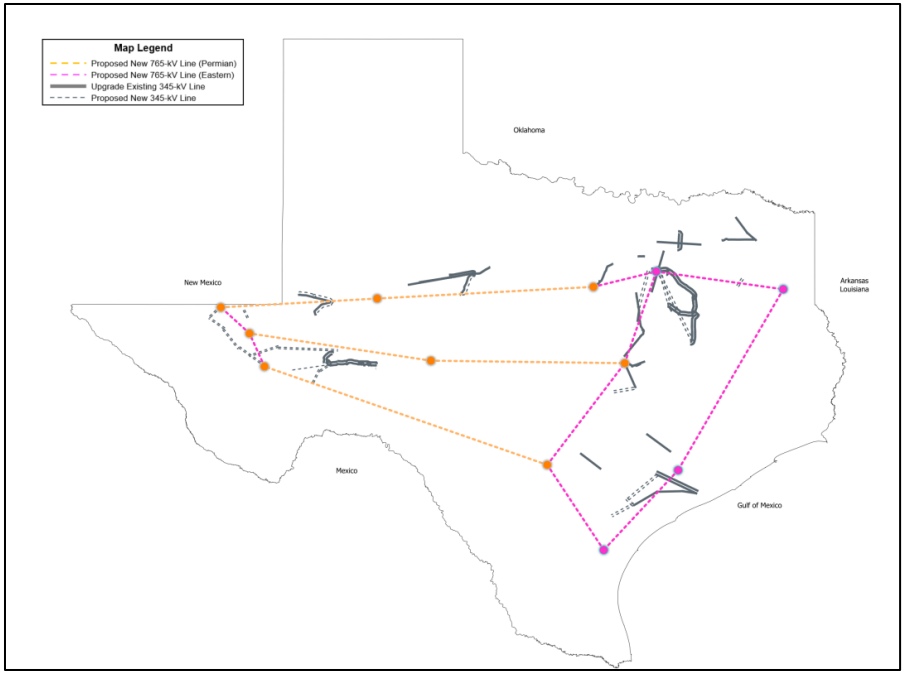
2024 RTP Analysis – Scope

- Two RTP assessments were performed under base scenario conditions
  - 345-kV Plan (without 765-kV Core plan)
    - Corrective Action Plans (CAPs) were developed for
      - N-1, G-1+N-1, X-1+N-1 under summer peak conditions
        - » Included 69-kV, 138-kV, and 345-kV violations
      - N-1-1 fall peak maintenance outage scenario
        - » Included contingencies with 69-kV, 138-kV, and 345-kV elements*
        - » Violations were resolved for 69-kV, 138-kV, and 345-kV elements
  - TX 765-kV STEP (with 765-kV Core plan)
    - CAPs were developed for
      - N-1, G-1+N-1, X-1+N-1 under summer peak conditions
        - » Included 69-kV, 138-kV, 345-kV, and 765-kV violations
      - N-1-1 fall peak maintenance outage scenario
        - » Included contingencies with at least one 345-kV or 765-kV element
        - » Violations were resolved for 69-kV, 138-kV, 345-kV, and 765-kV elements

[*] Only CAPs resulting from a contingency with at least one 345-kV element were included in the comparison to the Core plan

2024 RTP Analysis – Comparison





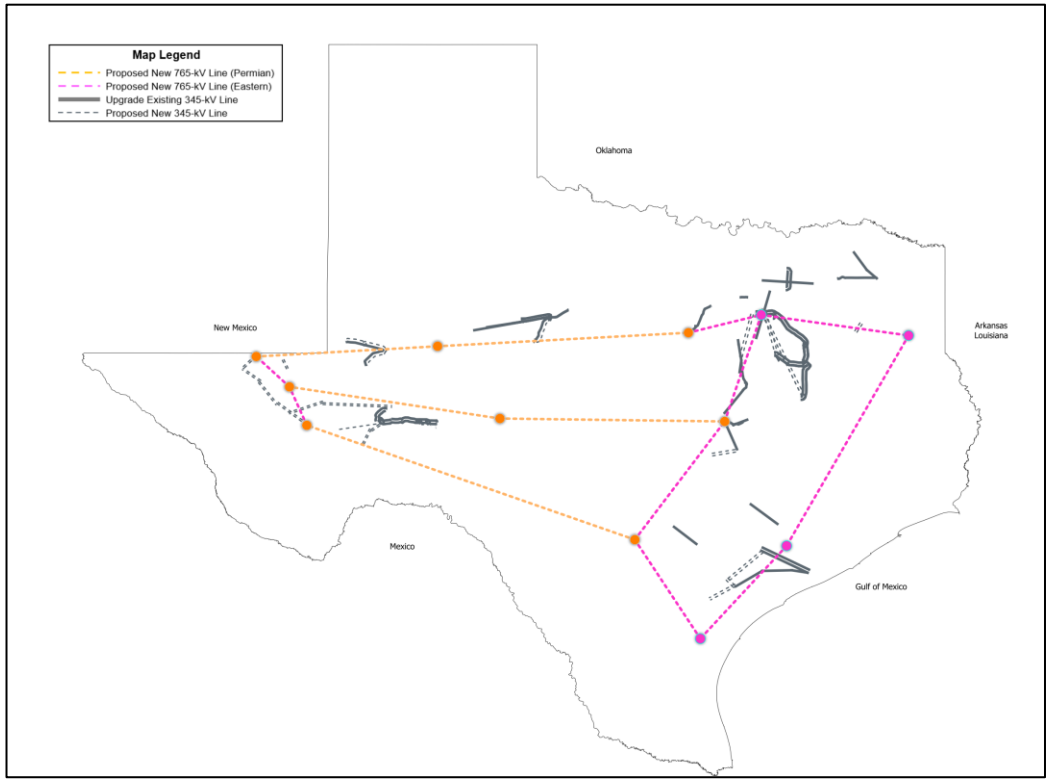
345-kV New Lines and Upgrades Needed
with the 345-kV Plan (Left) and TX 765-kV STEP (Right)
Including Permian Basin Import Paths and Local Projects

TX 765-kV STEP

- No changes to 765-kV option in Permian Basin study
- # of 765-kV Substations
  - Permian Basin = 8
  - Eastern = 4
- New 765-kV ROW Line Miles*
  - Permian Basin = 1,255
  - Eastern = 1,213
- # of 765/345-kV Transformers
  - Watermill, Hillje, Blu Lacy = 3
  - All others = 2
- Existing Line Upgrade Miles
  - 2,831

Texas 765-kV Strategic Transmission Expansion Plan (TX 765-kV STEP)

Critical components needed by 2030



[*] All mileage numbers include 20% routing adder on top of point-to-point distance.

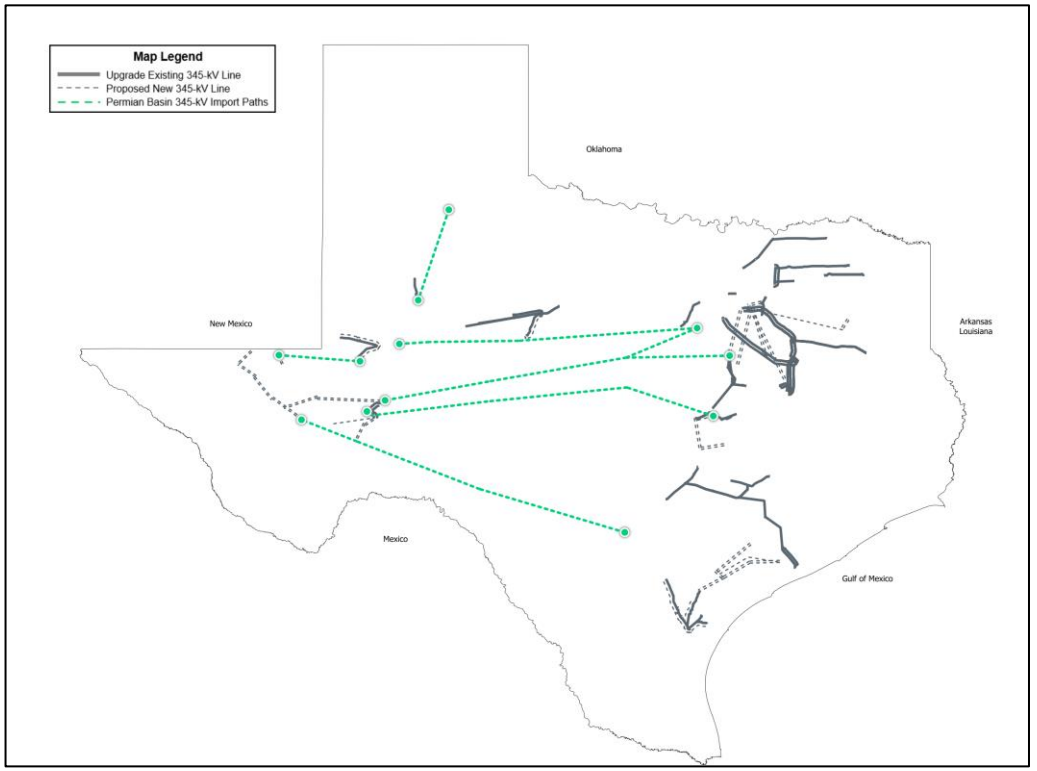
***NOTE**: Geographic locations for proposed new lines are meant to demonstrate general electrical point-to-point connections. Specific routing of any new transmission infrastructure is determined by the Public Utility Commission as part of the CCN process with Transmission Service Providers.*

345-kV Plan

- No changes to 345-kV option in Permian Basin study
- New ROW Line Miles*
  - 3,007
- Existing Line Upgrade Miles
  - 4,274

345-kV Plan

Critical components needed by 2030

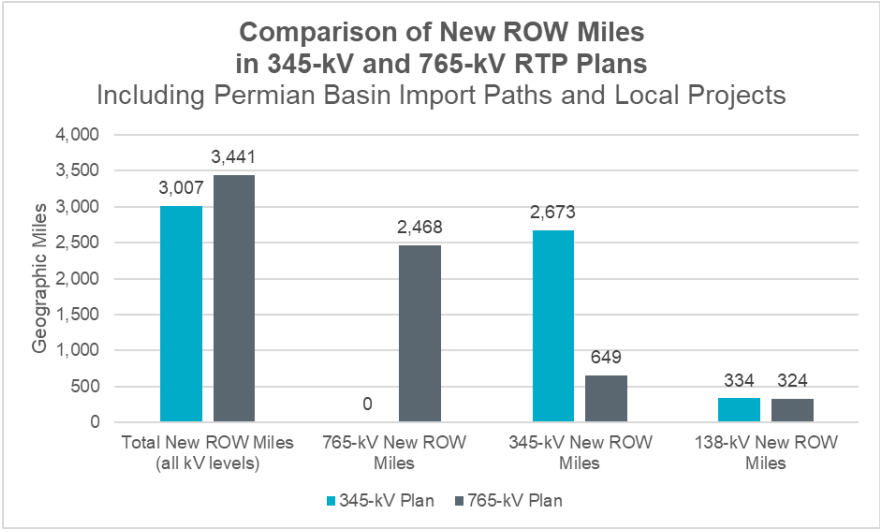


[*] All mileage numbers include 20% routing adder on top of point-to-point distance.

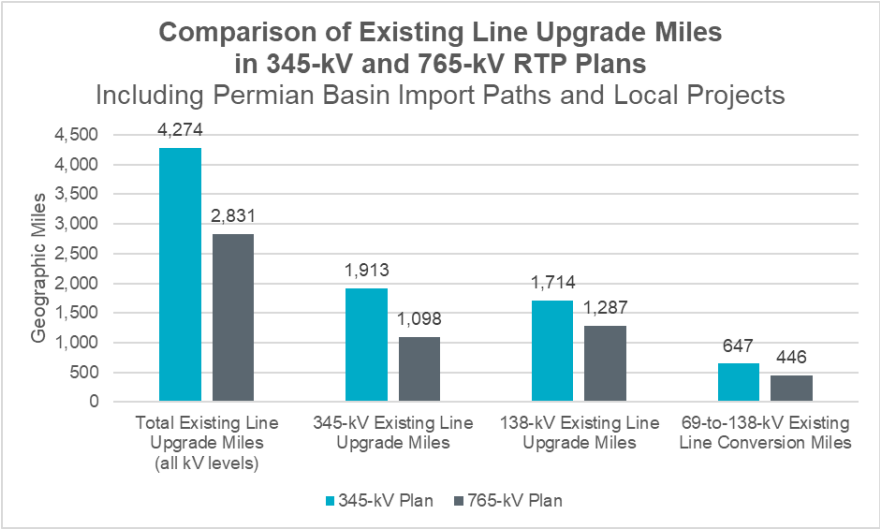
***NOTE**: Geographic locations for proposed new lines are meant to demonstrate general electrical point-to-point connections. Specific routing of any new transmission infrastructure is determined by the Public Utility Commission as part of the CCN process with Transmission Service Providers.*

2024 RTP Analysis – Comparison

345-kV Plan adds 434 fewer miles of new ROW miles



TX 765-kV STEP upgrades 1,443 fewer miles of existing lines



***NOTE**: All miles are geographic miles*
Ex: 100 miles of single-circuit line = 100 miles, and 100 miles of double-circuit lines = 100 miles

2024 RTP Analysis – Comparison

Summary of the Construction Cost Estimates ($Billion)

	345-kV Plan	TX 765-kV STEP
Permian Basin Reliability Plan Projects	12.95	13.77
2024 RTP Projects (beyond Permian Projects)	17.80	19.22
Total	**30.75**	**32.99**
		+2.24

Summary of the Construction Cost Estimates – with Live Reconductoring ($Billion)

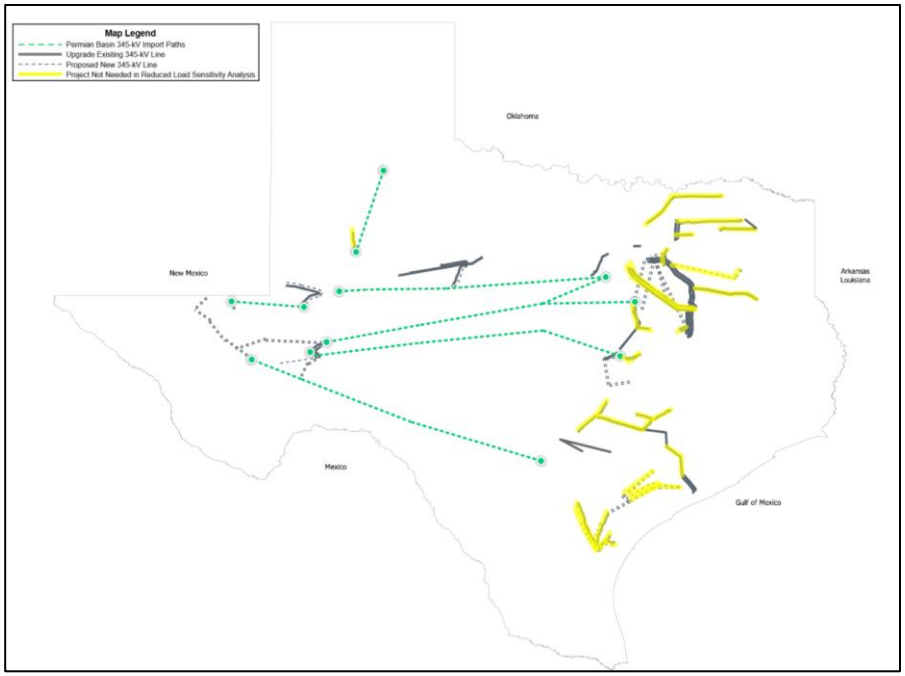
	345-kV Plan	TX 765-kV STEP
Permian Basin Reliability Plan Projects	12.95	13.77
2024 RTP Projects (beyond Permian Projects) *(with Live Reconductoring)*	19.60	20.13
Total	**32.55**	**33.90**
		+1.35

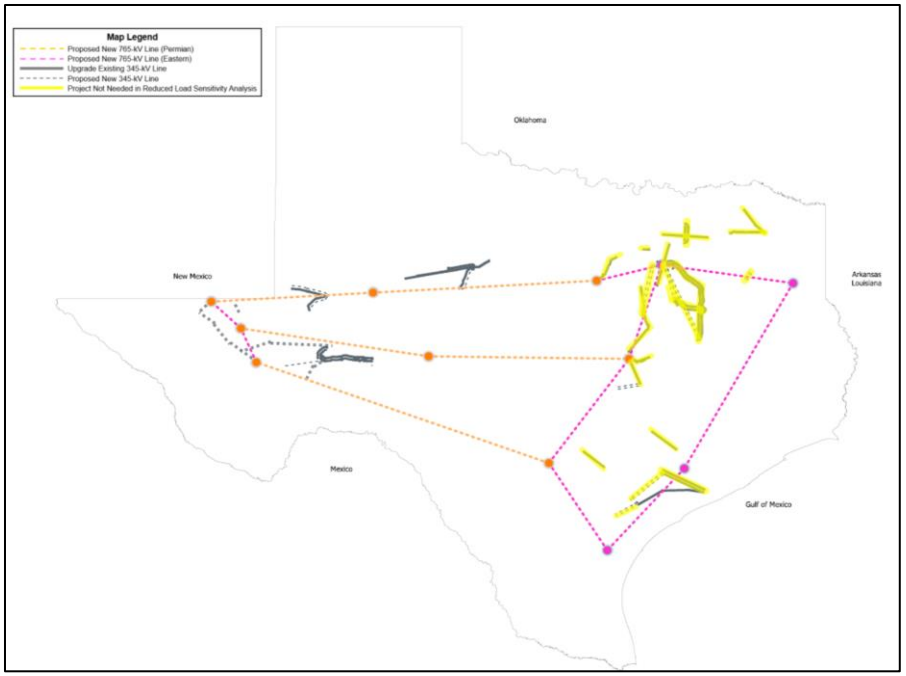
Factoring in cost increases from likely-needed live reconductoring, the cost difference between the two plans under base scenario conditions decreases $890M to $1.35B.

2024 RTP Sensitivity Analysis – Reduced Load

- Two RTP assessments were performed under reduced load scenario conditions (~ 20 GW less overall load)
  - 345-kV Plan (without 765-kV Core plan)
    - Corrective Action Plans (CAPs) were developed for
      - N-1, G-1+N-1, X-1+N-1 under summer peak conditions
        - » Included 69-kV, 138-kV, and 345-kV violations
      - No N-1-1 fall peak maintenance outage analysis was performed
  - TX 765-kV STEP (with 765-kV Core plan)
    - CAPs were developed for
      - N-1, G-1+N-1, X-1+N-1 under summer peak conditions
        - » Included 69-kV, 138-kV, 345-kV, and 765-kV violations
      - No N-1-1 fall peak maintenance outage analysis was performed

2024 RTP Sensitivity Analysis Comparison – Reduced Load



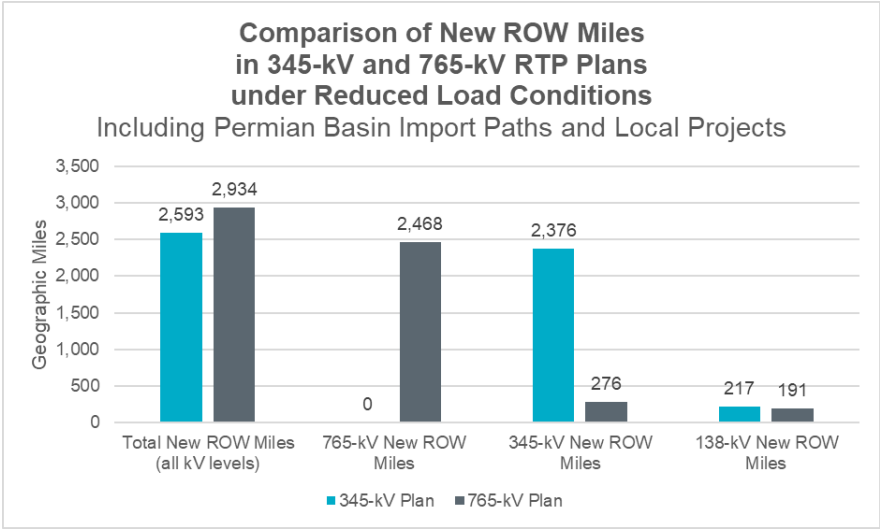


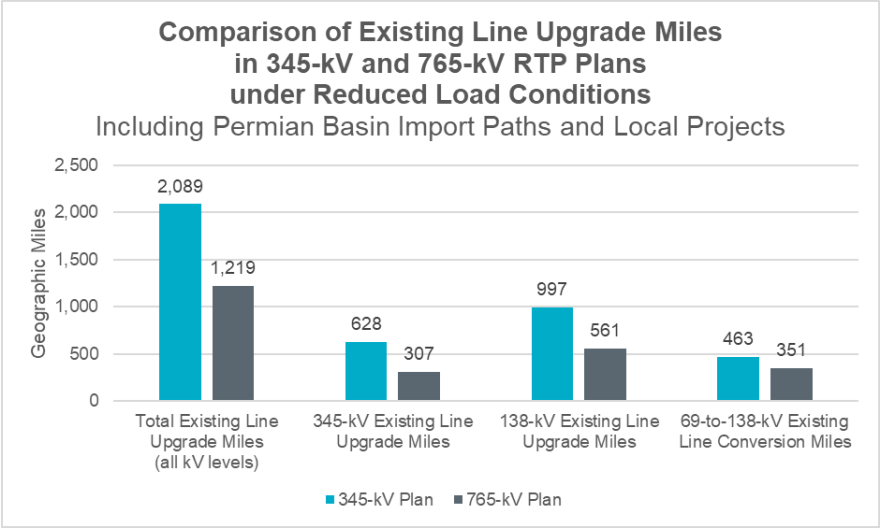
345-kV New Lines and Upgrades Needed
with the 345-kV Plan (Left) and TX 765-kV STEP (Right)
under Reduced Load Scenario Conditions
Including Permian Basin Import Paths and Local Projects
Highlighted projects not needed under reduced load conditions

2024 RTP Sensitivity Analysis Comparison – Reduced Load

345-kV Plan adds 341 fewer miles of new ROW miles

TX 765-kV STEP upgrades 870 fewer miles of existing lines





***NOTE**: All miles are geographic miles*
Ex: 100 miles of single-circuit line = 100 miles, and 100 miles of double-circuit lines = 100 miles

2024 RTP Sensitivity Analysis Comparison – Reduced Load

Summary of the Construction Cost Estimates ($Billion)

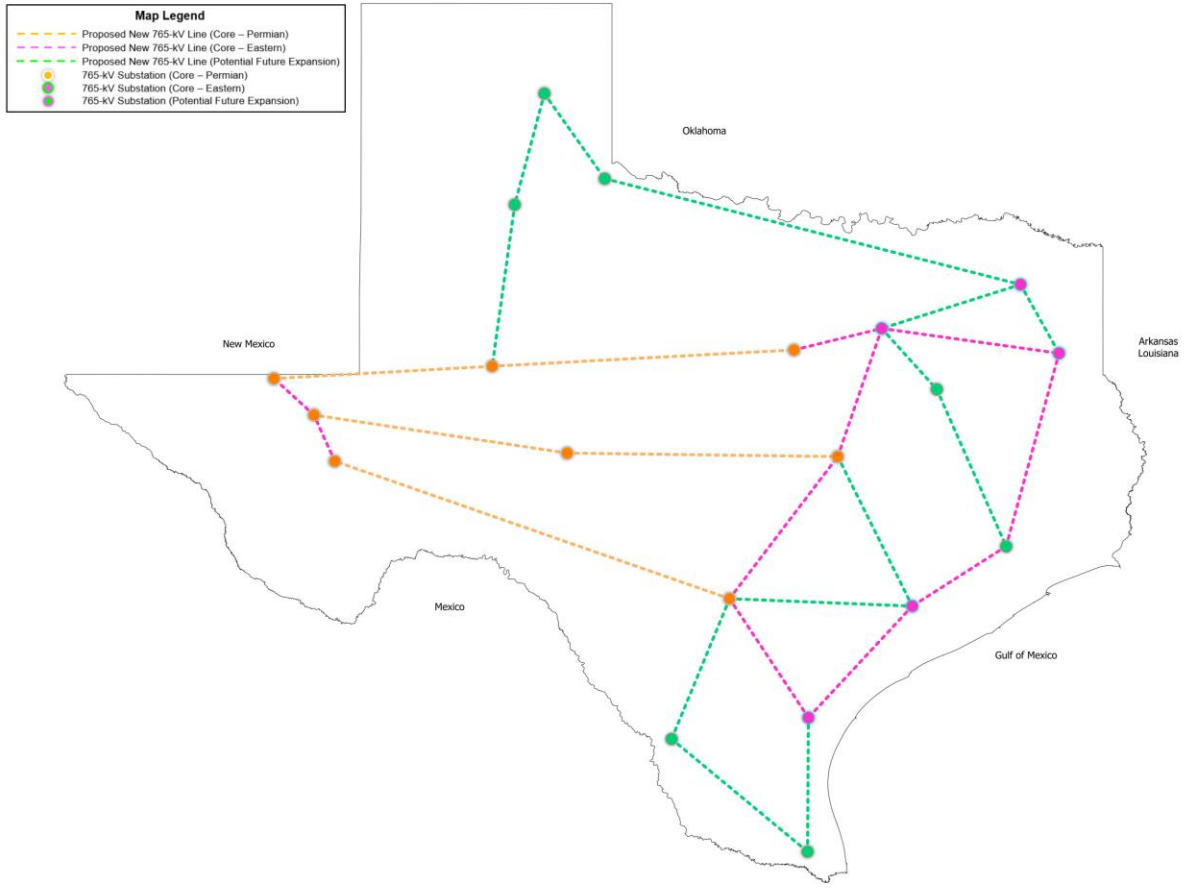
	345-kV Plan ($B)	TX 765-kV STEP ($B)
Permian Basin Reliability Plan Projects	12.95	13.77
2024 RTP Projects (beyond Permian Projects)	8.03	10.14
Total	**20.98**	**23.91**
		+2.93

Summary of the Construction Cost Estimates – with Live Reconductoring ($Billion)

	345-kV Plan ($B)	TX 765-kV STEP ($B)
Permian Basin Reliability Plan Projects	12.95	13.77
2024 RTP Projects (beyond Permian Projects) *(with Live Reconductoring)*	8.48	10.22
Total	**21.43**	**23.99**
		+2.56

Factoring in cost increases from likely-needed live reconductoring, the cost difference between the two plans under reduced load conditions decreases $370M to $2.56B.

TX 765-kV STEP Potential Future Expansion

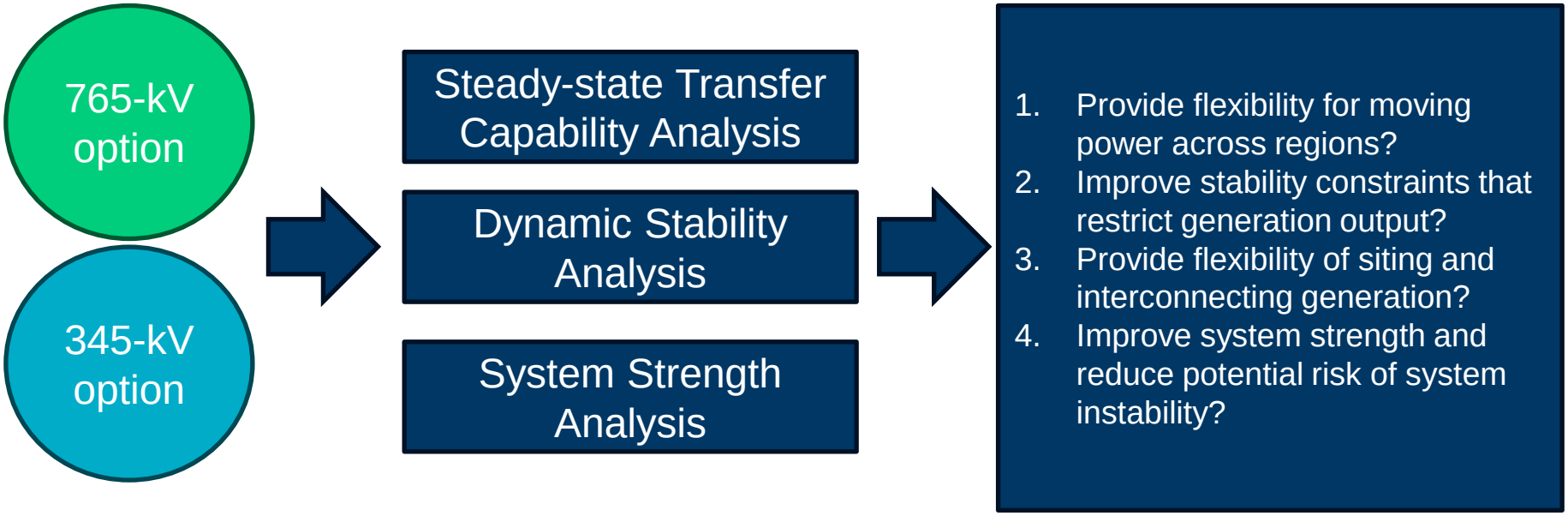


Potential future expansion could include lines into the Panhandle and Valley along with additional east-to-central pathways to serve more of the ERCOT system as need materializes.

Transfer Capability, Dynamic Stability, and System Strength Analysis

Additional Reliability Analyses

- ERCOT conducted additional reliability analyses to evaluate and compare benefits of 345-kV and 765-kV options



- These analyses provide us with a clearer picture of how each option could support reliability and grid stability

Steady-State Transfer Capability Analysis

- Objectives:
  - Evaluate steady-state power transfer capabilities for 345-kV and 765-kV options
  - Compare performance across eight scenarios
- Methodology:
  - Study Cases:
    - Case 1: 2024 RTP 2030 Summer Peak case – 345-kV Option
    - Case 2: 2024 RTP 2030 Summer Peak case – 765-kV Option
  - Contingencies: NERC Category P1 and P7 contingencies
  - Monitored Elements: Transmission facilities with 100 kV and above, focusing on thermal constraints and voltage collapse
  - Tool: TARA

Steady-State Transfer Capability Analysis (Continued)

- Scenarios Evaluated:

  Based on consideration of network connections, load, and generation, ERCOT tested the following eight scenarios, representing source-sink combinations within ERCOT:

  – West/Far West (WFW) to Dallas/Fort Worth (DFW)
  – WFW to Houston
  – WFW to South Central
  – WFW to South
  – Dallas-Fort Worth (DFW) to Houston
  – Houston to DFW
  – DFW to Corpus area (Corpus = Nueces and Refugio Counties)
  – Houston to Corpus area (Corpus = Nueces and Refugio Counties)

Steady-State Transfer Capability Analysis (Continued)

- Key Findings:
  - In general, both 345-kV and 765-kV options improve transfer capability, with 765-kV providing significantly more transfer capability
  - The 765-kV option outperforms the 345-kV option for transfers from WFW to major load centers, except DFW, where both perform similarly
  - For transfers from WFW to major load centers (excluding DFW), the 765-kV option adds 600 to 3,000 MW more transfer capability than the 345-kV option
  - Transfers from DFW to Houston gain 750 MW more with the 765-kV option compared to the 345-kV option
  - Transfers from Houston to DFW show similar performance for both options
  - No major differences were found for transfers from DFW or Houston to Corpus

Scenarios	Incremental Transfer Capability	
	345 kV Plan (MW)	765 kV Plan (MW)
WFW to DFW	3,450	3,450
WFW to Houston	3,750	6,750
WFW to South Central	1,050	1,650
WFW to South	550	1,650
DFW to Houston	3,000	3,750
Houston to DFW	1,725	1,725
DFW to Corpus	350	350
Houston to Corpus	350	350

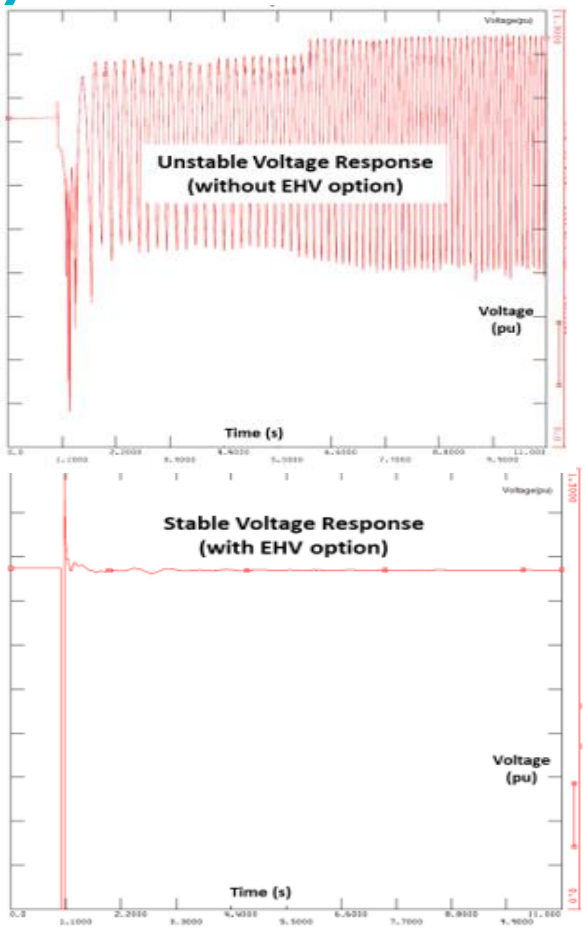
- Both the 345-kV and 765-kV options enhance transfer capability, with the 765-kV option offering substantially greater flexibility to accommodate future generation and load growth

Dynamic Stability Analysis

- Objectives:
  - Analyze the dynamic stability impacts of the 765-kV and 345-kV options on the West Texas Export and McCamey stability constraints
  - Compare the estimated stability limits of the two options to identify their relative effectiveness in mitigating these constraints
- Methodology:
  - ERCOT used the 2023/2024 DWG 2027 High Renewable Minimum Load (HRML) case, updated with synchronous condensers and generators, to develop two study cases:
    - Case 1: 345-kV Option
    - Case 2: 765-kV Option
  - NERC Category P1 and P7 contingencies related to the West Texas Export and McCamey area stability constraints were tested to determine stability limits for each option
  - A sensitivity analysis was performed to evaluate the impact of bypassing all existing series compensation devices in both the 765-kV and 345-kV cases
  - Tool: PSS/E v35

Dynamic Stability Analysis (Continued)

- Key Findings:
  - Impact on West Texas export stability constraint
    - Stability limit in the study base case (i.e., without any option) is estimated at 12.7 GW
    - West Texas Export Stability Limit:
      - 345-kV: 24.4% improvement (12.7 GW → 15.8 GW).
      - 765-kV: 27.6% improvement (12.7 GW → 16.2 GW).
  - Impact on McCamey area stability constraint:
    - No stability constraints were identified under N-1 contingencies in the base case or in cases involving each option
    - This is primarily due to the RPG-approved projects: new Bearkat-North McCamey-Sand Lake 345-kV line (In-service date: 2026) and new synchronous condensers at Bakersfield (In-service date 2027)
  - Bypassing all series capacitors had no impact on stability limits



- Both options improve stability limits, with 765-kV providing better performance
- Both options provide greater flexibility in siting resources and Large Load
- Note: the stability limits above are estimates for future conditions for N-1 conditions; GTCs will be reviewed and updated in the regular QSA process

System Strength Analysis

- Objectives:
  - Conduct system strength analysis to evaluate the impact and relative benefits of the options
- Methodology:
  - Cases used: Study cases developed for dynamic stability analysis
  - System strength is commonly measured by short-circuit current (or MVA), and ERCOT employed a weighted short-circuit MVA (WSCMVA) metric in this study

$$WSCMVA = \frac{\sum_{k=1}^{n} SCMVA_k * P_{GK}}{\sum_{k=1}^{n} P_{GK}}$$

where:

$SCMVA_k$: short-circuit MVA at the POI of the k-th IBR

PG_K: the capacity (MW) of the k-th IBR

  - Tool: PSS/E v35

System Strength Analysis (Continued)

- Key Findings:
  - The analysis concluded that both options offer similar overall system strength and benefits

EHV Options	WSCMVA (MVA)
345-kV Option	6,264
765-kV Option	6,289

- Both options provide similar system strength

Key Takeaways – Additional Reliability Analyses

- Steady-state transfer analysis shows superior performance of the 765-kV option, compared to the 345-kV options, providing 600 MW to 3,000 MW more transfer capability than the 345-kV option
- Dynamic stability analysis indicates a higher West Texas Export stability limit under N-1 conditions, with 16.2 GW for the 765-kV option, compared to 15.8 GW for the 345-kV option and 12.7 GW in the base case
- Both options show similar improvements in system strength, as measured by weighted short-circuit MVA, supporting grid stability
- The increased transfer capacity enhances flexibility to accommodate future demand while providing more options for siting new generation and interconnecting large loads across the system
- Improved stability constraints in both options are expected to reduce generation curtailments, lower reliance on series capacitors, and increase flexibility (e.g., operations and interconnection) while reducing SSO risks

Economic Analysis and Power Losses Reduction Study

Economic Analysis Overview

- When transmission congestion occurs, generators may be dispatched uneconomically to reduce flows on the congested lines.
  - The total congestion rent which ERCOT experienced was $2.3 billion and $1.97 billion respectively for 2023 and 2024.
- Economic analysis was performed to evaluate economic benefits of the 345-kV and 765-kV options using both the production cost savings test and the congestion cost savings test (measured by system-wide consumer energy cost reduction).
  - The production cost savings test evaluates economic impact of a transmission project from a “societal” perspective, whereas the congestion cost savings test estimates the impact of a transmission project on the energy costs for ERCOT consumers.

Base Cases for Economic Analysis

- Two base cases evaluated:
  - 2034 and 2039 base cases from the Current Trends scenario from the 2024 Long-Term System Assessment (LTSA).
  - The large loads substantiated by officer letters from the Transmission Service Providers (TSPs) in the 2024 Regional Transmission Plan were not included in the economic base cases.
    - The 2024 LTSA base cases started in 2023 and the capacity expansion was completed prior to the 2024 RTP load projections assumptions were finalized.

	Peak Demand (MW)	Annual Energy (GWh)
2034 Base Case	106,581	648,138
2039 Base Case	113,349	693,213

2034 Study Results

- For the 2034 study year, both the 345-kV plan and the TX 765-kV STEP showed savings in production cost and consumer energy cost compared to the base case.
- The TX 765-kV STEP had $133 million more savings in production cost but $136 million less savings in system-wide consumer energy cost compared with the 345-kV plan. The TX 765-kV STEP also had $94 million less congestion rent than the 345-kV plan in 2034.

Year	Project Description	Production Cost (M$)	Consumer Energy Cost (M$)	Congestion Rent (M$)
2034	Base Case	17,139	18,342	1,873
2034	345-kV Plan	16,969	18,143	1,539
2034	765-kV Plan	16,836	18,279	1,444
2034	Incremental Benefit (765-kV Plan-345-kV Plan)	133	-136	94

*All monetary numbers are in 2025 dollars

2039 Study Results

- For the 2039 study year, the TX 765-kV STEP continued to show savings in both production cost and consumer energy cost while the 345-kV plan showed an increase in the consumer energy cost.
- The TX 765-kV STEP had $28 million more production cost savings and $229 million more system-wide consumer energy cost reduction than the 345-kV plan in 2039.

Year	Project Description	Production Cost (M$)	Consumer Energy Cost (M$)	Congestion Rent (M$)
2039	Base Case	19,462	22,070	2,545
2039	345-kV Plan	19,088	22,143	2,261
2039	765-kV Plan	19,059	21,914	2,089
	Incremental Benefit (765-kV Plan-345-kV Plan)	28	229	172

*All monetary numbers are in 2025 dollars

Key Findings from Economic Study

- The economic study showed that the TX 765-kV STEP had demonstrated more consistent benefits through the years evaluated compared with the 345-kV plan in both the production cost savings and system-wide consumer energy cost reduction in the long-term planning horizon.
  - The TX 765-kV STEP had $28 million more production cost savings and $229 million more system-wide consumer energy cost reduction than the 345-kV plan in 2039.
    - When considering which option is more cost effective, it should be noted that the future conditions can differ from the study scenarios assumed here and economic benefits other than production cost savings and system-wide consumer energy cost reductions are not quantified here.

The 765-kV plan can produce more economic benefits in both production cost savings and system-wide consumer energy cost reduction in the long-term planning horizon.

Power Losses Reduction Study

- When the 765-kV transmission line transmits electricity at a higher voltage, it results in a lower current for the same power transfer, thereby significantly reducing power losses in the power lines due to the relationship between current and heat generation.
- ERCOT performed the AC power flow analysis for three snapshots (Peak, Off-Peak, and Light Load conditions) and compared the resulting power losses between the 345-kV plan and the TX 765-kV STEP.

Losses (% of Load)	345-kV	765-kV
Peak Load	1.97%	1.88%
Off-Peak Load	1.62%	1.61%
Light Load	1.61%	1.49%

Power Losses Reduction Study (continued)

- The power losses for both the 345-kV option and the TX 765-kV STEP were estimated for two study years (2034 and 2039).
  - The 8760-hour load duration curve was sorted for each of the two years from the highest to the lowest.
    - For the top 10% load duration curve, 1.97% and 1.88% transmission losses (Peak Load Condition) were used respectively for 345-kV and 765-kV plan. For the middle 60% to 90% of load duration curve, 1.62% and 1.61% transmission losses (Off-Peak Load Condition) were used respectively for 345-kV and 765-kV plan. For the bottom 60% load duration curve, 1.61% and 1.49% transmission losses (Light Load Condition) were used respectively for 345-kV and 765-kV plan.
- The TX 765-kV STEP can reduce the annual transmission losses by about 5% compared to the 345-kV option.

Project Description	Transmission Losses in 2034 (GWh)	Transmission Losses in 2039 (GWh)
345-kV Plan	10,764	11,518
765-kV Plan	10,224	10,941
Power Loss Saving in GWh	540	577
Power Loss Saving in %	5.02%	5.01%

The TX 765-kV STEP can reduce the annual systemwide transmission losses by about 5% compared to the 345-kV option (about 560 GWh each year, which is approximately equivalent to a thermal unit with 128-MW installed capacity operating at an 50% capacity factor).

Summary of the 345-kV & TX 765-kV STEP

Comparison of the Cost & Benefits

	345-kV Plan	TX 765-kV STEP
New ROW impact	434 fewer miles of ROW	
Existing System Upgrades impact		1,443 fewer miles of existing upgrades
Estimated New Construction Cost (345-kV $30.75 billion; TX 765-kV STEP $32.99 billion)	$2.24 billion less construction cost	
Estimated Additional cost: Live/Hot construction to facilitate existing upgrades		$890 million less in construction outage related cost
Estimated Consumer Energy Cost Savings (Long-term)		$229 million more annual Consumer Energy Cost Savings
Estimated Production Cost Savings (Long-term)		$28 million more annual Production Cost Savings
Estimated System Loss Reduction		560 GWh/year less energy loss
Incremental Transfer Capability		600 to 3,000 MW increase in power transfer capability
West Texas Stability Limit Improvement		13% more improvement
Potential Retirement of Series Capacitors	Comparable/Similar	
Improvement to the Overall System Strength	Comparable/Similar	

Questions/Comments

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