Houston Import Project – ERCOT Independent Review

Technical Advisory Committee (TAC)
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Background

- In July and August 2013 CenterPoint Energy, City of Garland and Cross Texas Transmission, and Lone Star Transmission separately identified a reliability need to increase the import capability into the Houston area by 2018
  - Each Transmission Service Provider submitted a project proposal to the Regional Planning Group (RPG) for review and comment
- ERCOT conducted a single, combined Independent Review of the proposals

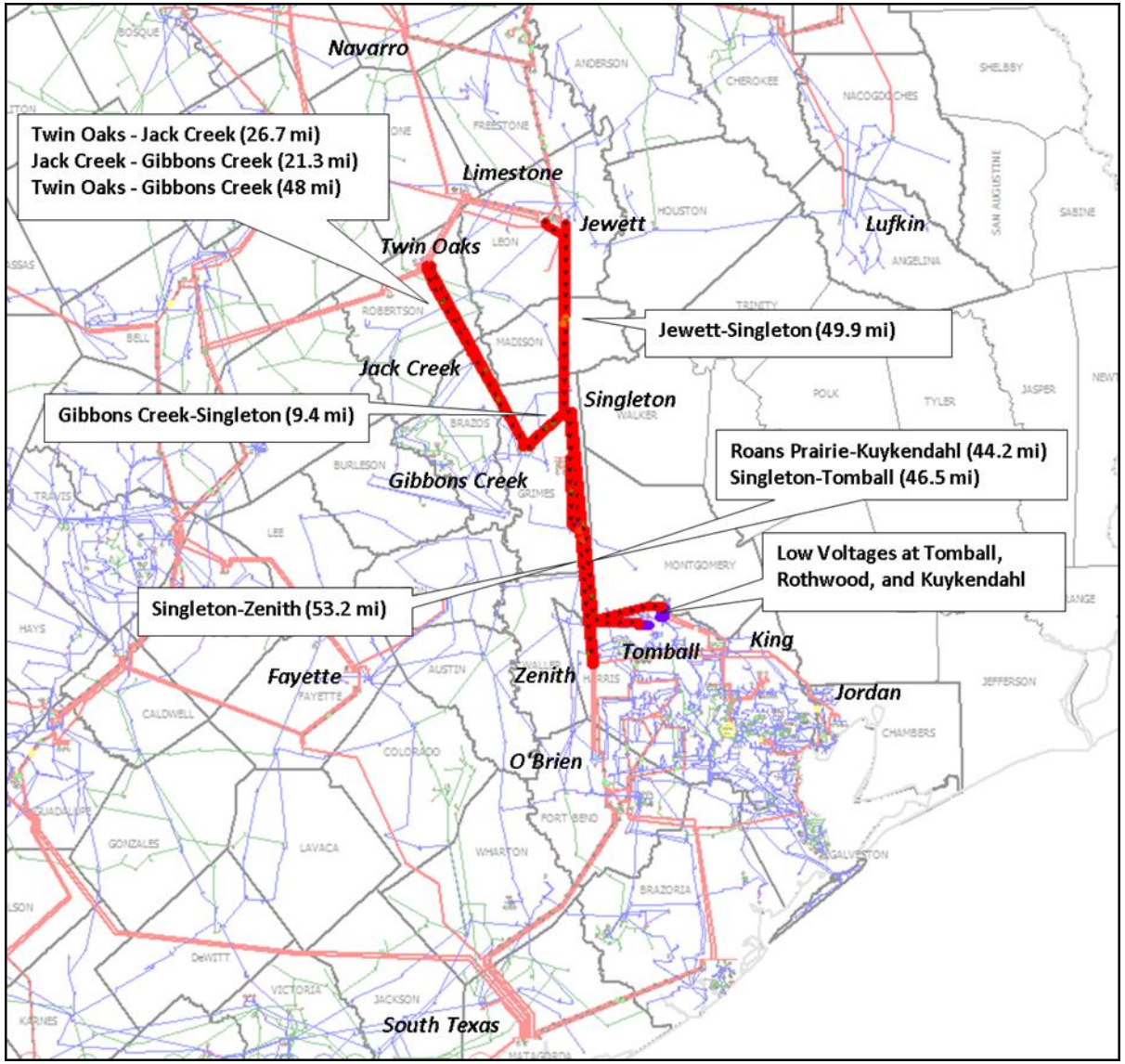
ERCOT Study Assumptions

- ERCOT Independent Review study assumptions are consistent with the 2013 and previous Regional Transmission Plans
  - Used the 2018 SE summer peak case
  - Generation assumptions per Planning Guide Section 6.9
  - Load in Coast, East, Southern, and South Central Weather Zones at peak, all other weather zones scaled down to balance load/ generation
    - ERCOT validated this assumption

NEED ASSESSMENT

Study Results

- Several planning criteria violations found
- Singleton-Zenith 345 kV lines are overloaded under N-1
- Multiple 345 kV lines (total length ~200 miles) and low voltages under G-1+N-1 conditions



Load Variations

- Since planning cases model non-coincident peaks for all areas throughout the system and it is not reasonable to expect that all areas will hit their coincident peaks at the same time, it is a reasonable variation of load to scale load down in areas outside of the study area

- During RPG discussions stakeholders commented that ERCOT's load scaling methodology may exacerbate the North-Houston line loading in the 2018 SE study case

Load Variations cont.

- To address stakeholder comments ERCOT analyzed three additional load variations to test the reliability need for a project using the ERCOT Steady-State Working Group (SSWG) cases
  - **Case 1**: 2018 SSWG case (2018 SUM1 Final 10/15/2013) with no changes to load or generation
  - **Case 2**: 2018 SSWG case with outside weather zone load scaled to the highest percentage load level between 2011 and 2013 when the Coast weather zone was at its peak
  - **Case 3**: 2018 SSWG case with outside weather zone load scaled to the percentage of load level when the Coast weather zone was at its peak in 2013

Load Variation Results

- The result of the G-1+N-1 analysis showed either overload or heavy flow on the existing 345 kV lines from the north into Houston
- The results confirm that the reliability need exists under several different reasonable variations of load

Overload Element (under G-1+N-1)	Case 1	Case 2	Case 3*
Singleton-Zenith double circuit	122%	128%	137%
Roans Prairie-Bobville #75	99%	104%	110%
Bobville-Kuykendahl #75	99%	103%	110%
Jewett North-Singleton #1	93%	99%	106%
Jewett South-Singleton #1	91%	97%	103%
Gibbons Creek-Singleton #75	92%	94%	101%
Gibbons Creek-Singleton #99	92%	94%	101%
Jack Creek-Twin Oak #1	92%	100%	102%
Singleton-Tomball #74	Below 90%	93%	99%
Gibbons Creek-Twin Oak #1	Below 90%	92%	95%
Gibbons Creek-Jack Creek #2	Below 90%	Below 90%	Below 90%

* Also showed low voltage issue (below 90%) at Tomball 345 kV bus

Load/ Generation Sensitivity

- ERCOT performed an additional sensitivity to determine how much generation additions/ load reduction would be required to defer the identified reliability issues by one year
  - Sensitivity performed by scaling down load in Coast weather zone until the thermal violations resolved (to below 100%)
  - Result indicated that ~1800 MW reduction would be needed
  - Actual generation additions or load reduction may need to be greater depending on shift factors
  - Older generation retirement in the Houston area may offset new generation additions

Need Assessment Summary

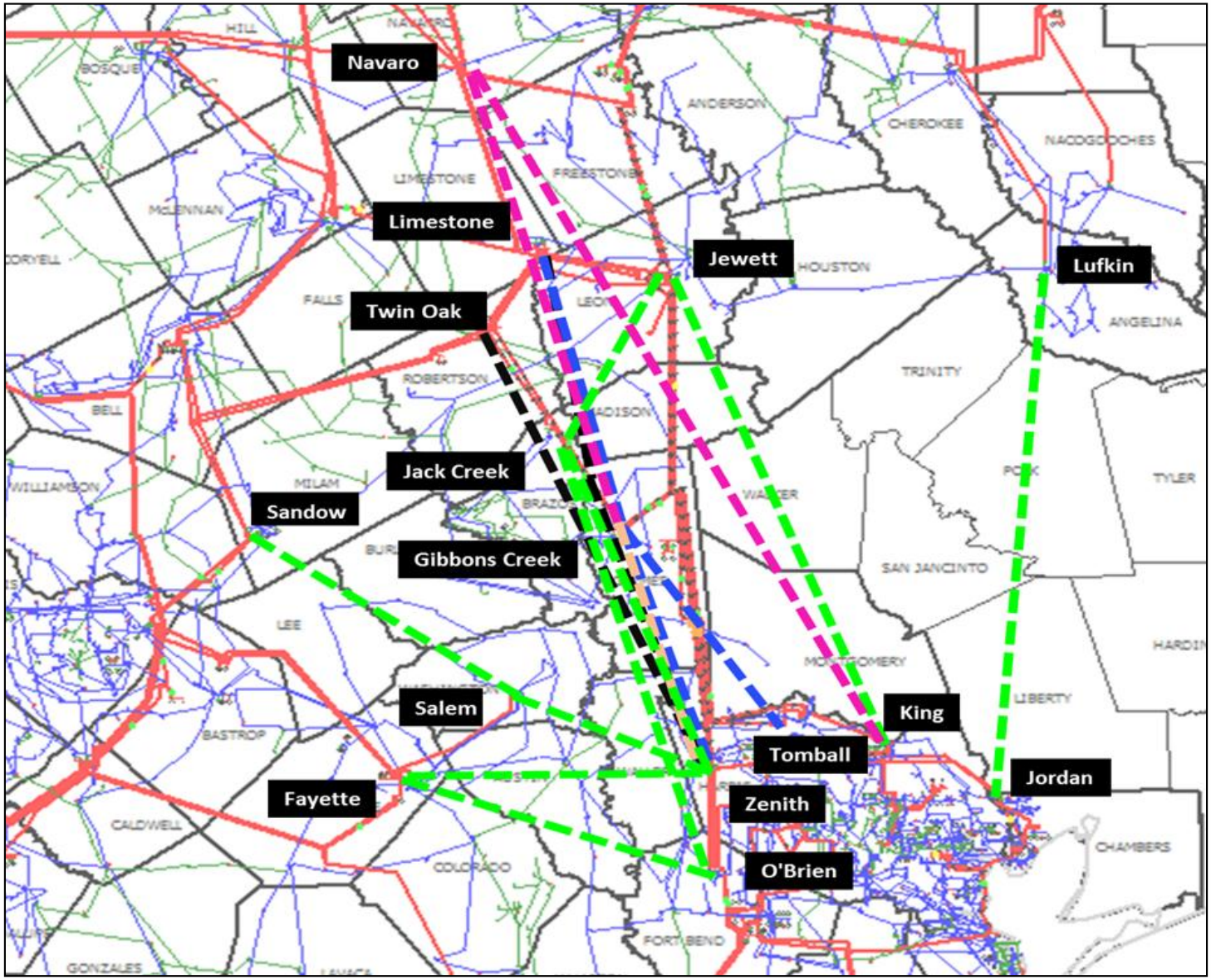
- ERCOT found several planning criteria violations along the North to Houston 345 kV import pathway
- ERCOT confirmed the need using several reasonable variations to load
- ERCOT found that a net of approximately 1800 MW of generation addition/ load reduction would defer the need to 2019
  - 1800 MW represents ~ 6.8% of the total projected load (2018) in the Coastal weather zone

PROJECT ALTERNATIVES

Project Alternative Evaluation

- ERCOT evaluated 21 project alternatives to address the identified reliability need (including project proposals from the TSPs)
- 8 of the projects would resolve the reliability criteria violations:
  - Option 1: Twin Oak-Zenith 345 kV with 25% series compensation
  - Option 2: Twin Oak-Zenith 345 kV with 50% series compensation
  - Option 3: Limestone-Ragan Creek-Zenith 345 kV
  - Option 4: Limestone-Gibbons Creek-Zenith 345 kV
  - Option 5: Jewett-Jack Creek-Zenith 345 kV
  - Option 6: Jewett-Jack Creek-Zenith 345 kV with 25% series compensation
  - Option 7: Jewett-Jack Creek-Zenith 345 kV with 50% series compensation
  - Option 8: Navarro-Gibbons Creek-Zenith 345 kV

Map of 21 Alternatives



Project Alternative Evaluation

- ERCOT performed the following analysis to determine which option would best meet the long-term needs of the system:
  - Assessment of potential future system upgrades and time value of money analysis of those upgrades
  - Voltage stability margin analysis
  - System needs analysis if older generation in the Houston area were to retire
  - NERC Category C and D contingency analysis
  - Production cost savings analysis
  - System loss analysis

Overall Comparison of Options

Description	Option 1 (TWZ-25comp-TA)	Option 2 (TWZ-50comp-TA)	Option 3 (LRZ-TA)	Option 4 (LGZ-TA)	Option 5 (JJZ-TA)	Option 6 (JJZ-25comp-TATJ)	Option 7 (JJZ-50comp-TATJ)	Option 8 (NGZ-TATJ)
System Performance (2018) (All options addressed the reliability need)	Met criteria	Met criteria	Met criteria	Met criteria	Met criteria	Met criteria	Met criteria	Met criteria
Capital cost in 2018 dollar ($ Million), (Based on $3.78 million per mile for T-cost)	554.8	572.0	610.2	590.1	596.3	617.1	629.1	805.9
NPV of the set of future upgrades under each option in 2018 dollar ($ Million)	387.0	390.6	399.5	383.1	652.9	419.5	435.2	537.5
Overall cost impact: Sum of the cost of each option and NPV of future upgrades in 2018 dollar ($ Million)	941.8	962.6	1009.7	973.3	1249.3	1036.6	1064.4	1343.4
Voltage stability Analysis (Estimated 2028 load level in Coast zone = 27931 MW)	28105 MW (beyond 2028)	28095 MW (beyond 2028)	28105 MW (beyond 2028)	28025 MW (beyond 2028)	27905 MW (2028)	28075 MW (beyond 2028)	28205 MW (beyond 2028)	28125 MW (beyond 2028)
Performance with the old units offline (AC power flow under N-1)	4 overloads	2 overloads	0 overload	0 overload	6 overloads	2 overload	0 overload	3 overloads
Amount of generation reduction from the old units without causing overload under G-1+N-1 (MW)	900.6	911.1	1061.3	1020.0	400.0	773.8	662.6	652.6
NERC Category C and D	Good	Good	Good	Good	Good	Good	Good	Good
Economic Benefit (Relative annual production cost savings in $ million, referenced to Option 8)	4.3	3.4	3.2	1.7	2.1	2.2	1.7	0.0
System Loss Reduction at Peak (MW)	44.7	38.8	47.6	31.2	38.2	44.8	35	32.7
New right of way	117 mi	117 mi	130 mi	129.9 mi	128.9 mi	128.9 mi	128.9 mi	177.9 mi
Sub-Synchronous Resonance (SSR) concern	Yes	Yes	No	No	No	Yes	Yes	No

ERCOT Recommendation

- **ERCOT will seek Board of Director endorsement of the following project (Option # 4) as the best option to address both the near-term and long-term reliability needs and to serve the future load in the Houston area:**
  - Construction of a new Limestone-Gibbons Creek-Zenith 345 kV double circuit to achieve 2988 MVA of emergency rating for each circuit
  - Upgrade of the substations at Limestone, Gibbons Creek and Zenith to accommodate the terminations of new transmission lines
  - Upgrade of the existing T.H. Wharton-Addicks 345 kV line to achieve 1450 MVA of emergency rating (~10.7 miles)

QUESTIONS?

APPENDIX

Study Base Case

- Total Load in Coast Weather Zone in the 2018 SE case
  - ~ 26,355 MW (CNP load = ~ 22800 MW)
  - The load is identical to the SSWG case load in the Coastal weather zone

- Status of future generators in the study case

  Online:
  - Deer Park Energy G6, Channel Energy GT3,
  - Deepwater Energy,

  Offline:
  - New W.A. Parish unit, Pondera King, Cobisa

Case Load Scaling Validation

	Average % of peak load of each weather zone during the top ten hourly peak load conditions at the Coast Weather Zone						
Year	East	South	South Central	Far West	West	North	North Central
2011	97%	98%	96%	94%	84%	68%	93%
2012	96%	96%	96%	93%	93%	79%	86%
2013	77%	99%	97%	96%	78%	91%	89%
Average	90%	97%	97%	94%	85%	79%	89%
Max	**97%**	**99%**	**97%**	**96%**	**93%**	**91%**	**93%**
Min	77%	96%	96%	93%	78%	68%	86%

Options Evaluated for N-1

ID	CenterPoint Options	Approximate Length (mi)
C1	Twin Oak-Zenith 345 kV double circuit	117.0
C2	Ragan Creek-Zenith double-circuit 345 kV double circuit	69.0
C3	Limestone-Ragan Creek-Zenith 345 kV double circuit	130.2
ID	**Lone Star Options**	**Approximate Length (mi)**
L1	Navarro-Gibbons Creek-Zenith 345 kV double circuit	165.0
L2	Navarro-King 345 kV double circuit	186.0
L3	Navarro-King 500 kV double circuit	186.0
L4	Navarro-King 345 kV double circuit with 50% Series Compensation	186.0
ID	**Cross Texas & Garland Power and Light Options**	**Approximate Length (mi)**
T1	Gibbons Creek-Tomball 345 kV double circuit	50.0
T2	Gibbons Creek-Zenith 345 kV double circuit	60.0
T3	Limestone-Gibbons Creek-Zenith 345 kV double circuit	122.0
ID	**ERCOT and Other Options**	**Approximate Length (mi)**
E1	Jewett-King 345 kV double circuit	142.5
E2	Lufkin-Jordan 345 kV double circuit	126.0
E3	Fayette-Zenith 345 kV double circuit	65.6
E4	Fayette-O'Brien 345 kV double circuit	73.9
E5	Jewett-Jack Creek-O'Brien 345 kV double circuit plus loop Twin Oak-Gibbons Creek into Jack Creek	154.6
E6	Jewett-Jack Creek-Zenith 345 kV double circuit plus loop Twin Oak-Gibbons Creek into Jack Creek	134.1
E7	Sandow-Salem-Zenith 345 kV double circuit	113.4
E6-a	Jewett-Jack Creek-Zenith 345 kV double circuit with 50% or 25% Series Compensation plus Loop Twin Oak-Gibbons Creek into Jack Creek	134.1
C1-a	Twin Oak-Zenith 345 kV double circuit with 50% or 25% Series Compensation	117.0

Result – N-1 Analysis

- Options that did not pass N-1 criteria:
  - **C2: Ragan Creek-Zenith 345 kV**
    - Overload of Twin Oak-Ragan Creek 345 kV, Jack Creek-Twin Oak 345 kV
    - Heavy flow* on Jewett-Singleton 345 kV
  - **T1: Gibbons Creek-Tomball 345 kV**
    - Overload of Jack Creek-Twin Oaks 345 kV
    - Heavy flow* on Jewett-Singleton 345 kV
  - **T2: Gibbons Creek-Zenith 345 kV**
    - Overload of Jack Creek-Twin Oaks 345 kV
    - Heavy flow* on Jewett-Singleton 345 kV
  - **E2: Lufkin-Jordan 345 kV**
    - Overload of ~50 miles of 138 kV lines in the Lufkin area
  - **E3: Fayette-Zenith 345 kV**
    - Overload of Singleton-Zenith 345 kV
  - **E4: Fayette-O'Brien 345 kV**
    - Overload of Singleton-Zenith 345 kV

ERCOT

* Heavy flow: contingency loading greater than 95%

Result – G-1+N-1 Analysis

- Options that did not meet the G-1+N-1 Analysis:
  - **C1: Twin Oak-Zenith 345 kV**
    - ✓ Heavy flow* on Singleton-Zenith 345 kV
  - **E1: Jewett-King 345 kV**
    - ✓ Overload of Singleton-Zenith 345 kV
  - **E5: Jewett-Jack Creek-O'Brien 345 kV**
    - ✓ Overload of Singleton-Zenith 345 kV
  - **E7: Sandow-Salem Zenith 345 kV**
    - ✓ Overload of Singleton-Zenith 345 kV
    - ✓ Heavy flow* on Jewett-Singleton 345 kV
  - **L3: Navarro-King 500 kV**
    - ✓ Overload of Singleton-Zenith 345 kV
  - **L4: Navarro-King 345 kV with 50% series compensation**
    - ✓ Overload of Singleton-Zenith 345 kV
  - **L2: Navarro-King 345 kV**
    - ✓ Overload of Singleton-Zenith 345 kV
    - ✓ Heavy flow* on Jewett-Singleton 345 kV

ERCOT

* Heavy flow: contingency loading greater than 95%

Selected Option for Further Analysis

- **Eight options selected for further study**
  - Option 1: Twin Oak-Zenith 345 kV with 25% series compensation (~117 miles)
  - Option 2: Twin Oak-Zenith 345 kV with 50% series compensation (~117 miles)
  - Option 3: Limestone-Ragan Creek-Zenith 345 kV (~130.2 miles)
  - Option 4: Limestone-Gibbons Creek-Zenith 345 kV (~122 miles)
  - Option 5: Jewett-Jack Creek-Zenith 345 kV (~134.1 miles)
  - Option 6: Jewett-Jack Creek-Zenith 345 kV with 25% series compensation (~134.1 miles)
  - Option 7: Jewett-Jack Creek-Zenith 345 kV with 50% series compensation (~134.1 miles)
  - Option 8: Navarro-Gibbons Creek-Zenith 345 kV (~165 miles)
- **Few upgrades of existing lines are also included as part of the options**
  - For all options above, upgrade
    - T.H. Wharton-Addicks 345 kV line (~10.7 miles)
  - For Option 6 and 7, upgrade
    - Jack Creek-Twin Oak double-circuit 345 kV line (terminal upgrade)
  - For Option 8, upgrade
    - Jack Creek-Twin Oak 345 kV #1 (terminal upgrade)
- **These select options moved to the next stage for further evaluation.**

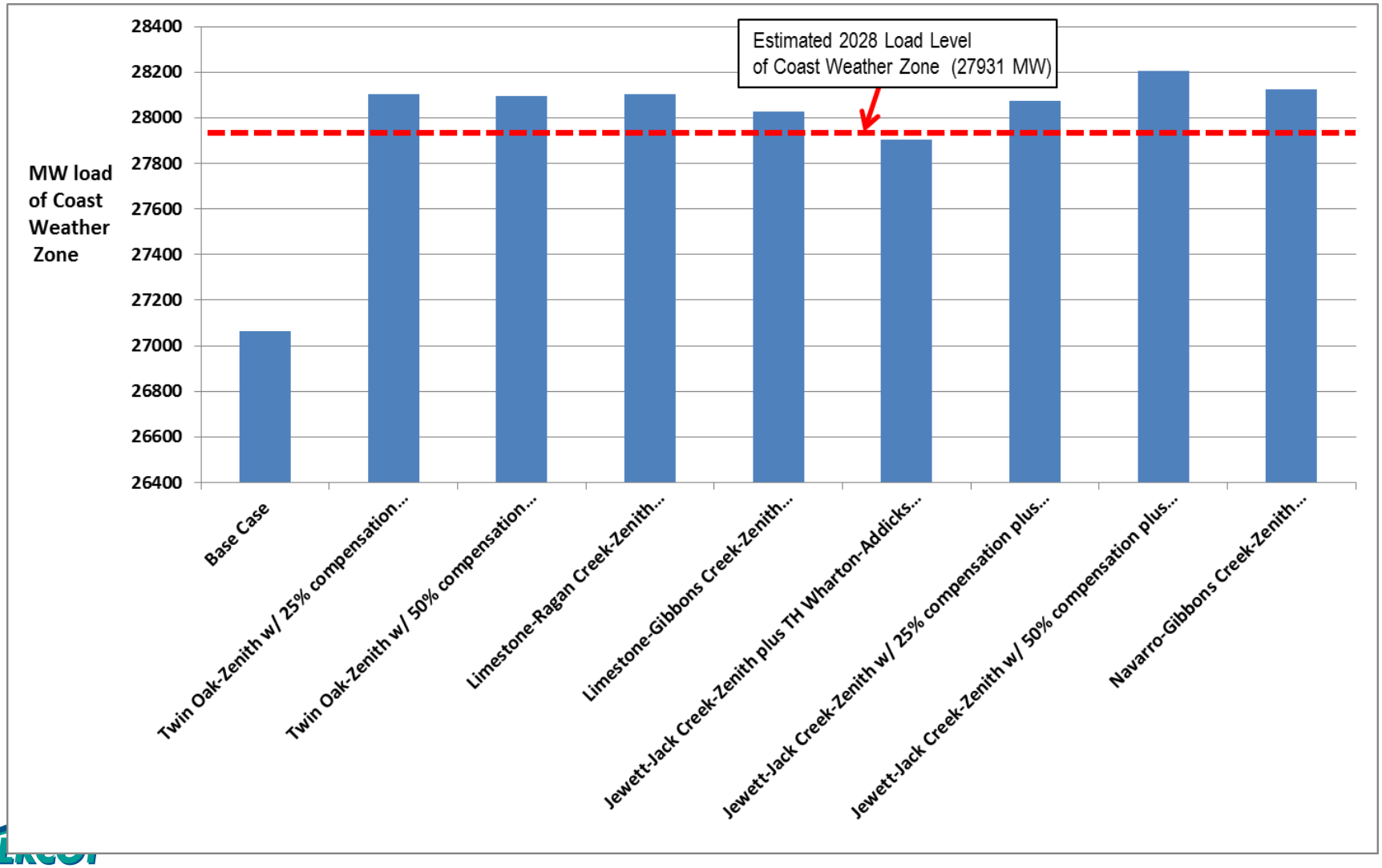
Result of Transfer Capability Analysis (Thermal Overload)

- Performed power transfer analysis and identified future thermal upgrades needed for each option over the next 15 years (2028)

Option		by 2025	by 2026	by 2027	by 2028
Option 1	Twin Oak-Zenith w/ 25% compensation plus TH Wharton-Addicks upgrade		Singleton-Zenith 345 kV (53.2 mi)	Big Brown-Jewett 345 kV (32.8 mi)	Zenith-TH Wharton 345 kV (15.1 mi)
Option 2	Twin Oak-Zenith w/ 50% compensation plus TH Wharton-Addicks upgrade		Big Brown-Jewett 345 kV (32.8 mi)		Singleton-Zenith 345 kV (53.2 mi), Zenith-TH Wharton 345 kV (15.1 mi)
Option 3	Limestone-Ragan Creek-Zenith plus TH Wharton-Addicks upgrade			Singleton-Zenith 345 kV (53.2 mi), Jack Creek-Twin Oak #1 (26.7 mi), Big Brown-Jewett 345 kV (32.8 mi)	Gibbons Creek-Ragan Creek 345 kV (9.6 mi)
Option 4	Limestone-Gibbons Creek-Zenith plus TH Wharton-Addicks upgrade			Singleton-Zenith 345 kV (53.2 mi), Big Brown-Jewett 345 kV (32.8 mi)	Jack Creek-Twin Oak #1 (26.7 mi)
Option 5	Jewett-Jack Creek-Zenith plus TH Wharton-Addicks upgrade	Singleton-Zenith 345 kV (53.2 mi)	Big Brown-Jewett 345 kV (32.8 mi), Twin Oak-Jack Creek 345 kV (26.7 mi)		Jewett-Singleton 345 kV (49.9 mi), Zenith-TH Wharton 345 kV (15.1 mi), Gibbons Creek-Singleton 345 kV (9.4 mi), Gibbons Creek-Jack Creek 345 kV (21.3 mi)
Option 6	Jewett-Jack Creek-Zenith w/ 25% compensation plus TH Wharton-Addicks & Twin Oak-Jack Creek upgrade		Big Brown-Jewett 345 kV (32.8 mi)	Singleton-Zenith 345 kV (53.2 mi)	Zenith-TH Wharton 345 kV (15.1 mi), Twin Oak-Jack Creek 345 kV (26.7 mi)
Option 7	Jewett-Jack Creek-Zenith w/ 50% compensation plus TH Wharton-Addicks & Twin Oak-Jack Creek upgrade		Big Brown-Jewett 345 kV (32.8 mi)		Singleton-Zenith 345 kV (53.2 mi), Zenith-TH Wharton 345 kV (15.1 mi), Twin Oak-Jack Creek 345 kV (26.7 mi)
Option 8	Navarro-Gibbons Creek-Zenith plus TH Wharton-Addicks & Twin Oak-Jack Creek upgrade		Jewett-Singleton 345 kV (49.9 mi), Gibbons Creek-Twin Oak & Gibbons Creek-Jack Creek-Twin Oak 345 kV (48 mi)	Singleton-Zenith 345 kV (53.2 mi)	

Result of Transfer Capability Analysis (Voltage Stability)

- MW load level at the point of voltage collapse under each select option <u>without any upgrades</u>
- Voltage collapse occurs beyond 2028 under every option except Option 5



Impact of Old Generator Retirement

- 11 units (total 1939 MW) are more than 50 year old by 2018
  - Sam Bertron G1, G2, G3, G4 and GT2
  - T.H. Warton GT1
  - W.A. Parish G1, G2, G3, G4, and GT1

- Result of AC power flow analysis with all these 50-year old units offline
  - System problems in the 2018 base case either under system intact or N-1 conditions:

    - Under system intact condition with the units offline,
      - Overload of Singleton-Zenith 345 kV line
      - Overload of Jewett-Singleton 345 kV line
      - Low voltage around Tomball, Kuykendahl, Bobville, Rothwood

    - Under N-1 contingency conditions,
      - Overload of Jewett-Singleton 345 kV line
      - Overload of the bus ties at Twin Oak/Oak Grove
      - Overload of Singleton-Zenith 345 kV line
      - Overload of Gibbons Creek-Twin Oak 345 kV line
      - Overload of Jack Creek-Twin Oak 345 kV line
      - Overload of Gibbons Creek-Singleton 345 kV line
      - Overload of Roans Prairie-Bobville-Kuykendahl 345 kV line
      - Heavy flow on Singleton-Tomball and Gibbons Creek-Jack Creek 345 kV line
      - Low voltages at 15 345-KV buses and 38 138-kV buses in Houston area

Impact of Old Generator Retirement

- Result of AC power flow analysis with each option:
  - ✓ No system problem under system intact condition
  - ✓ No low voltage issues under N-1 condition
  - ✓ Table below shows overload and heavy flow issues under N-1 conditions when the old units are offline

Elements	Jewett S-Singleton 345 kV line #1	Jewett N-Singleton 345 kV line #1	Twin Oak-Oak Grove 345 kV bus tie	Twin Oak 345 kV bus tie	Singleton-Zenith 345 kV line #98	Singleton-Zenith 345 kV line #99	Gibbons Creek-Twin Oak 345 kV #1	Gibbons Creek-Jack Creek 345 kV #2	Jack Creek-Twin Oak 345 kV #1	Jack Creek-Twin Oak 345 kV #2
Option 1			Overload	Overload	Overload	Overload				
Option 2			Overload	Overload						
Option 3			Heavy flow	Heavy flow	Heavy flow	Heavy flow			Heavy flow	
Option 4			Heavy flow	Heavy flow	Heavy flow	Heavy flow				
Option 5			Overload	Overload	Overload	Overload			Overload	Overload
Option 6			Overload	Overload	Heavy flow	Heavy flow				
Option 7			Heavy flow	Heavy flow					Heavy flow	Heavy flow
Option 8	Overload	Overload	Heavy flow	Heavy flow	Heavy flow	Heavy flow	Overload	Heavy flow	Heavy flow	

Impact of Old Generator Retirement

- Result of generation reduction analysis:
  - ✓ Tested G-1+N-1 while reducing the output from the old units
  - ✓ Estimated total MW output that can be reduced from the old unit under each select option without causing any thermal issues

Option	Description	Approximate MW generation reduction that starts causing overload under G-1+N-1
Option 1	Twin Oak-Zenith with 25% series compensation plus TH Wharton-Addicks upgrade	900.6
Option 2	Twin Oak-Zenith with 50% series compensation plus TH Wharton-Addicks upgrade	911.1
Option 3	Limestone-Ragan Creek-Zenith plus TH Wharton-Addicks upgrade	1061.3
Option 4	Limestone-Gibbons Creek-Zenith plus TH Wharton-Addicks upgrade	1020.0
Option 5	Jewett-Jack Creek-Zenith plus TH Wharton-Addicks upgrade	400.0
Option 6	Jewett-Jack Creek-Zenith with 25% series compensation plus TH Wharton-Addicks upgrade and Twin Oak-Jack Creek upgrade	773.8
Option 7	Jewett-Jack Creek-Zenith with 50% series compensation plus TH Wharton-Addicks upgrade and Twin Oak-Jack Creek upgrade	662.6
Option 8	Navarro-Gibbons Creek-Zenith plus TH Wharton-Addicks upgrade and Twin Oak-Jack Creek upgrade	652.6

Impact of NERC Category C and D

- Tested 23 severe events (NERC Cat. C and D contingencies) based on the past study and knowledge of the system

Options	Description	# of Unsolved Contingencies (NERC Cat. D)	Thermal Overload 345 kV 115% above	Low Voltage At 345 kV Buses (below 0.9 pu)
	Base Case	6	6	5
Option 1	Twin Oak-Zenith with 25% series compensation plus TH Wharton-Addicks upgrade	1	1	4
Option 2	Twin Oak-Zenith with 50% series compensation plus TH Wharton-Addicks upgrade	1	0	3
Option 3	Limestone-Ragan Creek-Zenith plus TH Wharton-Addicks upgrade	1	0	5
Option 4	Limestone-Gibbons Creek-Zenith plus TH Wharton-Addicks upgrade	1	0	5
Option 5	Jewett-Jack Creek-Zenith plus TH Wharton-Addicks upgrade	1	1	6
Option 6	Jewett-Jack Creek-Zenith with 25% series compensation plus TH Wharton-Addicks upgrade and Twin Oak-Jack Creek upgrade	1	0	5
Option 7	Jewett-Jack Creek-Zenith with 50% series compensation plus TH Wharton-Addicks upgrade and Twin Oak-Jack Creek upgrade	1	0	3
Option 8	Navarro-Gibbons Creek-Zenith plus TH Wharton-Addicks upgrade and Twin Oak-Jack Creek upgrade	1	0	5

System Loss Reduction

- System losses with each option modeled in the 2018 summer peak study case were compared to the base case
- In every option, significant loss reduction is expected

Option	Option 1 (TWZ-25%COMP-TA)	Option 2 (TWZ-50%COMP-TA)	Option 3 (LRZ-TA)	Option 4 (LGZ-TA)	Option 5 (JJZ-TA)	Option 6 (JJZ-25%COMP-TATJ)	Option 7 (JJZ-50%COMP-TATJ)	Option 8 (NGZ-TATJ)
System Loss Reduction (MW)	44.7	38.8	47.6	31.2	38.2	44.8	35	32.7

Sensitivity Analyses for Transfer Study

- A sensitivity analysis was performed using the latest SSWG case
  - Case used: As-built 2014 SSWG Data Set B 2018 base case
  - Results confirmed overload on Singleton-Zenith 345 kV double circuit line under the G-1+N-1 condition

- Power transfer analysis using different load scaling approach
  - Power transfer analysis was performed for certain options under N-1 conditions using the following two load scaling approaches:
    1) Scaling load down in North, North Central, West and Far West
    2) Scaling all load down except the load in Coast Weather Zone
  - The result indicates that:
    - There are reliability criteria violations in 2018 regardless of which approach is used
    - The need identification for the next set of upgrades may be deferred by a year or two if the all-load-scaling (#2) approach is used
      - For example, roughly 220~300 MW difference in the transfer capability, when the future overload issue on the Singleton-Zenith double-circuit 345 kV line occurs with each option

Cost Analysis

- Methodology and Assumptions:

  - ✓ In addition to the cost of each select option, the cost of each future upgrade (up to 2028) was also considered to capture the long-term reliability benefit of each select option.

  - ✓ Overall cost associated with each select option was calculated.

Overall cost = Construction cost* of each select option +
NPV† of construction cost** of future upgrades

* the construction cost of each select option in 2018 dollar.

** the future value of each future upgrade, estimated by using 3% inflation rate.

† 8% discount rate was used to calculate the NPV (in 2018 dollar) of the set of future upgrades under each select option.
(Reference of discount rate: www.puc.texas.gov/industry/electric/reports/31600/PUCT_CBA_Report_Final.pdf)

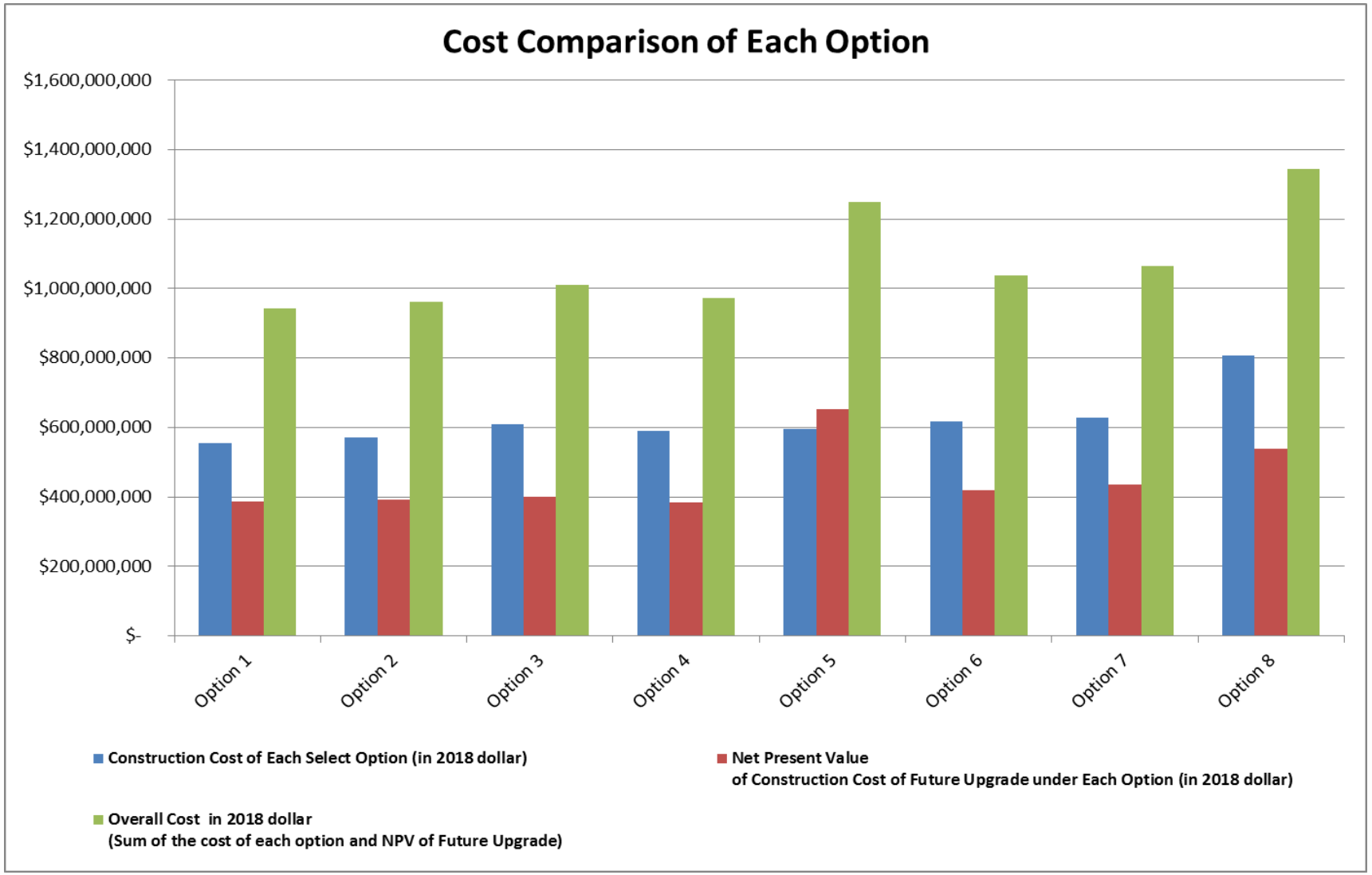
Result of Cost Analysis

Unit: $ Million

Option	Construction Cost * of Each Select Option (in 2018 dollar)	Net Present Value (NPV) of Construction Cost of the Set of Future Upgrades (in 2018 dollar)	Overall Cost (in 2018 dollar)
Option 1 (TWZ-25%)	554.8	387.0	941.8
Option 2 (TWZ-50%)	572.0	390.6	962.6
Option 3 (LRZ)	610.2	399.5	1,009.7
Option 4 (LGZ)	590.1	383.1	973.3
Option 5 (JJZ)	596.3	652.9	1,249.3
Option 6 (JJZ-25%)	617.1	419.5	1,036.6
Option 7 (JJZ-50%)	629.1	435.2	1,064.4
Option 8 (NGZ)	805.9	537.5	1,343.4

* $ 3.78 million-per-mile was assumed for T-line portion of the cost. ERCOT performed sensitivity analysis using different cost-per-mile assumption. No significant impact was found in selecting a best solution.

Result of Cost Analysis



Economic Analysis

- Although the Houston Import RPG review is purely driven by reliability need, ERCOT also performed an economic analysis for the year 2018 using the 2018 economic case.

- Relative annual production cost of each option was obtained by comparing the annual production cost of each option against the option with the highest annual production cost.

Unit: $ Million

Option	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
Relative Production cost savings (Referenced to Option 8)	4.3	3.4	3.2	1.7	2.1	2.2	1.7	0.0