Houston Import Project

Version 1.0

Document Revisions

Date	Version	Description	Author(s)
07/27/2010	1.0	Final draft	Ehsan Ur Rehman

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Houston Import Project

1. Introduction

The Houston metropolitan area is one of the major load centers in ERCOT. Load in the area is served by a combination of local generation and by importing power from outside of the area. Currently, there are nine 345 kV circuits that provide the bulk of the import capability into Houston from the rest of ERCOT (four circuits primarily from the north and five circuits primarily from the south):

North – Houston Import Circuits

- Singleton – Zenith (2011) 345 kV double circuit
- Singleton – Tomball 345 kV line
- Roans Prairie – Kuykendahl 345 kV line

South – Houston Import Circuits

- South Texas Project – Dow 345 kV double circuit
- South Texas Project – W A Parish 345 kV line
- W A Parish – Hillje 345 kV double circuit

Congestion has been experienced on the circuits importing power from the north in the last several years. Table 1 shows the 2007 through 2009 and 2010 year-to-date North to Houston zonal congestion costs:

Year	Congestion cost
2007	$39.8M
2008	$108.0M
2009	$10.5M
2010 (through May)	$0.56M

Table 1: 2007-2010 North-Houston Zonal Congestion Costs

Recent planning studies, including the ERCOT 2009 Five-Year Transmission Plan and the ERCOT 2008 Long-Term System Assessment (LTSA), have indicated that this congestion is expected to continue in the future unless bulk system upgrades are implemented. Table 2 below shows the congestion seen in the 2014 economic case of 2009 Five-Year Transmission Plan.

Limiting Element	Congestion (%)	Limiting Contingencies
Singleton – Zenith 345 kV line	16.31	Singleton – Tomball 345 kV Line
Jewett – Singleton 345 kV line	4.10	Gibbons Creek – Singleton 345 kV double circuit
Jack Creek – Twin Oak 345 kV line	10.39	Jewett – Singleton 345 kV double circuit

Table 2: Congestion in 2014 economic case

Additionally, the 2008 LTSA states, "As with the LTSA completed in 2006, this assessment indicates a need for additional future import capacity into Houston."[1] Furthermore, the 2008 LTSA indicated that additional Houston import capacity may be required in order to meet reliability criteria by 2018:

> "*Based on this analysis, the difference between installed generation capacity and the peak load in 2018 in the Houston area is expected to result in the need for about 5,600 MW of imported power at a minimum to fulfill the area's peak-load needs, not counting the need to hold some generation in reserve for real-time operational emergencies. Given these import needs, without the benefit of installation of a substantial amount of new generation resources, the Houston area will require additional high-voltage transmission infrastructure in place by the beginning of the 2018 summer period. This analysis indicates that in 2018 import capacity is likely to be restricted from both the south and the north.*"[2]

Sharyland Utilities and CenterPoint Energy both submitted project proposals to the ERCOT Regional Planning Group (RPG) to address the need to add more import capacity into the Houston area. Both projects received comments that were not able to be resolved through the RPG comment process. The unresolved comments were all related to the relative merits of each of the project proposals and were not related to the need for additional import capacity for Houston with the exception of a comment from one party that stated that the Sharyland Utilities project should be "rejected."

ERCOT performed a study of the absolute and relative merits of both project proposals, as well as multiple alternative projects identified by ERCOT and other stakeholders, to provide increased import capacity into the Houston area. This report provides the results of that study and also serves as the ERCOT Independent Review for both the Sharyland Utilities and CenterPoint Energy project proposals. A total of more than 32 options were studied, but only 22 options are described in this report since the omitted ones were either similar or were reasonably proven to be unfeasible in the CenterPoint Energy report submittal. Of the options studied in this Independent Review "Option 3" was identified as the most effective option. The upgrades involved in Option 3 are described as follows:

Option 3:

- Build Fayetteville – Zenith 345 kV double circuit line (approx. 60 miles on a new Right of Way (ROW)) so that each circuit Rate B is approximately 2800 MVA

[1] Long-Term System Assessment for the ERCOT Region December 2008, Executive Summary
[2] Long-Term System Assessment for the ERCOT Region December 2008, III A/C Contingency Analysis, B. Houston Study Region

- Loop Fayette Power Project – Salem 345 kV line into Fayetteville 345 kV substation
- Upgrade the Fayette Power Project – Fayetteville 345 kV double circuit line so that the circuit Rate B of each line is approximately 1900 MVA
- Expand the Fayetteville Substation with four new line terminations and Zenith Substation with two new line terminations
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively

The total cost estimate (based on CenterPoint Energy, LCRA TSC and ERCOT estimates) is approximately $175 million for these improvements. The ERCOT independent analysis of the upgrades, involved in Option 3, revealed approximately $13 million and $45 million in annual production cost savings and energy revenue savings, respectively for 2014.

It should be noted that the need to add additional import capacity into the Houston area was not considered to be necessary to meet reliability criteria in the timeframe of this analysis (2014) since the load in the area could reliably be served by generation in the Houston area and the existing import capacity[3]. For this reason each of the project alternatives were evaluated on economic criteria based on the ERCOT RPG Planning Charter and Procedures in order to evaluate each project's ability to reliably serve the load at an overall lower cost.

2. Study Approach

The analysis of the project alternatives primarily focused on the economic benefit of additional import capacity into the Houston area per the ERCOT RPG Planning Charter and Procedures Section 3.3. UPLAN was used to perform the economic analyses. Other software tools, including PSSE, MUST and PowerWorld, were also used to aid the analyses.

The latest 2009 Five-Year Transmission Plan model for the year 2014 served as the benchmark for the analysis. This case was selected because the majority of the proposed projects involve the construction of 345 kV lines on new ROW and it is not expected that they could be in-place before the year 2014. Also, at the time of the analysis, no future year economic models past 2014 were available. This model contained all of the PUCT Approved Competitive Renewable Energy Zone (CREZ) related transmission improvements. The model contained all existing generation plus generation with signed interconnection agreements (SGIA) at the start of the analysis.

Due to the unique nature of building an additional import line into a major load center the scope of this analysis was expanded above what would typically be performed. This was done to capture the merits of each of the alternative projects under a variety of scenarios since the assumptions affecting the study results may change over the life of the project and it was deemed important to evaluate the long-term robustness of each option.

The study was divided into three phases of which each phase involved a simulation of unique scenarios with variations of assumptions affecting the results. A total of ten different

[3] As noted in the 2008 LTSA, this project would eventually be required to meet reliability requirements, depending on load growth and generation additions net of retirements

scenarios were simulated to quantify the relative merit of each option. The three phases are described below:

1. **PHASE I (Base Scenario)**

   The base scenario involved using the typical economic planning criteria and assumptions from the 2009 Five-Year Transmission Plan to evaluate each option.

2. **PHASE II (Alternative Scenarios)**

   Options that passed the standard economic planning criteria from Phase I (as well as some that were close to passing) were further evaluated in several alternative scenarios in order to explore the relative merits of each option. The purpose of this phase was to select the best option from all of the alternative projects that passed the economic planning criteria by analyzing each option across a range of scenarios. A recommended project was selected at the end of this phase. These scenarios are described below.

   - CREZ Generation Scenario: Wind generation plants were added to the model so that the total amount of wind generation in each CREZ zone was equal to what was studied in Scenario 2 of the CREZ Transmission Optimization Study. The total wind generation capacity in this scenario was 18873 MW
   - Load Variation Scenarios: Coastal weather zone load was varied ±10% from the benchmark case
   - STP 3 & 4 Scenario: The proposed South Texas Project nuclear units 3 and 4 were added to the benchmark case
   - Gas Price Variation Scenarios: The price of natural gas was varied ± $3.00

3. **PHASE III (Sensitivity Scenarios)**

   A sensitivity analysis was performed for the recommended option in order to further evaluate the robustness of the project. The following scenarios, identified as having the potential to impact the merits of the project, were run as part of this sensitivity analysis:

   - Potential Gas Generation Inside Houston Area Scenario: New natural gas generation units in the Houston area were added to the model
   - New SGIAs Scenario: Changes in generation assumptions since the beginning of the analysis due to plant retirements/ mothballs and new plants with SGIAs were made to the benchmark case
   - Higher Transmission Line Cost Scenario: A higher per mile cost for 345 kV double circuit line construction was evaluated

Because the above mentioned economic analysis was conducted using a DC model, an additional steady-state voltage stability analysis was performed using an AC model to ensure that the system was stable for the increased levels of transfers into the Houston area.

3. Description of Project Alternatives

Below is a description and planning level capital cost estimate for each of the 22 options that ERCOT studied as a part of the Houston Import Project. The cost estimates assumed \$2.5 million per mile for 345 kV double circuit line construction. This per mile cost estimate is lower than the \$3.34 million that CenterPoint Energy used in their project submittal. While the CenterPoint Energy estimate was a reasonable conservative amount, CenterPoint Energy agreed that construction cost in the range of \$2.5 million to \$3.34 million per mile is appropriate and that using \$2.5 million per mile provides reasonable cost estimates. It should be noted that Sharyland Utilities informed ERCOT that their latest estimate was \$2.0 million per mile for Option 1 (Canal-Lufkin 345 kV double circuit). However, CenterPoint Energy and Oncor Electric Delivery (the owners of the endpoints of the potential line) agreed that \$2.5 million per mile was an appropriate estimate for that project.

For ease of communication this report will use the option number labels used in the CenterPoint Energy submittal. Options that were not included in the CenterPoint Energy submittal were given alphanumeric labels. Options that were proven to be unfeasible in the CenterPoint Energy submittal were not included which explains why some option numbers are skipped.

Throughout the Phase I analysis ERCOT sought to optimize the cost-effectiveness of each of the options. Hence, there may be certain details that are different between the projects submitted by Sharyland Utilities and CenterPoint Energy and the options described below.

Figure 1 below shows the region in ERCOT where 22 options were studied.

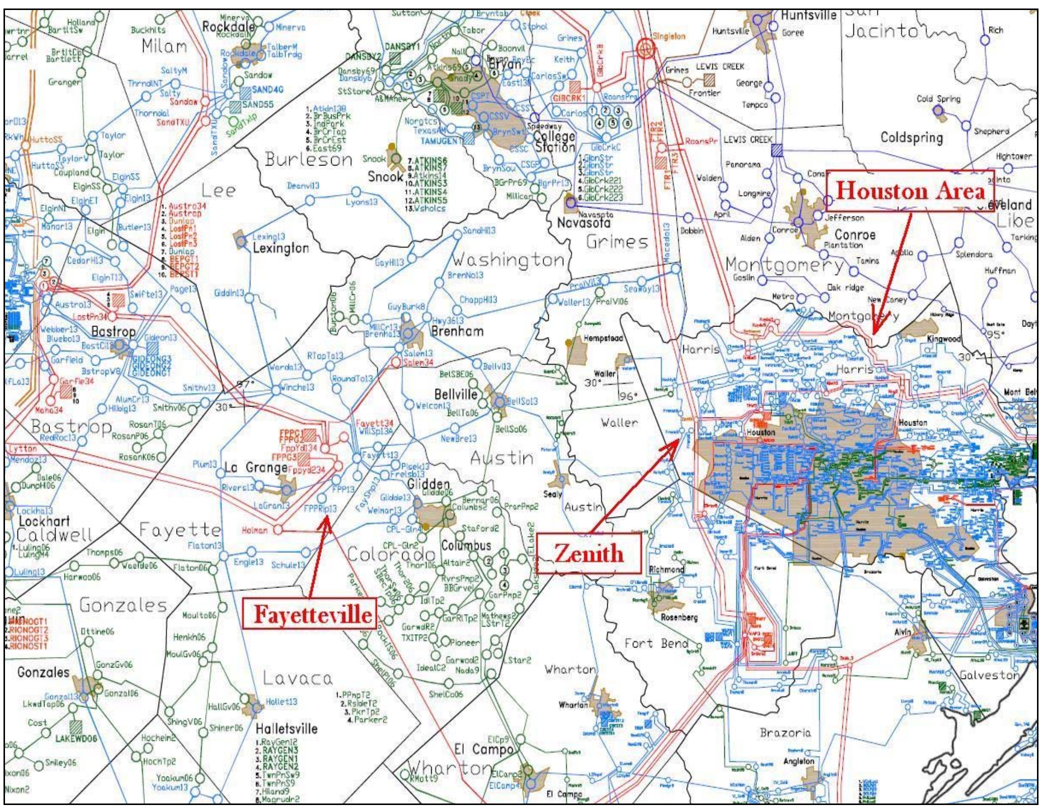

Figure I: Map of the Area of Interest in ERCOT

Option 1

- Build a new 345 kV substation Canal and loop the Chambers – King and Cedar Bayou – North Belt 345 kV lines into it
- Build Canal – Lufkin 345 kV double circuit line (approx. 110 miles on a new ROW) so that each circuit Rate B is approximately 2800 MVA
- Expand Lufkin 345 kV substation with the two additional line terminations
- Upgrade the Center – PH Robinson 345 kV line terminal equipment so that the circuit Rate B is 1450 MVA
- Upgrade the Cedar Bayou – Chambers 345 kV line terminal equipment so that the circuit Rate B is 2641 MVA
- Upgrade the Stryker Creek – Lufkin 345 kV line terminal equipment so that the circuit Rate B is 1072 MVA
- Add a second Mount Enterprise – Nacogdoches 345 kV circuit (approx. 30.7 miles) on the available tower position of the existing circuit so that the circuit Rate B is 1072 MVA
- Upgrade the Tyler Grande – Whitehouse – Walnut Tap – Troup Switch 138 kV line (approx. 13.4 miles) so that the circuit Rate B is 484 MVA

The total cost related to Option 1 upgrades is approximated to be $333 million.

Option 2

- Build Salem – Zenith 345 kV double circuit line (approx. 52 miles on a new ROW) so that each circuit Rate B is approximately 2800 MVA
- Expand the Fayetteville Substation with four new line terminations; and Zenith Substation and Salem Substation with two new line terminations, respectively
- Loop Fayette Power Project – Salem 345 kV line into Fayetteville 345 kV substation
- Upgrade Fayette Power Project – Fayetteville 345 kV double circuit line (each conductor approx. 8 miles) so that the circuit Rate B of each line is approximately 1900 MVA
- Upgrade the existing Fayetteville – Salem 345 kV line (approx. 8 miles) so that the circuit Rate B is 1631 MVA
- Build a new Fayetteville – Salem 345 kV line (approx. 25 miles) parallel to Fayette – Welcome – Salem 138 kV line so that the circuit Rate B is 1086 MVA
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively

The total cost related to Option 2 upgrades is approximated to be $222 million.

Option 3:

- Build Fayetteville – Zenith 345 kV double circuit line (approx. 60 miles on a new ROW) so that each circuit Rate B is approximately 2800 MVA
- Loop Fayette Power Project – Salem 345 kV line into Fayetteville 345 kV substation
- Upgrade Fayette Power Project – Fayetteville 345 kV double circuit line so that the circuit Rate B of each circuit is approximately 1900 MVA
- Expand the Fayetteville Substation with four new line terminations and Zenith Substation with two new line terminations
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively

The total cost related to Option 3 upgrades is approximated to be $175 million.

Option 3A:

- Build Fayetteville – Zenith 345 kV double circuit line (approx. 60 miles on a new ROW) so that each circuit Rate B is approximately 2800 MVA
- Add 30% series compensation on Fayetteville – Zenith 345 kV circuits
- Loop Fayette Power Project – Salem 345 kV line into Fayetteville 345 kV substation
- Upgrade Fayette Power Project – Fayetteville 345 kV double circuit lines so that the circuit Rate B of each line is approximately 1900 MVA
- Expand the Fayetteville Substation with four new line terminations and Zenith Substation with two new line terminations
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively

The total cost related to Option 3A upgrades is approximated to be $225 million.

Option 4:

- Build Gibbons Creek – Zenith 345 kV double circuit line (approx. 65 miles on a new ROW) so that each circuit Rate B is approximately 2800 MVA
- Expand the Gibbons Creek Substation and Zenith Substation with two new line terminations
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively

The total cost related to Option 4 upgrades is approximated to be $173 million.

Option 6:

- Build Fayetteville – Obrien 345 kV double circuit line (approx. 65 miles on a new ROW) so that each circuit Rate B is approximately 2800 MVA
- Loop Fayette Power Project – Salem 345 kV line into Fayetteville 345 kV substation
- Upgrade Fayette Power Project – Fayetteville 345 kV double circuit lines so that the circuit Rate B of each line is approximately 1900 MVA
- Expand the Fayetteville Substation with four new line terminations and Obrien Substation with two new line terminations
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively

The total cost related to Option 6 upgrades is approximated to be $189 million.

Option 6A:

- Build Fayetteville – Obrien 345 kV double circuit lines (approx. 65 miles on a new R.O.W) so that each circuit Rate B is approximately 2800 MVA
- Add 30% series compensation on Fayetteville – Obrien 345 kV lines
- Loop Fayette Power Project – Salem 345 kV line into Fayetteville 345 kV substation
- Upgrade Fayette Power Project – Fayetteville 345 kV double circuit lines so that the circuit Rate B of each line is approximately 1900 MVA
- Expand the Fayetteville Substation with four new line terminations and Obrien Substation with two new line terminations
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively

The total cost related to Option 6A upgrades is approximated to be $239 million.

Option 9:

- Build Gibbons Creek– Salem – Zenith 345 kV double circuit line (approx. 110 miles altogether on a new ROW) in such a way that only one circuit goes to Salem 345 kV substation and the other bypasses it and only terminates at Zenith. The circuit Rate B for each circuit is approximately 2800 MVA
- Expand the Salem Substation with two new line terminations; and Zenith and Gibbons Creek substations with two new line terminations, respectively

- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively

The total cost related to Option 9 upgrades is approximated to be $278 million.

Option 12:

- Build Gibbons Creek – Salem 345 kV double circuit line (approx. 50 miles on a new ROW) such that the circuit Rate B for each circuit is approximately 2800 MVA
- Build Fayetteville – Zenith 345 kV double circuit line (approx. 60 miles on a new ROW) such that the circuit Rate B for each circuit is approximately 2800 MVA
- Expand the Fayetteville Substation with four new line terminations; and Zenith, Gibbons Creek and Salem substations with two new line terminations, respectively
- Loop Fayette Power Project – Salem 345 kV line into Fayetteville 345 kV substation
- Upgrade Fayette Power Project – Fayetteville 345 kV double circuit line so that the circuit Rate B of each circuit is approximately 1900 MVA
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively
- Upgrade Bellaire – Kirby 345 kV line terminal equipment so that the circuit Rate B is 838 MVA
- Upgrade Zenith – T H Wharton 345 kV line terminal equipment so that the circuit Rate B is 1499 MVA

The total cost related to Option 12 upgrades is approximated to be $306 million.

Option 22:

- Build Fayetteville – Zenith 345 kV double circuit line (approx. 60 miles on a new ROW) so that each circuit Rate B is approximately 2800 MVA
- Add 50% series compensation on each Fayetteville – Zenith 345 kV circuit
- Loop Fayette Power Project – Salem 345 kV line into Fayetteville 345 kV substation
- Upgrade Fayette Power Project – Fayetteville 345 kV double circuit line so that the circuit Rate B of each circuit is approximately 1900 MVA
- Expand the Fayetteville Substation with four new line terminations and Zenith Substation with two new line terminations
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively

- Upgrade Zenith – T H Wharton 345 kV line terminal equipment so that the circuit Rate B is 1499 MVA

The total cost related to Option 22 upgrades is approximated to be $226 million.

Option J1:

- Build Sandow – Zenith 345 kV double circuit line (approx. 97 miles on a new ROW) so that the circuit Rate B is approximately 2800 MVA
- Expand the Sandow and Zenith substations with two new line terminations each
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively

The total cost related to Option J1 upgrades is approximated to be $253 million.

Option J1A:

- Build Sandow – Zenith 345 kV double circuit line (approx. 97 miles on a new ROW) so that the circuit Rate B is approximately 2800 MVA
- Add 30% series compensation on Sandow – Zenith 345 kV circuit
- Expand the Sandow and Zenith substations with two new line terminations each
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively
- Upgrade Zenith – T H Wharton 345 kV line terminal equipment so that the circuit Rate B is 1499 MVA

The total cost related to Option J1A upgrades is approximated to be $304 million.

Option J2:

- Build Marion – Holman – Obrien 345 kV double circuit line (approx. 157 miles on a new ROW) so that each circuit Rate B is approximately 2800 MVA
- Expand the Marion and Obrien substations with two new line terminations, respectively
- Expand the Holman Substation with six new line terminations
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively
- Upgrade Fayette Power Plant1 – Fayette Power Plant2 345 kV line terminal equipment so that the circuit Rate B is 1606 MVA

- Loop the Fayette Power Project 2 – Lytton Springs 345 kV line into Holman and upgrade the Holman – Fayette 345 kV double circuit (approx. 10.8 miles) such that each circuit Rate B is approximately 1900 MVA
- Upgrade Bellaire – Kirby 345 kV line terminal equipment so that the circuit Rate B is 838 MVA

The total cost related to Option J2 upgrades is approximated to be $420 million.

Option J3:

- Build Hillje – Obrien 345 kV double circuit line (approx. 65 miles on a new ROW) so that each circuit Rate B is approximately 2800 MVA
- Expand the Hillje and Obrien substations with two new line terminations each
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively

The total cost related to Option J3 upgrades is approximated to be $174 million.

Option E1:

- Build Twin Oak – Salem 345 kV double circuit line (approx. 80 miles on a new ROW) so that each circuit Rate B is approximately 2800 MVA
- Build Fayetteville – Zenith 345 kV double circuit line (approx. 60 miles on a new R.O.W) so that each circuit Rate B is approximately 2800 MVA
- Expand the Twin Oak, Salem, Zenith and Fayetteville substations with two new line terminations each
- Loop Fayette Power Project – Salem 345 kV line into Fayetteville 345 kV substation
- Upgrade Fayette Power Project – Fayetteville 345 kV double circuit line so that the circuit Rate B of each circuit is approximately 1900 MVA
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 516 MVA, respectively

The total cost related to Option E1 upgrades is approximated to be $379 million.

Option E4:

- Build Twin Oak – Zenith 345 kV double circuit line (approx. 110 miles on a new ROW) so that the circuit Rate B is approximately 2800 MVA
- Expand the Twin Oak and Zenith substations with two new line terminations each
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively

- Upgrade Zenith – T H Wharton 345 kV line terminal equipment so that the circuit Rate B is 1499 MVA

The total cost related to Option E4 upgrades is approximated to be $286 million.

Option E4A:

- Build Twin Oak – Zenith 345 kV double circuit line (approx. 110 miles on a new ROW) so that the circuit Rate B is approximately 2800 MVA
- Add 30% series compensation on Twin Oak – Zenith 345 kV lines
- Expand the Twin Oak and Zenith substations with two new line terminations each
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively
- Upgrade Zenith – T H Wharton 345 kV line terminal equipment so that the circuit Rate B is 1499 MVA

The total cost related to Option E4A upgrades is approximated to be $336 million.

Option E5:

- Build Twin Oak – Salem – Zenith 345 kV double circuit line (approx. 131 miles altogether on a new ROW) in such a way that only one circuit goes to Salem 345 kV substation and the second bypasses it and continues to terminate at Zenith 345 kV substation. Each circuit Rate B should be approximately 2800 MVA
- Expand the Twin Oak, Salem and Zenith substations with two new line terminations each
- Upgrade Zenith – T H Wharton 345 kV line terminal equipment so that the circuit Rate B is 1499 MVA
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively
- Upgrade Bellaire – Kirby 138 kV line terminal equipment so that the circuit Rate B is 838 MVA

The total cost related to Option E5 upgrades is approximated to be $346 million.

Option 19:

- Add 50% series compensation on each of the Hillje – W A Parrish 345 kV lines
- Loop the Fayette Power Project 2 – Lytton Springs 345 kV line into Holman and upgrade the Holman – Fayette Power Project 2 345 kV double circuit (approx. 10.8 miles) such that each circuit Rate B is approximately 1900 MVA

- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively

.The total cost related to Option 19 upgrades is approximated to be $62 million.

Option 24:

- Add 75% series compensation on each of the Hillje – W A Parrish 345 kV lines
- Loop the Fayette Power Project 2 – Lytton Springs 345 kV line into Holman and upgrade the Holman – Fayette Power Project 2 345 kV double circuit (approx. 10.8 miles) such that each circuit Rate B is approximately 1900 MVA
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 516 MVA, respectively
- Build Fayetteville – Zenith 345 kV double circuit lines (approx. 60 miles on a new R.O.W) so that the circuit Rate B is approximately 2800 MVA.
- Add 50% series compensation on each Fayetteville – Zenith 345 kV circuit
- Loop Fayette Power Project – Salem 345 kV line into Fayetteville 345 kV substation
- Upgrade Fayette Power Project – Fayetteville 345 kV double circuit lines so that the circuit Rate B of each circuit is approximately 1900 MVA
- Expand the Fayetteville substation with four new line terminations and Zenith and Holman substations with two new line terminations each

The total cost related to Option 24 Upgrades is approximated to be $300 million.

Option DC1:

- Build Brown – Zenith HVDC (approx. 247 miles, 2000 MW) line
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively
- Upgrade Zenith – T H Wharton 345 kV line terminal equipment so that the circuit Rate B is 1499 MVA

The total cost related to Option DC1 upgrades is approximated to be $787 million.

Option DC2:

- Build Scurry – Zenith HVDC (approx. 448 miles, 2000 MW) line
- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively

- Upgrade Zenith – T H Wharton 345 kV line terminal equipment so that the circuit Rate B is 1499 MVA

The total cost related to Option DC2 upgrades is approximated to be $923 million.

4. Analysis

The economic analysis was performed in UPLAN. The latest 2014 economic case from the 2009 Five-Year Transmission Plan that was available at the beginning of the study was used to perform the economic analysis. It should be noted that this case did not include all of the projects that may be present in the final version of the 2014 economic case since the analysis for the Houston Import Project began before the completion of 2009 Five–Year Transmission Plan. However, the 2014 model did include all of the CREZ transmission facilities and all of the Houston area projects proposed for the 2009 Five-Year Transmission Plan.

4.1. PHASE I

Phase I included the analysis under the "Base Scenario" to screen the economically justified options. The options meeting (or close to meeting) the economic planning criteria were then carried forward for Phase II of the analysis.

4.1.1. Base Scenario

All of the above-specified options were modeled individually in the 2014 benchmark case and production cost analysis was run for the entire year (2014). The Base Scenario analysis focused on the economic benefit associated with each option. In accordance with the ERCOT RPG Planning Charter and Procedures for a project to be economically justified, the annual production cost savings due to the addition of a project must be greater than or equal to the first year annual revenue requirement (roughly one sixth the capital cost of the project). If a project does not have sufficient production cost savings, the generator energy revenue savings may be used to justify the project. Table 3 below shows the production cost savings and energy revenue savings associated with each option.

Options	Cost ($million)	Savings Required ($million)	Production Cost Savings ($million)	Energy Revenue Savings ($million)
1	333	55.5	18.9	50.6
2	222	37.0	13.1	19.2
3	175	29.2	13.3	45.3
3A	225	37.5	11.4	58.3
4	173	28.8	11.0	-2.48
6	189	31.5	7.7	48.9
6A	239	39.8	12.1	43.3
9	278	46.3	11.7	52.2
12	306	51.0	12.3	46.4
19	62	10.3	3.1	6.4
22	226	37.6	11.7	46.1
24	300	50.0	11.6	43.8
J1	253	42.2	12.0	51.3
J1A	304	50.6	13.5	52.6
J2	420	70.0	10.8	41.0
J3	174	29.0	7.8	-10.6
E1	379	63.2	19.1	56.5
E4	286	47.6	16.4	41.9
E4A	336	56.0	16.5	34.6
E5	328	54.6	17.1	50.3
DC1	787	131.1	5.25	28.9
DC2	923	153.8	17.6	37.7

Table 3: Base Scenario Results

As shown in the above table, none of the options had sufficient production cost savings to justify the projects. However, Options 3, 3A, 6, 6A, 9, 22 and J1 had generator energy revenue savings greater than or equal to the approximate first year annual revenue requirement for the associated project.

Options 3, 3A, 6, 6A and 22 all involved variations of a new 345 kV double circuit from Fayetteville to either Zenith or Obrien. Since these projects were all similar and it was determined that the savings difference of Options 3A, 6, 6A and 22 compared with Option 3 did not justify the additional cost of these alternatives, only Option 3 was fully evaluated in Phase II.

Options 1 and E1 had the highest production cost savings and were close to having enough energy revenue savings to meet the criteria. Since these two options are also significantly different from the Option 3 variants, they were further evaluated in Phase II.

Although Option DC2 was not close to meeting the economic criteria in Phase I, it was evaluated in the CREZ scenario in Phase II since it could be expected that this option would experience the greatest savings with additional generation in west Texas.

None of the other options passed the economic criteria and thus, were not considered as good candidates for further analysis.

4.2. PHASE II

Phase II includes the modeling of various scenarios, simulating factors that may happen in the future and could have a significant impact on the relative merits of the various options. Options 1, 3, 9, J1, E1 and DC2 were analyzed in the Phase II analysis. In each alternative scenario, a new benchmark case was created for the changes in input assumptions necessary to model the scenario, and then an upgraded case for each option was created from that benchmark case. The production costs and energy revenues from the upgraded cases were then compared to the benchmark case for each option. The scenarios covered in Phase II analyses are discussed as follows:

4.2.1. CREZ Generation Scenario

A study was conducted in order to quantify the effect CREZ-level generation would have on the economic results for the selected options from Phase I. A CREZ generation scenario was created by modeling additional wind plants in each CREZ zone in the 2014 benchmark case to bring the total wind generation capacity in each zone to the level that was studied in the ERCOT CREZ Transmission Optimization Study. Table 4 below summarizes the results.

Options	Cost ($million)	Savings Required ($million)	Production Cost Savings ($million)	Energy Revenue Savings ($million)
1	333	55.5	12.8	148.3
3	175	29.2	17.1	87.5
9	278	46.3	11.2	98.6
J1	253	42.2	24.9	91.9
E1	379	63.2	31.5	115.3
DC2	923	153.8	77.0	171.3

Table 4: CREZ Generation Scenario Results

The above table shows Option DC2 saving significantly with CREZ generation. The main reason behind the savings is that the location of the HVDC line relieves both North to Houston and West export congestion significantly. Conversely, the other options primarily relieve North to Houston congestion.

Further evaluation showed that a few projects added in the north and around the Kendall area along with Option3 showed similar savings as were shown by Option DC2. Thus with an overall lower capital cost (due to smaller projects in the north and the Kendall area) similar savings could be achieved with Option 3. Since these incremental projects are not directly associated with increased transfer capacity into Houston, they were not added to the scope of Option 3 but will be considered in the Five-Year Transmission Planning process if Option 3 is selected and as CREZ generation develops.

Option DC2 was assumed to utilize conventional HVDC technology due to the line capacity. However, additional analysis showed that the Scurry Substation did not have sufficient fault current to support conventional HVDC. The nearest substation that had enough fault current to support a 2000 MW conventional HVDC terminal was Morgan Creek. Option DC2 was deemed to be infeasible and it was determined that the savings could be achieved at a lower overall cost. For these reasons Option DC2 was not evaluated further.

4.2.2. Load Variation Scenarios

The Load Variation Scenario studied the effect due to change in load levels (above or below the 2014 forecast) in and around the Houston area.

Many factors including but not limited to either growth in population, widespread use of electric vehicles or installation of new industries/factories over the passage of time would result in an increase in the electricity demand. In order to study the effect, the Coastal Weather Zone (representing the Houston area) load level was increased by 10% for all hours in the 2014 benchmark case. Options 1, 3, 9, J1 and E1 were tested. Table 5 below summarizes the results.

Options	Cost ($million)	Savings Required ($million)	Production Cost Savings ($million)	Energy Revenue Savings ($million)
1	333	55.5	23.0	123.0
3	175	29.2	14.5	114.7
9	278	46.3	12.7	110.6
J1	253	42.2	12.4	91.8
E1	379	63.2	15.1	122.6

Table 5: 10% load increase in Coastal Weather Zone Results

A scenario was also created to study the effect due to a decrease in electricity demand. Many factors including but not limited to a bad economy, energy efficiency and widespread use of rooftop photovoltaic solar panels could lead to an overall decrease in electricity demand. In order to study the effect of low demand on these options, a scenario was created with a 10% decrease in the Coastal Weather Zone loads. Table 6 below summarizes the results.

Options	Cost ($million)	Savings Required ($million)	Production Cost Savings ($million)	Energy Revenue Savings ($million)
1	333	55.5	14.5	5.4
3	175	29.2	6.0	55.0
9	278	46.3	6.3	17.2
J1	253	42.2	5.8	20.1
E1	379	63.2	8.4	27.5

Table 6: 10% load decrease in the Coastal Weather Zone Results

The results show that only Option 3 would have sufficient energy revenue savings to pass the economic criteria for a 10% decrease in Coastal Weather Zone load.

4.2.3. Gas Price Variation Scenarios

A study was conducted to analyze the effects of a variation in the natural gas price assumptions. The 2009 Five-Year Transmission Plan assumed a natural gas price of roughly $7/MMBTU for 2014. A simulation was run with the price of natural gas increased $3 for each option. The results are shown in Table 7.

Options	Cost ($million)	Savings Required ($million)	Production Cost Savings ($million)	Energy Revenue Savings ($million)
1	333	55.5	24.8	82.5
3	175	29.2	12.6	42.2
9	278	46.3	9.1	90.0
J1	253	42.2	12.1	89.2
E1	379	63.2	19.1	79.9

Table 7: $10 Gas Price Scenario Results

A second simulation was created to reflect the effect if natural gas prices decrease. In this simulation gas prices were decreased by $3 from the benchmark case. Table 8 below summarizes the results.

Options	Cost ($million)	Savings Required ($million)	Production Cost Savings ($million)	Energy Revenue Savings ($million)
1	333	55.5	18.2	39.4
3	175	29.2	7.3	31.6
9	278	46.3	7.5	24.7
J1	253	42.2	10.7	13.3
E1	379	63.2	11.7	33.6

Table 8: $4 Gas Price Scenario Results

The results show that only Option 3 would have enough energy revenue savings to justify the project in this scenario.

4.2.4. STP 3 & 4 Scenario

The expansion of the nuclear facilities at South Texas Project (STP) by 2840 MW could have a significant impact on power imports into the Houston area. It should be noted that the potential expansion of STP with two new units, STP 3 and 4, is public information, but these new units do not have an SGIA.

In order to study the effect, 2840 MW of additional generation from STP 3 and 4 along with the proposed upgrades from the STP 3 and 4 interconnection study were modeled in accordance with Option2A of the Interim Report for South Texas Project Units 3 and 4 (prepared by AEPSC, CenterPoint Energy, CPS Energy and Austin Energy on June 15, 2007). The Houston Import options were run under this scenario and Table 9 below summarizes the results.

Options	Cost ($million)	Savings Required ($million)	Production Cost Savings ($million)	Energy Revenue Savings ($million)
1	333	55.5	6.12	19.08
3	175	29.2	5.04	4.03
9	278	46.3	-2.69	39.9
J1	253	42.2	4.11	11.59
E1	379	63.2	-0.32	18.45

Table 9: STP 3 & 4 Scenario Results

The results show that none of the options passed the economic criteria in this scenario. It should be noted that even if STP 3 and 4 were to be built, they are not expected to be online for several years past the year 2014. Based on the level of annual generator revenue savings in the Base Scenario analysis of ~$45M, a significant portion of the cost of Option 3 could be covered by savings before the additional STP units are completed.

4.3. Discussion of the Results

The production cost savings and energy revenue savings are summarized in Table 10 below for the selected options for Phase I and Phase II analysis.

Option	1		3		9		J1		E1	
Total Cost ($M)	$333		$175		$278		$253		$379	
Needed for Justification	$55.5		$29.2		$46.3		$42.2		$63.2	
Base Scenario Annual Savings ($M)	$18.9	$50.7	$13.3	$45.4	$11.8	$52.3	$12.0	$51.3	$19.1	$56.5
CREZ Annual Savings ($M)	$12.8	$148	$17.1	$87.5	$11.2	$98.7	$24.9	$91.9	$31.6	$115
STP 3/4 Annual Savings ($M)	$6.1	$19.1	$5.0	$4.0	-$2.7	$39.9	$4.1	$11.6	-$0.3	$18.5
Low Coastal Load Annual Savings ($M)	$14.5	$5.4	$6.0	$55.0	$6.3	$17.2	$5.8	$20.1	$8.4	$27.5
High Coastal Load Annual Savings ($M)	$23.1	$123	$14.6	$114	$12.7	$111	$12.4	$91.8	$15.2	$123
$4 Gas Annual Savings ($M)	$18.3	$39.5	$7.3	$31.6	$7.5	$24.8	$10.8	$13.3	$11.8	$33.7
$10 Gas Annual Savings ($M)	$24.9	$82.5	$12.7	$42.3	$9.1	$90.1	$12.1	$89.3	$19.1	$80.0
PC = Production Cost; ER = Energy Revenue	PC	ER	PC	ER	PC	ER	PC	ER	PC	ER

Table 10: Summary of Results

Option 3 was determined to be the preferred option. It was the only option that met the economic planning criteria in all alternative scenarios besides the STP 3 and 4 scenario. In addition, it provided similar production cost and energy revenue savings to the other options at a substantially lower cost with less new ROW required.

One observation of note is that the two options with the highest capital cost, 1 and E1, generally provided slightly higher savings when compared to the other options and similar savings when compared to each other. However, the slightly higher savings of these options did not justify the significantly higher capital costs. But, Option E1 could be considered a future expansion of Option 3 since it contains most of the same upgrades plus the addition of a double circuit 345 kV line from Twin Oaks to Salem.

4.4. PHASE III

Phase III primarily involved performing sensitivity analyses on the preferred option, Option 3, to evaluate whether the preferred option was reasonably robust. The purpose was to perform additional studies to analyze the effect these different scenarios would have on the economics of Option 3. In each sensitivity scenario a new benchmark case was created for the given changes and then an upgraded case for Option 3 was created from that benchmark case. The production cost and energy revenue of the upgraded case were then compared to the benchmark case

4.4.1. Potential New Gas Generation Inside the Houston Area Scenario

Currently approximately 2116 MW of potential new natural gas generation in Harris County is going through the Full Interconnection Study Phase (per April 2010 ERCOT System Planning ROS report) of the interconnection process. It was felt necessary to analyze the economic benefit of Option 3 if some of these generation projects were constructed.

A scenario was created to study additional gas generation inside the Houston area. Approximately 1028 MW (50% capacity of the plants in the Full Interconnection Study Phase located in Harris County) was modeled in the study case. Each generation plant that is in the Full Interconnection Study Phase was modeled at the point of interconnection that it is being studied at with 50% of the plant's proposed capacity. Table 11 below summarizes the results.

Option	Cost ($million)	Savings Required ($million)	Production Cost Savings ($million)	Energy Revenue Savings ($million)
3	175	29.2	10.8	55.4

Table 11: Gas Generation Inside Houston Scenario Results

The results of this sensitivity analysis showed that Option 3 saved significantly more in energy revenue savings than what it required to be economically justified even with the addition of more natural gas generation plants in the Houston area.

4.4.2. New SGIA Scenario

During the course of the study several new generation plants became subject to an SGIA. A scenario was created by modeling the following plants in the study case and analyzing the results with Option 3:

1. Las Brisas - 1300 MW pet coke unit in Nueces County
2. Coleto Creek 2 - 660 MW coal unit in Goliad County
3. Panda Temple - 1300 MW combined cycle unit in Bell County

Additionally, some of the existing generation units in ERCOT were retired or mothballed during the course of the study. The following units were taken out of the study case:

1. Newman 5
2. Spencer 4 & 5

3. Tradinghouse 2
4. North Texas 1, 2 &3
5. Valley 1, 2 & 3
6. Coastal 1 & 2

The study case was then updated with the above mentioned generating unit changes. Table 12 summarizes the results.

Option	Cost ($million)	Savings Required ($million)	Production Cost Savings ($million)	Energy Revenue Savings ($million)
3	175	29.2	10.9	50.4

Table 12: New SGIA Scenario Results

The results of this sensitivity analysis showed that with the recent generation plant assumption changes, Option 3 was still economically justified based on the energy revenue savings.

It should be noted that generation changes occur on an ongoing basis. The owner of the S.R. Berton and Greens Bayou plants recently submitted to ERCOT a Notice of Suspension of Operation to mothball some of the units at these plants in the Houston area. These notices were received too late to include in this analysis.

4.4.3. Higher Transmission Line Cost Scenario

As mentioned earlier, CenterPoint Energy estimated the per mile cost of new 345 kV double circuit line construction to be $3.34 million. A scenario was created to analyze the economics of Option 3 if the line cost was raised from $2.5 million per mile to $3.34 million per mile. The following Table 13 summarizes the results with $3.34 million /mile:

Option	Cost ($million)	Savings Required ($million)	Production Cost Savings ($million)	Energy Revenue Savings ($million)
3	226	37.7	13.3	45.4

Table 13: Higher Transmission Line Cost Scenario Results

The results of this sensitivity analysis showed that Option 3 was still economically justified when using the higher per mile cost estimate.

5. Stability Analysis

The economic analysis described above was carried out in a software tool that uses a DC powerflow approximation. In order to ensure that the increased transfers into the Houston area could be accomplished without adversely affecting voltage stability, a steady state voltage stability analysis was performed. The following two AC cases were studied, since either could potentially be the worst case scenario with respect to voltage stability:

1. Peak Load Case
2. Maximum Import Flow Case

Peak Load Case

A power flow case used for the voltage analysis was created from the Steady State Working Group (SSWG) 2014 summer peak ERCOT base case that was originally created in December 2009 and updated in April 2010. Option 3 upgrades were added to the case. The generation dispatch was derived from the peak hour in the Option 3 upgraded UPLAN case from Phase I of the analysis. AC contingency analysis was run in MUST and the results revealed no voltage collapse violations in the Houston area.

Maximum Import Flow Case

The flow on the eleven (including Fayetteville-Zenith double circuit) 345 kV import lines into the Houston area was measured in the Option 3 upgraded UPLAN case from Phase I of the analysis. It was found that the maximum summed importing flow on these eleven lines from the annual production cost run was 7895 MW. The load level (approximately 54,000 MW total ERCOT load) and generation dispatch from the hour with this import level was exported from UPLAN and merged into the SSWG 2014 summer peak base case. Switched shunt settings were adjusted and an AC contingency analysis was run. The results showed no voltage collapse violations in the Houston area.

It should also be noted that CenterPoint Energy stated in its submittal (North to Houston Constraint Mitigation Project) that it would install reactive devices on its transmission system if there is an additional need/voltage violation.

6. Conclusion

Congestion has been experienced on the lines importing power into the Houston area in recent years. Future year planning studies have shown that this congestion is expected to continue and may become a reliability issue by 2018 or sooner if additional generation units in the Houston area suspend operation. Sharyland Utilities and CenterPoint Energy each submitted RPG project proposals in order to increase the Houston import capability so that the congestion will be reduced. ERCOT performed an Independent Review of the submitted upgrade alternatives along with several other options. This analysis showed that the energy revenue savings were enough to justify several of the upgrade projects. Several alternative scenario studies were performed and it was determined that Option 3 was the best project. Thus, ERCOT recommends building the following upgrades associated with Option 3:

- Build Fayetteville – Zenith 345 kV double circuit line (approx. 60 miles on a new ROW) so that each circuit Rate B is approximately 2800 MVA
- Loop Fayette Power Project – Salem 345 kV line into Fayetteville 345 kV substation
- Upgrade Fayette Power Project – Fayetteville 345 kV double circuit lines so that the circuit Rate B of each circuit is approximately 1900 MVA
- Expand the Fayetteville Substation with four new line terminations and Zenith Substation with two new line terminations

- Upgrade the Bellaire – Brays – H.O. Clarke Plant 138 kV line terminal equipment so that the circuit Rate B for the two 138 kV sections is 893 MVA and 561 MVA, respectively

7. Designated Providers of Transmission Facilities

In accordance with the ERCOT RPG Planning Charter and Procedures, ERCOT staff is to designate transmission providers for projects reviewed in the RPG. These providers can agree to provide or delegate the new facilities or inform ERCOT if they do not elect to provide them. For the project scope recommended in this report CenterPoint Energy and the LCRA Transmission Services Corporation (LCRA TSC) are the designated providers of all transmission facilities.