

VERSION 1.2

# ERCOT PANHANDLE RENEWABLE ENERGY ZONE AND LUBBOCK POWER & LIGHT INTEGRATION

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LCG CONSULTING

4962 El Camino Real, Suite 112  
Los Altos, CA 94022  
Tel: 650-962-9670  
[www.EnergyOnline.com](http://www.EnergyOnline.com)

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## 1. EXECUTIVE SUMMARY

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West Texas is experiencing a period of unprecedented investment in wind generation. From the beginning of 2015 through the end of February 2016, wind capacity in the Panhandle Renewable Energy Zone (PREZ) nearly doubled, from approximately 1,260 MW to over 2,450 MW. ERCOT ISO expects this growth to continue in the coming years. In addition, the likely integration of Lubbock Power and Light (LP&L) with the ERCOT grid may further impact the wind buildout in the PREZ area.

In light of the significant changes in Panhandle (PH), this report outlines the infrastructure challenges, current developments, wind curtailment due to congestion, and an outlook for wind generation in the Panhandle region. LCG Consulting (“LCG”) addresses these issues to give market participants an overview of the current conditions and what to expect in the coming years.

ERCOT has implemented the Panhandle Export Stability Interface in response to a series of studies which suggest that increasing regional wind capacity may cause voltage instability. Although as of March 2016 this interface had not yet been enforced at a binding level during normal system conditions, ERCOT has enforced a reduced limit during certain outage conditions. ERCOT’s Regional Planning Group is actively studying the configuration of transmission enhancement for integrating LP&L. ERCOT has released a preliminary scope document for a LP&L load integration study. AEPSC and Oncor have jointly submitted a proposal for transmission enhancement in the west.

The current operation export limit of 2,711 MW across the Panhandle Interface is proposed to be increased to 3,332 MW with a set of transmission upgrades - Stage 1<sup>i</sup> - in 2018. There are also proposals to further upgrade the interface limit - Stage 2<sup>ii</sup> - which will increase the Panhandle Interface limit to 4,680 MW when the Panhandle wind buildout reaches 6,552 MW. The LP&L integration<sup>iii</sup> with Stage 1 upgrades will improve the flow across the Panhandle Interface to 3,626 MW.

One ERCOT report shows that the savings with Stage 1 and Stage 2 upgrades will exceed the estimated cumulative cost of \$115M and \$560M respectively in six years, meeting the ERCOT economic criteria<sup>iv</sup>. LCG’s independent analysis indicates that the savings will be very close to the ERCOT estimate in the year 2021. The expected integration of LP&L will affect savings from the upgrades.

In this report, LCG reviews several scenarios of future wind buildout, the impact of Stage 1 and Stage 2 upgrades and LP&L integration in Panhandle. For the LP&L integration cases, we have analyzed transmission upgrade Option 8A, 8B and 4OW which were recently studied by the ERCOT planning group. We have conducted UPLAN simulations for both 5 GW and 6.5 GW of wind buildout in Panhandle for all the scenarios for the year 2021. The table below summarizes

the curtailment and the percentage of time that the flow is less than the Panhandle export limit under various scenarios.

**Table 1 – Summary of Scenario Simulation (2021)**

Case Description / Electricity Index		Panhandle Interface Export Limit (MW)	Average Production Cost (\$/MWh)	Total System Generation (GWh)	Curtailment	Percent of Time at the Export Limit	
Panhandle Wind Build (2021)	5,016 MW	Stage 1 Upgrade without LP&L (Case 2)	3,332	\$22.36	379,278	5.5%	24%
		Stage 1 & 2 Upgrades without LP&L (Case 2A)	4,680	\$22.29	379,278	0.0%	0%
		Stage 1 Upgrade & LP&L Opt 8B (Case 4)	3,626	\$22.37	381,800	2.9%	16%
		Stage 1 Upgrade & LP&L Opt 8A (Case 5)	3,831	\$22.36	381,799	1.7%	13%
		Stage 1 Upgrade & LP&L Opt 4OW (Case 6)	3,822	\$22.36	381,801	1.9%	11%
	6,552 MW	Stage 1 Upgrade without LP&L (Case 3)	3,332	\$22.16	379,278	19.9%	47%
		Stage 1 & Stage 2 Upgrades (Case 3A)	4,680	\$21.93	379,278	3.2%	17%
		Stage 1 Upgrade & LP&L Opt 8B (Case 4A)	3,626	\$22.11	381,800	14.3%	40%
		Stage 1 Upgrade & LP&L Opt 8A (Option 5A)	3,831	\$22.08	381,800	11.2%	35%
		Stage 1 Upgrade & LP&L Opt 4OW (Case 6A)	3,822	\$22.07	381,801	11.4%	36%

In Section 3, we review the proposed transmission upgrades without LP&L integration in 2021. Our simulations show that with only the Stage 1 upgrade, the curtailment is observed to be about 6% and 20% for 5,016 MW and 6,552 MW of wind penetration, respectively. If both Stage 1 and Stage 2 upgrades are implemented, the Panhandle wind curtailment is less than 4% with 6,552 MW wind penetration; however there is no curtailment with 5,016 MW wind penetration.

Section 4 discusses LP&L integration with ERCOT, which will add 594 MW of load and 185 MW of synchronized generation in Panhandle, ameliorating wind curtailment across Panhandle Interface. For the three LP&L integration options we studied, the results show that with Stage 1 upgrades and 5,016 MW of wind, the curtailment is less than 3%. However, if the wind penetration is 6,552 MW, the curtailment is in the range of 11% - 14%.

The Panhandle LMPs become negative whenever wind generation reaches the interface export limit and the wind output is curtailed. For the 5 GW wind penetration cases, the percentage of negative prices varies from 0 – 24% and for 6.5 GW of wind, the frequency of negative prices varies from 17% - 47%. For the 6.5 GW high wind buildout cases, the curtailment level is between 11% - 20% without the stage 2 upgrade, which suggests additional upgrades for the Panhandle interface will be desirable.

The Panhandle wind buildout, the stability limit, transmission upgrades, and LP&L integration have been actively studied by ERCOT. This report is intended to provide a review of current happenings and their impact using UPLAN simulation.

## 2. OVERVIEW OF THE PANHANDLE WIND GENERATION

Transmission infrastructure in the Panhandle region of Texas was developed under the Competitive Renewable Energy Zone, or CREZ, program. ERCOT established five CREZ zones in 2008: McCamey, Central, Central West, Panhandle A, and Panhandle B. ERCOT intended these projects to transmit 18,500 MW of wind power to serve load in ERCOT. Now in service, the CREZ lines have enabled wind power development in areas with high quality wind resources that previously did not have transmission infrastructure. The Panhandle A and Panhandle B CREZ Zones are collectively known as PREZ. This region in particular has seen more planned wind capacity development than initially planned.

Texas now ranks number one in the United States in wind generation capacity with 15,929 MW installed as of February 2016<sup>v</sup>, more than twice the amount of California, which is second. Wind capacity expansion is expected to continue. A large amount of planned capacity has interconnection agreements signed with the ERCOT ISO. The March 2016 ERCOT generator interconnection status report indicated that 11,002 MW of new potential wind capacity had signed interconnection agreements with ERCOT, of which 7,194 MW had posted requisite financial security and are expected to come online in the next two years. Of the wind units that have posted financial security, 2,761 MW have points of interconnection in the PREZ region. With the potential to achieve high capacity factors due to the high-quality wind resource, the Panhandle has become a very attractive area for wind development.

**Figure 1 - Panhandle 345 kV transmission infrastructures**



*Source: ERCOT System Planning. November 2015<sup>v</sup>, ERCOT Independent Review of Proposed Panhandle Transmission Upgrades.*

Figure 1 above depicts the ERCOT 345 kV topology in the Panhandle of Texas. The Panhandle Interface definition includes the transmission lines leaving the Cottonwood and Tesla substations toward the rest of the ERCOT system.

Panhandle area wind development, related transmission upgrades, interface limit and stability monitoring have been a frequent focus of discussion at ERCOT's monthly Regional Planning Group meetings and topics of interest of a variety of stakeholders in ERCOT.

Installed wind capacity in the PREZ region now exceeds the amount that original reactive equipment in the area was designed to support, even though the transmission lines have a significantly higher capacity. With no ERCOT load in the PREZ region, and generation limited to wind units, studies published by ERCOT indicate that voltage instability is expected as more wind capacity comes online in this area. The studies show that under weak grid conditions, small variations in reactive support lead to voltage instability. Therefore, ERCOT has announced it will enforce a PREZ export stability limit and set a maximum amount of power that can flow out of the PREZ region. The monitored lines subject to this constraint are collectively referred to as the Panhandle Interface. Wind generation with points of interconnection behind this interface will be subject to curtailment in the event that their simultaneous net generation exceeds the Panhandle Interface operations export limit.<sup>vii</sup> Congestion on the Panhandle Interface will have impacts on LMPs at settlement points in the Panhandle and on the revenues of wind units in the Panhandle.

In September 2015 ERCOT System Planning filed its Panhandle Transfer Capability Analysis study<sup>viii</sup> with the Public Utility Commission of Texas (PUCT). This report was in response to the PUCT's request that ERCOT evaluate transmission solutions to increase Panhandle export transfer capability by both the CREZ cost-effectiveness standard (Trial 1) and the standard ERCOT reliability and economic planning criteria (Trial 2) <sup>ix</sup>. Notably, the study indicated little difference between the two criteria. ERCOT found that with 3,604 MW of wind in the Panhandle, adding synchronous condensers at Alibates and Tule Canyon meets both criteria. In the cases of both 3,904 and 4,204 MW of wind capacity, the second 345 kV circuit on the Alibates-AJ Swope-Windmill-Ogallala-Tule Canyon (AAWOTC) line meets ERCOT requirements. According to ERCOT's February 2016 Generator Interconnection Status, existing and planned wind units that meet ERCOT Planning requirement exceed 4,204 MW.

In November 2015 ERCOT conducted an independent review of Panhandle upgrades<sup>x</sup> proposed by Duke-American Transmission Company and Sharyland<sup>xi</sup>. The proposed upgrades included synchronous condensers at the Alibates and Tule Canyon 345 kV substations intended to improve system strength in the Panhandle and increase export capacity. The independent review found that synchronous condensers at these locations met planning criteria protocols. Both the second circuit discussed above and the synchronous condensers have been approved and are expected to be operational in mid-2018.

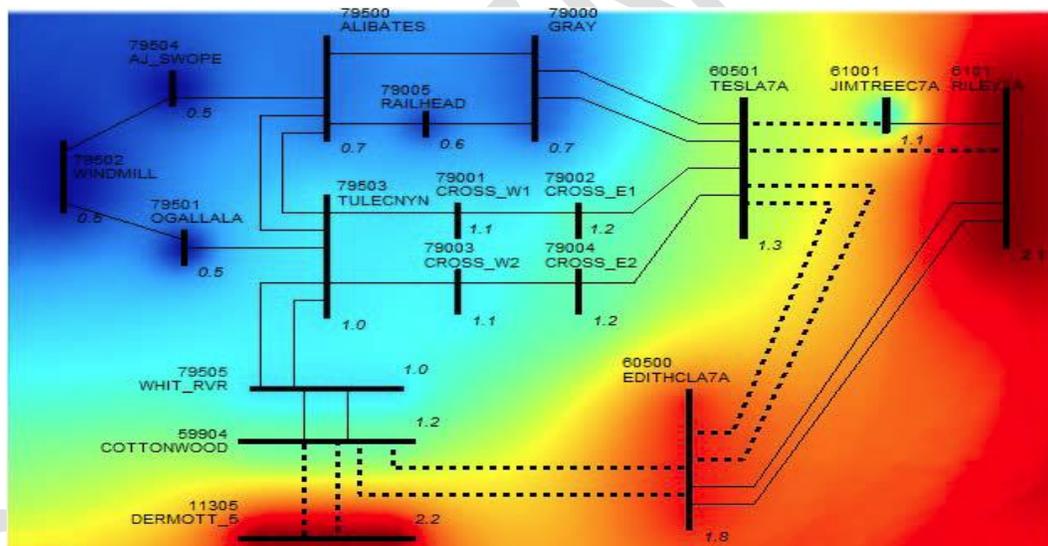
### 3. PROPOSED PANHANDLE UPGRADES

The PREZ transmission infrastructure is made up of 345 kV transmission lines that stretch into the Panhandle of Texas. The Panhandle transmission topology and Panhandle Interface constraint is defined as the total flow across the following transmission elements:

- Tesla – Riley (single circuit)
- Tesla – Jim Treece (single circuit)
- Tesla – Edith Clarke (double circuit)
- Cottonwood – Edith Clarke (double circuit)
- Cottonwood – Dermott Switch (double circuit)

All generation that is delivered to the ERCOT system through this interface is considered Panhandle generation. The Panhandle 345 kV transmission topology and interface definition are shown below in Figure 2.

**Figure 2 - Panhandle transmission topology and Panhandle Interface definition**



Source: ERCOT (2015). Panhandle Transfer Capability Analysis. Presentation to the Regional Planning Group. August 2015

ERCOT studies have found that the Panhandle grid is considered a “weak grid” with the integration of a large amount of wind generation because it is far from synchronous generation and load centers. Studies by ERCOT System Planning have used Weighted Short Circuit Ratio (WSCR) as a metric to determine system strength in the Panhandle region. Electranix study<sup>xii</sup> has confirmed that this methodology is appropriate in a February 2016 study contracted by ERCOT. The Panhandle Operations Export Limit is what will actually be enforced in the market and is expected to be approximately 90% of the maximum Panhandle Export Limit.

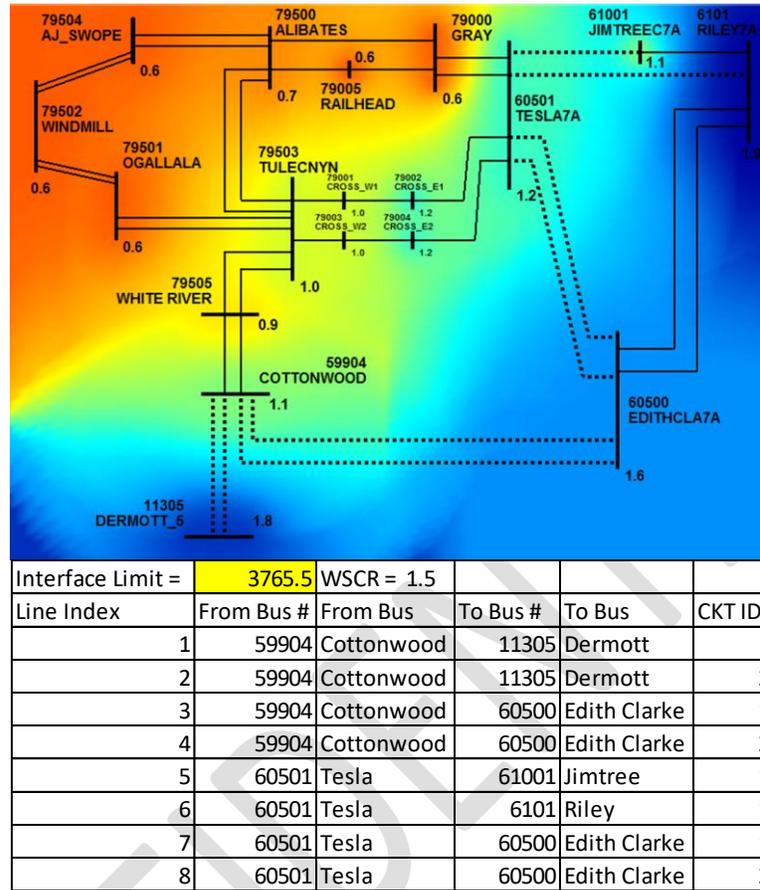
The April 2014 Panhandle Renewable Energy Zone (PREZ) Study Report released by ERCOT System Planning addressed system strength in the PREZ region to assess the transmission upgrades that would be necessary to accommodate larger amounts of wind capacity in the PREZ region. The study provided a “roadmap” pointing to the upgrades associated with various “trigger” levels of wind buildout. Four stages of transmission upgrades were identified, from 2,400 MW to 7,500 MW. Various transmission upgrade improvements were considered in this study, including shunt reactors, synchronous condensers, and second circuit additions on existing transmission towers. Upgrade Stages 1 and 2 would bring the Panhandle Export Stability Limit to 3,500 and 5,200 MW, respectively, with a cost of \$115M and \$560M. Upgrade Stages 3 and 4 that would bring the Panhandle Export Stability Limit to 7,500 MW were also outlined.

The following upgrades are expected to be in service in July 2018, according to ERCOT’s February 2016 Transmission Project and Information Tracking report:

- Installation of a second 345 kV circuit on the Alibates-AJ Swope-Windmill-Ogallala-Tule Canyon transmission line (AAWOTC line)
- Installation of a synchronous condenser connected to the Alibates 345 kV station
- Installation of a synchronous condenser connected to the Tule Canyon 345 kV station

The upgrades are intended to improve voltage stability and system strength, allowing a greater Panhandle Export Limit while maintaining a target level of 1.5 Weighted Short Circuit Ratio (WSCR), given a certain level of wind generation capacity in the Panhandle. Figure 3 below depicts the Panhandle transmission topology after the addition of the AAWOTC line and synchronous condensers at the Tule Canyon and Alibates substations. The dashed line indicates the Panhandle Interface definition.

**Figure 3 – Panhandle upgrades with AAWOTC line and synchronous condensers**



Source: ERCOT Independent Review of Proposed Panhandle Transmission Upgrades. ERCOT System Planning. November 2015.

The Independent Review of Proposed Panhandle Transmission Upgrades conducted by ERCOT included an economic analysis using UPLAN to estimate the benefit of the AAWOTC line and addition of synchronous condensers. The results of this study are shown below in Table 2. Here, the results of the synchronous condenser upgrade scenario include the added AAWOTC line.

**Table 2 - Results of ERCOT independent review of proposed Panhandle upgrades**

Panhandle Wind Capacity	Transmission Upgrade	Upgrade Cost Assumption (M\$)	Panhandle Export Limit (MW)	Panhandle Operation Export Limit (MW)	Annual Production Cost Savings/Capital Cost
4,304	None	0	3,012	2,711	N/A
4,304	AAWOTC Line	80	3,233	2,910	21%
4,304	Synchronous Condensers	64.25	3,702	3,332	34%

LCG studied several combinations of wind penetration and transmission upgrades and their impact on the PH congestion, wind curtailment, revenues and system benefits for years 2016 through 2023 using UPLAN. Table 3 summarizes the assumptions of the cases studied and referenced in this report.

**Table 3 – Description of the cases included in this report**

Case	Transmission Upgrades	Panhandle Wind Capacity (MW)	Panhandle Interface Operation Export Limit (MW)	Simulation Year
Case 1	None	5,016	2,711	2017
Case 1A	None	4,406	2,711	2017
Case 2	Stage 1 Upgrade without LP&L	5,016	3,332	2021
Case 2A	Stage 1 & 2 Upgrades without LP&L	5,016	4,680	2021
Case 3	Stage 1 Upgrade without LP&L	6,552	3,332	2021
Case 3A	Stage 1 & Stage 2 Upgrades without LP&L	6,552	4,680	2021
Case 4	Stage 1 Upgrade & LP&L Integration (Opt 8B)	5,016	3,626	2021
Case 4A	Stage 1 Upgrade & LP&L Integration (Opt 8B)	6,552	3,626	2021
Case 5	Stage 1 Upgrade & LP&L Integration (Opt 8A)	5,016	3,831	2021
Case 5A	Stage 1 Upgrade & LP&L Integration (Opt 8A)	6,552	3,831	2021
Case 6	Stage 1 Upgrade & LP&L Integration (Opt 4OW)	5,016	3,822	2021
Case 6A	Stage 1 Upgrade & LP&L Integration (Opt 4OW)	6,552	3,822	2021

LCG simulation of 2021 ERCOT shows that the annual saving with the Stage 1 upgrade and 6,552 MW of wind will be more than \$115 M in 6 years using ERCOT economic criteria. For the Stage 2 grade, the saving is very close to \$560 M in 2021. The expected integration of Lubbock Power and Light will impact the savings due to upgrades. LCG has analyzed a large number of cases with various Panhandle limits and LP&L integration to the ERCOT grid. Without upgrading existing infrastructure, the Panhandle export limit is expected to be 3,012 MW, with a Panhandle operation export Limit of 2,711 MW, 90% of the export limit value. The wind capacity in the Panhandle is expected to exceed 2,711 MW as early as May of 2016.

The simulations show that with only the Stage 1 upgrade, the curtailment is observed to be about 6% in Case 2 and 20% in Case 3 for 5,016 MW and 6,552 MW wind penetration, respectively. If both Stage 1 and Stage 2 upgrades are implemented, the PH wind curtailment is less than 4% in Case 3A with 6,552 MW wind penetration. However there is no curtailment with 5,016 MW wind penetration in Case 2A.

## 4. LUBBOCK POWER AND LIGHT INTEGRATION

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Lubbock Power and Light (LP&L) is a municipal electric provider for the Lubbock, Texas area. LP&L provides generation and distribution services to more than 103,000 customers. In 2014 LP&L issued an RFP for up to 600 MW of natural gas-fired or other firm generation. Recognizing that interconnection with ERCOT might also solve its generation needs; LP&L initiated the process of joining the ERCOT grid in 2019 upon the expiration of its contract with Xcel Energy, who is a member of the Southwest Power Pool. In response, PUCT has directed ERCOT to study the impact of LP&L integration. Integrating LP&L into ERCOT could significantly change the outlook for wind unit performance and wind curtailment in the region.

ERCOT is currently studying interconnection configurations for the integration of the LP&L system. In simulations, integrating LP&L into ERCOT significantly improves grid stability in the Panhandle, and thereby is expected to lead to an increase in the Panhandle Export Limit. Integration of LP&L into ERCOT will bring both synchronous generation and load from LP&L.

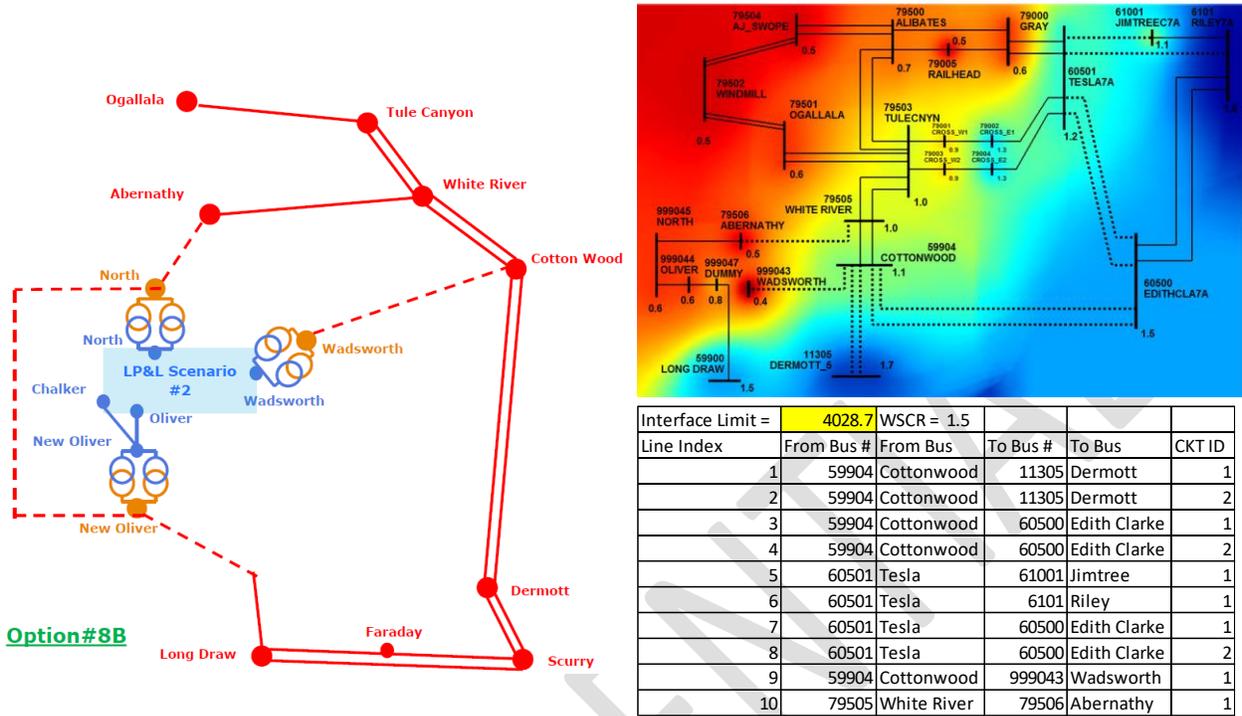
Projections show LP&L peak load in the range of 466 to 593.5 MW by 2021. A simulation by PWR Solutions showed that the integration of LP&L has a similar impact as the installation of 390 MVar of additional synchronous condensers<sup>xiii</sup>. Various transmission options also bolster system strength.

The LP&L system will likely intertie to the ERCOT 345 kV system at three substations: Wadsworth, North, and New Oliver. ERCOT is now identifying what transmission infrastructure will be necessary to integrate LP&L system into the ERCOT grid and most efficiently meet ERCOT and NERC standards. In the following we analyze the impact of LP&L integration in year 2021 although the integrated is anticipated to take place before 2021.

Recently ERCOT noted that it is narrowing down the list of potential interconnection options for LP&L integration<sup>xiv</sup>. In this report we first analyzed the benefit of LP&L integration Option 8B, followed by analysis of LP&L integration Option 8A and Option 4OW.

According to ERCOT, LP&L Option 8B improves the Panhandle export capability with a new White River to Long Draw 345 kV path. This integration option would allow Panhandle Base Case Export Limit increase by 263 MW to 4,028.7 MW. Additionally, Option 8B (Figure 4) provides the flexibility of adding the 345kV Ogallala – Abernathy segment in the future to transition to Option 8A thereby resulting in significant benefits to the ERCOT grid.

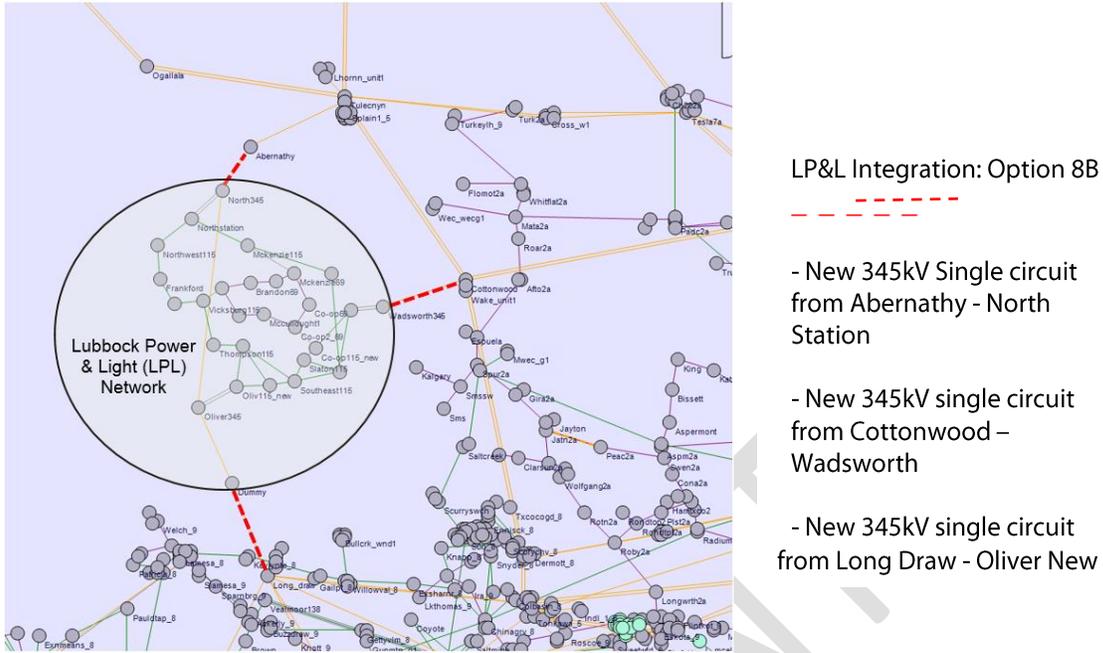
Figure 4 - Option 8B for LP&L Interconnection



Source: ERCOT\_LP&L Study Status Update for Regional Planning Group, Ben Richardson, March 22, 2016

All options studied by ERCOT in its March 2016 update showed a minimum increase to 3,902 MW of the Panhandle Export Interface. The average across all options was 4,027 MW. For Option 8B, the operating limit is 3,626 MW, 90% of 4,028.7 MW. These studies assumed LP&L and Antelope/Elk generators off-line for stability calculations. Including these units is likely to further increase the export limit.

**Figure 5 – Single line diagram view (UPLAN) of LP&L integration Option 8B**



Source: LCG Consulting PLATO & UPLAN Data Model

Meanwhile, LCG has conducted UPLAN simulations to examine the economic benefits of LP&L Option 8B using the ERCOT network for Option 8B. Two UPLAN simulations were performed for 2021 with Lubbock integration Option 8B.

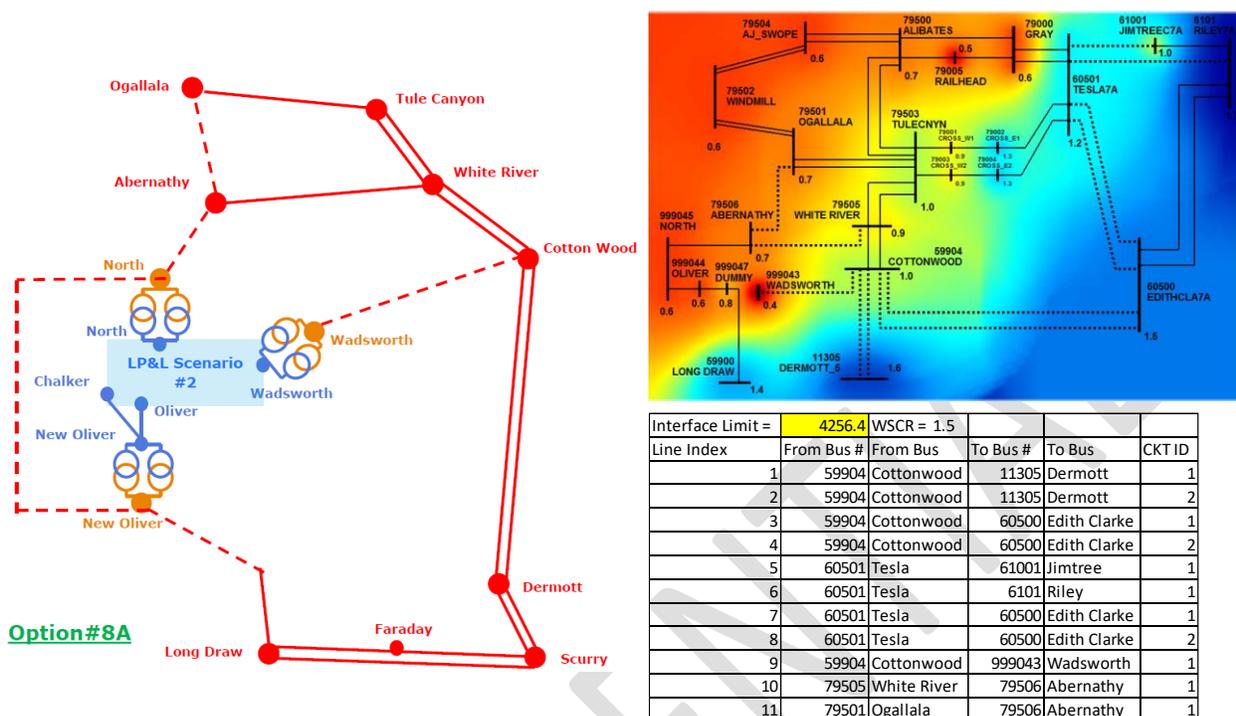
- LP&L integration to ERCOT Grid with configuration option# 8B as referenced in Figure 4 and Stage 1 upgrade. The wind buildout is assumed to be 5,016 MW (Case 4).
- LP&L integration to ERCOT Grid with the above configuration and 6,552 MW of wind buildout (Case 4A)

When LP&L is integrated with ERCOT, there will be additional 594 MW of load and 185 MW of synchronized generation in the Panhandle, reducing the wind curtailment across Panhandle Interface. With Stage 1 upgrade and 5,016 MW of wind, the curtailment is less than 3% in Case 4. However, if the wind penetration is 6,552 MW, the curtailment is close to 15% in Case 4A.

LCG has also studied LP&L Option 8A which increases the interface limit to 3,831 MW. The upgrades consist of a 345 kV transmission from Ogallala to Abernathy as shown in Figure 6.

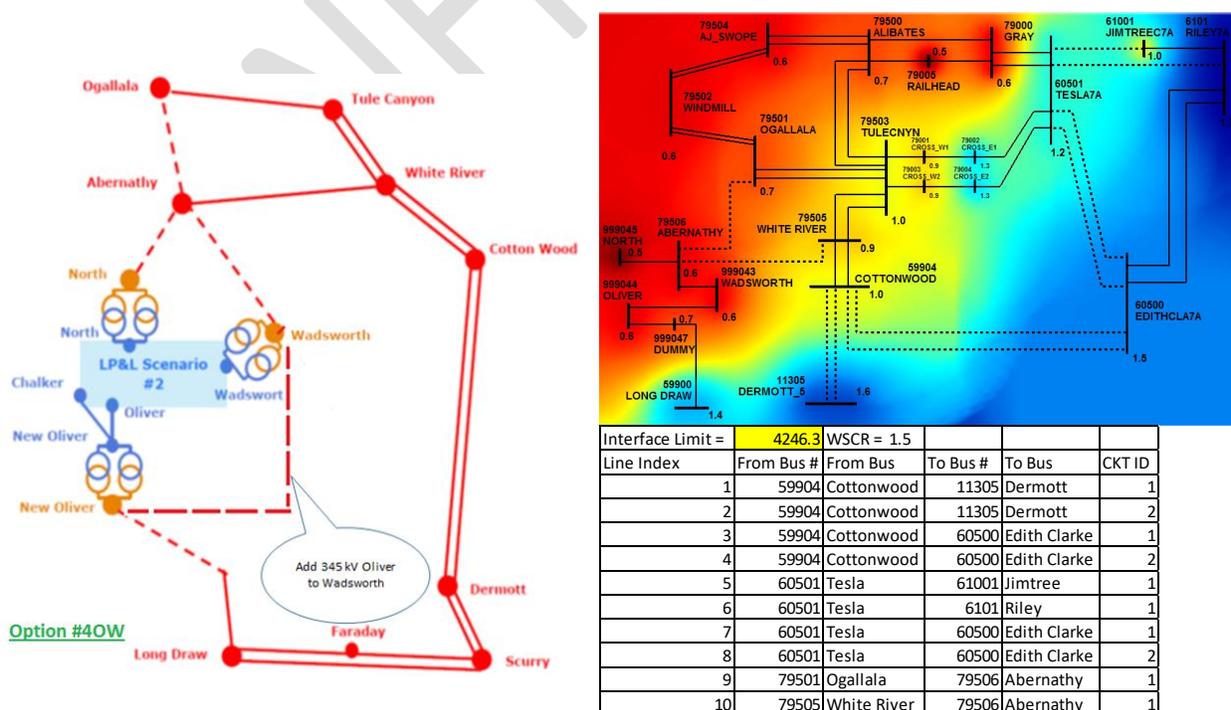
The additional Ogallala to Abernathy line would provide additional 228 MW of interface capacity. This will reduce the wind curtailment from average 14.3% in Case 4A LP&L Option 8B to approximately 11.2% under LP&L Option 8A (Case 5A).

Figure 6 – LP&L Option 8A



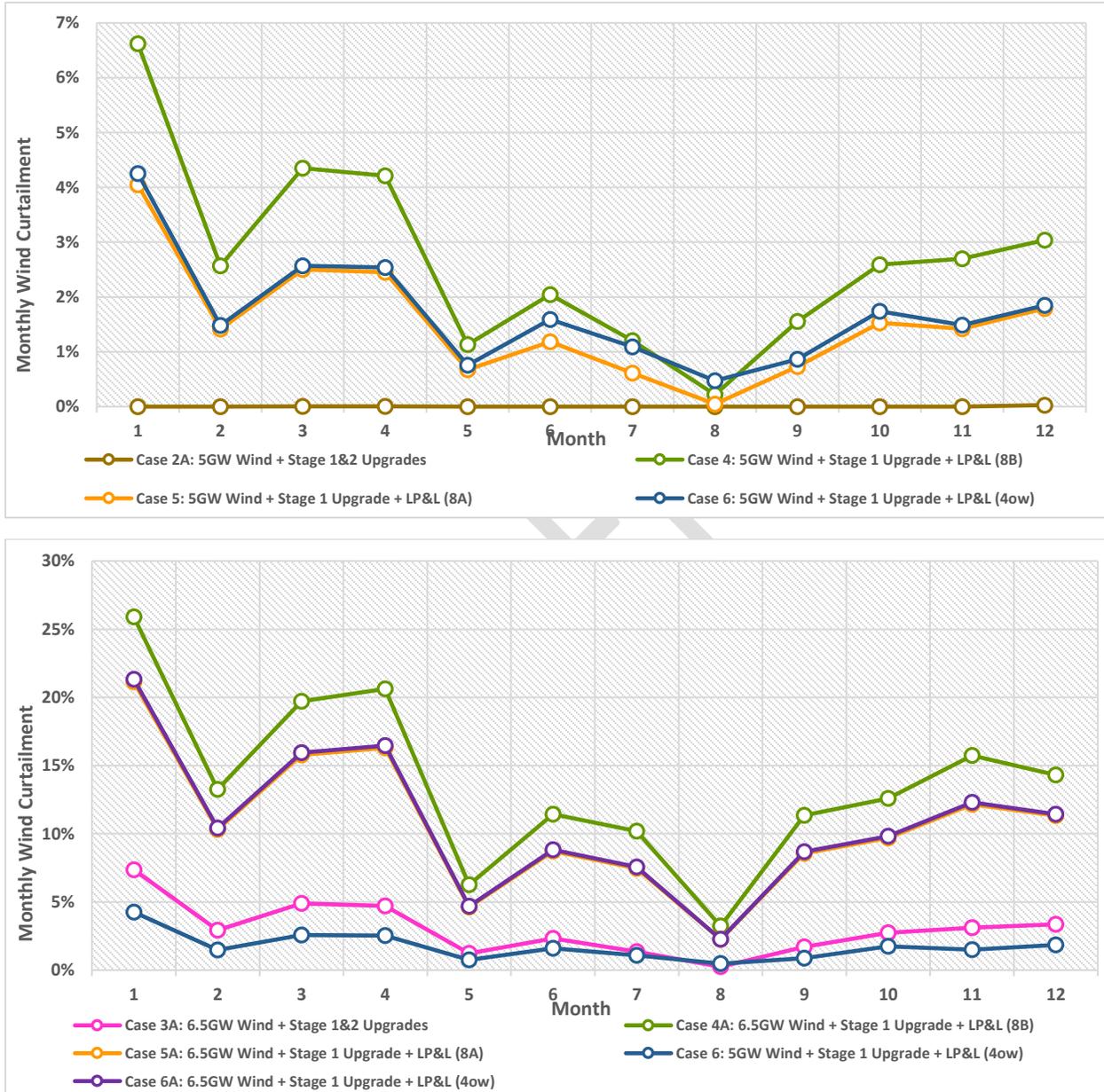
In the recent RPG meeting in May, 2016, LP&L Option 4OW (Figure 7) was presented as a desirable option because of its benefit cost ratio. LCG has analyzed this option for both 5 GW and 6.5 GW wind buildout cases.

Figure 7 – LP&L Option 4OW



The curtailments in PREZ for the scenarios studied in this report are presented in Figure 8.

**Figure 8 – Panhandle wind curtailment (5 GW & 6.5 GW) in 2021**



The overall analysis shows that considerable benefits accrued due to the Panhandle upgrades in terms of reduced curtailment and improved cost effectiveness of ERCOT as shown in Table 4.

**Table 4 – Annual Production Cost (2021) - ERCOT**

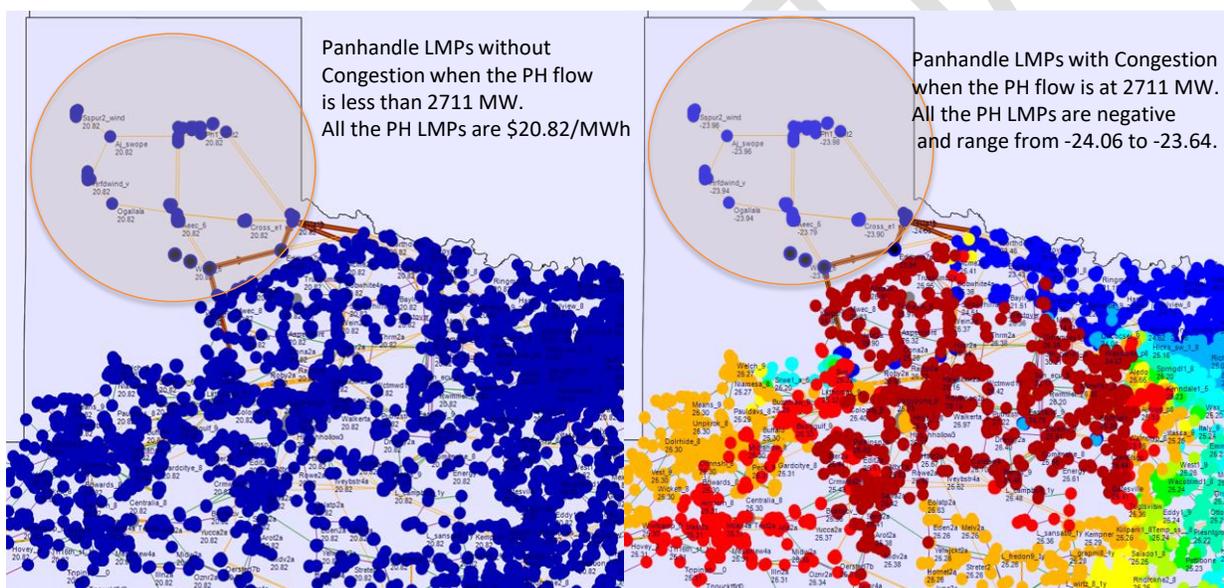
Case Description / Electricity Index			Average Production Cost (\$/MWh)
Panhandle Wind Build (2021)	5,016 MW	Stage 1 Upgrade without LP&L (Case 2)	\$22.36
		Stage 1 & 2 Upgrades without LP&L (Case 2A)	\$22.29
		Stage 1 Upgrade & LP&L Opt 8B (Case 4)	\$22.37
		Stage 1 Upgrade & LP&L Opt 8A (Case 5)	\$22.36
		Stage 1 Upgrade & LP&L Opt 4OW (Case 6)	\$22.36
	6,552 MW	Stage 1 Upgrade without LP&L (Case 3)	\$22.16
		Stage 1 & Stage 2 Upgrades (Case 3A)	\$21.93
		Stage 1 Upgrade & LP&L Opt 8B (Case 4A)	\$22.11
		Stage 1 Upgrade & LP&L Opt 8A (Option 5A)	\$22.08
		Stage 1 Upgrade & LP&L Opt 4OW (Case 6A)	\$22.07

## 5. DISCUSSION

The current Panhandle export limit is 2,711 MW, and the interface will be congested when the wind generation reaches the limit. During the congested hours, the LMPs in the region fall below zero. When Panhandle generation is below the current export limit, the LMPs in the Panhandle are similar to the prices on the other side of the interface. This phenomenon is clear in the two heat maps of UPLAN simulation results in Figure 9.

To avoid curtailment of wind units during congested hours, the wind generators in the region tend to bid negative, which is possible due to federal, state, and other tax incentives. Panhandle Interface constraints result in very significant revenue impacts for generating units in the region.

**Figure 9 – Heat maps of LMPs by UPLAN simulation (2016)**



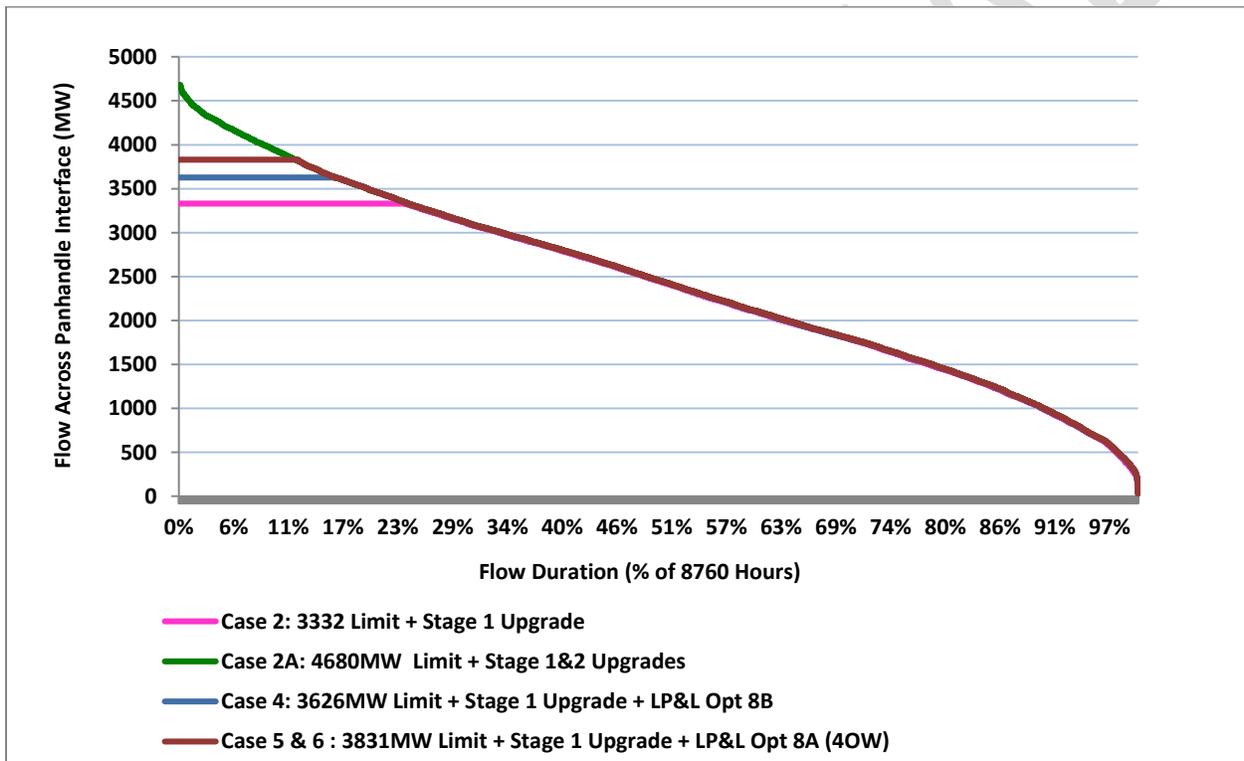
Source: LCG UPLAN simulation

In a recent stability study<sup>xv</sup>, ERCOT evaluated a variety of transmission upgrade options and found that at 3,000 MW of Panhandle wind generation without any upgrade, the expected curtailment is 6.3%. With Stage 1 upgrade, the curtailment is 0%. However, with 6,552 MW of wind capacity at Panhandle, the expected curtailment is 19.9% with a Stage 1 upgrade (Case 3) and 3.2% with Stage 2 upgrade and an export limit of 4,680 MW (Case 3A). In addition, the proposed integration of Lubbock Power & Light into the ERCOT grid will further impact Panhandle export capability and economic outcomes. LCG simulation indicates that with 6,552 MW wind penetration, the PH curtailment varies from 11.2% - 14.3% with stage 1 upgrade (Case 4A, 5A, and 6A).

LCG simulations indicate that the number of hours that the Panhandle Interface will be binding is highly sensitive to wind capacity expansion and the Panhandle Interface limit.

The flow duration diagram in Figure 10 below shows the congestion in the Panhandle Interface with 5,016 MW of wind buildout in 2021. Without any transmission upgrades (Case 1) in 2017, the interface limit is 2,711 MW and the interface is congested 43% of the time, 3740 hours. With Stage 1 upgrades (Case 2), the interface limit is 3,332 MW and the interface is congested 24% of the time, 2060 hours. With both Stage 1 and 2 upgrades (Case 2A), the interface limit is increased to 4,680 MW and there is no congestion. When LP&L is integrated with ERCOT, the interface limit is increased to 3,626 MW, 3,822, and 3,831 MW with LP&L Option 8B, 4OW, and 8A respectively and as a result the interface is congested 16%, 11%, and 13% of the time in Case 4, Case 6, and Case 5.

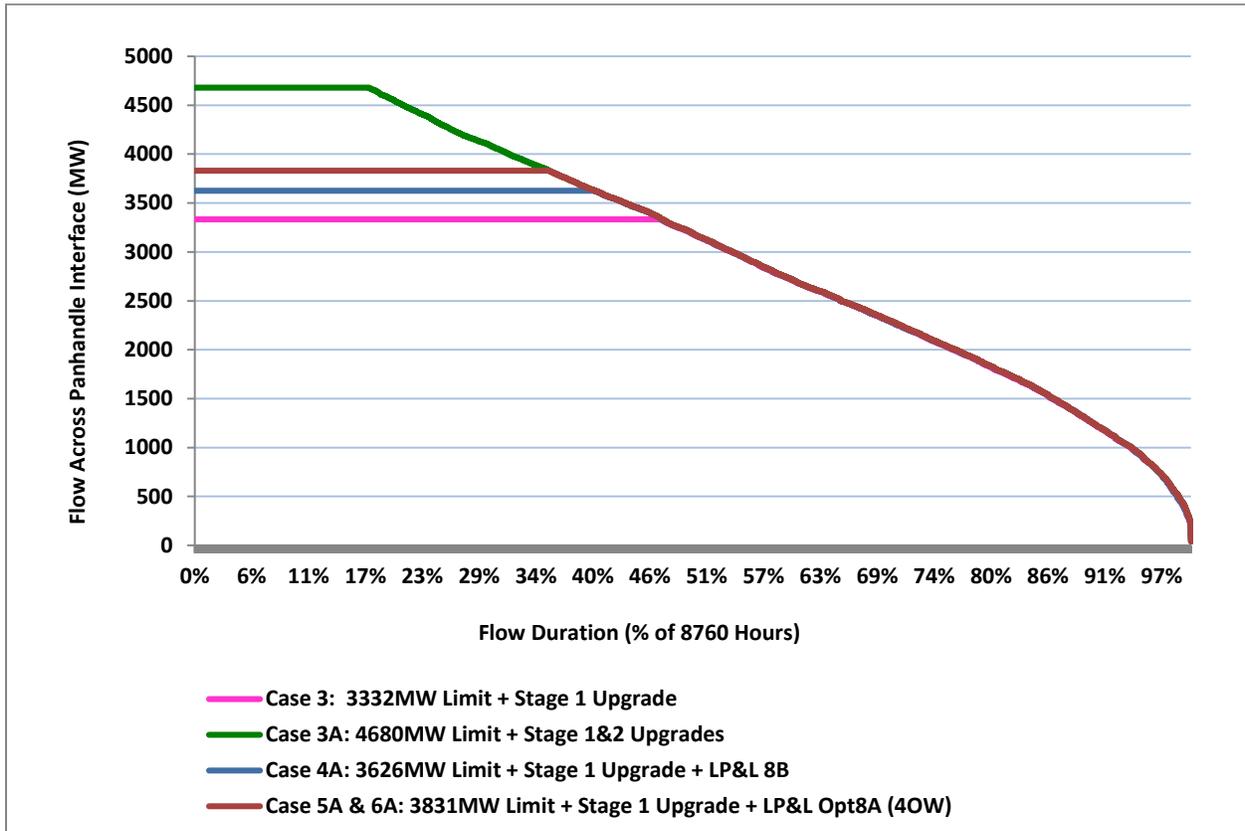
**Figure 10 – Flow duration curve with 5 GW wind buildout (2021)**



Source: LCG simulations

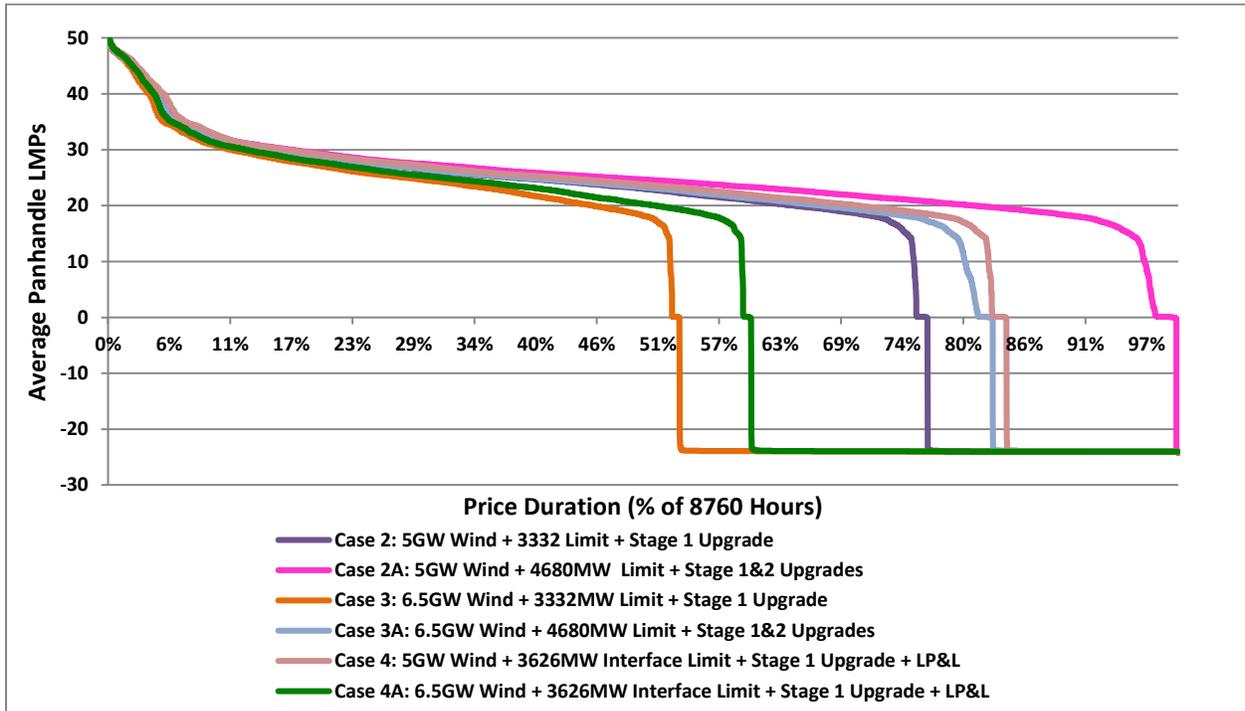
When more wind is developed in the PH area, the congestion increases considerably. Figure 11 below shows how the congestion picture changes with 6,552 MW of wind penetration. With Stage 1 upgrades (Case 3), the interface limit is 3,332 MW and the interface is congested 47% of the time, 4100 hours. With both Stage 1 and 2 upgrades (Case 3A), the interface limit is increased to 4,680 MW and the interface is congested 17% of the time, 1530 hours. When LP&L is integrated with ERCOT, the interface limit is increased and as a result the interface is congested 40%, 36% and 35% of the time respectively under Option 8B, 4OW and 8A.

Figure 11 – Flow duration curve with 6.5 GW wind buildout (2021)



Flow duration curves in figures 10 and 11 provide a comparison of congestion with 5 GW and 6.5 GW wind buildout. The impact on average PH prices corresponding to the flow duration is presented below in Figure 12. The average settlement point prices are calculated for each hour and for each generator bus in the Panhandle area.

Figure 12 – Price duration for average PH LMPs (2021)



The excess duration, which is (100% - duration %), is the percent of the time the average LMP is below a given limit. For example, for the 5 GW wind buildout with Stage 1 upgrade, the excess duration with negative SPP is (100% - 77% = 23%), which is same as the binding flow duration for the same scenario in the flow duration figure (Figure 10).

In these simulations we assume the Panhandle export limit will be dependent on the wind development, transmission upgrades and the integration of LP&L. However, according to ERCOT protocol, interface limit can also change based on outages and N-1 contingency.

## 6. END NOTES

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<sup>i</sup> Stage 1 Upgrade:

- Second 345 kV circuit on the Alibates-AJ Swope-Windmill-Ogallala-Tule Canyon (AAWOTC) line
- Synchronous Condensers at Alibates and Tule Canyon

<sup>ii</sup> Stage 2 Upgrade:

- New 345 kV double circuit line from Ogallala to Long Draw

<sup>iii</sup> LP&L Integration: Option 8B

- New 345kV Single circuit from Abernathy - North Station
- New 345kV single circuit from Cottonwood - Wadsworth
- New 345kV single circuit from Long Draw - Oliver New

<sup>iv</sup> ERCOT (2014). Panhandle Renewable Energy Zone (PREZ) Study Report. ERCOT System Planning. April 2014.

<sup>v</sup> ERCOT (2016). Generator Interconnection Status Report: February 2016. Released March 2016.

<sup>vi</sup> ERCOT System Planning: Independent Review of Proposed Panhandle Transmission Upgrades. November 2015.

<sup>vii</sup> The “operations export limit” refers to the limit at which the interface is enforced in real-time operations. This is expected to be approximately 90% of the maximum transfer capability as calculated by ERCOT to maintain system stability.

<sup>viii</sup> ERCOT System Planning, September 2015: Panhandle Transfer Capability Analysis.

<sup>ix</sup> Section 3.11.2 of the ERCOT Nodal Protocols

<sup>x</sup> Independent Review of Proposed Panhandle Transmission Upgrades.

<sup>xi</sup> Sharyland Utilities September 2014: Lubbock Power & Light ERCOT Integration Plan.

<sup>xii</sup> Electranix February 2016: System Strength Assessment of the Panhandle System PSCAD Study. Report Submitted to ERCOT.

<sup>xiii</sup> PWR Solutions December 2015: Lubbock Power & Light (LP&L) ERCOT Integration Study

<sup>xiv</sup> ERCOT March 2016: LP&L Study Status Update for Regional Planning Group

<sup>xv</sup> Panhandle Renewable Energy Zone (PREZ) Study Report by ERCOT system Planning, April 2014