Interconnection System Impact Study Report
REQUEST # GI-2004-12

199 MW Wind Generation Near Limon, Colorado Interconnecting the Pawnee to Daniels Park 230 KV Line

Xcel Energy Transmission Planning
May 2005

Executive Summary

This Interconnection System Impact Study Report summarizes the analyses performed by the Transmission Planning group of Public Service Company of Colorado (PSCo) to interconnect 199 MW of wind powered generation (Monarch Project) located near Limon, Colorado to the a new Corner Point 230 kV bus located on the Pawnee to Daniels Park 230 kV line approximately 54 miles south of Pawnee Station. The Customer proposed in-service date for commercial operation of the facility is December 1, 2005, with an assumed back-feed date of June 1, 2005. This request was studied as both an Energy Resource (ER) and as a Network Resource (NR) with the power going to PSCo customers. The request was studied primarily as a "stand-alone" project, but some sensitivity analyses were also performed to consider other projects in the Rocky Mountain Area OASIS queue[1].

Energy Resource:
The ER portion of this study determined that as a stand-alone project, the Customer could produce approximately **50 MW** of power on a firm basis before Network Upgrades for delivery would be required. Additional non-firm capability may be available depending on marketing activities, dispatch patterns, demand levels and the status of transmission facilities. The estimated cost to interconnect the project is approximately **$3.614 million** and includes:

- $ 0.335 million for PSCo-Owned, Customer Funded Interconnection Facilities
- $3.279 million for PSCo Network Upgrades for Interconnection

The time required to engineer, permit, and construct the facilities for interconnection is estimated to be at least 20 months. Therefore, it is not feasible to interconnect the project by the proposed in-service date.

Network Resource:
For the Project to be considered a Network Resource, the integration of the full 199 MW of new generation would require transmission additions and modifications in order to prevent unacceptable conditions on the regional system. The estimated cost of the

[1] www.rmao.com

recommended system upgrades for delivery of the project is approximately **$46.36** million (total project cost of $49.97 million) and would consist of:

- Between Pawnee Station and Smoky Hill Substation, uprate the existing 230 kV line from 500 MVA to 800 MVA.
- From Pawnee Station to Ft. Lupton Station rebuild the existing 64 mile 230 kV 413 MVA rated line to a double circuit 230 kV, 800 MVA per circuit configuration.

The uprate of the Pawnee to Smoky Hill 230 kV line is required to allow for construction outages of the Pawnee-Ft. Lupton 230 kV line.

The estimated time required to engineer, permit, and construct the Network Upgrade facilities for delivery is at least **36** months; therefore, it is not feasible to implement the interconnection or network upgrades for delivery of firm output by the proposed in-service date.

According to the interconnection request, the Customer would engineer, permit, construct, and finance the 230 kV transmission line to the proposed tap station.

A simple diagram of the Network Upgrades and the regional transmission system for this request is shown in Figure 1 and Figure 2 shows the interconnection one-line.

Sensitivity studies evaluated the system performance considering the higher queued Akron Area 300 MW wind project GI-2003-1. If GI-2003-1 and its associated system upgrades are considered to be in place, studies indicate that the total estimated cost of the recommended system upgrades to accommodate interconnection and firm delivery for GI-2004-12 would only include interconnection costs of approximately **$3.62 million** and include:

- $ 0.34 million for PSCo-Owned, Customer Funded Interconnection Facilities
- $ 3.28 million for PSCo Network Upgrades for Interconnection

Figure 1 - Regional Transmission Network with Recommended Upgrades for Delivery

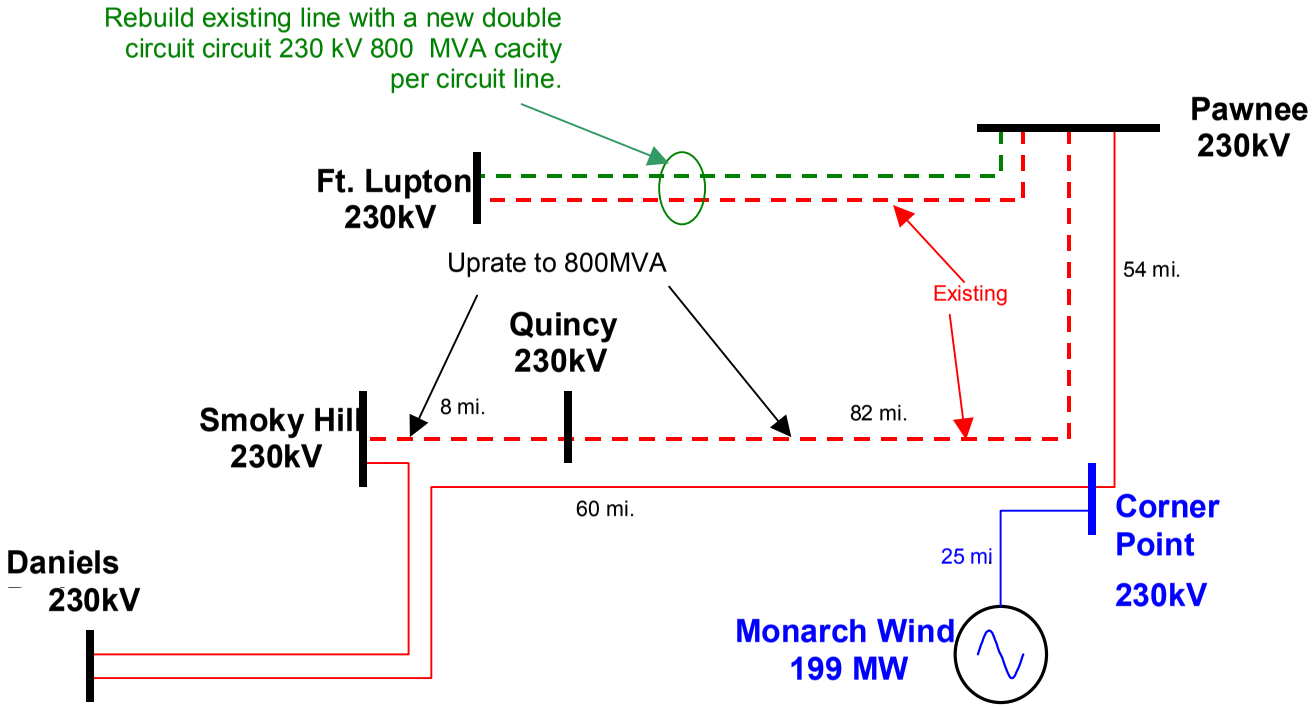
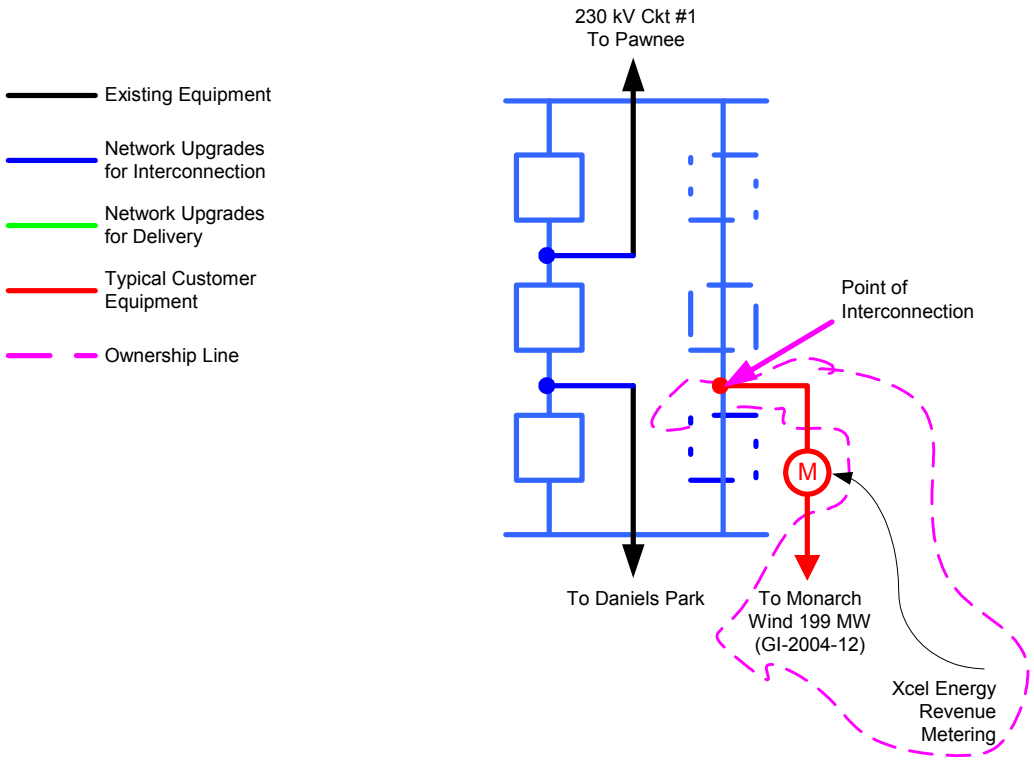


Figure 2 – Corner Point Switching Station One-line with GI-2004-12



Study Scope and Analysis

The Interconnection System Impact Study evaluated the transmission requirements associated with the proposed interconnection to the PSCo Transmission System.

The Study consisted of power flow, short circuit, and dynamic stability analyses. The power flow analysis identified thermal or voltage limit violations resulting for the interconnection, and identified Network Upgrades required to deliver the proposed generation to PSCo loads. The short circuit analysis identified circuit breaker short circuit capability limits exceeded because of the Interconnection, and the delivery of the proposed generation to PSCo loads. The dynamic stability analysis identified any limitations due to angular instability of the system for regional disturbances.

PSCo adheres to NERC / WECC Reliability Criteria, as well as internal Company criteria for planning studies. During system intact conditions, criteria are to maintain transmission system bus voltages between 0.95 and 1.05 per-unit of system normal conditions, and steady state power flows within 1.0 per-unit of all elements thermal (continuous current or MVA) ratings. Operationally, PSCo tries to maintain a transmission system voltage profile ranging from 1.02 per-unit or higher at generation buses, to 1.0 per-unit or higher at transmission load buses. Following a single contingency element outage, transmission system steady state bus voltages must remain within 0.90 per-unit to 1.10 per-unit, and power flows within 1.0 per-unit of the elements continuous thermal ratings.

Results indicate no significant impacts to neighboring utilities. These results have been shared with Platte River Power Authority (PRPA) and Western Area Power Administration (WAPA).

Powerflow Study Models

For this analysis, a power flow model was developed to reflect 2007 heavy summer (peak) loading conditions. Data representation in the area of study was reviewed and modified to accurately reflect the Rocky Mountain regional transmission system. To evaluate the capabilities and system requirements for firm transfer levels, the power flow models were modified to simulate high TOT 3 and TOT 7 path flows. The TOT 3 path flows were modeled with a North to South flow of approximately 1500 MW along with TOT 7 around 640 MW (TOT 3 Summer 2004 Limit = 1544 MW, TOT 7 Limit = 890 MW)). Transmission projects expected to be in-service for the 2007 summer season were represented in the models.

The 199 MW wind project was modeled as a conventional generator with a 0.95 per unit (p.u.) lagging power factor (overexcited) and a 0.90 p.u. leading power factor (under-excited) capability to simulate the VAR requirements of the generators, assumed to be GE 1.5 MW DFIG turbines.

The proposed project was connected to the Corner Point Switching Station 230 kV bus, via a single 25-mile 230 kV line, according to Customer provided data. The project generation was scheduled to PSCo peaking units located in and around the Denver-metro area.

Study Results

Power Flow Analysis

Energy Resource (ER) Study Results:

The results of the ER study indicate that with only the Customer Wind Facilities considered, the maximum amount of generation capability that can be accommodated with the existing system and existing firm path reservations is **50 MW**. Additional non-firm transmission capability on the PSCo system may be available depending on marketing activities, dispatch patterns, customer demand levels and the status of transmission facilities. Table 1 below shows the critical contingency.

Table 1: Contingency Results with GI-2004-12 at 50 MW and Without Network Upgrades

Critical Contingency	Limiting Element	Rating (MVA)	Pre-Load %	Cont-Load %
Pawnee-Quincy/Smoky Hill 230 kV	Pawnee-Ft. Lupton 230 Ckt1	413	71	100

Network Resource (NR) Study Results:

The NR study determined the network upgrades that will be required to accept the full 199 MW from the proposed wind project. Modeling the customer wind generation at 199 MW created local contingency overloads on the PSCo system. Table 2 shows contingency results with the full 199 MW injected at the point of interconnection.

Table 2: Contingency Results with GI-2004-12 at 199 MW and Without Network Upgrades

Critical Contingency	Limiting Element	Rating (MVA)	Pre-Load %	Cont-Load %
Pawnee-Quincy/Smoky Hill 230 kV	CornerPt.-Daniels Park 230 Ckt1	500	93	119/97
Pawnee-Quincy/Smoky Hill 230 kV	Pawnee-Ft.Lupton 230 Ckt1	413	75	110/104

From Table 2, the loss of the Pawnee-Quincy/Smoky Hill 230kV line will load the Pawnee-Ft. Lupton 230kV line to 110% of its thermal rating. Although the benchmark case exhibited loading beyond its rating for the same contingency, the

Pawnee-Ft. Lupton 230kV line loading increases by 8% of the line rating. The significant line loading change prompts a network upgrade of this existing line. The Pawnee-Quincy/Smoky Hill contingency also loaded the Corner Point to Daniels Park 230 kV line to 119%of its thermal rating, but the Monarch Project generators will trip off-line for faults any' where along the Pawnee to Daniels Park corridor. This results in loading the Corner Point to Daniels Park 230 kV Line to 97%, therefore not requiring an upgrade of this section. The Pawnee – Ft. Lupton still overloads for this contingency, but to 104 % of it thermal rating therefore the upgrade of this line is still needed.

The following is a general description of the recommended network upgrades required to alleviate the overloads and accommodate the generation for delivery:

- Between Pawnee Station and Smoky Hill Substation, uprate the existing 230 kV line from 500 MVA to 800 MVA.
- From Pawnee Station to Ft. Lupton Station rebuild the existing 64 mile 230 kV 413 MVA rated line to a double circuit 230 kV, 800 MVA per circuit configuration.

The Pawnee to Smoky Hill uprate is required to allow construction outages for the Pawnee to Ft. Lupton 230 kV line re-build.

Other delivery alternatives were analyzed in this study to accommodate the 199MW wind generation but were determined to be more costly than the recommended upgrade.

The total estimated cost for the recommended upgrades for interconnection and delivery is $49.97 million.

The Project was also evaluated taking into consideration the relevant projects ahead in the queue. This study considered GI-2003-1, which is 300 MW interconnected at the Pawnee Station 230 kV bus. With the delivery network upgrades for GI-2003-1 in place, no additional delivery network upgrades are required to deliver the 199 MW project on a firm basis. However, interconnection costs for GI-2004-12 of approximately **$**3.614 million are required and include:

- $ 0.335 million for PSCo-Owned, Customer Funded Interconnection Facilities
- $ 3.279 million for PSCo Network Upgrades for Interconnection

The details of GI-2003-1 can be seen on the RMAO web page at www.rmao.com.

Short Circuit Analysis

The short circuit analysis was conducted at the affected switchyards in the study area including faulting the 230kV busses at the Pawnee, Customer Wind Tap, and other busses with three-phase and phase-to-ground faults. The short circuit study

results showed that the addition of the 199 MW wind project and network upgrades did not significantly affect the fault currents at existing substations in the study area.

All fault values calculated for this System Impact Study assume no fault current contribution from the Customer wind-turbine generators. This is because of the lack of available wind turbine generator short circuit model data. More detailed short circuit models, and associated possible Customer generation fault contribution will need to be addressed in the following Interconnection Facilities Study.

Table 3: Short Circuit Study Results

Configuration	Fault Current (Amps)			
	Daniels Park	Smoky Hill	Corner Point	Pawnee
Benchmark Existing system 2008 system	26004	28987	NA	19382
(GI-2003-2)[2] Add proposed generation and Corner Point – Daniels Park 230kV line	27047	29630	15373	20505

For all of the fault cases studied, the wind turbines were modeled as conventional synchronous generators. A more accurate short circuit model is not currently available for such short circuit programs as Aspen or CAPE. This study was performed on CAPE.

Stability Analysis

Transient stability analyses were performed by modeling three-phase fault contingencies in the region of study. Dynamic models for the proposed project were prepared using Customer supplied data that assumed to use the GE 1.5 MW DFIG with low voltage ride through (LVRT) capability as low as 30% of nominal voltage. The analysis indicated the system is stable before, during, and after contingencies once network upgrades were implemented.

Even though the models used wind generators with LVRT as low as 30%, the models showed that the Monarch Project would trip off-line (self protection) for faults at Pawnee and Daniels Park.

Table 3: Transient Stability Results – Base Case without Network Upgrades (Monarch Project Off)

	Fault Location	Action	Result
1	3PH at Daniels Park	Trip Pawnee-Daniels	System Stable

[2] GI-2003-2 is a 500 MW Coal Generator also requesting interconnection at Corner Point. Details can be seen on the RMAO web page at www.rmao.com

	Fault Location	Action	Result
	230 kV bus, 6 cycles	Park 230 kV line	
2	3PH at Daniels Park 230 kV bus, 6 cycles	Trip Greenwood - Daniels Park 230 kV line	System Stable
3	3PH at Daniels Park 230 kV bus, 6 cycles	Trip Fuller -Daniels Park 230 kV line	System Stable
4	3PH at Ft. Lupton 230 kV bus, 6 cycles	Trip Pawnee – Ft. Lupton 230 kV line	System Stable
5	3PH at Ft. Lupton 230 kV bus, 6 cycles	Trip St. Vrain – Ft. Lupton 230 kV line	System Stable
6	3PH at Ft. Lupton 230 kV bus, 6 cycles	Trip Green Valley – Ft. Lupton 230 kV line	System Stable
7	3PH at Smoky Hill 230 kV bus; 6 cycles	Trip Pawnee – Quincy-Smoky Hill 230 kV line	System Stable
8	3PH at Smoky Hill 230 kV bus; 6 cycles	Trip Spruce-Smoky Hill 230 kV line	System Stable
9	3PH at Smoky Hill 230 kV bus; 6 cycles	Trip Sulphur-Smoky Hill 230 kV line	System Stable
10	3PH at Pawnee 230 kV bus; 6 cycles	Trip Pawnee-Daniels Park 230 kV line	System Stable
11	3PH at Pawnee 230 kV bus; 6 cycles	Trip Pawnee – Quincy-Smoky Hill 230 kV line	System Stable
12	3PH at Pawnee 230 kV bus; 6 cycles	Trip Pawnee–Ft. Lupton 230 kV line	System Stable
13	3PH at Pawnee 230 kV bus; 6 cycles	Trip Pawnee–Story 230 kV line	System Stable

Table 4: Transient Stability Results – Case with 199 MW Monarch Wind Project and Network Upgrades

#	Fault Location	Action	Result
1	3PH at Daniels Park 230 kV bus, 6 cycles	Trip Corner Point-Daniels Park 230 kV line	System Stable Monarch Gen Trips
2	3PH at Daniels Park 230 kV bus, 6 cycles	Trip Greenwood - Daniels Park 230 kV line	System Stable Monarch Gen Trips
3	3PH at Daniels Park 230 kV bus, 6 cycles	Trip Fuller -Daniels Park 230 kV line	System Stable Monarch Gen Trips
4	3PH at Ft. Lupton 230 kV bus, 6 cycles	Trip Pawnee – Ft. Lupton 230 kV line	System Stable
5	3PH at Ft. Lupton 230 kV bus, 6 cycles	Trip St. Vrain – Ft. Lupton 230 kV line #1 and #2	System Stable
6	3PH at Ft. Lupton 230 kV bus, 6 cycles	Trip Green Valley – Ft. Lupton 230 kV line	System Stable
7	3PH at Smoky Hill 230 kV bus; 6 cycles	Trip Pawnee – Quincy-Smoky Hill 230 kV line	System Stable
8	3PH at Smoky Hill	Trip Spruce-Smoky Hill	System Stable

#	Fault Location	Action	Result
	230 kV bus; 6 cycles	230 kV line	
9	3PH at Smoky Hill 230 kV bus; 6 cycles	Trip Sulphur-Smoky Hill 230 kV line	System Stable
10	3PH at Pawnee 230 kV bus; 6 cycles	Trip Pawnee-Corner Point 230 kV line	System Stable Monarch Gen Trips
11	3PH at Pawnee 230 kV bus; 6 cycles	Trip Pawnee – Quincy-Smoky Hill 230 kV line	System Stable Monarch Gen Trips
12	3PH at Pawnee 230 kV bus; 6 cycles	Trip Pawnee–Ft. Lupton 230 kV line #1 and #2	System Stable Monarch Gen Trips
13	3PH at Pawnee 230 kV bus; 6 cycles	Trip Pawnee–Story 230 kV line	System Stable Monarch Gen Trips
14	3PH at Corner Pt. 230 kV bus; 6 cycles	Trip Pawnee-Corner Point 230 kV line	System Stable Monarch Gen Trips
15	3PH at Corner Pt. 230 kV bus; 6 cycles	Trip Daniels Park - Corner Point 230 kV line	System Stable Monarch Gen Trips
16	3PH at Monarch 230 kV bus; 6 cycles	Trip Monarch -Corner Point 230 kV line	System Stable Monarch Gen Trips

The results from Table 4 show that the transient stability of the region is not affected by proposed project. The system is stable and will continue to be stable with the 199 MW wind project.

Cost Estimates and Assumptions

The estimated total cost for the required upgrades is $49.97 Million

The estimated costs shown are “indicative” (+/-30%) preliminary budgetary costs in 2005 dollars and are based upon typical construction costs for previously performed similar construction. These estimated costs include all applicable labor and overheads associated with the engineering, design, and construction of these new PSCo facilities. The estimates do not include any costs for any Customer-owned, supplied, and installed equipment and associated design and engineering, other than the transmission line between the generation and Corner Point. This estimate also does not include any costs that may, or may not be required for other entities’ systems. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines

Based upon the System Impact Study performed here, in order for PSCo to provide an interconnection for the Customer, the Corner Point facilities must be constructed.

PSCo Network Upgrades for Interconnection:
Table 5 and Table 6 describe the costs associated with providing an interconnection and network upgrades to PSCo’s system for interconnection. This does not include all of the costs required for full delivery of the generation.

Table 5: Customer Interconnection Facilities

Location	Description	Cost (millions)
New 230kV Switching Station (Corner Point)	Interconnect Customer's 230kV line to a new 230kV switchyard. The new equipment required includes: • 230kV bi-directional revenue metering • required steel supporting structures • associated metering control and relaying	**$335k**
	Total Estimated Cost for Interconnection Facilities	**$335k**

Table 6: PSCo Network Upgrades for Interconnection

Location	Description	Cost (millions)
New 230kV Switching Station (Corner Point)	Install a new three breaker ring bus switchyard approximately adjacent to PSCo's existing 230kV Pawnee-Daniels Park Trans Line. The following equipment will be required: • three (3) 230kV 3000 amp 50kA circuit breakers • eight (8) 230kV switches • CCVT's • site development • control building • misc. supporting steel • electrical bus work • associated metering control and relaying	**$2.896**
	Transmission line tap structure & tap	**$0.204**
	Siting and Land Rights acquisition & permitting	**$0.197**
	Total Estimated Cost for Network Upgrades for Interconnection	**$3.279**
Time Frame		**20 Months**

Table 7 describes the costs associated with providing network upgrades for delivery to PSCo Customers.

Table 7: PSCo Network Upgrades for Delivery

Location	Description	Cost (millions)
Pawnee Station	New 230KV double circuit line termination and additional bay to Ft. Lupton. The new equipment required includes: • two 230KV, 3000 amp gas circuit breakers; • fourteen 230KV, 3000 amp gang switches; • supporting station wiring, cable, foundations and structures; • associated communication upgrades, transmission line and bus relaying and testing	**$1.290**

Location	Description	Cost (millions)
Ft. Lupton Station	New 230KV double circuit line termination and additional bay to Ft. Lupton - which will require rearranging of the existing line terminations for the Henry Lake and Green Valley lines. The new equipment required includes: • three 230KV, 3000 amp gas circuit breakers; • ten 230KV, 3000 amp gang switches; • supporting station wiring, cable, foundations and structures; • associated communication upgrades, transmission line and bus relaying and testing	**$1.280**
Smoky Hill Substation	Upgrade existing facilities on the Pawnee 230KV line termination. The new equipment required includes: • two 230KV, 3000 amp gas circuit breakers; • four 230KV, 3000 amp gang switches; • supporting bus, insulators, station wiring, cable, foundations and structures • required communication upgrades (2000 amp line trap)	**$0.960**
Transmission	Rebuild existing 413 MVA 230kV line from Pawnee to Ft. Lupton with new double circuit 230kV 834 MVA transmission utilizing existing ROW as much as possible	**$42.01**
	Uprate the existing Pawnee to Quincy/Smoky Hill 230KV Line to 800 MVA from 500 MVA by installing approximately 15 phase raisers.	**$0.220**
Siting and Permitting	Obtain necessary siting, permits, and ROW as required.	**$0.600**
	Total Cost Estimate for PSCo Network Upgrades for Delivery	**$46.36**
Time Frame		**36 Months**

Assumptions

- The cost estimates provided are “scoping estimates” with an accuracy of +/- 30%.
- Estimates are based on 2005 dollars.
- PSCo (or it’s Contractor) crews will perform all construction and wiring associated with PSCo owned and maintained facilities.

- The estimated time for design and construction of PSCo network upgrades for interconnection at the Corner Point Switching Station is at least 20 months, and is completely independent of other queued projects and their respective ISD's.
- It is anticipated that in order to construct the PSCo network upgrades for delivery, a Certificate of Public Convenience and Necessity (CPCN) will be required by the Colorado Public Utilities Commission (CPUC). The application for a CPCN will not be submitted until the Interconnection Agreement is fully executed. The estimated time frame for the CPCN process, siting, permitting, easement and right-of-way acquisition, design and construction for the PSCo network upgrades is at least 36 months from the time the Interconnection Agreement is fully executed. This time frame is also based on other identified assumptions for Siting and Land Rights, Substation Engineering and Transmission Engineering as listed below.
- The Customer will be responsible for funding and constructing the transmission line from the wind farm to the point of interconnection (Corner Point Switching Station).
- The last span into Corner Point Switching Station from the Customer owned 230 kV line will be a slack span between the PSCo substation dead-end and the Customer's last structure, which is assumed to be a dead-end tangent structure.
- A siting study will not be required if network upgrades for delivery (transmission line construction) is in existing right-of-way. Extensive public involvement is anticipated. Permit applications and possible minor right-of-way acquisition will be required. Land use permits will be required from multiple local jurisdictions.