



**DRAFT**

**Interconnection Feasibility Study Report  
Request # GI-2008-7**

900 MW Gas Fired, Combined Cycle Generation Addition at Pawnee

PSCo Transmission Planning  
February 4, 2009

**Executive Summary**

The purpose of the Interconnection Feasibility Study is to provide a preliminary evaluation of the system impact and cost of interconnecting the Generating Facility to the Transmission Provider's Transmission System, the scope of which is described in the Standard large Generator Interconnection Procedures.

On August 18, 2008, Public Service Company of Colorado (PSCo) Transmission received a generation request to determine the feasibility of interconnecting 900 MW of gas fired, combined cycle generation at the PSCo owned Pawnee Substation. Initially the Customer requested a primary Point of Interconnection (POI) to the PSCo network at the 230 kV bus. However, PSCo Engineering reviewed the request and indicated that an interconnection at the 230 kV bus would result in a high level of flow across the 230/345 kV transformers during steady state conditions, causing them to be overloaded. Therefore, it was determined for the generation interconnection to be studied at the 345 kV bus.

The Customer's project facility would consist of three (3) combustion turbines and two (2) steam turbines, as well as adequate transformation to step up the generators output voltage to 345 kV. PSCo and the Customer discussed that PSCo will interconnect its Pawnee Substation to the generation at the Customer built 345 kV switchyard located near the generation facility. The Customer proposed commercial operation date is June 1, 2013 with a back-feed date of September 1, 2012. Based on projected equipment lead-times and other transmission project in service dates, the commercial operation and back-feed dates requested by the Customer are not feasible. An approximate in service date for the generation interconnection would be upon the completion of the Pawnee – Daniels Park and Smoky Hill – Daniels Park 345 kV lines in 2016.



This request was studied as both a Network Resource (NR)<sup>1</sup>, and as an Energy Resource (ER)<sup>2</sup>. The study included steady-state power flow and short-circuit studies only, and did not include transient dynamic stability analysis. The request was studied as a “stand-alone” project only, with no evaluations made of other potential new generation requests that may exist in the Large Generator Interconnection Request (LGIR) queue, other than the generation projects that are already approved and planned to be in service by the summer of 2013. The main purpose of this Feasibility Study was to evaluate the potential impact on the PSCo transmission infrastructure as well as that of neighboring utilities, when injecting the new 900 MW of generation into the Pawnee 345 kV bus, and delivering the additional generation to native PSCo loads. The costs to interconnect the project with the transmission system at Pawnee Substation have been evaluated by Engineering.

### Energy Resource

Interconnection to the PSCo network is feasible however, firm capacity is not available due to existing overloads and firm transmission commitments, and is not possible without the construction of network reinforcements. Non-firm transmission capability may be available depending on marketing activities, dispatch patterns, generation levels, demand levels, import path levels (TOT 3, etc.) and the operational status of transmission facilities.

### Network Resource

The results of the NR analysis indicate that the Customer could provide 900 MW if the following is completed:

- Pawnee – Smoky Hill 345 kV Project: A 345 kV transmission line is installed between the Pawnee Substation and the Smoky Hill Substation, proposed in accordance to SB07-100, with an in service date of December 2013.
- Pawnee – Daniels Park 345 kV Project: A 345 kV transmission line is installed between Pawnee Substation and Daniels Park Substation along with a 345 kV transmission line between Smoky Hill Substation and Daniels Park Substation, with an in service date of May 2016.

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<sup>1</sup> **Network Resource Interconnection Service** shall mean an Interconnection Service that allows the Interconnection Customer to integrate its Large Generating Facility with the Transmission Provider's Transmission System (1) in a manner comparable to that in which the Transmission Provider integrates its generating facilities to serve native load customers; or (2) in an RTO or ISO with market based congestion management, in the same manner as all other Network Resources. Network Resource Interconnection Service in and of itself does not convey transmission service.

<sup>2</sup> **Energy Resource Interconnection Service (ER Interconnection Service)** shall mean an Interconnection Service that allows the Interconnection Customer to connect its Generating Facility to the Transmission Provider's Transmission System to be eligible to deliver the Generating Facility's electric output using the existing firm or non-firm capacity of the Transmission Provider's Transmission System on an as available basis. Energy Resource Interconnection Service in and of itself does not convey transmission service



- Upgrade substation facilities in the PSCo area that presently limit the ratings of certain lines in the study area below their thermal ratings. These facility enhancements are being evaluated as part of PSCo's Transmission Facility Equipment Ratings Project and would be funded through PSCo's Five Year Capital Construction Budget.
- Upgrade the 150 MVA Daniels Park 230-115 kV transformer. PSCo plans to upgrade this transformer through its Five Year Capital Budget process.
- Studies identified three contingency overloads that could occur on the PSCo system if the customer plans to provide 900 MW to PSCo native loads - a contingency overload of the Happy Canyon – Crowfoot Valley 115 kV line, a contingency overload of the Happy Canyon – Daniels Park 115 kV line, and a contingency overload of the Daniels Park 230-115 kV transformer. These criteria violations may be mitigated by upgrading the Daniels Park – Castle Rock 115 kV transmission line from 159 MVA to 287 MVA.

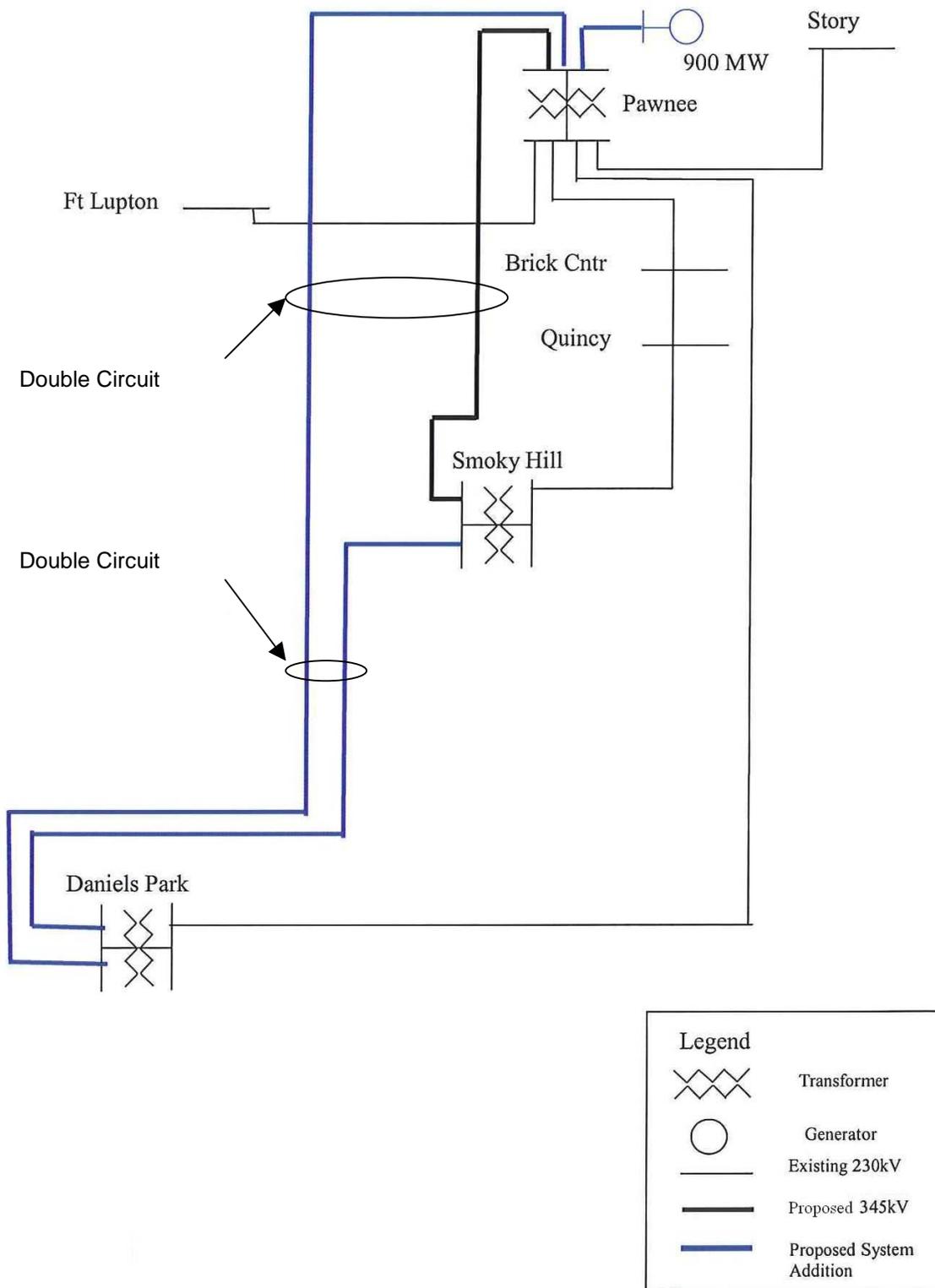
The cost for the transmission interconnection (in 2008 dollars):

#### **Transmission Proposal**

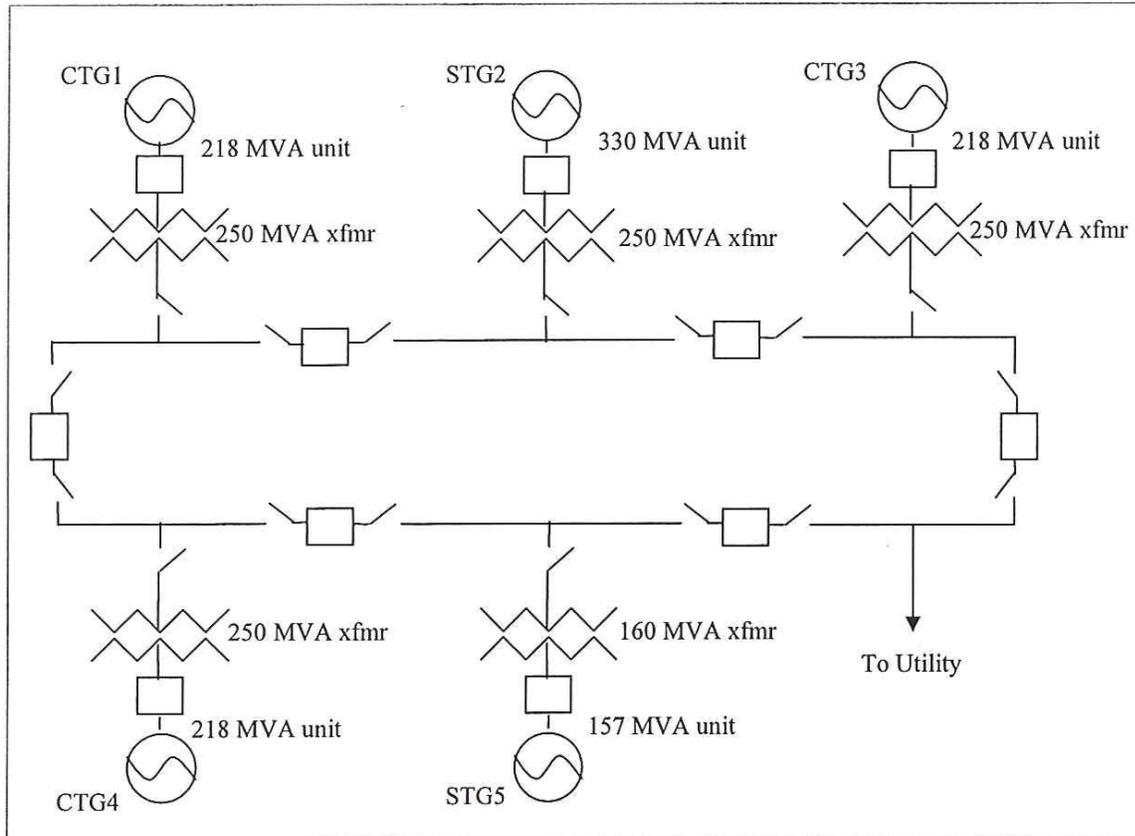
The total estimated cost of the recommended system upgrades to interconnect the project is approximately **\$ 204,600,000** million and includes:

- \$ 0.870 million for PSCo-Owned, Customer-Funded Interconnection Facilities
- \$ 2.065 million for PSCo-Owned, PSCo-Funded Network Upgrades for Interconnection
- \$ 201.665 million<sup>2</sup> for PSCo Network Upgrades for Delivery

A partial one-line of the Pawnee Substation detailing the Interconnection and Delivery is shown in Figure 1. In addition, a conceptual one-line of each generator interconnection and the interconnection to the Pawnee Substation is shown in Figure 2.



**Figure 1: Proposed Pawnee One-Line Diagram (Upgrades Marked in Blue)**



**Figure 2: Proposed One-Line Diagram of Generator and Utility Interconnection**



## **Introduction**

PSCo Transmission received a large generator interconnection request (GI-2008-7) to interconnect three (3) combustion turbines and two (2) steam turbines for a combined total generation capability of 900 MW, with the proposed commercial operation date of June 1, 2013 and back-feed date of September 1, 2012. However, due to projected equipment lead-times, construction times and potential transmission in service dates, the commercial operation and back-feed dates requested will not be achievable. The earliest possible in service date for the generation interconnection would be upon the completion of the Pawnee – Daniels Park and Smoky Hill – Daniels Park 345 kV lines in May 2016.

The proposed gas fired combined cycle generation facility would be located approximately 6 miles from the Pawnee Substation, near a new 345 kV Switchyard. The customer and PSCo discussed that the customer would be responsible for the installation of this new 345 kV switchyard. Initially the Customer requested a primary Point of Interconnection (POI) on the 345 kV bus at the 345 kV Switchyard from the 230 kV bus at Pawnee Substation. However, PSCo Engineering reviewed this request and indicated that an interconnection at the 345 kV Switchyard from the 230 kV bus at the Pawnee Substation would result in a high level of flow across the 230/345 kV transformers located at the Pawnee Substation. Therefore, it was determined to study the interconnection at the 345 kV bus and not at the 230 kV bus. The Customer POI would interconnect into the PSCo transmission network through a single 345 kV transmission line.

The Customer has requested that this project be evaluated as a Network Resource (NR) and an Energy Resource (ER), with the energy delivered to PSCo customers.

## **Study Scope and Analysis**

The Interconnection Feasibility Study evaluated the transmission requirements associated with the proposed 900 MW combined cycle generation interconnection to the PSCo Transmission System at the Pawnee Substation. It consisted of power flow and short circuit analyses. The power flow analysis provided a preliminary identification of any thermal or voltage limit violations resulting for the interconnection, and for a NR request, a preliminary identification of network upgrades required to deliver the proposed generation to PSCo loads. The short circuit analysis identified any circuit breaker short circuit capability limits exceeded as a result of the Interconnection and for a NR request, the delivery of the proposed generation to PSCo loads.

PSCo adheres to NERC / WECC Reliability Criteria, as well as internal Company criteria for planning studies. During system intact conditions, transmission system bus voltages are to be maintained between 0.95 and 1.05 per-unit of system nominal /



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 1.03 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.

For this project, potential affected parties include Western Area Power Administration (WAPA), and Tri-State G&T (Mountain View EA). PSCo has contacted affected utilities during the course of this study.

### **Power Flow Study Models**

The power flow studies were based on a PSCo-developed 2015 heavy summer stressed TOT 3 base case that was developed from the approved Western Electricity Coordinating Council (WECC) 2015 heavy summer base model.

### **Power Flow Study Process**

Automated contingency power flow studies were completed on all case models, switching out single elements one at a time for all of the elements (lines and transformers) in the study area.

The 2015 heavy summer base case was modified by the removal of future generation additions that did not apply to this study. The TOT3 interface flow was at 1313.9 MW for the base case.

The project was first studied by connecting the 900 MW of proposed gas fired combined cycle generation at the 345 kV bus at the Pawnee substation as described in the initial request. The following modifications were applied to the base case for this project:

1. 345 kV bus and 345 kV line were added for the project and connected to the Pawnee 345 kV bus. Three 218 MVA generators, one 330 MVA generator, and one 157.77 MVA generator were tied to the new 345 kV bus as described in the proposal and adjusted to meet the 900 MW of total generation.
2. The 900 MW of generation was sunk to three locations as described below:
  - a. Fountain Valley – 205 MW
  - b. Lamar DC – 300 MW
  - c. Comanche – 395 MW
3. For the 345 kV option, the units were set to hold voltage at the developers 345 kV bus to 1.03. The units total output was adjusted to make 900 MW at the 345 kV bus. Note as in figure 2 above that there is a 250 MVA transformer connecting the 330 MVA unit restricting the output of this unit.



## Stand Alone Power Flow Results

### Energy Resource (ER):

Interconnection to the PSCo network is feasible however, firm capacity is not available due to existing overloads and firm transmission commitments, and is not possible without the construction of network reinforcements. This Study has determined that any increase in the generation injected at the Pawnee 345 kV bus directly increases the loading / overloading on the PSCo regional transmission system. Firm capacity is not available as a result of these overloads and other firm transmission commitments, and is not possible without the construction of network reinforcements. Non-firm transmission capability may be available depending of marketing activities, dispatch patterns, generation levels, demand levels, import path levels (TOT 3, etc.) and the operational status of transmission facilities.

### Network Resource (NR):

This Study has determined that any increase in the generation injected at the Pawnee 345 kV bus directly increases the loading / overloading on the PSCo regional transmission system. Therefore, the 900 MW NR value requested will require interconnection and Transmission Network Upgrades.

**NR = 900 MW (with required Network Upgrades)**

## Short Circuit Study Results

A short circuit study was conducted to determine the fault currents (single-line-to ground or three-phase) at the Pawnee Substation 345 kV bus (#2055). The study was conducted including the addition of the proposed 900 MW of generation from the High Plains Energy Associates Switchyard. Fault current contributions from the 230 kV transformers were summed together and included through the 345 kV north bus (#2054) at Pawnee. Table 1 summarizes the approximate fault currents at the Pawnee 345 kV Bus with the addition of the GI-2008-7 facility.

**Table 1: Short-Circuit Study Results With the Proposed 900 MW of Generation**

System Condition	Three-phase (amps)	Thevenin System Equivalent Impedance (R,X) (ohms)	Single-line-to-ground (amps)	Thevenin System Equivalent Impedance (R,X) (ohms)
System Intact	I <sub>1</sub> =16,480.4 I <sub>2</sub> =I <sub>0</sub> =0 I <sub>A</sub> =I <sub>B</sub> =I <sub>C</sub> =16,480.4	Z <sub>1</sub> (pos)= 0.81301, 12.0589 Z <sub>2</sub> (neg)= 0.82426, 12.0778 Z <sub>0</sub> (zero)= 1.34652, 11.7450	I <sub>1</sub> =I <sub>2</sub> =5,532.08 I <sub>0</sub> =16,596.2 I <sub>A</sub> =16,596.2 I <sub>B</sub> =I <sub>C</sub> =0	Z <sub>1</sub> (pos)= 0.81301, 12.0589 Z <sub>2</sub> (neg)= 0.82426, 12.0778 Z <sub>0</sub> (zero)= 1.34652, 11.7450

PSCo Substation Engineering indicated that the addition of 900 MW gas fired, combined cycle generation will require an additional circuit breaker position to be installed on the existing North 345 kV bus at the Pawnee Substation. This additional circuit breaker position creates a breaker and a half setup, increasing the system



reliability. This setup prevents the loss of the PSCo Daniels Park and Smoky Hill 345 kV transmission lines in the event of a breaker failure.

**Costs Estimates and Assumptions**

GI-2008-7 (Feasibility Study Report)

The estimated total cost for the required upgrades for is **\$ 204,600,000**. The estimated costs shown are (+/-30%) estimates in 2008 dollars (no escalation applied) and are based upon typical construction costs for previously performed similar construction. These estimated costs include all applicable labor and overheads associated with the siting, engineering, design, procurement and construction of these new Xcel Energy facilities. This estimate does not include the cost for any other Customer owned equipment and associated design and engineering.

The following tables list the improvements required to accommodate the interconnection and the delivery of the Project. The cost responsibilities associated with these facilities shall be handled as per current FERC guidelines. System improvements are subject to change upon more detailed analysis.

**Table 2: PSCo Owned; Customer Funded Interconnection Facilities**

Element	Description	Cost Est. Millions
<b>PSCo's Pawnee 345kV Substation</b>	Interconnect Customer at PSCo's Pawnee 345kV Substation. New 345kV equipment required for interconnection includes: <ul style="list-style-type: none"> <li>• one 345kV, 3000 amp gang switch</li> <li>• 345kV bi-directional metering</li> <li>• relaying, communication and associated equipment</li> <li>• foundations and structures</li> </ul>	<b>\$0.627</b>
	Transmission tie line into substation.	<b>\$0.042</b>
	Customer Load Frequency and Automatic Generation Control (LF/AGC) and Generator Witness Testing.	<b>\$0.191</b>
	Siting and Land Rights for required easements, reports, permits and licenses.	<b>\$0.010</b>
	<b>Total Cost Estimate for Customer Interconnection Facilities</b>	<b>\$0.870</b>
<b>Time Frame</b>	<b>To site, design, procure and construct</b>	<b>12 Months</b>



**Table 3: PSCo Owned; PSCo Funded Interconnection Facilities**

Element	Description	Cost
<b>PSCo's Pawnee 345kV Substation</b>	Interconnect Customer at PSCo's Pawnee 345kV Substation. New 345kV line termination equipment required: <ul style="list-style-type: none"> <li>• four 345kV, 40 KA dead tank circuit breakers``</li> <li>• seven 345kV, 3000 amp gang switches</li> <li>• electrical bus work; station wiring</li> <li>• foundations and structures</li> <li>• minor site work (grading, grounding)</li> </ul>	<b>\$2.064</b>
<b>Time Frame</b>	<b>To site, design, procure and construct</b>	<b>12 Months</b>

**Table 4: PSCo Network Upgrades for Delivery**

Element	Description	Cost Est. Millions
<b>Pawnee-Smoky Hill 345kV OH Line</b>	Construct approximately 94 miles of new 345kV overhead line from Pawnee Substation to Smoky Hill Substation – double circuit (stringing one), bundled 1272 kcmil conductor.	<b>\$82.769</b>
<b>Pawnee 345kV Substation</b>	Construct new 345kV substation and line termination equipment.	<b>\$18.424</b>
<b>Smoky Hill 345kV Substation</b>	Construct new 345kV substation and line termination equipment.	<b>\$20.650</b>
<b>Siting and Permitting</b>	Obtain necessary siting, permits, easements and ROW as required.	<b>\$9.157</b>
		<b>\$131.000</b>
<b>Pawnee-Daniels Park 345kV OH Line</b>	Construct approximately 120 miles of new 345kV overhead line from Pawnee Substation to Daniels Park Substation – double circuit (stringing one), bundled 1272 kcmil conductor.	<b>\$58.340</b>
<b>Pawnee 345kV Substation</b>	Construct 345kV line termination equipment.	<b>\$1.320</b>
<b>Smoky Hill 345kV Substation</b>	Construct 345kV line termination equipment.	<b>\$1.220</b>
<b>Daniels Park 345kV Substation</b>	Construct new 345kV substation and line termination equipment.	<b>\$2.940</b>
<b>Siting and Permitting</b>	Obtain necessary siting, permits, easements and ROW as required.	<b>\$1.200</b>
		<b>\$65.020</b>
<b>Daniels Park-Castle Rock 115kV Line</b>	Rebuild/upgrade 12.2 miles of the Daniels Park-Castle Rock 115kV line to a higher continuous amp rating (239 MVA, 1200 amp)	<b>\$5.645</b>
	<b>Total Cost Estimate for PSCo Network Upgrades for</b>	<b>\$201.665</b>



Element	Description	Cost Est. Millions
	Delivery	
	Total Cost of Project	\$204.600
Time Frame	To site, design, procure and construct	60 Months

### **Assumptions for Alternatives**

- The cost estimates provided are “scoping estimates” with an accuracy of +/- 30%.
- Estimates are based on 2008 dollars (no escalation applied).
- There is no contingency added to the estimates.
- AFUDC is not included for network upgrades or delivery upgrades.
- Labor is estimated for straight time only – no overtime included.
- PSCo (or it’s Contractor) crews will perform all construction and wiring associated with PSCo owned and maintained facilities.
- The Generation Site is not in PSCo’s service territory. The local utility will provide station service power to the generator.
- The estimated time for design and construction of PSCo network upgrades for interconnection is at least 60 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 12-15 months from the time the Interconnection Agreement is fully executed (or receiving authorization to proceed). This time frame is also based on other identified assumptions for Siting and Land Rights, Substation Engineering and Transmission Engineering as listed below.
- Implementation of the recommended infrastructure for delivery will require that existing facilities be taken out of service for sustained periods. In most cases, these outages cannot be taken during peak load periods due to operational constraints. As a result, the estimated time frame for implementation could be increased by 3-6 months.
- A siting study will be required if network upgrades for delivery. 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.



1. No additional land will be required at the Pawnee Substation site – may need additional land at other substation sites.

## Appendix

### A. Generation Dispatch

The power flow studies were based on a PSCo-developed 2015 heavy summer base case that originated from the study model developed in early 2009 as part of PSCo's normal annual 5-year transmission capital budget project identification process. Load levels reflect 2015 heavy summer peak system. In order to evaluate the capabilities of the existing transmission system and the potential reinforcements that would be required for firm transfer levels, the power flow model was modified to simulate high flows from northern Colorado to the south. Specifically, generation was reduced by 395 MW from the Comanche units, and generation from Fountain Valley was reduced by 205 MW. In addition the Lamar DC tie schedule was changed from 100 MW importing to 200 MW exporting, equivalent to 300 MW of power flow change. Table 5 lists where the 900 MW of generation was utilized in the case.

**Table 5: Generation Sinks Assumed in the Study Benchmark Case**

- Fountain Valley – 205 MW
- Lamar DC – 300 MW
- Comanche – 395 MW

### B. Power Flow Contingency Results

The initial study results are based on the installation of 345 kV transmission lines from Pawnee to Daniels Park and Smoky Hill to Daniels Park. Without the inclusion of these 345 kV transmission lines the interconnection of 900 MW at the Pawnee Substation is not feasible. The initial study indicated a single contingency overload on the PSCo system before the inclusion of the 900 MW at the Pawnee Substation. However, the inclusion of the 900 MW at the Pawnee Substation resulted in three significant overloads on the PSCo system. The results of the power flow studies are summarized in Table 6 below. The elements identified in this study report as overloaded in these contingency runs are limited to the new or significantly increased overloads, and do not address all of the elements that may have been indicated as overloaded in the contingency runs.

When opening the Bayou – Franktown 115 kV circuit, the 150 MVA Daniels Park 115/230 kV transformer on the PSCo system will experience a higher contingent loading will become overloaded. PSCo is planning to upgrade the Daniels Park 115/230 kV transformer through its Five Year Capital Budget process. In addition, when the Bayou – Franktown 115 kV circuit is opened, two 115 kV transmission lines, Happy Canyon – Crowfoot Valley and Happy Canyon – Daniels Park on the PSCo system



experience contingency overloads. These criteria violations will also be mitigated through PSCo's Five Year Capital Budget Process.

Table 6 provides a list of elements that experience contingency overloads for the highly stressed south-to-north case. The table includes a column that describes the network upgrades required in PSCo's system that would be mitigated through PSCo's Five Year Capital Construction Budget.



				Branch N-1 Loading Without GI-2008-07		Branch N-1 Loading With GI-2008-07 Opt. 9		
Monitored Facility (Line or Transformer) From Bus To Bus	Type	Line Owner	Branch Rating MVA	N-1 Flow in MVA	N-1 Flow in % of Rating	N-1 Flow in MVA	N-1 Flow in % of Rating	N-1 Contingency Outage From Bus To Bus
70138 DANIELPK 115 70139 DANIELPK 230 T1	TR	PSCo	150	183	122.0	204.6	136.4	70518 BAYOU 115 70574 FRANKTWN 115 1
70115 HPCYN 115 70117 CRWFTVLY 115 1	LN	PSCo	155	136.3	87.9	156.1	100.7	70518 BAYOU 115 70574 FRANKTWN 115 1
70115 HPCYN 115 70138 DANIELPK 115 1	LN	PSCo	155	153.3	98.9	173.1	111.7	70518 BAYOU 115 70574 FRANKTWN 115 1

**Table 6: Summary Listing of Differentially Overloaded Elements on the PSCO System With 900 MW Injection at Pawnee Opt. 9**

### C. One Line Diagram

