High Plains Express Transmission Project

Feasibility Study Report

June 2008

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Introduction and Executive Summary

The High Plains Express (HPX) initiative is a roadmap for transmission development in the Desert Southwest and Rocky Mountain region to significantly strengthen the eastern portion of the Western grid. It would potentially incorporate the transmission projects already under development within the HPX footprint.[1] With added North-South and East-West transmission capability, markets for renewable energy would be broadened, system reliability would be enhanced, and the ability to make economic transfers of energy would provide cost-savings opportunities for consumers in the states of Wyoming, Colorado, New Mexico, and Arizona.

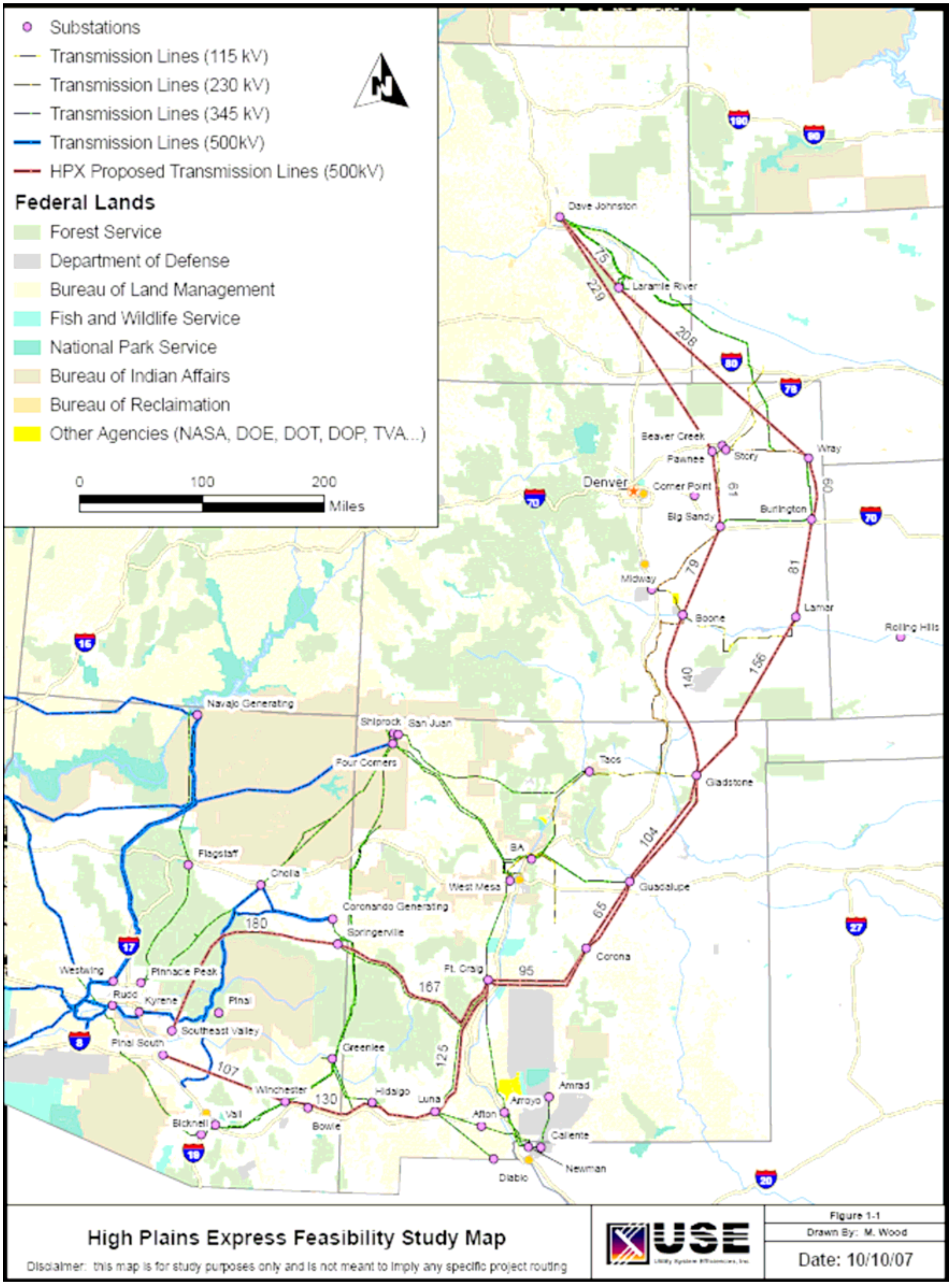
Seven electric utilities, three state agencies, and an independent transmission development company joined in an effort to evaluate the preliminary technical and economic feasibility of this initiative.[2] This feasibility evaluation has been conducted as an open process providing opportunities for stakeholder input and participation. The results of initial feasibility studies are presented in this report.

The HPX concept would extend the 500 kV AC transmission system that is used throughout much of the Western Electricity Coordinating Council (WECC) region, to connect the states of Wyoming, Colorado, New Mexico, and Arizona. This system would provide opportunities to upload power from a variety of economic resources, as well as download power for customer use within each HPX state, and would be integrated with existing generation and power delivery systems. The feasibility study focused on power transfers from northeast to southwest, but HPX could be used to transfer power in both directions.

[1] Eastern Plains Transmission Project (EPTP), Wyoming-Colorado Intertie (WCI), New Mexico Wind Collector, and SunZia Southwest Transmission Project

[2] Colorado Springs Utilities (CSU), Platte River Power Authority (PRPA), Public Service of New Mexico (PNM), Salt River Project (SRP), Trans-Elect, Tri-State G&T, Western Area Power Administration (Western), Xcel Energy, Colorado Clean Energy Development Authority (CEDA), New Mexico Dept. of Energy, Minerals & Natural Resources (NM-EMNR), and the Wyoming Infrastructure Authority (WIA)

***Figure ES-1*: Conceptual Routing of the HPX Project**



A. Primary Conclusions

Primary conclusions from this preliminary feasibility study effort are summarized as follows:

1) Primary Benefits: The primary benefits expected to be realized from the HPX Initiative:
   a) Enhances the reliability of the eastern portion of the WECC grid;
   b) Facilitates substantial new renewable energy integration consistent with public policy;
   c) Provides for efficient energy transfers and associated economic benefits for customers and consumers in each of the HPX states;
   d) Provides economic development stimuli for all HPX states; and
   e) Provides a "roadmap" for local and regional transmission expansion.

2) Technical Studies and Costs: Power flow simulation studies, under the direction of the HPX participants, indicate that two 500 kV AC transmission lines could effectively carry as much as 4,000 MW of bulk power. Alternatively, two double-circuit 500 kV lines could accommodate 7,000 to 8,000 MW of transfers. These lines could be connected to several substations along the HPX path. For this Feasibility Study, fourteen substation interconnections were evaluated: two in Wyoming, six in Colorado, four in New Mexico, and two in Arizona.

   Installed costs for two 500 kV lines and associated substations were estimated at $5.1 billion (in 2007 dollars), with indicative economics shown for potential major line segments below. As shown, effective transmission rates are dependent upon the extent to which a transmission line is utilized.

Segment	Ave. Miles	Cost ($MM)	Line Losses	Indicative Transmission Rates		
				$/kw-mo	$/MWh @ 40% Use	$/MWh @ 80% Use
Wyoming - Colorado	335	$1,366	2.4%	$3.21	$10.99	$5.50
Colorado - New Mexico	420	$1,680	3.1%	$3.94	$13.49	$6.75
New Mexico - Arizona	525	$2,087	3.8%	$4.90	$16.78	$8.39

3) Conceptual Routing (*Figure ES-1*): Two—1,300 mile long conceptual transmission routes were identified for purposes of study modeling. They would traverse renewable energy resource areas and nearby substations within the HPX states. These conceptual routes do not imply preliminary, specific, or final routing selections that would be evaluated in the next phase of the project's feasibility taking into account wildlife and myriad other factors. The two routes are largely separate, although they would most likely converge in New Mexico before turning west to Arizona. Routes in Wyoming and Colorado would largely be on private land, while in New Mexico and Arizona, significant portions are likely to be on Federal (BLM and Forest Service) lands.

4) Loads and Resources: The electrical generation capacity of the four HPX states approaches 50,000 MW with a majority of generation used internally and a portion exported to adjoining states. The vast majority of this generation is from fossil base

load resources, particularly coal. In the coming years, demand for electricity, particularly energy from renewable resources, is expected to expand – notwithstanding demand-side and energy efficiency programs under development by the utilities within each HPX state.

a) The region's transmission grid was developed by owners of large, jointly owned, base load power plants in order to facilitate the transfer of power from those plants to the owning utilities and for reliability purposes. As a result, Wyoming is primarily a power exporting state, New Mexico and Arizona are net exporters, and Colorado is largely self-sufficient, although it also imports power from Wyoming.
b) The use of the existing transmission grid within the HPX states for delivering renewable energy is limited by (1) the general absence of available transmission capacity and (2) undersized or non-existent transmission lines within the renewable resource areas.
c) Power demand peaks during the daylight hours and summer months for the HPX states, with a lesser peak during the winter months. These demand profiles do not align with the availability of renewable resources when aggregated as a whole, so supplemental resources will likely be required to match load requirements.

5) Estimated Power Delivery Costs: It is expected that HPX will improve the diversity, performance, and costs of resources available for use within each HPX state, largely without displacing opportunities for in-state renewable development. Intermittent wind from in-state resources generally provides the lowest cost energy supply option within each HPX state, followed by fossil generation whose costs will be influenced by future carbon regulations. It is anticipated that geographical diversity of wind and solar resources delivered by HPX will supplement local renewable options, further reducing reliance on fossil generation and reducing renewable energy integration costs.

6) Economic Analysis: Benefit/Cost studies were conducted for six 3,500 MW resource mix scenarios using a screening tool that was developed in the Frontier Line transmission study.[3] Sensitivity analyses were conducted for different CO_2 penalty levels for various resource mixes generally compared against new gas fired generation located within the load centers. While most scenarios indicate economic feasibility (i.e., benefits outweigh costs), the renewable-dominated scenarios performed progressively better at higher CO_2 penalty costs, and the reverse was true for the fossil-dominated scenarios. A "balanced" scenario consisting of near equal amounts of fossil and renewable energy performed the best under a range of circumstances.

[3] The HPX benefit/cost analysis used the FEAST model developed by PG&E and the Frontier Line Economics Sub-Committee (www.ftloutreach.com) which is characterized as follows: "FEAST is a screening tool, and is not intended as a substitute for necessary, in-depth analysis using production costing and/or market simulation tools."

7) Potential Benefits to HPX States: In addition to improved reliability and economic development that would be realized by all HPX states, additional benefits could include the following (which will be studied in subsequent phases of the project's development):

   a) Arizona: Ability to increase its reliance on renewables as a cost-effective power supply source by blending and supplementing in-state renewables with renewables imported from the "upstream" HPX states, particularly New Mexico;

   b) Colorado and New Mexico: Ability to optimize renewable energy use for in-state and export purposes by taking advantage of geographical diversity afforded by HPX's development, without limiting in-state renewable energy development prospects;

   c) Wyoming: Ability to export its high-quality, low-cost resources, particularly wind to the "downstream" HPX states to enhance the performance and reliability of the resources used within and exported by those states;

B. Next Steps

During the course of this feasibility study work, a number of additional issues were raised which will need to be addressed in subsequent detailed feasibility assessment and project development phases. These include the following:

1. Studies to identify corridors for siting transmission lines: these studies would incorporate assessments of wildlife habitat and migration, terrain, land management and ownership, permitting requirements, potential for shared corridors, community impact, avoidance of critical areas, impact mitigation/avoidance, and a wide range of other issues;
2. Sequential development: construction of individual segments of the HPX initiative over time following a "roadmap" approach to transmission expansion suited to each HPX state's needs, potentially incorporating the transmission projects currently under development within the HPX footprint. Options could include designing facilities to allow for initial operation at lower voltages, future expansion of conductors and adding future circuits;
3. Operational modeling to assess the performance and costs of renewable resource integration and dispatch;
4. Assessment of public and regulatory policies potentially applicable to HPX, particularly those regarding renewable development and transmission financing;
5. Further quantification of the overall cost impacts and benefits that could be achieved from the HPX initiative. This would include production cost modeling of various resource mixes, including those suggested for analysis by stakeholders;
6. Cost allocation and cost recovery mechanisms, and potential for a regional tariff for segments and/or the entire HPX project. Cost-causation and beneficiary pays principles would be applied to the largest extent possible, and where appropriate.

7. Continuing an open stakeholder approach and outreach to secure input on the transmission planning process. Begin WECC rating process and ensure the HPX initiative is properly included in the sub-regional and WECC transmission planning venues;
8. Identification of business structures, ownership shares, development funding requirements, work plans, and project development schedules for consideration in further assessing the viability of the HPX initiative.

II. Background

A. Objectives:

The primary objectives of this Feasibility Study were to:

1. Develop transmission expansion alternatives to significantly increase reliability and power transfer capabilities between the states of Wyoming, Colorado, New Mexico, and Arizona.
2. Identify potential transmission interconnection points that would allow for up-loading renewable and other economic generation resources, and dropping-off power to regional loads.
3. Examine the potential for synergies among other projects within the HPX footprint.
4. Determine economic viability of the transmission alternatives.
5. Perform high level screening analysis to determine potential siting and corridor routes, and approximate transmission line mileages.

B. Vision

In the fall of 2006 utility members from the Rocky Mountain and Desert Southwest regions met to discuss the potential for a transmission study that would coordinate efforts of individual transmission development projects throughout the region. The goal of this effort was to determine if transmission projects could be developed and coordinated in a manner that would enhance the reliability of the overall transmission system in the region, provide benefits to all interested stakeholders, provide economic benefits to consumers within each state, and facilitate future resource injection areas.

C. Memorandum of Understanding

Preliminary meetings to discuss concepts, interest, and scope lead to the development of an agreement for a transmission feasibility study. Each of the interested parties felt that the best way to conduct a joint study was to pool resources and have an independent consultant perform the bulk of the transmission studies. A Memorandum of Understanding (MOU) was drafted to enable parties to participate in the HPX Feasibility Studies. The following parties signed the MOU:

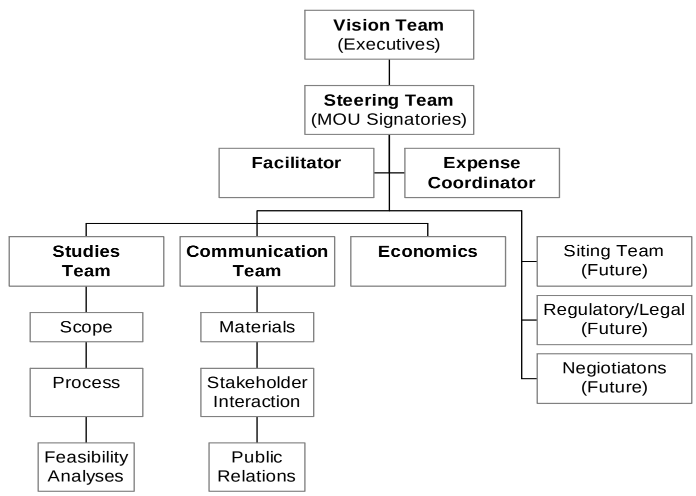
- Utilities:
  - Colorado Springs Utilities – a municipal utility
  - Platte River Power Authority - a public power authority
  - Public Service Company of New Mexico (PNM) – an investor-owned utility
  - Salt River Project (SRP) – a public power authority
  - Tri-State G&T – a rural electrical generation and transmission cooperative
  - Western Area Power Administration (Western) – a federal marketing administration
  - Xcel Energy – an investor-owned utility

- State Agencies
  - Colorado Clean Energy Development Authority (CEDA)
  - New Mexico Energy, Minerals and Natural Resources Department (NM-EMNRD)
  - Wyoming Infrastructure Authority (WIA)
- Independent Transmission: TransElect Development Company

D. Organization

The participants in the Feasibility Study organized into teams that could facilitate the various tasks of the study. *Figure 1* illustrates how the organization was designed.

Figure 1: **Organization Design**



The Vision Team developed the overall study approach with the first phase being the feasibility analyses. Subsequent phases will advance the project towards development and implementation by furthering the development of the Project scope, structure and governance.

The Steering Team consisted of representatives from each of the parties that signed the MOU, and managed the feasibility study process.

The Studies Team was responsible for managing the transmission system studies. This process began in April 2007, was followed shortly thereafter with the first stakeholder meeting in March 2007, and culminated with the second stakeholder meeting in December 2007.

The Communication Team helped manage the flow of information during this feasibility study to the public and stakeholders.

E. Process

1. Scope

Initial discussions began in the fall of 2006 among parties developing transmission projects within what has become the HPX footprint. It was noted that there were several plans for significant transmission development in the footprints of the representative utilities. These projects included the—TransWest Express Project, the Eastern Plains Transmission Project (EPTP), the TOT3 Expansion Project (now known as the Wyoming-Colorado Intertie (WCI), the Northern New Mexico Import proposal, and the SunZia Southwest Project. Most agreed that there was a need for transmission expansion in the region to accommodate renewable energy, increase reliability, and evaluate synergies among the other planned projects. The genesis of the HPX initiative was to jointly evaluate a high voltage transmission plan that could coordinate study efforts in the Rocky Mountain and Desert Southwest regions of WECC.

2. Consultant

Various consultants were interviewed and Utility System Efficiencies (USE) was chosen to perform the initial transmission feasibility studies.

3. Communication

The Feasibility effort was designed as an open process in order to facilitate stakeholder input. Two stakeholder meetings were held. The first was a kickoff meeting held on March 23, 2007 at the Embassy Suites Hotel, near Denver International Airport. Approximately 100 people attended. The second meeting provided stakeholders with an overview of the study results and was held on November 11, 2007 at the Holiday Inn Denver International Airport. Again, nearly 100 stakeholders attended. In addition to the two stakeholder meetings, the Studies Team held meetings on a weekly basis. These meetings were also open to interested stakeholders. There were approximately 35 participants on the contact list for the Studies Team.

Status reports were also provided at numerous WECC regional and sub-regional (CCPG and SWAT) meetings throughout the process. A website was formed for maintaining materials from this phase of the process at http://www.rmao.com/wtpp/HPX_Studies.html.

III. Loads and Resources

DOE has compiled the electrical generation resources and requirements for each of the HPX states for 2005 – the last year for which such data are publicly available (*Table 1*). These data indicate that nearly 50,000 MW of generation capacity is available within these states, with the vast majority of the capacity from coal and gas plants. The 3,500-4,000 MW that would be delivered by the HPX project would serve a small portion of overall load growth (tempered by the success of demand side management, energy efficiency, and conservation measures), as well as supply energy from renewable resources to meet the HPX states' Renewable Portfolio Standards (RPS).

***Table 1*—HPX States' 2005 Loads & Resources (Source: DOE)**

CAPACITY (MW)	WYOMING	COLORADO	NEW MEXICO	ARIZONA	TOTAL	SHARE
Coal	5,847	4,928	3,957	5,430	20,162	41%
Oil & Gas	166	4,706	2,031	12,647	19,550	40%
Nuclear	0	0	0	3,875	3,875	8%
Hydroelectric	303	652	82	2,720	3,757	8%
Renewables	287	238	410	16	951	2%
TOTAL	6,707	11,087	6,480	24,904	49,178	100%
Growth @ 2%/yr to 2020	2,320	3,835	2,241	8,614	17,009	35%
RPS Requirements (UCS)	NA	2,396	1,282	2,004	5,682	
GENERATION (MWH)	**WYOMING**	**COLORADO**	**NEW MEXICO**	**ARIZONA**	**TOTAL**	**SHARE**
Coal	43,345,685	35,570,135	29,947,248	40,143,310	149,006,378	64%
Oil & Gas	367,277	11,940,336	4,224,127	28,936,475	45,468,215	20%
Nuclear	0	0	0	25,807,446	25,807,446	11%
Hydroelectric	808,375	1,415,296	164,993	6,410,064	8,798,728	4%
Renewables	717,264	810,561	799,274	73,995	2,401,094	1%
TOTAL	45,567,307	49,614,265	35,135,642	101,478,655	231,795,869	100%
CAPACITY FACTOR	**WYOMING**	**COLORADO**	**NEW MEXICO**	**ARIZONA**	**TOTAL**	
Coal	85%	82%	86%	84%	84%	
Oil & Gas	25%	29%	24%	26%	27%	
Nuclear	NA	NA	NA	76%	76%	
Hydroelectric	30%	25%	23%	27%	27%	
Renewables	29%	39%	22%	53%	29%	
AVERAGE	78%	51%	62%	47%	54%	
LOADS	**WYOMING**	**COLORADO**	**NEW MEXICO**	**ARIZONA**	**TOTAL**	
Megawatt Hours	14,137,727	48,353,236	20,638,951	69,390,686	152,520,600	
% of Generation	31%	97%	59%	68%	66%	

In contrast to capacity, generation was dominated by coal-fired plants, which comprised 64% of the generation and which operated at an average 84% capacity factor. Hydroelectric and renewable power sources together comprised only 5% of the HPX states' generation mix in 2005. These resources were used primarily as follows:

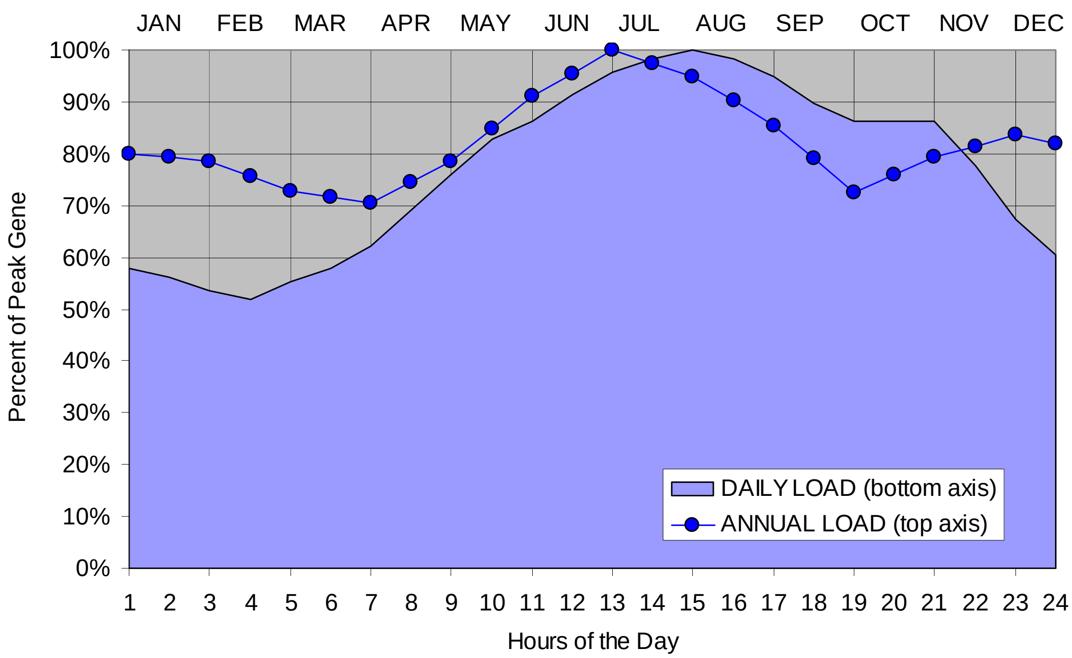
- Coal: Baseload dispatchable resource that is fully utilized
- Gas: Transitional to peaking dispatchable resource, some excess capacity?
- Nuclear: Baseload dispatchable resource that is fully utilized (Palo Verde)

- Renewables: Intermittent resource used when available (non-dispatchable)
- Hydro: Used when available (Spring runoff), limited by drought and other uses; minor pumped storage

The relationship between loads and generation for the HPX states provides an indication of the extent to which theses states participate in regional import/export power markets. The data would indicate that about one-third of the power generated in the HPX states is exported outside of the region (primarily to California), with Wyoming standing out as primarily an exporting state and Colorado as one in which its loads and resources are balanced (suggesting minimal current involvement in regional import/export power markets).

An approximation of the shape of the load profile for the HPX states on an hourly and monthly basis are shown in *Figure 2*[4]. As shown, the demand for electricity peaks during the daylight hours before dropping off gradually during the evening hours. Customer demand also peaks during the summer months, with a lesser peak near the end of the year. The low demand periods occur during the late evening and early morning hours and during the Spring and Fall seasons.

Figure 2: **Load Shapes for the HPX States**



[4] Hourly values from PSCo wind integration study; monthly values from WECC for Rocky Mtn. Power Area

IV. Transmission Studies

A. Basic Criteria and Methodology

This high level, conceptual transmission study evaluated power capacity levels of high voltage transmission alternatives that interconnected multiple points on the existing electrical system. The study considered impacts on the low voltage transmission system, but did not evaluate upgrades to address those issues.

This study consisted of traditional powerflow analysis and typical transmission planning methodologies were utilized. Post-transient, transient, and short-circuit studies were not performed. It is anticipated that those types of analyses may be done in subsequent phases of the initiative. System performance was evaluated based on system intact (N-0) and single contingency (N-1) conditions. In the WECC powerflow models, the region of interest consisted of powerflow areas 10 (Arizona), 14 (New Mexico), 70 (Public Service Company of Colorado), and 73 (Western Area Power Administration's Colorado/Missouri - WACM). The contingency analyses modeled outages of every element 230kV and above in these powerflow areas. Performance was documented through powerflow geographic diagrams and spreadsheets depicting element loadings. Element loadings were reported under contingency conditions if the loadings exceeded 100% of the elements emergency rating and if the loadings were 1% greater than the loadings in the benchmark simulations. Appendices B and C contains a listing of all of the contingencies that were run for this study.

Transmission alternatives were evaluated in the course of the Feasibility analysis. Since the objective was to interconnect the transmission with a number of energy resource zones to allow implementation of economic resources, studies were limited to Alternating Current (AC) alternatives. Direct Current (DC) transmission can be more economical to deliver large amounts of power over long distances from a single delivery point to a single point of receipt. However, it is not a favorable technology for accommodating numerous interconnection points due to high costs of AC/DC converter stations.

B. Study Models

This study utilized powerflow models that represented 2017 peak summer loading conditions. The base case modeling data was developed from the WECC 2015HS1-S case, which modeled 2015 Heavy Summer loading conditions. Participants reviewed the models and provided modifications to update case topology and increase loads to 2017 peak summer levels. No new generation resources were added to the starting point base case other than fully committed projects (except for Arizona)[5]. Imports from other areas were used to make up for any resource deficiencies that may have remained after adding fully committed projects.

[5] This Arizona generation addition did not have a significant impact on these study results, since once the High Plains Express project was added to the cases and the Arizona imports were increased, this new generation was no longer needed.

1. **Load and Resource Data**
   Table 2 below summarizes the benchmark load and generation in the regional powerflow areas before additional resources were added.

***Table 2*—Base Case Loads and Resources**

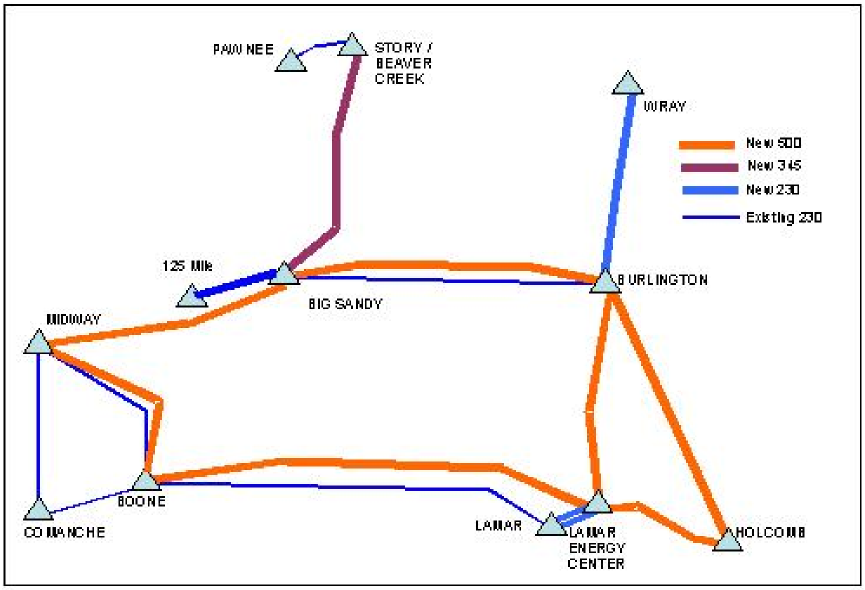
Powerflow Area	Load[6] (MW)	Generation (MW)	Imports (MW)
Wyoming (Area 73)	5,897	6,398	-501
Colorado (Area 70)	9,769	9,430	339
New Mexico (Area 10)	3,062	3,406	-344
Arizona (Area 14)	25,477	32,308	-6,831

2. **Regional Project Consideration**
   The base model included transmission and generation projects that utilities had relatively concrete plans put in service by the 2017 time frame. Other projects that were considered more conceptual were not represented in the study models.

   Significant transmission projects modeled in the base case include
   - The Eastern Plains Transmission Project (EPTP). At the time of this study, the EPTP was envisioned as a joint high-voltage project sponsored by Tri-State Generation and Transmission and Western Area Power Administration. The project consisted of over 300 miles of 230kV and 660 miles of new 500kV transmission in Kansas and eastern Colorado as shown in *Figure 3*. The EPTP modeling was included in the WECC base case, and left in the preliminary models for HPX studies. Subsequent sensitivity analyses were performed that modeled EPTP as an integral piece of HPX.

[6] Load includes customer load plus transmission losses.

Figure 3: **Eastern Plains Transmission Project**



Study handling of proposed, or conceptual regional projects

- The Wyoming – Colorado Intertie (WCI) Project is being considered by, TransElect, the Wyoming Infrastructure Authority, and Western. It has been planned as a single high voltage transmission line between Dave Johnston and Laramie River Station in Wyoming, and continuing south to the Pawnee Substation, located northeast of the Denver-metro area. Since the HPX contemplates having a transmission line from the Dave Johnston/LRS to the Pawnee area, this study considered the WCI to be an integral segment of the HPX. Therefore, a separate WCI project was not modeled.

- New Mexico Wind Collector System: Public Service Company of New Mexico has been evaluating conceptual transmission options that could deliver power from potential wind resource locations to load centers in the state or to adjacent transmission systems. No specific projects have been recommended to date, so there were no high-voltage collector system options modeled for the HPX studies. It is expected that the collector options, if pursued, will provide much of the same benefit as a comparable portion of the HPX project in New Mexico and will be designed to integrate and eliminate duplication.

- SunZia: The SunZia Southwest Transmission Project is contemplated as a 500kV transmission system that would run between southern New Mexico and southern Arizona. The SunZia Southwest Transmission Project would allow potential future development of power from renewable energy sources, such as geothermal, wind, and solar, to be transported by the

SunZia Project to the Arizona and New Mexico regional transmission systems. For this study, the SunZia project was considered to be an integral segment of the HPX. Therefore, a separate SunZia project was not modeled.

- TransWest Express Project: The TransWest Express project has been contemplated by the Arizona Public Service Company to deliver power from Wyoming resources to the Phoenix load center. The primary component of the project is a 500kV DC line, which would be routed west out of Wyoming, through Utah, and terminate either near Las Vegas, Nevada. The completion of the TransWest Express Project would provide Arizona and other western states increased capability to access electricity generated in Wyoming from coal, wind and other resources. At the time of this study, the TransWest project was conceptual in nature, primarily DC operation, and was geographically outside of the High Plains study region. Therefore, the TransWest was not modeled in the HPX study.

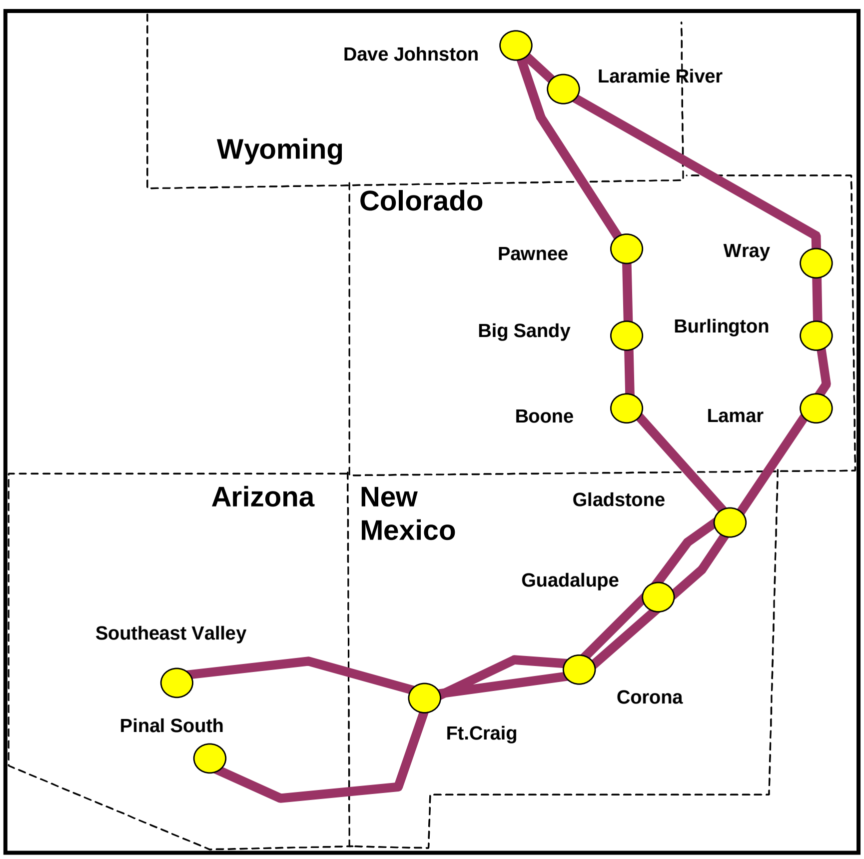
3. Interconnection Selection

Various interconnection points were evaluated in the four states within the HPX footprint in order to provide transmission access to potential resource zones. Wyoming has some of the highest potential in the nation for coal, natural gas, and wind resource development. Recent legislation in Colorado has resulted in the identification of several Energy Resource Zones that have the potential for renewable and other resource development. New Mexico also has regions where the interest in wind resource development is very strong. Based on an examination of the existing transmission system, potential resource zones, and major load centers, a list of interconnection points was developed. *Table 3* summarizes the interconnection points and the range of resource uploads modeled at each point. It also gives an indication of which points can be considered to be "downloads" for serving regional load. *Figure 4* shows the general geographic locations of the interconnections. It should be noted that the resource levels accommodated by the High Plains Express project are significantly less than the actual levels of requests for generator interconnection in each area, and less than what some documentation shows as potential renewable resource development. However, the levels were chosen to match the type of transmission envisioned for this project.

Table 3—**HPX Upload and Download Scenarios**

Interconnectio Points	**Upload (MW)**	**Download (MW)**	**Interconnection Points**	**Upload (MW)**	**Download (MW)**
Wyoming			**New Mexico**		
Laramie River	500-2000		Gladstone	300-750	
Dave Johnston	500-2000		Guadalupe	300-750	✓
Total Wyoming	1000-4000		Corona	300-750	
Colorado			Ft. Craig		✓
Pawnee	300-1000	☐	Luna		✓
Wray	300	☐	**Total New Mexico**	**900-2250**	**900-1000**
Big Sandy	300	☐	**Arizona**		
Burlington	300-500	☐	Pinal South		✓
Boone	300-500	☐	Southeast Valley		✓
Lamar	300-1000	☐	Springerville		✓
			Winchester		✓
Total Colorado	**1800-3400**	**1800-2500**	**Total Arizona**		**1000-4000**

Figure 4: **Transmission Modeling**



4. **Transmission Modeling**
   Once the interconnection locations were identified, potential transmission routing was determined in order to estimate mileages for the development of transmission models. Based on input from participants and the interconnection locations, the group agreed to model two corridors from Wyoming, through eastern Colorado, into New Mexico, south through central and south-central New Mexico and on to the load areas of Phoenix and Tucson (*Figure ES-1)*.

   Routing for each of these two corridors was determined by utilizing knowledge of where the resource and load development will likely occur to determine upload and download locations. Routing of the transmission lines between the various upload and download points was performed using input from the study participants as well as publicly available information on the locations of sensitive areas (e.g., Bureau of Indian Affairs lands, National Monuments, etc.). It should be emphasized that the routing assumed for this feasibility study is very preliminary and was only done to determine approximate transmission line distances. These distances were then used to determine the line parameters to input into the study model.

   Westerly Route: The western route started in Wyoming at the Dave Johnston Power Plant and ran through the Colorado interconnection points of Pawnee, Big Sandy, and Boone. From Boone the line continued into New Mexico and connected to Gladstone. In New Mexico, from Gladstone to just west of Ft. Craig, a transmission corridor common to both routes was modeled. Intermediate interconnection points were modeled at Guadalupe and Corona. From New Mexico the western corridor took a more northerly route to Arizona. This route would connect to the Springerville power plant in eastern Arizona and the continued on to the northeast Phoenix-metro area to an interconnection at Southeast Valley.

   Easterly Route: This route also began at the Dave Johnston Power Plant, but followed a more easterly route passing through Laramie River Station, and connecting to the eastern Colorado points of Wray, Burlington, and Lamar. From Lamar the line continued into New Mexico and connected to Gladstone. In New Mexico, from Gladstone to just west of Ft. Craig, the same transmission corridor was assumed as with the Westerly Route. Intermediate interconnection points were modeled at Guadalupe and Corona. The eastern corridor followed a route south from central New Mexico to southern New Mexico, then roughly followed I-10 west, and terminated southeast of the Phoenix-metro area at Pinal South. A potential variation of the easterly route was discussed that would stay in the eastern plains of New Mexico to southern New Mexico then head west to the El Paso area where the corridor would again roughly follow I-10. This alternative was not evaluated in the feasibility study, but would be expected to provide similar benefit if necessary to accommodate renewable resources in southeastern New Mexico.

The two transmission corridors and segment mileages for studies are summarized in *Table 4*.

***Table 4*—Transmission Mileages for Studies**

High Plains Express Line Segment Mileages							
Western Route				Eastern Route			
Starting Location	**Ending Location**	**Circuit**	**Miles**	**Starting Location**	**Ending Location**	**Circuit**	**Miles**
Dave Johnston	Beaver Creek	1	229	Dave Johnston	Laramie River Sta.	1	75
Beaver Creek	Big Sandy	1	61	Laramie River Sta.	Wray	1	208
Big Sandy	Boone	1	79	Wray	Burlington	1	60
Boone	Gladstone	1	140	Burlington	Lamar	1	81
Gladstone	Guadalupe	2	104	Lamar	Gladstone	1	156
Guadalupe	Corona	2	65	Gladstone	Guadalupe	1	104
Corona	Fort Craig	2	95	Guadalupe	Corona	1	65
Fort Craig	Springerville	1	167	Corona	Fort Craig	1	95
Springerville	Southeast Valley	1	180	Fort Craig	Luna	1	125
				Luna	Winchester	1	130
				Winchester	Pinal South	1	107
Total Mileage - Western (Approximate)			**1120**	**Total Mileage - Eastern (Approximate)**			**1206**

Total Mileage (Approximate)	**2326**

C. Benchmark Analysis

Once the powerflow base case model was established, some cursory analyses were performed to evaluate base system performance without any HPX transmission alternatives. With loads modeled at projected 2017 levels, the Arizonia powerflow area was deficient of sufficient generation resources. Therefore, fictitious generation was added west of the Phoenix area to meet resource requirements in the benchmarks analysis. This resulted in several performance issues in and around the Phoenix load center. The group recognized that these issues were associated with the modeling used to solve the initial case. The benchmark analyses also revealed several localized load-serving issues. These issues were documented so that they would not be considered to be problems associated with any proposed High Plains Express transmission additions.

D. Transmission Alternatives

The studies began with evaluating the capability of a single 500kV AC line and then moved to assessing the capabilities of two 500kV lines. Early studies modeled resource injections in Wyoming and moved the power straight through to Arizona by reducing the generation there (no resource additions were made in Colorado or New Mexico). Subsequent studies examined the various resource development scenarios in *Table 3* to see if these additional resources affected the overall transfer capability of the project. The level of resource injection along the transmission path was first adjusted so that the increase in generation matched the corresponding state's resource requirement. Therefore, the powerflow on each HPX transmission alternatives remained relatively constant throughout its length. Next, scenarios were developed that looked at increasing the level of up-load as the High Plains transmission progressed through the states. The flows on the High Plains transmission increased as the lines passed through each state. The two types of scenarios are depicted in *Figures 5 and 6*.

Figure 5: **Moderate Upload**

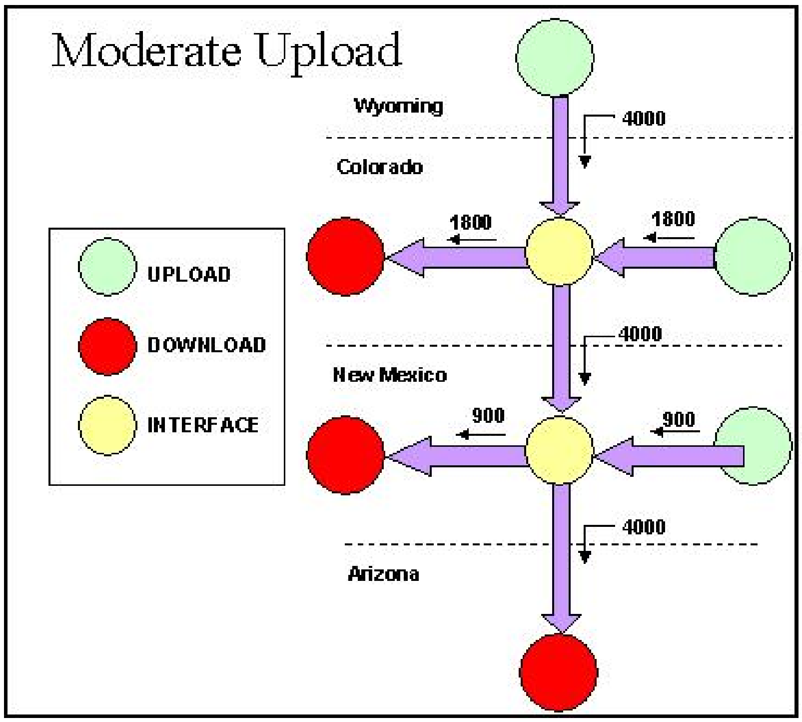
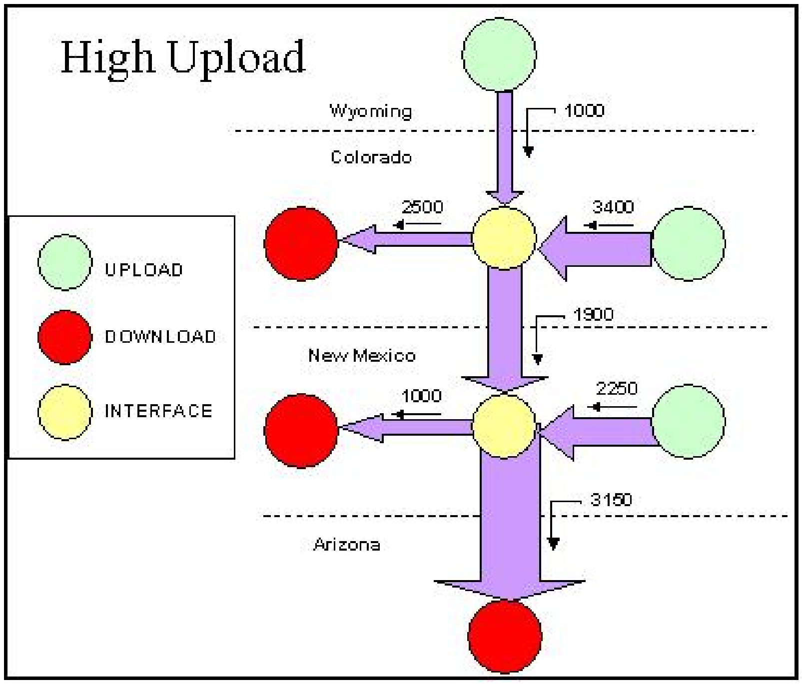


Figure 6: **High Upload**



After these resource development scenarios were examined, an ultimate build out scenario was reviewed that consisted of two double circuit 500 kV lines, one on the eastern route and one on the western route. This scenario was developed to provide information regarding the maximum feasible transfer capability that could be used to accommodate higher than expected resource development scenarios.

The final step involved evaluating potential synergies between the EPTP and High Plains Express to determine if combining the two projects along certain routes could result in similar performance while reducing the overall cost of both projects and reducing their combined environmental impacts.

E. Series Compensation

Initial studies evaluated transfer capabilities from Wyoming to Arizona without adding any series compensation to the High Plains transmission lines. After these transfer capabilities were determined, various levels of series compensation were introduced to asses what benefits could be provided, such as improved transfer capabilities and reduced system losses. Typically adding series compensation increases the amount of power that flows on the series compensated circuits. If these circuits have a lower resistance than the underlying system (which is usually the case), then overall system losses are reduced and more energy is available to serve end use customers. In addition to reducing losses, series compensation also reduces flows on the underlying transmission system, which can improve transfer capacity.

The series compensation analysis looked at three different levels of series compensation. The three levels examined were: no series compensation, 50% series compensation, and 70% series compensation. The series compensation was modeled on each individual High Plains transmission segment in equal percentages.

The analysis performed was a very basic study to determine if there were benefits to adding series compensation to the High Plains Express lines. Results were reviewed to see if any overloads were reduced or eliminated. If some overloads were reduced or eliminated for a particular level of series compensation, then it was assumed that additional transfer capacity would be available. The loss savings for this analysis are provided *Table 5*.

***Table 5*—Series Compensation Loss Savings**

Scenario	Transfers (MW)	Total Transmission Losses (MW)		
		0% Compensation	50% Compensation	70% Compensation
Western Corridor	2000	6726	6608	6636
Eastern Corridor	2000	6747	6685	6707
Two Lines	3000	6819	6730	6746

Even though the loss levels increased slightly when going from 50% series compensation to 70% series compensation, the results of the power flow analysis *(Appendix A)* indicate that higher transfer capacities may justify the higher levels of compensation. Therefore, 70% series compensation was used as the series compensation level for the remainder of the feasibility study.

It should be noted that additional studies will need to be undertaken before the final series compensation levels for each of the High Plains Express line segments is determined. This study assumed equal percentage compensation in all line segments. Some of the shorter line segments may not need compensation or the compensation for these segments may be able to be moved to other locations to reduce the overall project cost. Some of the additional studies noted above will be used to make this determination.

Summary results of the studies are provided below. Detailed results are provided in *Appendix A.*

1. **Results: Single 500 kV**

   After developing the base case, studies were run first on the single line scenarios to determine the maximum probable transfer capability from Wyoming to Arizona. Generation was added at Dave Johnston and Laramie River Station as appropriate and generation west of Phoenix at the Palo Verde/Hassayampa hub was reduced to accommodate the transfers. The results of these studies demonstrated that the easterly and westerly single line routes had roughly equal transmission capacity of 1000 to 1500 MW. These limits were based on overloads to the regional system for loss of the 500kV line segments.

In New Mexico, limits on the underlying 115 kV transmission system occurred with addition of the alternatives prior to adding transfers from Wyoming. For the westerly route, the overloads occur on the Gladstone-Springer 115 kV line and the Belen to Elephant Butte 115 kV line. For the easterly route, overloads occur only on the Gladstone-Springer 115 kV line. The addition of the alternatives with a tie at Gladstone creates a strong source at Gladstone resulting in base flows on the 115 kV lines that are close to a limit. Flows exceed the limit for outages of 345 kV and project line segments south of Gladstone. System improvements, protective schemes, or operating procedures would need to be implemented to address these overloads for the single line alternatives.

Series compensation of 50% and 70% was explored on the single 500 kV line scenarios. In New Mexico the contingency overloads for on the Belen-Elephant Butte 115 kV line with the westerly route were eliminated and overloads of the Gladstone-Springer 115 kV were significantly reduced for both routing alternatives. The Gladstone-Springer 115 kV loading reached 125% of rating for the worst single contingency with a transfer of 2000 MW and 70% series compensation.

2. **Results: Two Single-Circuit 500kV lines**

For the two single circuit studies, the two 500 kV lines on the eastern and western corridors were added to the model. Generation was added in equal amounts at Dave Johnston and Laramie River Station while generation was again reduced in Arizona at the Palo Verde/Hassayampa hub to accommodate the scheduled power transfers. The study results indicated that the two uncompensated 500 kV lines have a combined transfer capability somewhere between 1500 and 2000 MW.

The two line system integrated reasonably well with the New Mexico system, however, overloads of the Gladstone-Springer 115 kV line were observed when transfers from Wyoming to Arizona were increased to 1000 MW or more. The overloads are well below those observed with the single line systems and could potentially be addressed through protective schemes or operating procedures.

3. **Results: Two Single Circuit 500 kV Lines with 70% Series Compensation**

The addition of series compensation increased the flow on the HPX lines and reduced contingency impacts on the underlying system. Series compensation studies were performed for the two-line cases adding 70%

series compensation to the High Plains Express lines. The results of this analysis indicate that two 500 kV lines series compensated to 70% can allow a transfer capability of between 3500 and 4000 MW level, one HPX line exhibited the potential for overloads for an outage of a parallel HPX line.

In New Mexico, transfers of 3000 MW were accommodated prior to seeing contingency overloads of the Gladstone-Springer 115 kV line. At transfers of 3500 MW, the loading reached 114% of rating with 70% compensation under the worst single contingency. This should be manageable through RAS schemes or operating procedures.

4. Results: Renewable Generation Dispatch Scenarios

After performing sensitivity studies to evaluate series compensation for these modeling scenarios, additional studies were undertaken to determine what, if any, impacts additional uploads and downloads along the High Plains Express route would have on the transfer capability of the project. The various dispatch scenarios described in *Table 3* were run and detailed results are provided in *Appendix A*. For the most part, the impact of these dispatch scenarios on the overall transfer capability of the High Plains Express was minimal. However, in the situations involving significant renewables dispatched in New Mexico along with high Wyoming to Arizona transfers, some potentially significant impacts were observed. Because the uploads in the New Mexico system occur upstream of the downloads (e.g., at Gladstone, Guadalupe, and Corona), this dispatch creates fairly significant flows on the High Plains Express facilities even when no transfers are scheduled between Wyoming and Arizona. When through-transfers are added on top of this flow, overloads occur at transfer levels lower than without these uploads and downloads. Further analysis will need to be done in later phases of the project development cycle to see what reinforcements might be needed to mitigate this impact.

The results in New Mexico were generally favorable. Improvements to address overloads of the Gladstone-Springer 115 kV line are likely needed for scenarios where significant resource amounts are injected at Gladstone. The worse case contingency at project injections of 4000 MW resulted in loadings of 135% of rating. Some 115 kV loadings in the Albuquerque area were identified for certain combinations of upload and download. These overloads were largely due to dispatch assumptions to accommodate the project uploads and are not directly tied to the HPX addition. Contingency overloads of HPX project elements were found when project uploads above 3500 MW or more were modeled. The highest project loadings (118% of rating) occurred on the Fort Craig to Corona 500 kV lines for a contingency of the parallel line.

5. **Two Double-Circuit 500kV lines with 70% Series Compensation**
   A limited sensitivity analysis was performed to determine the transfer capability High Plains Express if each single circuit 500 kV line was replaced with a double circuit line. This analysis was performed using a case with 900 MW of renewable upload and download in New Mexico and 1800 MW of renewable upload and download in Colorado. Detailed results of this analysis are provided in *Appendix A*. The results of this sensitivity analysis indicated that two double-circuit 500kV transmission lines had the potential for 6500 to 7000 MW of transfer capability.

6. **EPTP Sensitivity Analysis**
   This analysis looked at possible synergies between the High Plains Express project and the EPTP. There is a possibility that combining the two projects in certain areas where the two projects have parallel routes could result in acceptable system performance while reducing the overall cost and environmental impact of both projects.

   The sensitivities examined looked at cases where the High Plains Express Big Sandy – Boone 500 kV line was removed and replaced with the Big Sandy – Midway – Boone 500 kV line that is proposed as part of the EPTP. In addition, the EPTP Burlington – Lamar 500 kV line was removed and the High Plains Express Lamar – Gladstone 500 kV line termination at Lamar was moved to the Energy Center 500 kV bus. These changes effectively removed approximately 80 miles of potentially duplicative transmission from the sensitivity cases.

   The detailed results of this sensitivity analysis are provided in *Appendix A*. It appears that there is a potential for some synergies between these two projects. There are some additional contingencies that cause overloads in this sensitivity. However, there are no new facilities overloaded and the maximum loading on each facility does not increase. Additional analysis will still need to be done, but there appears to be a potential to combine some of the facilities of the High Plains Express and the EPTP.

F. Results and Recommendations

- A single 500 kV transmission alternative could provide only 100-1500 MW of transfer capability.
- Two 500 kV transmission lines showed the potential for up to 4000 MW of transfer capability. Based on the results of the analyses, this is the minimum configuration to support a reasonable portion of the planned resource development in the region.
- In order to achieve 4000 MW, the HPX lines would have to include series compensation. Studies showed that 70% could be a level that would warrant further analysis.
- Two double-circuit 500 kV lines could provide up to 8000 MW of transfer capability.

- Based on the results, 345 kV transmission, would not be adequate to accommodate the long-term demands of the region. To improve initial economic performance as the HPX project develops; it may be necessary to initially operate segments or the HPX project at 345 kV.
- Separate transmission corridors are recommended to allow the interconnection of the dispersed resources proposed for development throughout the region and to provide for better transmission system reliability.

V. Cost Estimates

For the purpose of this analysis, estimates were developed based on several recent transmission studies (Frontier Line, Rocky Mountain Area Transmission Study). Those studies also focused on the feasibility of long-distance high voltage transmission lines. Consideration of these studies, updated with more recent information from the HPX participants, resulted in the cost assumptions noted below, which drove the overall estimate of HPX costs:

- Design and construction costs/mile on new Right-of-Way – for 500-kV = $1.5 million/mile
- New substation and upgrade requirements – new 500/230-kV substation = $60 million; upgrades = $8 million
- Series compensation costs - $20/kVAr – 3000 amp, 39 ohms per 100-mile line section – installed 35% at each end.
- Dynamic voltage requirements (Static VAr Compensators) – one per state - $35 million per location

The HPX Study overall costs:

- Two separate 500 kV AC lines
- $1.5 Mil/mile for 1,280 miles x 2 = $3.84 billion
- Substations (10 new/5 upgraded): $640 million
- Series Compensation: $512 million
- SVC: $140 million
- **Total Costs: $5.13 billion**

VI. Preliminary Routing

Preliminary routing for the High Plains Express project was performed to develop an estimate of the line lengths to use in calculating the transmission line parameters for the power flow analysis and to connect known renewable resource areas with load centers. In developing this routing, parallel transmission lines were considered where feasible and new rights-of-way (ROWs) were assumed where needed for reliability. This preliminary routing was performed using the following steps.

1. Gather non-confidential public information to determine the locations of potentially sensitive areas. Data was gathered primarily from the Geographic Information System (GIS) that was used to develop the map shown in *Figure ES-1*. Examples of the non-confidential public information used are:
   - Federal Lands,
   - Hydrology Features (rivers, streams, lakes),
   - Transportation Features,
   - State boundaries,
   - County boundaries, and
   - Cities.

2. In addition to non-confidential information, some confidential transmission data (CEII[7]) was used. This data was used primarily to locate the interconnection points between the High Plains Express project and the existing transmission grid. Examples of the confidential information used and the entity contributing it are:
   - SRP - Select Arizona transmission features (Substations, Transmission Lines) and Hydrology Features (rivers, streams, lakes),
   - PNM - New Mexico Substations and Transmission Lines,
   - Tri-State GT - Select WY, CO, NM substations and transmission lines as well as EPTP information, and
   - WAPA hard copy mapping data (which was used for reference purposes).

Once the above data had been collected, preliminary routes were then selected. Once these preliminary routes were established, the project study team was requested to help locate any additional sensitive area that might have been missed on the first draft. Based on input from the study team, the following additional areas were designated for avoidance:

- DOD Maneuver Area in Colorado,
- Santa Fe Trail, and
- BIA Lands.

The routes used for the technical studies documented in this report are shown in *Figure ES-1*.

[7] Critical Energy Infrastructure Information

VII. Economic Evaluation

The High Plains Express initiative is a concept for expanding markets for renewable energy, strengthening the region's transmission system, and providing economic benefits to the states of Wyoming, Colorado, New Mexico, and Arizona, including savings in power costs for customers in those states. Seven utilities, three state agencies, and an independent transmission company, have joined in this effort to consider the technical and economic aspects of the project's development.[8] The results of initial feasibility studies are presented below.

The HPX concept is to develop a high-capacity interconnected AC transmission project that would connect at substations within the states of Wyoming, Colorado, New Mexico, and Arizona (*Figure ES-1*). While several configurations were studied, the primary alternative evaluated herein consists of two 500 kV lines with a combined capacity of 3,500 MW that would materially expand the transmission linkages between the four HPX states. This system would provide power upload/download opportunities within each HPX state. It is contemplated that the primary power flows would be from northeast to southwest, although power flows in the reverse direction may also occur (but were not studied).

A preliminary assessment of the economic feasibility of the HPX project was conducted to get an indication as to whether the project is cost-effective. This was determined via a Benefit/Cost analysis in which the delivered cost of power including HPX transmission line costs was compared against the delivered cost of power not involving HPX. This determination was made using a newly-created screening tool developed by PG&E and the stakeholders to the Frontier Line feasibility assessment: FEAST (Frontier Economic Analysis Screening Tool). As described in the April 2007 Frontier Line Economic Analysis Subcommittee report (www.ftloutreach.com):

"FEAST is a simple tool for sophisticated users. It focuses on incremental resources, not a complete supply stack, and facilitates quantification of regional cost differences. FEAST is a screening tool, and is not intended as a substitute for necessary, in-depth analysis using production costing and/or market simulation tools."

A. Assumptions

A large number of input assumptions are used in the FEAST model. Since many of these are generic assumptions applicable throughout the West that were thoroughly vetted by the Frontier Line stakeholders, they have been used herein without modification, with the sole exception of resource capital costs which were adjusted to current values[9]. However, new input assumptions had to be devised for the HPX initiative to reflect the specific aspects of HPX and

[8] Colorado Springs Utilities, Platte River Power Authority, Public Service of New Mexico (PNM), Salt River Project, Trans-Elect, Tri-State G&T, Western Area Power Administration (Western), Xcel Energy, Colorado Clean Energy Development Authority (CEDA), New Mexico Dept. of Energy, Minerals & Natural Resources (NM-EMNR), and the Wyoming Infrastructure Authority (WIA)

[9] The Frontier Line used 2015 projected capital costs for resources that are 35% less than current costs.

the unique operating characteristics of the wind resources from the HPX states (*Table 6*). The wind assumptions used were based on NREL projections of wind performance, as follows:

- Wyoming: 48% capacity factor, 39% dependability (summer peak)[10]
- Colorado: 42% capacity factor, 28% dependability (summer peak)
- New Mexico: 40% capacity factor, 36% dependability (summer peak)
- Arizona: 30% capacity factor, 45% dependability (summer peak)

Table 6—FEAST Input Assumptions (Bus-Bar)

	RESOURCE CHARACTERISTICS & COSTS								LEVELIZED COST	
Plant Type	Heat-Rate BTU/kWh	Capacity Factor	Depend. Capacity Factor	Installed Cost $/kW	Fixed O&M* $/kW-Yr	Other Fixed* $/kW-Yr	Total $/kW-Yr	Variable O&M* $/MWh	Merchant Financing $/MWh	Utility Financing $/MWh
Coal - Arizona	8,860	85%	100%	2,633	47.2	109.8	400	1.7	75.5	68.0
Coal - Colorado	9,870	85%	100%	2,498	46.8	87.6	365	1.9	60.4	54.1
Coal - New Mexico	8,860	85%	100%	2,633	47.2	109.8	400	1.7	68.3	60.7
Coal - Wyoming	9,870	85%	100%	2,498	46.8	87.6	365	1.9	54.0	47.6
Gas - Combined Cycle	6,920	78%	100%	1,350	13.7	52.9	205	2.4	80.7	76.8
Solar Concentrating	NA	40%	100%	4,253	38.0	101.3	580	1.5	165.5	138.3
Wind - Arizona	NA	30%	45%	1,755	11.5	9.5	200	5.5	87.5	77.5
Wind - Colorado	NA	42%	28%	1,755	11.5	7.2	198	5.5	59.3	52.7
Wind - New Mexico	NA	40%	36%	1,755	11.5	7.2	198	5.5	62.0	55.1
Wind - Wyoming	NA	48%	39%	1,755	11.5	7.2	198	5.5	52.6	46.8

Input Cell   Calculation Cell

HPX transmission costs and line losses were supplied by the HPX study team based on input from the HPX utility participants, input from consultants, and assumptions developed in the Frontier Line studies. The configuration selected for economic feasibility analysis consisted of two 500 kV lines with a combined capacity of 3,500 MW. The estimated installed cost of this configuration is $5.132 billion. The breakdown of these costs for the segments linking each HPX state and associated estimated transmission tariffs (assuming utility financing) are presented in *Table 7*.

Table 7—HPX Transmission Components ($2007)

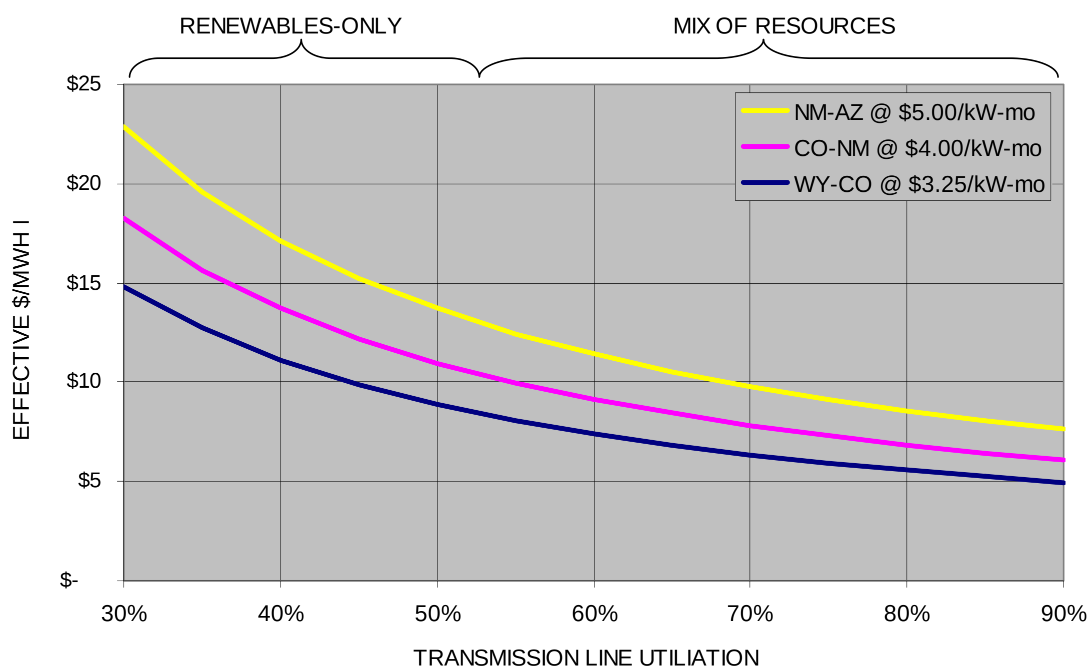
				Indicative Transmission Rates		
Segment	Ave. Miles	Cost ($MM)	Line Losses	$/kw-mo	$/MWh @ 40% Use	$/MWh @ 80% Use
Wyoming - Colorado	335	$1,366	2.4%	$3.21	$10.99	$5.50
Colorado - New Mexico	420	$1,680	3.1%	$3.94	$13.49	$6.75
New Mexico - Arizona	525	$2,087	3.8%	$4.90	$16.78	$8.39

[10] These Wyoming wind values were also used in the Frontier Line studies

B. Resource Delivery Costs

As an intermediate step before conducting the Benefit/Cost analysis for various resource mix scenarios, projections of delivered power prices were developed for each resource considered: pulverized coal, combined cycle gas, wind, and solar. These projections included the all-in generation cost (including a return) for each resource, plus an applicable transmission charge that assumed a 75% line utilization level. While such a utilization level (and associated effective $/MWh rates) would not be achieved by the renewable resources alone, it does provide an indication of HPX's effective rates if it were operated as an integrated transmission project that accommodates a mix of resources *(Figure 7)*. In the case of local resources (i.e., not delivered via HPX), no transmission charges were applied, although they may be involved.

***Figure* 7: Indicative HPX Segment Transmission Rates vs. Line Utilization**



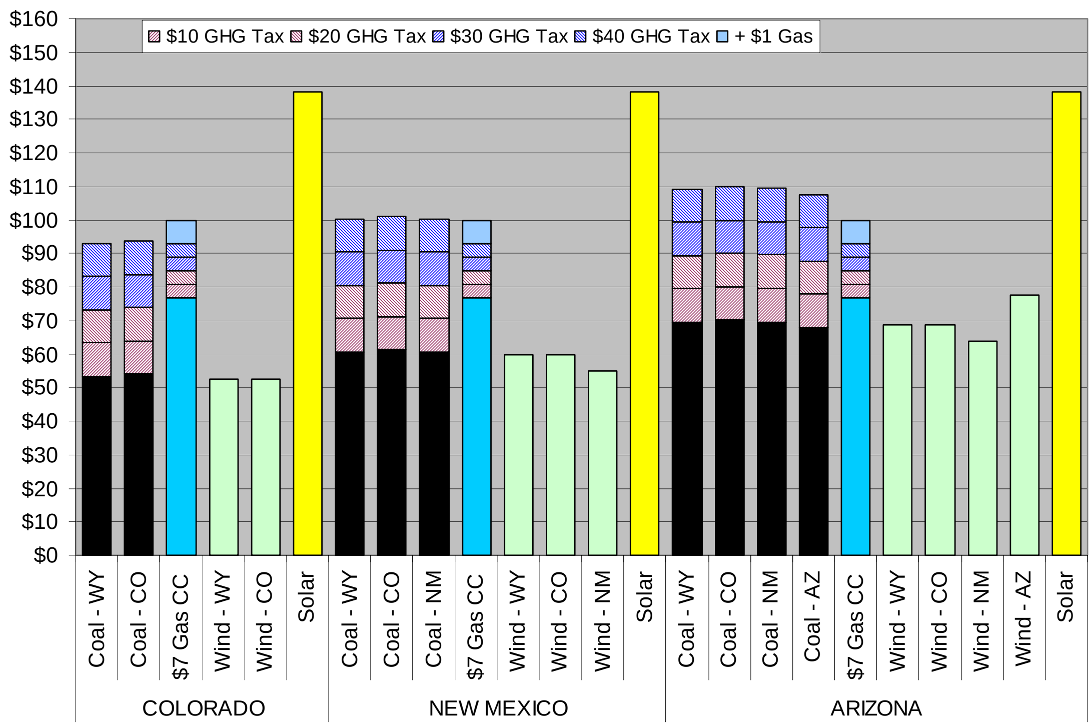
Projections were made for power delivered via HPX and compared against the projections for in-state resources (*Figure 8*). Subsidies currently available to the solar and wind industries[11] were not incorporated in the analysis, as those subsidies may change or be eliminated by HPX's proposed on-line date of 2017. In addition, the effect of varying "CO_2 tax" scenarios where modeled

[11] A Production Tax Credit (PTC) of $20/MWh is currently available to the wind industry (expiring in 2008), while the solar industry currently enjoys a 10% investment tax credit and accelerated depreciation over 5 years.

for the carbon-emitting resources (coal and gas) in $10/ton increments from $10/ton to $40/ton (*Figure 8*). The cost of integrating wind was not included in this part of the assessment, although a $3/MWh charge was applied in the FEAST Benefit/Cost analysis.

Assuming a 75% HPX utilization level, the results generally indicate that wind and coal are the lowest cost resources for each HPX state and that the delivered power costs gradually increase with proximity from Wyoming – regardless of whether they are supplied from in-state resources or delivered via HPX. However, the application of CO_2 taxes to the fossil resources materially tips the balance towards wind, with coal[12] affected more significantly than gas ($9.90/MWh and $4.00/MWh, respectively, for each $10/ton increment of CO_2 tax). Solar is the highest cost resource in all HPX states.

***Figure 8*: Estimated Resource Delivery Costs (75% transmission utilization) - $/MWh**



With regard to deliveries of wind, New Mexico wind offers the lowest delivered prices in both New Mexico and in Arizona, and Wyoming and Colorado wind offer similar delivered prices in each HPX delivery state (although higher than New Mexico wind for deliveries into New Mexico and Arizona). For coal, there don't appear to be any material differences in the delivered cost of coal within individual HPX states, whether it is delivered via

[12] Though not modeled herein, carbon separation and sequestration would materially reduce coal's CO_2 emissions and result in a $1.50/MWh penalty for each $10/ton increment of CO_2 tax.

HPX or is burned locally. For gas, only locally sited gas at $7/mmBtu was considered in this projection, with the effect of a $1/mmBtu change in gas prices also shown.

C. Scenarios & Modeling Approach

The six scenarios identified for FEAST modeling took into account both traditional and newly-emerging public policy agendas focused on fossil-based resources and renewable-based resources, respectively. As such, three renewable-dominated scenarios were developed and the results compared against two fossil-dominated scenarios and one "balanced" scenario involving near-equal amounts of energy from both resource categories.

In all of these cases, with the exception of the renewables-only scenario, HPX was modeled to meet the load requirements profile and achieve an average 75% utilization level. While this is readily achievable with fossil resources, which are "dispatchable" (coal and gas), it is a much greater challenge when material amounts of "non-dispatchable" renewable resources (wind and solar) are involved. Two of the renewable-dominated scenarios approached this problem by fist dispatching the HPX line's full capacity with renewables, and backfilling/firming with fossil resources in order to meet load requirements when renewable energy isn't available (the "renewables-first" scenarios). Such an approach is likely to involve many operational and economic challenges.

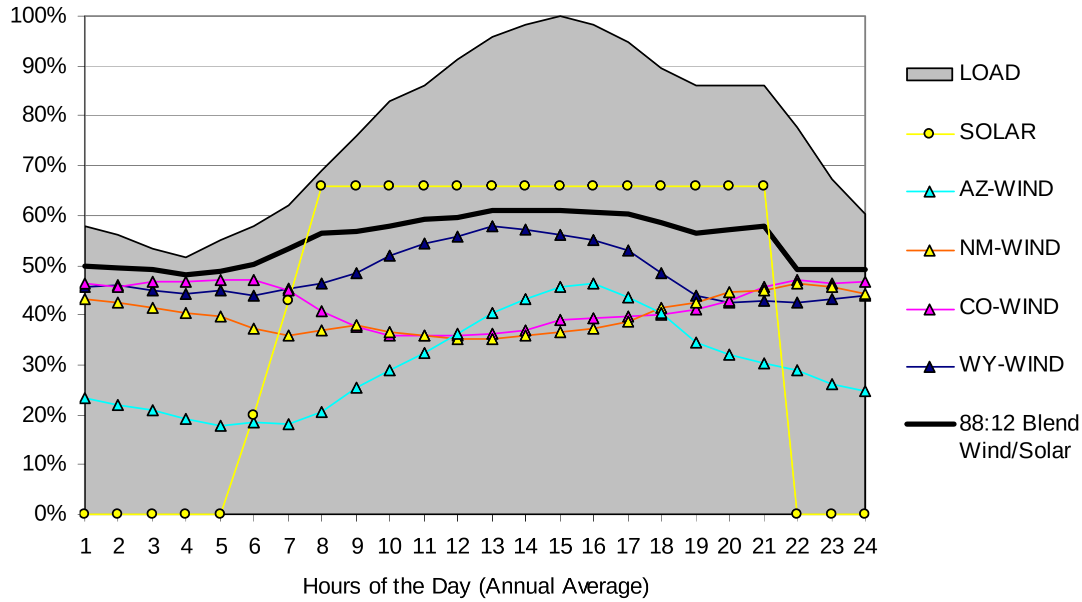
The use of FEAST to determine Benefit/Cost ratios involved the comparison of delivered power costs for a mix of resources delivered by HPX (including the cost of HPX) in comparison to a resource mix from in-state sources for each of the HPX states (i.e., a source vs. sink comparison). Sensitivity analyses were conducted for varying levels of CO_2 taxes ranging from $0/ton to $40/ton. Positive B/C ratios indicate that the benefits exceed the costs and HPX project feasibility. The six HPX source vs. sink scenarios evaluated herein are as follows:

1. Renewables Only vs. Fossil (50:50 Coal/Gas at Sink)
2. Renewables-First vs. Gas at Sink
3. Renewables-First vs. Fossil (50:50) + 20% Renewables at Sink
4. Coal + Renewables Firmed with Gas vs. Gas at Sink
5. Fossil (50:50 Coal/Gas) vs. Fossil (50:50) + 20% Renewables at Sink
6. Balanced (50:50 Fossil/Renewables) vs. Gas at Sink

All of the renewable scenarios involved the blending of renewable resources to take advantage of geographic diversity and matching up wind with solar during daylight hours when wind performance commonly drops off. This involved blending 500 MW of solar (including a short-term storage component) with wind from multiple sites within all of the "upstream" HPX states in which the wind component was "overbuilt" by 10%.[13] Such an approach yields an 88:12 wind/solar blend and is expected to reduce the intermittence of renewable resource and the amounts of dispatchable fossil resources needed to meet load requirements. The results of this approach are illustrated on an hourly and monthly basis in *Figures 9 and 10*, respectively.[14]

The hourly plot (*Figure 9*) would indicate that an 88:12 wind/solar blend will provide more power during the daylight peaking hours than the off-peak hours, thereby minimizing the amount of dispatchable fossil resources needed to meet load requirements. However, the monthly plot (*Figure 10*) suggests that there will be major shortfalls in renewable energy during the summer months that will have to be supplemented with significant amounts of dispatchable fossil resources to meet load requirements. This situation is illustrated by actual data from a 200 MW wind farm in New Mexico where there is a major mismatch between the wind farm's performance and Public Service of New Mexico's load requirements (*Figure 11*).

Figure 9: **Hourly Wind & Solar Performance vs. Load Requirement**



[13] This approach involves building more wind generation capacity than is available on a transmission line and results in higher transmission utilization and lower effective transmission rates, with any excess wind distributed via non-firm transmission paths on connected underlying transmission systems.

[14] Arizona's wind is not included in the solar/wind blend and is shown only for illustrative purposes. All wind projections are from NREL modeled for a 1.5 MW GE turbine at a 70 meter hub height.

Figure 10: **Monthly Wind & Solar Performance vs. Load Requirement**

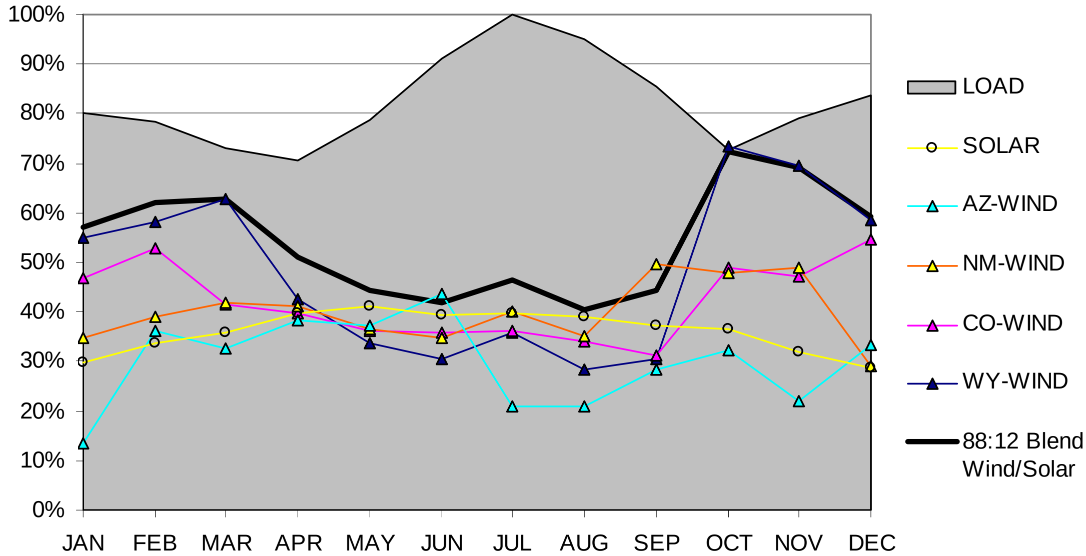
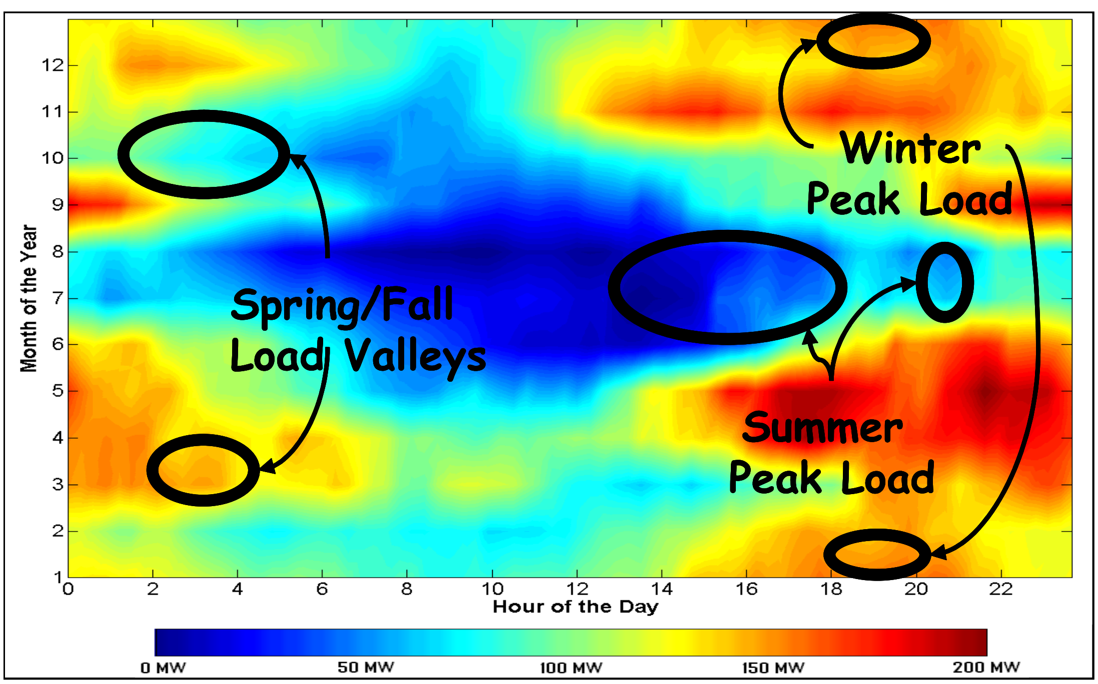


Figure 11: **Performance of a 200 MW New Mexico Wind Farm vs. PNM Load**



D. Results

The results of the FEAST Benefit/Cost analyses for the six scenarios modeled are summarized in *Table 8,* along with the savings/costs that would accrue to customers on an annual and $/MWh basis. Also listed are the resulting transmission line utilization levels and HPX resource mixes (energy basis) for each scenario. The two renewable-first scenarios yield a 75:25 energy mix for renewables/fossil generation. The scenarios that involve a mix of renewable and fossil resources yields a 75% utilization level for HPX, while the renewable-only scenario in which overbuilt wind supplemented with solar yields a 56% HPX utilization level.

The sensitivity analysis of CO_2 taxes indicates that the renewable-dominated scenarios perform progressively better at higher CO_2 taxes, while the reverse is true for the fossil-dominated scenarios (*Figure 12*). The balanced scenario appears to be the least affected by differences in CO_2 taxes and provides the most consistently positive B/C ratios of all scenarios considered. At low CO_2 taxes, the renewable-dominated scenarios do not perform well. The fossil-only scenario does not provide positive B/C ratios for any CO_2 tax scenario.

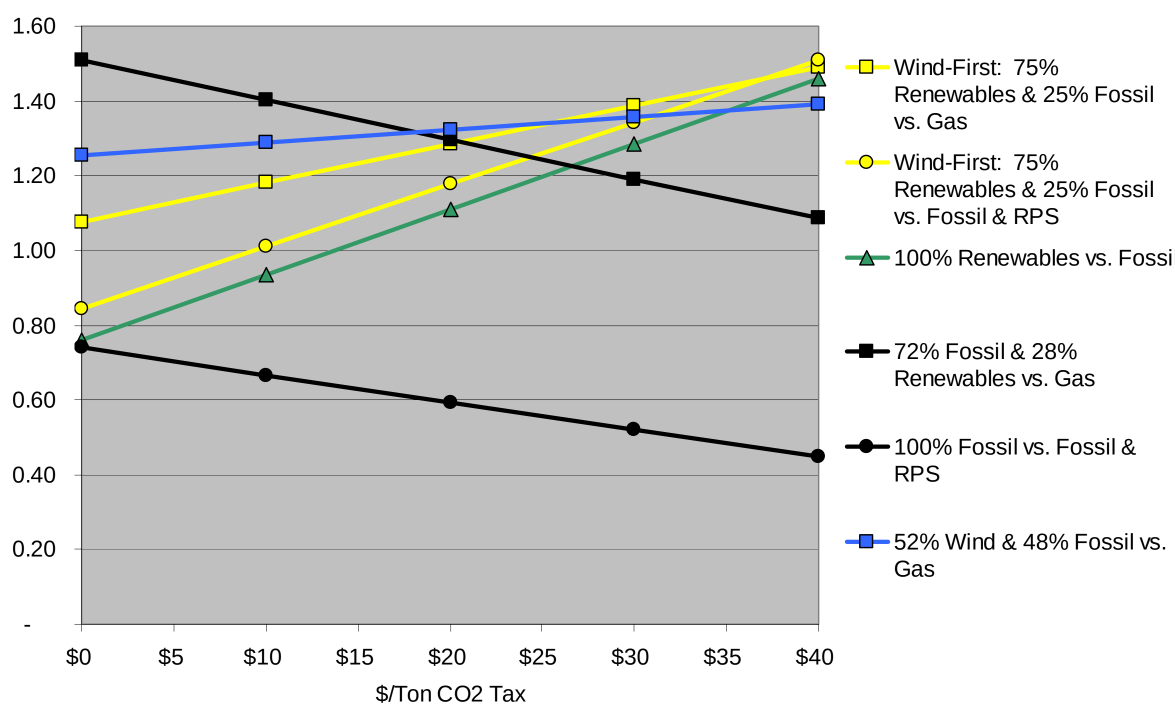
The B/C results would indicate that HPX would provide economic benefits to customers in the HPX states over a variety of resource mixes and CO_2 tax scenarios, with the sole exception of a fossil-only scenario. As such, HPX's economic feasibility appears to be sufficiently positive and consistent with emerging public policy to warrant further investigations, thereby justifying the advancement of the HPX initiative to Stage II feasibility studies.

Table 8—HPX Benefit/Cost Analyses Results

			HPX FEASIBILITY				HPX ENERGY MIX			
SOURCE	SINK	GHG	B/C	$MM/YR	$/MWH	UTLZ	WIND	SOLAR	COAL	GAS
RENEWABLES-ONLY	DISPATCHABLES (COAL/GAS)	$10	0.94	($32)	($1.87)	56%	90%	10%	-	-
		$20	1.11	$56	$3.21	56%	90%	10%	-	-
		$30	1.28	$144	$8.30	56%	90%	10%	-	-
		$40	1.46	$232	$13.36	56%	90%	10%	-	-
RENEWABLES-FIRST FIRMED WITH COAL & GAS	GAS	$10	1.18	$91	$3.97	75%	67%	8%	13%	12%
		$20	1.28	$144	$6.25	75%	67%	8%	13%	12%
		$30	1.39	$196	$8.52	75%	67%	8%	13%	12%
		$40	1.49	$248	$10.79	75%	67%	8%	13%	12%
RENEWABLES-FIRST FIRMED WITH COAL & GAS	DISPATCHABLES + 20% RPS	$10	1.01	$5	$0.24	75%	67%	8%	13%	12%
		$20	1.18	$90	$3.89	75%	67%	8%	13%	12%
		$30	1.34	$174	$7.55	75%	67%	8%	13%	12%
		$40	1.51	$258	$11.21	75%	67%	8%	13%	12%
COAL + RENEWABLES FIRMED WITH GAS	GAS	$10	1.40	$204	$8.86	75%	28%	-	61%	11%
		$20	1.30	$150	$6.53	75%	28%	-	61%	11%
		$30	1.19	$97	$4.20	75%	28%	-	61%	11%
		$40	1.09	$43	$1.88	75%	28%	-	61%	11%
50:50 RENEWABLES & DISPATCHABLES	GAS	$10	1.29	$146	$6.38	75%	52%	-	25%	23%
		$20	1.32	$163	$7.12	75%	52%	-	25%	23%
		$30	1.36	$180	$7.85	75%	52%	-	25%	23%
		$40	1.39	$197	$8.59	75%	52%	-	25%	23%
DISPATCHABLES-ONLY (COAL/GAS)	DISPATCHABLES + 20% RPS	$10	0.67	($169)	($7.33)	75%	-	-	52%	48%
		$20	0.59	($205)	($8.93)	75%	-	-	52%	48%
		$30	0.52	($242)	($10.53)	75%	-	-	52%	48%
		$40	0.45	($279)	($12.13)	75%	-	-	52%	48%

B/C <1 | 1.0 - 1.2 | 1.2 - 1.4 | > 1.4

Figure 12: HPX Benefit/Cost Analyses Results



STAKEHOLDER QUESTIONS AND RESPONSES

Q1. What is the planned generation resource mix for HPX?

- HPX is planned to enable renewable and other economic resource development.
- Dispatchable resources are needed to maximize transmission utilization to firm renewables.
- Studies indicate that economics (B/C ratios) are most favorable with renewable/fossil resource mix.
- Fossil only and Renewable-only scenarios were the least favorable.

Q2. Will solar power be a part of the HPX resource mix?

- At this time, solar is more expensive than wind resources. However, its availability during the times when wind generally isn't available supported its inclusion into HPX's resource mix for economic evaluation.
- The general route for HPX does not pass through solar regions in Colorado, but does in New Mexico. Transmission to accommodate Colorado solar will continue to be evaluated through SB07-100 studies.

Q3. Why is HPX needed?

- To meet a portion of the expanding energy needs in the region.
- To provide a cost-effective "pipeline" to access & deliver economic energy throughout the region.
- To expand markets for renewable power resources.
- To improve the reliability of the transmission grid.

Q4. Will the State Regulatory Authorities be asked to assist with rate recovery for HPX?

- To the extent that HPX serves/benefits native load.
- There will be merchant components, particularly for exports in excess of resources displaced by imports, which may require public policy support.

Q5. What is the role of State Transmission Authorities?

- Integral in planning and in public policy development and support.
- Potential role in cost recovery support.
- Potential source of low-cost financing backed by bonds.

Q6. Have routes been selected?

- Routes have NOT been selected – a process that will involve extensive public input prior to and during permitting activities. To date, only conceptual routing has been considered, which has been focused on intersecting major renewable resource zones within each affected state.

Q7. Will you consider avoidance of Military Training Facilities?

- HPX will seek input from the Military, as such activities are prevalent along potential HPX routes

Q8. Are you aware of sensitive habitat for species such as the Lesser Prairie Chicken in SE Colorado?

- Wildlife and vegetation habitat will be mapped and HPX routes devised to mitigate and avoid impacts
- Western Resource Advocates & WGA recently sponsored a wildlife/transmission planning workshop to coordinate activities

Q9. Is HPX competing with other sub-regional transmission plans?

- No. Participants in other sub-regional projects have indicated that the individual projects can be considered as “building blocks” of the HPX project. Although each project may be developed independently, coordination would be addressed through existing regional and sub-regional planning processes.

Q10. How will HPX interact with projects such as the TransWest Project?

- Although the Feasibility Study did not include TransWest or other “mega” projects, we expect that HPX will be complimentary.
- As each of these projects matures, interactions will be studied in more detail. WECC and other processes require such studies.

Q11. Will HPX compete with and/or preclude the development of in-state resources?

- HPX is likely to provide only a portion of each state’s energy needs, thereby leaving much to be supplied from in-state sources.
- HPX could enable the development of import/export markets for renewables, which don’t currently exist, thereby expanding markets for renewables.
- To some extent, HPX may facilitate the displacement of in-state fossil fuel development with renewables, although those resources will be needed to “firm” wind.

Q12. To what extent are there benefits for each HPX state?

- Wyoming: Exports of wind and associated economic development
- Colorado: Reduced power costs, blending with imported wind & downstream exports
- New Mexico: Reduced power costs, blending with imported wind & downstream exports
- Arizona: Reduced power costs and blending with imported wind

Q13. Did you consider DC Alternatives?

- While DC transmission lines may be cheaper, it is very difficult to identify benefits for parties/states along a DC line that wouldn’t have access to power carried on the line, unless expensive converters were installed
- DC does little to improve reliability to the region’s transmission grid

Q14. To what extent has generator tripping been considered in HPX planning?

- The intent has been to design a project that will not require generation tripping for most contingency conditions.

Q15. Did you consider 765 kV?

- Comment that Transwest studies indicated that for a cost increase of 25% could double capacity.
- There are no 765kV lines in WECC.
- Siting/Routing Issues
- Costs are disputed, since HPX is looking at many more interconnection points.
- Conclusion: Not a good technical alternative. Better chance of success with Double-circuit 500kV.

Q16. Why was solar upload not considered in Arizona?

- We recognize the potential for solar development in Arizona, but our focus was delivering power to Arizona.
- We did consider a significant amount of solar power in the resource mix for economic studies (10%).

Q17. In the Economic Studies, was the GHG adder in terms of metric tons or carbon equivalence (Steve Brown – PUC)?

- Not sure, but most likely metric tons of CO2.

Q18. Production cost credit carried though all years of study? (Ron Lehr – AWEA)

- Yes, it is planned to be gone in 2015, but may be renewed.

Q19. Did you make any assumptions regarding (fossil fuel) unit retirements? (Ron Lehr)

- No.

Q20. You should not assume that 2 500kV lines would increase the reliability of the system. (Inez Dominguez – CPUC)

- Studies performed using NERC/WECC criteria.
- If transfer capability is increased without impacting performance, reliability is improved.
- Jeff Mechenbier addressed Inez' comment later.

Q21. Did you consider that the cost of coal might increase over time? (Glustrom)

- Not for these studies.
- We also recognize that the cost of solar may decrease.
- Both of those factors would increase B/C of HPX.

Q22. You should call "dispatchable" resources "fossil fuel" resources. (Leslie Glustrom)

Q23. Can you assume that existing peaking plants would be used to firm the renewable (to increase the utilization) if they are already being used (to meet local load requirements)? (Craig Cox)

- Possible in some areas.

Q24. Have you involved all of the appropriate parties? Seems like potential purchasers are missing, including APS, SCE. (Doug Larson)

- APS and other entities have participated in the Studies Team.
- Will need to address additional participation in subsequent phases.

Q25. Will you post the slides?

- Yes

Q26. Have you studied interactions with Transwest?

- Not at this phase.
- Will address as projects become more defined.
- WECC processes.

➢ Please come to Baca County. We have the best wind in Colorado. (Peter Dawson – Commissioner in Baca County)

➢ Comment regarding military operations in Wyoming and Colorado.

 ➢ Addressed earlier.