What's That Transmission Line Worth?

Using AURORAxmp to Evaluate Transmission Expansion

September 10, 2008
2008 Electric Market Forecasting Conference
Stevenson, WA

Presentation Outline

I. Problem Formulation
II. Valuation Methodology
III. Implementation using AURORAxmp
IV. Select Study Results
V. Conclusions

Problem Formulation

Suppose …

that a developer has proposed a new transmission project

- 500 kV line between Wyoming and Southern Nevada
- Paintbrush Powerlink Project (named after Wyoming’s state flower)

Problem Formulation

Problem Formulation

- **The project is being advanced on the premise that there is an economic opportunity, i.e. that it would:**
  - Facilitate export of lower cost power to higher cost power areas
  - Facilitate large-scale development of the local resource potential
  - Facilitate lower cost compliance of state renewable portfolio standards (RPS), after accounting for system integration costs, line losses, and shaping
  - Provide other benefits such as improvements in grid reliability, fuel diversification, security of supply, etc.

Problem Formulation

- **Different analyses are needed to persuade different stakeholders:**
  - Creation of shareholder value
  - Ratepayer savings (ratepayers)
  - Regional market arbitrage opportunities (would-be usage rights holders)
  - Consistency with policy objectives and compliance with policy measures (policy-makers and regulators)
  - Environmental (air, land use, water, and vegetation and wildlife) benefits (environmental groups and siting and permitting agencies)

July 19, 2008

Texas Approves a $4.93 Billion Wind-Power Project

Problem Formulation

FitchRatings KNOW YOUR RISK

Corporate Finance

Global Power/North America
Special Report

Frayed Wires: U.S. Transmission System Shows Its Age

Analysts
Karen L. Anderson
+1 312 368-3165
karen.anderson@fitchratings.com

Denise Furey
+1 212 908-0672
denise.furey@fitchratings.com

Karima Omar
+1 212 908-0592
karima.omar@fitchratings.com

■ Overview

The U.S. electric transmission system consists of more than 150,000 miles of high-voltage transmission lines that link generators to load centers within three major regions — the Eastern Interconnection, the Western Interconnection and the Electric Reliability Council of Texas (ERCOT). Within these interconnections, more than 140 control areas manage electricity operations for local areas and coordinate reliability through eight reliability councils. The network was built in large part

canada.com WHERE PERSPECTIVES CONNECT

Powerlines plan a must

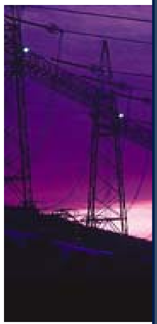
Build top five projects or risk huge losses

Paul Luke
The Province

Tuesday, July 22, 2008

Failure to build the top five planned transmission-line projects in the Pacific Northwest could cost the region $55 billion to $85 billion annually in economic activity and nearly 1.8 million jobs over 30 years, a new report says.

The region will also face a greater likelihood of rolling brownouts or blackouts from congestion of the existing grid if the lines don't proceed, according to the report released yesterday at a meeting of the Pacific NorthWest Economic Region in Vancouver.



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Competition would not be strong enough to keep regional power costs down and ratepayers would have a higher likelihood of rate increases if the lines were not built,
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United States Department of Energy
Office of Public Affairs
Washington, DC 20585

NEWS MEDIA CONTACT:
Julie Ruggiero, (202) 586-4940

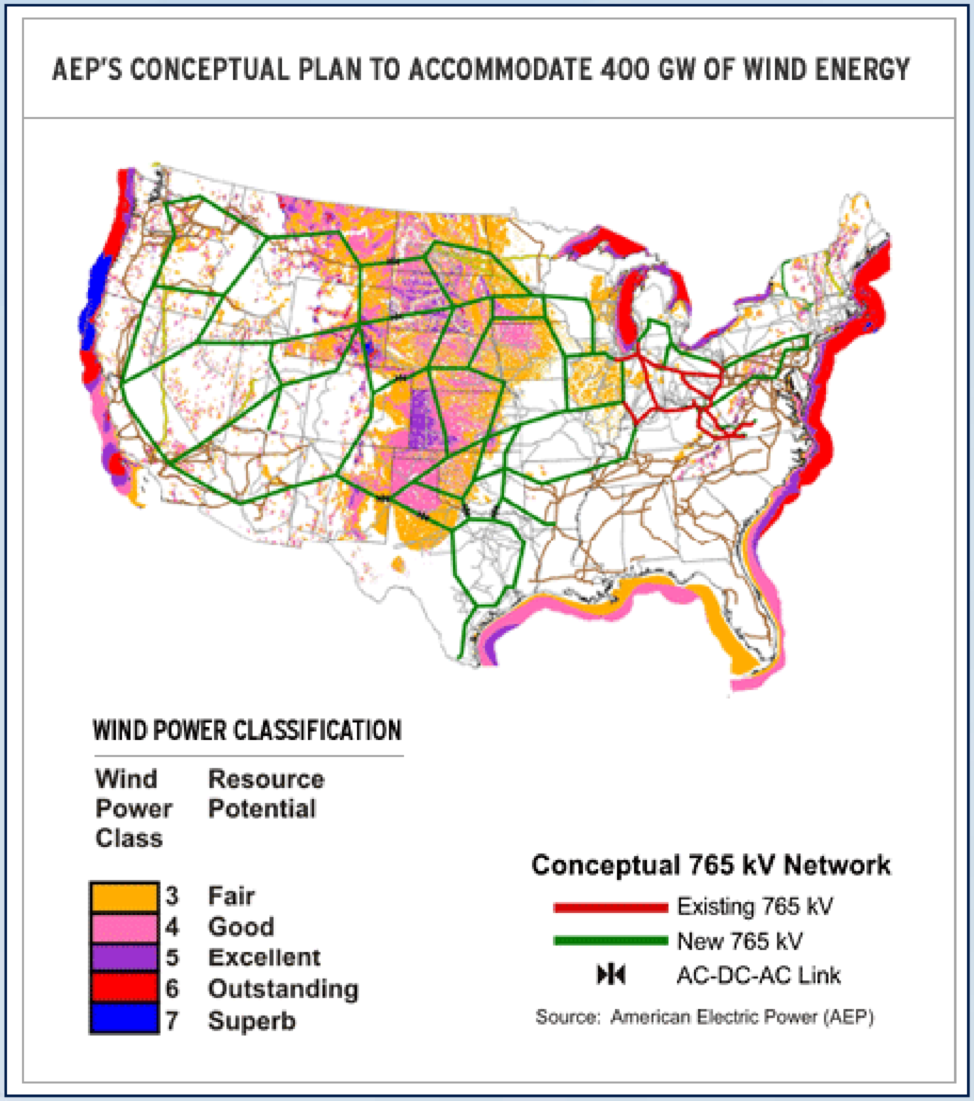
FOR IMMEDIATE RELEASE
Tuesday, October 2, 2007

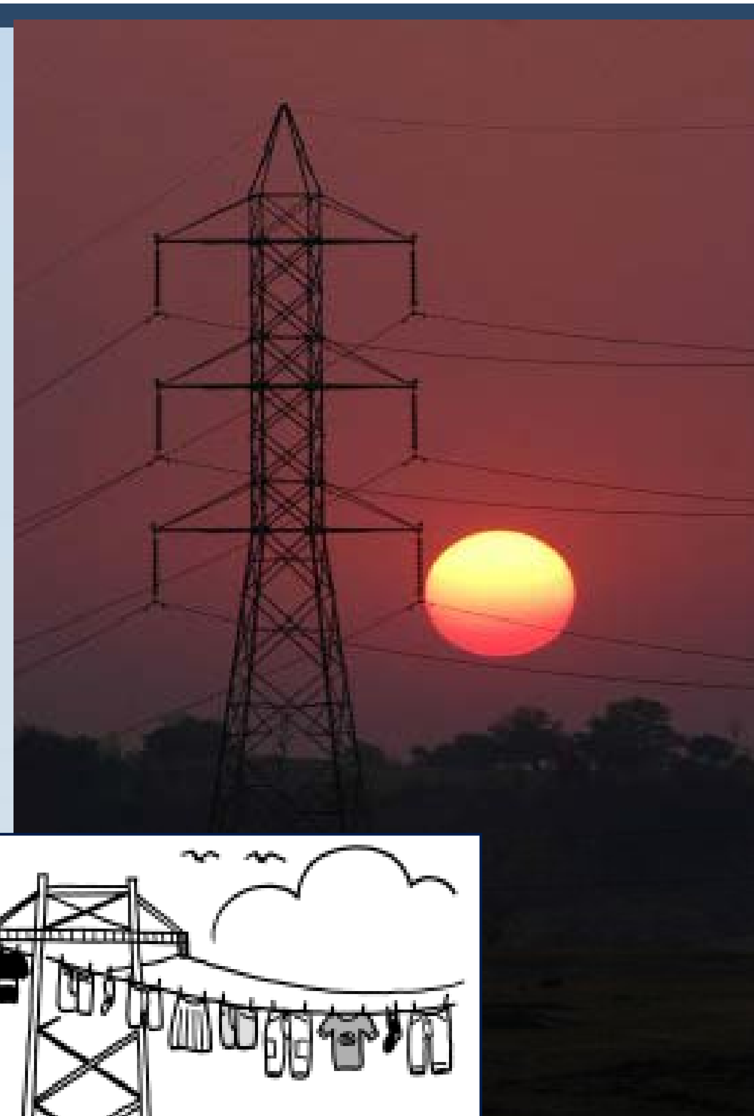
DOE Designates Southwest Area and Mid-Atlantic Area National Interest Electric Transmission Corridors

WASHINGTON, DC – U.S. Department of Energy (DOE) Assistant Secretary for Electricity Delivery and Energy Reliability Kevin M. Kolevar today announced the Department's designation of two National Interest Electric Transmission Corridors (National Corridors) -- the Mid-Atlantic Area National Interest Electric Transmission Corridor, and the Southwest Area National Interest Electric Transmission Corridor. These corridors include areas in two of the Nation's most populous regions with growing electricity congestion problems. The Department based its designations on data and analysis showing that persistent transmission congestion exists in these two areas.

Power line benefits downsized; project expected to save customers $85 million a year, not $447 million

Problem Formulation





Valuation Methodology

- **For the purposes of this study, our focus is on demonstrating value to the ratepayer, e.g., as part of a CPCN application**
- **We further focus on one piece of the value proposition: the potential benefits associated with facilitating export of low cost power and increasing grid efficiency**
  - We will refer to these benefits as energy benefits
- **We will not consider the larger benefit set, nor the costs, of our hypothetical transmission project**
  - Energy benefits are additive to any other quantifiable benefits (such as those that might be had by facilitating lower cost achievement of state RPS targets)
  - The total expected project benefits can then be compared against the cost of developing the transmission project (and expected O&M)

Valuation Methodology

- **We will look at a change in cost to load (i.e. consumer surplus) to all U.S. ratepayers within the WECC**
  - Cost To Load = SUM ($Load_i$ * LMP_i) for load bus i=1,…,n in WECC
  - We will not consider changes in generator profitability or changes in congestion costs as components of the PBPL energy benefit, although this could readily be done
- **Explore PBPL value over various futures through scenario and stochastic analysis**
  - We are -- in a sense -- trying to bridge the analytical gap between resource planning and transmission planning methods
  - For purposes of this study, we consider random forced outages and load volatility only

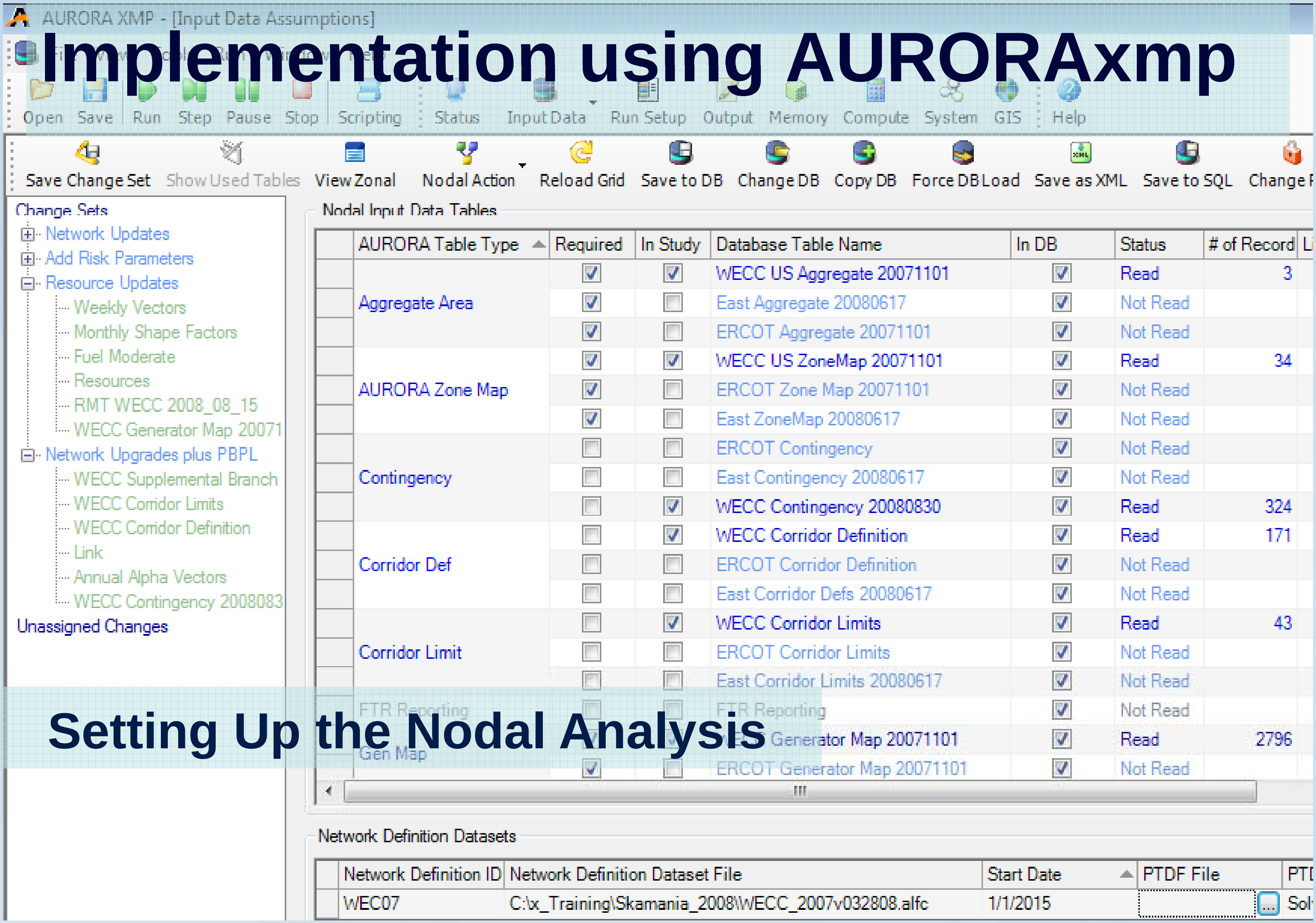
Valuation Methodology

- **We want to use a well calibrated zonal model as well as a more detailed network model**
- **The use of the network model allows for a better representation of the power flows in a transmission system**
  - In particular, want to explore benefits under N-1 conditions, i.e. via security constrained optimal power flow (SCOPF)
- **Explore one or more representative years, interpolate and extrapolate the rest**
  - Building a network model for each year of the study horizon would be extremely burdensome
  - The further one goes out the more grandiose the set of assumption
  - Likely to provide no more than an illusion of accuracy
- **Fruit of analysis is deterministic and stochastic expected energy benefits from PBPL**
  - Will not take further step to determine cost-effectiveness or explore alternatives

Implementation using AURORAxmp

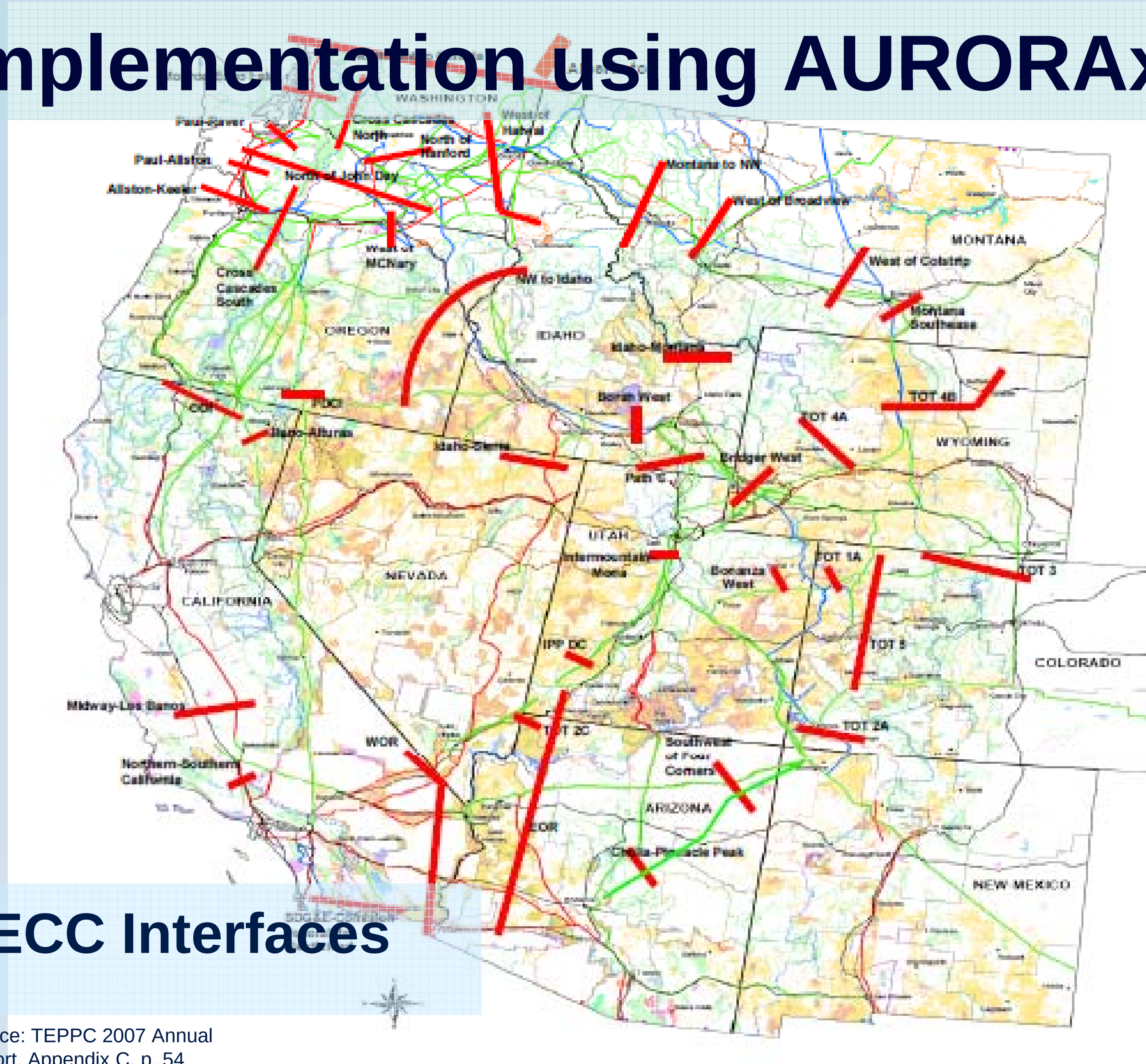
- **We need a tool for our energy benefits analysis with the following capabilities:**
  - Network model and power flow optimization
  - Detailed generator representation for commitment and dispatch
  - Ability to treat key value drivers as random (stochastic) variables
  - Advanced data management capabilities and scenario handling
  - Quick simulation turn around times
  - A tried and true (i.e. proven) solution
- **What do you say, ?**

Implementation using AURORAxmp



Setting Up the Nodal Analysis

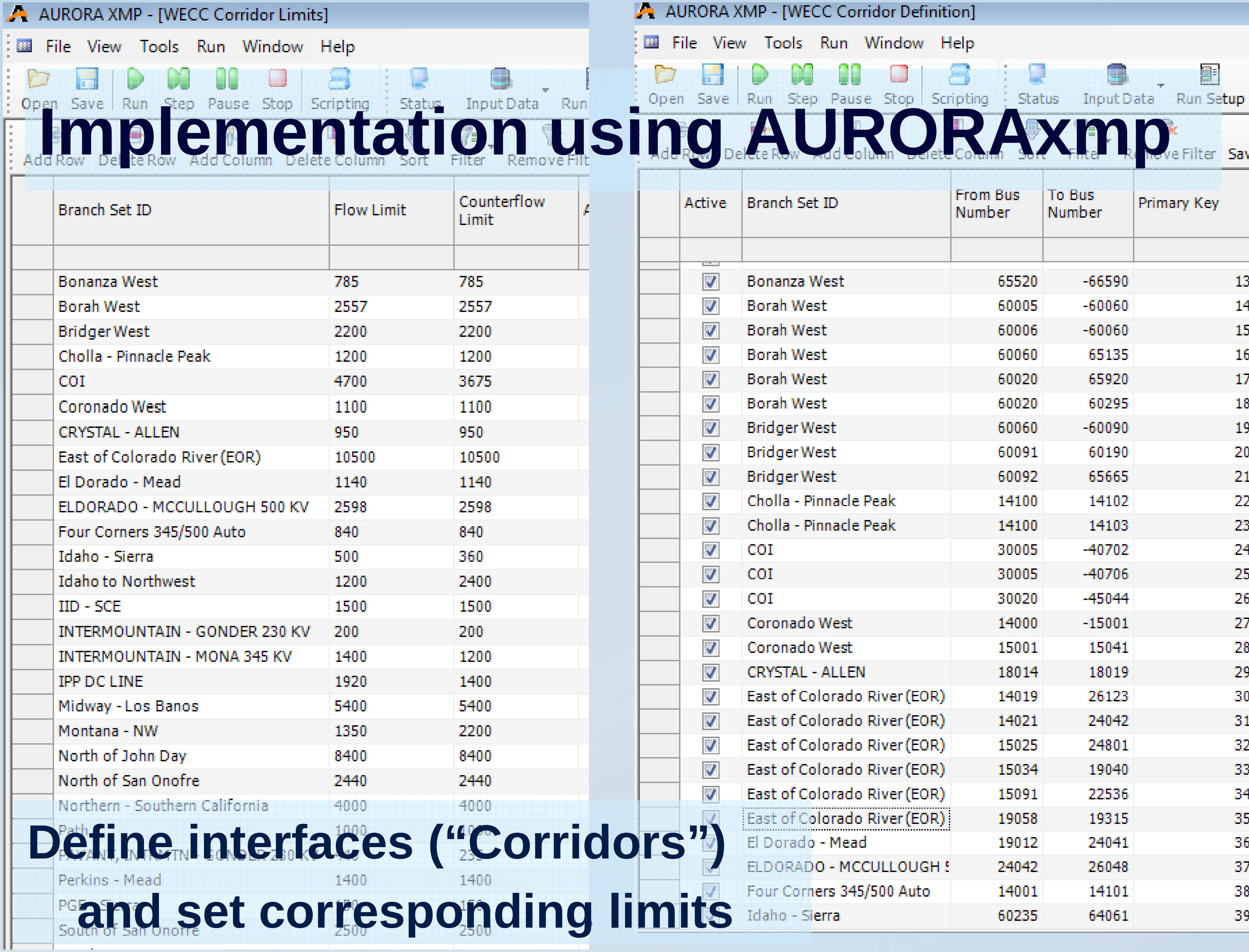
Implementation using AURORAxmp



WECC Interfaces

Source: TEPPC 2007 Annual Report, Appendix C, p. 54

Implementation using AURORAxmp



AURORA XMP - [WECC Corridor Limits]

File View Tools Run Window Help

Open Save Run Step Pause Stop Scripting Status Input Data Run

Add Row Delete Row Add Column Delete Column Sort Filter Remove Filt

Branch Set ID	Flow Limit	Counterflow Limit
Bonanza West	785	785
Borah West	2557	2557
Bridger West	2200	2200
Cholla - Pinnacle Peak	1200	1200
COI	4700	3675
Coronado West	1100	1100
CRYSTAL - ALLEN	950	950
East of Colorado River (EOR)	10500	10500
El Dorado - Mead	1140	1140
ELDORADO - MCCULLOUGH 500 KV	2598	2598
Four Corners 345/500 Auto	840	840
Idaho - Sierra	500	360
Idaho to Northwest	1200	2400
IID - SCE	1500	1500
INTERMOUNTAIN - GONDER 230 KV	200	200
INTERMOUNTAIN - MONA 345 KV	1400	1200
IPP DC LINE	1920	1400
Midway - Los Banos	5400	5400
Montana - NW	1350	2200
North of John Day	8400	8400
North of San Onofre	2440	2440
Northern - Southern California	4000	4000
Path [illegible]	1000	[illegible]
PAVANT, INTRMTN - GONDER 230 KV	[illegible]	235
Perkins - Mead	1400	1400
PGE - Sierra	[illegible]	[illegible]
South of San Onofre	2500	2500

AURORA XMP - [WECC Corridor Definition]

File View Tools Run Window Help

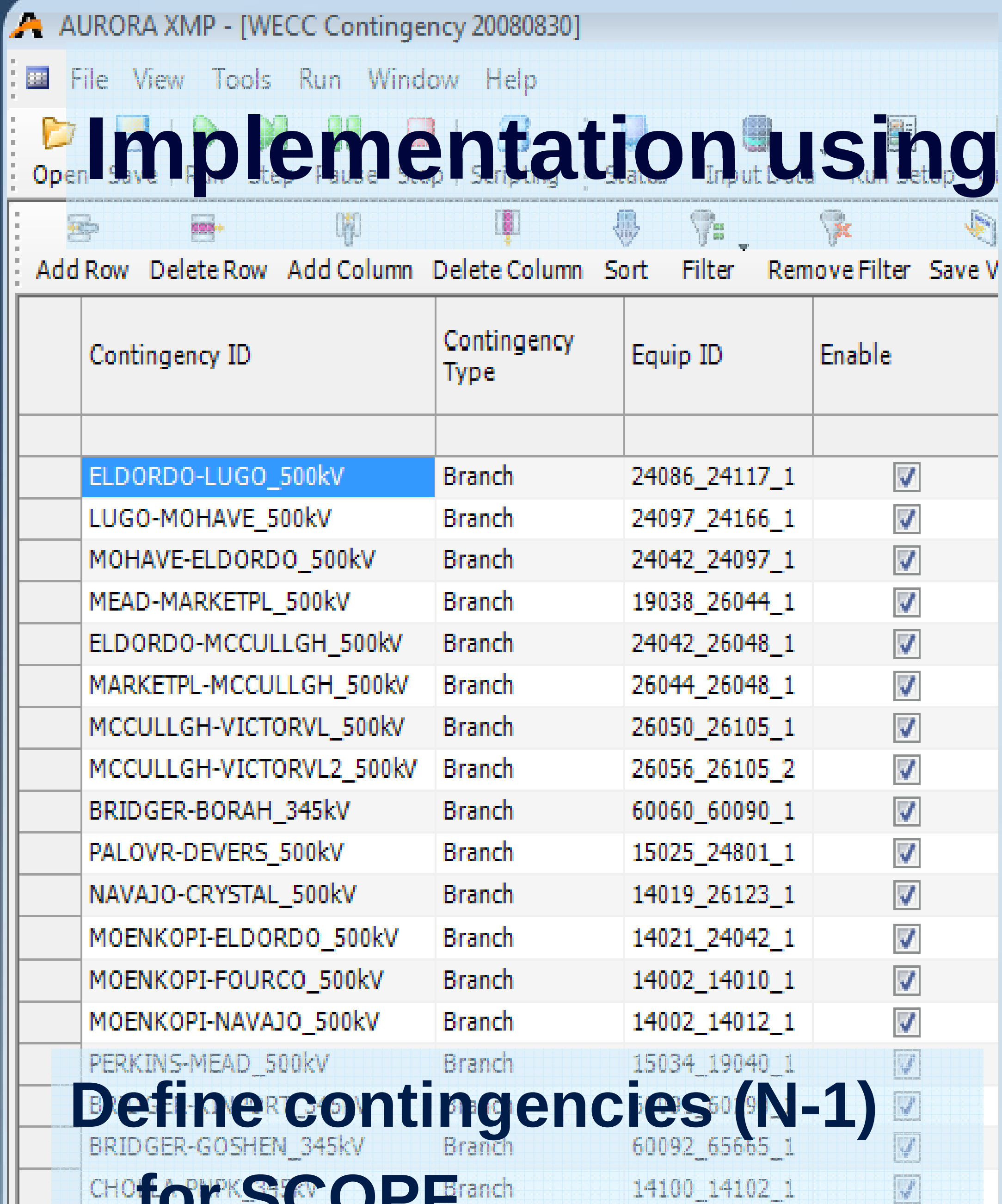
Open Save Run Step Pause Stop Scripting Status Input Data Run Setup

Add Row Delete Row Add Column Delete Column Sort Filter Remove Filter Save

Active	Branch Set ID	From Bus Number	To Bus Number	Primary Key
☑	Bonanza West	65520	-66590	13
☑	Borah West	60005	-60060	14
☑	Borah West	60006	-60060	15
☑	Borah West	60060	65135	16
☑	Borah West	60020	65920	17
☑	Borah West	60020	60295	18
☑	Bridger West	60060	-60090	19
☑	Bridger West	60091	60190	20
☑	Bridger West	60092	65665	21
☑	Cholla - Pinnacle Peak	14100	14102	22
☑	Cholla - Pinnacle Peak	14100	14103	23
☑	COI	30005	-40702	24
☑	COI	30005	-40706	25
☑	COI	30020	-45044	26
☑	Coronado West	14000	-15001	27
☑	Coronado West	15001	15041	28
☑	CRYSTAL - ALLEN	18014	18019	29
☑	East of Colorado River (EOR)	14019	26123	30
☑	East of Colorado River (EOR)	14021	24042	31
☑	East of Colorado River (EOR)	15025	24801	32
☑	East of Colorado River (EOR)	15034	19040	33
☑	East of Colorado River (EOR)	15091	22536	34
☑	East of Colorado River (EOR)	19058	19315	35
☑	El Dorado - Mead	19012	24041	36
☑	ELDORADO - MCCULLOUGH 5	24042	26048	37
☑	Four Corners 345/500 Auto	14001	14101	38
☑	Idaho - Sierra	60235	64061	39

Define interfaces ("Corridors") and set corresponding limits

Implementation using AURORAxmp

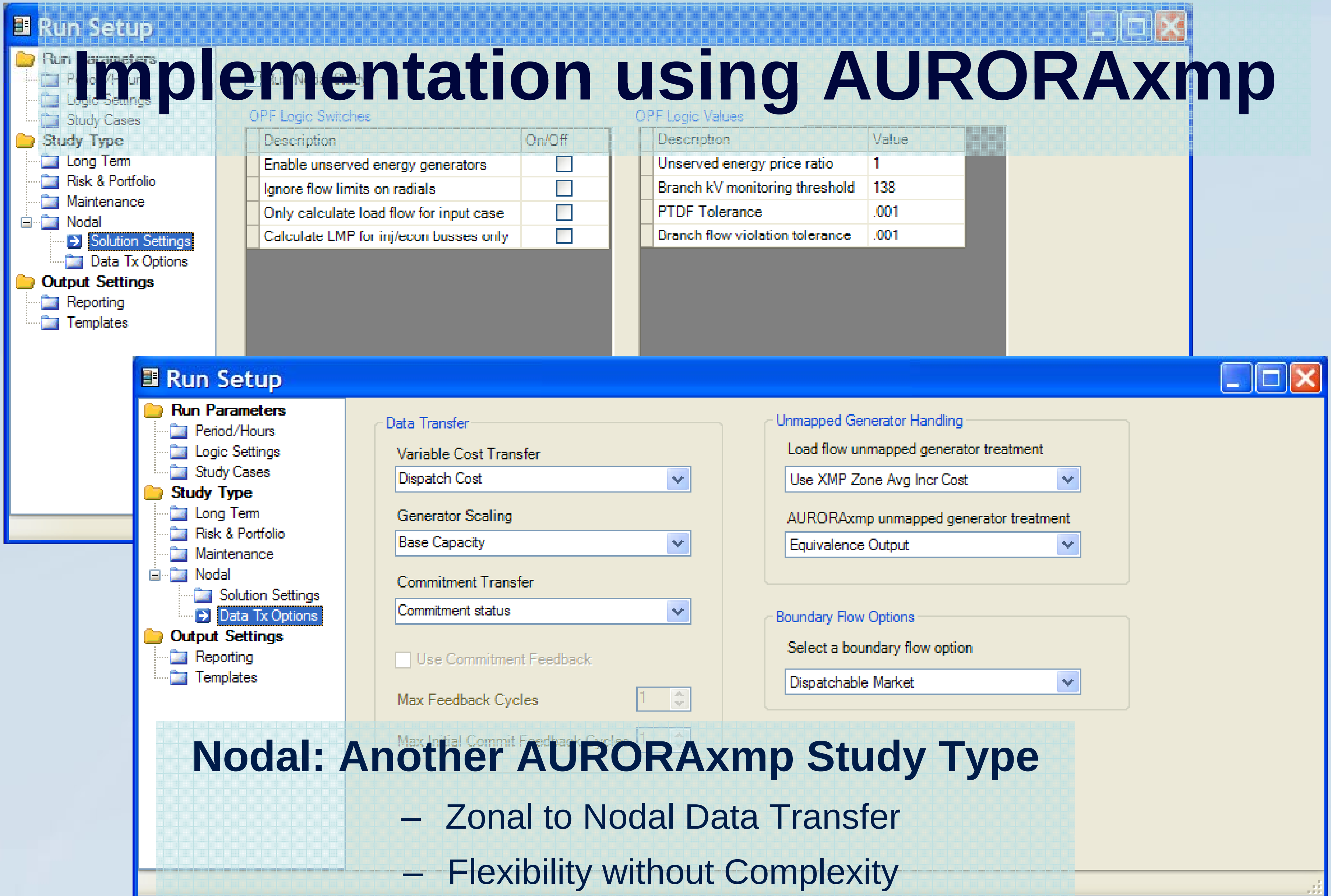


Contingency ID	Contingency Type	Equip ID	Enable
ELDORDO-LUGO_500kV	Branch	24086_24117_1	☑
LUGO-MOHAVE_500kV	Branch	24097_24166_1	☑
MOHAVE-ELDORDO_500kV	Branch	24042_24097_1	☑
MEAD-MARKETPL_500kV	Branch	19038_26044_1	☑
ELDORDO-MCCULLGH_500kV	Branch	24042_26048_1	☑
MARKETPL-MCCULLGH_500kV	Branch	26044_26048_1	☑
MCCULLGH-VICTORVL_500kV	Branch	26050_26105_1	☑
MCCULLGH-VICTORVL2_500kV	Branch	26056_26105_2	☑
BRIDGER-BORAH_345kV	Branch	60060_60090_1	☑
PALOVR-DEVERS_500kV	Branch	15025_24801_1	☑
NAVAJO-CRYSTAL_500kV	Branch	14019_26123_1	☑
MOENKOPI-ELDORDO_500kV	Branch	14021_24042_1	☑
MOENKOPI-FOURCO_500kV	Branch	14002_14010_1	☑
MOENKOPI-NAVAJO_500kV	Branch	14002_14012_1	☑
PERKINS-MEAD_500kV	Branch	15034_19040_1	☑
[illegible]	Branch	[illegible]	☑
BRIDGER-GOSHEN_345kV	Branch	60092_65665_1	☑
[illegible]	Branch	14100_14102_1	☑

Define contingencies (N-1) for SCOPF

SCOPF study: No single element loaded (1) above its normal continuous thermal rating under pre-contingency conditions or (2) above its emergency ratings under contingency conditions

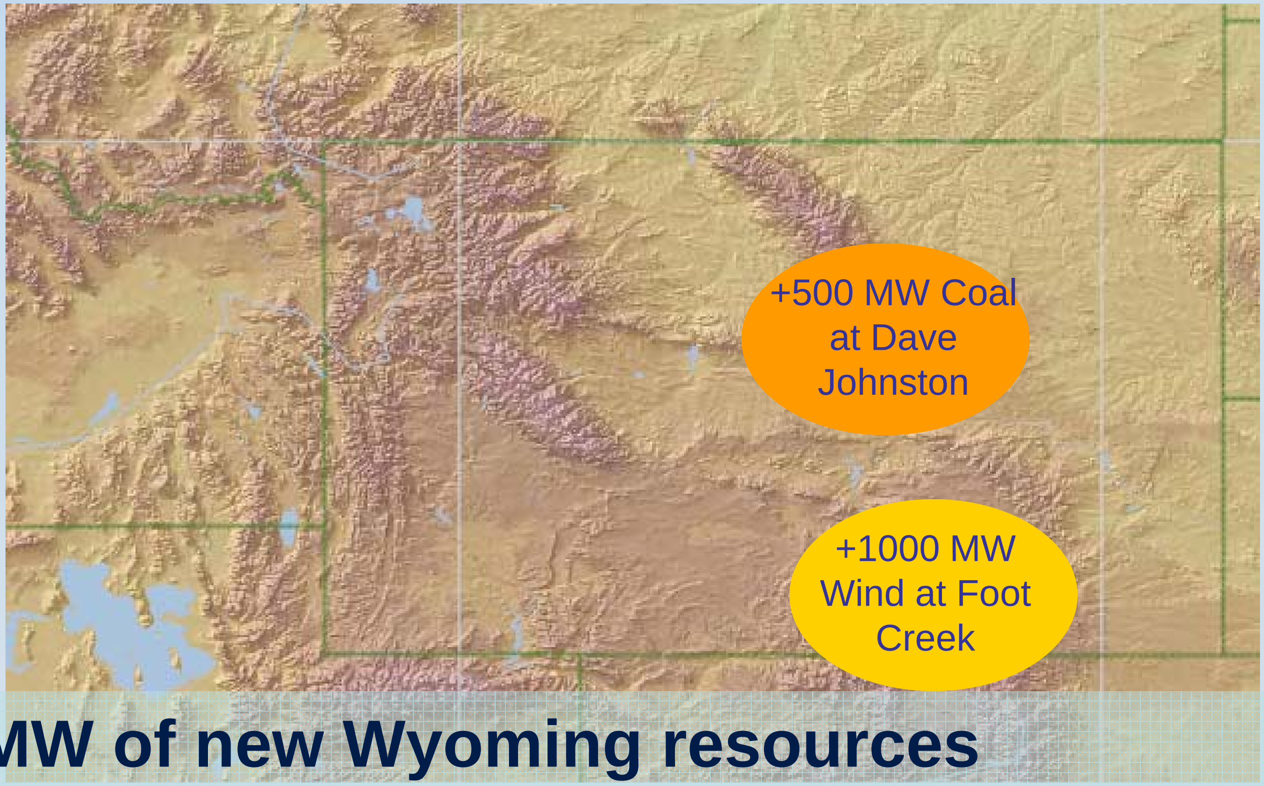
Implementation using AURORAxmp



Nodal: Another AURORAxmp Study Type

- Zonal to Nodal Data Transfer
- Flexibility without Complexity

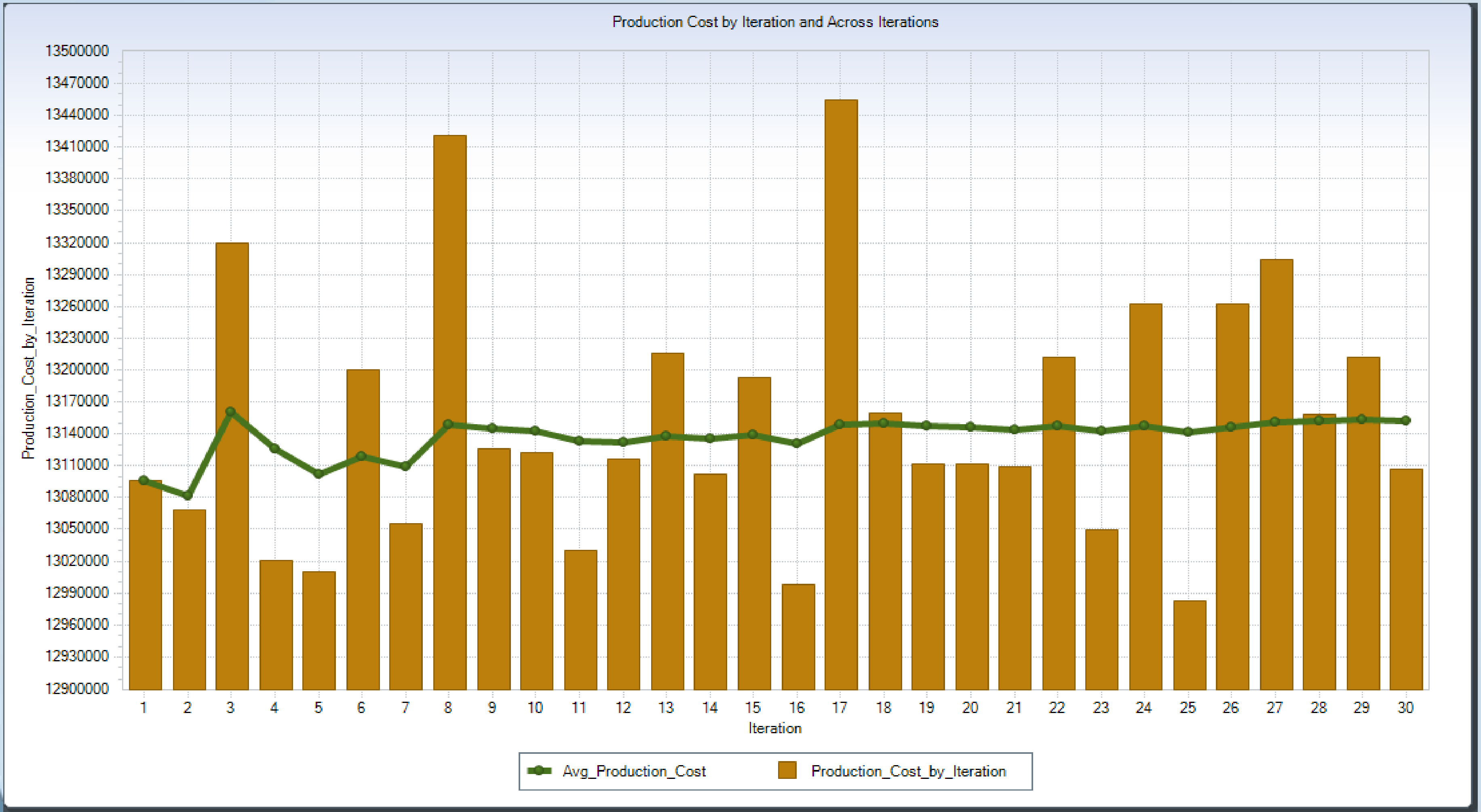
Implementation using AURORAxmp



- **1500 MW of new Wyoming resources**
- **Otherwise WECC Long-Term expansion consistent with default Resource Modifier Table (RMT) from North American 2008-02 Database Release**

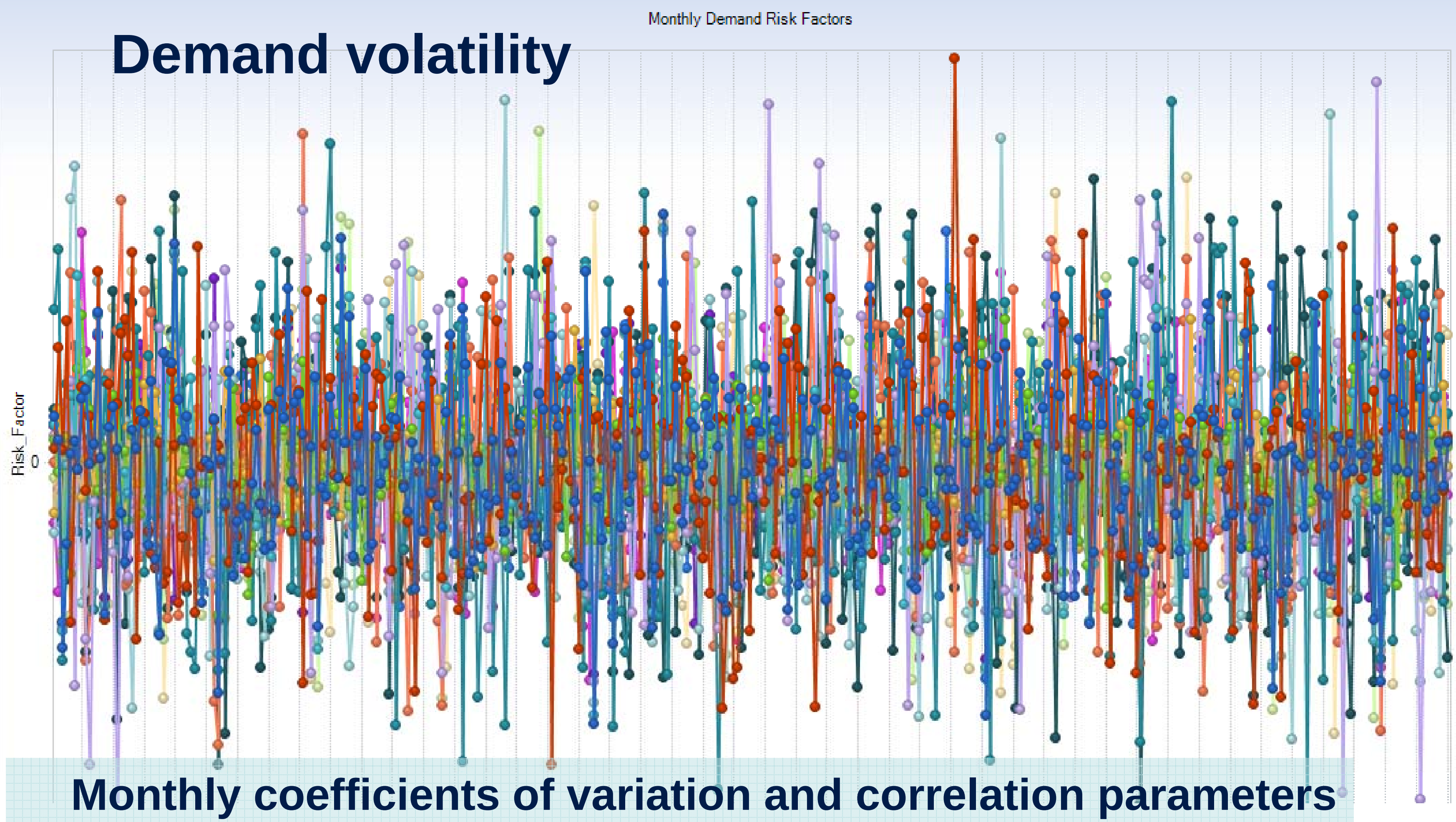
Implementation using AURORAxmp

Random forced outages on baseload units (nuclear, coal, CCGT)



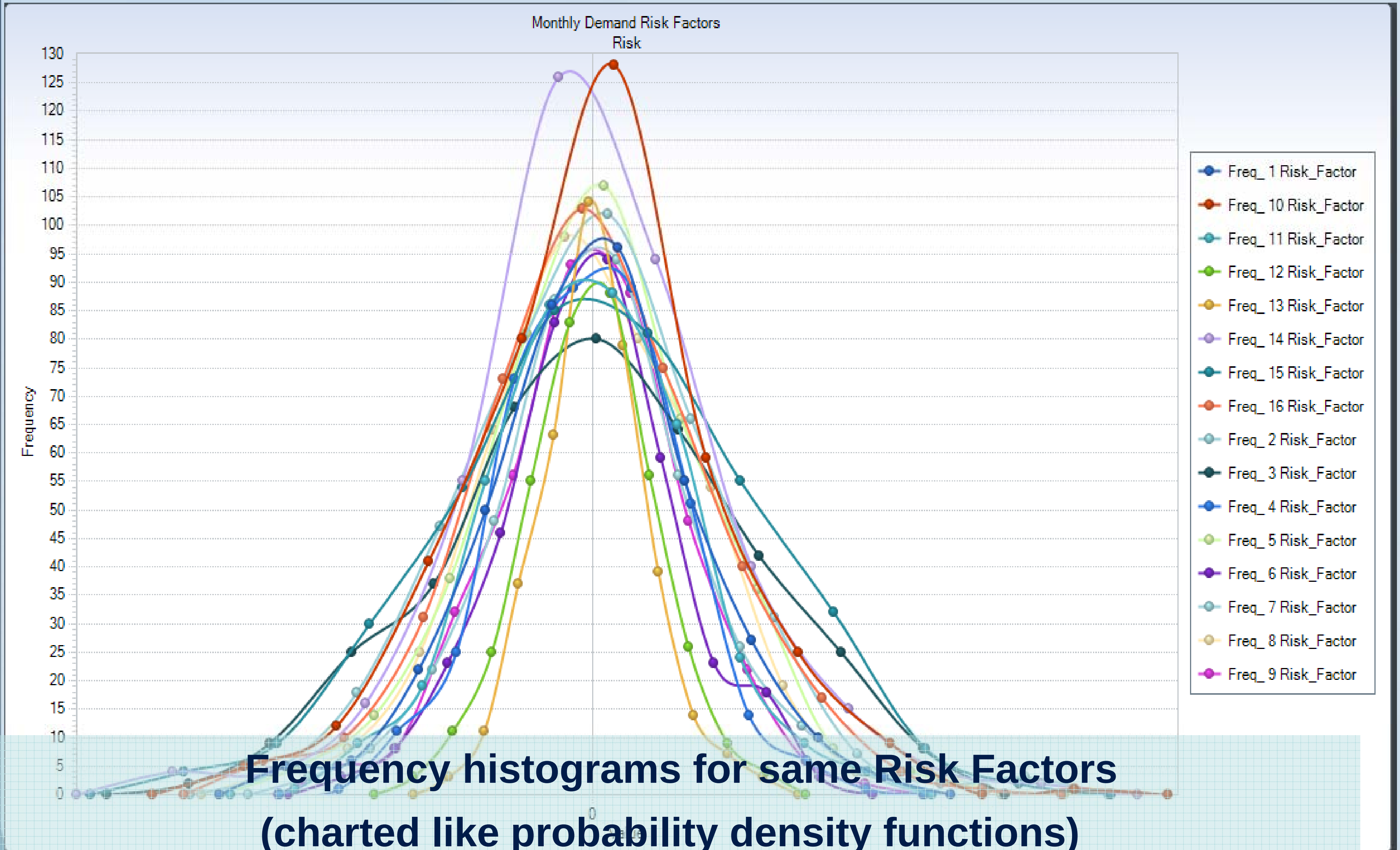
Implementation using AURORAxmp

Demand volatility



Monthly coefficients of variation and correlation parameters used to develop Risk Factors for Demand

Implementation using AURORAxmp



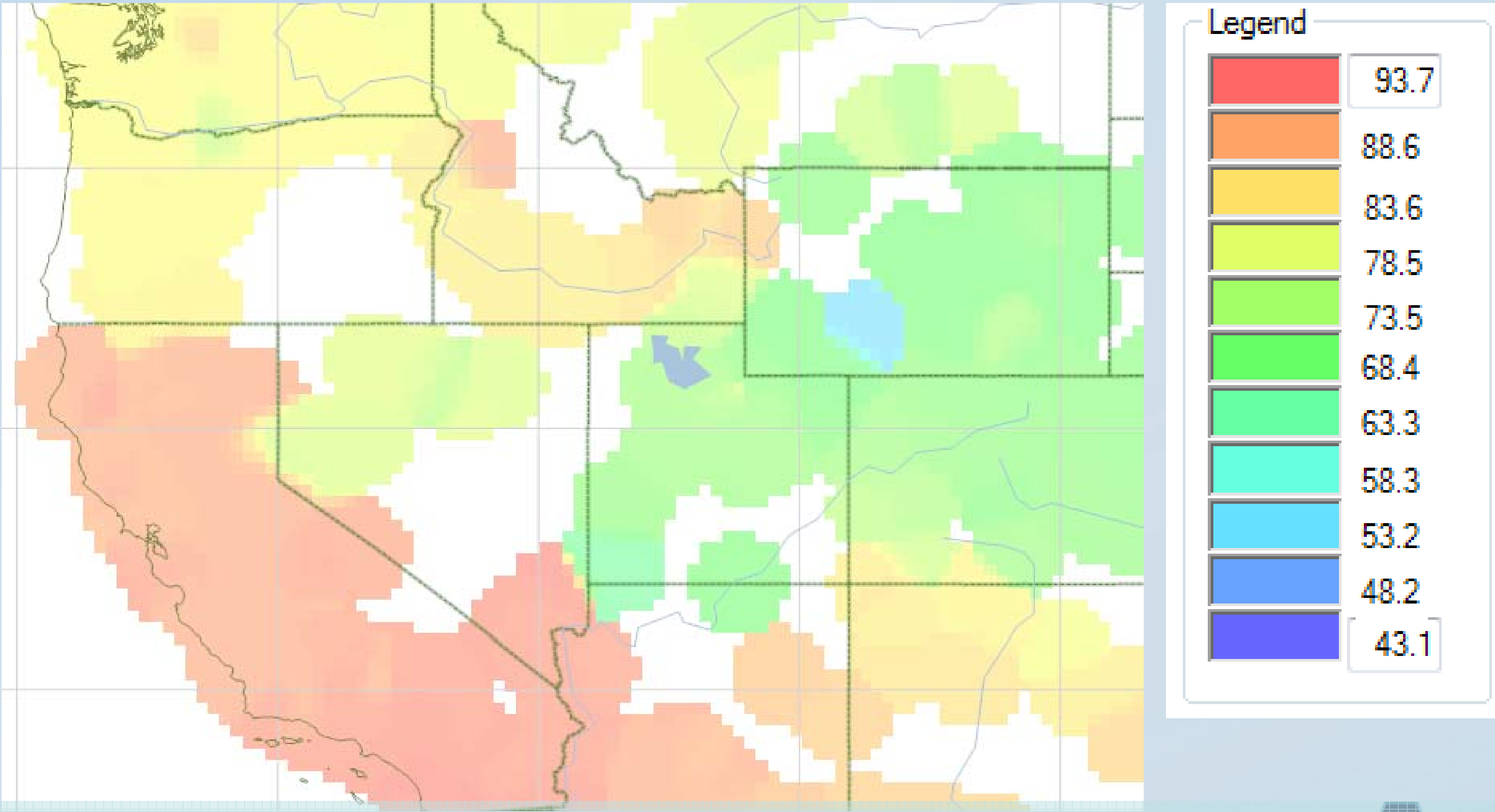
Frequency histograms for same Risk Factors

(charted like probability density functions)

Implementation using AURORAxmp

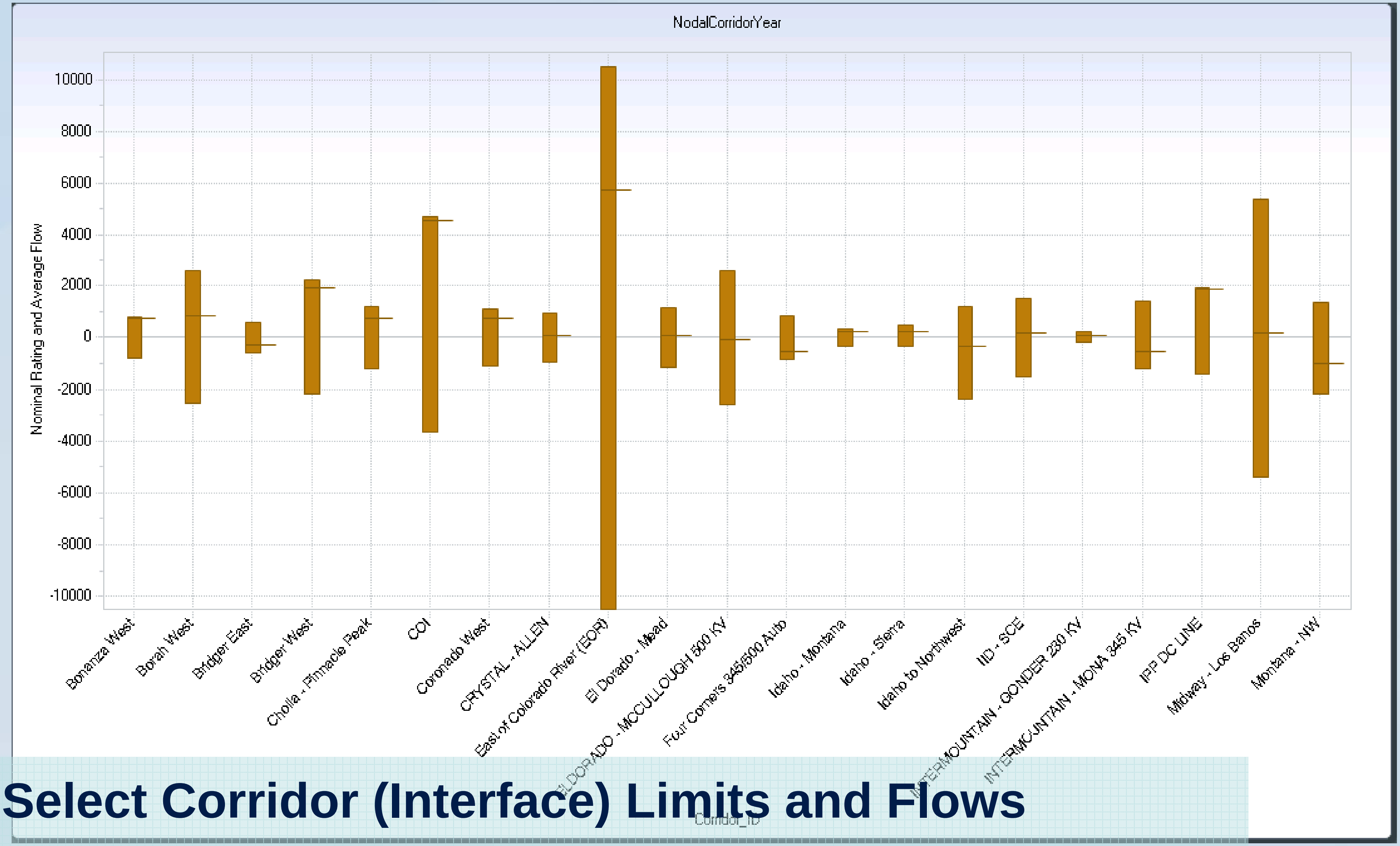
- **Change Sets used to manage data changes**
  - Second Network Definition file (.alfc) that includes the PBPL project
- **Power Transfer Distribution Factors (PTDFs) computed once and saved to file for re-use in stochastic studies**
- **Reporting Template SQL queries used to compute CTL and other outputs of interest**

Select Study Results



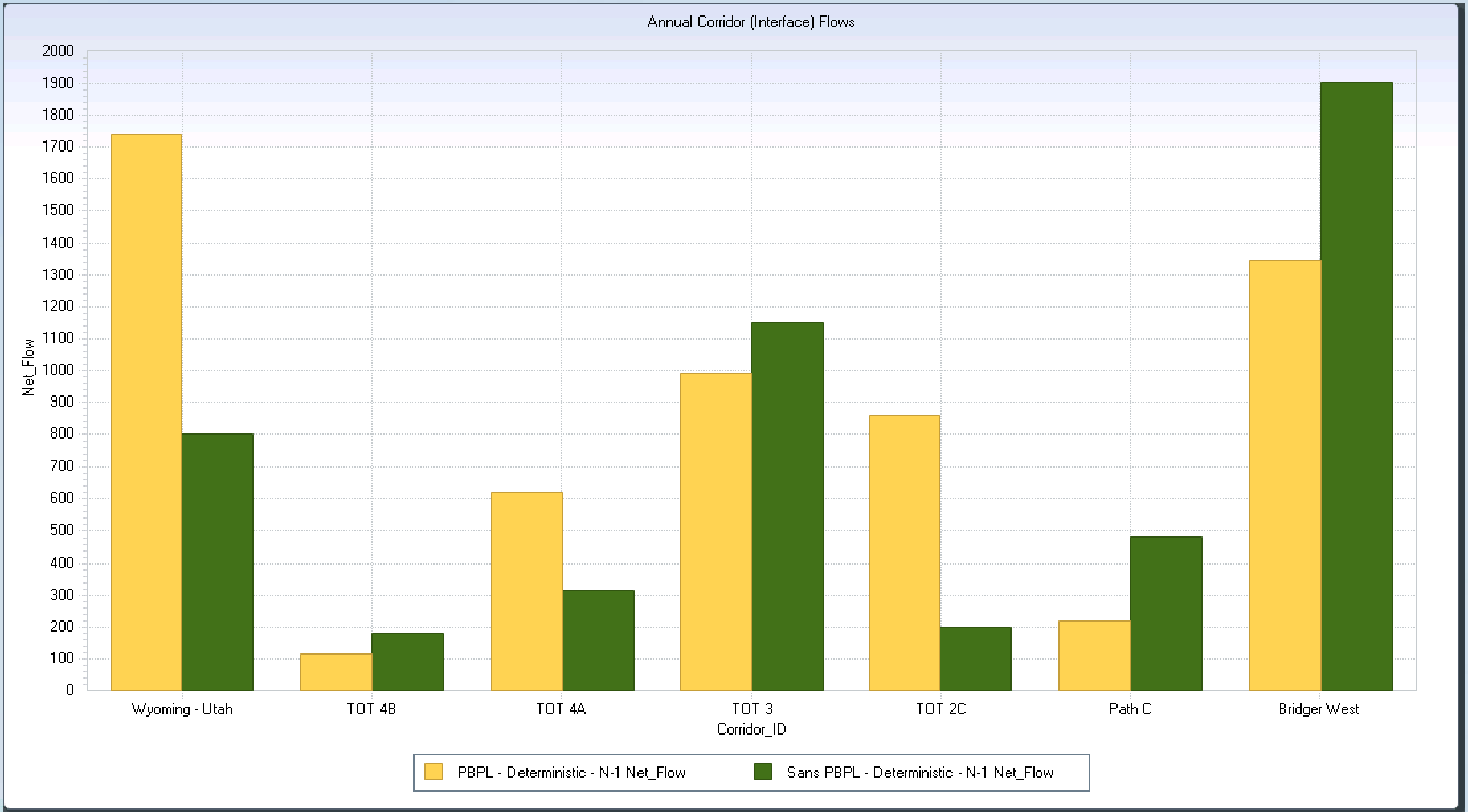
Average Annual Price Contour (Heat) Map – PBPL

Select Study Results



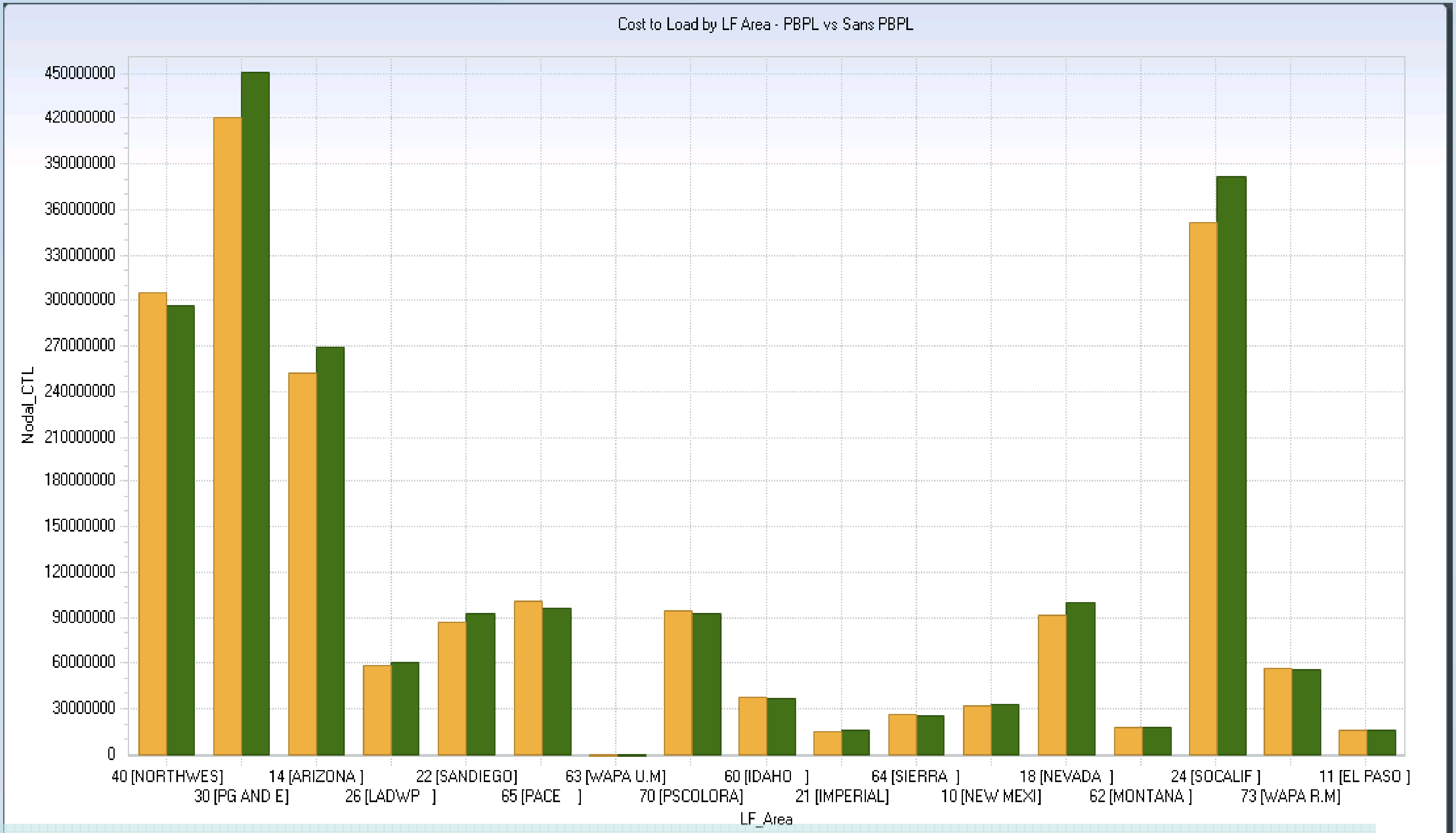
Select Corridor (Interface) Limits and Flows

Select Study Results



Select Corridor (Interface) Flows – PBPL & *Sans* PBPL

Select Study Results



Cost to Load by LF Area – PBPL vs *Sans* PBPL

Select Study Results

Estimated Annual Energy Benefits* ($000)

	Zonal	Nodal	
		N-0	N-1
Deterministic	228,405	274,366	259,772
Stochastic	(51,638)		331,128

** Change in CTL for WECC excluding California, Alberta, BC, and Baja California*

Conclusions

- **We want to understand the potential economic benefit from a new transmission line**
- **AURORAxmp can be used as an important component of the analysis tool set**
  - Network model and power flow optimization
  - Detailed generator representation for commitment and dispatch
  - Ability to treat key value drivers as random (stochastic) variables
  - Advanced data management capabilities and scenario handling
  - Quick simulation turn around times
  - Tried and true (i.e. a proven solution)

Conclusions

- **Nodal analysis allows opportunity for valuable insights**
  - However, many detailed assumptions need to be made
    - Large effort is required to develop and validate data assumptions
      - Garbage in, garbage out
      - Illusion of accuracy
    - As much as possible best to rely on existing regional planning efforts, e.g. TEPPC in WECC, for long-term analyses
- **Data and scenario management**
  - Efficient input and output data management is critical for successful analysis
  - Hourly output valuable but costly to report in terms of run time and disk space
    - Can easily get over 40 billion output records and large databases (e.g. 10 GB)
      - However, this should not be used as an excuse to avoid detailed validation of results
    - Memory tables can help in this regard
  - Use SQL Server (or MySQL) to facilitate queries and custom templates to explore assumptions and results

Conclusions

- **More analytical opportunities not considered in this study**
  - Transmission expansion & LT Capacity Expansion
    - LT analysis can reflect transmission expansion assumptions and therefore provide a consistent set of resource and transmission expansion results
      - LT, however, limited to zonal analysis
  - RPS compliance cost benefits
    - Could be assessed using AURORAxmp*
  - Emissions
  - Enhanced stochastics
    - All key drivers represented
    - Choice of number of iteration based on statistical tests
    - Short- and long-term (two-factor) processes
  - Line loss modeling

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