



Economic Evaluation of Palo Verde Devers Line # 2

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Purpose

Part 1:

Overview of the methodology

Part II:

Preliminary results of CAISO analysis of Palo Verde Devers #2



Part II: Outline

- Discussion of cases
 - List of cases
 - Probabilities
- Preliminary Results
 - Benefits
 - Power flow on major interfaces
 - Discussion on modifications & additions



CALIFORNIA ISO

**Preliminary Results
Subject to Change**

Part I



The Key Components

- **Benefits Framework**
 - Standardized benefit cost frame work consisting of regional/sub regional classification and member classification
- **Network representation**
 - Modeling of physically feasible flows, a full network model with linearized DC approximation and nodal pricing
- **Market prices**
 - Utilize dynamic generation bidding to capture beyond the cost aspects and the non -competitive market conditions.
- **Uncertainty**
 - Measurable and non-measurable variations in system conditions
 - Analysis using deterministic or stochastic system conditions or a combination of both
 - Compute expected value, most likely range, and insurance value of a proposed upgrade
- **Resource substitution**
 - Evaluate other alternatives to transmission expansion



Benefits Framework

- **Consumer Benefits**
 - Change in the cost to consumers
- **Producer Benefits**
 - Change in the cost to producers
- **Transmission Rental**
 - Change in congestion revenue
- **Total Societal**
 - Change in production costs
- **Modified Societal**
 - Societal, net of monopoly rent
- **ISO Ratepayers**
 - Total societal to the ratepayers, net of monopoly rent *
- **ISO Participants**
 - Total societal to the participants, net of monopoly rent

* Here the monopoly rent is indirect and can be called windfall rent



Total Societal Benefit

- The increase in social surplus as a result of the upgrade

$$\mathbf{TS} = \Delta\mathbf{CS} + \Delta\mathbf{PS} + \Delta\mathbf{TR}$$

Where,

TS = Total Societal

CS = Consumer Surplus

PS = Producer Surplus

TR = Transmission Rental

- The difference in total system cost before and after upgrade



Modified Societal Benefit

- The societal benefits net of the Monopoly Rent

$$MS_{WECC} = TS_{WECC} - \Delta \text{Monopoly Rent}$$

Where,

MS = Modified Societal Benefits

TS = Total Societal Benefits

- Modified societal assumes that the reduction in monopoly rent/profits from the exercise of the market power should be transferred to the consumers.



Monopoly Rent

Monopoly Rent

$$\text{MRent} = (P^M - P^C) * Q^M$$

Competitive Rent

$$\text{CRent} = \text{PS}^M - \text{MRent}$$

Where,

PS = Producer Surplus

- Capturing P^C requires fixing dispatch in 2nd iteration and doing a 3rd iteration with dispatch on marginal cost

The Calculated Monopoly Rent

$$\text{MRent} \approx (P^M - P^C) * Q^M$$



ISO Ratepayers

- Entities that fund the project within the control area -- consumers, transmission owners, and utility generators

ISO Ratepayer Benefit

$$= \Delta CS_{\text{ISO}} + \Delta PS_{\text{ISO-URG}} + \Delta TR_{\text{ISO}}$$

Where,

CS_{ISO} = Consumer Surplus

$PS_{\text{ISO-URG}}$ = Producer Surplus for utility retained generation

TR_{ISO} = Transmission rental for the ISO control area



ISO Participants

- Ratepayers and merchant generators

ISO Participant Benefit

$$= \Delta \mathbf{CS}_{\text{ISO}} + \Delta \mathbf{CRent}_{\text{ISO}} + \Delta \mathbf{TR}_{\text{ISO}}$$

Where,

\mathbf{CS}_{ISO} = Consumer Surplus

$\mathbf{CRent}_{\text{ISO}}$ = Merchant generator competitive rent excluding monopoly rent

\mathbf{TR}_{ISO} = Transmission rental for ISO control area

- To promote merchant generation investment



Not Included in Quantified Benefits

- Improvements to system reliability
- Improvements to system operation
- Strategic environmental benefits
- Capacity benefits
- Ancillary service benefits
- Reduction in losses
- RMR generation reduction



Network

- Full network for the interconnected area
- Linearized DC OPF
- Nodal pricing
- Regional sub classification
- Controllable devices
- Nomograms & Interfaces
- Transmission losses*
- Wheeling charges *

* Not included in the methodology



Market Pricing Modeling

- Integrated market behavior with transmission network
- Dynamic hourly bidding
- First time with integrated full network modeling
- Potential enhancements underway



Uncertainty

- Measurable vs. Non-Measurable
 - Load variations
 - Fuel price variations
 - Hydro conditions
 - Generator additions & retirements
 - Generator location siting
 - Exercise of market power
 - Nuclear plant outage
 - Major DC intertie outages
 - Forest Fires



Approaches to Uncertainty

- **Deterministic**
 - Average system conditions
- **Stochastic**
 - Distribution of conditions with probability
- **Scenario Analysis**
 - Discrete conditions with known probability distributions.
- **Extreme conditions**
 - With no known probability



Resource Substitution

- Local area generation
- Demand Side Management (DSM)
- Renewable generation standards
- State mandated Resource Adequacy Standards
- Transmission Remedial Action Schemes (RAS)
- Alternative transmission upgrade
- Combinations of any of the above

*



Models

- PLEXOS (www.draytonanalytics.com) of Drayton Analytics of Australia





OPF and LMP

- Loop Flow – Kirchhoff's Laws
- Phase Shifter optimization
- DC flow optimization
- Transmission nomograms (linear) & interface limits
- Choice of “Standard” and “Large Scale” OPF
 - Large Scale (used for the study)
 - Topography is static within one simulation
 - Transmission losses calculated ex-post
 - Standard
 - Transmission losses and impact of marginal loss factors on nodal prices
 - Transmission outages and other topographical changes



Competition

- Dynamic Bid Cost Markup (BMU)
 - Residual Supply Index Analysis (RSI)
 - Used for the study and the theory developed by Dr. Anjali Sheffrin & Dr. Jing Chen of CAISO



Residual Supply Index (RSI)

- Lerner Index calculated dynamically from the regression variables input
- Computes the BMU
- Applied to each firm in each hour
- Applied to each generator and solved with new bids



Residual Supply Index (RSI)

- A Residual Supply Index provides a good measure on the extent to which the largest supplier in the market is “pivotal” to meeting demand.

$$RSI = \left(\frac{\text{Total Supply} - \text{Largest Supplier's Supply}}{\text{Total Demand}} \right)$$

- An RSI value less than 1 indicates the largest supplier is pivotal in meeting demand.
- In the CAISO markets, RSI values less than 1.2 have generally been associated with market prices in excess of estimated competitive levels.
- RSI can capture the impact of transmission upgrade on supply/demand balance.



RSI -The Basic Approach

- Develop historical relationship (regression) between price-cost markups and certain system conditions.
- Use the regression results to predict bid-cost markups (BMU) under future system conditions.
- Apply the bid-cost markups to the supply bids and re-dispatch and estimate market clearing prices.
- *Note:*
 - Historical Price-Cost Markups are based on the difference between actual zonal market prices and estimated competitive prices.
 - Bid-Cost Markups are estimated and used prospectively in the transmission study.
 - Bid-Cost Markups reflect the difference between the variable cost of a generating unit and a market-based bid.



Price-Cost Markup Regression

- Estimate relationship between price-cost markups (PMU) and system conditions
 - Using hourly data covering Nov-99 to Oct-00 and Jan – Dec 2003.
 - The price-cost markup (PMU) is expressed as the Lerner Index.
 - Lerner Index at region i and hour t is:

$$PMU_{it} = (P_{it} - C_{it}) / P_{it}$$

where P_{it} = Actual price in region i and hour t

C_{it} = Estimated competitive price in region i and hour t



Regression Results

Dependent: Lerner Index	Model 1	Model 2
Intercept	0.14 [11.08]	0.57 [14.77]
RSI (gross RSI specification)	-0.53 [72.76]	-1.81 [35.55]
RSI_Square (RSI*RSI)		0.54 [27.75]
Pct_load_unhedged	0.65 [70.98]	0.6 [66.77]
Normalized Load (hourly load/annual average load)		0.4 [32.89]
Dummy for Peakhour	0.086 [23.77]	0.018 [4.00]
Dummy for Summer Months	0.15 [48.19]	0.1 [30.83]
R Squared	0.46	0.49
Number of Observations	31333	31333

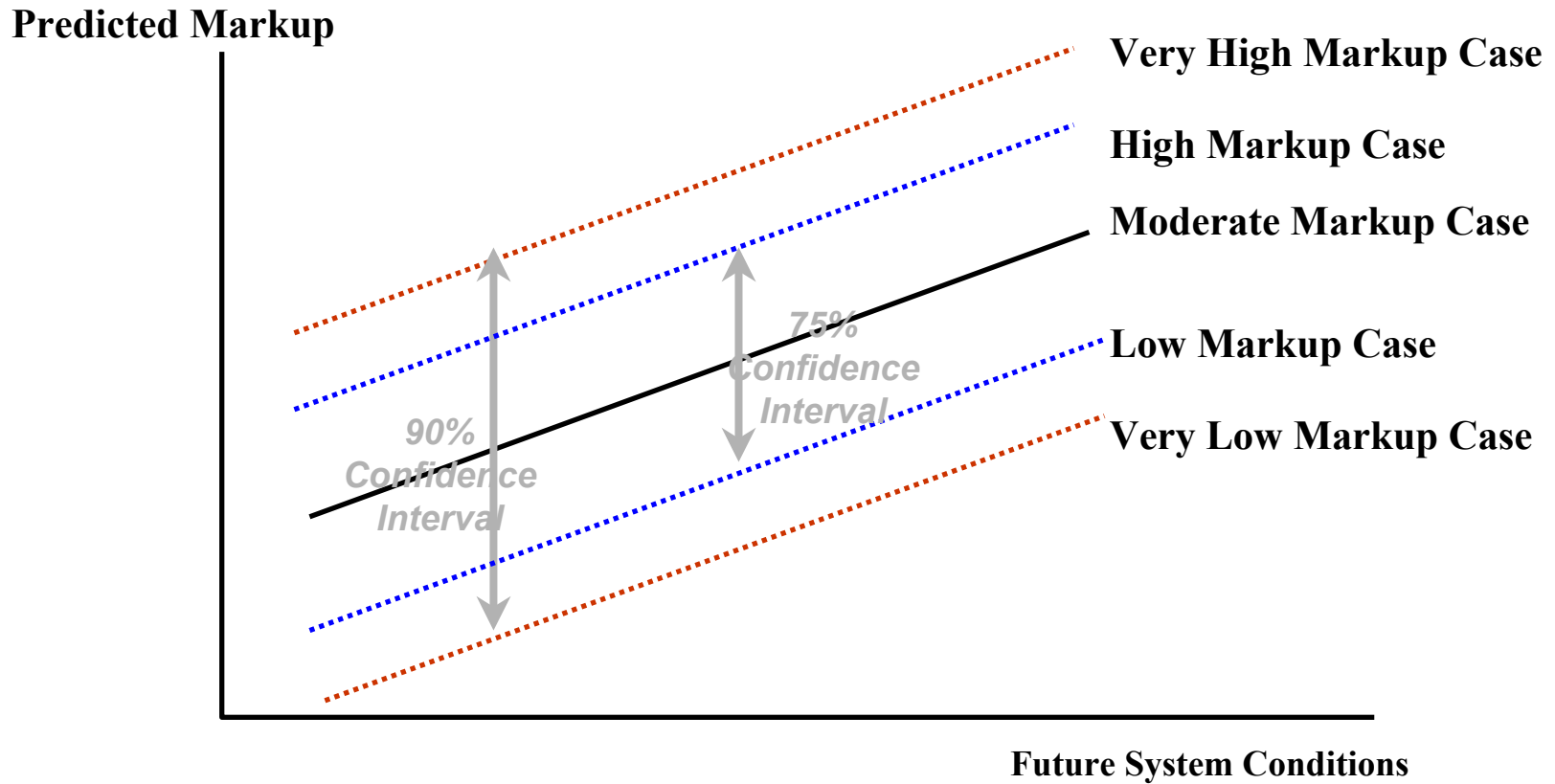


Regression Results to BMU

- Apply regression results prospectively to predict hourly price-cost markups.
- Use predicted price-cost markups as bid-cost markups.
- Markups are estimated separately for each hour and each demand region in California ISO control area
- Levels of Bid-Cost Markups:, Very High, High, Moderate Very Low & Low.
- Base Markup Case: directly derived using regression coefficient estimates.
- Very High and Very Low Markup Cases: derived based on 90% confidence intervals of predicted markups.
- High and Low Markup Cases: derived based on 75% confidence intervals of predicted markups.



Markups

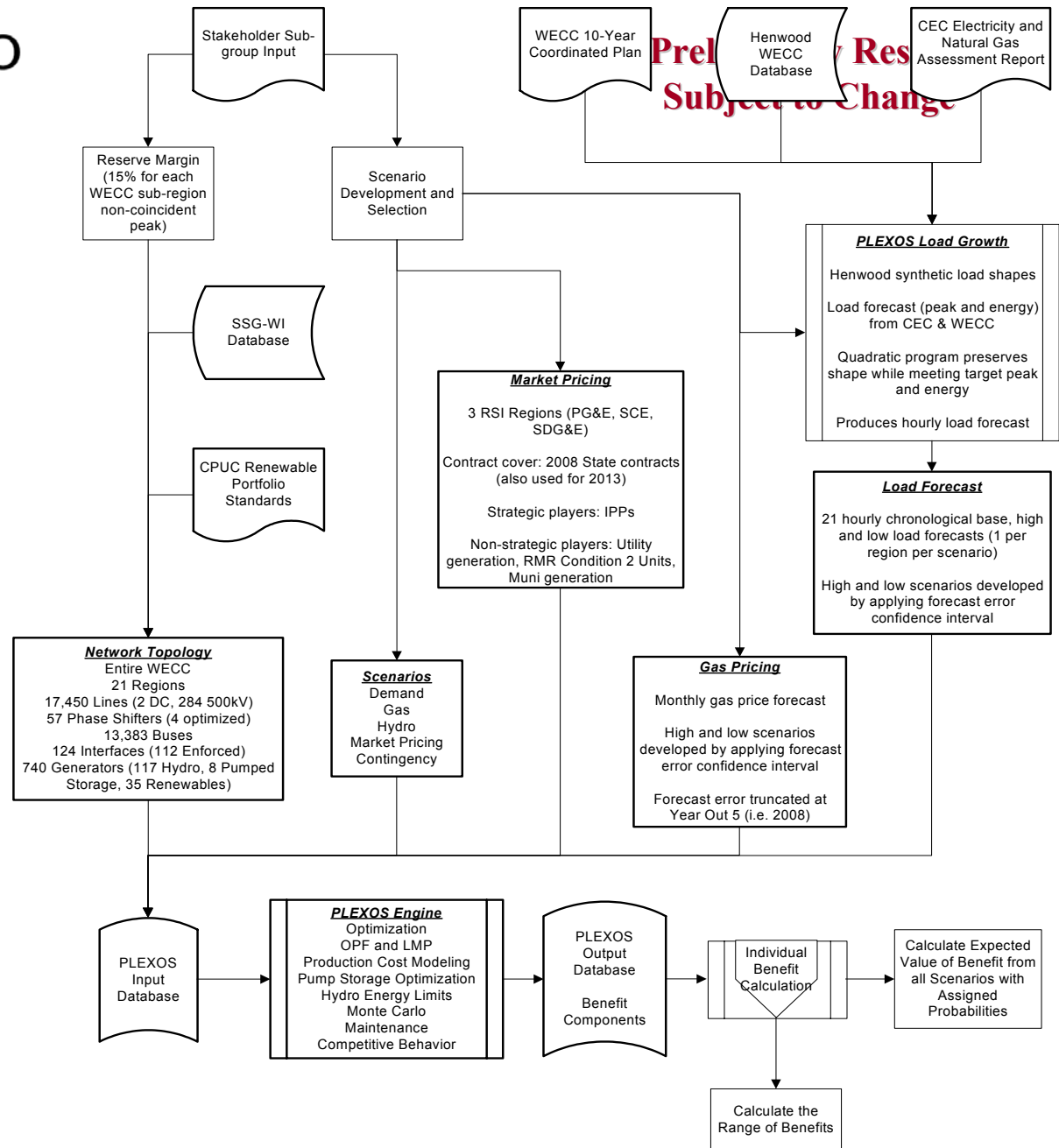




Bid-Cost Markup in PLEXOS

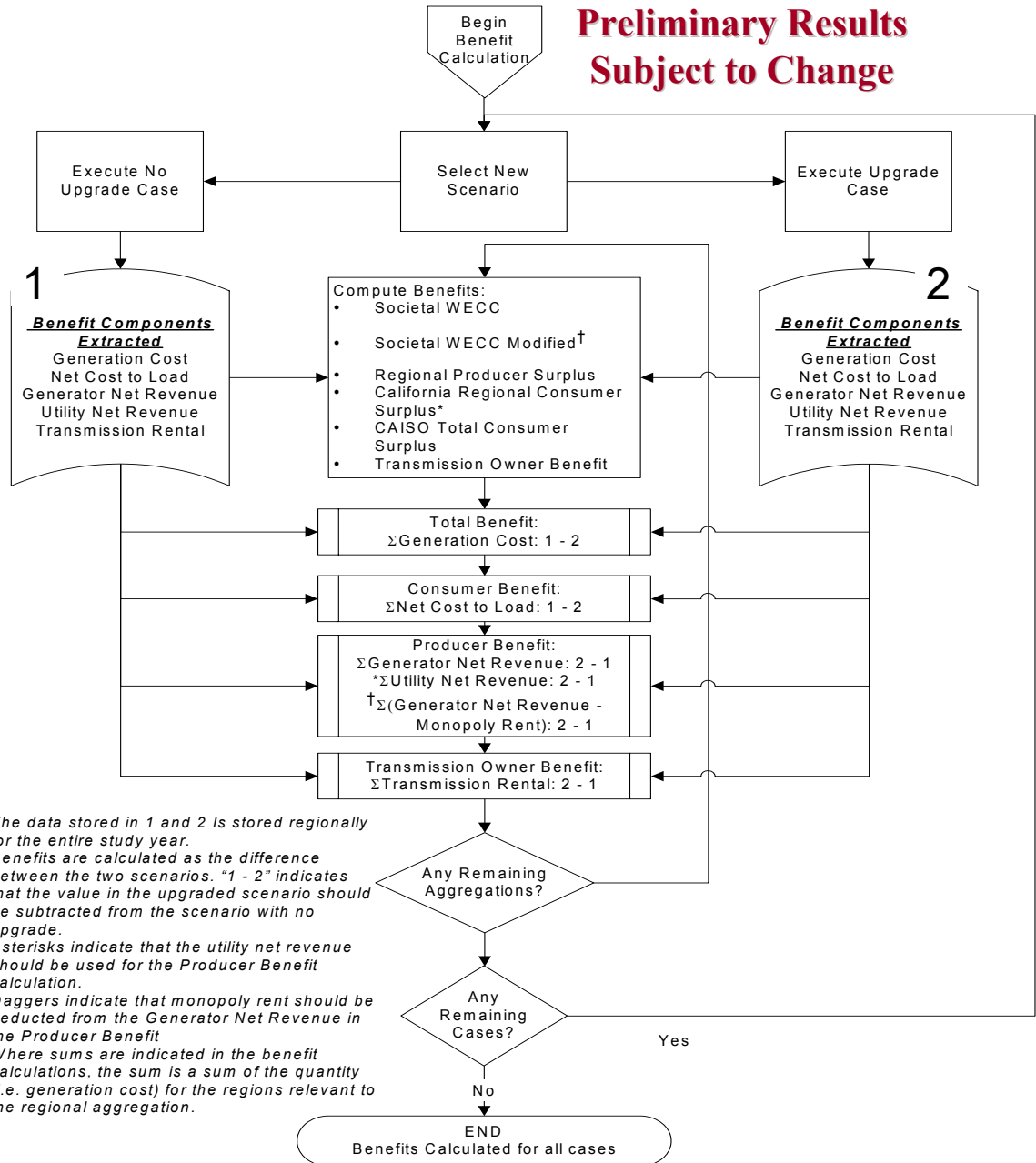
- Bid-Cost Markup functionality incorporated in PLEXOS
 - RSI and other determinants of predicted bid-cost markups is computed internally in PLEXOS
 - The projected bid-cost markups is dynamically incorporated into the market-price run
 - The benefits are computed directly in PLEXOS

The Study Development



Benefit Calculation

**Preliminary Results
Subject to Change**



- The data stored in 1 and 2 is stored regionally for the entire study year.
- Benefits are calculated as the difference between the two scenarios. "1 - 2" indicates that the value in the upgraded scenario should be subtracted from the scenario with no upgrade.
- Asterisks indicate that the utility net revenue should be used for the Producer Benefit calculation.
- Daggers indicate that monopoly rent should be deducted from the Generator Net Revenue in the Producer Benefit
- Where sums are indicated in the benefit calculations, the sum is a sum of the quantity (i.e. generation cost) for the regions relevant to the regional aggregation.



- Load (Base, Very High, High, Low & Very Low)
 - 90% Confidence interval of the CEC load forecast error (Very High & Low)
 - 75% Confidence interval of the CEC load forecast error (High & Low)
 - Demand is assumed to be approximately normally distributed, so is demand forecast error.
- Gas Prices (Base, Very High, High, Low & Very Low)
 - 90% Confidence interval of the CEC gas index forecast error (Very High & Low)
 - 75% Confidence interval of the CEC gas index forecast error (High & Low)
 - Gas price is assumed to be approximately log-normally distributed.
 - Gas price forecast error is assumed to be normally distributed



Scenarios *(Contd...)*

- Markup (Moderate, Very High, High, Very Low & Low)
 - 90% confidence intervals of predicted markups (very high)
 - 75% confidence intervals of predicted markups (high)
- Hydro Energy (Normal, Wet & Dry)
 - Selected years from a 60 – 80 year historic values to represent the Normal, Wet & Dry conditions*

* Courtesy of Kurt Granat of PacifiCorp from the study done for the SSGWI planning group



Events & Probabilities

- Events – Collection of Scenarios
- Probabilities - Uses the individual marginal distribution of load, gas price & markup to assign the joint probability distribution
- Categorize the events
 - Category 1: for expected benefit calculation
 - Events selected using “Importance Sampling”
 - Category 2: for benefit range calculation
 - Events selected using “Random Drawing”
 - Category 3: for insurance value calculation
 - Uses the contingency cases with no known distribution



Part II: The Proposed Study

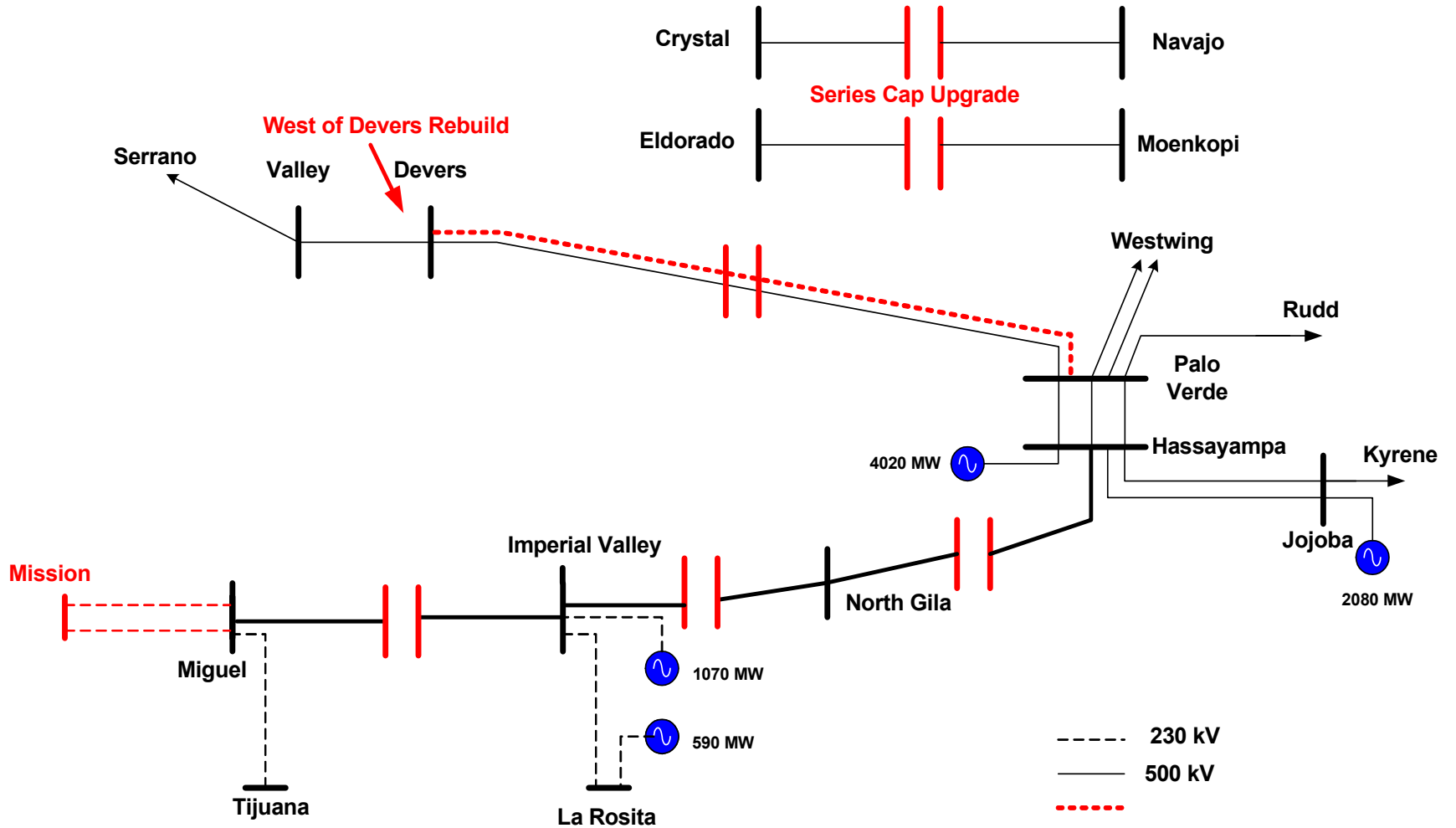


The Proposed Study - Palo Verde Devers #2





The Proposed Study - Palo Verde Devers #2





The Upgrade

- The study on the upgrade of Palo Verde Devers #2, connecting between nodes, Palo Verde in Arizona and Devers in Southern California



Input Assumptions



The Interface Upgrades

The Capacity (MW)	EOR	SCIT	WOR
Before	8,050	19,091	10,623
After	9,250	20,391	11,823



Data Modeling Limitations

- Hydro not optimized
 - Using the hourly hydro profile used in SSG-WI studies
- Wind
 - Using the hourly profile used in SSG-WI studies
- Transmission losses *
- Wheeling charges *
- Commitment variables *

* Not used in the study.

Case List

The **Variables** that varied among the cases,
for two years of analysis, 2008 & 2013

1. Gas Prices (Very High, Base, Very Low)
2. Load (Very High, Base, & Very Low)
3. Hydro (Base Wet & Dry)
4. Markup (Moderate, Very High, Very Low)
5. Economic Entry and Retirement (Base)
6. San Onofre permanent outage
7. PDCI line outage
8. Mohave plants coming back in service
9. COI and EOR with reduced OTCs

* The final list of cases still under development, subject to change.

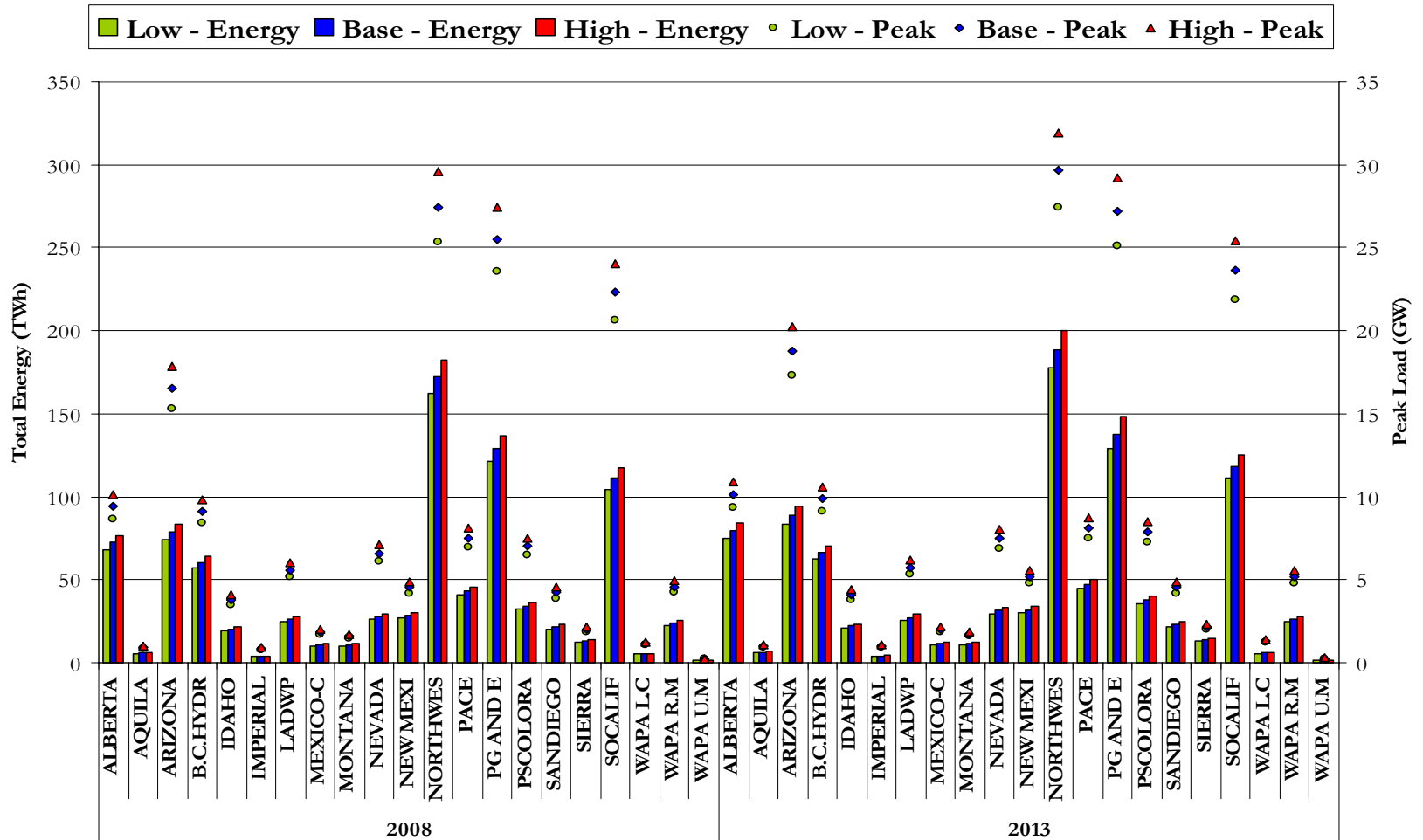


The Basic Ingredients – Year 2008

The System	WECC
Transmission Lines	Total 17,450 3 DC lines 284 lines 500KV or above
Phase Shifters	57 Phase Shifters – 7 optimized
Nodes	13,383
Interfaces	129 Interfaces Not all enforced
Regions	21
Generators	760 Total 117 Hydro 8 Pumped Storages Approx 40 Renewables (Wind, Biomass)



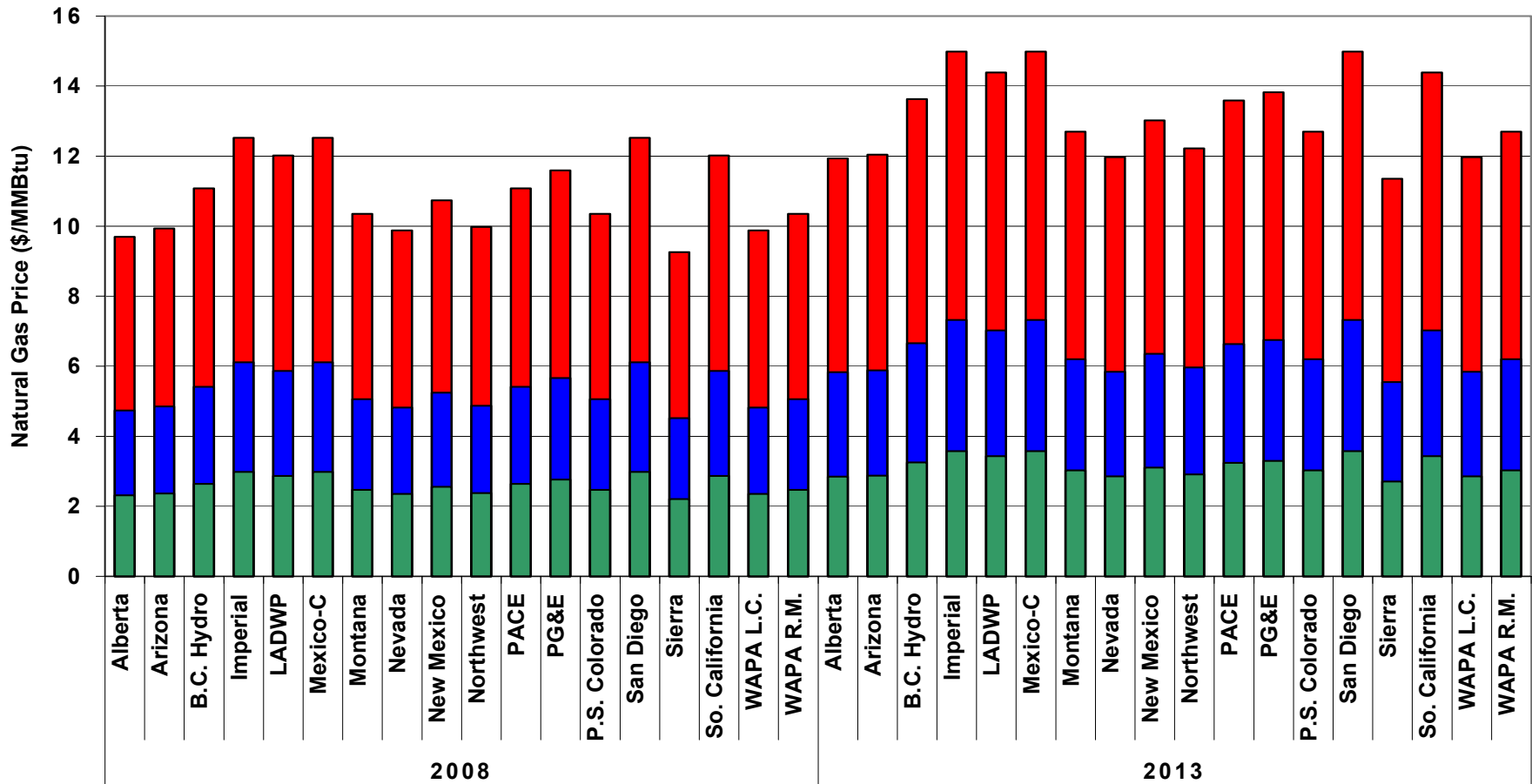
Peak Load & Energy





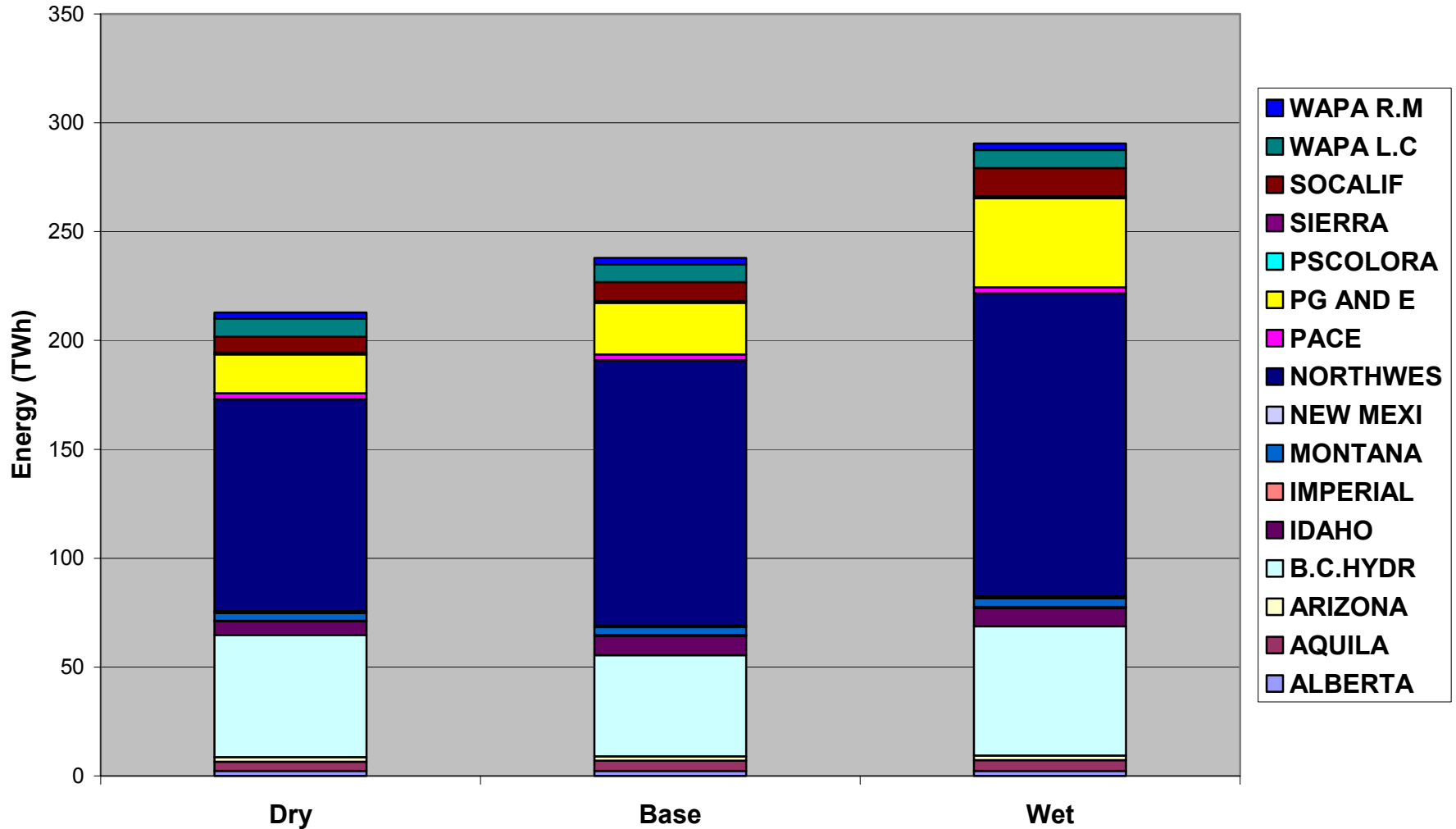
Gas Prices - Annual Average by Region

Very High Gas Forecast Base Gas Forecast Low Gas Forecast





Hydro Energy





Market Pricing

Market Price Regions	3 regions in California PG&E, SCE & San Diego
Contracts	Existing State contracts of 2008. Assumed same for 2013.
RMR	Year 2004 Condition 2 units of CAISO system
Strategic Players	IPP
Non Strategic Players	Utility Generation RMR Units Municipal Generation

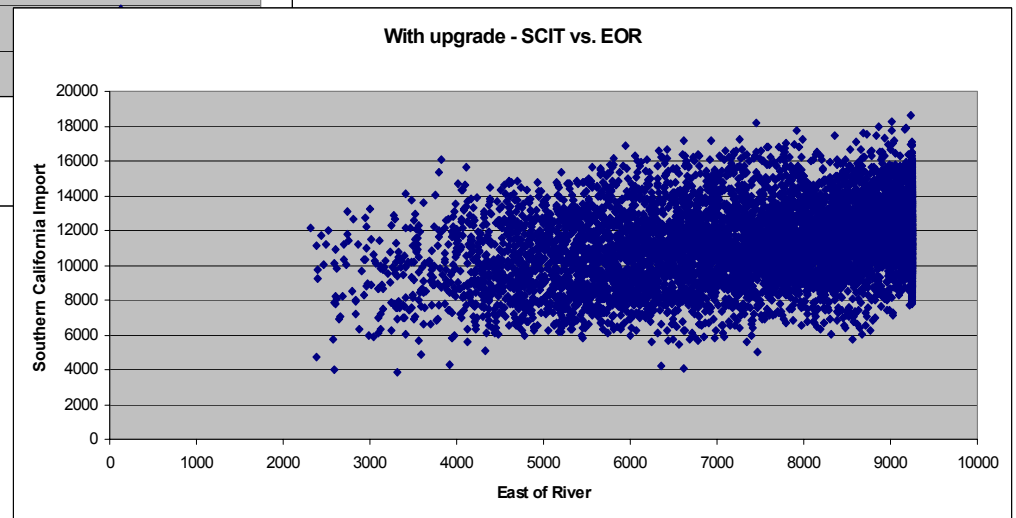
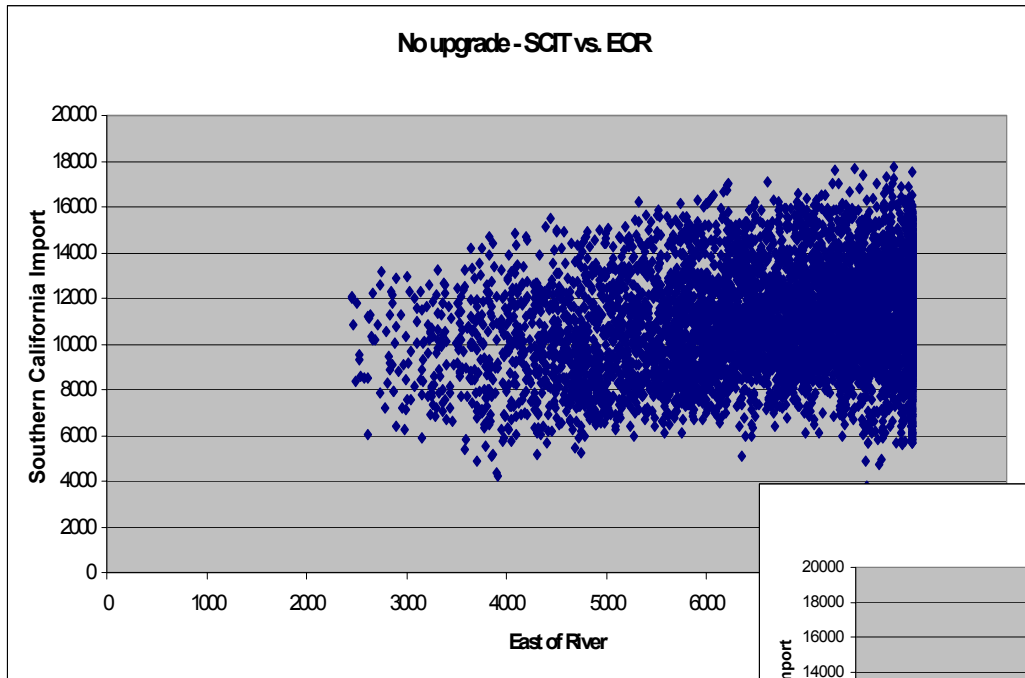


Results

Reference Case 2008
Market Power

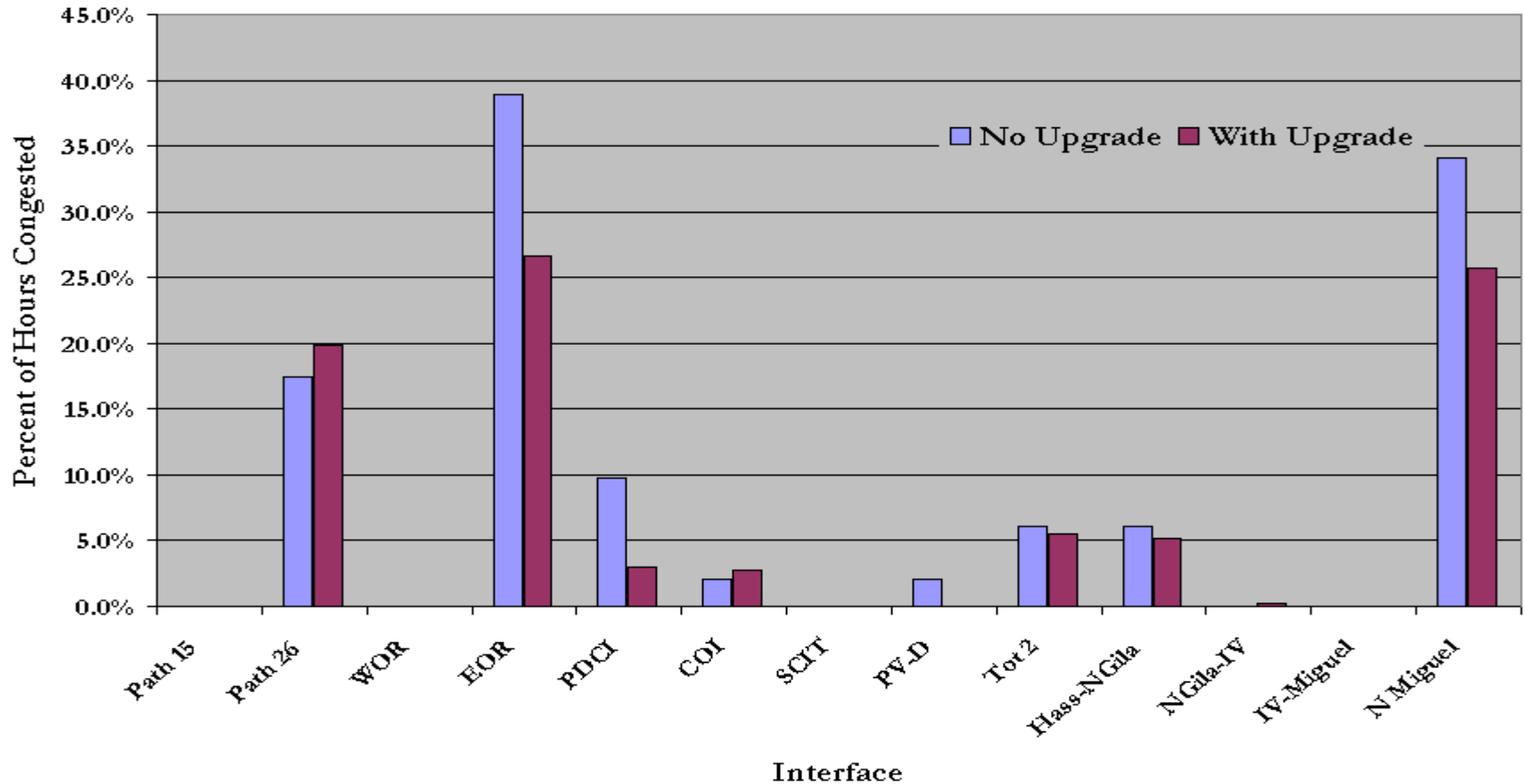


SCIT Before and After Upgrade





Congestion on Major Paths





The Benefits

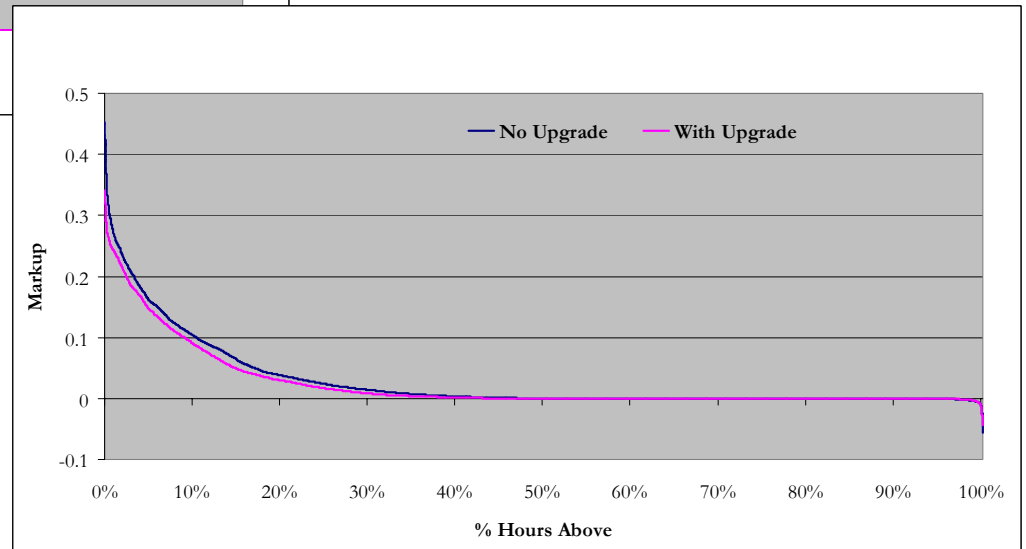
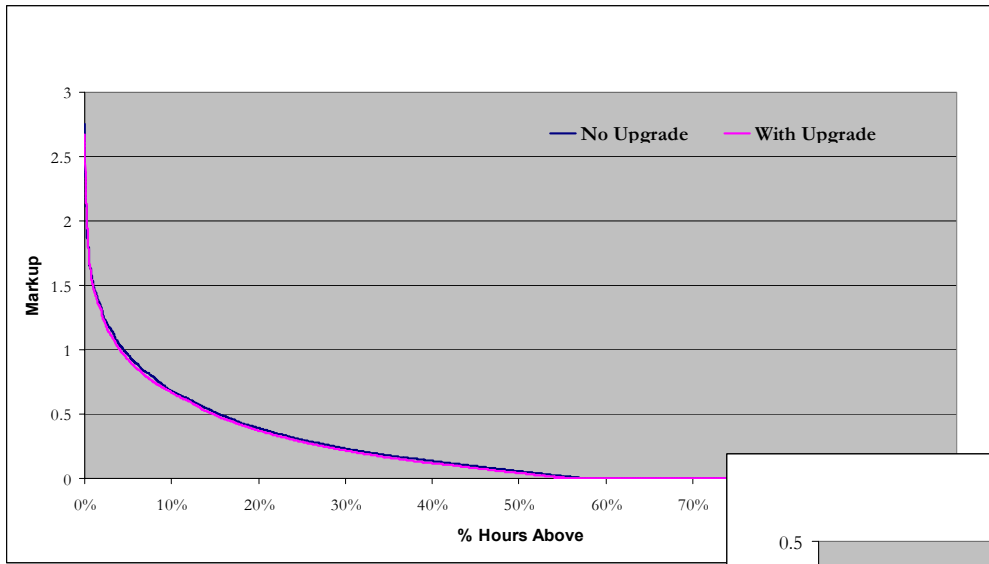
Summary of Benefits for Palo Verde Devers 2 Upgrade
Case Description – MD1, 2008 BBBM

Year 2008

Perspective	Description	Consumer Benefit (mil. \$)	Producer Benefit (mil. \$)	Trans. Rental (mil. \$)	Total Benefit (mil. \$)	Production Cost Savings (mil. \$)	Notes
<i>Societal</i>	<i>WECC</i>	231.87	(8.66)	(181.78)	41.43	41.426	
						17,600.40	Production Cost before upgrade
						17,558.97	Production Cost after upgrade
<i>Modified Societal</i>	<i>WECC</i>	231.87	8.77	(181.78)	58.86		Excludes monopoly rent, Except for utility generation in CAISO control area
<i>California Competitive Rent</i>	<i>ISO Ratepayer Subtotal</i>	157.61	(64.17)	(86.95)	6.50		Includes consumers, UDC generators and ISOPTOs. SMUD and some munis are treated as part of the CAISO due to data limitations. Consumers, producers and transmission owners participating in CAISO markets.
	<i>ISO Participant Subtotal</i>	157.61	(45.80)	(86.95)	24.86		

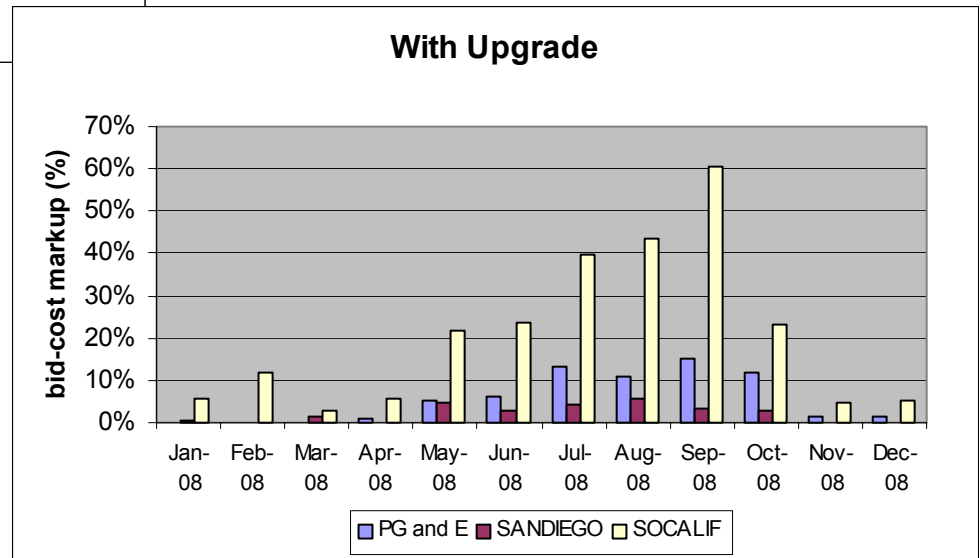
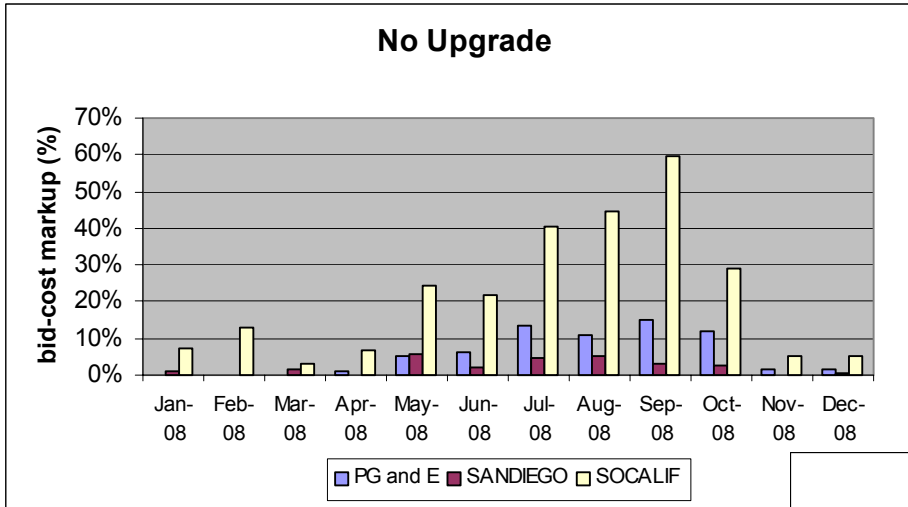


Bid Cost Mark Up & Price Cost Mark Up



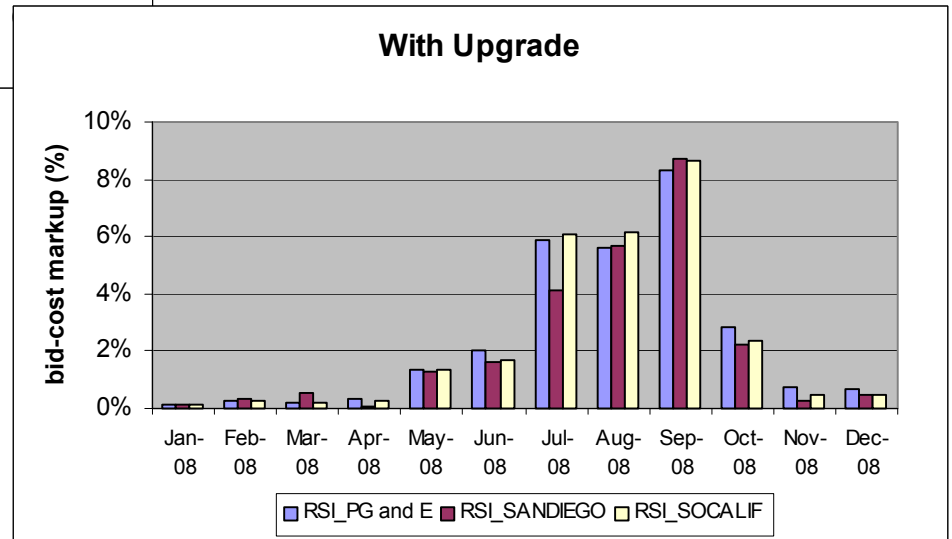
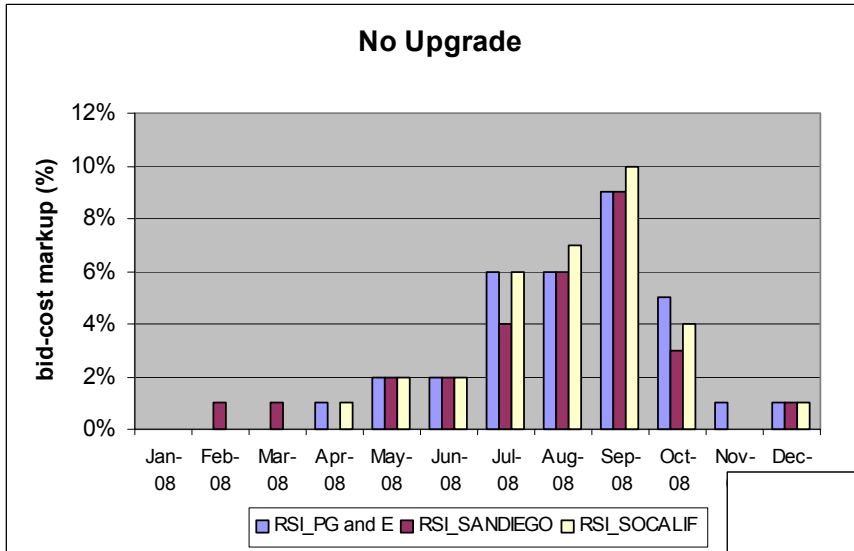


Average Monthly Bid Cost Markup





Average Monthly Price Cost Markup



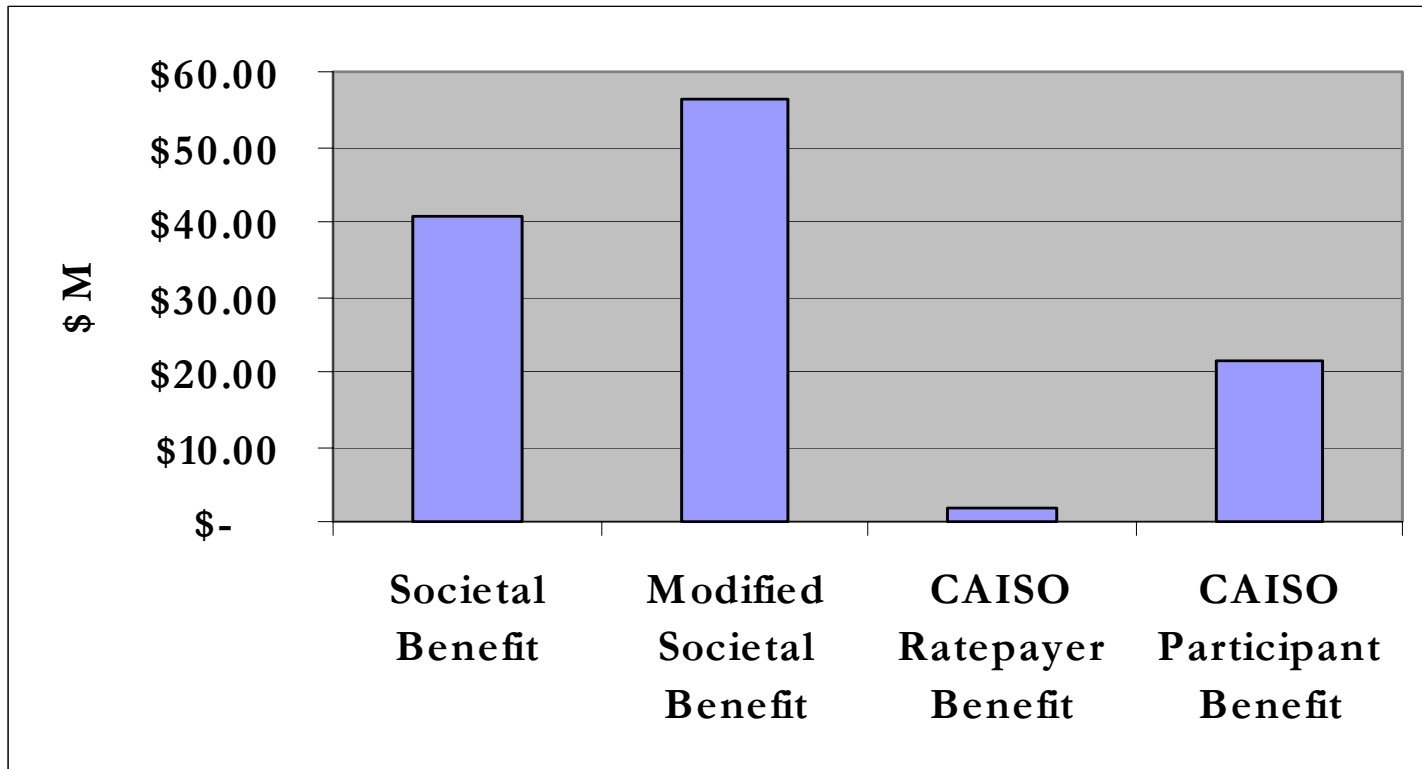


Societal Benefits - Market Based

Demand	Gas Prices	Hydro	Markup	Benefits (\$ M)
Base	Base	Base	Moderate	\$ 41.43
Base	Base	Base	V High	\$ 44.96
Base	Base	Base	V Low	\$ 32.59
Base	V High	Base	Moderate	\$ 83.04
Base	V Low	Base	Moderate	\$ 5.94
Base	V High	Base	V High	\$ 68.54
V High	Base	Base	V High	\$ 48.90
V Low	Base	Base	Moderate	\$ 34.44



Probability Weighted Expected Benefits Year 2008



Other cases included as well in this analysis

The probabilities and case lists are subject to change



Contingency Analysis (Mohave I/S)

<u>Benefits</u>	<u>Year 2008</u>
WECC Total Societal	\$ 50.84 M
WECC Total Modified Societal	\$ 63.57 M
CAISO Participants Modified	\$ 41.18 M
CAISO Ratepayers Modified	\$ 28.02 M



HHDM Year 2008

Summary of Benefits for Palo Verde Devers 2 Upgrade
Case Description – M08. 2008 HHDM

Year 2008

Perspective	Description	Consumer Benefit (mil. \$)	Producer Benefit (mil. \$)	Trans. Rental (mil. \$)	Total Benefit (mil. \$)	Production Cost Savings (mil. \$)	Notes
<i>Societal</i>	<i>WECC</i>	404.05	220.20	(521.18)	103.06	103.063	
						35,174.86	Production Cost before upgrade
						35,071.79	Production Cost after upgrade
<i>Modified Societal</i>	<i>WECC</i>	404.05	318.67	(521.18)	201.54		Excludes monopoly rent, Except for utility generation in CAISO control area
<i>California Competitive Rent</i>	<i>ISO Ratepayer Subtotal</i>	515.24	(181.85)	(287.02)	46.37		Includes consumers, UDC generators and ISO PTOs. SMUD and some munis are treated as part of the CAISO due to data limitations. Consumers, producers and transmission owners participating in CAISO markets.
	<i>ISO Participant Subtotal</i>	515.24	(113.85)	(287.02)	114.37		



Scenarios Under Investigation

- Scenarios Under Investigation to be included in the reference case
 - Additional constraint on transfers between Arizona and Southern California
 - Remove phase shifters from optimization
 - Add forward contracts to cover SCE load from Arizona (In design stage)



Additional Constraint Added

- Enforcing an additional constraint on Hassyampa – North Gila and Palo Verde Devers

Before the Upgrade	After the Upgrade
3600 MW	4800 MW



Benefit Summary with Additional Constraint

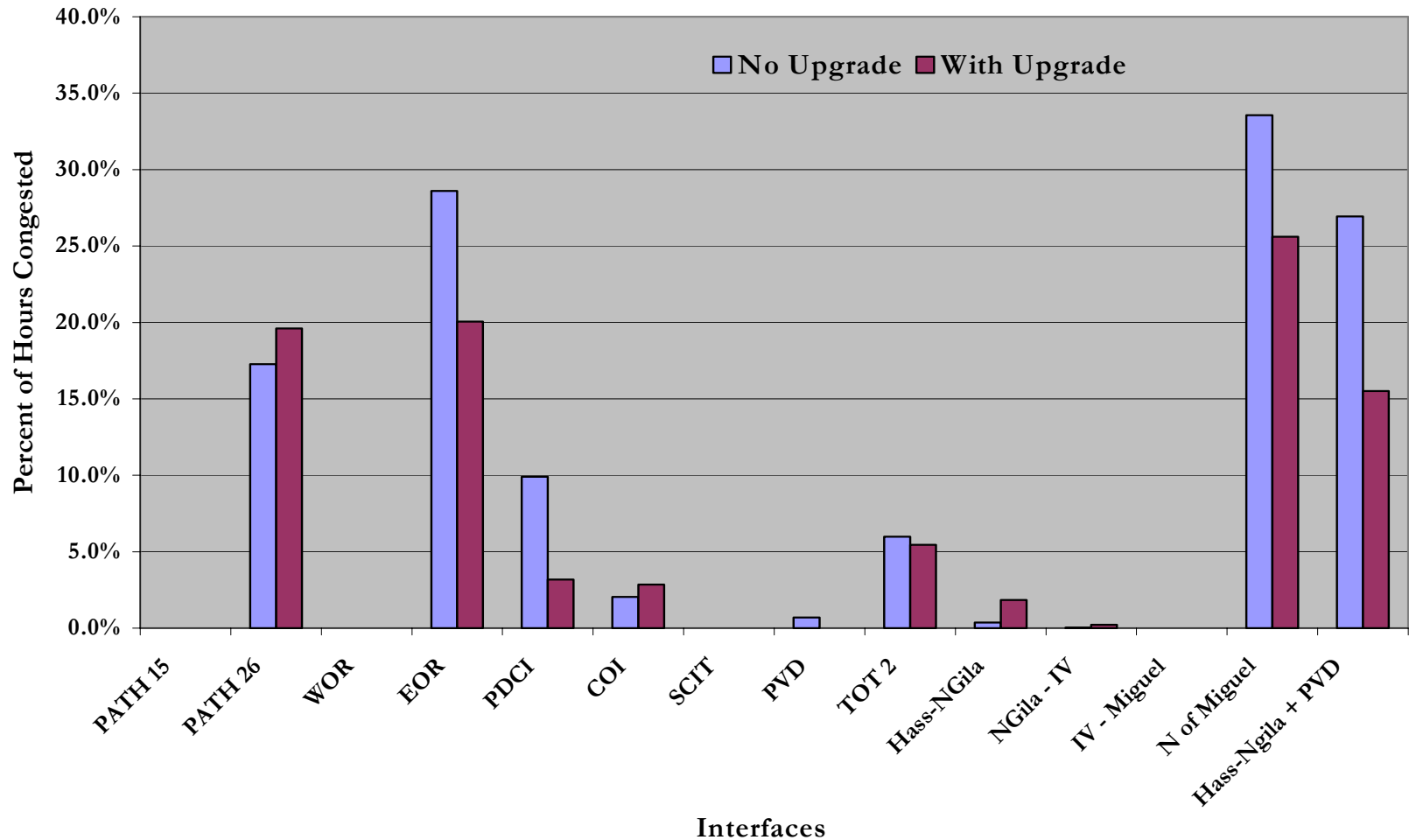
Summary of Benefits for Palo Verde Devers 2 Upgrade Case Description – M01. 2008 BBBM

Year 2008

Perspective	Description	Consumer Benefit (mil. \$)	Producer Benefit (mil. \$)	Trans. Rental (mil. \$)	Total Benefit (mil. \$)	Production Cost Savings (mil. \$)	Notes
<i>Societal</i>	<i>WECC</i>	228.71	(0.22)	(184.82)	43.67	43.672	
						17,604.54	Production Cost before upgrade
						17,560.87	Production Cost after upgrade
<i>Modified Societal</i>	<i>WECC</i>	228.71	19.30	(184.82)	63.19		Excludes monopoly rent, Except for utility generation in CAISO control area
<i>California Competitive Rent</i>	<i>ISO Ratepayer Subtotal</i>	161.51	(65.46)	(89.13)	6.91		Includes consumers, UDC generators and ISO PTOs. SMUD and some munis are treated as part of the CAISO due to data limitations.
	<i>ISO Participant Subtotal</i>	161.51	(42.40)	(89.13)	29.98		Consumers, producers and transmission owners participating in CAISO markets.



Congestion on Major Paths With Additional Constraint Added





Without Phase Shifter Optimization

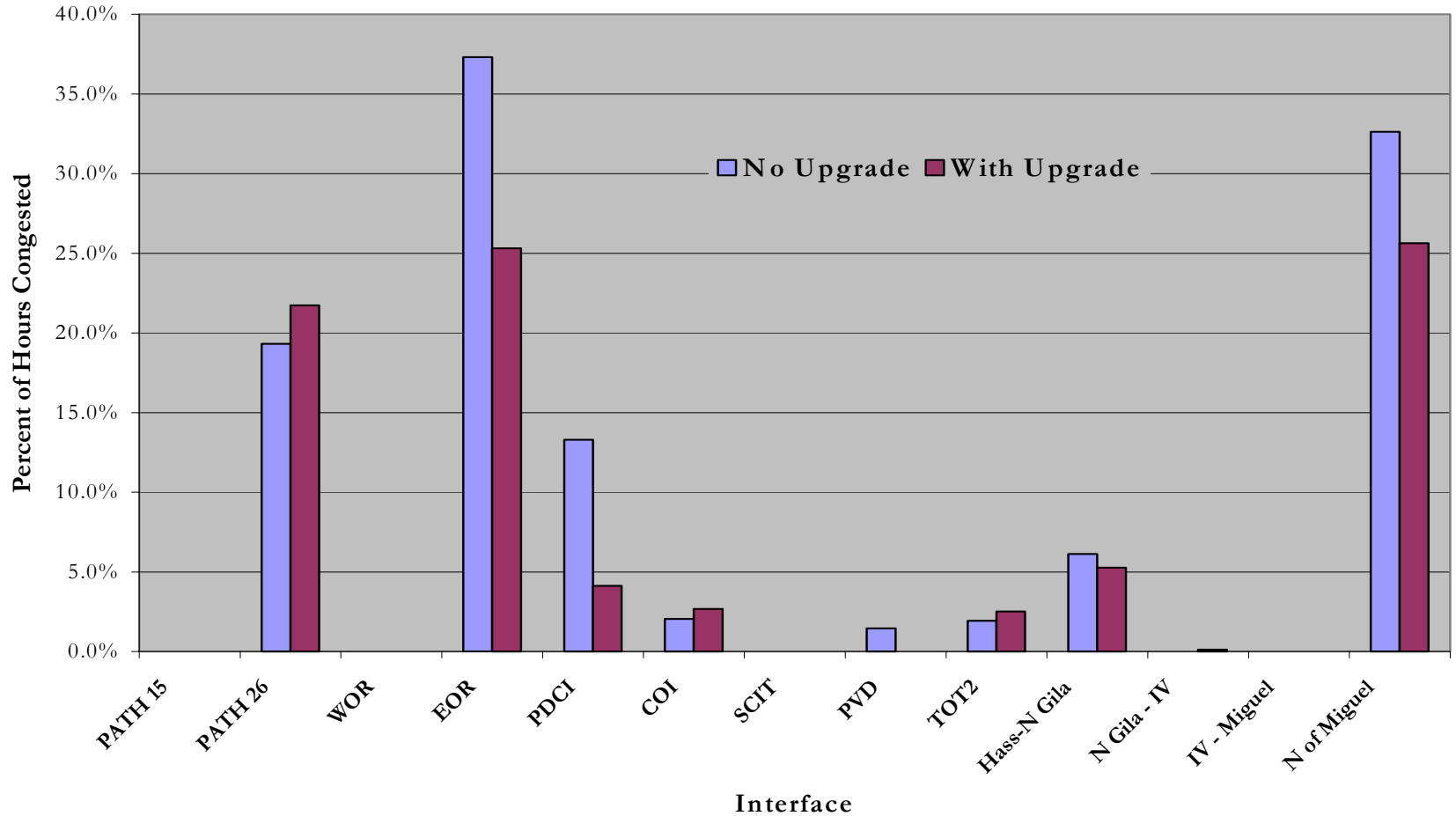
Summary of Benefits for Palo Verde Devers 2 Upgrade
Case Description – MD1. 2008 BBBMNO PHS

Year 2008

Perspective	Description	Consumer Benefit (mil. \$)	Producer Benefit (mil. \$)	Trans. Rental (mil. \$)	Total Benefit (mil. \$)	Production Cost Savings (mil. \$)	Notes
<i>Societal</i>	<i>WECC</i>	242.85	(20.55)	(178.74)	43.56	43.557	
						17,624.69	Production Cost before upgrade
						17,581.13	Production Cost after upgrade
<i>Modified Societal</i>	<i>WECC</i>	242.85	(1.46)	(178.74)	62.65		Excludes monopoly rent, Except for utility generation in CAISO control area
<i>California Competitive Rent</i>	<i>ISO Ratepayer Subtotal</i>	164.50	(66.95)	(89.39)	8.16		Includes consumers, UDC generators and ISO PTOs. SMUD and some munis are treated as part of the CAISO due to data limitations.
	<i>ISO Participant Subtotal</i>	164.50	(49.14)	(89.39)	25.96		Consumers, producers and transmission owners participating in CAISO markets.



Without Phase Shifters



With New Constraint and No Phase Shifters

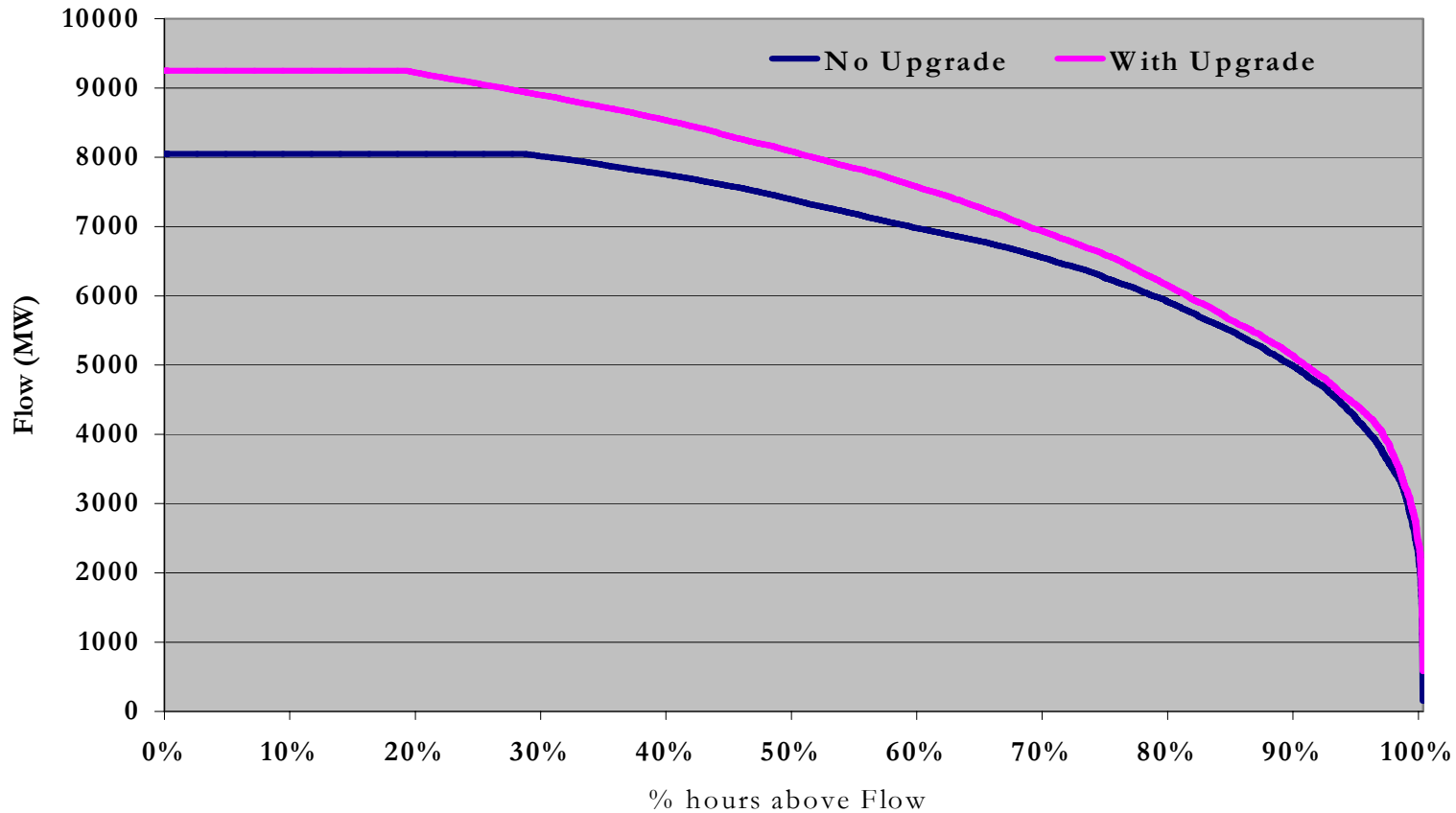
Summary of Benefits for Palo Verde Devers 2 Upgrade Case Description – M01. 2008 BBBM

Year 2008

Perspective	Description	Consumer Benefit (mil. \$)	Producer Benefit (mil. \$)	Trans. Rental (mil. \$)	Total Benefit (mil. \$)	Production Cost Savings (mil. \$)	Notes
<i>Societal</i>	<i>WECC</i>	239.86	(14.63)	(179.92)	45.31	45.314	
						17,628.28	Production Cost before upgrade
						17,582.97	Production Cost after upgrade
<i>Modified Societal</i>	<i>WECC</i>	239.86	6.73	(179.92)	66.67		Excludes monopoly rent, Except for utility generation in CAISO control area
<i>California Competitive Rent</i>	<i>ISO Ratepayer Subtotal</i>	166.56	(67.31)	(90.53)	8.72		Includes consumers, UDC generators and ISO PTOs. SMJD and some munis are treated as part of the CAISO due to data limitations.
	<i>ISO Participant Subtotal</i>	166.56	(45.10)	(90.53)	30.92		Consumers, producers and transmission owners participating in CAISO markets.

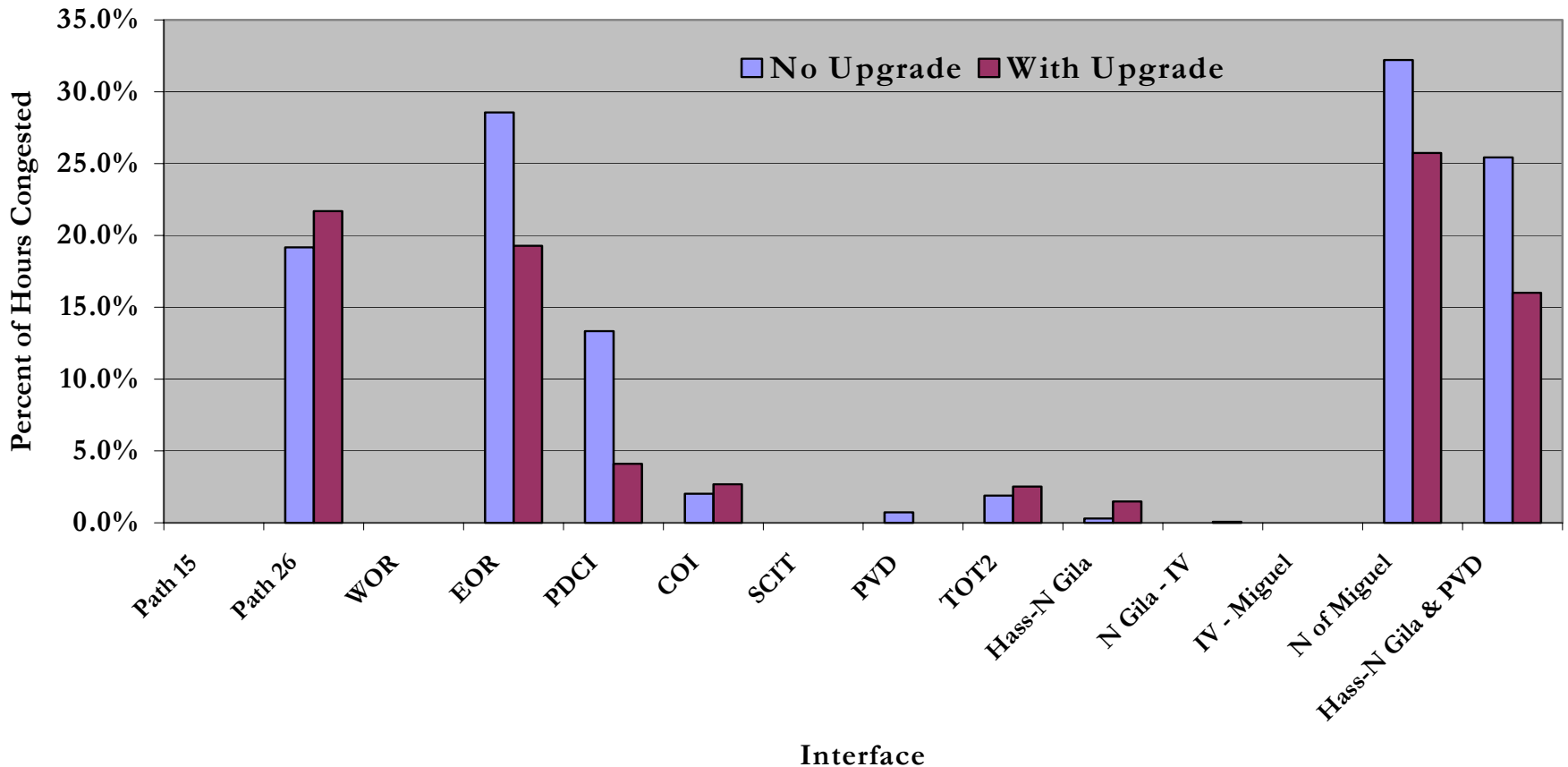


EOR Before and After Upgrade





Congestion on Major Paths





Hassaymapa – N Gila with PVD

