March 12, 2003

Attn: Parties of CPUC Docket # I.00-11-001

> RE: Docket # I.00-11-001, Order Instituting Investigation Into Implementation of Assembly Bill 970 Regarding the Identification of Electric Transmission and Distribution Constraints, Actions to Resolve Those Constraints, and Related Matters Affecting the Reliability of Electric Supply

Dear Parties:

Enclosed please find the California Independent System Operators presentation to be used during the workshop to be held on March 14, 2003.

Thank you.

Sincerely,

Jeanne M. Solé
Regulatory Counsel

Cc: Attached Service List

Proposed Methodology for Evaluating the Economic Benefits of Transmission Expansions in a Restructured Wholesale Electricity Market

Developed by

California ISO and London Economics LLC

PG&E Workshop
March 14, 2003

Presented by

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Manager Market Analysis & Mitigation

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Overview of Proposed Methodology

- **Objective** – Develop a comprehensive methodology to evaluate the economic benefits of transmission (TX) expansions in a restructured market environment.
- Critical Components
  - ✓ Interdependence of generation and transmission investments
  - ✓ Impact of TX expansion on market competitiveness
  - ✓ Assessment of benefits under a wide range of system conditions
  - ✓ Regional representation for large TX expansions
  - ✓ Benefits measured regionally and separately for consumers and producers

Background

- Proposed methodology developed jointly by CAISO and London Economics LLC (LE).
- Involved over a year of research and development with input and review provided by
  - A Steering Committee comprised of
    - Representatives of the IOUs (PG&E, SCE, SDG&E)
    - Representatives of various state agencies (CPUC, CEC, EOB)
  - The CAISO Market Surveillance Committee (MSC)

Today's Objective

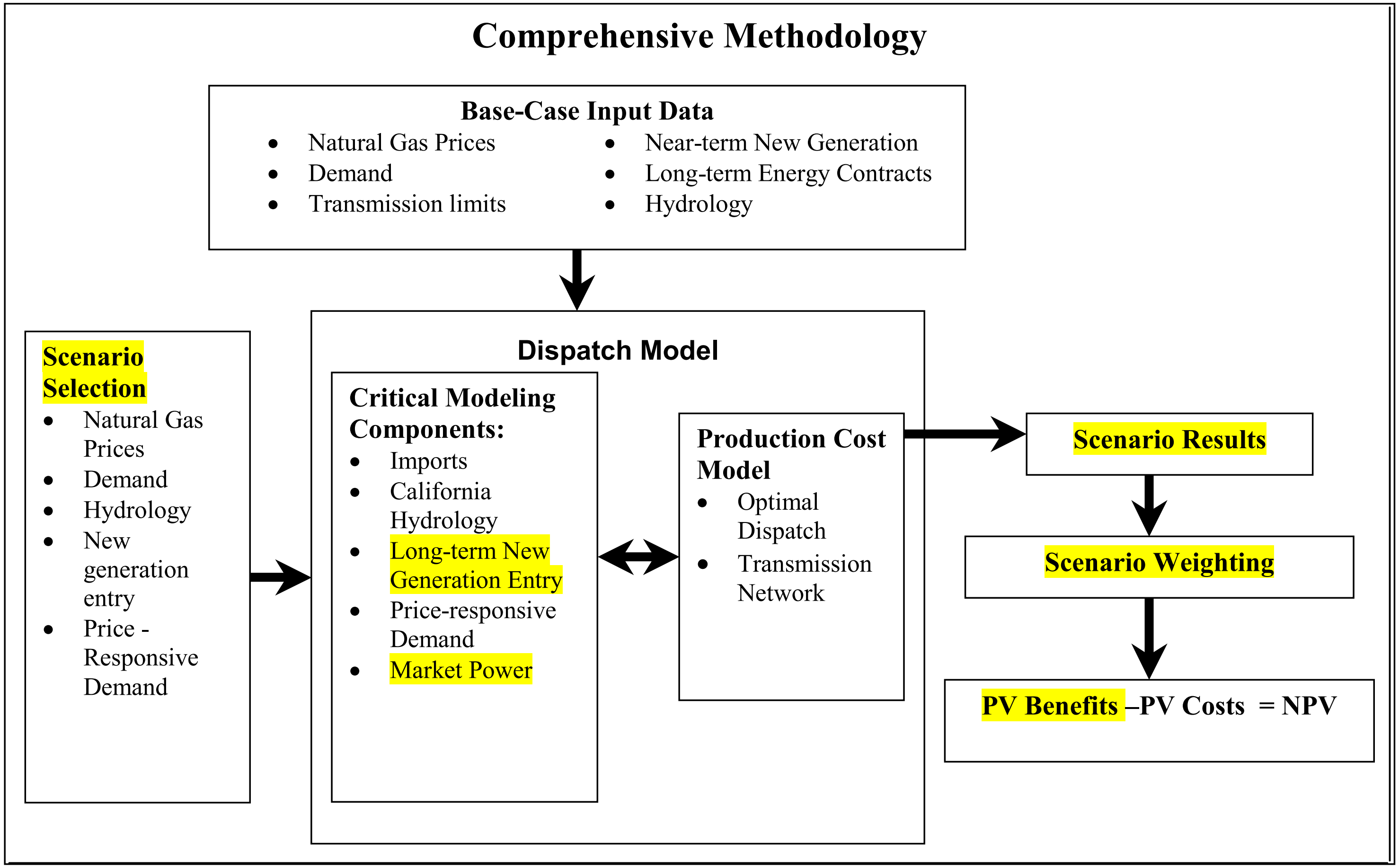
I. Review Methodology
  - High-level overview of overall methodology
  - Detail review of some of the main modeling components:
    - ➢ Modeling interdependence between generation and transmission investments.
    - ➢ Methodologies for choosing and weighting modeling scenarios.
    - ➢ Modeling market power.

II. Review some illustrative examples based on a Path 26 expansion.

III. Discuss what modeling factors should be held constant in assessing TX valuation methodologies in the evidentiary hearings.
  - Input data
  - Transmission network representation
  - Dispatch algorithms for thermal and hydroelectric generation, etc..

IV. Discuss candidate transmission projects for the evidentiary hearings.

Comprehensive Overview



Comprehensive Methodology

Base-Case Input Data

- Natural Gas Prices
- Demand
- Transmission limits
- Near-term New Generation
- Long-term Energy Contracts
- Hydrology

Scenario Selection

- Natural Gas Prices
- Demand
- Hydrology
- New generation entry
- Price - Responsive Demand

Dispatch Model

Critical Modeling Components:

- Imports
- California Hydrology
- Long-term New Generation Entry
- Price-responsive Demand
- Market Power

Production Cost Model

- Optimal Dispatch
- Transmission Network

Scenario Results

Scenario Weighting

PV Benefits –PV Costs = NPV

Modeling Interdependence between Generation and Transmission Investments

- New generation entry in the near-term (approx. 2-3 years) should be based on an assessment of plants under construction or fully permitted.
- New generation entry in the long-term (beyond approx. 3-years) should be determined by the TX valuation software base on an assessment of the profitability of new generation investment.
- New generation entry decisions should based on future <u>expected profits</u> under different future system conditions.
- The profitability of new generation investment can be impacted by a TX expansion.
  - New Generation investment in an import-constrained area can, to some extent, <u>substitute</u> for a transmission upgrade into that area.
  - A transmission expansion out of an export-constrained area can <u>complement</u> new generation investment within that area.

Modeling Interdependence between Generation and Transmission Investments

- The profitability of new generation investment can be impacted by a number of other factors:
  - Future load and hydro conditions
  - Future gas prices
- The locational siting cost of new generation investment can vary significantly (e.g. San Francisco Peninsula versus central California).
- New generation investment may be impeded by;
  - Permitting and approval processes
  - Environmental and local community concerns
- Given the impediments and uncertainty of new generation investment, the optimal generation investment profile derived from the model should be supplemented with sensitivity analysis (i.e. scenario analysis).

Modeling Interdependence between Generation and Transmission Investments

The Basic Approach-

- Annual Revenue Requirements (ARR) are derived for 2-new unit types
  - Peaker Unit - Single cycle gas turbine (SCGT)
  - Base-load Unit - Combined cycle gas turbine (CCGT)
- Annual Entry Trigger Prices (ETP) are derived from the market simulation software for each zone based on the annual capacity factors of each new unit type and its corresponding ARR.
- The market simulation software calculates the average Annual Unit Revenue (AUR) for each new unit type in each zone.
- ETPs and AURs are calculated separately for 3-different demand scenarios (very-low, base, and very-high)

Modeling Interdependence between Generation and Transmission Investments

The Basic Approach cont.

- "Expected" ETPs and AURs are determined by assigning risk-adjusted probability weights to the ETPs and AURs derived under each demand scenario
  - Very High Demand = 10% weight
  - Base Demand = 67% weight
  - Very Low Demand = 23% weight
- Example -

$$\textit{Expected}\ \ ETP_i = .10 * ETP_{D_{VH},i} + .67 * ETP_{D_B,i} + .23 * ETP_{D_{VL},i}$$

- Expected profits under very high demand are give a low weight to reflect investment risk aversion
- Entry of new capacity is based on a comparison of the 5-year forward looking rolling average of ETPs and AURs for each zone.

Modeling Interdependence between Generation and Transmission Investments

Near-term unit retirement assumptions -

Plants	***Size***	***Zone***	***Date of Retirement***
Alamitos 7	134 MW	SP15	12/31/2003
El Segundo1 & 2	339 MW	SP15	12/31/2002
Etiwanda 5	130 MW	SP15	12/31/2003
Huntington Beach 5	128 MW	SP15	12/31/2002
San Bernardino 1 & 2	126 MW	SP15	12/31/2002

Modeling Interdependence between Generation and Transmission Investments

Near-term New Generation Entry Assumptions

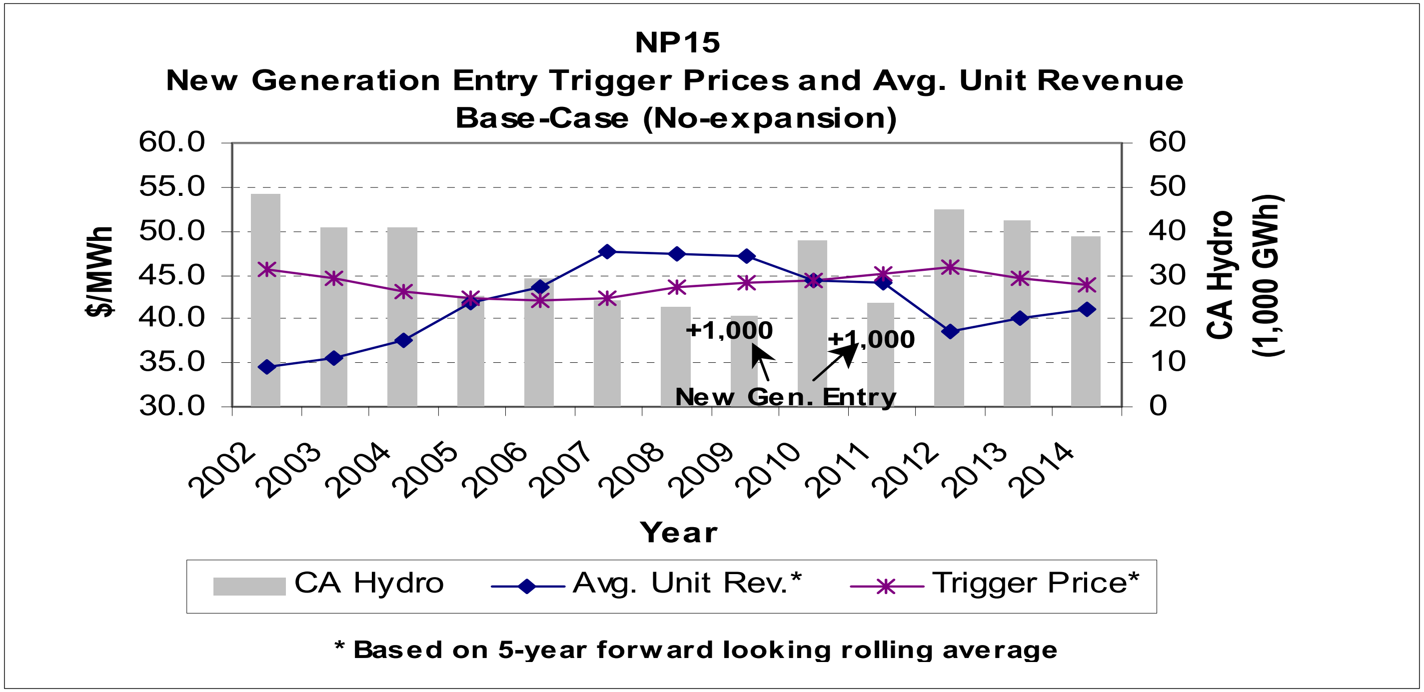
Ownership	Name	Region	DNC	Year in	Unit Type
CPCO	Feather River	NP15	45	2002	Peaker
CPCO	Goosehaven Energy Center	NP15	49	2002	Peaker
CPCO	Lambie Energy Center	NP15	49	2002	Peaker
CPCO	Los Esteros	NP15	195	2003	CCGT
MISC	Tracy Project	NP15	169	2003	Peaker
CPCO	Wolfskill Energy Center	NP15	49	2003	Peaker
		NP15 Total	555		
MISC	Huntington Beach	SP15	225	2002	CCGT
MISC	Springs	SP15	40	2002	Peaker
MISC	Blythe Energy Project	SP15	517	2003	CCGT
MISC	Central La Rosita I	SP15	160	2003	CCGT
MISC	Central La Rosita II, Phase 2	SP15	155	2003	CCGT
MISC	High Desert	SP15	850	2003	CCGT
CPCO	Pastoria Power Project	SP15	755	2003	CCGT
CPCO	Pastoria Project	SP15	750	2003	CCGT
MISC	Termoelectrica De Mexicali	SP15	600	2003	CCGT
MISC	Wind Project (Windridge)	SP15	20	2003	Wind
		SP15 Total	4,072		
SDGE	Elk Hills Power Project	ZP26	530	2003	CCGT
SCEC	Sunrise Power Project, Phase II	ZP26	200	2003	Peaker
		ZP26 Total	730		
		Grand Total	5,357		

Capital Cost Assumptions for New Generation

Baseload Unit (CCGT)	2005	2014
capital cost - real $/kW	$600	$565
average heat rate - Btu/kWh	7,300	6,259
indicative load factor	85%	85%
variable O&M - real $/MWh	$1.5	$1.5
fixed O&M - real $/kW/year	$17.1	$17.1
leverage	70%	70%
debt rate	10%	10%
after-tax required equity return	20%	20%
corporate income tax rate	35%	35%
debt financing lifetime (yrs)	10	10
capital recovery lifetime for equity portion (yrs)	20	20

Peaking Unit (SCGT)	2005	2014
capital cost - real $/kW	$350	$329
average heat rate - Btu/kWh	11,000	9,631
indicative load factor	10%	10%
variable O&M - real $/MWh	$1.9	$1.9
fixed O&M - real $/kW/year	$8.0	$8.0
leverage	30%	30%
debt rate	10%	10%
after-tax required equity return	25%	25%
corporate income tax rate	35%	35%
financing lifetime (yrs)	10	10
capital recovery lifetime for equity portion (yrs)	10	10

Long-term New Generation Entry (NP15) in the Illustrative Path 26 Analysis



- Long-term new generation entry was found to be profitable for CCGT units in NP15 for 2009 and 2011.
- The Path 26 expansion was not found to have a significant impact on the profitability of new generation entry.

Modeling Interdependence between Generation and Transmission Investments cont..

Summary of Long-term New Generation Entry Scenarios (MW)

New Generation Entry No Expansion and Path 26 Expansion				
Type of Entry	**Zone**	**2009**	**2011**	**Total**
Normal	NP15	1000	1000	2000
Normal	ZP26	0	0	0
Normal	SP15	0	0	0
	Total	**1000**	**1000**	**2000**
Over	NP15	1500	1500	3000
Under	ZP26	(171)	(171)	(342)
Over	SP15	500	400	900
	Total	**1829**	**1729**	**3558**
Under	NP15	500	500	1000
Over	ZP26	200	200	400
Under	SP15	(481)	(510)	(991)
	Total	**219**	**190**	**409**

New Generation - Under Entry Retirements No Expansion and Path 26 Expansion		
Zone	2009	2011
ZP26	MORBAY_7_UNIT 2	MORBAY_7_UNIT 1
SP15	ALAMIT_7_UNIT 6	SOBAY_7_SY1 & SY2 ENCINA_7_EA1 & EA3

Methodologies for Choosing and Weighting Scenarios

Background -

- In a restructured market environment, variations in system conditions can have a significant impact on market prices and the value of a TX expansion. Therefore, it is critical to examine the value of a TX expansion under a wide range of possible system conditions (scenarios).
- There are two critical aspects to scenario analysis;
  1. Selecting important and representative scenarios
  2. Determining how to weight the estimated benefits under each scenario in order to derive the "expected benefit" of the TX expansion.
- The proposed methodology provides innovative approaches to addressing both of these aspects.

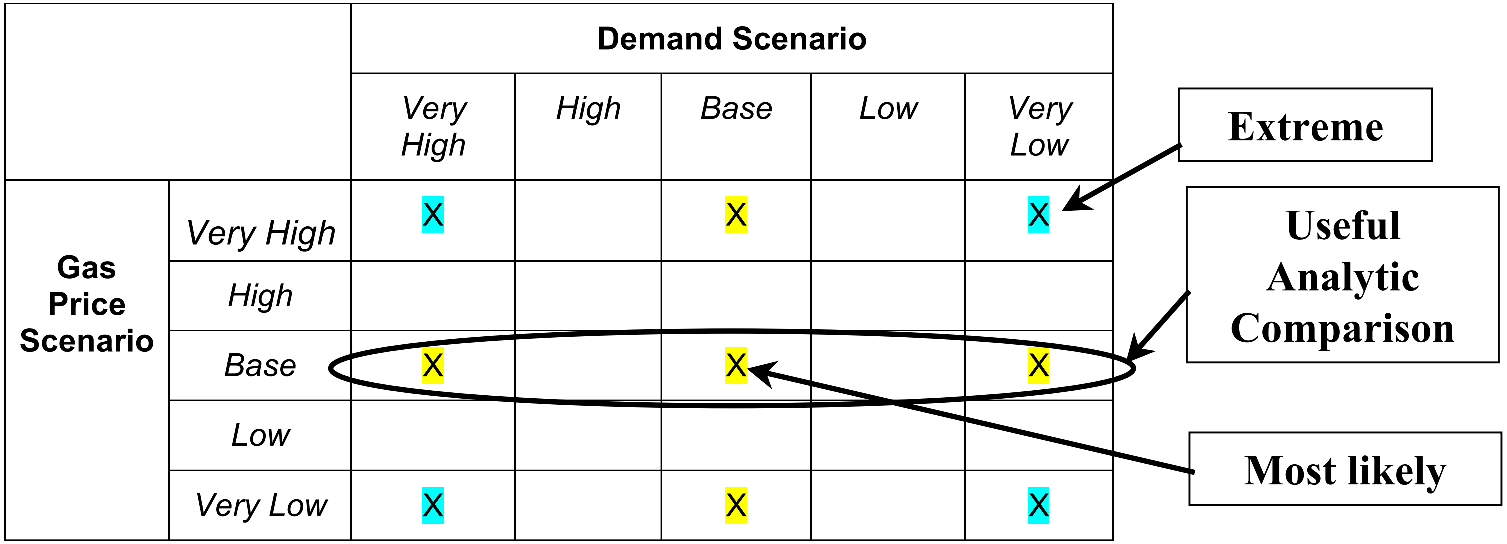
Methodologies for Choosing and Weighting Scenarios

- Selection of Scenarios
  - Stage 1- Importance Sampling
    - Select interesting and extreme scenarios
    - Select most likely scenarios
  - Stage 2 – Select representative sample using Latin Hypercube Sampling techniques
- Weighting of Scenarios
  - Stage 1 – Estimate joint probabilities of natural gas price and demand forecast scenarios using Moment Consistent Linear Programming (LP) Approach.
  - Stage 2 – Min-Max LP Approach using Stage 1 results as a constraint:
    - Choose joint probabilities of natural gas price, demand, and new generation entry forecasts that **maximize** the expected benefits of the expansion.
    - Choose joint probabilities of natural gas price, demand, and new generation entry forecasts that **minimize** the expected benefits of the expansion.

Selection of Scenarios – Importance Sampling

Purpose of importance sampling –

- Ensure extreme or most interesting scenarios are capture
- Ensure most likely scenarios are captured
- Ensure scenario combinations that provide useful analytic comparisons
- Example:



		Demand Scenario				
		Very High	*High*	*Base*	*Low*	*Very Low*
Gas Price Scenario	*Very High*	X		X		X
	High					
	Base	X		X		X
	Low					
	Very Low	X		X		X

Selection of Scenarios – Random Sampling

- Purpose of random sampling –
  - Ensure a representative sample of scenarios
- Sampling technique – “Latin Hypercube”
  - Random selection of scenarios without replacement
- 2-Examples of Latin Hypercube (LH) Sampling:

		Demand Scenario				
		Very High	*High*	*Base*	*Low*	*Very Low*
Gas Price Scenario	*Very High*	X		O		
	High		X		O	
	Base		O	X		
	Low				X	O
	Very Low	O				X

The LH sampling technique ensures there is a selection in every column and every row of the matrix.

Scenario Selection – Combining Importance Sampling with Latin Hypercube Sampling

Applying the combined sampling approach to the illustrative Path 26 expansion resulted in 14-different demand and gas price scenarios

		Demand Scenario				
		Very High	*High*	*Base*	*Low*	*Very Low*
Gas Price Scenario	*Very High*	X		X		X
	High			L		L
	Base	X		X	L	X
	Low		L			
	Very Low	X		X	L	X

Scenario Selection for Long-term New Generation Entry Levels

- Two step approach of importance sampling supplemented with random sampling using the Latin Hypercube sampling technique can be used to select scenarios for different levels of new generation entry.
- Example-
  - "Base-line" or "Normal" new generation entry levels are derived from the model for each year and each zone (NP15, ZP26, SP15), which can be expressed as (N,N,N), where "N" = Normal Entry.
  - Over ("O") and Under ("U") entry scenarios can be derived for each zone based on +/- 50% of the annual base-line new generation entry levels.
  - This will result in 27 zonal new generation entry scenarios (e.g. (O,U,O), (U,N,O), (N,N,N) etc.).
  - Importance sampling and LH sampling can be performed to select a subset of the 27 potential new generation entry scenarios.

Scenario Selection for Long-term New Generation Entry Levels

- In the illustrative Path 26 analysis only 3 of the 27 zonal new generation entry scenarios were considered.
  - (NNN) - Normal entry in all three zones
  - (OUO) - Over-entry in NP15 and SP15, Under-entry in ZP26
  - (UOU) – Under-entry in NP15 and SP15, Over-entry in ZP26
- Applying the 3 new generation entry scenarios to all 14 demand and gas price scenarios results in a total of 42-scenarios for each transmission expansion option (i.e. no-expansion, Path 26 expansion).
- Due to time limitations only a subset of the 42-scenarios were examined.

Scenario Selection – Scenarios selected for the illustrative Path 26 analysis

Scenario	Demand	Gas	Generation Entry
1	*Very high*	*Very high*	*NNN*
2	*Very high*	*Base*	*NNN*
3	*Very high*	*Very low*	*NNN*
4	*Base*	*Very high*	*NNN*
5	*Base*	*Base*	*NNN*
6	*Base*	*Very low*	*NNN*
7	*Very low*	*Very high*	*NNN*
8	*Very low*	*Base*	*NNN*
9	*Very low*	*Very low*	*NNN*
10	*Very high*	*Very high*	*OUO*
11	*Very high*	*Very low*	*OUO*
12	*Base*	*Base*	*OUO*
13	*Very low*	*Very high*	*OUO*
14	*Very low*	*Very low*	*OUO*
15	*Very high*	*Very high*	*UOU*
16	*Very high*	*Very low*	*UOU*
17	*Base*	*Base*	*UOU*
18	*Very low*	*Very high*	*UOU*
19	*Very low*	*Very low*	*UOU*

A subset of 19 scenarios were considered in the illustrative Path 26 analysis.

Determining Scenario Weighting Factors

Background -

- Scenarios (different combinations of system variables (i.e. future demand, gas prices, and new generation entry)) represent different future states of the world with each having a certain probability of occurring.
- If we knew the marginal probabilities of each system variable, the correlations between system variables, and had a representative sample of each, determining the joint probabilities of each combination of system variables (scenario) would be relatively straight forward.
- Unfortunately we do not have good information on the marginal probabilities and correlations of all system variables nor do we necessarily have an unbiased- representative sample and therefore must resort to estimating the joint probabilities (weighting factors) through other means.

Determining Scenario Weighting Factors

- Illustrative Path 26 Analysis involves 19 scenarios involving the following system variables:
  - Future demand levels
  - Future gas prices
  - Future new generation entry
- A 2-stage linear programming (LP) approach is adopted to estimate the joint probabilities (weighting factors) of each scenario.
  - Moment Consistent LP Approach for determining the joint probabilities of the 9 different combinations of demand and natural gas prices.
  - Min-Max LP Approach for determining the joint probabilities of the 19-different combinations of demand, natural gas prices, and new generation entry.
- A 2-stage approach is used because we have much better information on the probability distributions of future demand and gas price scenarios than we do for new generation entry.

Stage 1 - Moment Consistent LP Approach

- Joint probabilities of combinations of demand and natural gas prices are selected to match the moments (mean, variance) of the estimated probability distributions of each variable and their covariance.
- The mean and variance of demand and natural gas price scenarios are estimated from historical CEC forecast errors.
  - Mean and variances of these variables tend to increase with longer forecast outlooks (e.g. 1-year outlook, 2-year outlooks, ….13-year outlook)
- Each demand and gas price scenarios can be expressed in terms of a forecast error (e.g. the forecast error of realizing the base demand scenario is 0 (i.e. demand was perfectly predicted)).
- Since the forecast errors of each demand and natural gas price scenario vary in each year of the study period, due to the fact that the mean and variances of forecast errors increase with longer forecast outlooks, the forecast errors are standardized using each years estimated mean and variance.
- Once the demand and gas price scenarios are standardized across all years, the Moment Consistent LP approach can be applied to any year to determine the joint probabilities of the entire 13-year scenarios.

Stage 1: Moment Consistent LP Approach

Objective Function:

$$\underset{p_1, p_2, \ldots, p_m}{Min} \sum_{i=1}^{m} p_i^2 + [\sum_{i=1}^{m} p_i (D_i - \hat{\mu}_D)^3]^2 + [\sum_{i=1}^{m} p_i (G_i - \hat{\mu}_G)^3]^2$$

Choose joint probabilities to minimize the sum of the squared probabilities[1] and the skew of each variable[2].

1. **Minimizing the square of probabilities ensures the selected probabilities are more evenly distributed.**
2. **Minimizing the skew of each variable reflect the assumption that the true skew of each variable is zero (i.e. symmetric distribution).**

Constraints:

st

Match the mean of each variable

$$\sum_{i=1}^{m} p_i D_i = \hat{\mu}_D \quad \ldots\ldots \quad (1)$$

$$\sum_{i=1}^{m} p_i G_i = \hat{\mu}_G \quad \ldots\ldots \quad (2)$$

Match the variance of each variable

$$\sum_{i=1}^{m} p_i (D_i - \hat{\mu}_D)^2 = \hat{\sigma}_D^2 \quad \ldots\ldots \quad (3)$$

$$\sum_{i=1}^{m} p_i (G_i - \hat{\mu}_G)^2 = \hat{\sigma}_G^2 \quad \ldots\ldots \quad (4)$$

Match the covariance between demand and gas prices (assumed=0)

$$\sum_{i=1}^{m} p_i (D_i - \hat{\mu}_D)(G_i - \hat{\mu}_G) = \hat{\sigma}_{DG} \quad \ldots\ldots \quad (5)$$

$$\sum_{i=1}^{m} p_i = 1 \quad \ldots\ldots \quad (6)$$

$$p_i \geq 0 \quad \ldots\ldots \quad (7)$$

Stage 1: Moment Consistent LP Approach – Estimated Joint Probabilities

Scenarios	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Demand	VH	VH	VH	B	B	B	VL	VL	VL
Gas Price	VH	B	VL	VH	B	VL	VH	B	VL
Joint Probability	0.0121	0.1606	0.0121	0.1606	0.3092	0.1607	0.0121	0.1606	0.0121

Determining Scenario Weighting Factors

- Stage 2 – Min-Max LP Approach
  - Used to determine the joint probabilities of the 19-different combinations of demand, natural gas prices, and new generation entry.
  - Max LP Approach: Choose joint probabilities of natural gas price, demand, and new generation entry forecasts that **maximize** the expected benefits of the expansion.
  - Min LP Approach: Choose joint probabilities of natural gas price, demand, and new generation entry forecasts that **minimize** the expected benefits of the expansion.
  - The Min-Max LP Approach "bookends" the expected benefits of the TX expansion.
  - Transmission expansion benefits must be estimated prior to running the Min-Max optimizations.

Stage 2 – Min-Max LP Approach

$$\underset{f_1, f_2, \dots, f_k}{Max} \quad \sum_{j=1}^{k} f_j B_j \quad or \quad \underset{f_1, f_2, \dots, f_k}{Min} \quad \sum_{j=1}^{k} f_j B_j$$

Joint Probabilities (f_k) are chose under two optimizations:

1. Maximize expected benefits (B_j)

2. Minimize expected benefits (B_j)

Subject to the following constraints:

$$\sum_{j=1}^{k} f_j * INT_j[(D_j / G_j) = (D/G)_i] = p_i^*$$

Joint probabilities of demand and gas price scenarios derived in Stage 1 must be observed

$$\sum_{j=1}^{k} f_j * INT_j(newgen_j = NNN) \geq \sum_{j=1}^{k} f_j * INT_j(newgen_j = OUO)$$

$$\sum_{j=1}^{k} f_j * INT_j(newgen_j = NNN) \geq \sum_{j=1}^{k} f_j * INT_j(newgen_j = UOU)$$

Probability of base-case new generation entry must be greater than the probability of over or under entry.

$$f_j \geq 0 \ \forall j.$$

Joint probabilities must be non-negative

Modeling Market Power

- A transmission expansion can provide significant consumer benefits by reducing the ability of suppliers to exercise market power.
- A transmission expansion is just <u>one of several actions</u> that can be taken to reduce market power. Therefore, the market power mitigation benefits of a transmission expansion should be examined under different assumptions concerning:
  - Price responsive demand
  - Forward contracting
  - New generation entry

Modeling Market Power

- Two approaches to modeling market power are provided in this methodology.
  - Game theoretic approach:
    - Largest suppliers are modeled as strategic players
    - Each strategic player bids to maximize profits given the bidding strategies of other strategic players.
    - Model iterates to convergence when no strategic player can increase its profits given the bidding strategies of all other strategic players.
  - Empirical approach:
    - Relationships between price-cost markups and certain system parameters are derived from historical market data.
    - Estimated relationship is applied prospectively in the transmission study to determine price-cost markups (i.e. market power).

Game Theoretic Approach to Modeling Market Power

Background:

- Game theoretic models of strategic bidding generally involve several strategic players with each seeking to maximize its profits in response to the bidding strategies of others.
- Equilibrium is attained when no player can increase its expected profit given the bidding strategy of all other players.
- In very simplistic models, an equilibrium can be solved for mathematically.
- In more complicated models, an equilibrium is derived through an iterative process where each player's bid is optimally adjusted based on the bidding behavior of all other players in the previous iteration.
- A game theoretic model in a transmission study must recognize the major transmission constraints and the location of each player's supply within the network. Incorporating these features makes the model too complex to solve mathematically and necessitates an iterative convergence approach to deriving an equilibrium.

Game Theoretic Approach to Modeling Market Power

- An iterative convergence based model of strategic bidding, "ConjectureMOD" was developed by London Economics and applied in the illustrative Path 26 analysis.
- The iterative procedure begins with each bidder ***i*** predicting that each other bidder ***j*** is bidding its marginal cost at output level $\mathbf{q_j}$.
- Then, each bidder ***i*** chooses its offered bid pair (price and quantity) to maximize its net profits in view of its residual demand function (total demand (D) less its prediction of other bidders' supplies).
- For the iterative procedure thereafter, each firm conjectures that each players bid is their profit maximizing bid from the previous iteration.

Game Theoretic Approach to Modeling Market Power

ConjectureMOD Strategic Bidding Function:

$$B_{jZ}(q_{jz}) = [MC_{jZ}(q_{jZ}) - k]\mu + k, \qquad \underbrace{b_{jZ}(q_{jZ}) \leq 1000}_{\boxed{\$1{,}000 \text{ bid cap}}}$$

Where

$MC_{jZ}(q_{jZ})$ = marginal cost of generator ***j*** in zone Z

k = constant (indexed to prevailing gas prices)

μ = discrete strategy choice (e.g. 1, 1.1, 1.3, 1.5, 2, 3, 4, 5, 10, 15, …40)

q_{jZ} = residual demand facing generator ***j***

- Players are assumed to bid their marginal cost for the first third of their unit's capacity (i.e. only the last two thirds of the unit's capacity is assumed strategic)
- Convergence Rule – The model is deemed to have converged if
  - profits of the last 2-iterations do not diverge by more than 1% or
  - 50-iterations are completed

Empirical Approach to Modeling Market Power

- The empirical approach to modeling market power involves:
  - Deriving statistical relationships between price-cost markups and certain system parameters from historical market data.
  - Applying these derived relationships prospectively in the transmission study to determine price-cost markups (i.e. market power).

Empirical Approach to Modeling Market Power

Regression Specification:

$$\mathrm{PMU}_{i,j} = a + b\,\mathrm{RSI}_{i,j} + c\,\mathrm{TUC}_{i,j} + d\,\mathrm{LD}_{i,j} + e\mathrm{S}P_{i,j} + f\mathrm{NS}_{i,j}$$

Where

$\mathrm{PMU}_{i,j}$ = The price-cost markup for hour (i) in zone (j).

$\mathrm{RSI}_{i,j}$ = Residual Supply Index in hour (i) for zone (j)

$\mathrm{TUC}_{i,j}$ = Total Uncommitted Capacity of largest single supplier in hour (i) for zone (j)

$\mathrm{LD}_{i,j}$ = Actual load in hour (i) for zone (j)

$\mathrm{SP}_{i,j}$ = Dummy for summer periods (May-Oct)

$\mathrm{NS}_{i,j}$ = Dummy for whether the zone is NP15 or SP15

Empirical Approach to Modeling Market Power

Price-Cost Markup (PMU)

The Price-Cost Markup is actually expressed as the Lerner Index, which is equal to the following:

$$\text{Lerner Index} = ((P_{i,j} - C_{i,j})/P_{i,j})$$

Where

$P_{i,j}$ = Actual price in hour (i) and zone (j)

$C_{i,j,}$ = Estimated competitive price in hour (i) and zone (j)

Empirical Approach to Modeling Market Power

Residual Supply Index (RSI)

The Residual Supply Index ($RSI_{i,j}$) in each hour (i) and for each zone (j) will be calculated according to the following formula:

$$RSI_{i,j} = \frac{TS_{i,j} - Max(TUC_{i,j})}{RND_{i,j}}$$

Where,

$TS_{i,j}$ = Total Available Supply (available imports + the uncommitted capacity of independent generator owners)

$Max(TUC_{i,j})$ = Total Uncommitted Capacity of Largest Single Supplier

$RND_{i,j}$ = Actual zonal demand less utility owned generation output - QF generation - Long-term Contracts.

- **The RSI measures the extent to which the largest supplier is “pivotal” in the sense that demand could not be met absent its supply.**
- **An RSI value less than 1 indicates the largest supplier is pivotal and thus able to exercise market power.**

Price-cost Markup Regression Results

Dependent Variable: Lerner Index

Explanatory Variables	Parameter Estimate	t-Statistics
RSI	-0.26	[41.11]***
Zonal Load	4.55*E-5	[54.88]***
Uncommitted Supply of the Largest Supplier	1.35*E-4	[22.90]***
Dummy for Summer Months	0.22	[62.27]***
Dummy for Two Zone (NP15=1; SP15=0)	0.16	[14.49]***
Intercept	-0.84	[26.97]***
R Squared		0.62
Number of Observations		16,378

Source: data in CAISO Market (November 1999 to October 2000).

**** Significant at 1% level.

Empirical Approach to Modeling Market Power

- Applying the regression estimation in the previous slide prospectively in the illustrative Path 26 analysis resulted in extremely high price-cost markups in the later years of the study (2012-2014).
- This result seems to be primarily driven by the fact that one of the explanatory variables, Zonal Load, is at levels in the later years of the study that are well beyond the original range of load values used to estimate the regression.
- The CAISO has been experimenting with other regression specifications including:
  - Normalizing the Zonal Load variable by dividing it by annual average load for each year of the study period.
  - Omitting the Zonal Load variable from the regression specification.
- These alternative specifications have produced comparable explanatory power (i.e. R-square, statistically significant explanatory variables).

Pros and Cons of Game Theoretic versus Empirical Approach to Modeling Market Power

- Game theoretic models:
  - may allow for a better assessment of how certain fundamental changes in the market structure will effect supplier's ability to exercise market power such as an increase in price responsive demand.
  - must be fairly simplistic in order to solve in tractable manner, which may limit their predictive capability.
  - are <u>not</u> derived from empirically established relationships between market power and system conditions and therefore may have limited predictive capability.
- Empirical models:
  - are derived from empirically established relationships between market power and system conditions and therefore should have good predictive capability.
  - may require additional analysis if significant demand response can be expected.

Illustrative Path 26 Examples

II. Illustrative Application of the Methodology to Path 26

- **Outline of Presentation -**
  - Review the proposed Path 26 expansion (Capital Cost, MW)
  - Review transmission capacity assumptions
  - Review annual consumer surplus benefits for 3 of the 19 scenarios considered
    - Base natural gas prices
    - Base new generation entry levels
    - 3-different demand scenarios (Very Low, Base, Very High)
  - Review total (2002-2014) consumer surplus benefits for all 19 scenarios.
  - Review Min-Max LP results for assigning probability weights to each of the 19 scenarios
- **All numeric examples are based on the game theoretic approach to modeling strategic bidding (ConjectureMOD)**

The Proposed Path 26 Expansion

		Long-term	
	Short-term	**Option 1**	**Option 2**
Capital	$2,100,000	$138,750,000	$143,000,000
Upgrade	400 MW	600 MW	600 MW
On-line Dates	2003	2005	2005

Total Transmission Capacity for Path 15 and Path 26

Year	Path 15		Path 26 No-Expansion		Path 26 Expansion	
	S -> N	**N->S**	**S -> N**	**N->S**	**S -> N**	**N->S**
2002	3,900	1,275	3,000	3,000	3,000	3,000
2003-04	3,900	1,275	3,000	3,000	3,400	3,400
2005-13	3,900	1,275	3,000	3,000	4,000	4,000

Adjusted Transmission Capacity to Reflect Unused Existing Transmission Contracts (ETCs)

Year	Path 15		Path 26 No-Expansion		Path 26 Expansion	
	S -> N	N->S	S -> N	N->S	S -> N	N->S
2002	3,230	806	2,035	2,552	2,035	2,552
2003	3,230	806	2,035	2,552	2,435	2,952
2004	3,340	806	2,630	2,742	3,030	3,142
2005	3,423	806	2,720	2,742	3,720	3,742
2006	3423	806	2,720	2,742	3,720	3,742
2007	3584	806	2,820	2,742	3,820	3,742
2008-13	3593	806	2,820	2,742	3,820	3,742
2014	3817	806	2,820	2,742	3,820	3,742

Change in Consumer Surplus ($1,000)* from a Path 26 Expansion by Zone based on Competitive Bidding Simulations

	Very High Demand			Base Demand			Very Low Demand		
	NP15	*ZP26*	*SP15*	*NP15*	*ZP26*	*SP15*	*NP15*	*ZP26*	*SP15*
2002	0	0	0	0	0	0	0	0	0
2003	800	0	4,600	4,000	0	10,800	900	(200)	6,800
2004	100	0	200	(400)	0	(600)	900	100	1,400
2005	0	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	(500)	0	600
2007	4,300	500	9,500	500	0	700	(100)	0	(100)
2008	100	(1,600)	(28,300)	3,900	100	1,600	(200)	0	(200)
2009	3,800	300	6,000	(500)	0	(200)	500	0	900
2010	2,500	(1,000)	(18,800)	6,200	400	9,300	3,100	200	5,200
2011	(5,300)	600	10,900	4,300	1,500	27,900	(100)	0	400
2012	(64,700)	(10,500)	55,700	(58,700)	(13,600)	30,900	(60,400)	(15,400)	40,600
2013	36,100	2,400	108,400	(8,900)	(1,900)	34,100	(13,000)	(5,100)	45,400
2014	(8,600)	(600)	100,100	5,400	(100)	45,400	(47,100)	(5,000)	35,100
Total	**(30,800)**	**(9,800)**	**248,200**	**(44,200)**	**(13,600)**	**159,900**	**(116,000)**	**(25,400)**	**136,000**

*** Values are adjusted for inflation (real 2002 $) but not discounted to present value.**

Observations –

- **Benefits of TX expansion increase with level of demand.**
- **Benefits in SP15 are generally positive.**
- **Benefits are largest in the later years (2012-2014).**

Change in Consumer Surplus ($1,000)* from a Path 26 Expansion by Zone based on Strategic Bidding Simulation

	Very High Demand/Base Gas Price			Base Demand/Base Gas Price			Very Low Demand/Base Gas Price		
	NP15	*ZP26*	*SP15*	*NP15*	*ZP26*	*SP15*	*NP15*	*ZP26*	*SP15*
2002	0	0	0	0	0	0	0	0	0
2003	600	0	4,300	3,700	0	10,800	900	(200)	7,000
2004	200	0	300	(200)	0	(200)	100	0	100
2005	(4,400)	0	(400)	0	0	400	900	0	400
2006	49,300	100	2,200	200	0	200	(1,100)	200	3,200
2007	(50,200)	(300)	(5,200)	92,900	100	2,200	19,900	4,500	82,100
2008	8,300	300	5,500	(900)	(100)	(1,800)	1,300	100	1,400
2009	(2,700)	(500)	(7,900)	900	(100)	(2,200)	200	(5,700)	(105,000)
2010	57,100	2,800	50,300	5,500	400	8,500	13,800	300	6,200
2011	43,300	9,000	178,800	22,000	3,400	61,700	1,700	100	2,800
2012	(93,900)	(12,700)	97,200	(55,700)	(13,100)	57,900	(57,400)	(15,000)	45,500
2013	144,300	10,200	280,500	(100)	(1,200)	69,400	(13,800)	(4,900)	48,500
2014	93,800	7,300	275,300	14,300	300	67,300	(44,700)	(4,700)	40,200
Total	**245,700**	**16,400**	**880,900**	**82,600**	**(10,400)**	**274,200**	**(78,200)**	**(25,400)**	**132,400**

*** Values are adjusted for inflation (real 2002 $) but not discounted to present value.**

Observations –

- **Benefits of TX expansion increase with level of demand.**
- **Benefits in SP15 are generally positive.**
- **Benefits in NP15 and ZP26 negative under "Very Low Demand" but become less negative or positive under higher demand levels.**
- **Benefits are largest in the later years (2012-2014).**

Comparison of Competitive and Strategic Bidding Simulations - Total Change in Consumer Surplus ($1,000)* for 2002-2014 from a Path 26 Expansion by Zone

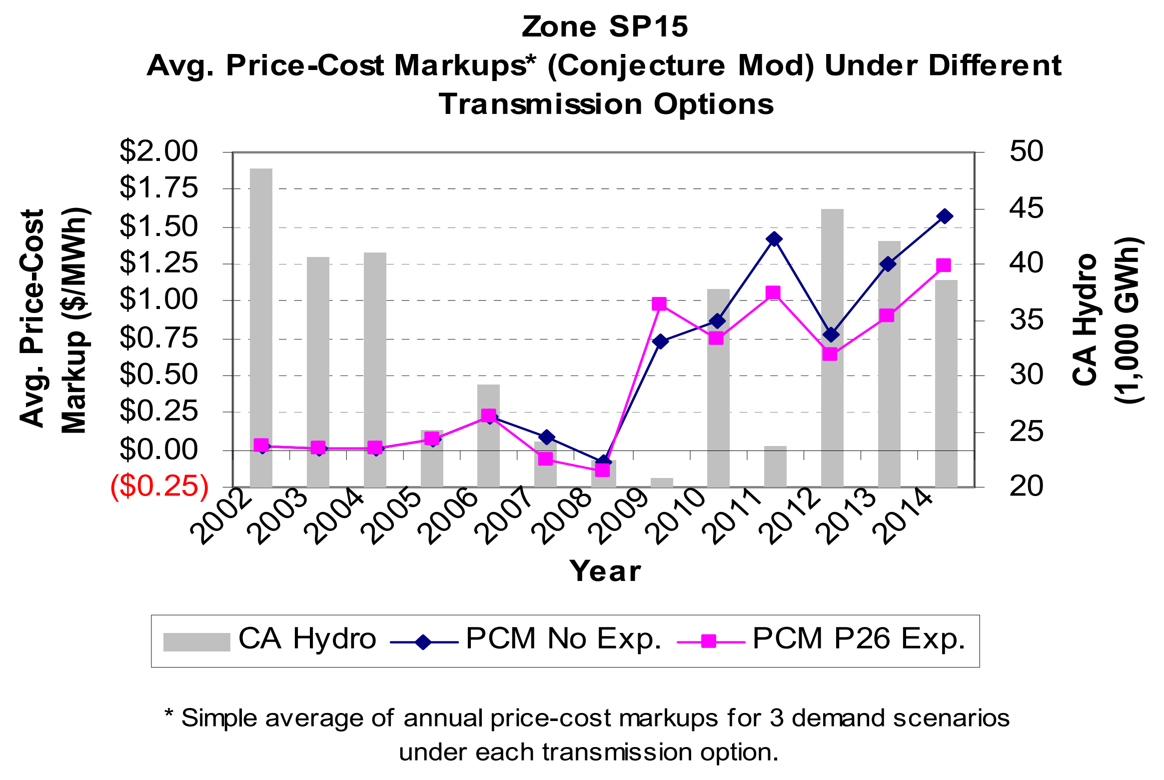
	Very High Demand			Base Demand			Very Low Demand		
	NP15	*ZP26*	*SP15*	*NP15*	*ZP26*	*SP15*	*NP15*	*ZP26*	*SP15*
Competitive Bidding	(30,800)	(9,800)	248,200	(44,200)	(13,600)	159,900	(116,000)	(25,400)	136,000
Strategic Bidding	245,700	16,400	880,900	82,600	(10,400)	274,200	(78,200)	(25,400)	132,400
*** Based on Normal Generation Entry Levels and Base Gas Prices**									

*** Values are adjusted for inflation (real 2002 $) but not discounted to present value.**

Observations –

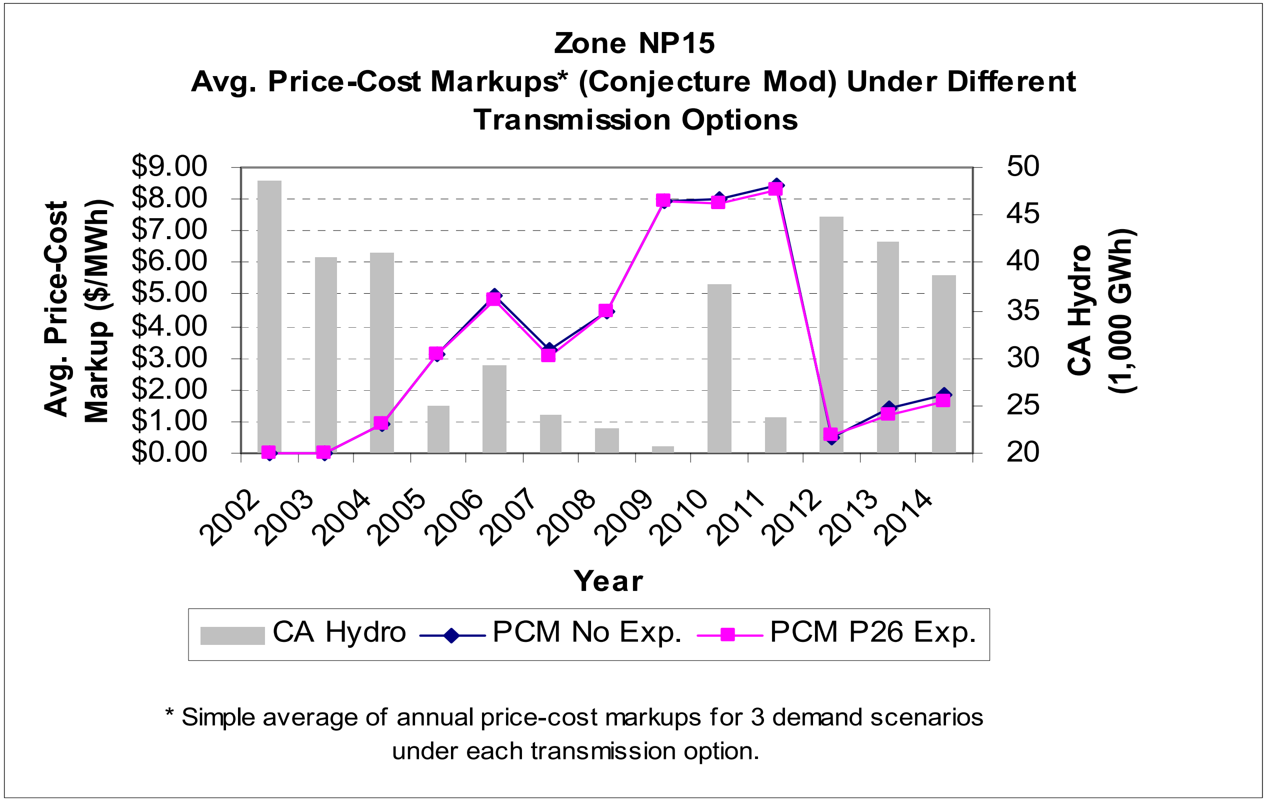
- **Very little difference in results under “Very Low Demand”**
- **Benefits in SP15 increase significantly with Strategic Bidding under “Base” and “Very High Demand” scenarios.**
- **Benefits in NP15 switch from negative to positive with Strategic Bidding under “Base” and “Very High Demand” scenarios.**

Comparison of Average Price-Cost Markups with and Without the Expansion (SP15)



* Simple average of annual price-cost markups for 3 demand scenarios under each transmission option.

Comparison of Average Price-Cost Markups with and Without the Expansion (NP15)



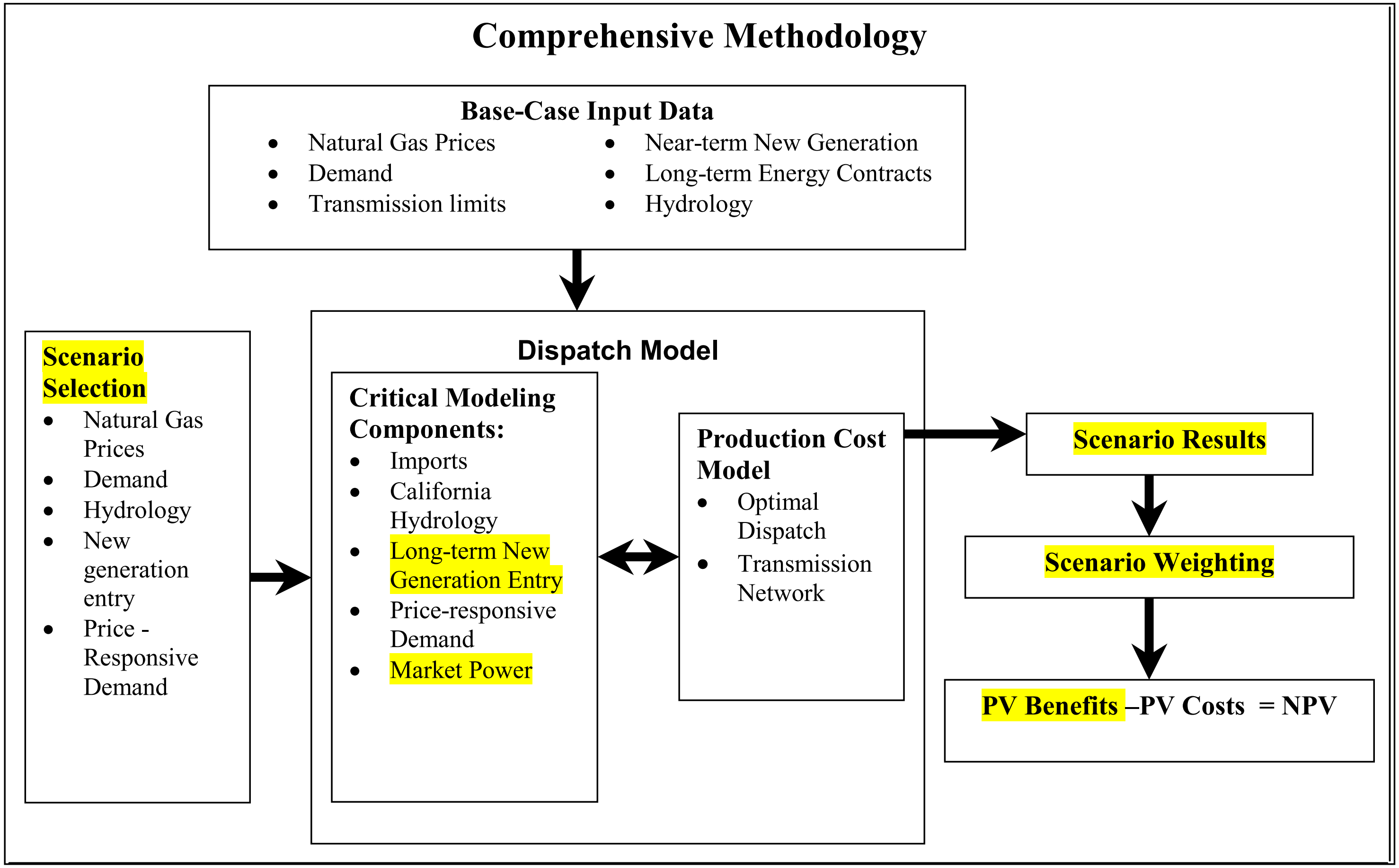
* Simple average of annual price-cost markups for 3 demand scenarios under each transmission option.

Assessment of Uncertainty – Weighting Scenarios Utilizing Min-Max LP Approach to Determine the Expected Benefits of a Transmission Expansion

Scenarios					Benefit Minimization		Benefit Maximization	
	Demand	Gas Price	Entry	Present Value (PV $M)	Joint Probability (JP)	Weighted Benefit JP*PV	Joint Probability (JP)	Weighted Benefit JP*PV
1	*Very High*	*Very High*	*NNN*	($340)	0.0101	($3.44)	0.0010	($0.34)
2	*Very High*	*Base*	*NNN*	$572	0.1606	$91.80	0.1606	$91.80
3	*Very High*	*Very Low*	*NNN*	$101	0.0010	$0.10	0.0010	$0.10
4	*Base*	*Very High*	*NNN*	$242	0.1607	$38.90	0.1607	$38.90
5	*Base*	*Base*	*NNN*	$200	0.0010	$0.20	0.3072	$61.54
6	*Base*	*Very Low*	*NNN*	$71	0.1607	$11.49	0.1607	$11.49
7	*Very Low*	*Very High*	*NNN*	$106	0.0010	$0.11	0.0101	$1.07
8	*Very Low*	*Base*	*NNN*	$30	0.1606	$4.80	0.1606	$4.80
9	*Very Low*	*Very Low*	*NNN*	($3)	0.0101	($0.03)	0.0010	($0.00)
10	*Very High*	*Very High*	*OUO*	$178	0.0010	$0.18	0.0101	$1.80
11	*Very High*	*Very Low*	*OUO*	$11	0.0101	$0.11	0.0010	$0.01
12	*Base*	*Base*	*OUO*	$158	0.0010	$0.16	0.0010	$0.16
13	*Very Low*	*Very High*	*OUO*	$98	0.0010	$0.10	0.0010	$0.10
14	*Very Low*	*Very Low*	*OUO*	($1)	0.0010	($0.00)	0.0010	($0.00)
15	*Very High*	*Very High*	*UOU*	$152	0.0010	$0.15	0.0010	$0.15
16	*Very High*	*Very Low*	*UOU*	$141	0.0010	$0.14	0.0101	$1.43
17	*Base*	*Base*	*UOU*	$125	0.3072	$38.28	0.0010	$0.12
18	*Very Low*	*Very High*	*UOU*	$96	0.0101	$0.97	0.0010	$0.10
19	*Very Low*	*Very Low*	*UOU*	$12	0.0010	$0.01	0.0101	$0.12
				Total	***1***	***$ 184 M***	***1***	***$213 M***

- ***Output shown in this table is intended solely to illustrate the methodology and does not represent a definitive assessment of the economic benefits of expanding Path 26.***

Methodology Summary



Comprehensive Methodology

Base-Case Input Data

- Natural Gas Prices
- Demand
- Transmission limits
- Near-term New Generation
- Long-term Energy Contracts
- Hydrology

Scenario Selection

- Natural Gas Prices
- Demand
- Hydrology
- New generation entry
- Price - Responsive Demand

Dispatch Model

Critical Modeling Components:

- Imports
- California Hydrology
- Long-term New Generation Entry
- Price-responsive Demand
- Market Power

Production Cost Model

- Optimal Dispatch
- Transmission Network

Scenario Results

Scenario Weighting

PV Benefits –PV Costs = NPV

III. Discussion of Common Modeling Components and Input Data to be used in the Evidentiary Hearings

- Objective – To develop a common set of data and modeling assumptions in order for all parties to provide a more meaningful assessment of the proposed methodology in the context of the evidentiary hearings.
- Potential data and modeling assumptions for consideration.
  - Non-confidential input data (e.g. load levels, gas prices)
  - Transmission network representation
  - Dispatch algorithms for thermal and hydroelectric generation
  - Other???

IV. Discuss Candidate Transmission Projects for the Evidentiary Hearings

PROOF OF SERVICE

I hereby certify that on March 12, 2003, I served to the service in Docket 00-11-001, by electronic and U.S. mail, the California Independent System Operator's presentation to be used during the workshop to be held on March 14, 2003.

DATED at Folsom, California on March 12, 2003.

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