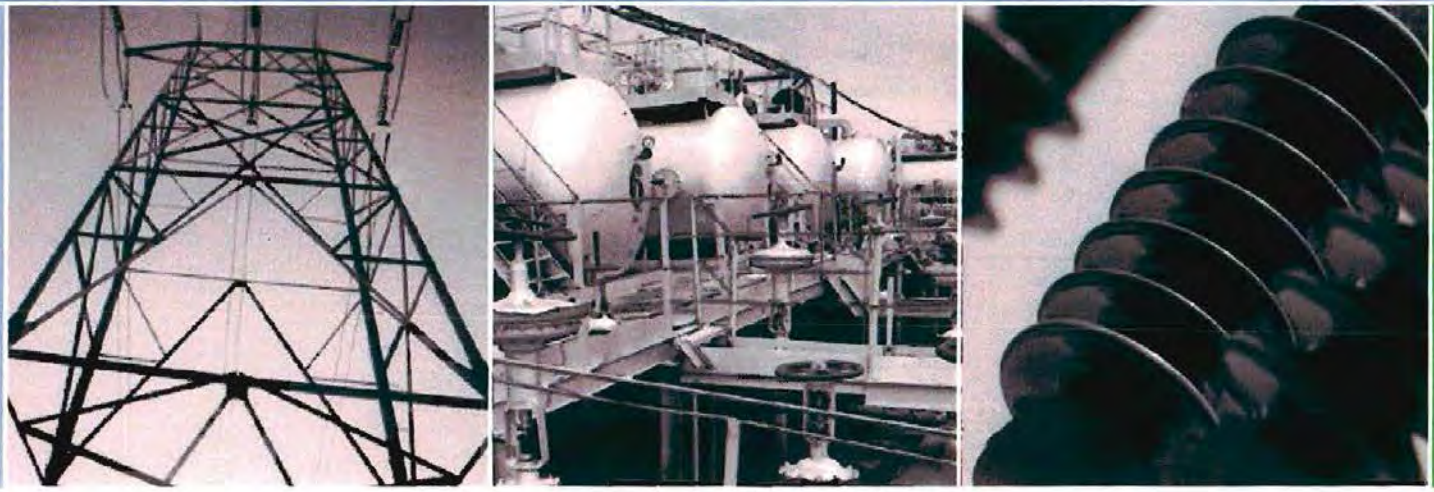


ACHIEVING CALIFORNIA'S 33 PERCENT RENEWABLES AND CLIMATE CHANGE GOALS

Presentation to the California Energy Commission

Jonathan Lesser, Ph.D.

Spencer Yang, Ph.D.

July 11, 2007

BATES WHITE

Outline of Presentation

- Background and purpose
- Benefits of a portfolio analysis planning approach
- Description of portfolio analysis methodology
- Evaluation of California's proposed 2020 "Business-as-usual" generation portfolio
- Analysis of alternative generation portfolios
- Summary

BATES WHITE



Background and purpose

California energy policy

- Renewable resources have potential benefits
  - No fuel price risk (except biomass), offers price stability to ratepayers
    - Utilities may have little or no incentive to reduce fuel costs if those costs are passed along automatically to consumers
    - Stand-alone costs for some renewables may be less than those of fossil fuel resources
  - Environmental benefits
    - Reduce greenhouse gas emissions and emissions of Clean Air Act criteria pollutants
  - Reduce dependence on fossil fuels, greater energy independence
- Goal of meeting electric demand with 33% renewable resources by 2020; AB 32 adds urgency to reduce GHG emissions
  - Interim goal of 20% by 2010
  - Currently, renewable energy supplies approximately 11%

BATES WHITE

Can California renewable energy policy goals be met?

- 2006 IEPR concluded that CA unlikely to meet 2010 goal
  - Report identified five barriers:
    1. Inadequate transmission infrastructure to connect remotely located renewable resources.
    2. Uncertainty regarding whether projects with supplemental energy payment awards will be able to obtain project financing.
    3. Complexity and lack of transparency in the Renewable Portfolio Standard program implementation for investor owned utilities (IOUs).
    4. Insufficient attention to the possibility for contract failure and delay.
    5. Lack of progress in re-powering aging wind facilities.
- Another barrier: cost
  - Some renewable resources are more costly on a stand-alone basis than fossil fuel alternatives

BATES WHITE

Purpose

- Demonstrate mean-variance portfolio optimization with placeholder inputs
- One alternative approach to perform this type of cost-benefit analysis is to use techniques from financial modeling
  - Portfolio analysis techniques
  - Use a mean-variance approach, similar to Capital Asset Pricing Model
  - Identify an "efficient frontier:" i.e., "best" tradeoffs between expected cost and risk
  - Determine whether the 2020 – BAU is an "efficient" portfolio
    - If not, California can do better, reducing both expected cost and risk

BATES WHITE

Caveats

- Realistic constraints on amounts (upper and lower bounds) of each technology type must be determined
  - Technical and economic potential
  - In-state, out-of-state, RECs?
- A more complete analysis will consider transmission and integration constraints, to regional and local levels
- It may be difficult to constrain estimates of future volatility and covariance.
  - However, there are methodologies that can isolate the uncertainties that matter most.

BATES WHITE

Limitations of our analysis

- Mean-variance portfolio analysis assumes specific risk structures
  - Risks are symmetric (e.g., bell-shaped curves)
  - Variance captures all risk attributes
    - If risks are asymmetric, this will not generally be true
- Analysis ignored certain risks
  - Wind resource intermittency and transmission stability issues
    - Ignored wind saturation levels at the local level
  - Ignored geothermal steam resource constraints
- Analysis did not address
  - Non-linear impacts: add too many renewables and costs and risk will increase
    - Important to model detailed interactions among resources
  - Price interactions associated with changing supply and demand
    - Technology costs and fossil-fuel prices will be affected by resource constraints
    - Increases the non-linear dynamics of analysis

BATES WHITE



Benefits of portfolio analysis

Need to evaluate risk and uncertainty in energy markets

- Electric industry and markets today face significant risks and uncertainty
  - Energy market volatility has increased
  - Uncertainty over future environmental policies
- Evaluating only stand-alone costs of new generating resources ignores important information
  - What are the costs of wrongly forecasting the future?
  - How do different resources interact?
  - What is the value of using renewable resources as a financial "hedge" against future market volatility?
  - Essentially, stand-alone analysis "throws away" valuable information. Why not use it instead?
- Given uncertainties, identifying a "least-cost" portfolio is likely impossible
  - Least-cost may have significant cost risk

BATES WHITE

Why portfolio analysis?

- Portfolio analysis techniques are rooted in modern finance theory
  - Widely used by financial investors to create low risk, high return portfolios under various economic conditions
  - Different financial assets respond differently to changes in market conditions
  - Goal: maximize expected return for any given level of risk
    - Equivalently, minimize risk for any given expected return
  - Example: individual retirement accounts – most people hold a mix of different funds to diversify financial risk
    - Different investors have different risk tolerance, different investment horizons, and so forth
    - No single unique "right answer" for all investors
  - As a result, investors look for "efficient portfolios"
    - Definition: An efficient portfolio is one that maximizes the expected return for any given level of risk, while minimizing risk for every level of expected return

BATES WHITE

Why portfolio analysis (cont.)?

- Given uncertainty in electric industry and markets, apply the same principles
  - Rather than evaluating individual resources, evaluate portfolios of resources
  - Identify opportunities where renewable resources provide hedging benefit
  - Identify amount of the hedging benefit
  - Identify generation portfolio efficient frontier
- Once such a frontier is identified, policy makers can choose what cost-risk combination is appropriate
  - Identify alternative renewable resource combinations and their impacts
    - Example: more wind, less geothermal; more biomass, less wind; etc.
  - Determine how adding different types of resources affect overall tradeoffs

BATES WHITE

Renewable resources have the highest payoff when fossil fuel prices are high

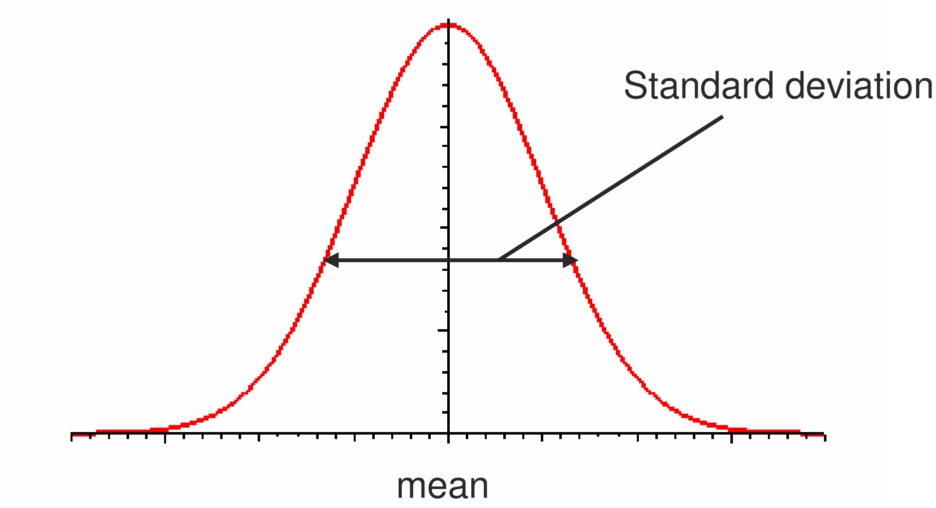
- Typically, renewable resources hedge portfolio risk
  - Example: solar PV
    - If fuel prices decrease, consumers are better off, but the value of solar PV falls
    - If fuel prices increase, consumers are worse off, but the value of solar PV increases
  - In finance theory, this is known as a “negative beta” asset, i.e., one whose value is inversely correlated with the value of the market
- Stand-alone analysis ignores this hedging value

BATES WHITE

Description of portfolio analysis methodology

Portfolio analysis – basic concepts

- Our approach is based on “mean-variance” analysis
  - Assumes that risk can be represented completely by one parameter: variance
  - Variance measures the “dispersion” of a probability distribution
    - Standard deviation is just the square root of variance



Portfolio analysis – basic concepts

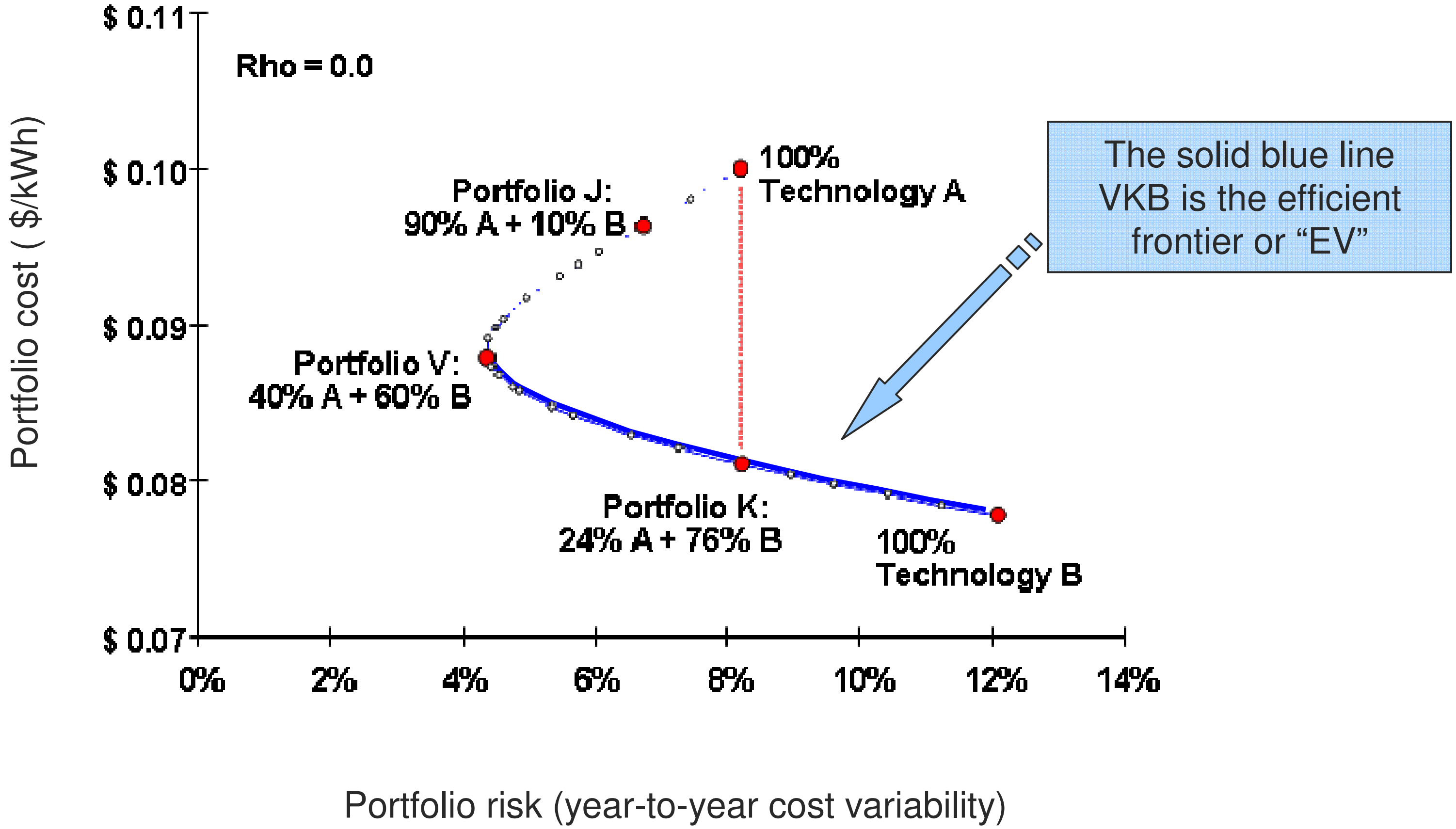
- Expected portfolio cost
  - Equals the weighted average of the expected costs of the individual generating resources
- Portfolio risk
  - Equals the weighted average of the individual generating resource variances plus the weighted average of their co-variances
  - It is these covariance values that are the key to portfolio analysis
    - Covariance terms capture the risk hedging values (2-asset example)

$$E(\sigma_p) = \sqrt{X_1^2 \sigma_1^2 + X_2^2 \sigma_2^2 + 2 X_1 X_2 \rho_{12} \sigma_1 \sigma_2}$$

  - The ρ_{12} term is called the "correlation coefficient" and equals covariance divided by the product of their individual standard deviations
  - If ρ_{12} is negative, then total portfolio risk is less than the individual asset risks

BATES WHITE

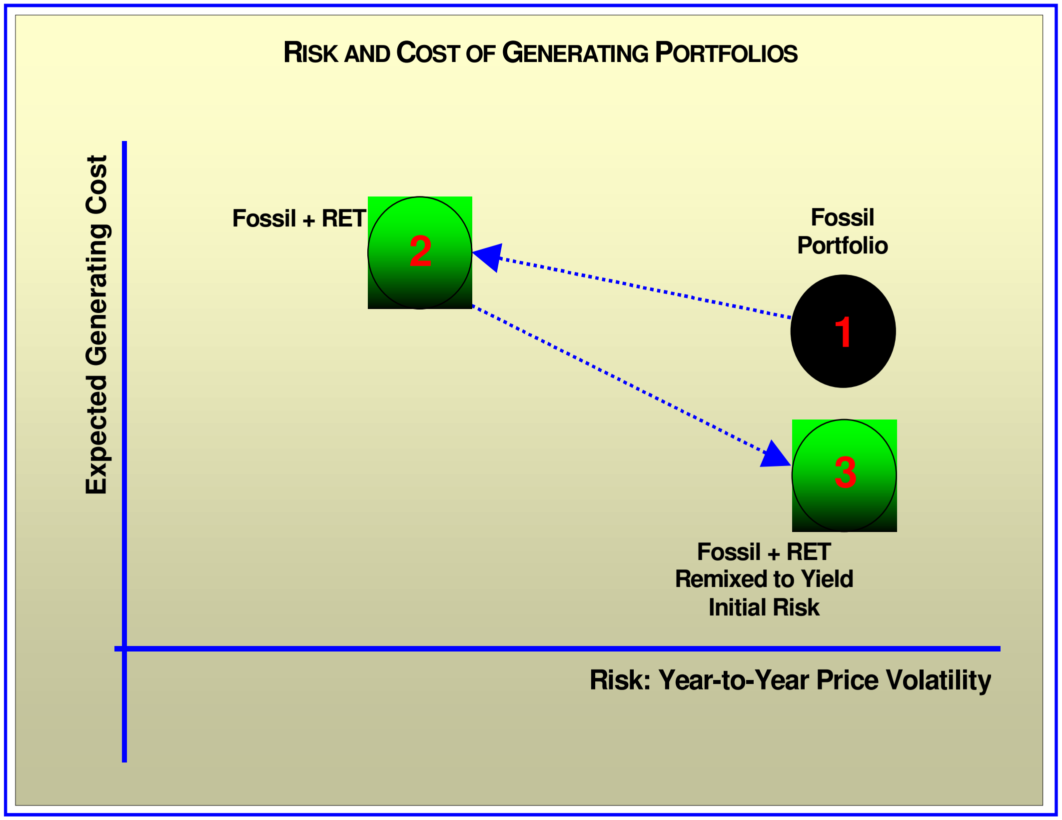
A 2-resource portfolio example



EV represents "best" combinations of risk and cost, i.e., for any portfolio on the EV, there are no alternative portfolios with both lower cost and lower portfolio risk

How renewable resources can reduce costs and risk

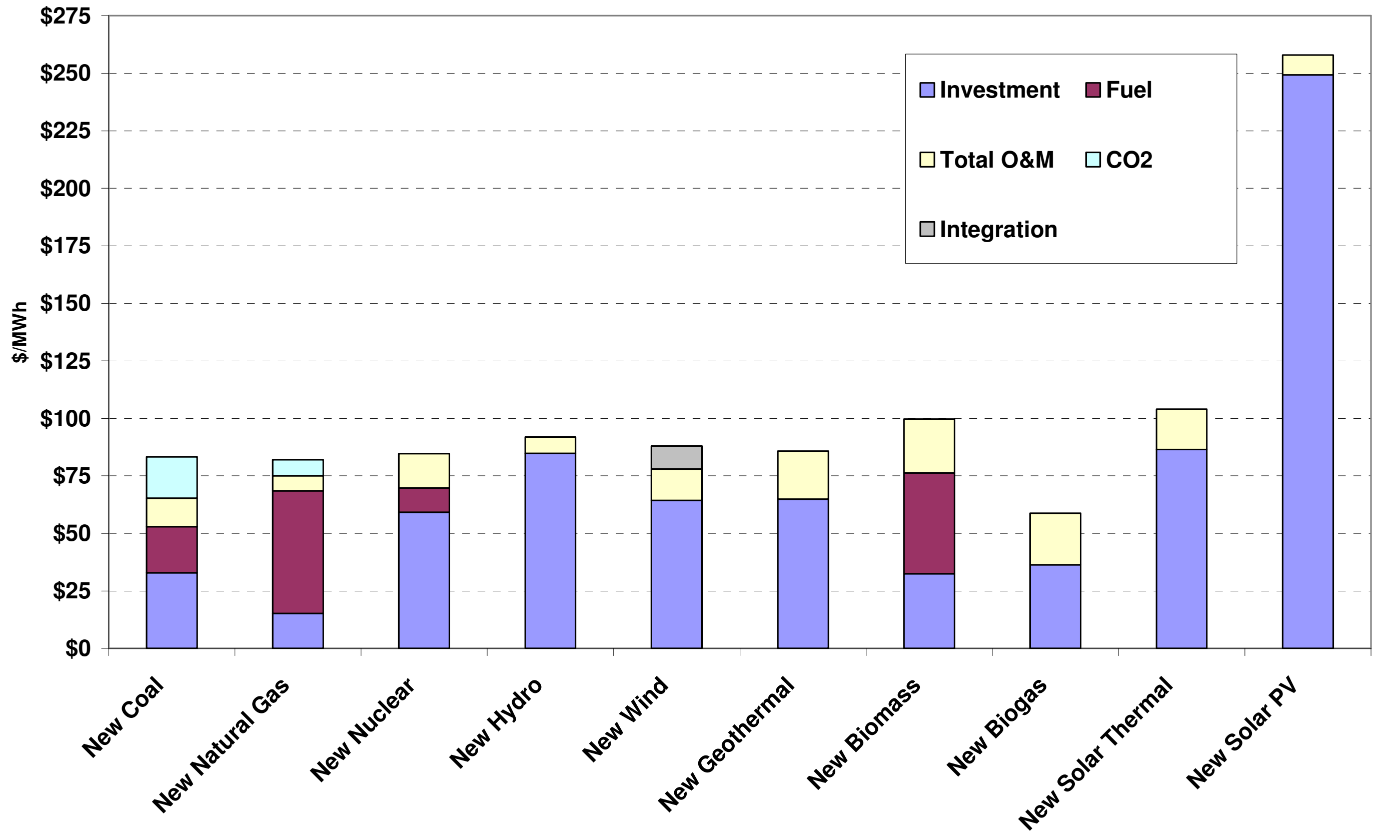
Renewable Technologies Help the Generating Mix
They Affect Portfolio Cost *and* Risk



BATES WHITE

Evaluation of California's proposed 2020 "Business-as-usual" generation portfolio

Assumed stand-alone the 2020 BAU generation portfolio



Source: CEC Staff Cost-of-generation report; TECHPOLE
Note: assumes $20/tonne CO2 cost

BATES WHITE

Stand-alone risk parameters

- Four types of stand-alone risk parameters for all generating resources
  - Investment (capital) cost risk
    - Existing resources – no risk since they are already built
    - New resources – based on World Bank reports, developer interviews
  - Fuel cost risk
    - Zero for all renewables except biomass
    - Fossil fuel & nuclear, based on analysis of historic price data
  - Non-fuel operations and maintenance (O&M) cost risk
    - Based on data collected by Energy Information Administration
  - CO_2 cost risk
    - There is uncertainty as to what future CO_2 costs will be
      - Example: type of CO_2 regulations (emissions tax, cap-and-trade, etc.), implementation dates, stringency, and so forth

BATES WHITE

Stand-alone risk parameters (summary)

Technology Risk Estimates				
Generating Resource	**Investment**	**Fuel**	**Total O&M**	**CO_2**
Coal	0.35	0.049	0.054	0.260
Biomass	0.20	0.133	0.108	-
Natural Gas	0.20	0.291	0.105	0.260
Nuclear	0.40	0.346	0.055	-
Hydro - Large	0.35	0.000	0.153	-
Hydro - Small	0.20	0.000	0.153	-
Wind	0.20	0.000	0.080	-
Solar Thermal	0.10	0.000	0.080	-
Biogas	0.20	0.133	0.108	-
Solar PV	0.10	0.000	0.034	-
Geothermal	0.20	0.000	0.153	-

BATES WHITE

Portfolio risk parameters – fuel and CO2 price correlations

- Portfolio risk parameters are the correlation coefficients between risks and resources
  - Example: Future CO2 prices and fossil fuel prices
    - Intuitively, expect that higher CO2 costs would reduce demand for all fossil fuels. Thus, CO2 price and fossil fuel prices would be all negatively correlated
    - Not the entire story. CO2 prices most affect highest carbon resources
    - Higher CO2 price causes substitution to lower carbon fuel (natural gas) away from higher carbon fuels (coal)
      - Net result is that CO2 price is positively correlated with natural gas price
  - Negative correlation between price of nuclear fuel and price of fossil fuels

BATES WHITE

Portfolio risk parameters – fuel and CO2 price correlations

- Table below shows the correlation matrix
  - The bold values are all 1.00 because each individual price is perfectly correlated with itself
    - Note the positive correlation between CO2 price and natural gas price

Generating Resource	Coal	Biomass	Natural Gas	Uranium	CO_2
Coal	**1.00**	0.39	0.53	-0.25	-0.49
Biomass	0.39	**1.00**	0.30	-0.27	0.00
Natural Gas	0.53	0.30	**1.00**	-0.16	0.68
Uranium	-0.25	-0.27	-0.16	**1.00**	0.00
CO_2	-0.49	0.00	0.68	0.00	**1.00**

- Note also the negative correlation between the price of nuclear fuel (uranium) and the price of other fossil fuels
  - Suggests a potential opportunity for further risk diversification

BATES WHITE

Portfolio risk parameters – O&M cost correlations

- Correlation matrix for O&M costs

Generating Resource	Coal	Gas	Nuclear	Hydro	Wind	Geo	Solar	Bio
Coal	**1.00**	0.25	0.00	0.03	-0.22	0.14	-0.39	0.18
Gas	0.25	**1.00**	0.24	-0.04	0.00	-0.18	0.05	0.32
Nuclear	0.00	0.24	**1.00**	-0.41	-0.07	0.12	0.35	0.65
Hydro	0.03	-0.04	-0.41	**1.00**	0.29	-0.08	0.30	-0.18
Wind	-0.22	0.00	-0.07	0.29	**1.00**	-0.28	0.05	-0.18
Geo	0.14	-0.18	0.12	-0.08	-0.28	**1.00**	-0.48	-0.70
Solar	-0.39	0.05	0.35	0.30	0.05	-0.48	**1.00**	0.25
Bio	0.18	0.32	0.65	-0.18	-0.18	-0.70	0.25	**1.00**

Total portfolio cost and risk estimates

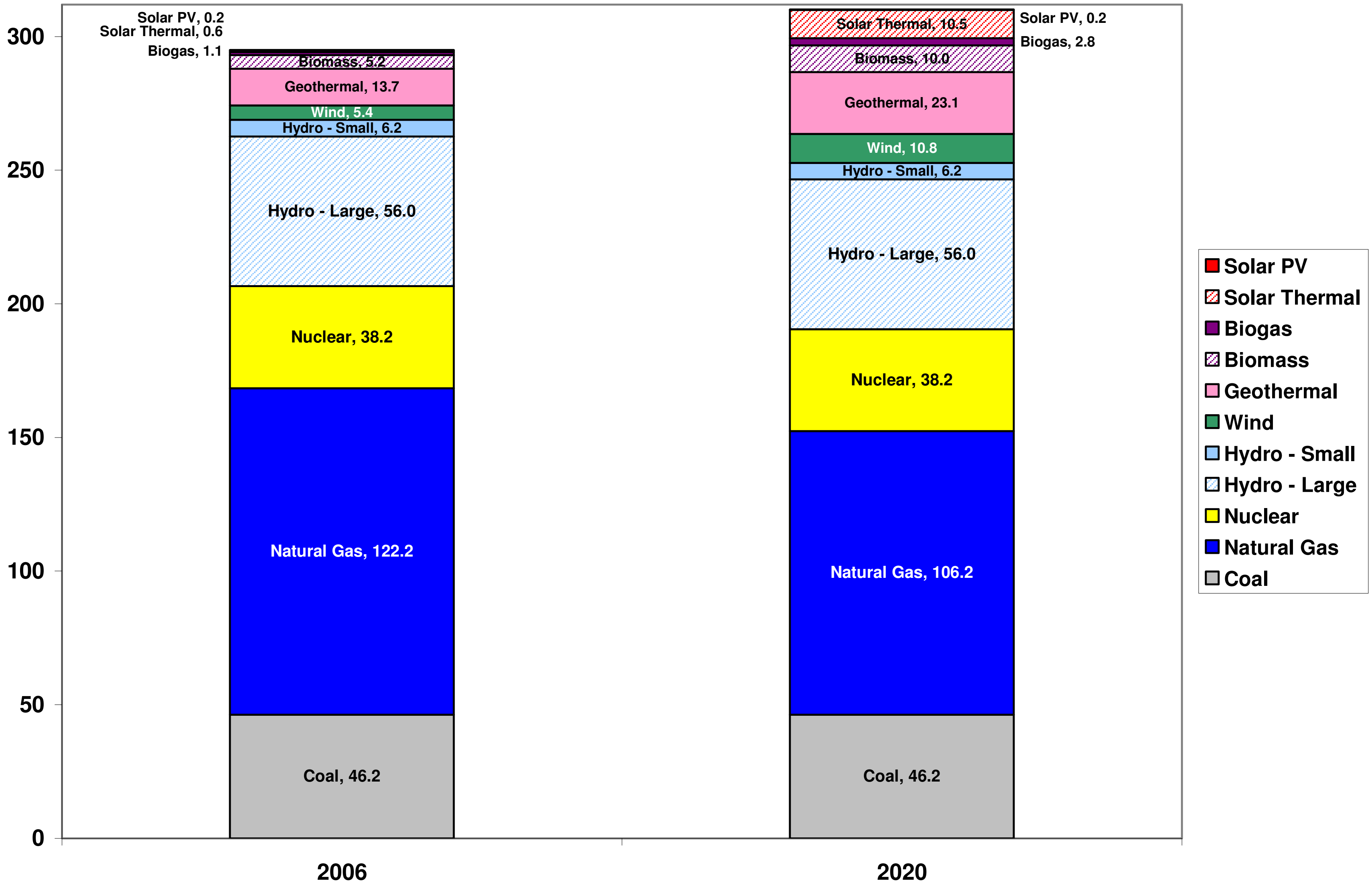
- We combine the different own-price risks and correlation coefficients using a more general form of the equation shown previously to determine an overall stand-alone risk for each generating resource technology

$$E(\sigma_p) = \sqrt{X_1{}^2\sigma_1{}^2 + X_2{}^2\sigma_2{}^2 + 2X_1X_2\rho_{12}\sigma_1\sigma_2}$$

- The weights (X_1, X_2, … etc.) are given by the proportional values of the levelized cost components, e.g., capital, fuel, O&M, and CO2 costs
- Result is a map of individual generating resource expected costs and risk

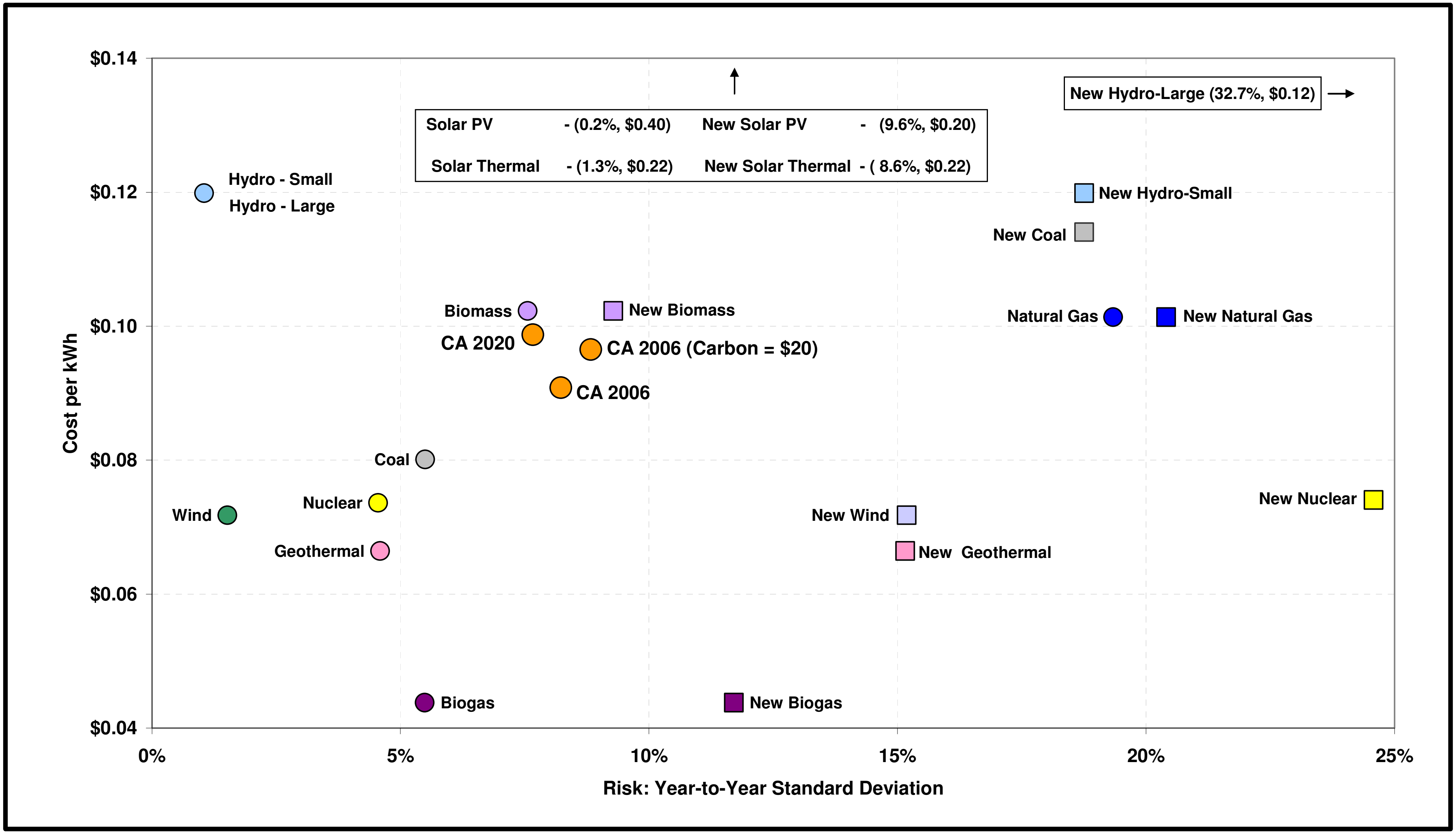
BATES WHITE

Existing and 2020 BAU generating mix (TWh)



BATES WHITE

Cost and risk of existing and new CA generating alternatives in 2020



BATES WHITE

BATES WHITE

Analysis of alternative generation portfolios

Alternative generation portfolios - description

- Infinite number of potential portfolios
  - Limited our analysis to “boundary” portfolios relative to 2020 BAU
- Developed four portfolio alternatives to 2020 BAU

1. Mix P is a high-cost/low-risk portfolio.
   - This portfolio is the most resource diverse
2. Mix N is an equal-cost/low-risk portfolio.
   - This portfolio is the lowest overall risk for a portfolio having the same expected cost as the 2020 BAU
3. Mix S is an equal-risk/low-cost portfolio
   - This portfolio is the lowest expected cost portfolio having the same portfolio risk as the 2020 BAU
4. Mix Q is a low-cost/high-risk portfolio
   - Much less diverse portfolio

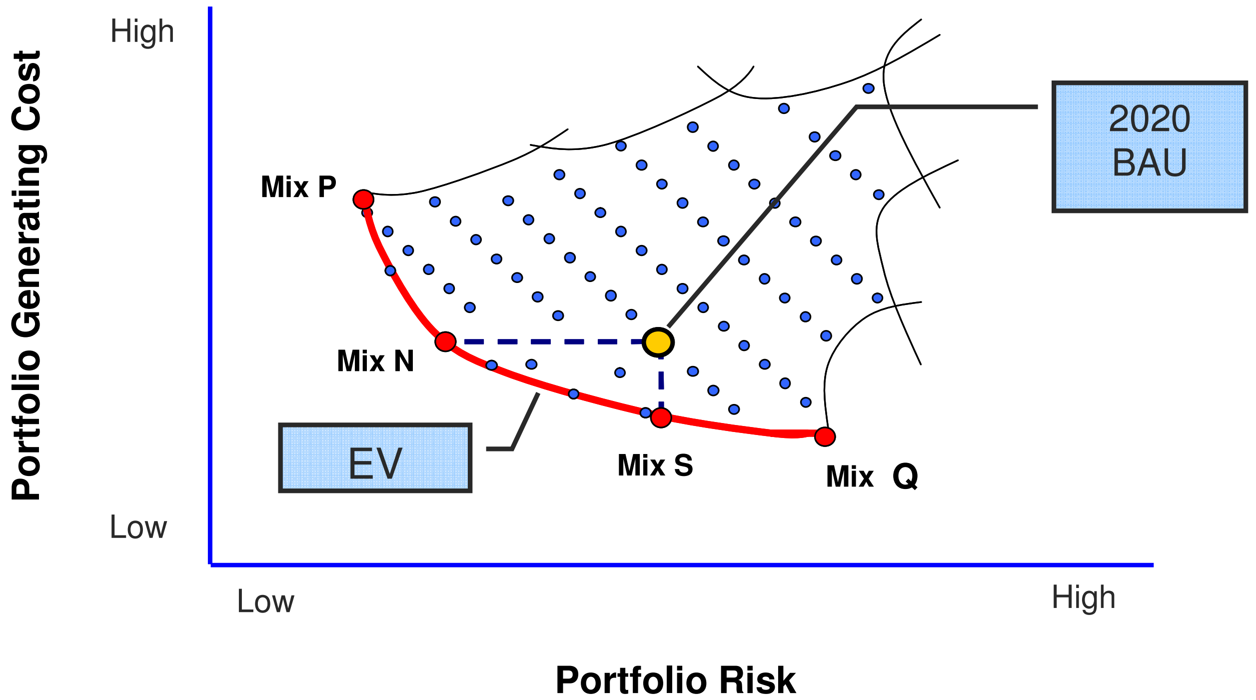
BATES WHITE

Alternative generation portfolios – assumptions

- Did not address certain resource constraints and risks
- Wind Power
  - Intermittency risk
  - Transmission stability and localized wind saturation
  - Could be addressed by defining sub-categories of wind, adding capital cost
- Geothermal
  - Loss of steam resources over time
  - Could be addressed by increasing capital cost

BATES WHITE

Alternative generation portfolios – efficient frontier



Because the 2020 BAU mix lies above and to the right of the EV, policy makers can select an alternative portfolio with a lower expected cost and lower risk

Alternative generation portfolios - assumptions

- No *new* investment in coal, nuclear, and large hydro generation
  - 2005 IEPR reaffirmed California's policy that suspended construction of new nuclear power plants beginning in 1976.
  - Senate Bill 1368 limits GHG emissions to below CCGT emissions
    - We also assume that carbon sequestration will not be sufficiently mature to allow new coal-fired generation before 2020
- Allow up to 30% new gas-fired generation
- Assumptions for new renewable resources
  - Up to 10% each of new biomass, biogas, small hydro, solar (thermal and PV)
  - Up to 25% of new geothermal
  - Up to 30% wind
- Lower bounds for existing coal and gas – 5%
- Lower bounds for existing nuclear, large hydro – 80% of 2020 BAU levels

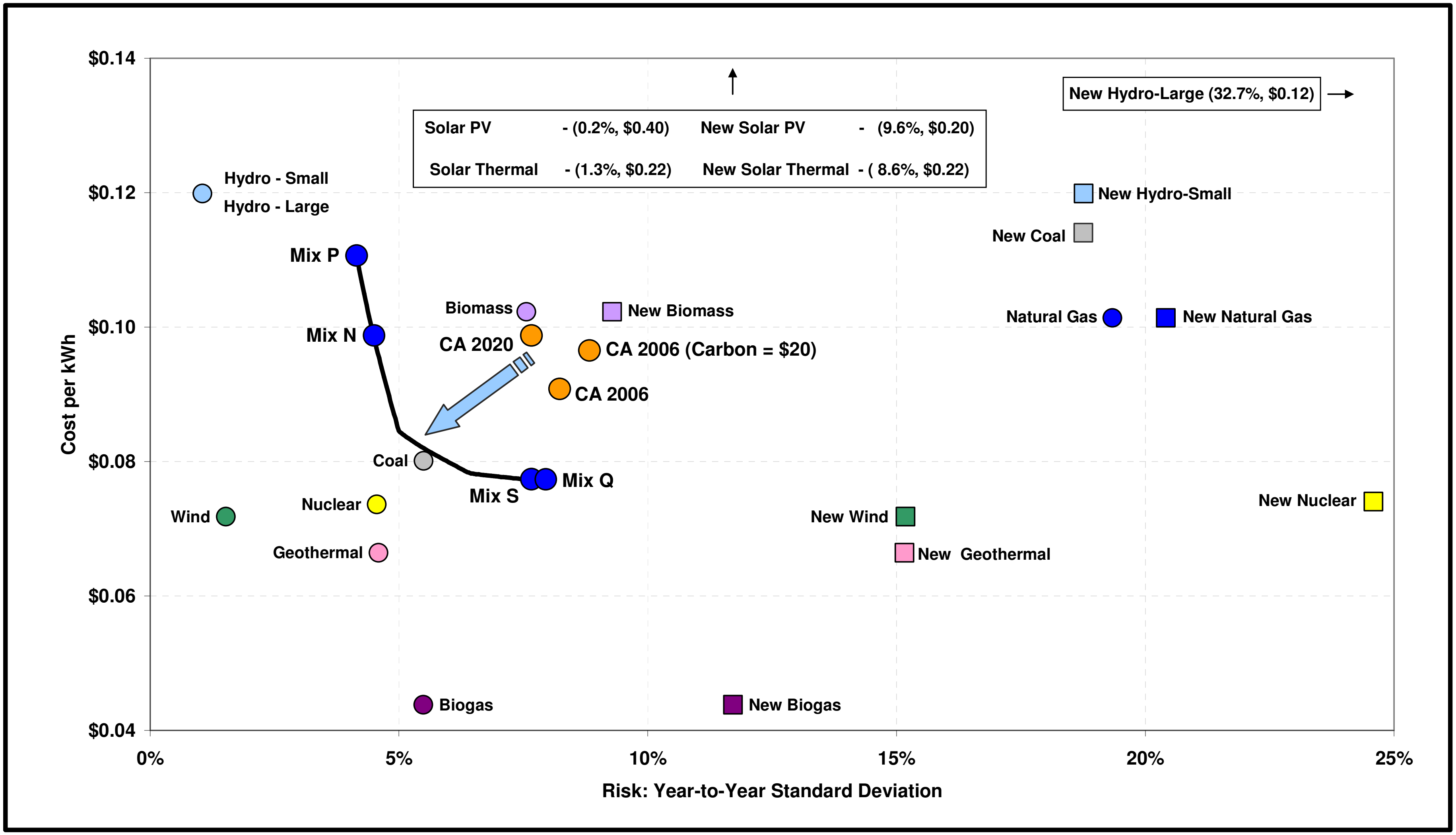
BATES WHITE

Alternative generation portfolios – summary of lower and upper bounds for generating resources

Technology	Realizable Lower bound	Realizable Upper bound
Coal	**5.0%**	14.9%
Biomass	0.8%	1.7%
Natural Gas	**5.0%**	34.2%
Nuclear	**9.8%**	12.3%
Hydro - Large	**14.5%**	18.1%
Hydro - Small	1.0%	2.0%
Wind	0.9%	1.7%
Geothermal	2.2%	4.4%
Solar Thermal	0.1%	0.2%
Biogas	0.2%	0.4%
Solar PV	0.0%	0.1%
New Coal	0.0%	**0.0%**
New Biomass	0.0%	10.0%
New Natural Gas	0.0%	30.0%
New Nuclear	0.0%	**0.0%**
New Hydro-Large	0.0%	**0.0%**
New Hydro-Small	0.0%	10.0%
New Wind	0.0%	30.0%
New Solar Thermal	0.0%	10.0%
New Biogas	0.0%	10.0%
New Solar PV	0.0%	10.0%
New Geothermal	0.0%	25.0%

BATES WHITE

Analysis results



Note location of CA 2020 BAU relative to Efficient Frontier – can reduce risk and lower expected cost

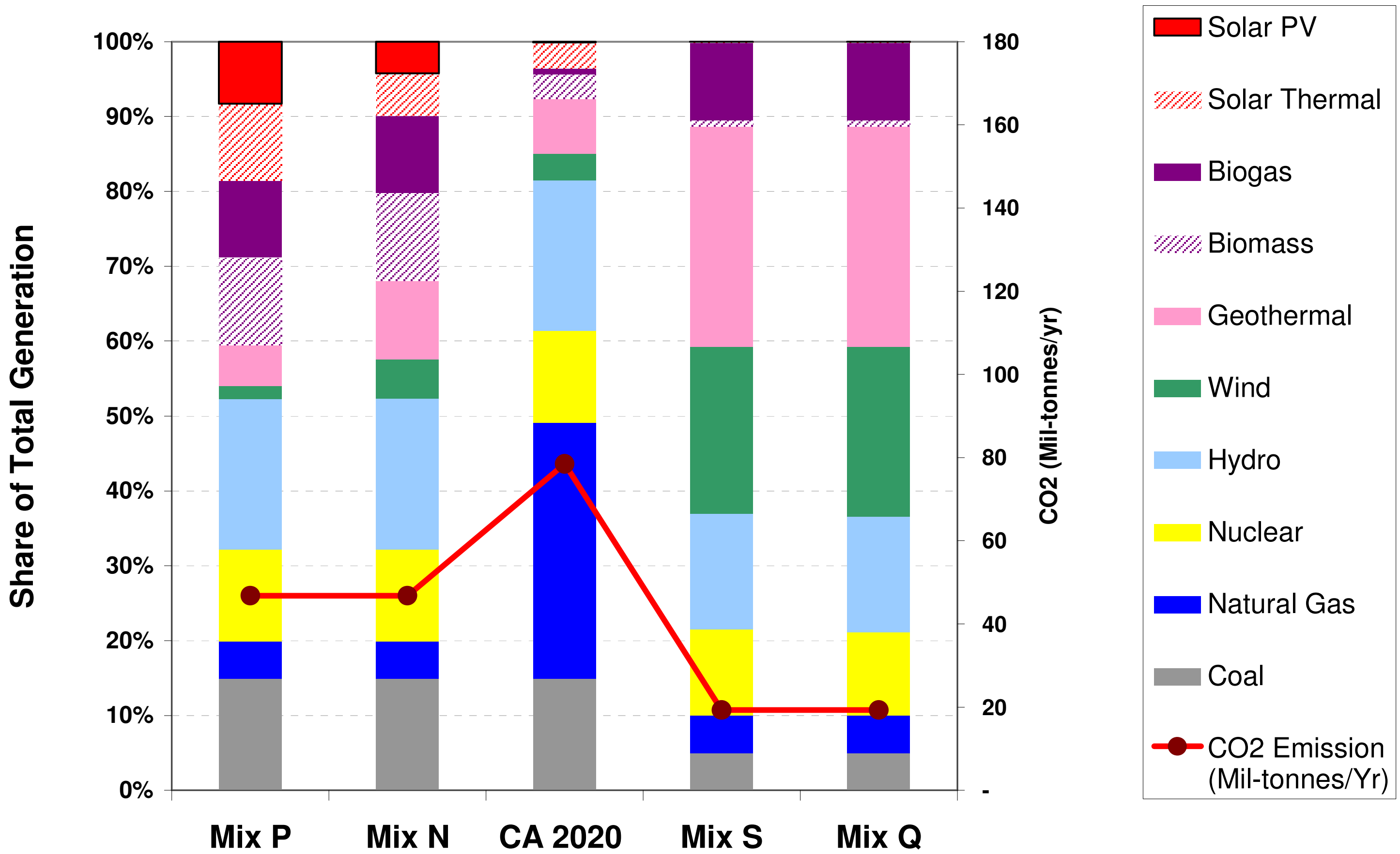
BATES WHITE

Cost and risks of alternative portfolios vs. 2020 BAU

	CA-2020 BAU	Portfolio P	Portfolio N	Portfolio S	Portfolio Q
RISK	7.7%	4.2%	4.5%	7.7%	8.0%
COST: cents/KWh	9.9	11.1	9.9	7.7	7.7
CO2: Mil-tonnes/Yr	78	47	47	19	19
Generating Resource			**Generating Shares**		
Coal	15%	15%	15%	5%	5%
Natural Gas	34%	5%	5%	5%	5%
Nuclear	12%	12%	12%	12%	11%
Hydro	20%	20%	20%	15%	15%
Wind	4%	2%	5%	22%	23%
Geothermal	7%	5%	11%	29%	29%
Biomass	3%	12%	12%	1%	1%
Biogas	1%	10%	10%	10%	10%
Solar Thermal	3%	10%	6%	0%	0%
Solar PV	0%	8%	4%	0%	0%
Renewables Share	20%	41%	45%	64%	64%

BATES WHITE

Technology shares and CO2 emissions



BATES WHITE

Key findings

- Share of renewables could be increased from 20 percent to 45 percent without an increase in expected portfolio costs (i.e., transition from the 2020 BAU to portfolio N).
  - Mix N also reduces CO2 emissions by 31 million tonnes per year relative to projected 2020 BAU portfolio without increasing expected costs.
- Analysis shows that the share of renewables could be increased from 20 percent to 64 percent with a decrease in expected portfolio costs of 2.2 cents per kWh (i.e., transition from 2020 BAU to portfolio S).
  - Mix S reduces CO2 emissions by 59 million tonnes per year relative to projected 2020 BAU portfolio without increasing expected portfolio risks.
- Precise relationship between technology shares, CO2 emissions, and cost-risk is non-linear
  - Increasing renewable shares too much increases costs and portfolio risk

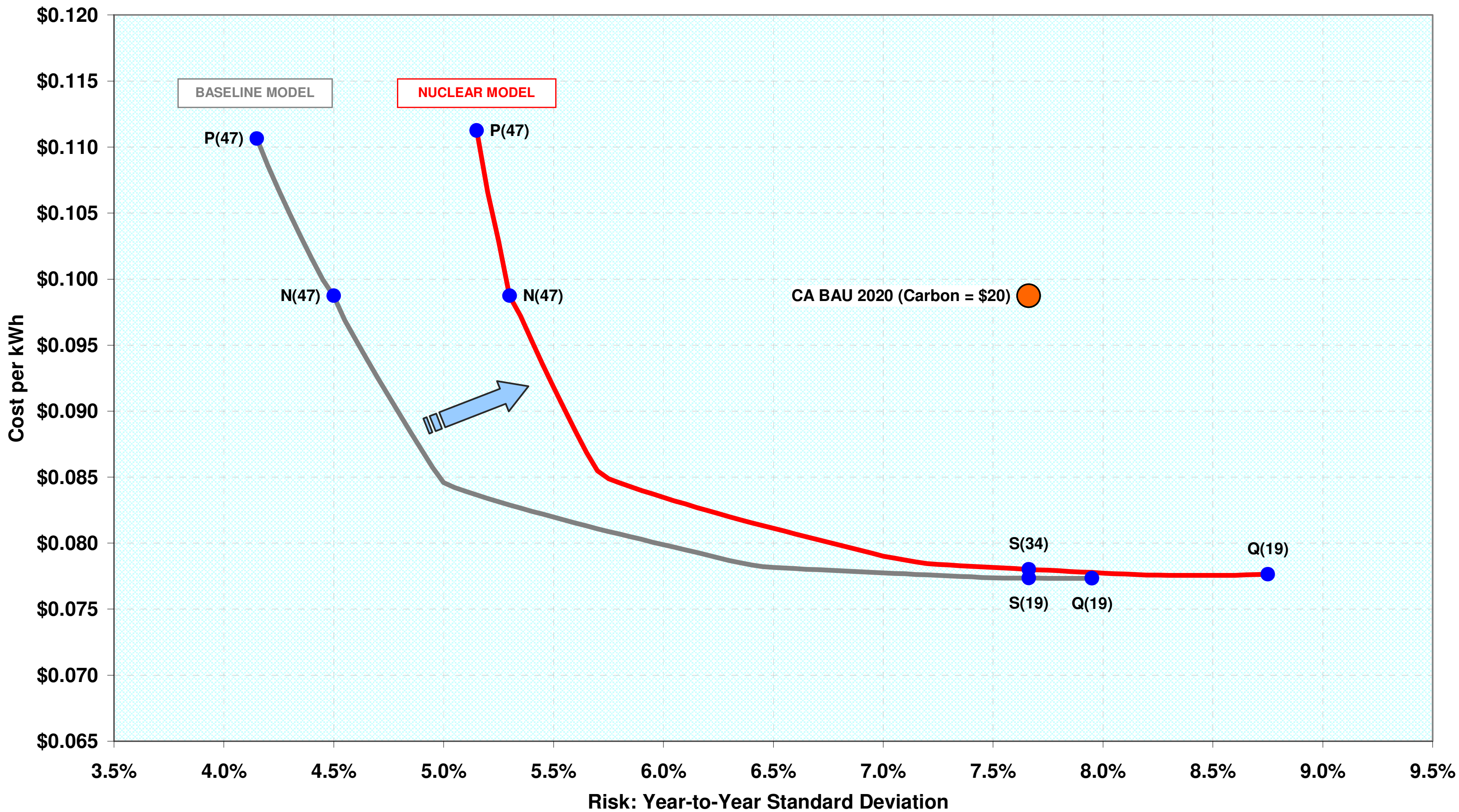
BATES WHITE

Effects of alternative nuclear policy

- Examined policy of promoting nuclear power, contrary to existing CA policy
  - Evaluated portfolios containing 10% new nuclear generation
  - Other generating resources subject to previous constraints
  - CO_2 tax assumed to be $20/tonne

BATES WHITE

Results – alternative nuclear policy



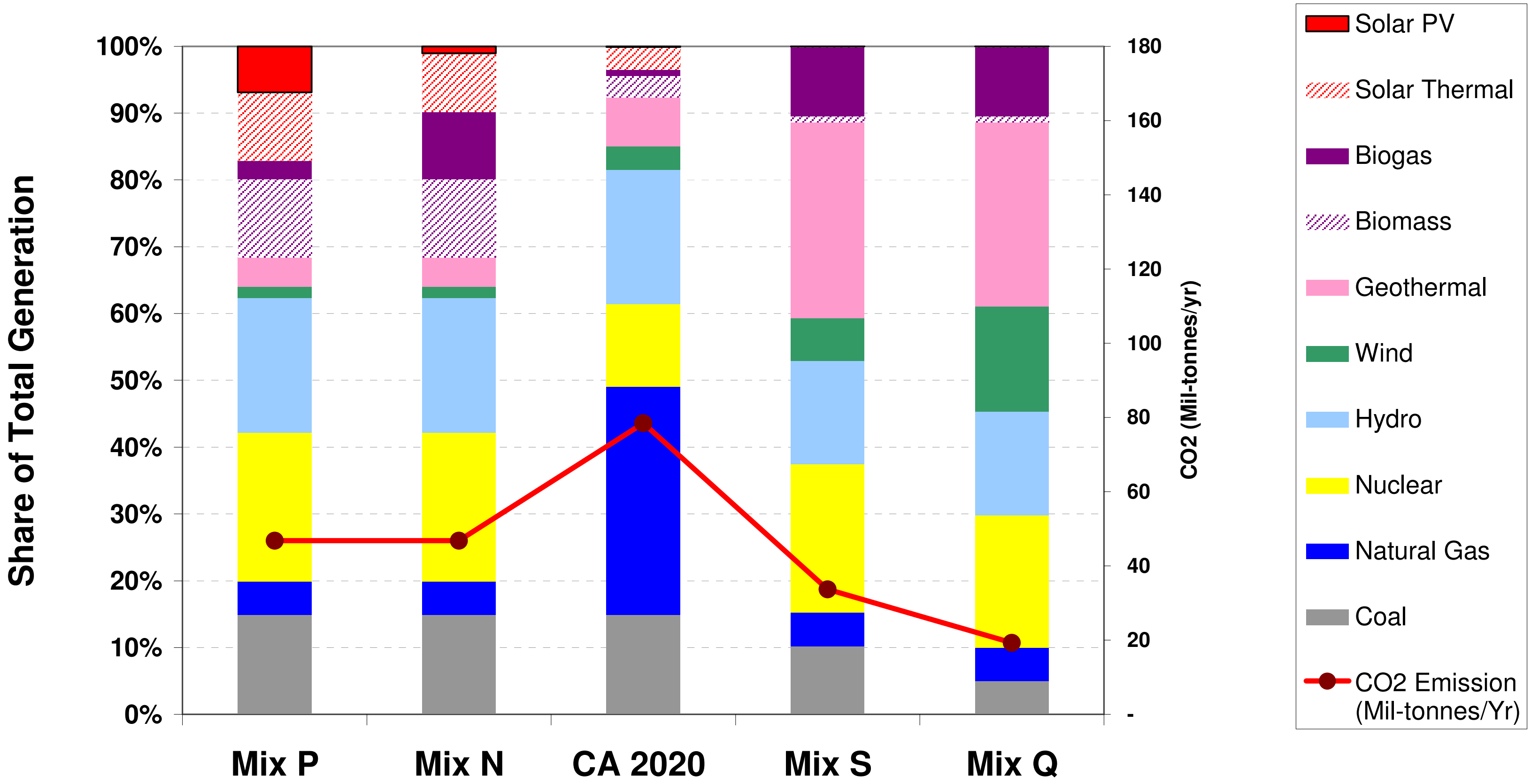
Nuclear promotion policy shifts efficient frontier up and to the right (higher cost, higher risk)

Portfolio mix details – alternative nuclear policy

	CA-2020 BAU	Portfolio P	Portfolio N	Portfolio S	Portfolio Q
RISK	7.7%	5.1%	5.3%	7.7%	8.8%
COST: $-cents/KWh	9.9	11.1	9.9	7.8	7.8
CO2: Mil-tonnes/Yr	78	47	47	34	19
Generating Resource			Generating Shares		
Coal	15%	15%	15%	10%	5%
Natural Gas	34%	5%	5%	5%	5%
Nuclear	12%	22%	22%	22%	20%
Hydro	20%	20%	20%	15%	15%
Wind	4%	2%	2%	6%	16%
Geothermal	7%	4%	4%	29%	28%
Biomass	3%	12%	12%	1%	1%
Biogas	1%	3%	10%	10%	10%
Solar Thermal	3%	10%	9%	0%	0%
Solar PV	0%	7%	1%	0%	0%
Renewable Share	20%	33%	39%	48%	56%

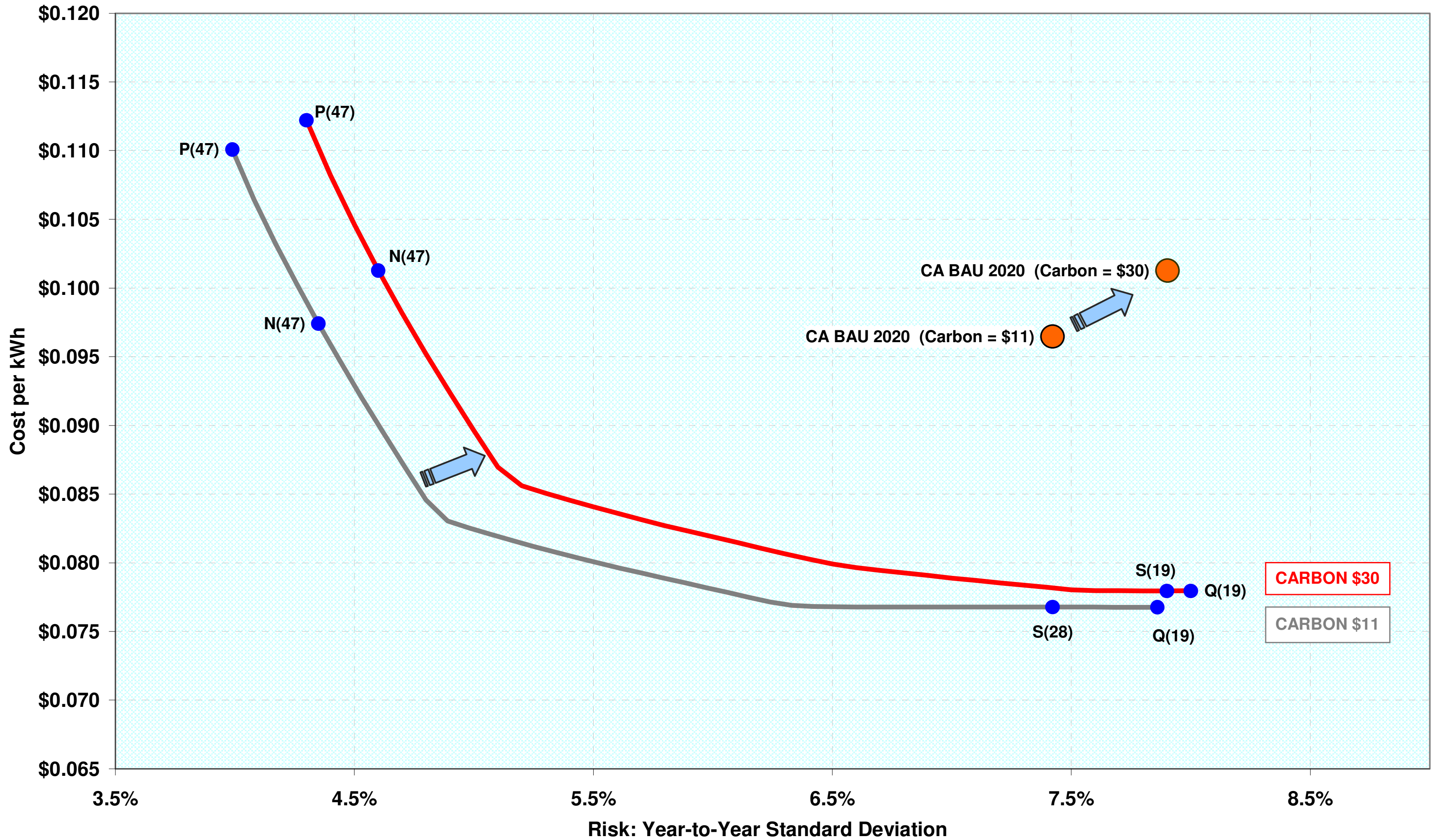
BATES WHITE

Technology shares and CO2 emissions – nuclear promotion case



BATES WHITE

Analysis of higher CO2 prices



Not surprisingly, higher CO2 prices raise the efficient frontier

BATES WHITE



Summary and conclusions

Renewables can reduce overall expected cost and risk

- Portfolio analysis allows for planners to evaluate resources in combination, rather than on a stand-alone basis
  - Renewables may be more expensive on a stand-alone basis, but can still reduce expected costs and risks
  - Sensitivity and scenario analysis are inadequate and error-prone tools – they do not capture key portfolio impacts
    - Increasingly uncertain energy markets increase the importance of using portfolio analysis methods
- Analysis shows that California policymakers can improve cost and risk of proposed BAU 2020 generating portfolio

Recommendations for further research

- Incorporate additional risks, including asymmetric risks
- More detailed analysis of wind resources at local level
  - Add local wind resources with specific constraints
- Incorporate fuel and technology cost feedbacks
  - Fuel-price mean reversion
- Additional research on nuclear technology costs and risks
- Develop "no-regrets" analysis
  - Assumes natural gas prices decrease
- Develop decision model approach (dynamic programming)
  - Rather than snapshot of generation in 2020, examine how CA policymakers should react as conditions change over time