Collaborative EPRI Analysis of CO₂ Price Impacts on Western Power Markets: Ongoing Results for Discussion

Vic Niemeyer, EPRI
Lew Rubin, Portal Solutions
Webcast Background

• Been working with 9 utilities to examine impact of CO₂ price on WECC power markets and emissions

• Have lots of exciting results to share

• Dealing with complex issues so results are preliminary and feedback is welcome

• Second public webcast addresses issues raised earlier
  – Impact of state energy efficiency programs
  – Implications of ramped vs. flat CO₂ price scenarios
WECC Collaborative Overview

• Many proposals at national level to regulate CO$_2$

• Goal is to conduct a broad-brush, indicative assessment of the effects of CO$_2$ price on WECC power markets and electric sector over time
  – Power prices
  – CO$_2$ emissions
  – Generation demand for natural gas
  – Cash flows to generation categories

• Effects on overall economy not covered

• Collaborative effort by diverse set of nine companies
WECC and Participating Companies
Study is EPRI Product

• **This is an EPRI analysis** – focuses on CO₂ price impacts on western power market through 2030

• **The Reference Case is not a forecast** – rather a point of reference for gaining insights about how climate price would impact power markets, customers, and emissions

• **The results are highly sensitive to input assumptions so numerous sensitivity cases were examined**

• **Preliminary results reflect EPRI’s best estimates at this point and do not necessarily reflect the views of the project participants**

• **This report should be viewed as a interim step in an ongoing voyage of discovery** – feedback and comments from all parties are welcome
Summary of Key WECC Assumptions

• Model and data update
  – Calibration to 2006 actual data

• Hydro capacity and generation
  – ~200 TWh in 2006, remains flat at normal levels in the future

• Load growth and elasticity assumptions
  – Load grows at 1.73%/year; elasticity assumed at -0.5 long term

• Fuel and capital costs
  – Gas in real 2006 dollars; pegged to 5/6 NYMEX
  – Capital examples: Coal ($2,850/kW); Nuclear ($4,350); Renewables ($2,820)

• Renewables assumptions
  – RPS targets are assumed met as baseline

• Timing assumptions for technology introductions
  – Nuclear constraint pre-2019
  – Only “on-the-shelf” technologies are assumed deployable
CO₂ Policy Can Have a Dramatic Impact on Generation Costs, Power Prices, and Cash Flows

- Each dollar of CO₂ value boosts fossil dispatch costs
  - ~ $1.00/MWh for coal-fired generation
  - ~ $0.40/MWh for gas-fired CC
  - ~ $0.60/MWh for gas-fired CT/boiler

- But higher dispatch costs mean higher power prices

- Net impact on cash flow depends on net balance of cost impacts against net revenue impacts from a CO₂ price
CO₂ Price Impacts Electric Market Price and Generator Net Revenue for Each Hour of Dispatch

**CO₂ at $0**

- **Market Price**: $50
- **Sets Price**: $25
- **Net Revenue**: $50

**Generation**
- Hydro: $1
- Nuclear: $5
- Coal: $25
- Gas: $50

**CO₂ at $20**

- **Market Price**: $50
- **Sets Price**: $10
- **Net Revenue**: $20

**Generation**
- Hydro: $1
- Nuclear: $5
- Coal: $25
- Gas: $50

© 2008 Electric Power Research Institute, Inc. All rights reserved.
Modeling System Integrates All Major Options for Reducing Electric Sector CO₂ Emissions

• Combines three CO₂ reduction activities for generation in integrated cost-minimizing mix
  – Redispatch existing generation (short-term effect)
  – Add new generation to cover growth and retirements (long-term effect)
  – Substitute new generation to cut existing source emissions (long-term effect)

• Reflects lead times to build new capacity

• Does not incorporate detailed system constraints on operations, transmission or new investment

• Includes role of customer load response to higher power prices (and the interaction over time with needs for new generation)
Analysis is Based on Market Model of Behavior

• Tracks impacts of a range of CO₂ prices on the power market
  – Price scenarios reveal impacts on power sector, but are not meant to model specific tax or cap & trade policies
  – Allowance allocation is not addressed
    • Not expected to affect prices in a competitive market
    • Not expected to affect incentives for investment

• Expects competitive market behavior to continue
  – Systems operate to minimize cost, maximize value
  – Add new generation only if cost can be recovered
Supply Stack and Load Duration Curve Capture Operation of the System Each Year

Load Duration Curve and Supply Stack – CO₂ at $0 ($/ton)

- Renewables
- Hydro
- Nuclear
- Coal
- Gas
- Load

Hours Operated per Year

Dispatch Price ($/MWh)

Generation Stack Position (MW)
What Happens When CO₂ Has a Price? $0 per ton

Supply Stack – CO₂ at $0 ($/ton)

- Renewables
- Hydro
- Nuclear
- Coal
- Gas
- Ref. Case

Generation Stack Position (MW)

Dispatch Price ($/MWh)
What Happens When CO₂ Has a Price?

$40 per ton

Supply Stack – CO₂ at $40 ($/ton)
Analysis Results
Impact of CO₂ Price on Wholesale Power Prices: Year 2012

Reference Case: Year 2012 – Wholesale Power Price by CO₂ Price

Electricity Price ($/MWh) vs. CO₂ Price ($/ton)
Impact of CO₂ Price on Wholesale Power Prices: Year 2030

Reference Case: Year 2030 – Wholesale Power Price by CO₂ Price
Emissions Response to CO₂ Prices: Year 2012

Reference Case: Year 2012 – CO₂ Emissions by CO₂ Price

WECC CO₂ Emissions Tons (millions)

CO₂ Price ($/ton)

CO₂ Tons

© 2008 Electric Power Research Institute, Inc. All rights reserved.
Emissions Response to CO₂ Prices: Year 2020

Reference Case: Year 2020 – CO₂ Emissions by CO₂ Price

WECC CO₂ Emissions Tons (millions)

CO₂ Price ($/ton)

CO₂ Tons

2012

2020
Emissions Response to CO\textsubscript{2} Prices: Year 2030

Reference Case: Year 2030 – CO\textsubscript{2} Emissions by CO\textsubscript{2} Price

![Graph showing CO\textsubscript{2} emissions by CO\textsubscript{2} price for the years 2012, 2020, and 2030. The graph illustrates the decrease in emissions with increasing CO\textsubscript{2} price.](image)

© 2008 Electric Power Research Institute, Inc. All rights reserved.
Emissions by CO₂ Price

WECC Reference Case CO₂ Tons

Year

CO₂ Price

© 2008 Electric Power Research Institute, Inc. All rights reserved.
Evolution of the Generation Output and CO₂: Reference Case at $0 per ton

- Renewables growth keeps pace with demand; gas growth in later years
- Post-2015, existing generation is not backed out; emissions increase
Evolution of the Generation Output and CO₂: Reference Case at $50 per ton

- Coal generation declines as CO₂ price increases; gas increases
- Demand is tempered through price response
- Emissions start to stabilize once capital changeover starts
Evolution of the Generation Output and CO₂: Reference Case at $85 per ton

- X-coal generation declines further
- Non-emitting generation penetration tempers the electric price
- Price response slows down in later years
- Emissions shrinkage flattens out a bit
Evolution of the Generation Output and CO₂: Reference Case at $100 per ton

- X-coal generation essentially disappears at this price
- Again price response slows down in later years; emissions shrinkage flattens out a bit
How the System Cuts Emissions: Year 2012

WECC Reference Case – Electricity Supply by Source: 2012

• X-gas substitutes for x-coal
  (emissions % reduction: 1% @ $50, 9% @ $85, 17% @ $100)
How the System Cuts Emissions: Year 2020

WECC Reference Case – Electricity Supply by Source: 2020

- Material price increase and price response
- X-coal disappears at the higher CO₂ price levels
- Non-emitters have not yet penetrated
  (emissions % reduction: 17% @ $50, 51% @ $85, 60% @ $100)
How the System Cuts Emissions: Year 2030

WECC Reference Case – Electricity Supply by Source: 2030

- Material price increase and price response
- Non-emitters are established in the market
  (emissions % reduction: 25% @ $50, 66% @ $85, 71% @ $100)
Wholesale Electric Prices

WECC Reference Case – Wholesale Electric Price $/MWh

- % increase in 2012: 69% @ $50, 119% @ $85, 141% @ $100
- % increase in 2030: 25% @ $50, 38% @ $85, 41% @ $100
Impact of CO₂ Price on Retail Electric Rates

• 2006 Benchmark
  – $94/MWh - weighted average retail price for WECC
  – $58/MWh - wholesale price for WECC
  – $36/MWh - average delivery expense (38% of retail)

• CO₂ price implications in 2012
  – CO₂ price @ $0 - $95/MWh retail (1% over 2006)
  – CO₂ price @ $50 - $136/MWh retail (43% increase over $0 case)
  – CO₂ price @ $85 - $165/MWh retail (74% increase over $0 case)
  – CO₂ price @ $100 - $178/MWh retail (87% increase over $0 case)

• CO₂ price implications in 2030
  – CO₂ price @ $0 - $116/MWh retail (23% over 2006)
  – CO₂ price @ $50 - $136/MWh retail (17% increase over $0 case)
  – CO₂ price @ $85 - $146/MWh retail (26% increase over $0 case)
  – CO₂ price @ $100 - $149/MWh retail (28% increase over $0 case)
Gas Burn Is Highly Sensitive to a Higher CO$_2$ Price in Early Years

- 2012 gas burn greatly increases with high CO$_2$ prices
- Increased demand for gas will increase price
- Buts…
  - Electric sector 1/3 of use
  - Other 2/3 will have incentive to cut demand ($1/ton → $0.058/MMBtu)
  - LNG may be swing supply
- Impact on gas market a critical unknown
Summary of Sensitivity Analyses

• Gas prices higher than projected
  – Higher emissions absent a price, but higher CO\textsubscript{2} price reverses this

• A high load growth case driven by PHEV penetration
  – Higher power emissions, more than offset by transportation reductions

• Higher capital costs for new generation
  – Delayed emitter to non-emitter turnover; higher prices, higher emissions

• No new nuclear generation is built in future
  – Renewable technologies and new gas substitute, but power prices/emissions higher

• “Wild Card” – several adverse outcomes happen simultaneously
  – With multiple drivers negatively impacted, response flexibility is limited
  – Much higher power prices and emissions

• R&D success for CCS
  – Provides a valuable alternative to nuclear, renewables
  – Major source of generation supply if nuclear is limited
The “Wild Card” Case: Defined by a Collection of Adverse Outcomes Simultaneously

- High load growth
  - 2.2% annually

- High gas prices
  - $2 above Reference Case

- Low customer demand response
  - (0.25) long-term price elasticity

- High plant capital costs
  - 25% above Reference Case

- No new nuclear
  - Constrained from capacity addition pre-2030
The “Wild Card” Adverse Outcomes Case: Electric Price in Year 2012

- Electric prices rise for the most part proportionately
- Tempered slightly at higher CO₂ prices by the increase in coal burn
The “Wild Card” Adverse Outcomes Case: Electric Price in Year 2030

- Electric prices must be high enough to encourage new resources at higher plant costs for the “Wild Card” case

![Graph showing electric price comparison between Wild Card and Reference cases.](chart.png)
• “Wild Card” case has only modest emissions impact in 2012
• Higher gas prices force higher coal burn
• Gas price differences become more acute at higher CO$_2$ prices
The “Wild Card” Adverse Outcomes Case: Emissions in Year 2030

Compare Cases: CO2 tons  Year of Interest  2030

- Higher cost of new plant, nuclear constraint, leads to more generation from existing coal, higher emissions
Energy Efficiency Sensitivity Analysis

• What would be the effect of reducing the assumed load growth to reflect state-mandated energy efficiency programs?

• By-request sensitivity analysis provides insights on the interaction of energy efficiency w. climate policy

• Reference Case load growth rate assumed 1.73% annually (extends a recent historical growth rate 1995 to 2005)
  – Demand response to electric rate increases in the reference case give realized growth rate to 1.38%

<table>
<thead>
<tr>
<th>2006-2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total WECC Load Growth absent EE Programs Mandated by States</td>
</tr>
<tr>
<td>Total WECC Load Growth with EE Programs Mandated by States</td>
</tr>
</tbody>
</table>
Simulation of a “Conservation/Energy Efficiency” Case

• Model specification
  – Lower the WECC load growth rate to 1.35% annual, to represent the effects of mandated programs

• Also… it is possible the demand response to price signals in this world will be muted, because the programs have already absorbed some of the response potential
  1. Lower the price elasticity to -0.4 long-term
  2. Maintain the price elasticity at reference level of -0.5
     – We tested both assumptions

• Results
  – Surprising
Wholesale Power Price Comparison

WECC Comparison – Price Comparison
(CO₂ Price at $0/ton)

Price

$0 $20 $40 $60 $80 $100 $120 $140

Year

2006 2010 2014 2018 2022 2026 2030

Reference Case
Energy Efficiency 40
Energy Efficiency

Case Energy Efficiency 40
Energy Efficiency
Wholesale Power Price Comparison

WECC Comparison – Price Comparison
(CO₂ Price at $85/ton)

Price

$140
$120
$100
$80
$60
$40
$20
$0

Year

2006
2010
2014
2018
2022
2026
2030

Reference Case
Energy Efficiency 40
Energy Efficiency

© 2008 Electric Power Research Institute, Inc. All rights reserved.
Emissions Comparison

WECC Comparison – CO₂ Tons Comparison
(CO₂ Price at $0/ton)

CO₂ Tons

Year

Reference Case
Energy Efficiency 40
Energy Efficiency
Emissions Comparison

WECC Comparison – CO₂ Tons Comparison
(CO₂ Price at $85/ton)

<table>
<thead>
<tr>
<th>Year</th>
<th>Reference Case</th>
<th>Energy Efficiency 40</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>400</td>
<td>350</td>
</tr>
<tr>
<td>2010</td>
<td>300</td>
<td>250</td>
</tr>
<tr>
<td>2014</td>
<td>250</td>
<td>200</td>
</tr>
<tr>
<td>2018</td>
<td>200</td>
<td>150</td>
</tr>
<tr>
<td>2022</td>
<td>150</td>
<td>100</td>
</tr>
<tr>
<td>2026</td>
<td>100</td>
<td>50</td>
</tr>
<tr>
<td>2030</td>
<td>50</td>
<td>0</td>
</tr>
</tbody>
</table>
Generation Mix Comparison – No CO₂ Price: Gas Generation on Margin

• Assuming no CO₂ policy, slightly less new gas generation is needed
Generation Mix Comparison – $85/ton CO₂ Price: Gas Generation on Margin

• At a higher CO₂ price level, the differences are – if anything – even more minimal
Insights: So Why Are the Energy Efficiency/Conservation Results so Modest?

• With zero CO$_2$ price effects on emissions and prices are modest because marginal generation source is gas w. low emission rates

• With $85$ CO$_2$ price effects are also modest as gas is still the marginal generation source

• Some of the impact of the impact of EE/Conservation programs on loads is offset by fewer opportunities for price response by customers
Flat vs. Ramped CO₂ Price Paths

- The approach in this study so far has been to model CO₂ price at a flat annual level over the entire analysis period (2012-2030)

- Approach designed to reveal electric system’s response to a CO₂ price rather than suggest any particular policy protocol

- Result is severe power price increases in first year (2012) at higher CO₂ price levels

- What is the effect of ramping the price gradually over the policy period?
  - Can this approach achieve similar emissions reductions?
  - Can this approach mitigate the price increases as well?

- Sensitivity case explores implications of ramped CO₂ scenarios
CO₂ Price Path Sensitivity Analysis Structure

- Ramped price starts in 2012, rises linearly to 2030
- Flat price starts in 2012 and remains constant through 2030

Alternative $50/ton CO₂ Price Path Scenarios
Wholesale Power Price Comparison

WECC Comparison – Power Price Comparison
(CO₂ Price at $50/ton)

- The power price effects are considerably damped...
Wholesale Power Price Comparison

WECC Comparison – Power Price Comparison
(CO₂ Price at $100/ton)

• The power price impacts are even more mitigated...
Cumulative (through 2030) Emissions Comparison

WECC Comparison – CO₂ Cumulative Emissions Comparison

(CO₂ Price at $50/ton)

- ...but cumulative emissions are almost 1 billion tons higher by 2030
Cumulative (through 2030) Emissions Comparison

WECC Comparison – CO₂ Cumulative Emissions Comparison
(CO₂ Price at $100/ton)

• ...and now the cost in cumulative emissions is closer to 2 billion tons
• At lower CO₂ price levels (before price incentives can induce non-emitters into the market) the differences are quite small
• A small amount of additional new gas generation enters the market to meet the increased load
At higher CO₂ price levels (once non-emitters begin entering the market) the differences are more pronounced.

Both coal and gas are burned more heavily, because the non-emitters have been delayed by delayed price signals.
What Level of Ramped \( \text{CO}_2 \) Price is Equivalent to a Given Level of Flat Price Imposition?

- Clearly the flat \( \text{CO}_2 \) policy outperforms the ramped approach in reducing emissions.

- As the \( \text{CO}_2 \) price level is raised, the flat policy results in increasingly better cumulative emissions reduction results than the ramped policy.

- This is largely due to changeover in the generation fleet:
  - The higher the \( \text{CO}_2 \) price in a flat policy world, the greater (and earlier) the generating stock is incentivized to change.
  - An equivalent ramped price falls further and further behind in incentivizing such change because the key price signals are delayed.
Conclusions

• Higher electric prices will be inescapable in order to cut CO₂ emissions below historic benchmarks
  – $50 CO₂ price stabilizes emissions
    (retail price +45% in 2012, +15% in 2030)
  – $75-$100 CO₂ price significantly cuts emissions
    (retail price +90% in 2012, +30% in 2030)
• In a “Wild Card”/adverse effects world…
  – $75 min price achieves stabilization
    (retail price +60% in 2012, +20% in 2030)
  – $125-$150 price achieves significant cuts
    (retail price +100% in 2012, +37% in 2030)
• Large reductions in emissions possible if given time to add significant amounts of nuclear, renewables and CCS
• Customer price response helps avoid emissions but imposes real cost to society
• Availability of natural gas critical to achieving near-term emission reductions
• RPS threshold adding generation that cuts CO₂ at implied price of $90/ton
What I Learn From This

• It’s expensive to cut electric sector emissions due to…
  – High price of natural gas (vis-à-vis coal)
  – High cost of new construction

• Lots of uncertainties drive specific results
  – Gas prices, construction costs, constraints on nuclear and renewables, demand response, new technology
  – Response of gas market to increased gas generation

• Meeting targets may be harder in the short term due to lead-times for new generation and demand response
Final Thoughts

• This analysis should be viewed as an interim step in an ongoing study of a critical but complex issue

• Feedback and comments from all parties are appreciated

• Next steps
  – Post slides at http://globalclimate.epri.com
  – Possible technical webcast focused on methodology and assumptions – please email us if you are interested

Vic Niemeyer, EPRI
(650) 855-2744 / niemeyer@epri.com

Lew Rubin, Portal Solutions
(831) 459-8084 / portal@cruzio.com