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Collaborative EPRI Analysis of CO_2 Price Impacts on Western Power Markets:

Ongoing Results for Discussion

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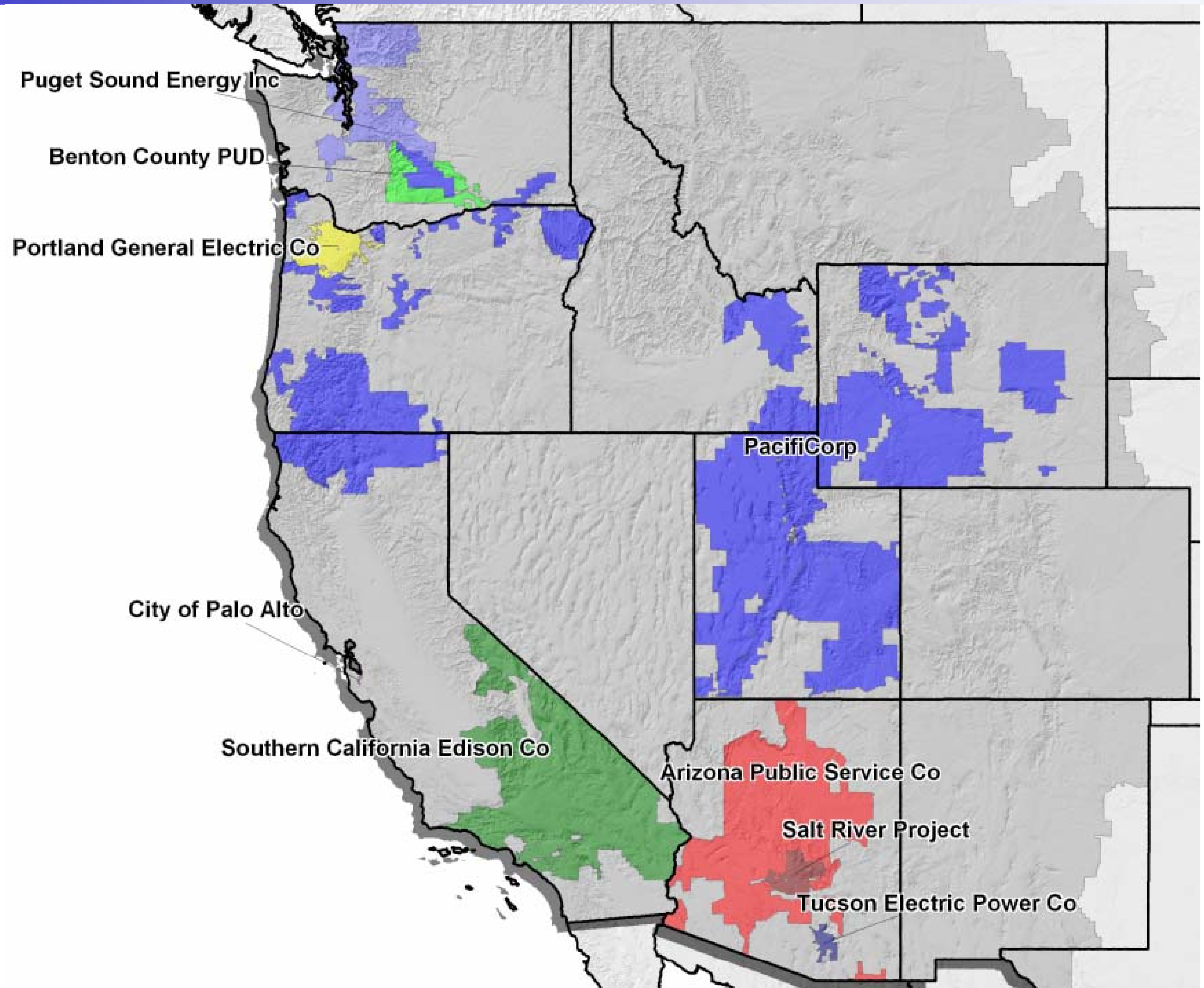
Webcast Background

- Been working with 9 utilities to examine impact of CO_2 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 CO_2 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 CO_2 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

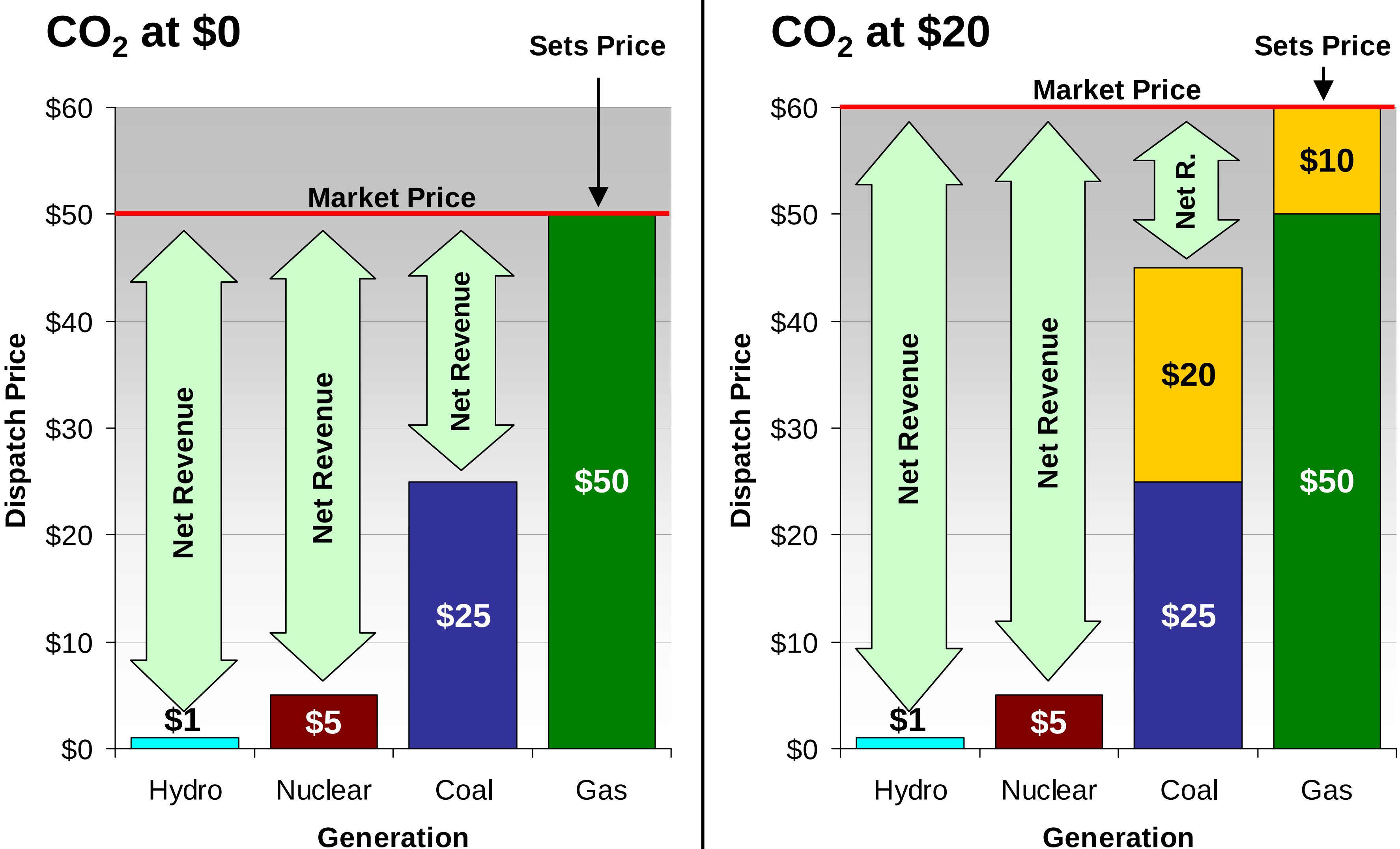
Summary of Key WECC Assumptions

- 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

CO_2 Policy Can Have a Dramatic Impact on Generation Costs, Power Prices, and Cash Flows

- Each dollar of CO_2 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 CO_2 price

CO_2 Price Impacts Electric Market Price and Generator Net Revenue for Each Hour of Dispatch



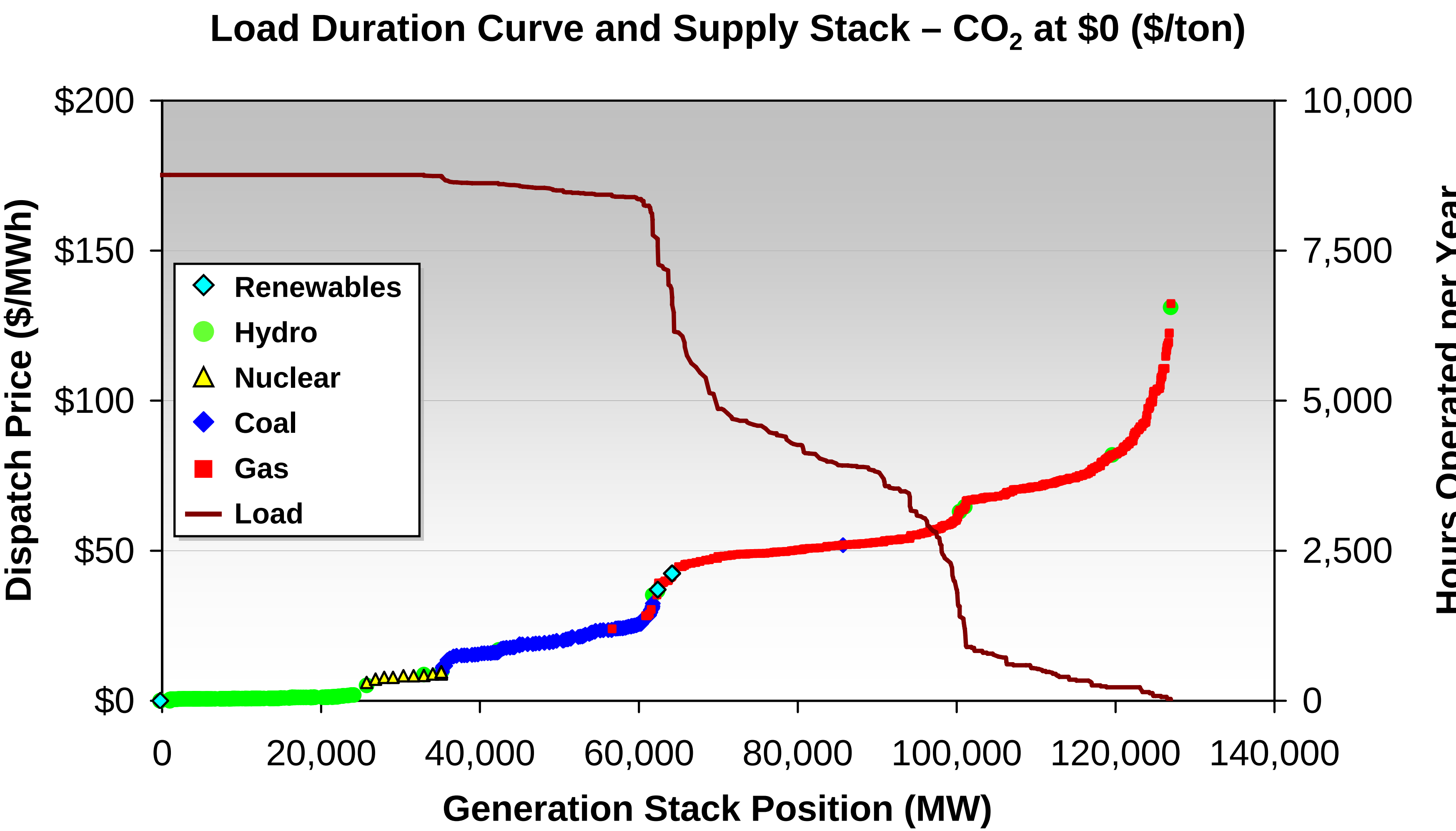
Modeling System Integrates All Major Options for Reducing Electric Sector CO_2 Emissions

- Combines three CO_2 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)

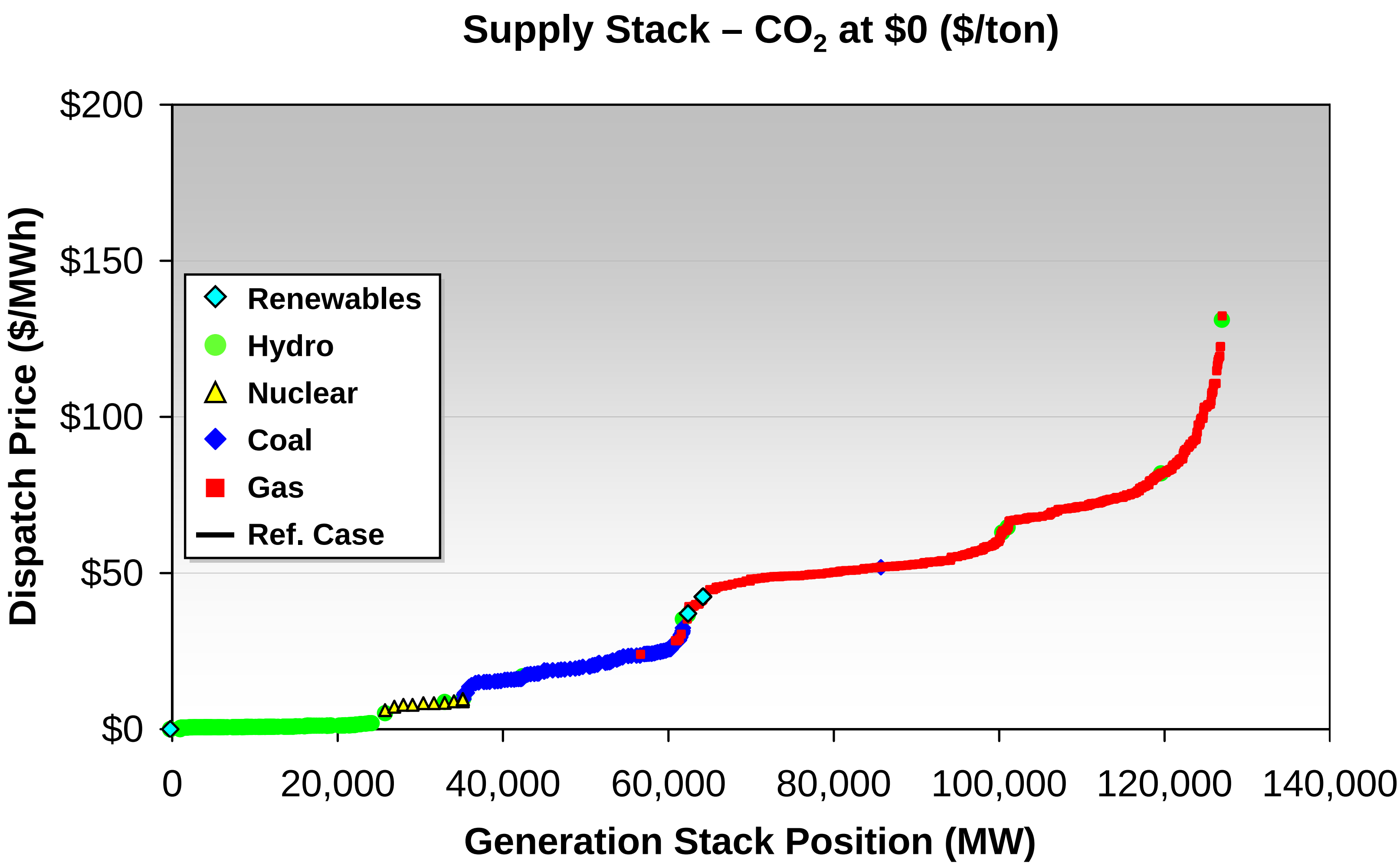
Analysis is Based on Market Model of Behavior

- Tracks impacts of a range of CO_2 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

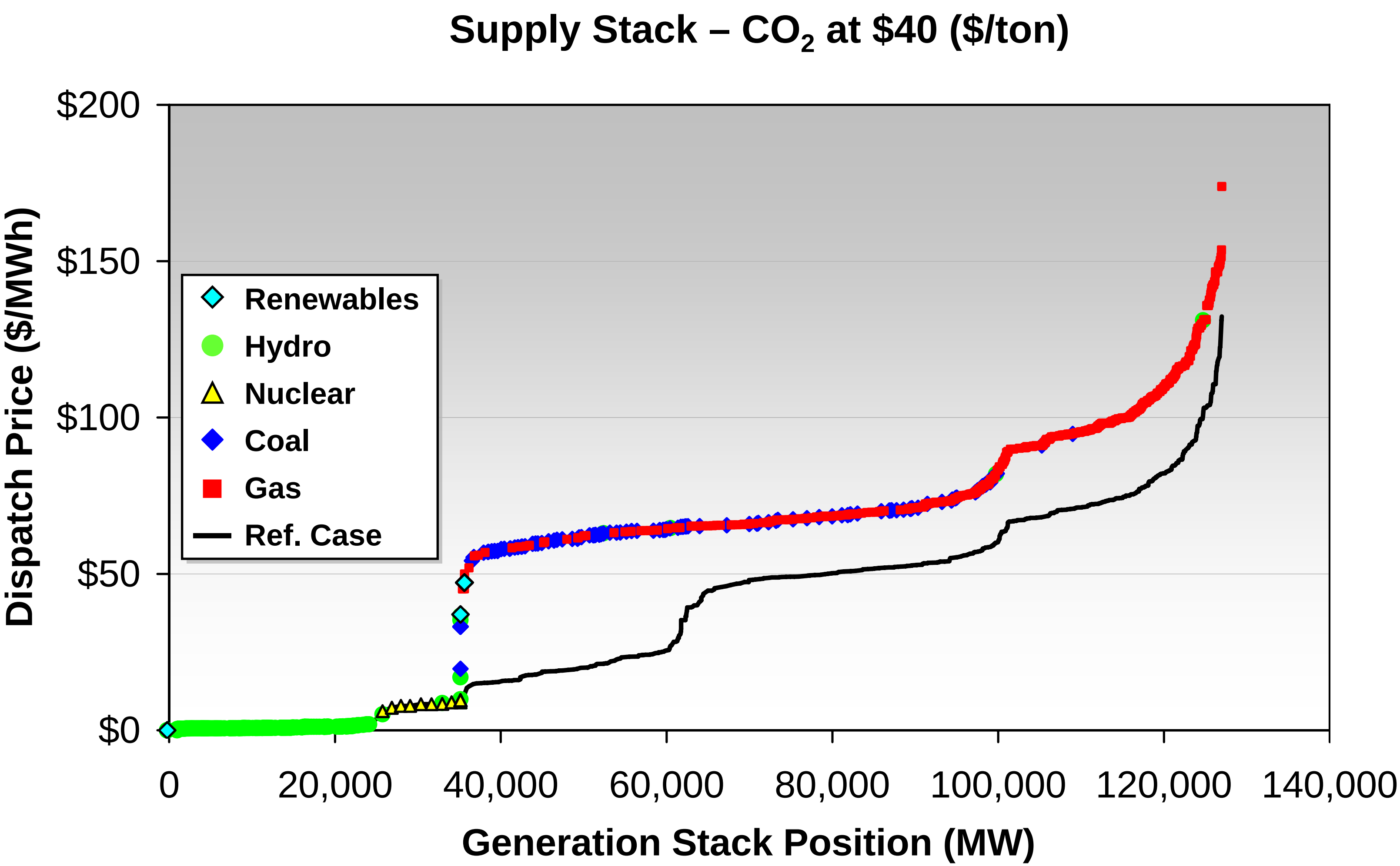
Supply Stack and Load Duration Curve Capture Operation of the System Each Year



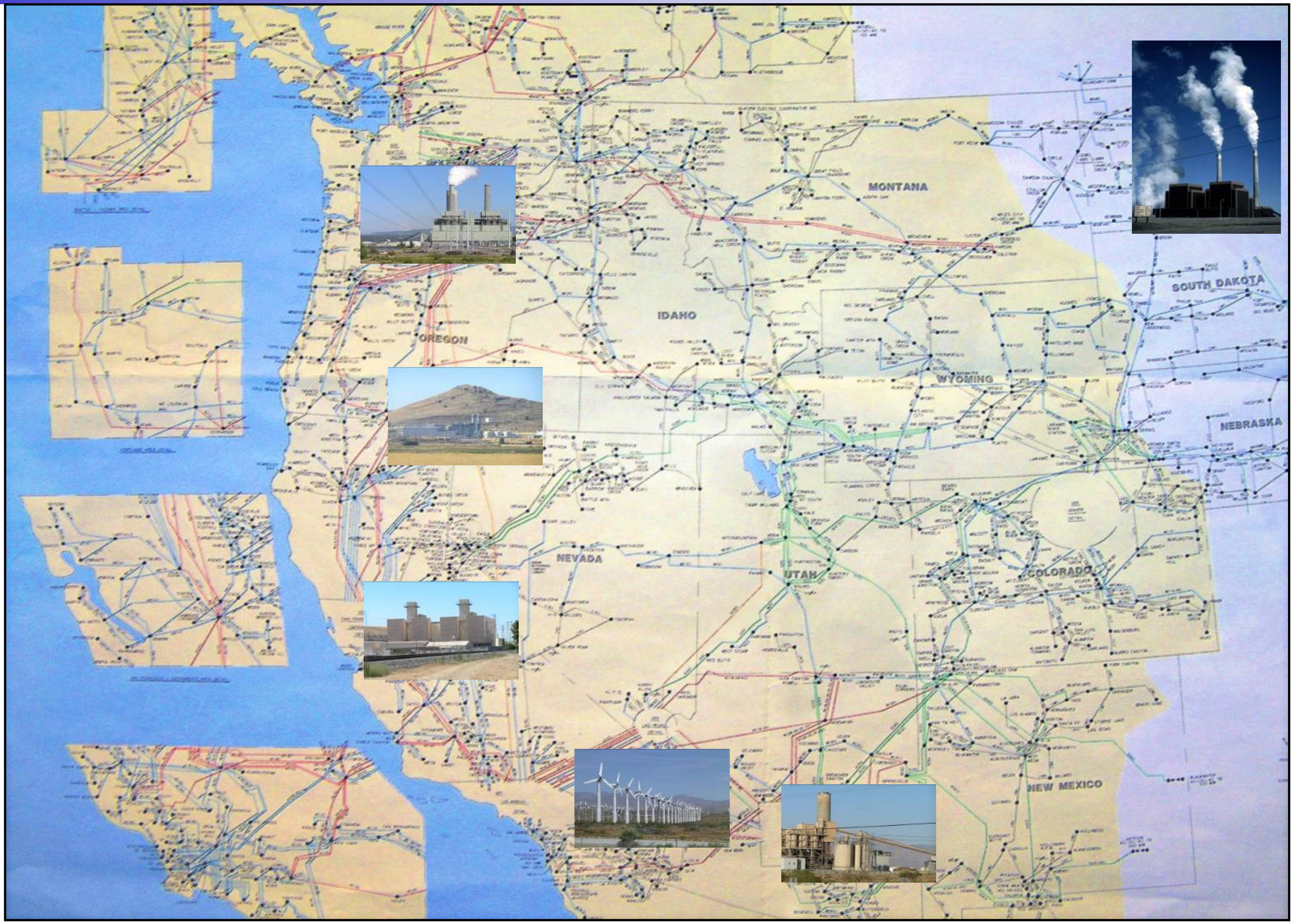
What Happens When CO_2 Has a Price? $0 per ton



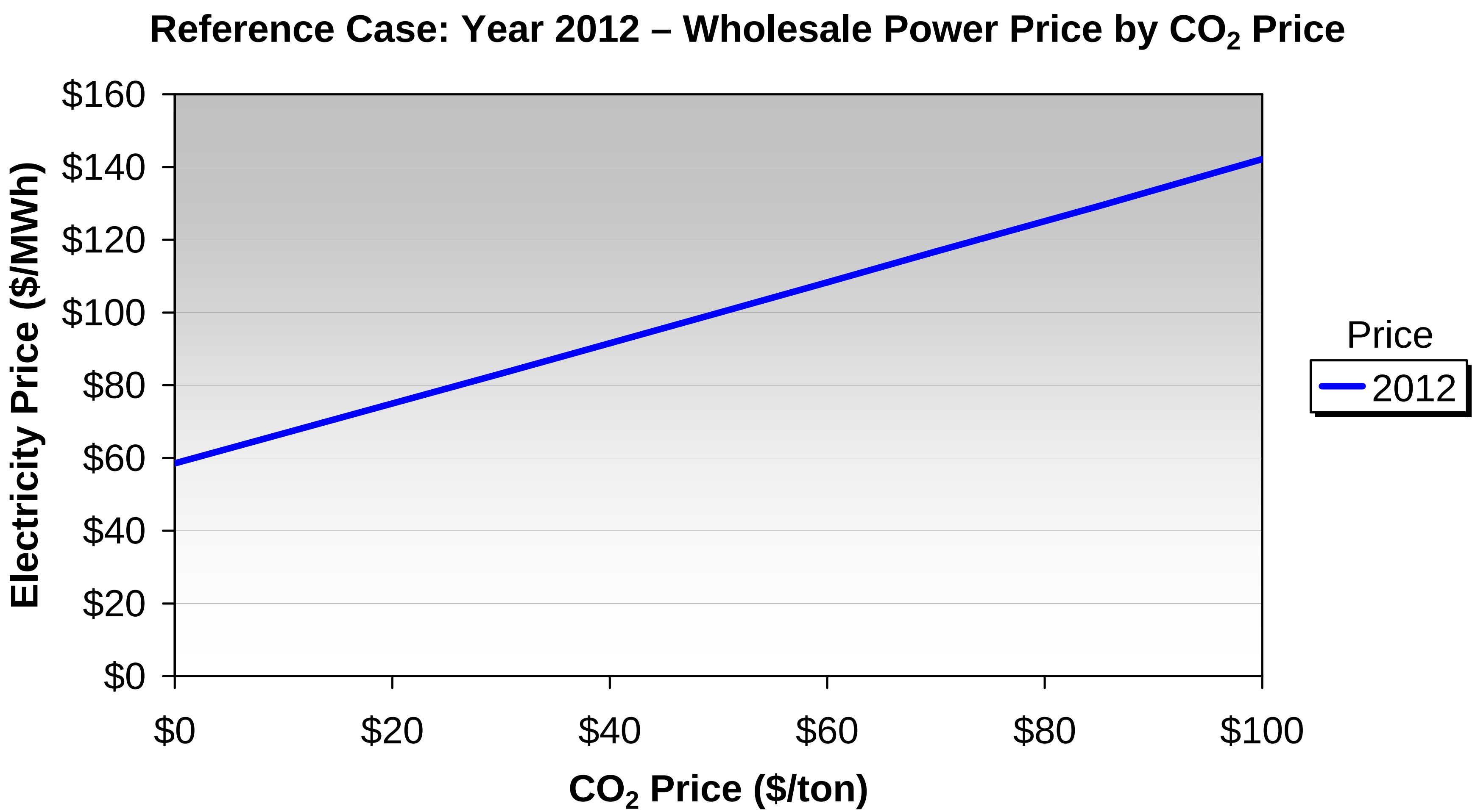
What Happens When CO_2 Has a Price? $40 per ton



Analysis Results



Impact of CO_2 Price on Wholesale Power Prices: Year 2012



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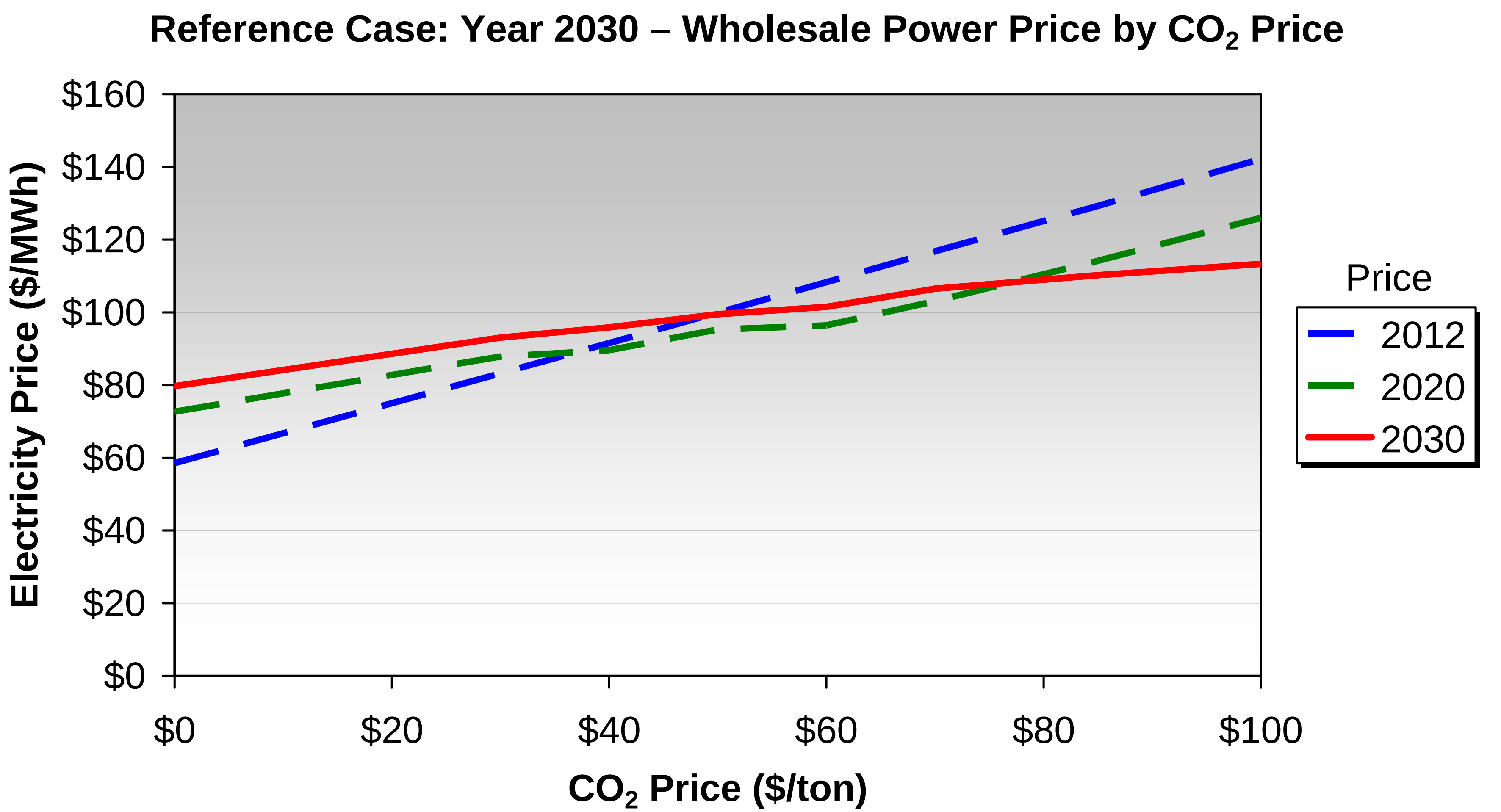
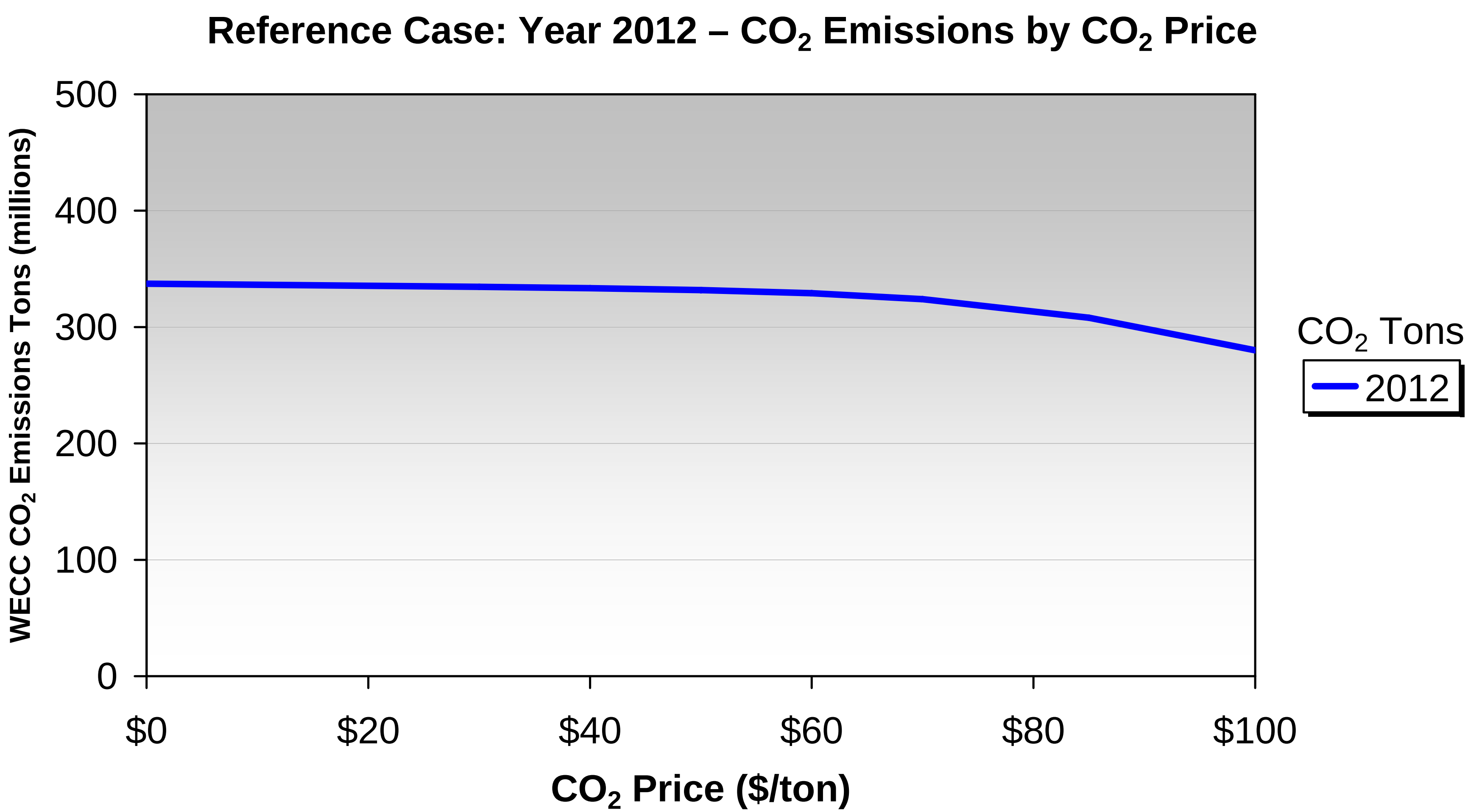
Impact of CO_2 Price on Wholesale Power Prices: Year 2030



Emissions Response to CO_2 Prices: Year 2012



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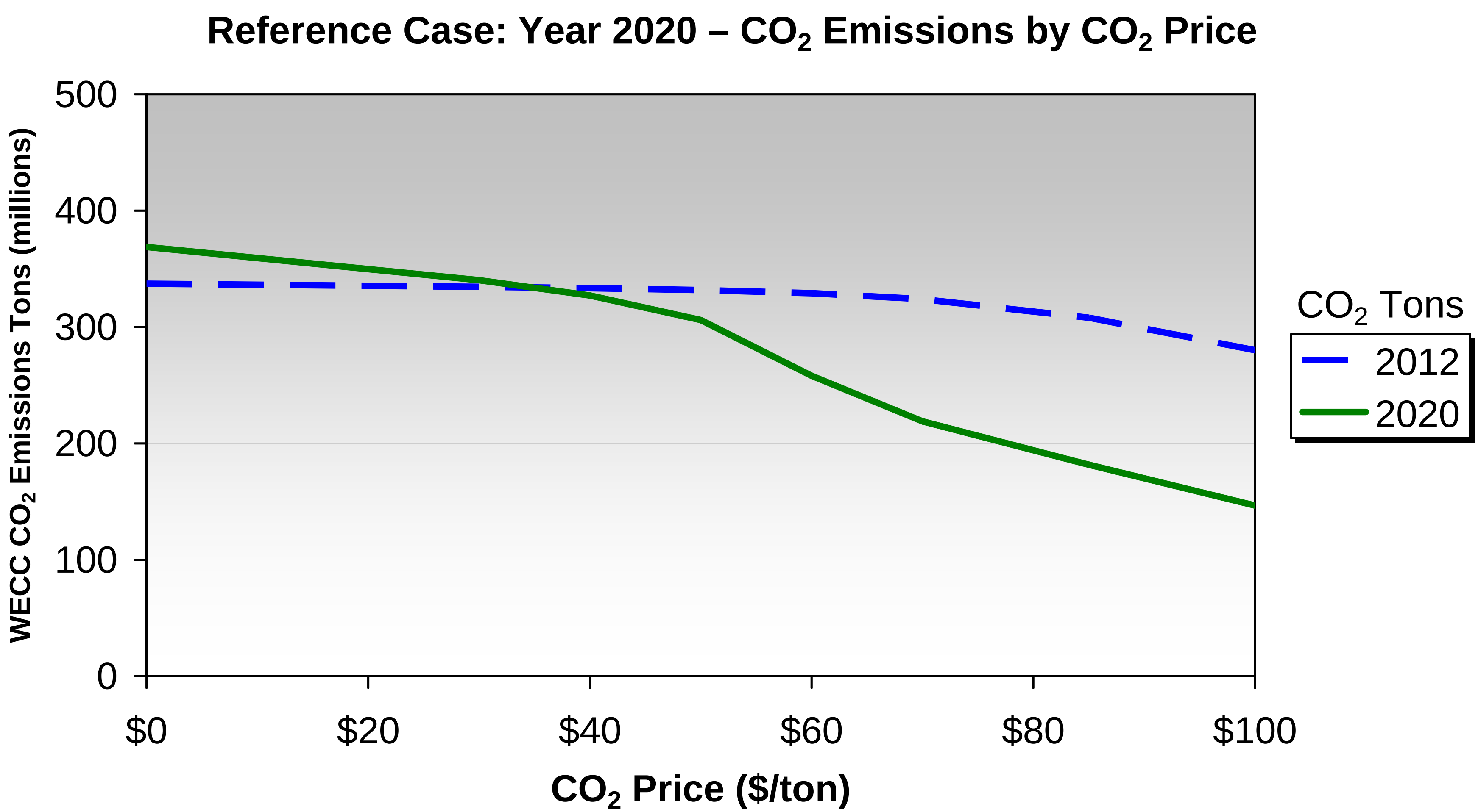
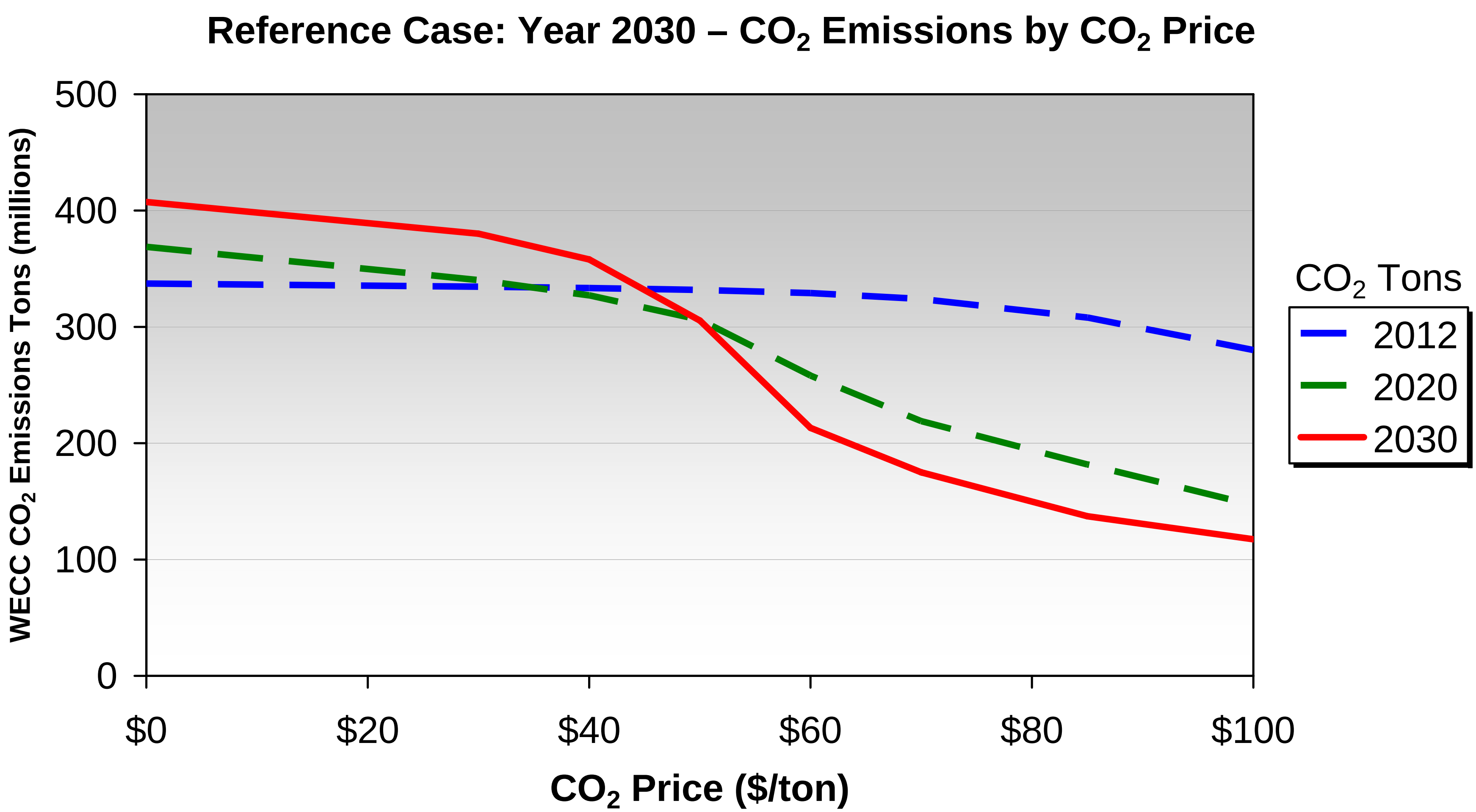
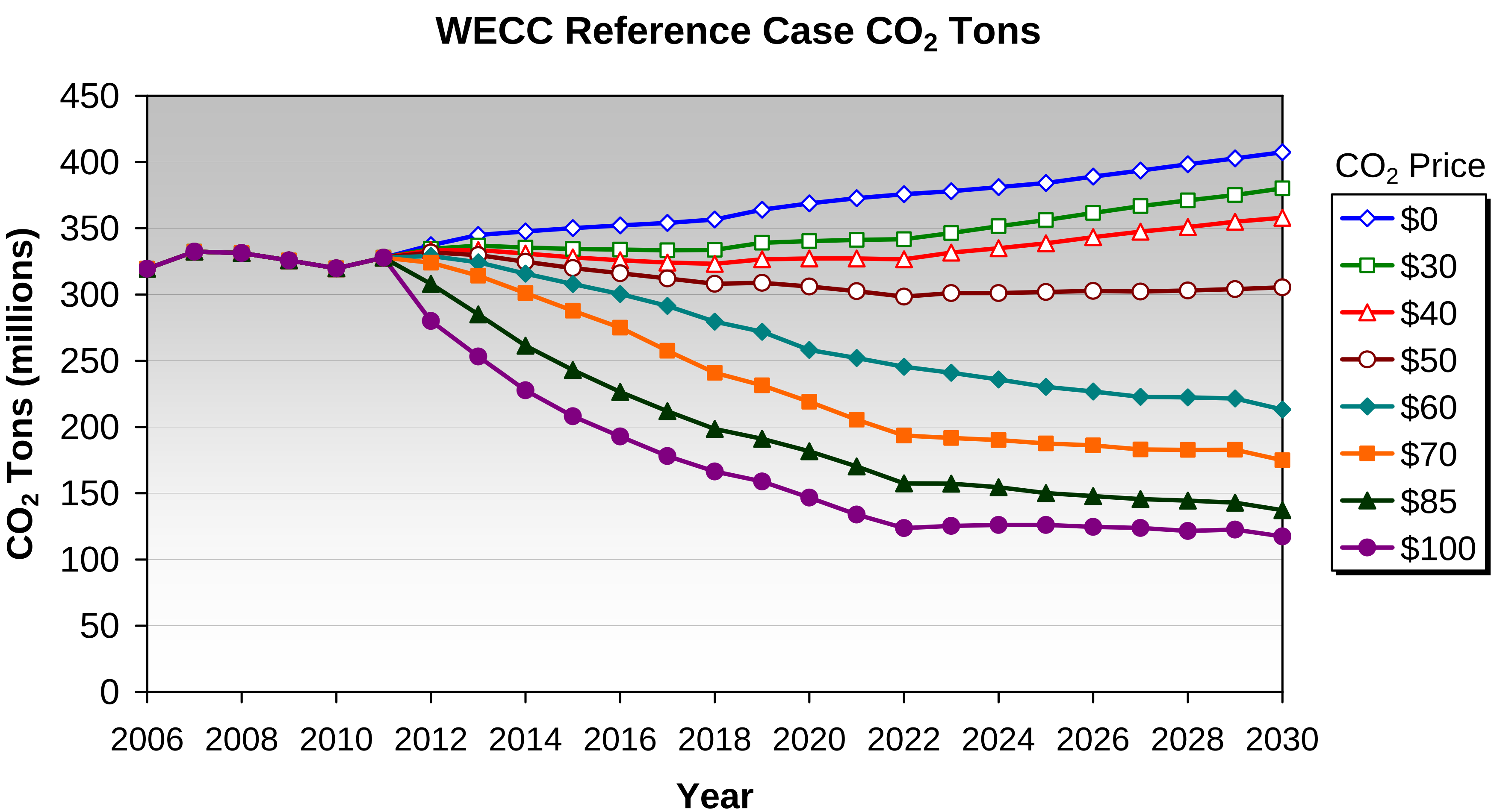
Emissions Response to CO_2 Prices: Year 2020



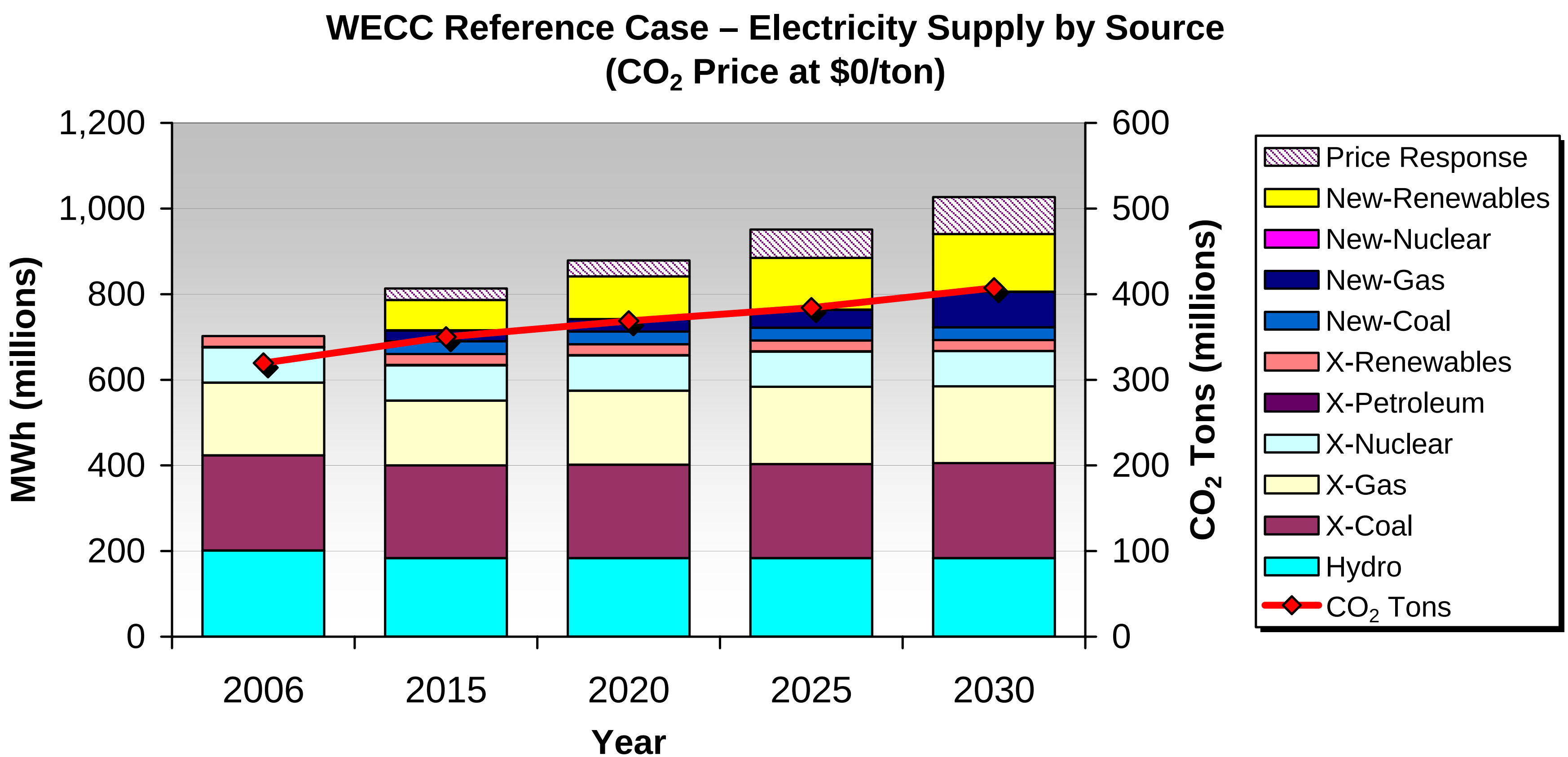
Emissions Response to CO_2 Prices: Year 2030



Emissions by CO_2 Price



Evolution of the Generation Output and CO_2: 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

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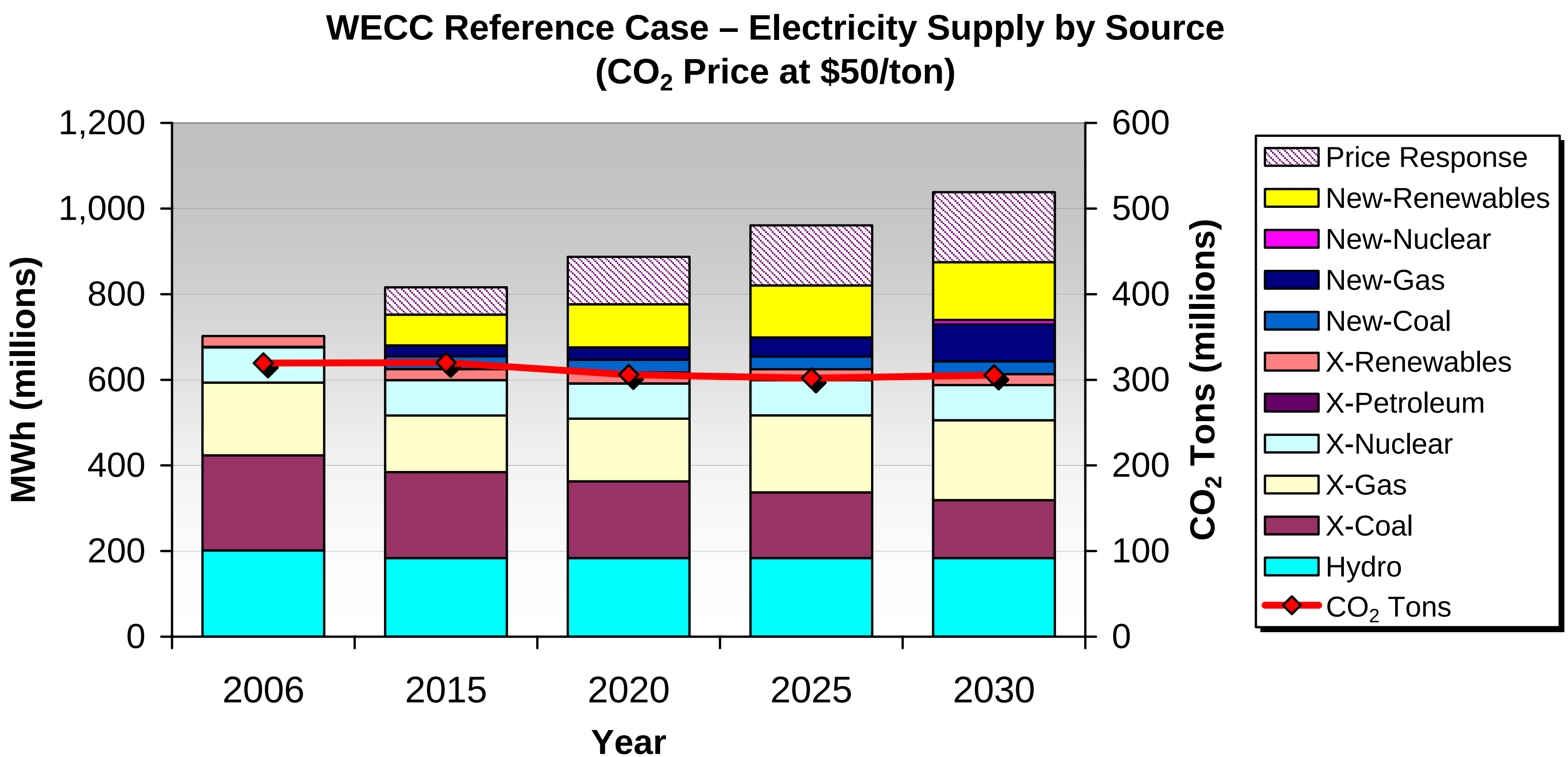
Evolution of the Generation Output and CO_2: Reference Case at $50 per ton



- Coal generation declines as CO_2 price increases; gas increases
- Demand is tempered through price response
- Emissions start to stabilize once capital changeover starts

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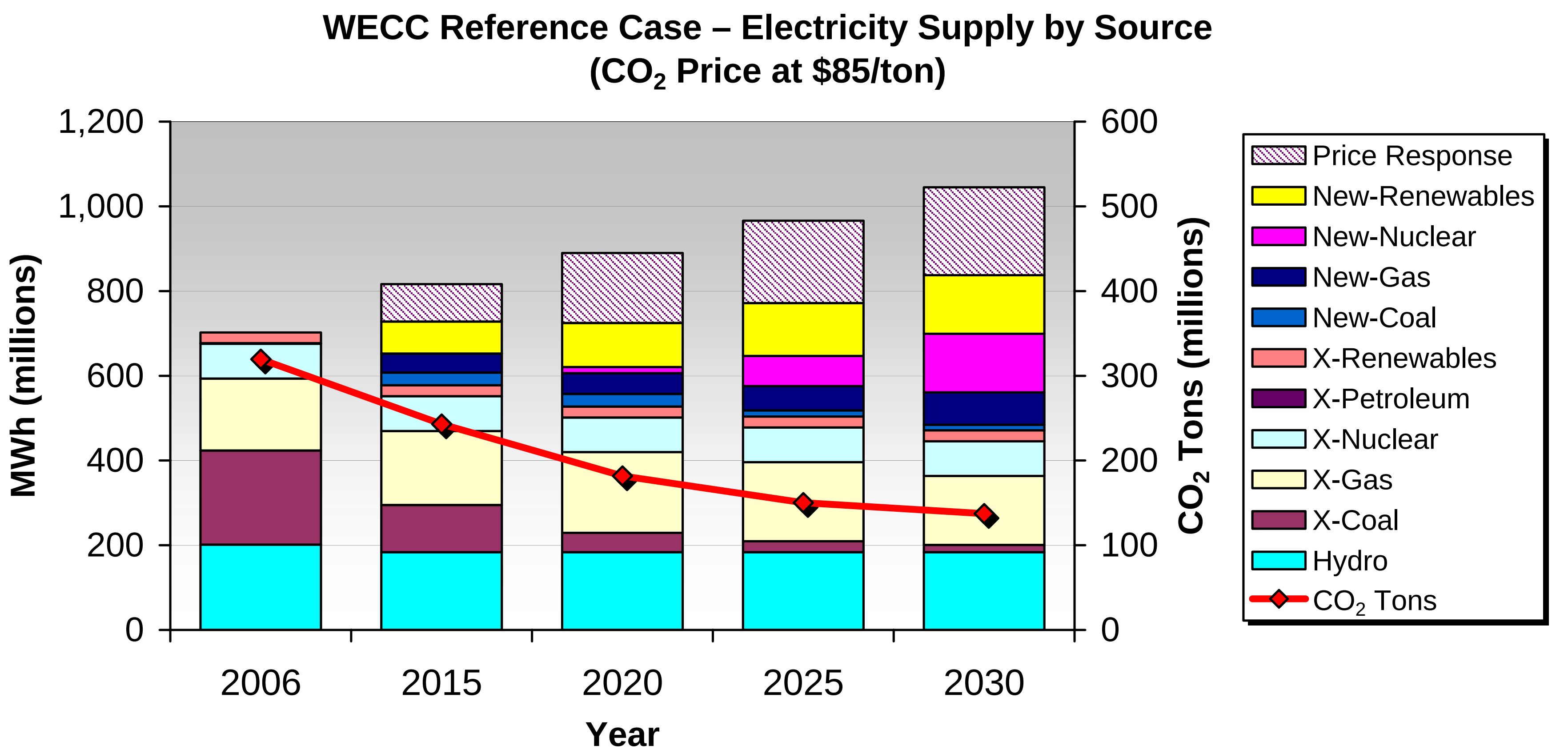
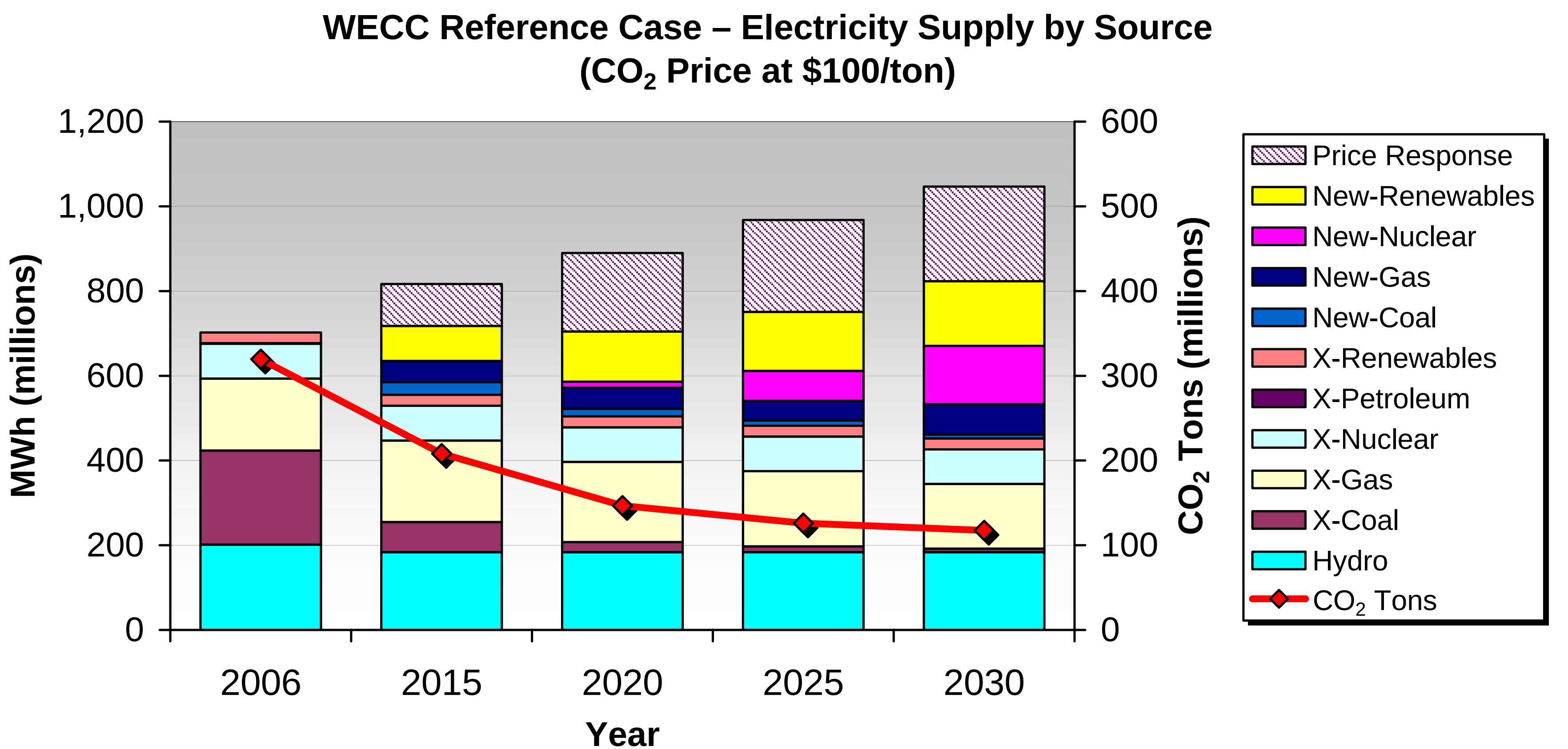
Evolution of the Generation Output and CO_2: Reference Case at $85 per ton



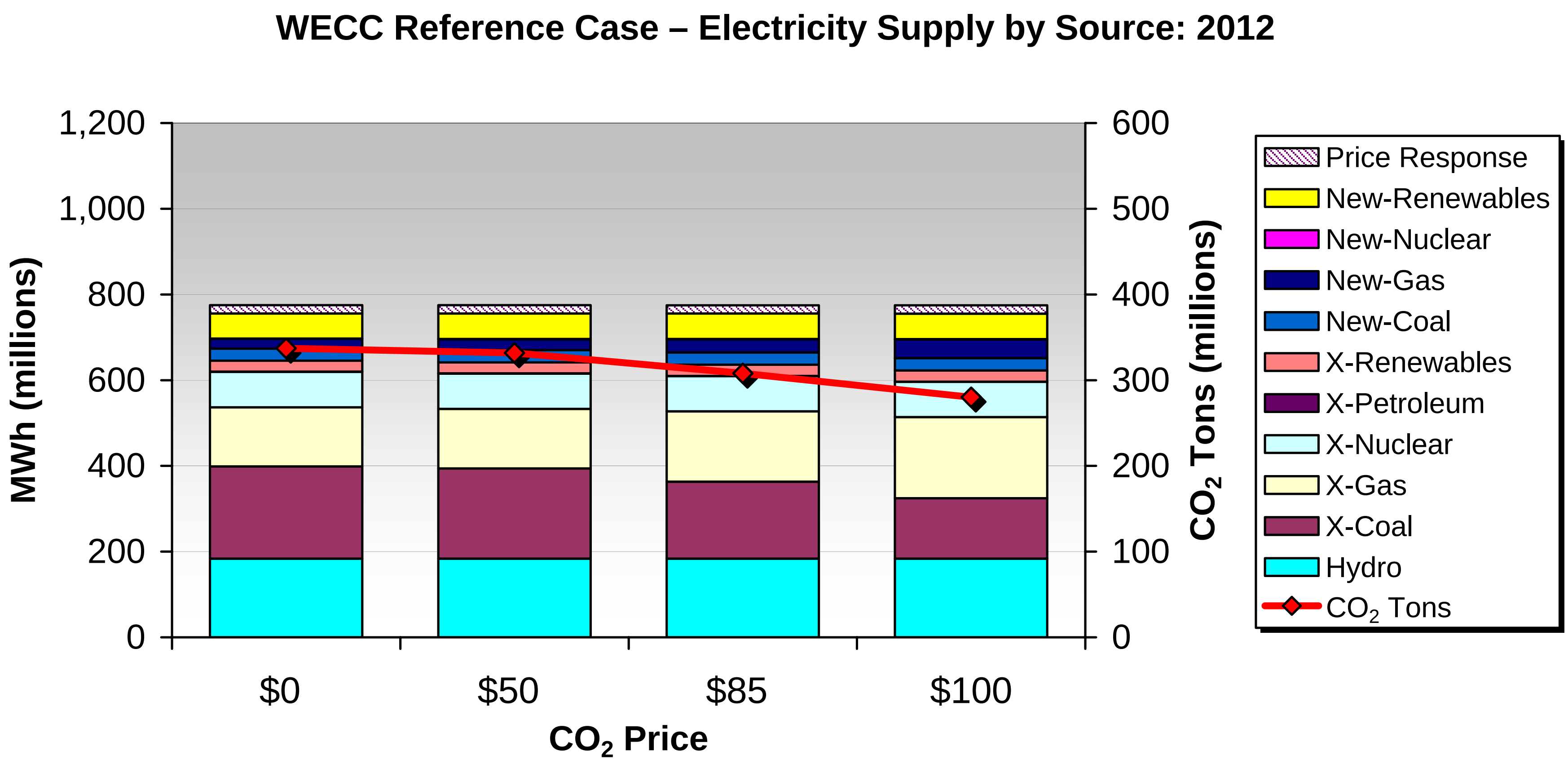
- X-coal generation declines further
- Non-emitting generation penetration tempers the electric price
- Price response slows down in later years
- Emissions shrinkage flattens out a bit

Evolution of the Generation Output and CO_2: Reference Case at $100 per ton



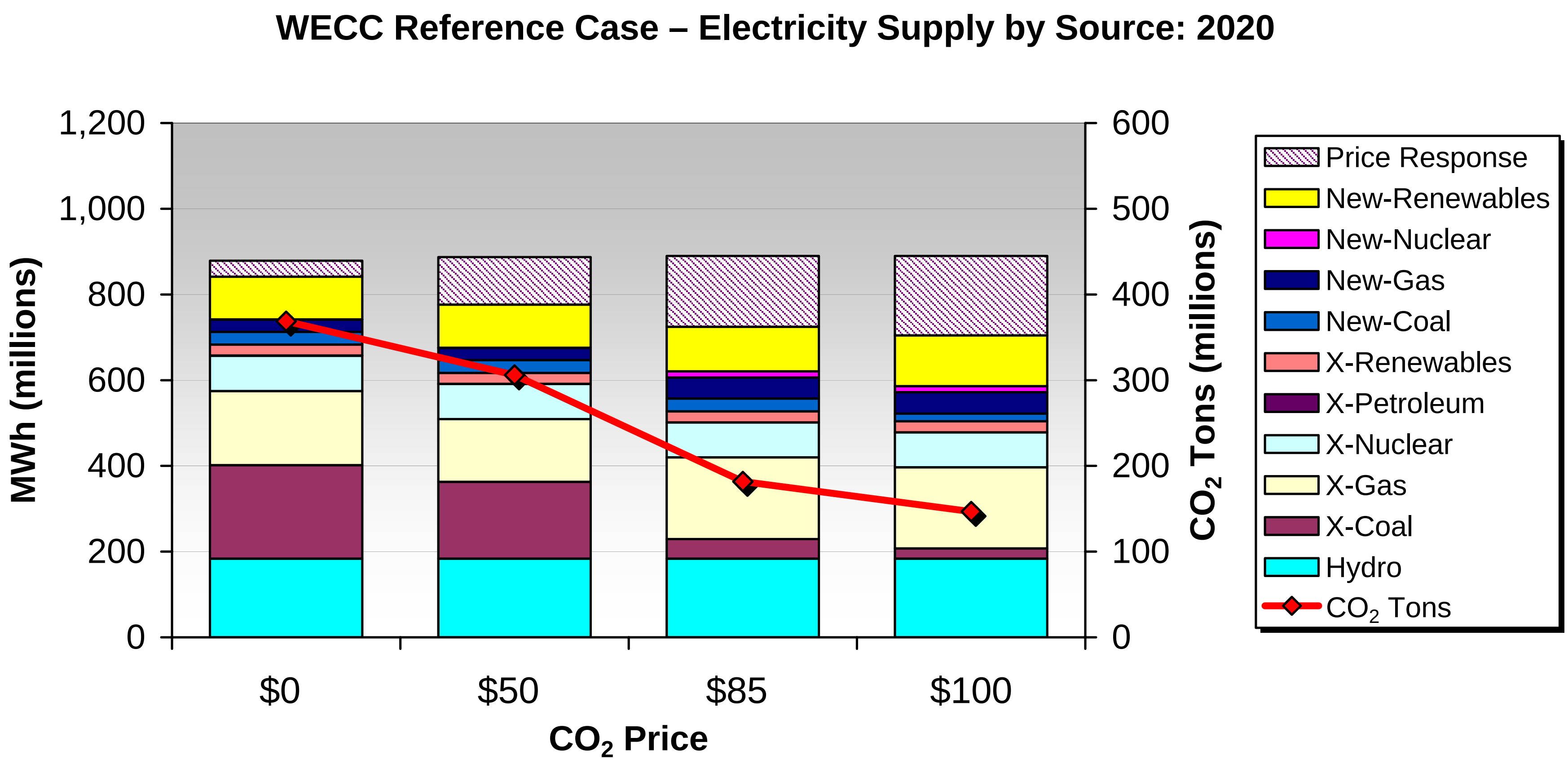
- X-coal generation essentially disappears at this price
- Again price response slows down in later years; emissions shrinkage flattens out a bit

How the System Cuts Emissions: Year 2012



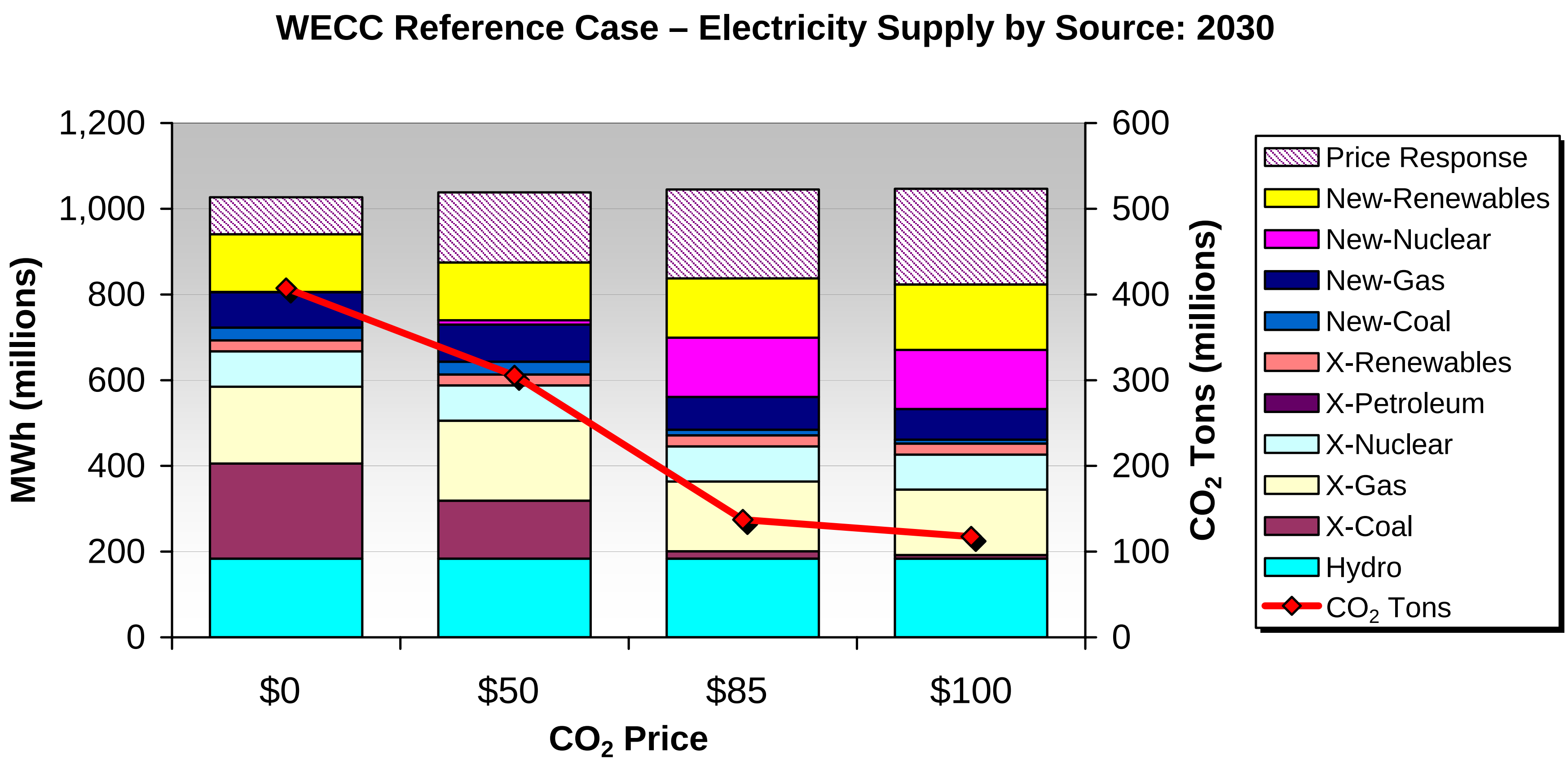
- X-gas substitutes for x-coal
  (emissions % reduction: 1% @ $50, 9% @ $85, 17% @ $100)

How the System Cuts Emissions: Year 2020



- Material price increase and price response
- X-coal disappears at the higher CO_2 price levels
- Non-emitters have not yet penetrated
  (emissions % reduction: 17% @ $50, 51% @ $85, 60% @ $100)

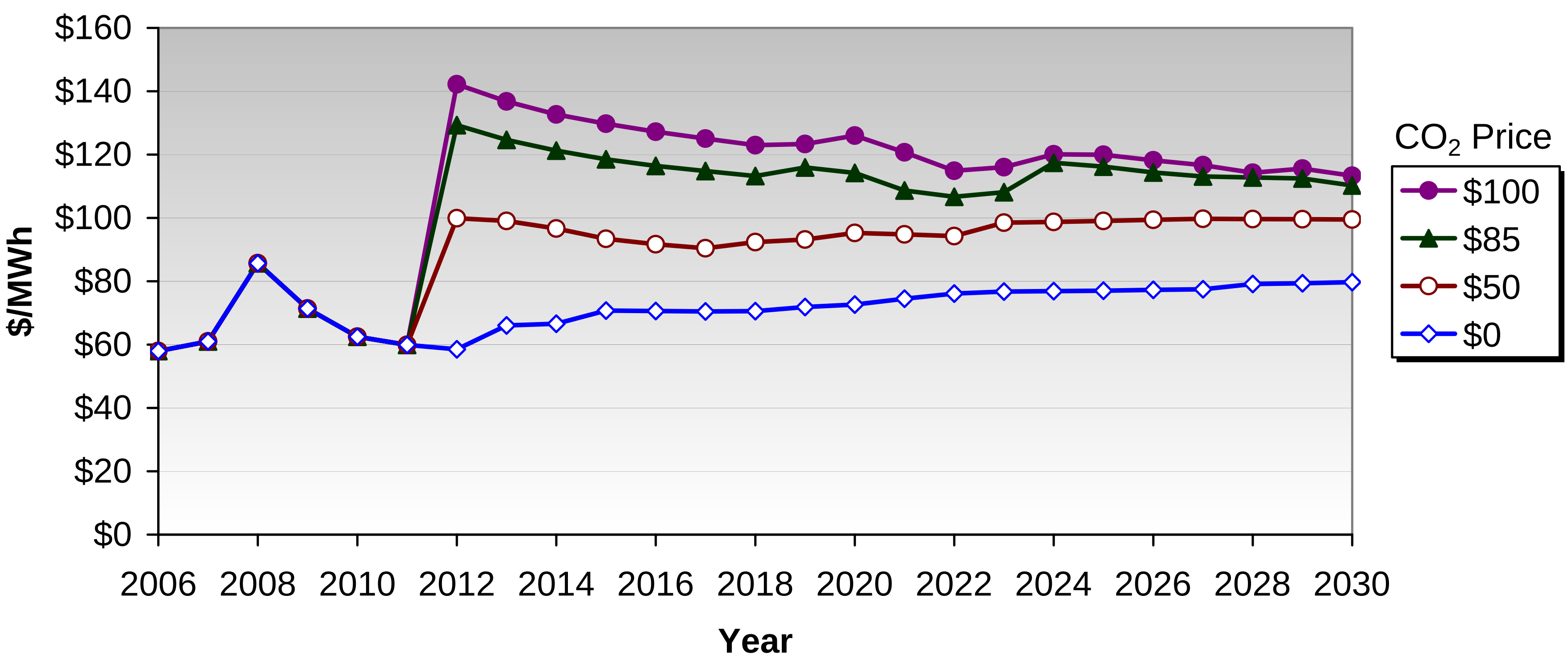
How the System Cuts Emissions: Year 2030



- 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

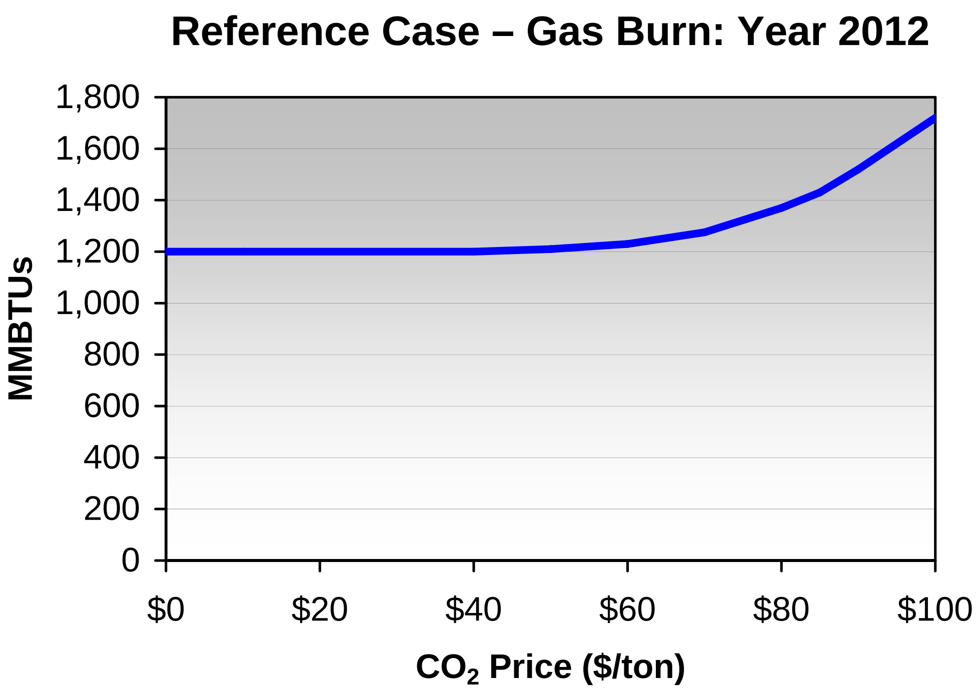


- % increase in 2012: 69% @ $50, 119% @ $85, 141% @ $100
- % increase in 2030: 25% @ $50, 38% @ $85, 41% @ $100

Impact of CO_2 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)
- CO_2 price implications in 2012
  - CO_2 price @ $0 - $95/MWh retail (1% over 2006)
  - CO_2 price @ $50 - $136/MWh retail (43% increase over $0 case)
  - CO_2 price @ $85 - $165/MWh retail (74% increase over $0 case)
  - CO_2 price @ $100 - $178/MWh retail (87% increase over $0 case)
- CO_2 price implications in 2030
  - CO_2 price @ $0 - $116/MWh retail (23% over 2006)
  - CO_2 price @ $50 - $136/MWh retail (17% increase over $0 case)
  - CO_2 price @ $85 - $146/MWh retail (26% increase over $0 case)
  - CO_2 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**

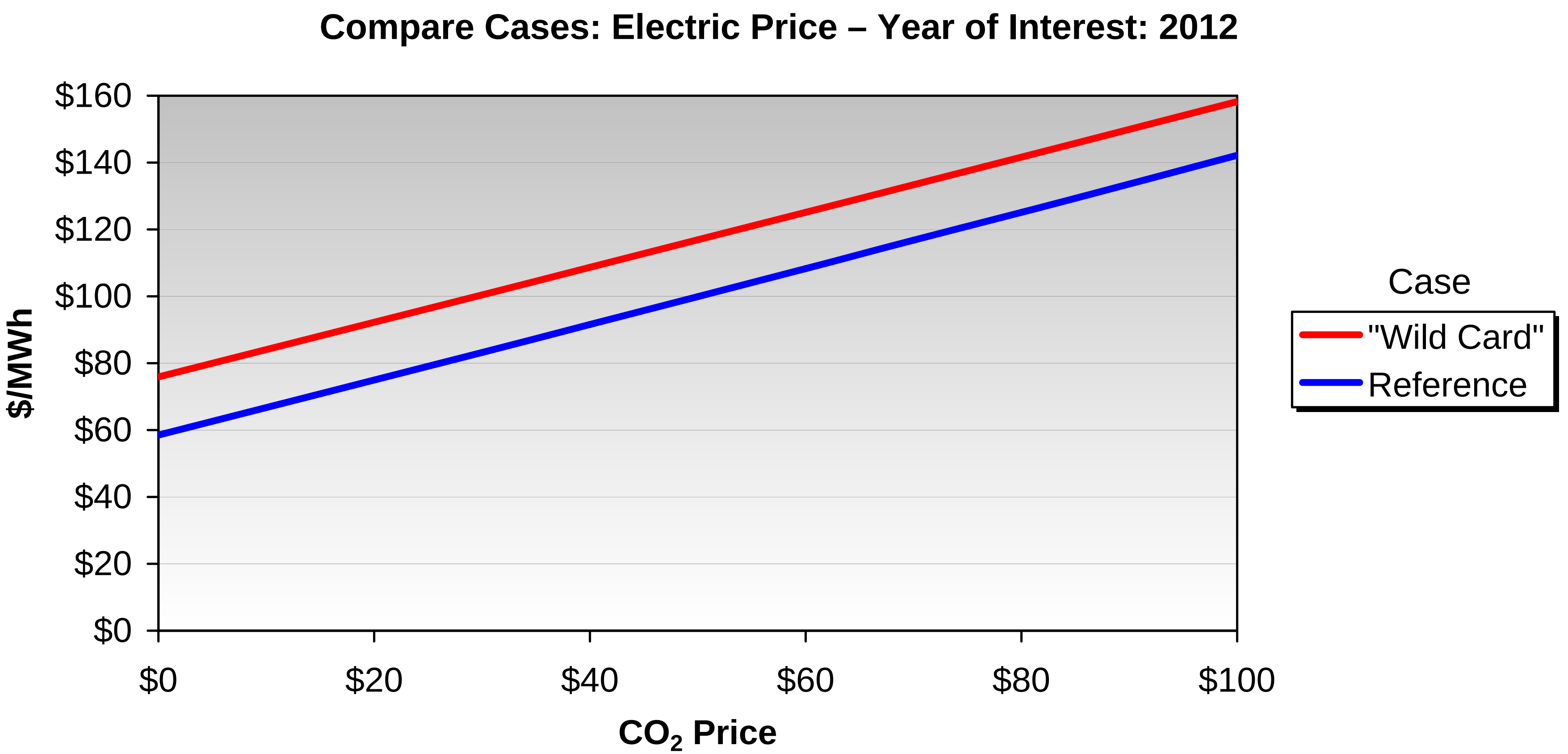
Summary of Sensitivity Analyses

- Gas prices higher than projected
  - Higher emissions absent a price, but higher CO_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

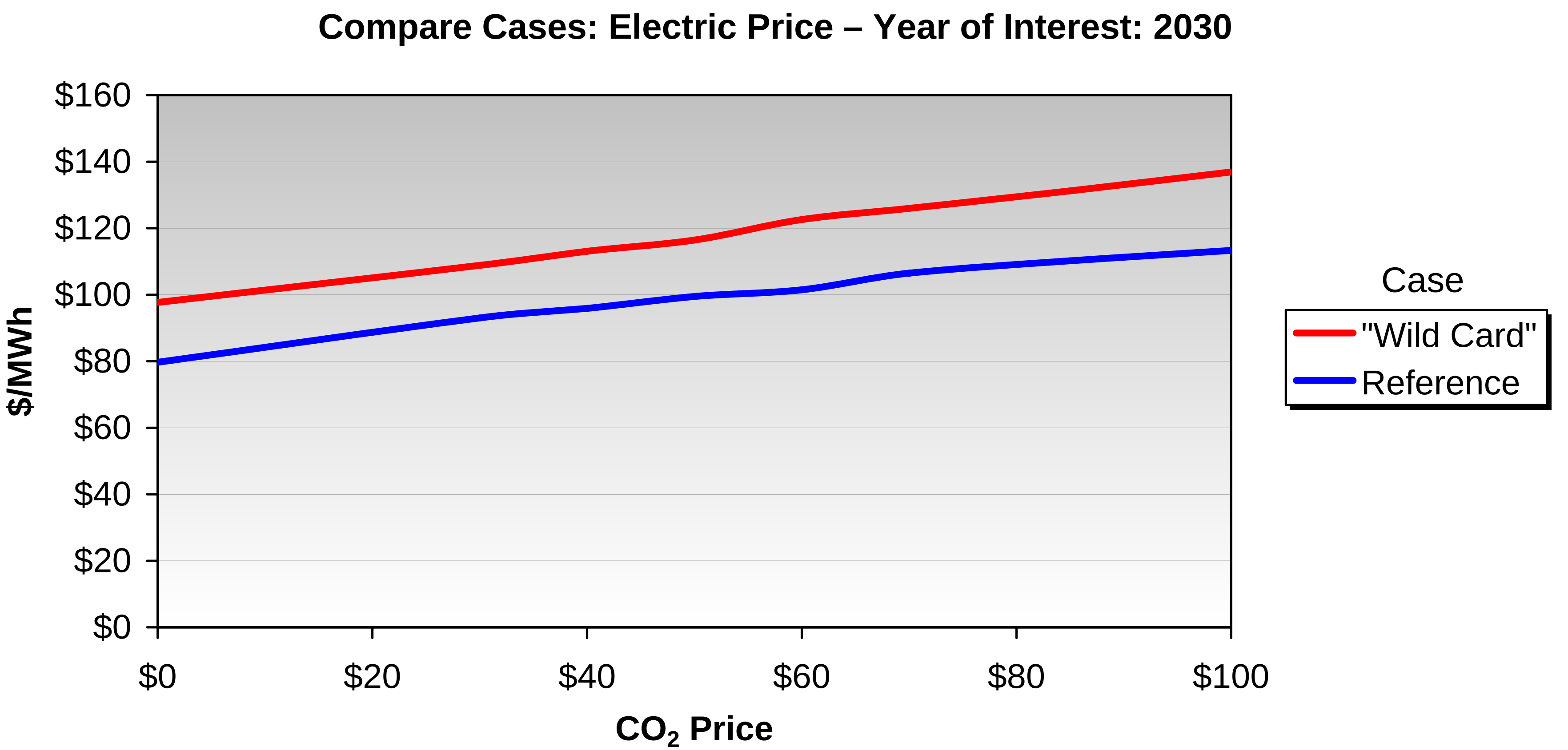
- High load growth
  - 2.2% annually
- High gas prices
  - $2 above Reference Case
- Low customer demand response
  - (0.25) long-term price elasticity
- High plant capital costs
  - 25% above Reference Case
- No new nuclear
  - Constrained from capacity addition pre-2030

The "Wild Card" Adverse Outcomes Case:
Electric Price in Year 2012



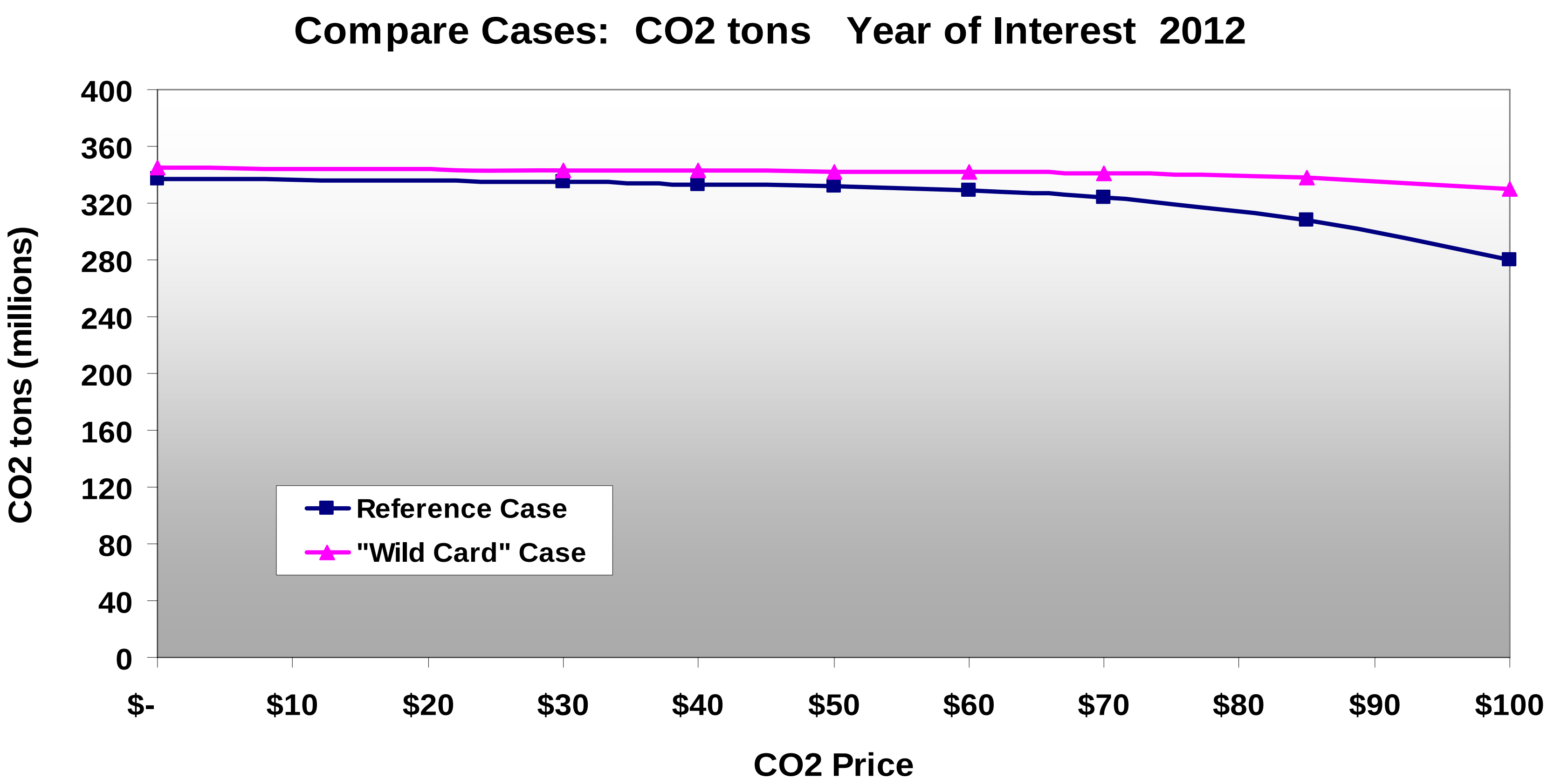
- Electric prices rise for the most part proportionately
- Tempered slightly at higher CO_2 prices by the increase in coal burn

The "Wild Card" Adverse Outcomes Case:
Electric Price in Year 2030



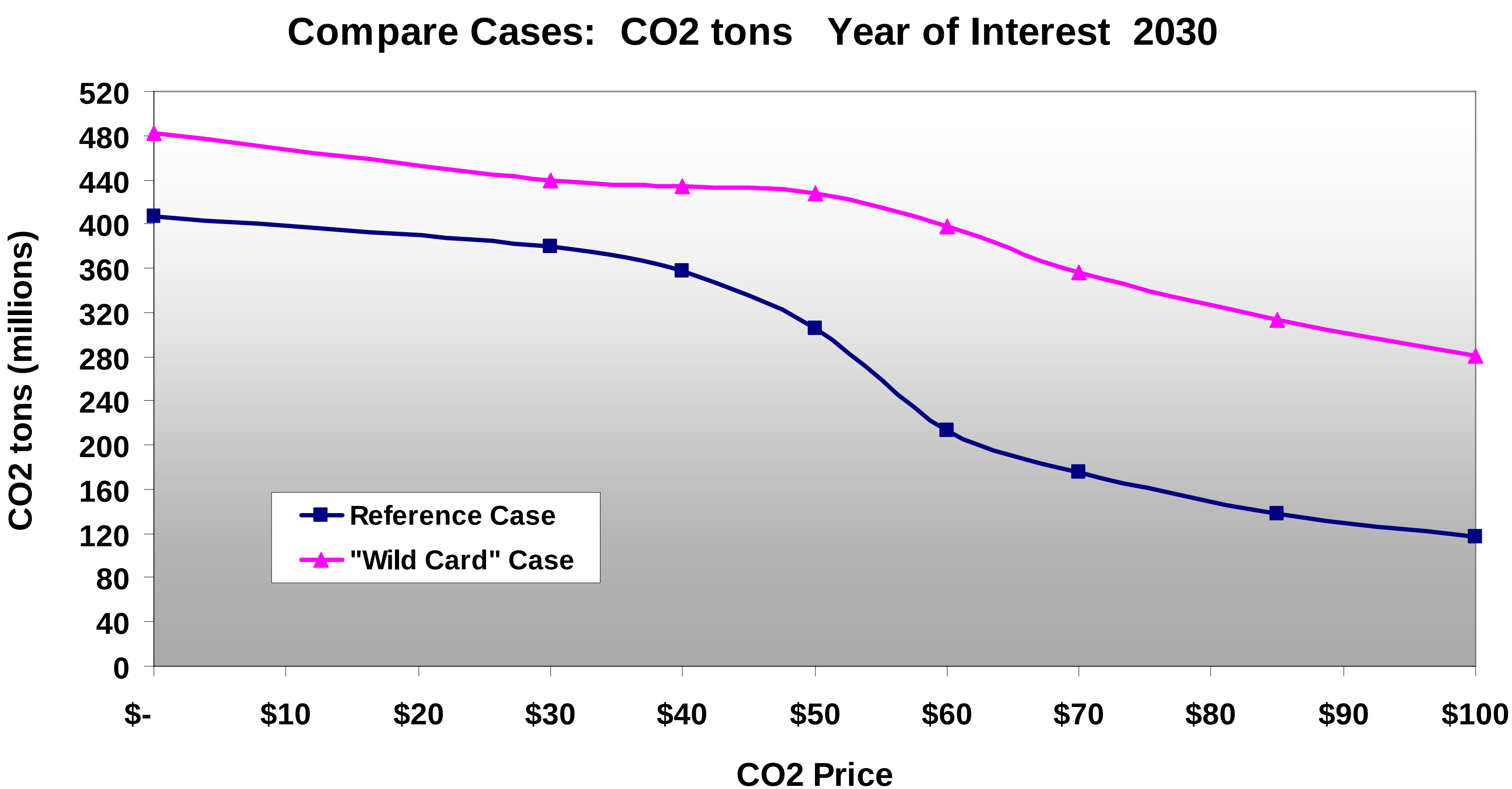
- Electric prices must be high enough to encourage new resources at higher plant costs for the "Wild Card" case

The "Wild Card" Adverse Outcomes Case:
Emissions in Year 2012



- "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



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

Energy Efficiency Sensitivity Analysis

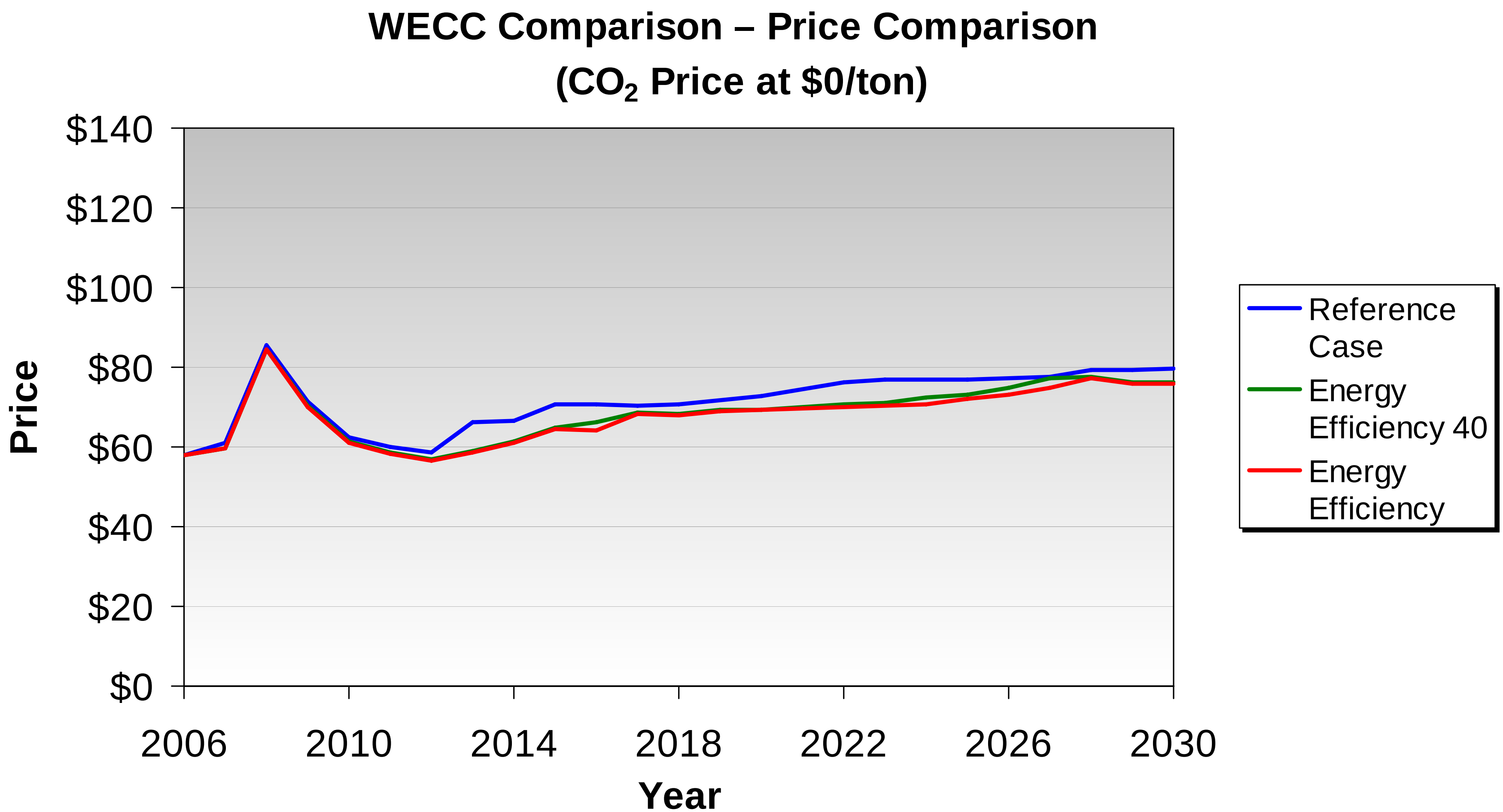
- What would be the effect of reducing the assumed load growth to reflect state-mandated energy efficiency programs?
- By-request sensitivity analysis provides insights on the interaction of energy efficiency w. climate policy
- Reference Case load growth rate assumed 1.73% annually (extends a recent historical growth rate 1995 to 2005)
  - Demand response to electric rate increases in the reference case give realized growth rate to 1.38%

	2006-2030
Total WECC Load Growth absent EE Programs Mandated by States	**1.73%**
Total WECC Load Growth with EE Programs Mandated by States	**1.34%**

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



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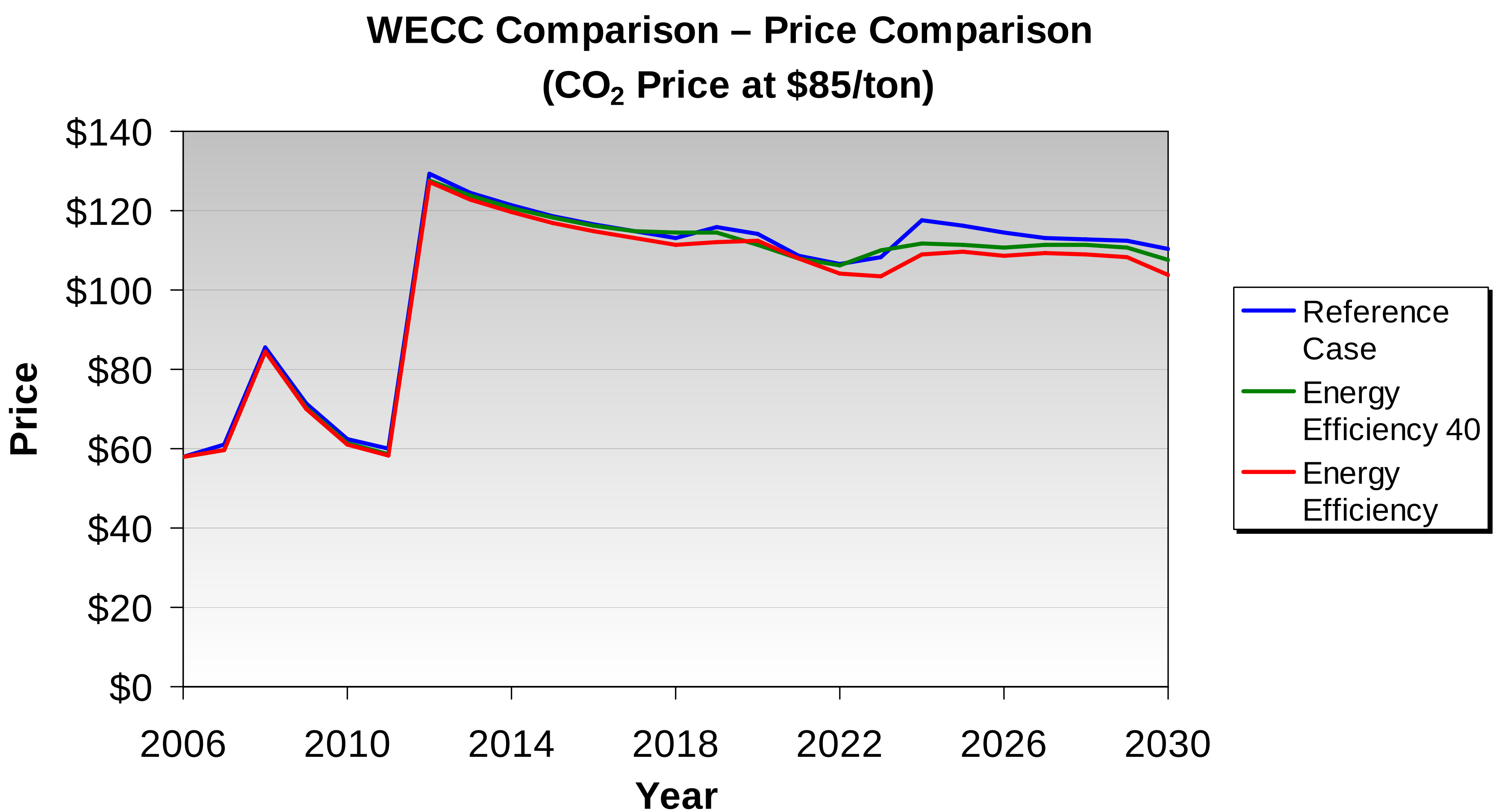
Wholesale Power Price Comparison



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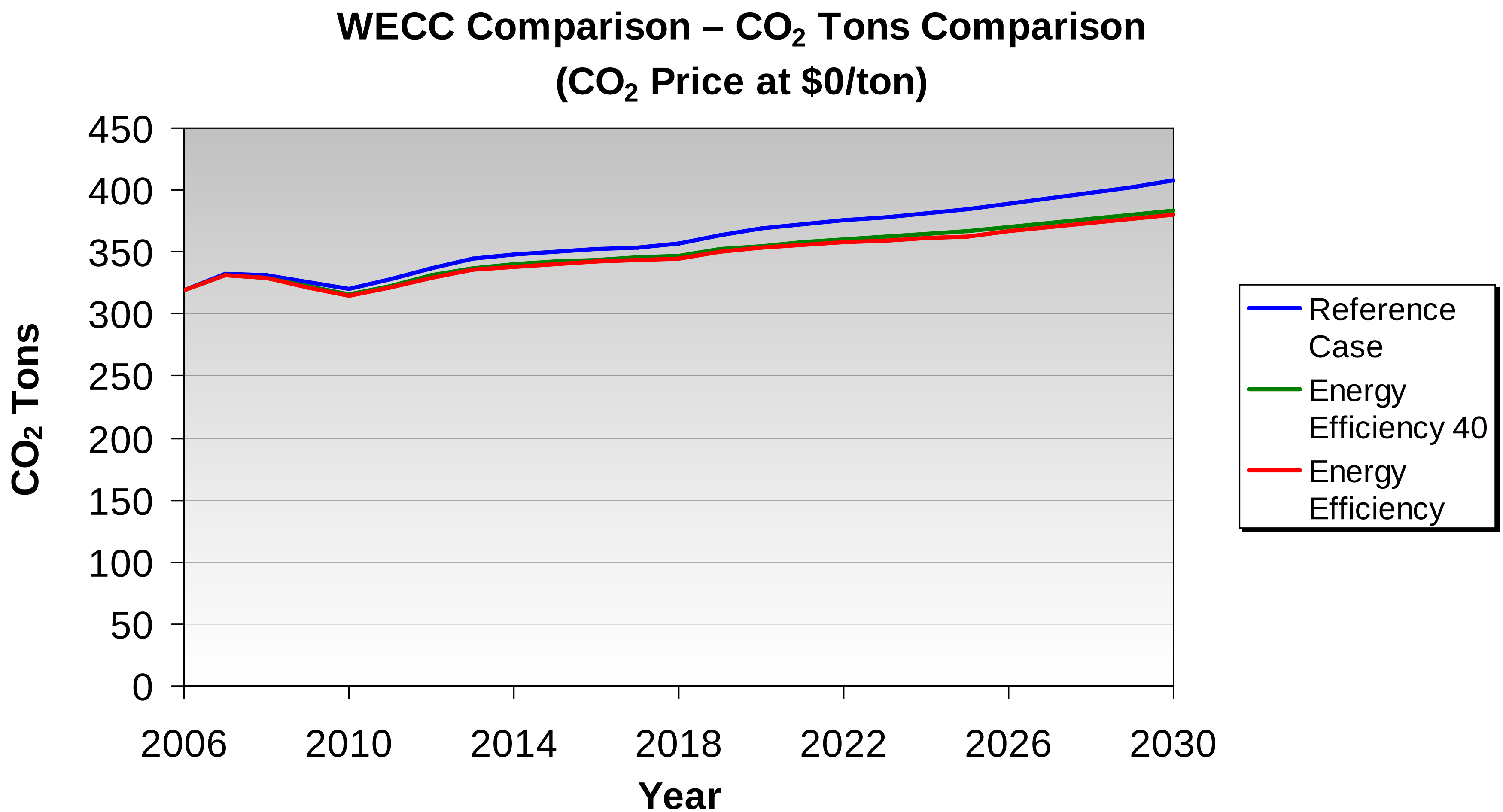
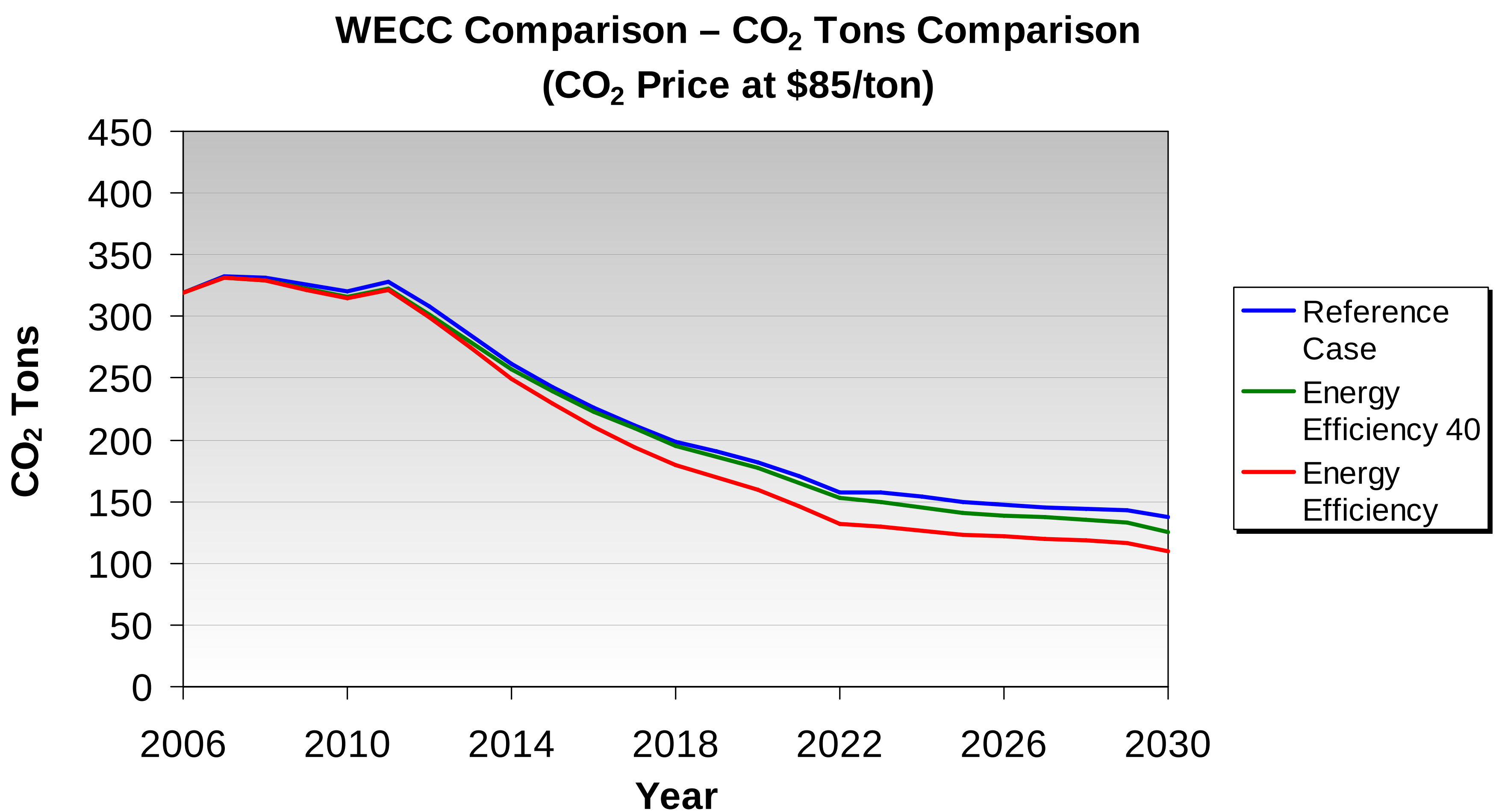
Emissions Comparison



Emissions Comparison



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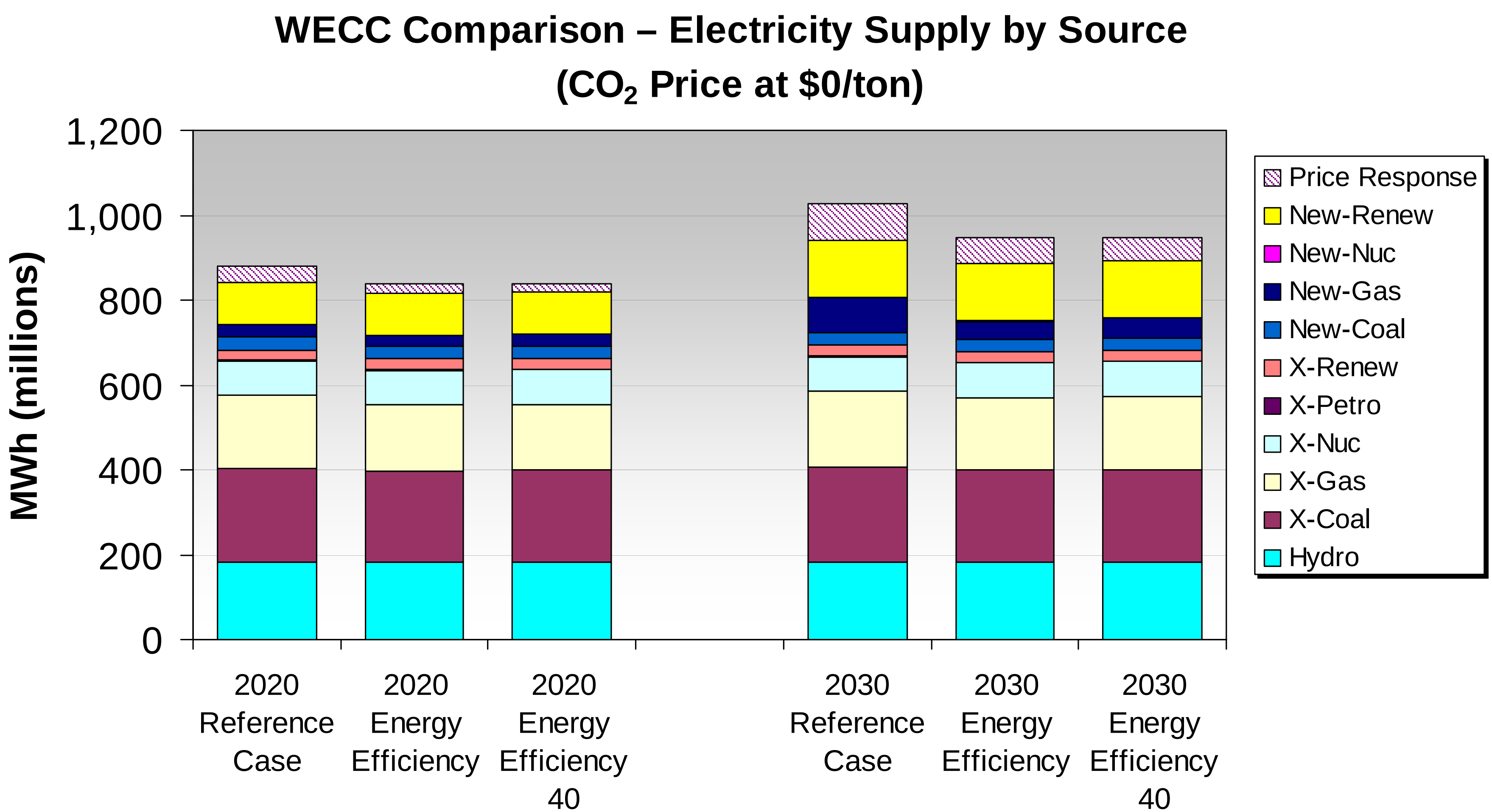
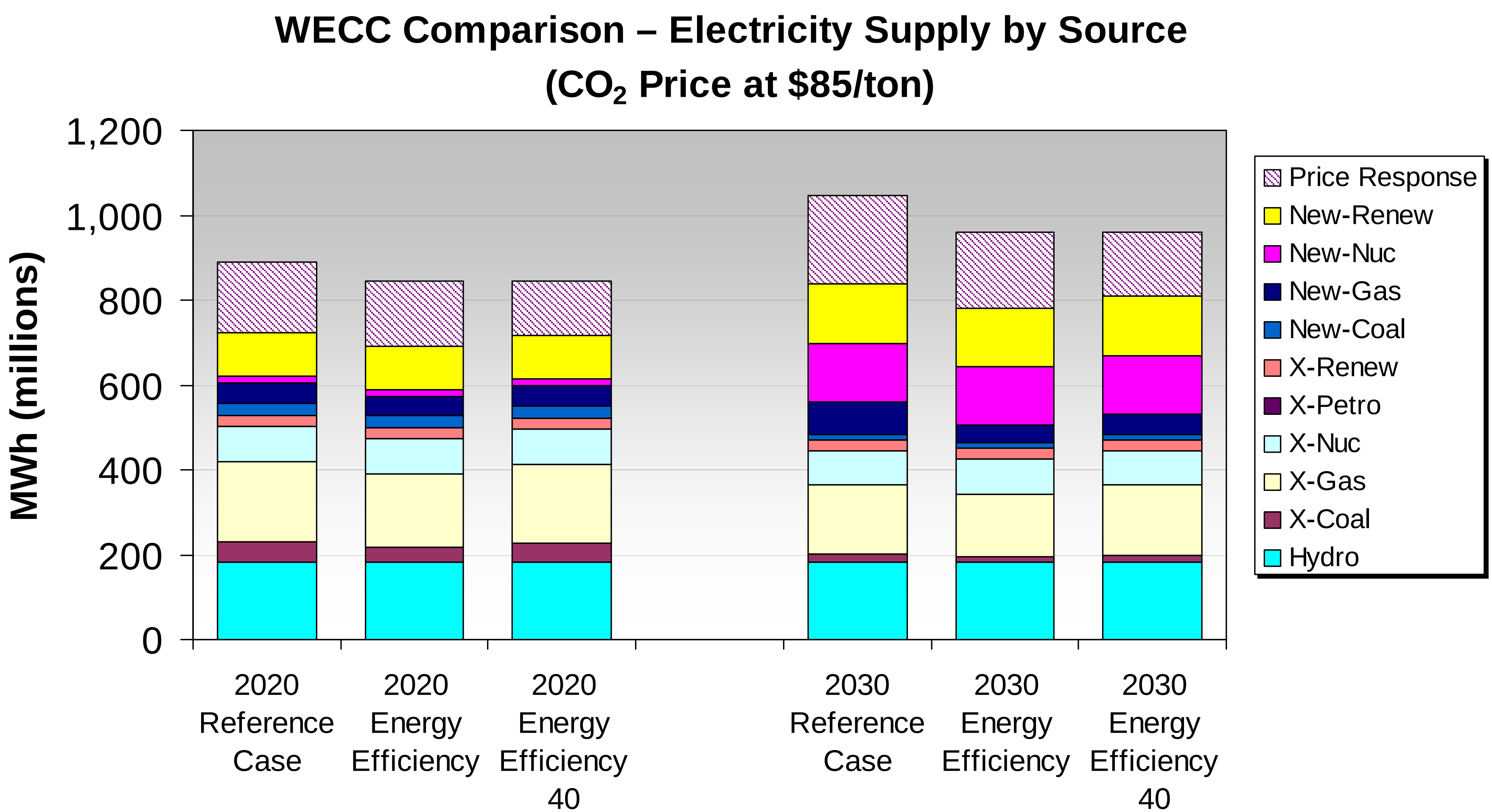
Generation Mix Comparison – No CO_2 Price: Gas Generation on Margin



- Assuming no CO_2 policy, slightly less new gas generation is needed

Generation Mix Comparison – \$85/ton CO_2 Price: Gas Generation on Margin



- At a higher CO_2 price level, the differences are – if anything – even more minimal

Insights: So Why Are the Energy Efficiency/Conservation Results so Modest?

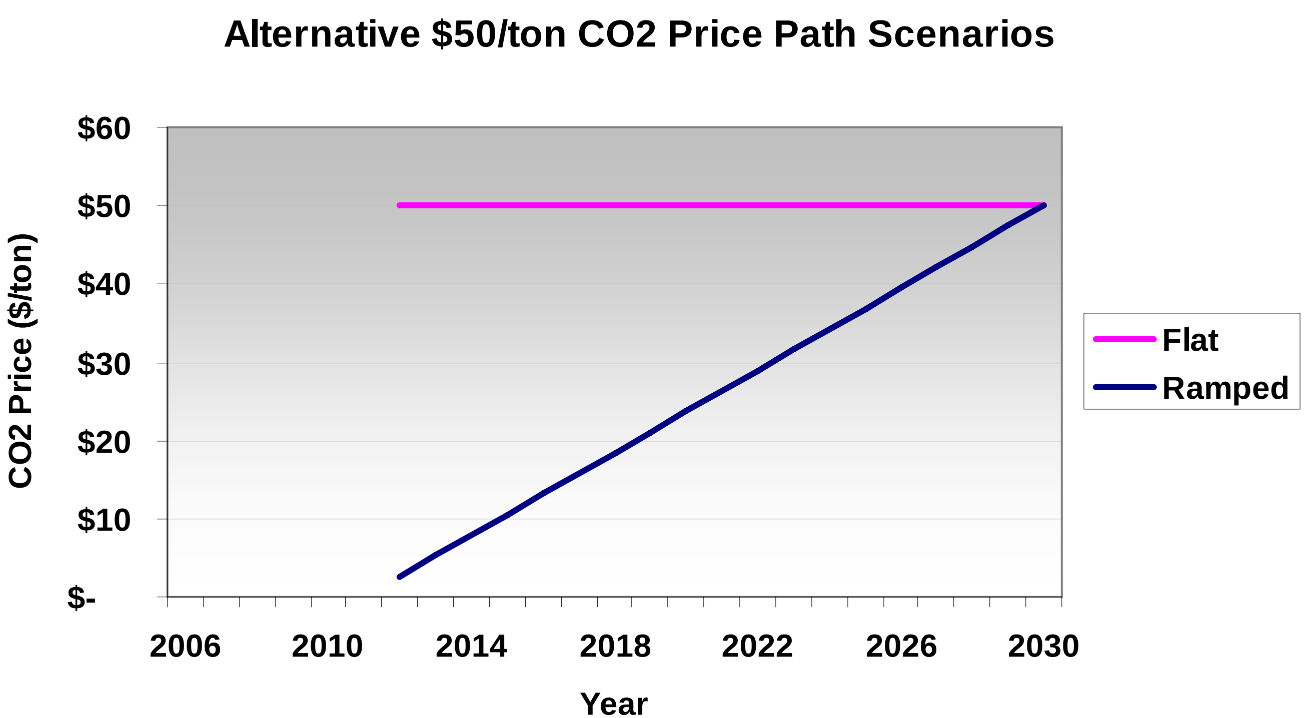
- With zero CO_2 price effects on emissions and prices are modest because marginal generation source is gas w. low emission rates
- With $85 CO_2 price effects are also modest as gas is still the marginal generation source
- Some of the impact of the impact of EE/Conservation programs on loads is offset by fewer opportunities for price response by customers

Flat vs. Ramped CO_2 Price Paths

- The approach in this study so far has been to model CO_2 price at a flat annual level over the entire analysis period (2012-2030)
- Approach designed to reveal electric system's response to a CO_2 price rather than suggest any particular policy protocol
- Result is severe power price increases in first year (2012) at higher CO_2 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 CO_2 scenarios

CO_2 Price Path Sensitivity Analysis Structure

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



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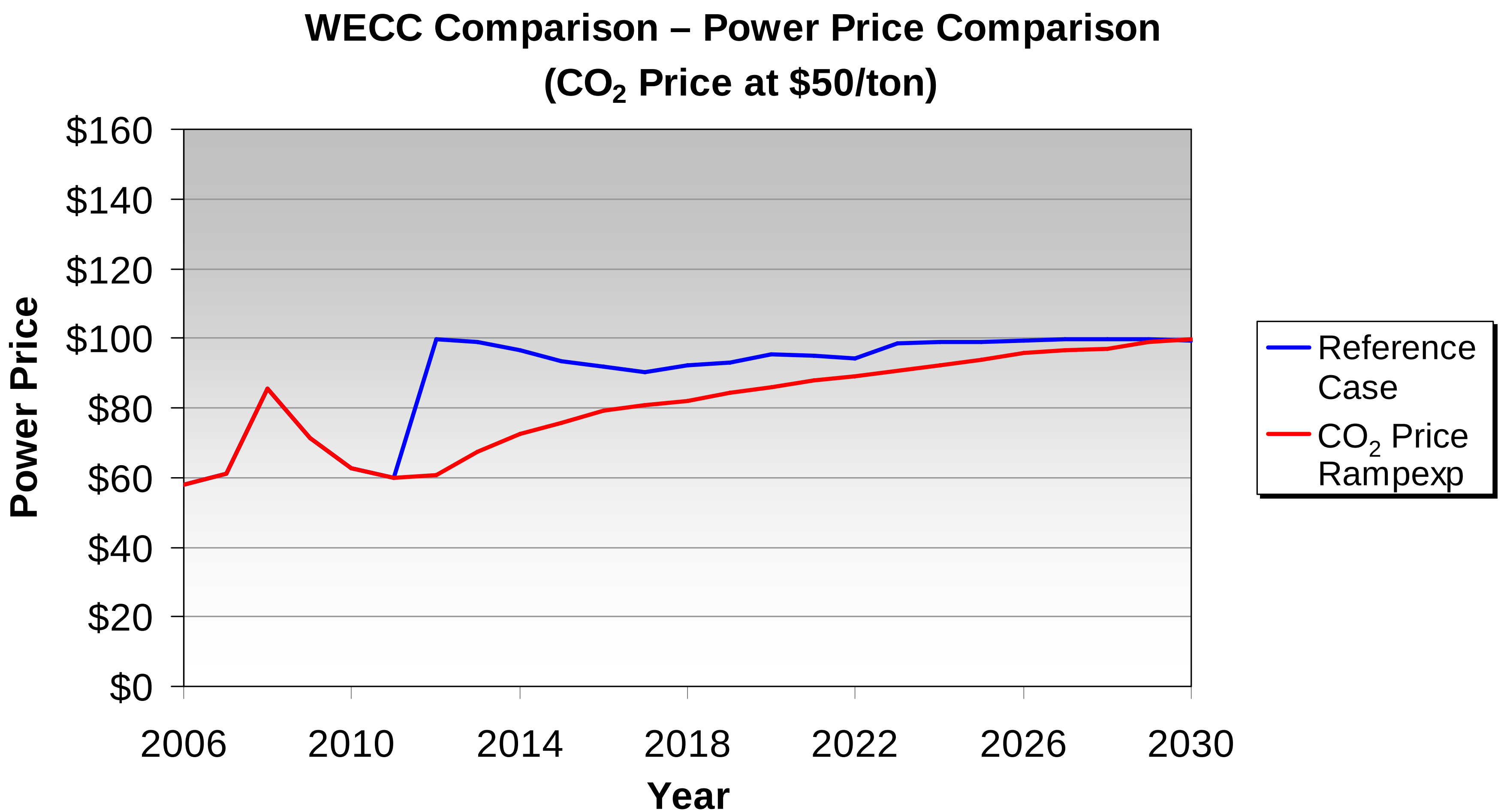
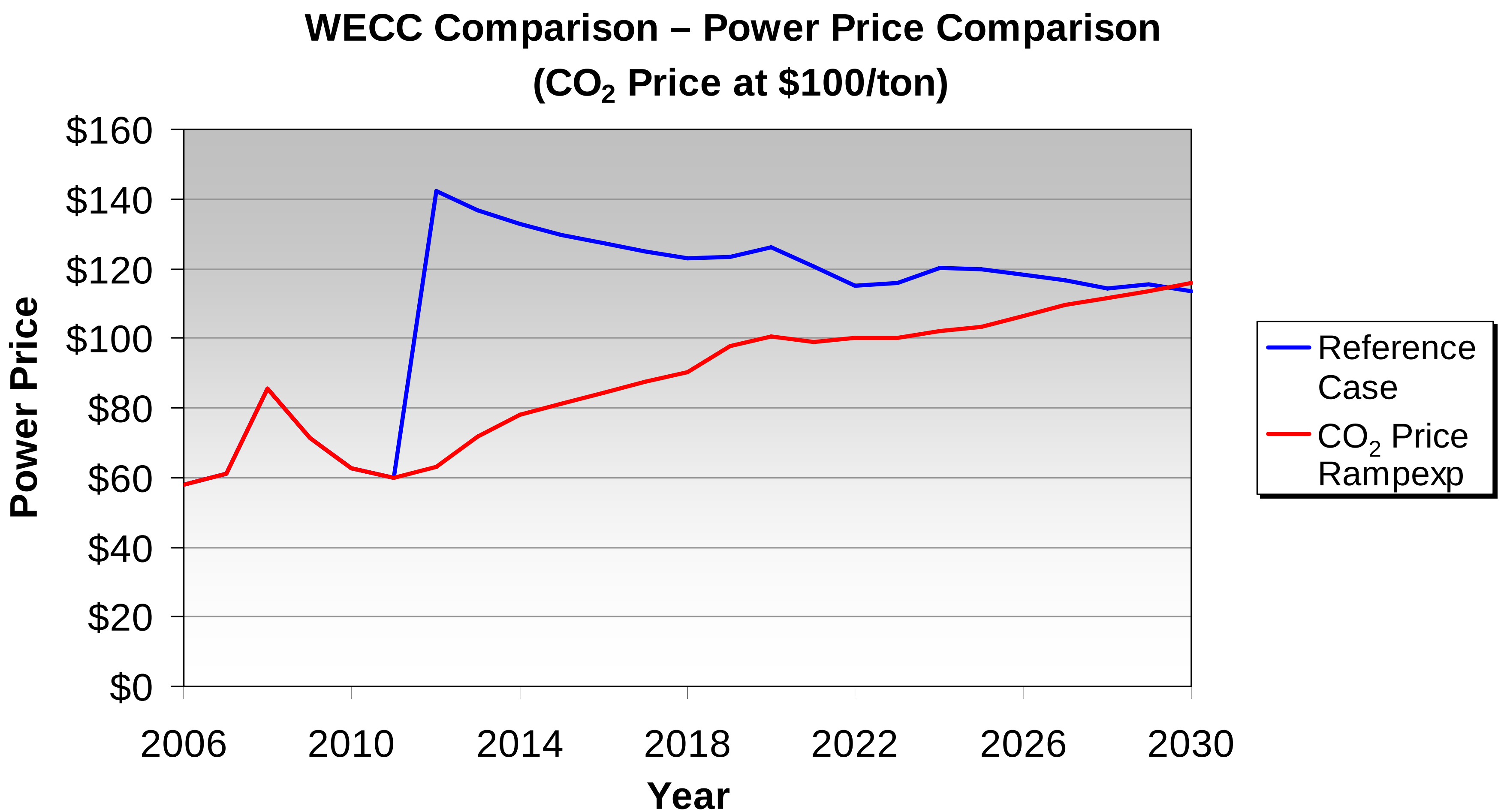
Wholesale Power Price Comparison



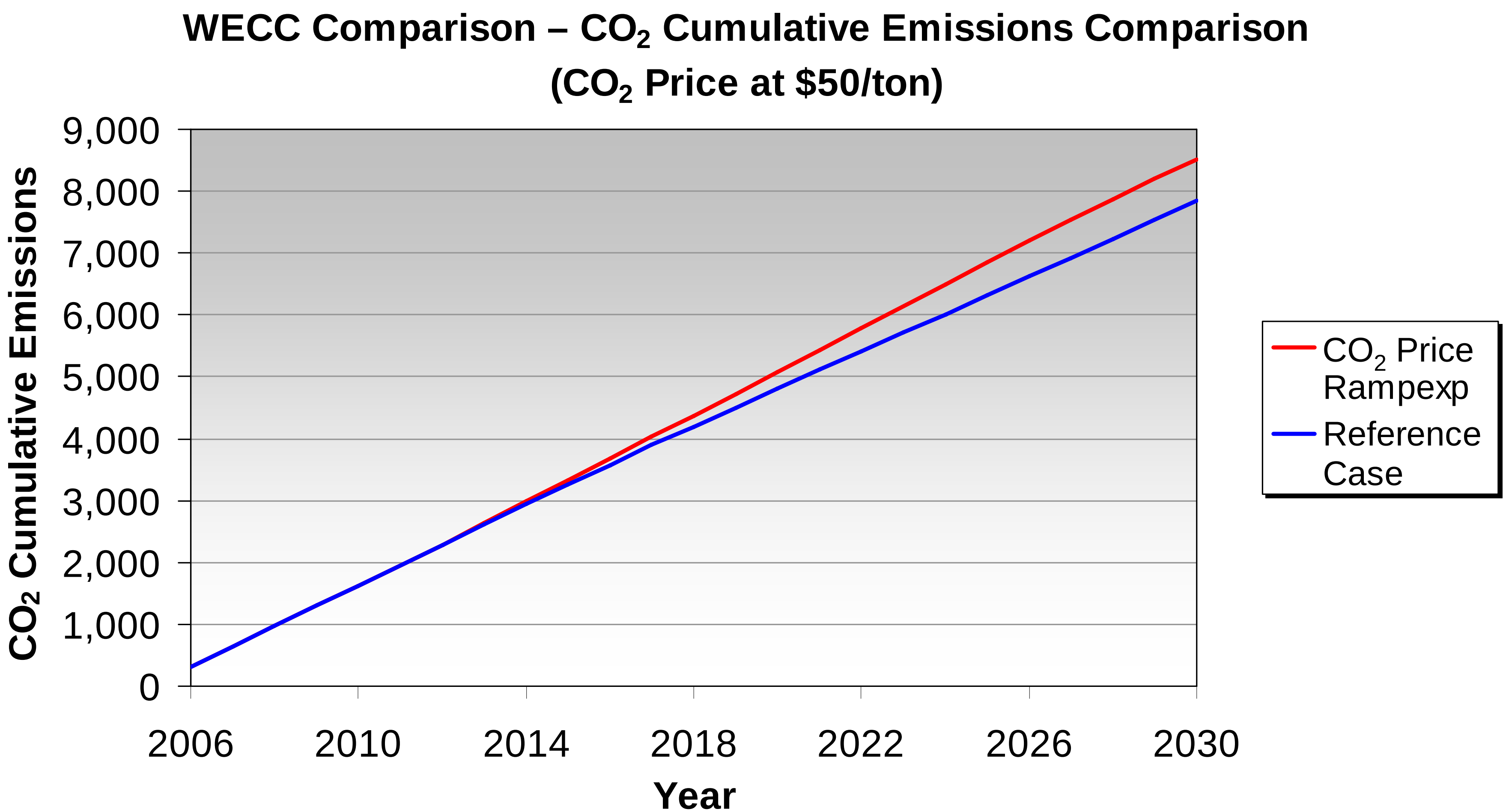
- The power price effects are considerably damped...

Wholesale Power Price Comparison



- The power price impacts are even more mitigated...

Cumulative (through 2030) Emissions Comparison



- …but cumulative emissions are almost 1 billion tons higher by 2030

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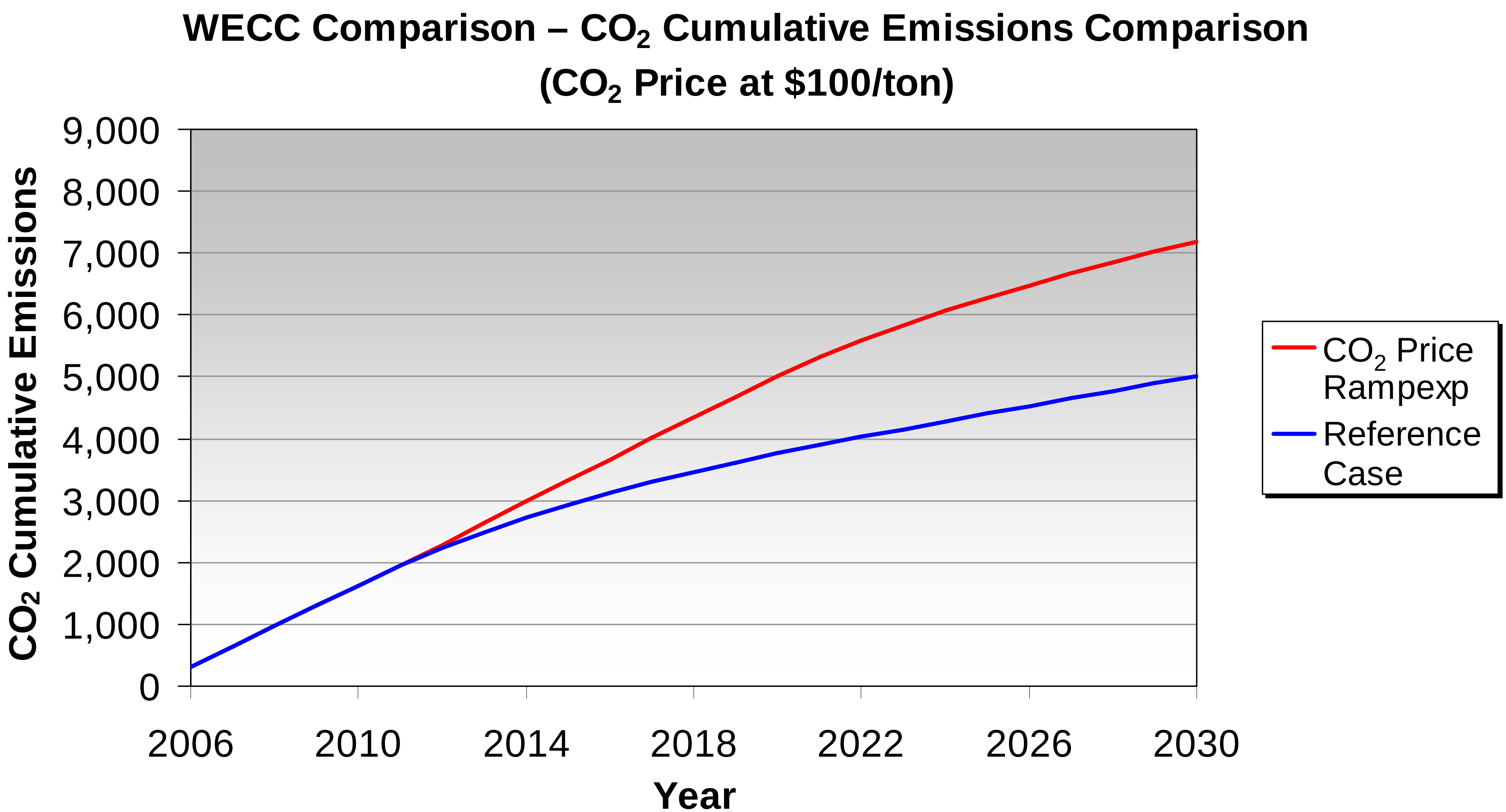
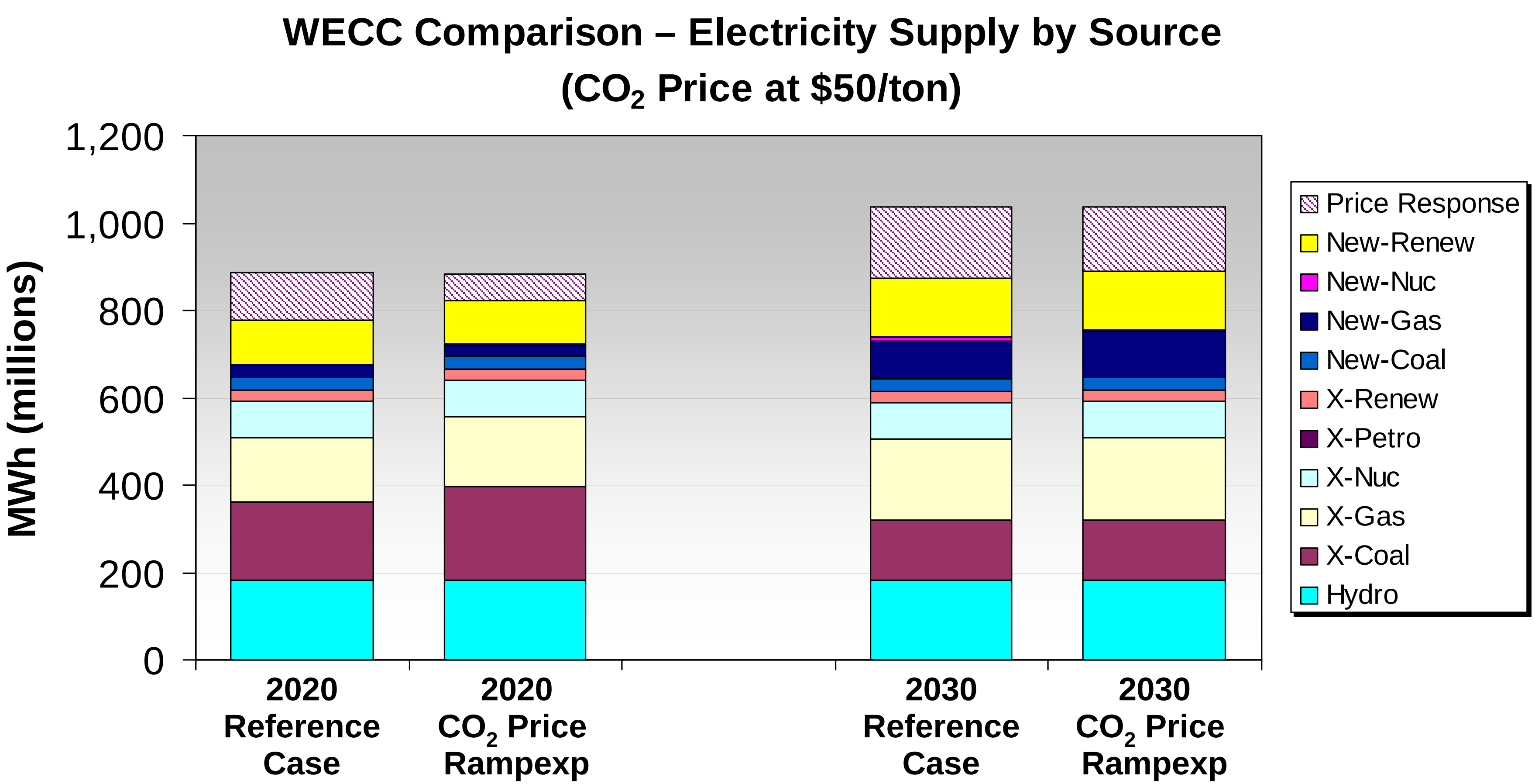
Cumulative (through 2030) Emissions Comparison



- …and now the cost in cumulative emissions is closer to 2 billion tons

Generation Mix Comparison – $50 CO_2 Price



- At lower CO_2 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

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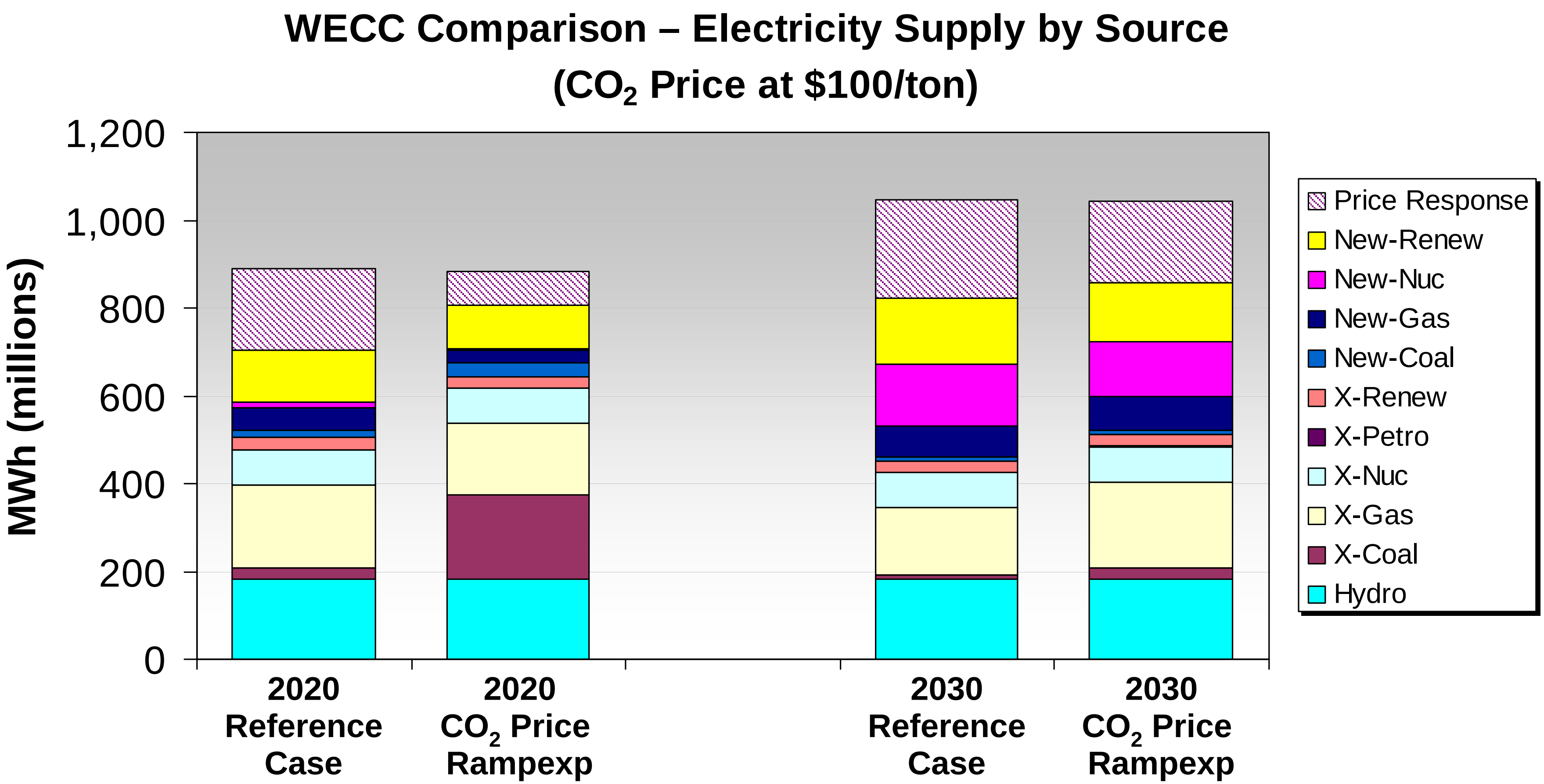
Generation Mix Comparison – $100 CO_2 Price



- At higher CO_2 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

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What Level of Ramped CO_2 Price is Equivalent to a Given Level of Flat Price Imposition?

- Clearly the flat CO_2 policy outperforms the ramped approach in reducing emissions
- As the 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 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 CO_2 emissions below historic benchmarks
  - $50 CO_2 price stabilizes emissions (retail price +45% in 2012, +15% in 2030)
  - $75-$100 CO_2 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 CO_2 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

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