Modeling GHG Emission Reduction Policies in Support of AB32 Using ENERGY 2020

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Outline of Presentation

1. Project Overview
2. Model & Data Sources
3. What’s Changed?
4. Reference Projection
5. Policies Modeled
6. Policy Modeling Results
Project Overview

Goal:
- Provide the ARB with the modeling capability to analyze policy options for reducing greenhouse gas emissions across all sectors of the California economy. This capability is required for the ARB to fulfill its legislative mandate under AB 32, which requires that the ARB implement a program that reduces the State’s GHG emissions to 1990 levels by 2020.

Key Tasks
- Update Reference Case to reflect recent economic downturn
- Incorporate current/approved Model policies specified by the ARB
- Model impacts of key Complementary Policies and potential Cap-and-Trade configurations
- Model Sensitivity Cases
ENERGY 2020
Model Overview and Data Sources
Overview of ENERGY 2020

- Integrated model of North American economy, energy and emissions, which includes:
  - All U.S. States and Canadian Provinces (model for California limited to WECC jurisdictions).
  - Disaggregated energy demand by end-use by sector.
  - Energy supply for electricity, oil, gas, coal, and renewables.
- Models each type of air emission:
  - Greenhouse Gas (CO2, N2O, CH4, SF6, HFC, PFC)
Model Structure & Relationships

ENERGY 2020

CAC and GHG Emissions

DEMAND
- Residential
- Commercial
- Industrial
- Transportation

SUPPLY
- Electric Utility/IPP's
- Gas Supply
- Oil Supply
- Coal Supply
- International Supply
- International Trade

Demand
Prices
Policy Costs: (investments, permits, taxes...)

Gross Investments
Gross Output
Utilization
Tax Rates, Inflation
Interest Rates

MACROECONOMIC MODEL (EDRAM)

Financials

Tax Rates
Inflation
Interest Rates
Information Exchange between Models

EDRAM
- GSP, GDP
- Gross Output
- Investments
- Personal Income
- Employment
- Population
- Interest Rates

Energy Output, Financial Conditions

Energy 2020
- Sectoral Energy Use
- Technology Choices
- Sectoral GHG Emissions
- Energy Prices
- Energy supply and demand investments

Energy Investment, Tax Revenues
Modeling Principles

- Key Decisions are Endogenous
- Based on Stocks and Flows
- Simulates decisions at the margin (not average)
- Causality vs. Correlation
- Actual vs. Optimal Decisions
- Dynamically describes the behavior of both energy suppliers and consumers for all fuels and for all end-uses
Experience with ENERGY 2020

- Over 30 years of experience analyzing energy policy.
- Model has been used to simulate impacts of electric system deregulation, model Integrated Resource Plans (IRP’s), and model energy and climate plans.
- Climate change policies modeled for several US states and Canadian provinces and Environment Canada.
- Currently being applied to model the impacts of the cap-and-trade program proposed by the Western Climate Initiative (WCI).
## Sources for Key Inputs

<table>
<thead>
<tr>
<th>Input Category</th>
<th>Data for California</th>
<th>Data for Other West</th>
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<tbody>
<tr>
<td><strong>Population and Macroeconomic Data</strong></td>
<td>California State Sources</td>
<td>Census EIA, BEA</td>
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<tr>
<td>Fuel Prices</td>
<td>CA state sources E3 for electric sector EIA for other</td>
<td>EIA</td>
</tr>
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<td>Energy Use and Consumption</td>
<td>CEC/ARB GHG Inventory</td>
<td>EIA State Energy Consumption, Price, and Expenditure Estimates (SEDS)</td>
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<td>Emissions</td>
<td>CEC/ARB GHG Inventory</td>
<td>EPA</td>
</tr>
<tr>
<td>Electricity Generation Capacity and Operational Data</td>
<td>FERC and NERC CPUC GHG Modeling process</td>
<td></td>
</tr>
</tbody>
</table>
What’s Changed?
Review of Model Updates

- Updated macroeconomic forecast to include economic downturn.
- Updated energy price forecast to use more recent AEO 2009 projection (see next slide).
- Review of planned and committed power plants, complementary policies modeling assumptions and power imports.
- Added RPS requirements for each US state and renewable targets for Canadian provinces.
Updated Energy Price Forecast (AEO 2009)

- Projected increase in oil prices is higher than 2007 AEO forecast used in 2008 modeling.

Change in Fuel Price Projections
2008 Modeling vs AEO 2009 REV

Motor Gasoline
AEO 2009

Diesel
AEO 2009

Motor Gasoline CA
2008 Modeling

Diesel CA
2008 Modeling

Modeling carried out in 2008 based on AEO 2007 Reference Projection of energy prices.
Reference Projection
Reference Projection

Key policies and assumptions included:

- AEO 2009 Reference Price forecast
- Economic forecast includes downturn
- Low Carbon Fuel Standard for California (10% reduction in carbon content by 2020)
- Pavley Vehicle Standard for California (35.5 mpg by 2016)
- 2007 EISA requirements for other states
  - CAFÉ provisions (new vehicles average 35.5 mpg by 2020).
  - Biofuels mandate
- RPS:
  - California - 20% of electricity sales from renewables.
  - All other jurisdictions meet their State/Provincial targets.
Summary of Reference Case

- Economic output and emissions in 2020 lower than in modeling completed last year.
- Growth in Gross Output averaged 3.1% growth (2007 to 2020) in prior Reference Case compared to 2.7% in updated 2009 model.
- Total emissions for CA approximately 492 Mt CO2e in 2020 (including emissions associated with power imports).
- Limited emissions growth (~10 Mt) between 2006 and 2020.
- Graphs which follow show pattern of change & emissions by source/sector in new Reference Case.
Total secondary energy use increases by 0.1% per year to 2020.
Passenger transportation and industry energy use decline slightly while other sectors see modest growth (all less than 1% except freight).
## Reference Case - Electricity

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>85,684</td>
<td>84,905</td>
<td>88,362</td>
<td>93,265</td>
<td>0.6%</td>
</tr>
<tr>
<td>Commercial</td>
<td>114,324</td>
<td>107,852</td>
<td>110,728</td>
<td>120,057</td>
<td>0.4%</td>
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<tr>
<td>Industrial</td>
<td>61,523</td>
<td>55,760</td>
<td>55,663</td>
<td>55,506</td>
<td>-0.7%</td>
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<tr>
<td>Transportation</td>
<td>2,613</td>
<td>3,068</td>
<td>3,115</td>
<td>3,162</td>
<td>1.4%</td>
</tr>
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<td>Street/Misc</td>
<td>6,073</td>
<td>6,073</td>
<td>6,073</td>
<td>6,073</td>
<td>0.0%</td>
</tr>
<tr>
<td>Resale</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>#N/A</td>
</tr>
<tr>
<td>Total</td>
<td>270,216</td>
<td>254,773</td>
<td>263,941</td>
<td>278,063</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

- Electricity sales decline in 2009 to 2011 period then continue growth.
- Total electricity sales increase by average of 0.2% per year to 2020.
## Reference Projection – Power Sector

<table>
<thead>
<tr>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas/Oil</td>
<td>83,708</td>
<td>64,498</td>
<td>54,650</td>
<td>50,937</td>
<td>-3.5%</td>
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<tr>
<td>Coal</td>
<td>2,946</td>
<td>2,367</td>
<td>2,341</td>
<td>2,367</td>
<td>-1.6%</td>
</tr>
<tr>
<td>Nuclear</td>
<td>31,560</td>
<td>31,560</td>
<td>31,560</td>
<td>31,560</td>
<td>0.0%</td>
</tr>
<tr>
<td>Hydro</td>
<td>48,114</td>
<td>48,140</td>
<td>48,199</td>
<td>48,199</td>
<td>0.0%</td>
</tr>
<tr>
<td>Biomass</td>
<td>5,674</td>
<td>5,844</td>
<td>6,013</td>
<td>6,312</td>
<td>0.8%</td>
</tr>
<tr>
<td>Wind</td>
<td>4,818</td>
<td>5,973</td>
<td>7,101</td>
<td>8,979</td>
<td>4.5%</td>
</tr>
<tr>
<td>Other Renewable</td>
<td>13,584</td>
<td>14,855</td>
<td>16,127</td>
<td>18,247</td>
<td>2.1%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>190,405</strong></td>
<td><strong>173,238</strong></td>
<td><strong>165,990</strong></td>
<td><strong>166,601</strong></td>
<td><strong>-0.9%</strong></td>
</tr>
</tbody>
</table>

- Wind and renewables increase to meet RPS requirements.
- Fossil generation (gas/oil/coal) decline from about 45% of in-state generation in 2006 to 32% in 2020.
- Imports increase over period from 30% of sales to about 40% by 2020.
Reference Projection – Transportation

### Marginal Vehicle Efficiency (miles/gallon)

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Light Gasoline</td>
<td>24.2</td>
<td>32.4</td>
<td>38.9</td>
<td>42.6</td>
<td>4.1%</td>
</tr>
<tr>
<td>Medium Gasoline</td>
<td>24.2</td>
<td>32.4</td>
<td>38.9</td>
<td>42.6</td>
<td>4.1%</td>
</tr>
<tr>
<td>Heavy Gasoline</td>
<td>17.3</td>
<td>21.7</td>
<td>25.1</td>
<td>26.5</td>
<td>3.1%</td>
</tr>
<tr>
<td>Heavy Diesel</td>
<td>17.3</td>
<td>21.5</td>
<td>24.8</td>
<td>26.2</td>
<td>3.0%</td>
</tr>
<tr>
<td>Fleet Average</td>
<td>21.4</td>
<td>28.6</td>
<td>33.9</td>
<td>36.6</td>
<td>3.9%</td>
</tr>
</tbody>
</table>

### Renewable Shares

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Ethanol/Gasoline</td>
<td>3.8%</td>
<td>8.4%</td>
<td>11.7%</td>
<td>15.0%</td>
<td>11.3%</td>
</tr>
<tr>
<td>Biodiesel/Diesel</td>
<td>0.0%</td>
<td>9.5%</td>
<td>19.1%</td>
<td>35.0%</td>
<td>35.0%</td>
</tr>
</tbody>
</table>

- New vehicle efficiency increases to meet targets under Pavley (slightly exceeds target of 35.5 mpg by 2020).
- Ethanol and biodiesel increase as a share of total fuel to meet LCFS.
- Passenger VMT grows by about 2% per year.
- Freight VMT rises by 2.7% per year (2006 to 2020).
- Some shift to larger vehicles as efficiency improvement reduces cost of driving (~1% shift from 2006 to 2020 to larger vehicles).
Emissions increase in all sectors except energy intensive industry, passenger transportation and power sector.

Growth in ‘other industry’ sector related to non-energy emissions.
Reference Projection – GHG Emissions

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>27.9</td>
<td>29.0</td>
<td>30.2</td>
<td>31.6</td>
<td>0.9%</td>
</tr>
<tr>
<td>Commercial</td>
<td>14.1</td>
<td>15.3</td>
<td>16.0</td>
<td>16.7</td>
<td>1.3%</td>
</tr>
<tr>
<td>Energy Intensive</td>
<td>67.7</td>
<td>63.1</td>
<td>64.1</td>
<td>64.1</td>
<td>-0.4%</td>
</tr>
<tr>
<td>Other Industry</td>
<td>27.9</td>
<td>38.7</td>
<td>44.6</td>
<td>54.2</td>
<td>4.9%</td>
</tr>
<tr>
<td>Passenger</td>
<td>167.5</td>
<td>168.2</td>
<td>162.1</td>
<td>150.7</td>
<td>-0.8%</td>
</tr>
<tr>
<td>Freight</td>
<td>37.9</td>
<td>38.9</td>
<td>40.5</td>
<td>42.8</td>
<td>0.9%</td>
</tr>
<tr>
<td>Power Sector Including Imports</td>
<td>105.7</td>
<td>84.5</td>
<td>87.2</td>
<td>92.7</td>
<td>-0.9%</td>
</tr>
<tr>
<td>Waste</td>
<td>9.8</td>
<td>10.9</td>
<td>11.5</td>
<td>12.4</td>
<td>1.7%</td>
</tr>
<tr>
<td>Agriculture (non energy)</td>
<td>23.6</td>
<td>25.0</td>
<td>25.7</td>
<td>27.0</td>
<td>1.0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>482.1</strong></td>
<td><strong>473.6</strong></td>
<td><strong>481.9</strong></td>
<td><strong>492.3</strong></td>
<td><strong>0.1%</strong></td>
</tr>
</tbody>
</table>

Note – Power Sector includes emissions associated with imports

- Emissions from passenger transportation, energy intensive industry, and power sector decline. Commercial and other industry sectors see emissions increase.
- Total GHG emissions rise slightly (10 Mt) by 2020; growing on average by 0.1% per year.
Comparison to Other Projections:

Electricity demand projection shows similar growth to latest CEC staff projection, though starting point not aligned.

- CEC projection of Personal Income used in staff projection shows growth of roughly 21% from 2009 to 2018.
- Projection used for ENERGY 2020 shows similar (26%) growth.
Comparison with Other Projections
AEO 2009 (Pacific Region – not direct comparison with CA)
Policies Modeled
Complementary Policies Modeled

<table>
<thead>
<tr>
<th>Policy</th>
<th>Region</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavley Vehicle Standards II</td>
<td>California</td>
<td>• 42.5 mpg average new vehicle efficiency by 2020.</td>
</tr>
<tr>
<td>Renewable Portfolio Standard (now Renewable</td>
<td>California specific</td>
<td>• RPS increased from 20% of electricity sales supplied from renewable resources to 33%.</td>
</tr>
<tr>
<td>Electricity Standard)</td>
<td>increase</td>
<td>• New resource additions based on projected resource mix from CEC.</td>
</tr>
<tr>
<td>Energy efficiency</td>
<td>California</td>
<td>• 10% in electricity use in 2020 or about a 1% per year reduction in electricity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>consumption.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 4% of projected natural gas use in 2020.</td>
</tr>
<tr>
<td>Combined Heat and Power</td>
<td>California</td>
<td>• Increase CHP use by 30,000 GWh</td>
</tr>
</tbody>
</table>
## Complementary Policies Modeled

<table>
<thead>
<tr>
<th>Policy</th>
<th>Region</th>
<th>Goal</th>
</tr>
</thead>
<tbody>
<tr>
<td>VMT Reduction Measure</td>
<td>CA Only</td>
<td>VMT decrease of 4% from Reference Case levels by 2020</td>
</tr>
<tr>
<td>Other Transportation and</td>
<td>CA Only</td>
<td>Heavy-duty vehicle efficiency and ship use of off-shore power. Total reduction &lt;2 MMT</td>
</tr>
<tr>
<td>Goods Movement Policies</td>
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</tr>
</tbody>
</table>
Policies Modeled – Cap & Trade

- **Region**
  - California

- **Covered GHG Pollutants**
  - CO2, CH4, N2O, SF6, PFC, and HFC

- **2020 Goal**
  - 14% below 2006 base emissions (Target of 427 MMT in 2020)

- **Covered Sectors:**
  - 2012-2014 - Narrow Scope:
    - Electricity and Industrials emitting >25,000 tCO2e
  - 2015-2020 - Broad Scope
    - Narrow Scope plus transportation fuels, commercial and residential fuels and small industrial.

*Note* - Consistent with WCI Phase 3 Main Cap and Trade Case
Policies Modeled – Cap & Trade

- **Banking**
  - Allowed without limitation

- **Allowance Allocation** for Electricity generation (two cases)
  - 100% Auction
  - 0% Auction

- **Offsets** - Two cases
  (based on 100% auction scenario)
  1. No offsets
  2. Offsets at approximately $20 per tonne for up to 49% of reduction from initial cap levels.
### Policies Modeled – Summary

<table>
<thead>
<tr>
<th>No.</th>
<th>Scenario Name</th>
<th>Allocation (% gratis reduction)</th>
<th>Offsets (as % of reduction)</th>
<th>Complementary Policies</th>
<th>VMT</th>
<th>Pavley II</th>
<th>CHP</th>
<th>EE</th>
<th>RPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S0_CT01 No Auction with offsets</td>
<td>100%</td>
<td>49%</td>
<td>-4%</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>33%</td>
</tr>
<tr>
<td>2</td>
<td>S0_CT02 No Auction/no offsets</td>
<td>100%</td>
<td>0%</td>
<td>-4%</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>33%</td>
</tr>
<tr>
<td>3</td>
<td>S0_CT03 Auction with offsets</td>
<td>0%</td>
<td>49%</td>
<td>-4%</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>33%</td>
</tr>
<tr>
<td>4</td>
<td>S0_CT04 Auction/no offsets</td>
<td>0%</td>
<td>0%</td>
<td>-4%</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>33%</td>
</tr>
<tr>
<td>5</td>
<td>S1_CT01 Lower Transport CP</td>
<td>100%</td>
<td>49%</td>
<td>0%</td>
<td>50%</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
<td>33%</td>
</tr>
<tr>
<td>6</td>
<td>S2_CT01 Less Efficiency</td>
<td>100%</td>
<td>49%</td>
<td>-4%</td>
<td>Y</td>
<td>50%</td>
<td>50%</td>
<td>20%</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>S3_CT01 Less Trans &amp; Efficiency</td>
<td>100%</td>
<td>49%</td>
<td>0%</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
<td>20%</td>
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</tr>
</tbody>
</table>

- Modeled four Cap-and-Trade configurations and three sensitivity cases.
Policy Modeling Results
Policy Modeling Results: C&T 100% Allocation (Gratis)/No Offsets

Change from the Reference Case in 2020:

- Secondary energy use declines by over 7%, with all sectors showing a decrease from Reference levels.
- Passenger transportation energy use declines by ~6%.
- Electricity sales decline by almost 18% due to increases in self-generation and energy efficiency.
- In-state generation plus imports meet 33% RPS/RES goal.
- Allowance prices rise to $37/tonne by 2020.
- GHG emissions fall by about 60 Mt CO2e by 2020, or over 14%, relative to Reference Case.
Policy Modeling Results:
C&T 100% Allocation (Gratis)/No Offsets

- Electricity prices for rise by about 3%.
- Energy prices rise by 20% for natural gas, 14-16% for fuel oil and 9-12% for transportation fuels as carbon costs are added.
- Fuel expenditures decline for all sectors as efficiency gains exceed energy price increases.
- Average energy expenditures, across all sectors, decline by about 9% in real terms.
Policy Modeling Results:
C&T 100% Allocation (Gratis) with Offsets

Change from the Reference Case in 2020:

- Allowance prices rise to $21/tonne by 2020.
- Secondary energy use declines by 6.5% (slightly less than in case with no offsets).
- Electricity sales decline by almost 19%.
- Electricity & fuel price increases lower than in case with no offsets (reflecting lower carbon price).
- GHG emissions fall by over 67 Mt CO2e by 2020, or over 13%, relative to Reference Case.
- Availability of offsets/lower carbon price results in somewhat lower efficiency gains and GHG emission reductions from capped sources.
Policy Modeling Results: GHG Emissions

California GHG Emissions Minus Offsets

- Reference
- No Auction with offsets

GHG Emissions (CO2e)

GHG Emissions m

- Auction/no offsets
- Smaller Transportation Efficiency Gains
- Smaller Efficiency Gains
- Smaller Transportation & Efficiency Gains

**Policy Modeling Results: Summary**

<table>
<thead>
<tr>
<th>No.</th>
<th>Scenario Results for 2020</th>
<th>GHG Emissions (Mt CO2e)</th>
<th>Change from RC (Mt CO2e)</th>
<th>Offsets Used (Mt CO2e)</th>
<th>Emissions net of Offsets (Mt CO2e)</th>
<th>2020 Bank Inventory (Mt CO2e)</th>
<th>Allowance Price (2007$/tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No Auction with offsets</td>
<td>430</td>
<td>68</td>
<td>13</td>
<td>417</td>
<td>5</td>
<td>$21</td>
</tr>
<tr>
<td>2</td>
<td>No Auction/no offsets</td>
<td>426</td>
<td>71</td>
<td>-</td>
<td>426</td>
<td>16</td>
<td>$37</td>
</tr>
<tr>
<td>3</td>
<td>Auction with offsets</td>
<td>430</td>
<td>67</td>
<td>10</td>
<td>420</td>
<td>21</td>
<td>$19</td>
</tr>
<tr>
<td>4</td>
<td>Auction/no offsets</td>
<td>428</td>
<td>69</td>
<td>-</td>
<td>428</td>
<td>12</td>
<td>$34</td>
</tr>
<tr>
<td>5</td>
<td>Smaller Transportation Efficiency Gains</td>
<td>436</td>
<td>61</td>
<td>15</td>
<td>421</td>
<td>19</td>
<td>$20</td>
</tr>
<tr>
<td>6</td>
<td>Smaller Efficiency Gains</td>
<td>453</td>
<td>44</td>
<td>27</td>
<td>426</td>
<td>1</td>
<td>$59</td>
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<tr>
<td>7</td>
<td>Smaller Transportation &amp; Efficiency Gains</td>
<td>457</td>
<td>40</td>
<td>31</td>
<td>426</td>
<td>0</td>
<td>$83</td>
</tr>
</tbody>
</table>

- GHG emissions minus offsets fall to or below State target in all cases.
- Allowance prices approximately 80% higher in cases without offsets.
- On-going banking results in some inventory at end of period. Generally highest in cases with lower allowance price.
- Less effective complementary policies result in higher allowance price, greater offset use, and lower GHG reductions.
Policy Modeling Results: Allowance Prices

California Allowance Costs

- No Auction with offsets
- No Auction/no offsets
- Auction with offsets
- Auction/no offsets
- Smaller Transportation Efficiency Gains
- Smaller Efficiency Gains
- Smaller Transportation & Efficiency Gains
## Policy Modeling Results: Summary

<table>
<thead>
<tr>
<th>No.</th>
<th>Scenario Name</th>
<th>Allowance Price (2007 $/Tonne)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No Auction with offsets</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>No Auction/no offsets</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>Auction with offsets</td>
<td>13</td>
</tr>
<tr>
<td>4</td>
<td>Auction/no offsets</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
<td>Smaller Transportation Efficiency Gains</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>Smaller Efficiency Gains</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>Smaller Transportation &amp; Efficiency Gains</td>
<td>11</td>
</tr>
</tbody>
</table>

- Allowance price approximately doubles over period in scenarios 1-4.
- Change in transportation efficiency and VMT have relatively minor impact on allowance price.
- Less energy efficiency results in higher allowance price, particularly in 2019 and 2020.
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