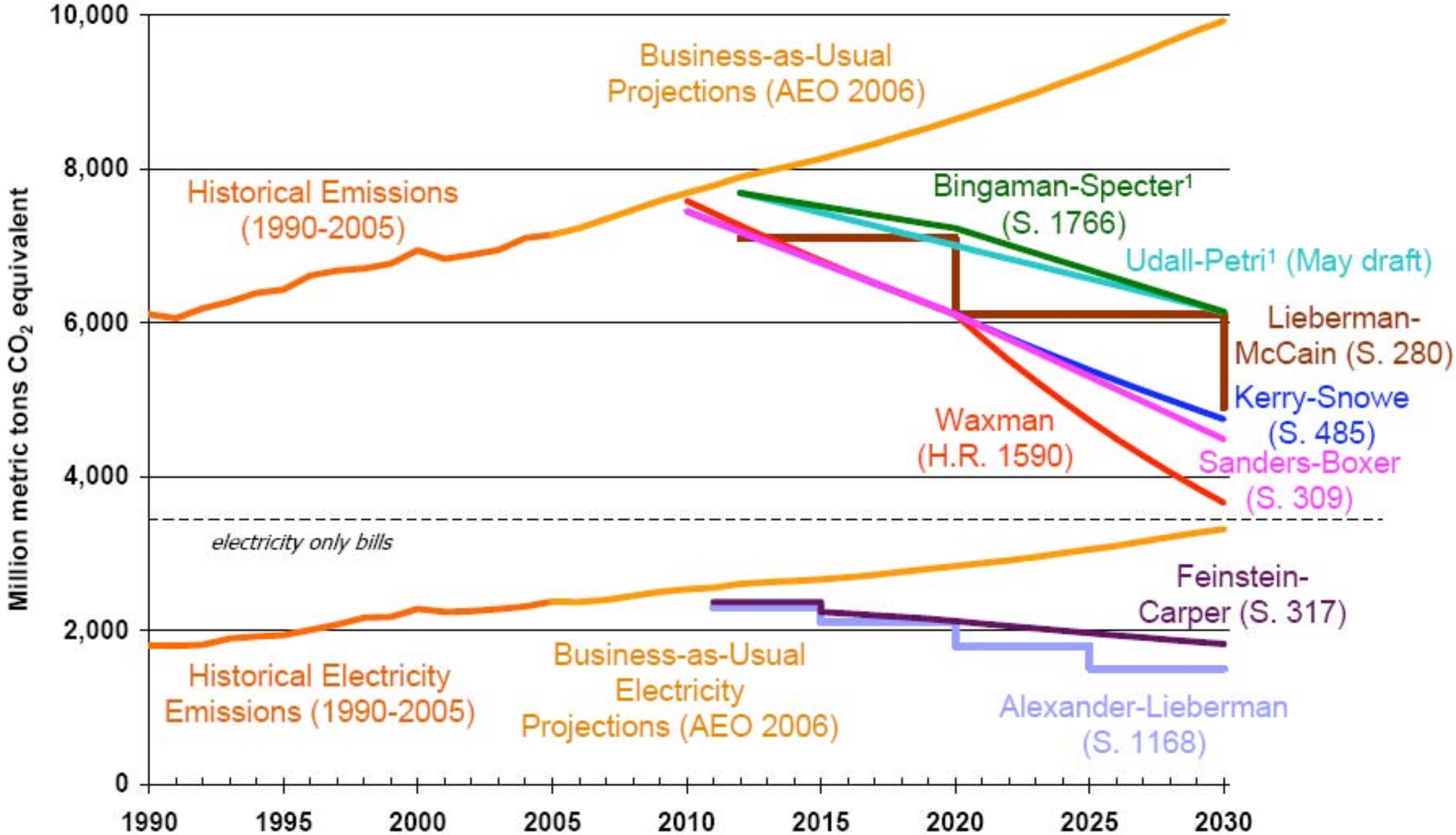
# Overview of the Economics of Climate Change

Billy Pizer

Presidential Management Forum on Global Climate Change

RESOURCES FOR THE FUTURE

# Comparison of Emissions Reduction Goals in Legislation in the 110th Congress (as of July 11, 2007)




RESOURCES FOR THE FUTURE

This graph depicts emissions targets from some of the major climate change bills in Congress. Targets are based on comparison with historical year emissions. Kerry-Snowe, Sanders-Boxer, and Waxman specify future emissions as a percentage of 1990 emissions. For Lieberman-McCain, Udall-Petri, and Bingaman-Specter, emissions targets for covered sectors are related to historical emissions for those sectors, and total emissions are assumed to match those in the corresponding historical year.

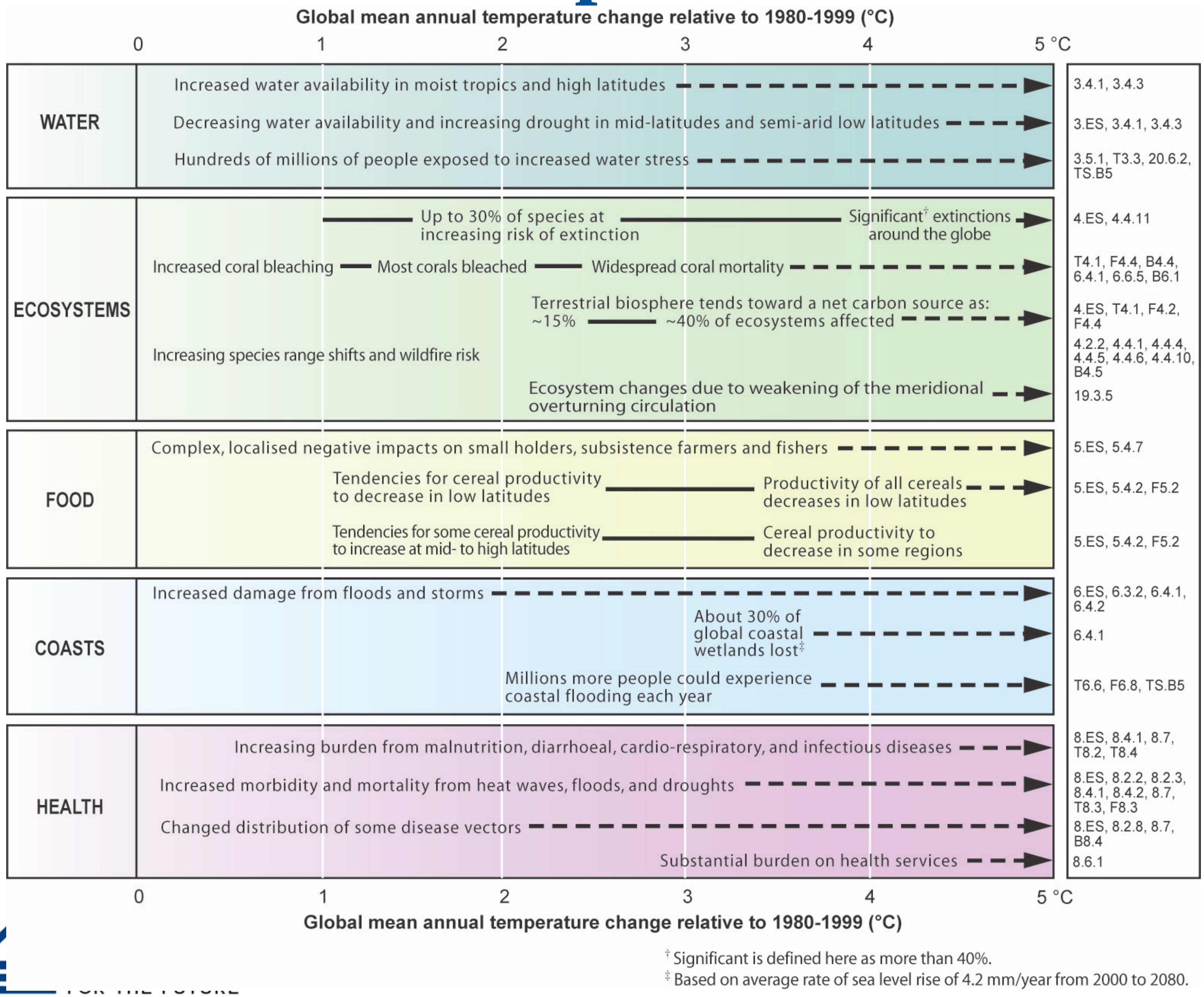
[1] Bill contains flexibility mechanisms which allow actual emissions to rise above the target.

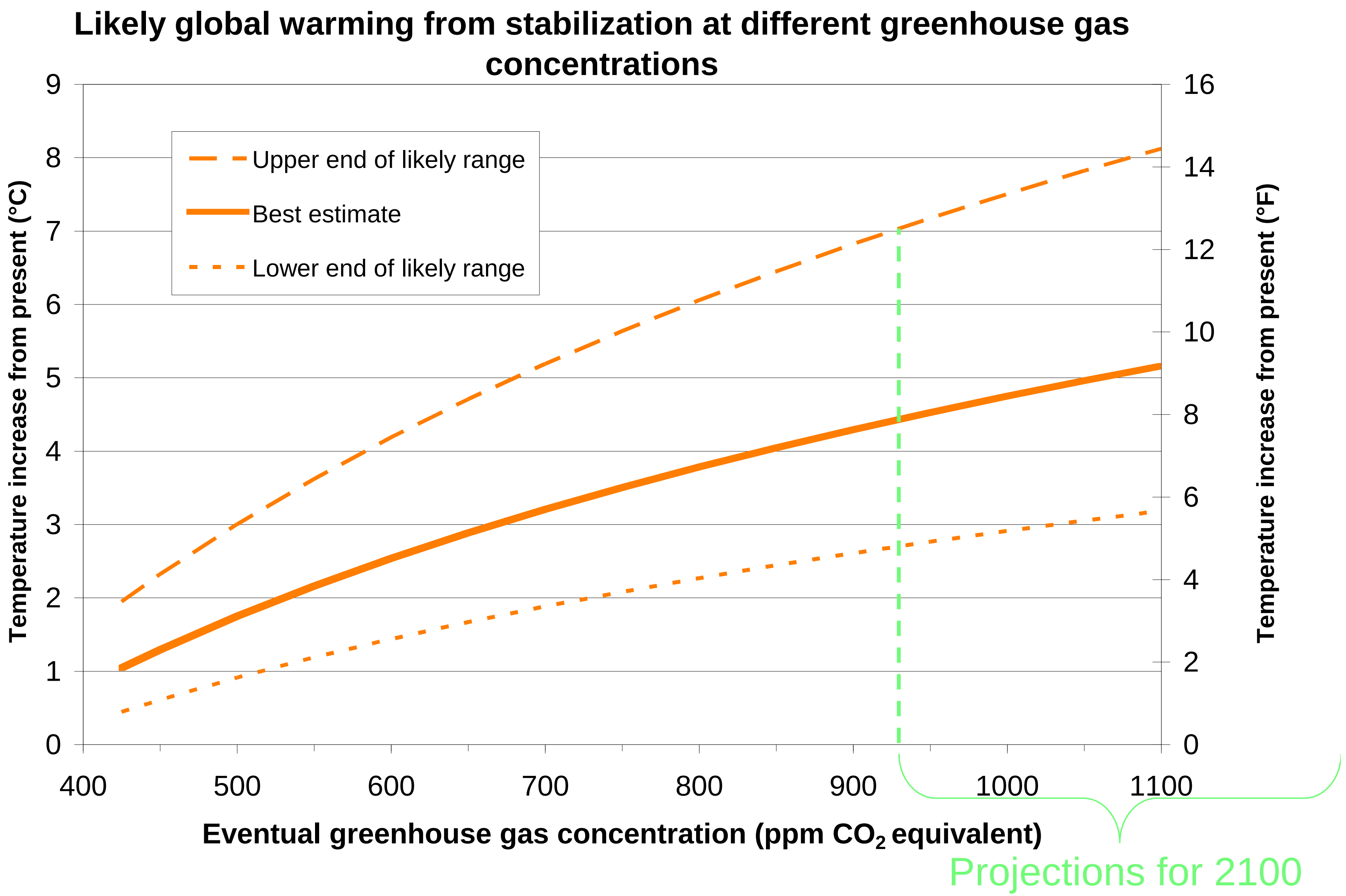
## Summary of Market-Based Climate Change Legislation Introduced in the 110th Congress

As of July 25, 2007

| | Who's Regulated | Allowance Allocation | Price Stability (Safety Valve & Borrowing) | Offsets | Technology |
|---|---|---|---|---|---|
| Bingaman-Specter (S. 1766) | Economy-wide emissions regulation: coal and process emissions at emitters; oil refiners, NG processors, and oil/NG importers; and F-gas producers and importers. | 55% grandfathered to industry (phased out over time). 22% auctioned to support technology, transition assistance, and adaptation. 14% set aside for CCS and sequestration. 9% to states. | \$12/metric ton $CO_2$ safety valve, rising at 5% per year above inflation. | Unlimited domestic offsets including methane and $SF_6$ reductions. Domestic agricultural sequestration offsets limited to 5% of cap. Use of international offsets limited to 10%. | Detailed technology development programs funded from allowance auction revenues (12% of allowances auctioned in 2012, steadily increased to 26% by 2043). |
| Udall-Petri (based on May draft and discussion with Udall-Petri staff) | Economy-wide emissions regulation: primarily upstream sources (e.g., producers and importers of fuels). | 20% grandfathered to industry. 80% auctioned to support RD&D, developing-country engagement, adaptation and dislocation aid, sequestration, and debt reduction. | \$12/metric ton $CO_2$ safety valve, rising at 2% above inflation in first 2 years, and 2%-8% thereafter. | Unlimited geological sequestration offsets. 5% of allowances set aside to fund biological sequestration and 1% for CCS projects. | Establishes Advanced Research Projects Agency-Energy to fund technology advancement and sequestration projects with 30% of allowances. |
| Lieberman-McCain (S. 280) | Economy-wide emissions regulation: large downstream at emitter; transport emissions regulated at refinery. | Some allowances given free to covered entities, others auctioned to fund transition assistance, adaptation measures, and technology support. Distribution at discretion of EPA. | Borrowing (with interest) – up to 25% of allowances, for no more than 5 years. | Up to 30% of obligation can be met with domestic sequestration projects and international offsets. | Revenues from some auctioned allowances used to finance advanced technology development, demonstration, and deployment. |
| Kerry-Snowe (S. 485) | Economy-wide emissions regulation: point of regulation at discretion of EPA Administrator. | Discretion of the President. | No provisions. | Secretary of Agriculture sets rules for domestic biological sequestration. | Each bill includes: vehicular emissions rules; energy efficiency & renewable standards for electric generation. All but Waxman have additional bill-specific mandates. |
| Waxman (H.R. 1590) | | | | No provisions. | |
| Sanders-Boxer (S. 309) | Economy-wide cap on U.S. emissions. Discretion to implement a market-based allowance program to achieve this cap is left to the EPA Administrator. | | | | |
| Feinstein-Carper (S. 317) | Electricity-sector emissions regulated at the power plant. (S. 1168 also regulates $SO_2$, $NO_X$, and mercury emissions from power plants.) | 85% grandfathered to industry, based on generation. Free allocation phased out by 2036. | Borrowing (with interest) – up to 10% of allowances, for no more than 5 years. | Up to 25% through int'l offsets; extensive domestic biological sequestration offsets. | Distributes auction revenues to multitude of technology programs. |
| Alexander-Lieberman (S. 1168) | | 75% grandfathered to industry, based on heat input. | No provisions. | Domestic offsets in five categories, including methane, $SF_6$, efficiency, and forest sequestration. | New source performance standard for $CO_2$ emissions from electric generation units. |
| Stark (H.R. 2069) | Economy-wide fossil fuel emissions regulated at the point of production. | Equivalent to 100% auction. (This legislation is an emissions tax.) Revenues to the general fund. | Tax on fuels of \$3/metric ton of $CO_2$ emissions, rising by \$3 each year. | Tax refunds for fuels used in processes which sequester carbons (e.g., CCS, or manufacture of plastics). | No provisions. |

# Impacts

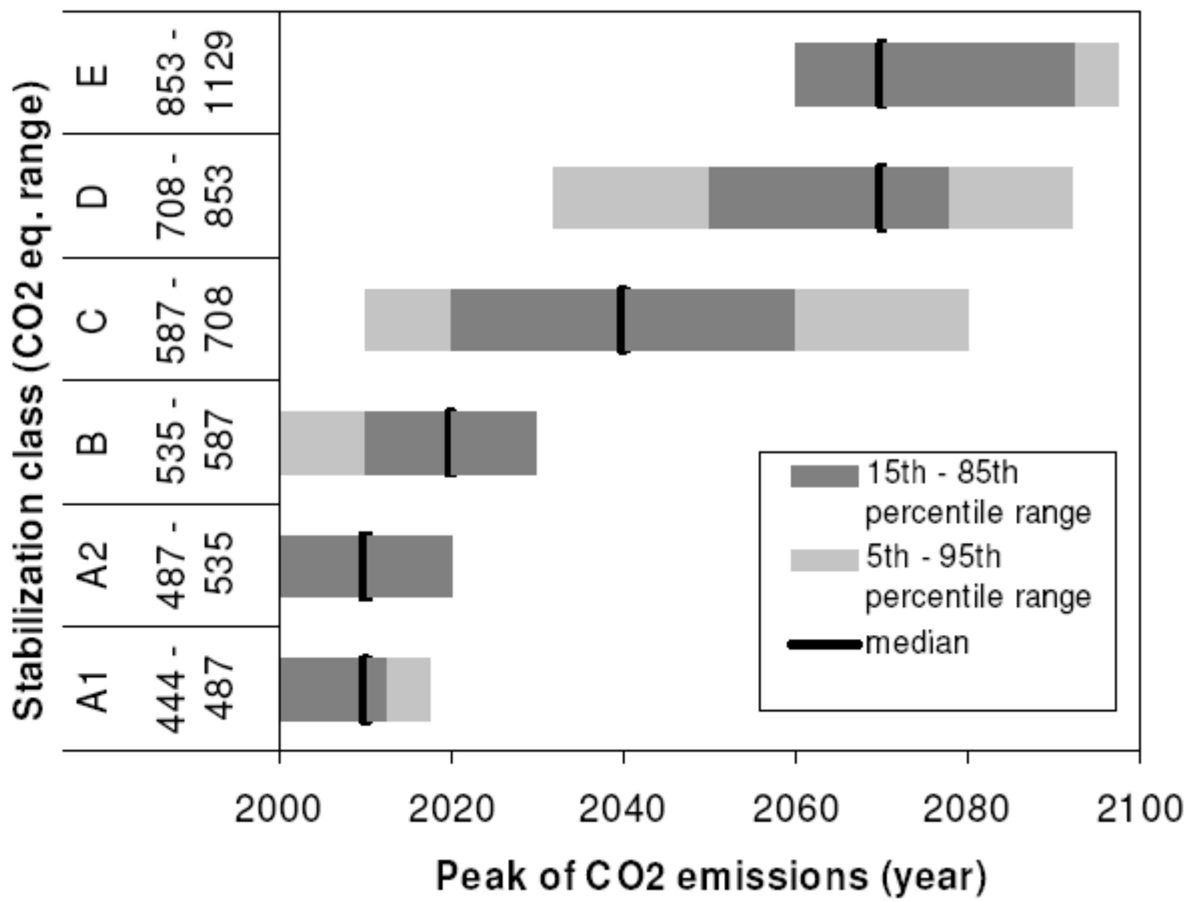

Global mean annual temperature change relative to 1980-1999 (°C)
0
1
2
3
4
5 °C
WATER
Increased water availability in moist tropics and high latitudes
3.4.1, 3.4.3
Decreasing water availability and increasing drought in mid-latitudes and semi-arid low latitudes
3.ES, 3.4.1, 3.4.3
Hundreds of millions of people exposed to increased water stress
3.5.1, T3.3, 20.6.2, TS.B5
ECOSYSTEMS
Up to 30% of species at increasing risk of extinction
Significant† extinctions around the globe
4.ES, 4.4.11
Increased coral bleaching
Most corals bleached
Widespread coral mortality
T4.1, F4.4, B4.4, 6.4.1, 6.6.5, B6.1
Terrestrial biosphere tends toward a net carbon source as:
~15%
~40% of ecosystems affected
4.ES, T4.1, F4.2, F4.4
Increasing species range shifts and wildfire risk
4.2.2, 4.4.1, 4.4.4, 4.4.5, 4.4.6, 4.4.10, B4.5
Ecosystem changes due to weakening of the meridional overturning circulation
19.3.5
FOOD
Complex, localised negative impacts on small holders, subsistence farmers and fishers
5.ES, 5.4.7
Tendencies for cereal productivity to decrease in low latitudes
Productivity of all cereals decreases in low latitudes
5.ES, 5.4.2, F5.2
Tendencies for some cereal productivity to increase at mid- to high latitudes
Cereal productivity to decrease in some regions
5.ES, 5.4.2, F5.2
COASTS
Increased damage from floods and storms
6.ES, 6.3.2, 6.4.1, 6.4.2
About 30% of global coastal wetlands lost‡
6.4.1
Millions more people could experience coastal flooding each year
T6.6, F6.8, TS.B5
HEALTH
Increasing burden from malnutrition, diarrhoeal, cardio-respiratory, and infectious diseases
8.ES, 8.4.1, 8.7, T8.2, T8.4
Increased morbidity and mortality from heat waves, floods, and droughts
8.ES, 8.2.2, 8.2.3, 8.4.1, 8.4.2, 8.7, T8.3, F8.3
Changed distribution of some disease vectors
8.ES, 8.2.8, 8.7, B8.4
Substantial burden on health services
8.6.1
0
1
2
3
4
5 °C
Global mean annual temperature change relative to 1980-1999 (°C)
† Significant is defined here as more than 40%.
‡ Based on average rate of sea level rise of 4.2 mm/year from 2000 to 2080.




Note: "Likely" is defined as greater than a 66% probability of occurrence. Source: IPCC Fourth Assessment Report.

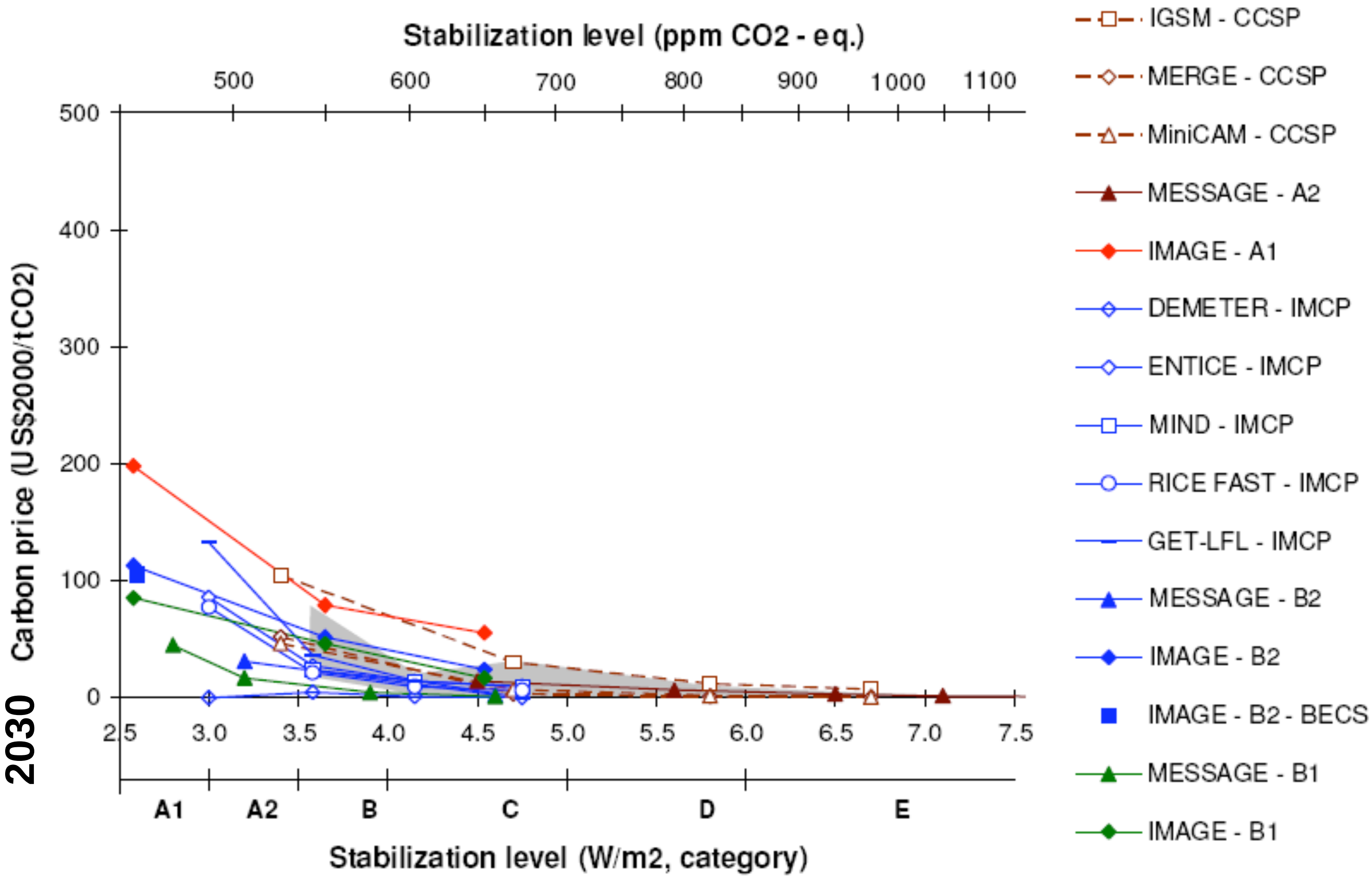
RESOURCES FOR THE FUTURE

# Key Feature: Peak Emissions




RESOURCES FOR THE FUTURE

# $CO_2$ Price




RESOURCES FOR THE FUTURE

# $CO_2$ prices?

| Yearly cost per tons of C02 equivalents | | Amount reduced (Gigatons) |
|---|---|---|
| **High** cost | **<$100** per ton | **16–31** Gt |
| **Medium** cost | **<$50** per ton | **13–26** Gt |
| **Low** cost | **< $20** per ton | **9–18** Gt |

## What It Means For Consumers

**49¢** more for a gallon of gasoline

**$52** more a month for electricity from a coal-fired utility

**$44** more a month for electricity from oil

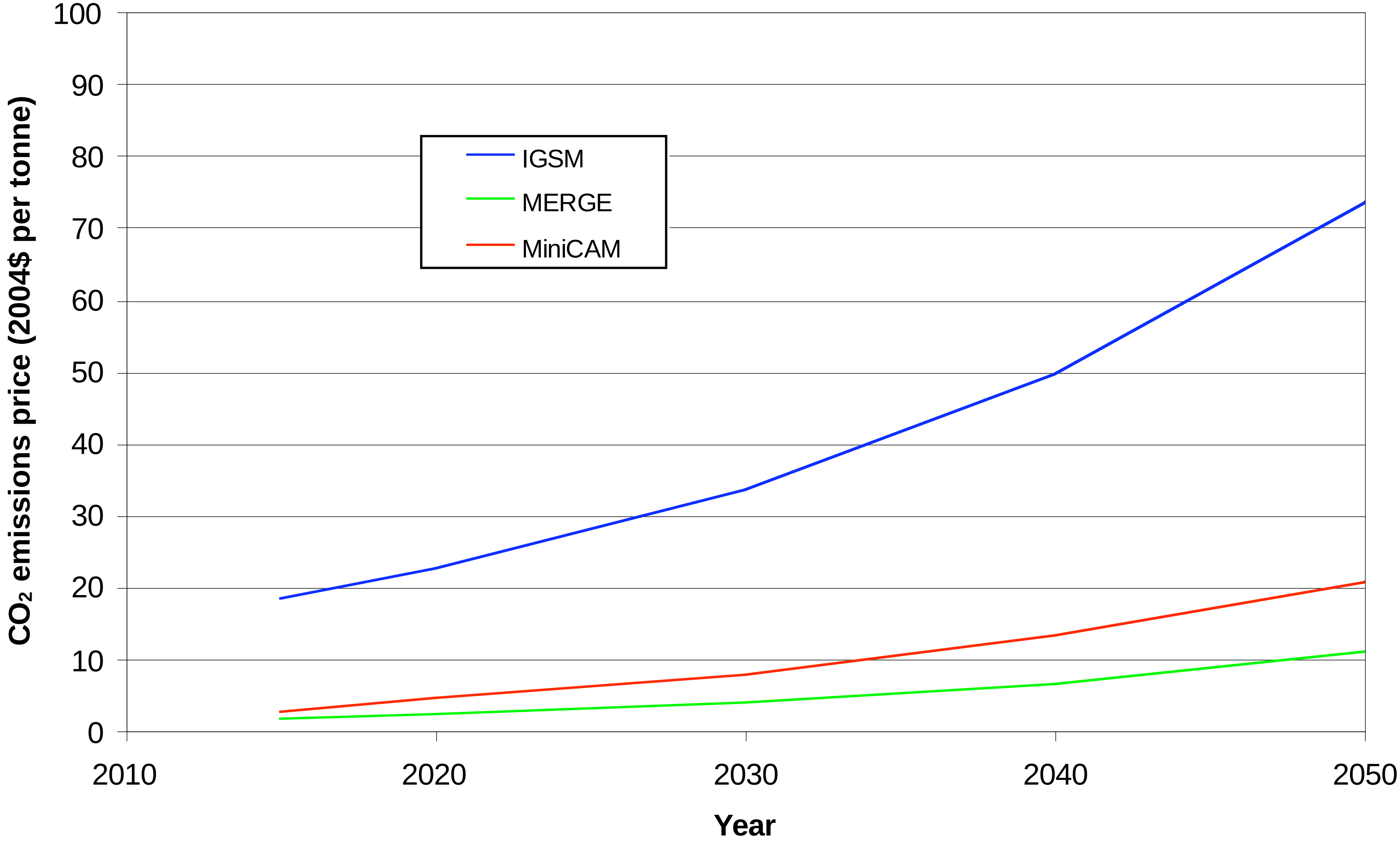
**$28** more a month for electricty from gas-fired utility

**$0** more a month for electricity from nuclear power

**$0** more a month for electricity from wind or solar power

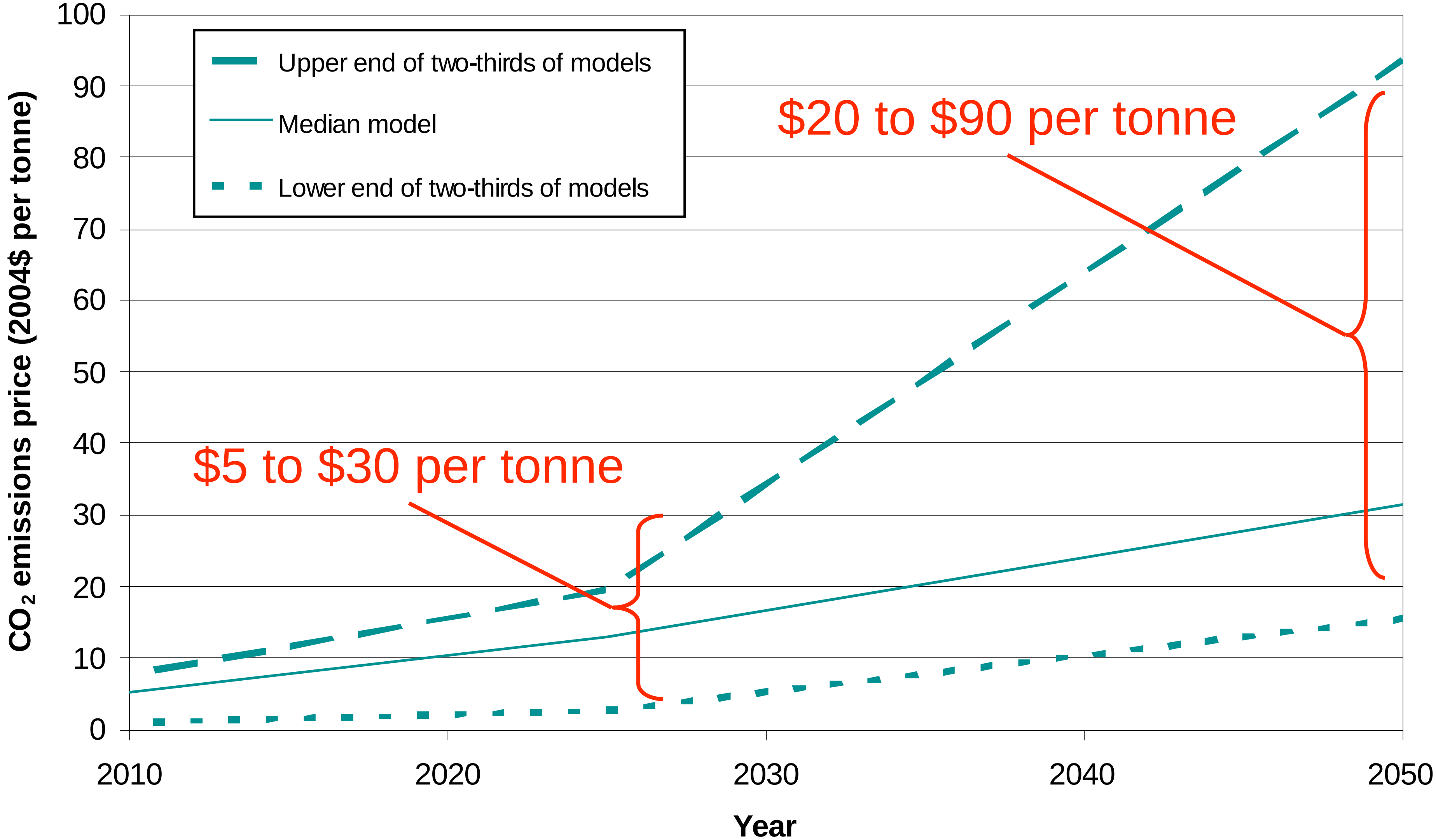
*Average monthly electricity bill ~ $80*

## $CO_2$ emissions price from CCSP: 5 ~650 ppm $CO_2$e stabilization




RESOURCES FOR THE FUTURE

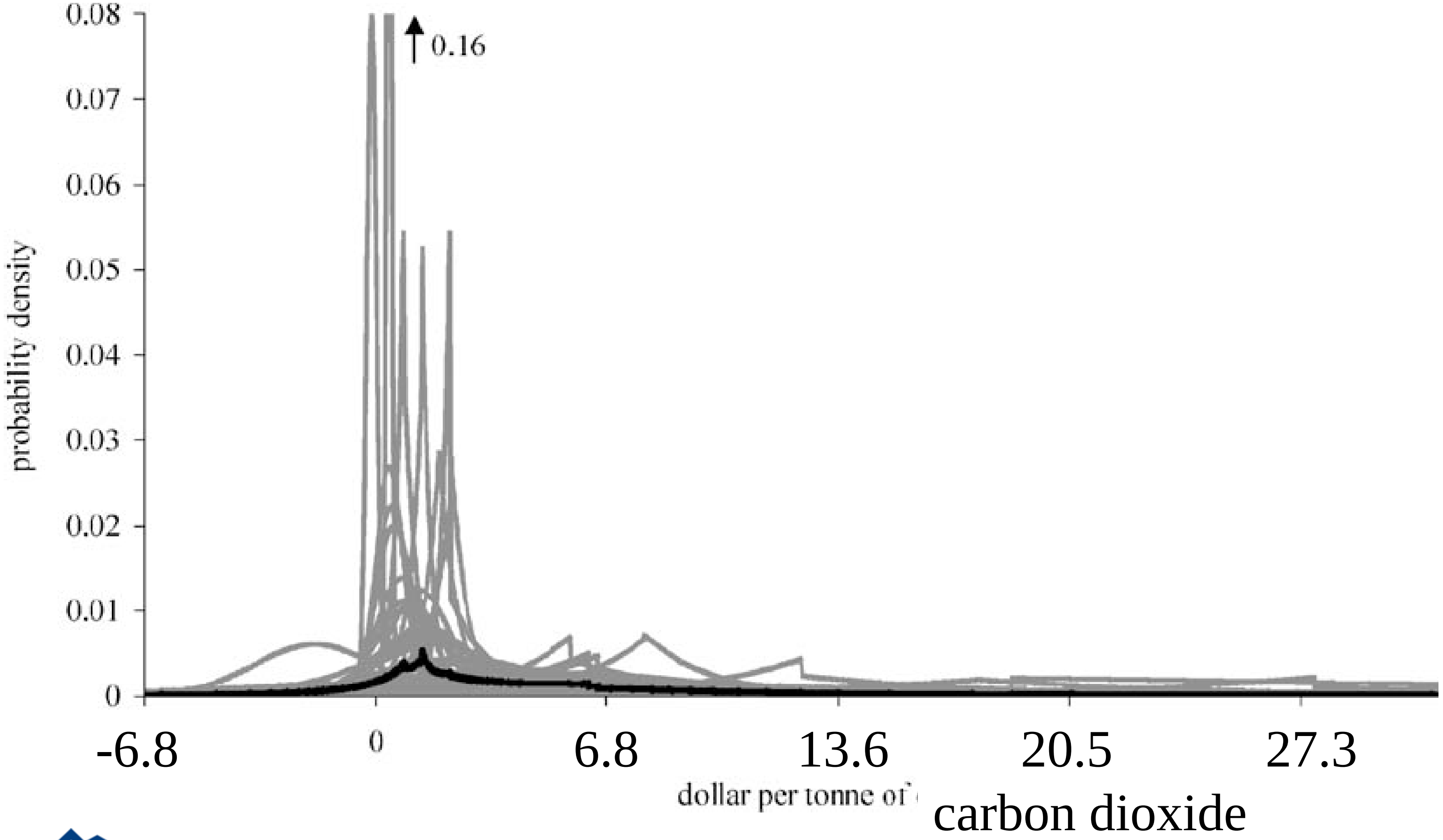
## $CO_2$ emissions price from EMF-21: 5 ~650 ppm $CO_2$e stabilization




RESOURCES FOR THE FUTURE

# Marginal Benefit (Tol)

R.S.J. Tol / Energy Policy 33 (2005) 2064–2074



# Marginal Benefits (Nordhaus 2007)

| | l | 2010 | 2100 |
|---|---|---|---|
| | 2005 US $ per ton C $O_2$ | | |
| **No controls** | | | |
| 250 year delay | | 0.1 | 4.7 |
| 50 year delay | | 0.1 | 56.3 |
| **Optimal** | | 8.1 | 56.1 |
| **Concentration limits** | | | |
| Limit to 1.5X CO2 | | 27.6 | 223 |
| Limit to 2X CO2 | | 8.9 | 130 |
| Limit to 2.5X CO2 | | 8.1 | 57.1 |
| **Stern Review discountin** | | 42.0 | 259 |

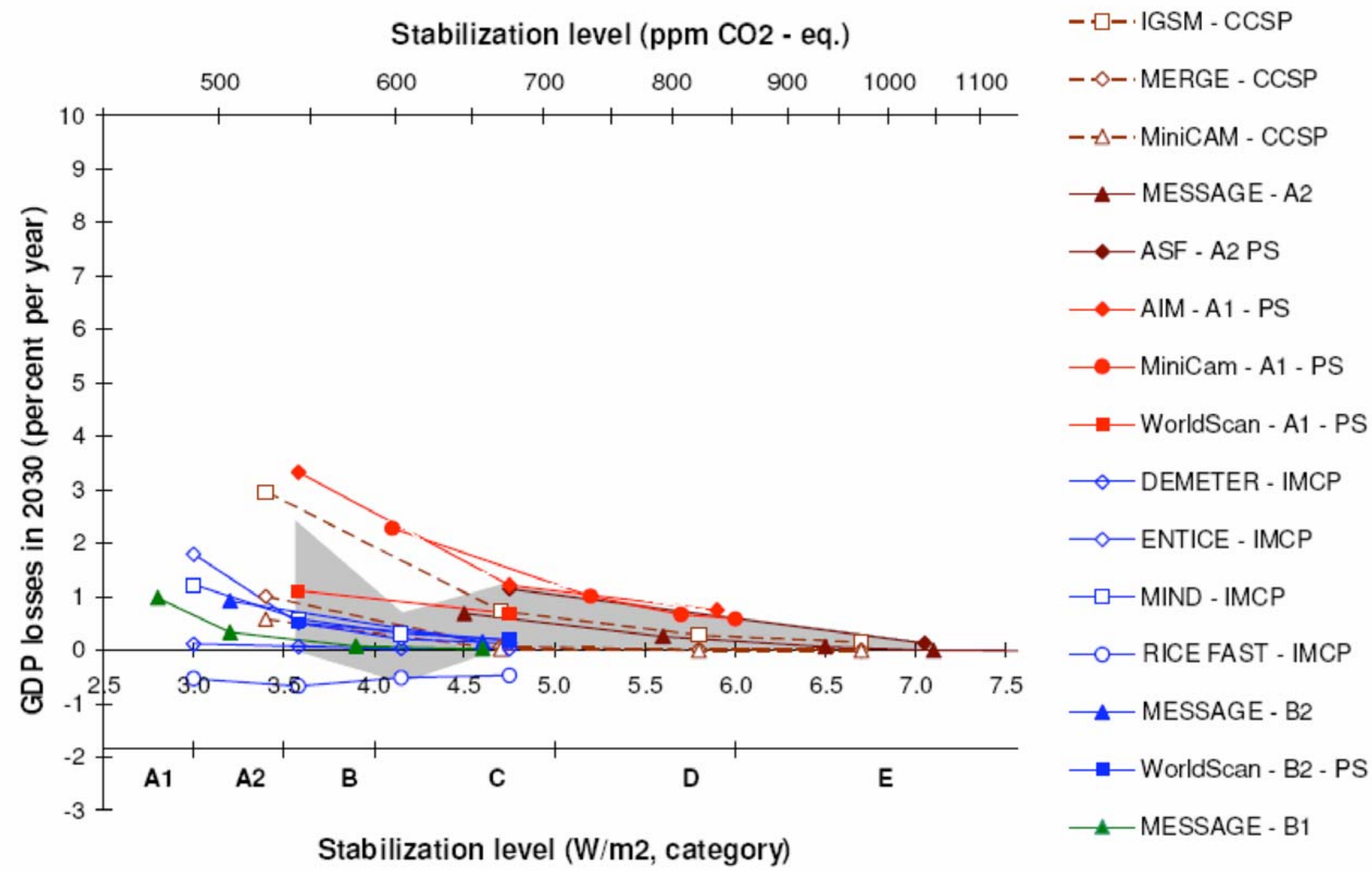
RESOURCES FOR THE FUTURE

# Effect of discount rate uncertainty on discounted climate damages

| | | Benefits from 1 ton of carbon mitigation | Relative to constant rat |
|---|---|---|---|
| Government bond rate (4%) | Constant 4% rate | $5.74 | — |
| | Random walk model | $10.44 | +82% |
| | Mean-reverting model | $6.52 | +14% |
| 2% rate | Constant 2% rate | $21.73 | — |
| | Random walk model | $33.84 | +56% |
| | Mean-reverting model | $23.32 | +7% |
| 7% rate | Constant 7% rate | $1.48 | — |
| | Random walk model | $2.88 | +95% |
| | Mean-reverting model | $1.79 | +21% |

RESOURCES FOR THE FUTURE

# Costs




RESOURCES FOR THE FUTURE

# Costs Estimates

**Table 4**. Core price and welfare results: U.S. + World Policy.

| | **$CO_2$-e Price** ($/t$CO_2$-e) | | | **Change in Welfare** (%) | | |
|---|---|---|---|---|---|---|
| | **287 bmt** | **203 bmt** | **167 bmt** | **287 bmt** | **203 bmt** | **167 bmt** |
| **2015** | 18 | 41 | 53 | 0.01 | –0.04 | –0.07 |
| **2020** | 22 | 50 | 65 | –0.13 | –0.32 | –0.55 |
| **2025** | 26 | 61 | 79 | –0.36 | –0.69 | –1.05 |
| **2030** | 32 | 74 | 96 | –0.45 | –1.08 | –1.47 |
| **2035** | 39 | 90 | 117 | –0.19 | –0.77 | –1.51 |
| **2040** | 47 | 109 | 142 | –0.12 | –0.92 | –1.84 |
| **2045** | 57 | 133 | 172 | –0.24 | –1.28 | –1.90 |
| **2050** | 70 | 161 | 210 | –0.18 | –1.45 | –1.79 |

# Scenario Comparison

## GHG Allowance Prices

**Table: Allowance Price Comparisons (2005 $/tCO2e)**

| | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| **2) S. 280 Senate Scenario** | | | | | | | | |
| ADAGE | $13 | $16 | $21 | $27 | $34 | $43 | $55 | $70 |
| IGEM | $15 | $20 | $25 | $32 | $41 | $52 | $67 | $85 |
| **3) S. 280 Scenario with Low International Actions** | | | | | | | | |
| ADAGE | $13 | $16 | $21 | $27 | $34 | $43 | $55 | $70 |
| IGEM | $15 | $20 | $25 | $32 | $41 | $52 | $67 | $85 |
| **4) S. 280 Scenario Allowing Unlimited Offsets** | | | | | | | | |
| ADAGE | | | | | | | | |
| IGEM | $10 | $13 | $16 | $21 | $26 | $34 | $43 | $55 |
| **5) S. 280 Scenario with No Offsets** | | | | | | | | |
| ADAGE | | | | | | | | |
| IGEM | $40 | $51 | $65 | $82 | $105 | $134 | $171 | $219 |
| **6) S. 280 Scenario with Lower Nuclear Power Generation** | | | | | | | | |
| ADAGE | $14 | $17 | $22 | $28 | $36 | $46 | $58 | $74 |
| IGEM | | | | | | | | |
| **7) S. 280 Scenario with No Carbon, Capture & Storage Technology** | | | | | | | | |
| ADAGE | $19 | $25 | $31 | $40 | $51 | $65 | $83 | $105 |
| IGEM | | | | | | | | |

# Scenario Comparison

## GDP Impacts (Percentage Change)

**Table: GDP Comparisons (% Change from Reference)**

| | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
|---|---|---|---|---|---|---|---|---|
| **2) S. 280 Senate Scenario** | | | | | | | | |
| ADAGE | -0.22% | -0.36% | -0.40% | -0.55% | -0.61% | -0.67% | -0.69% | -1.07% |
| IGEM | -0.79% | -1.04% | -1.32% | -1.60% | -1.94% | -2.30% | -2.73% | -3.21% |
| **3) S. 280 Scenario with Low International Actions** | | | | | | | | |
| ADAGE | | | | | | | | |
| IGEM | -0.79% | -1.05% | -1.31% | -1.60% | -1.94% | -2.30% | -2.73% | -3.19% |
| **4) S. 280 Scenario Allowing Unlimited Offsets** | | | | | | | | |
| ADAGE | | | | | | | | |
| IGEM | -0.54% | -0.71% | -0.89% | -1.07% | -1.31% | -1.58% | -1.88% | -2.25% |
| **5) S. 280 Scenario with No Offsets** | | | | | | | | |
| ADAGE | | | | | | | | |
| IGEM | -1.76% | -2.26% | -2.78% | -3.31% | -3.93% | -4.58% | -5.30% | -6.08% |
| **6) S. 280 Scenario with Lower Nuclear Power Generation** | | | | | | | | |
| ADAGE | -0.23% | -0.38% | -0.42% | -0.58% | -0.63% | -0.70% | -0.72% | -1.11% |
| IGEM | | | | | | | | |
| **7) S. 280 Scenario with No Carbon, Capture & Storage Technology** | | | | | | | | |
| ADAGE | -0.57% | -0.70% | -0.83% | -0.97% | -1.14% | -1.34% | -1.58% | -1.82% |
| IGEM | | | | | | | | |

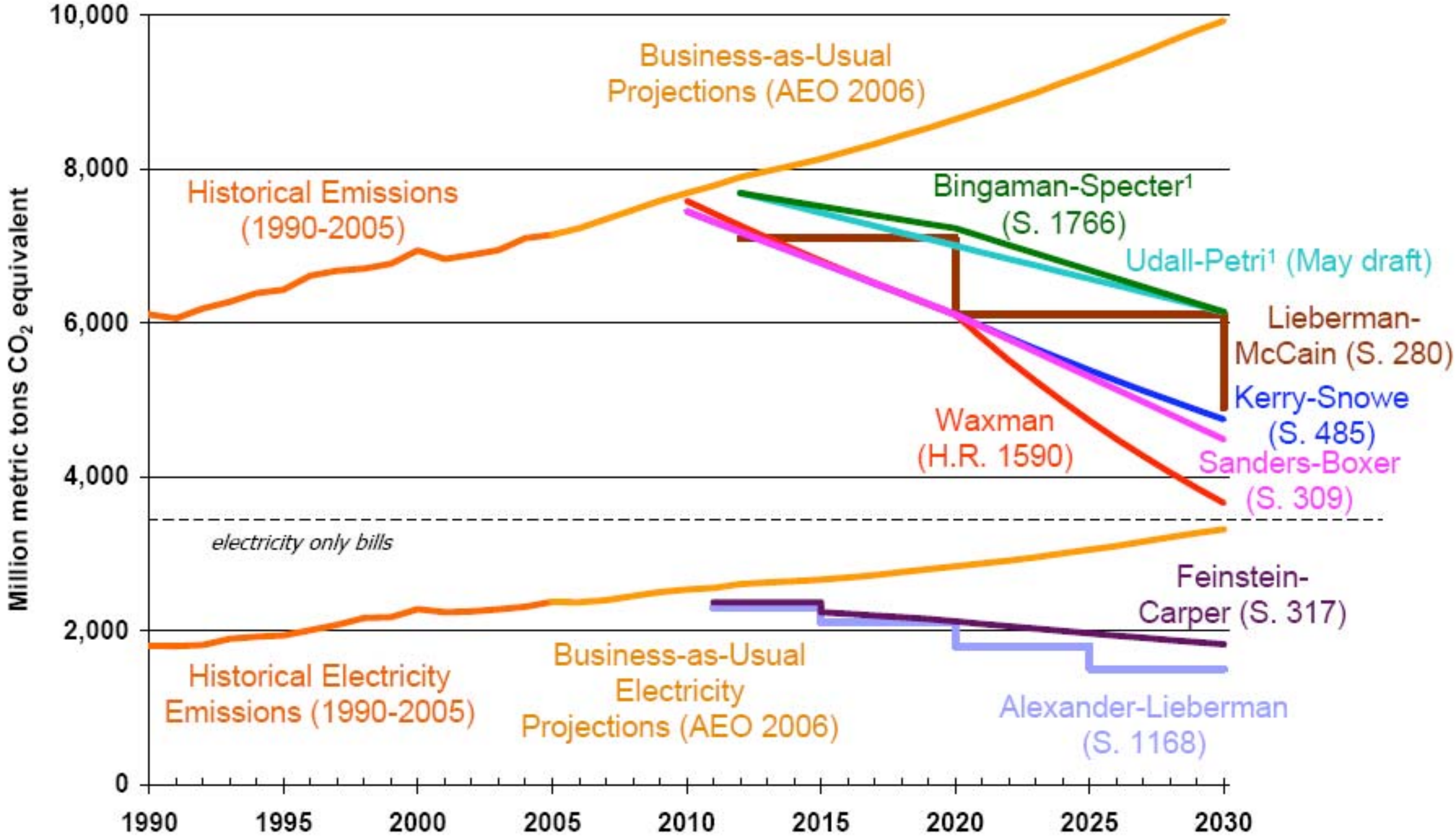
# Summary

| Target | Impacts (2100) | Price (2030) | Cost (2030) | Benefits |
|---|---|---|---|---|
| 450 ppm $CO_2e$ | <2°C | *Requires global peaking <10 years* | ? 3% ? | *Avoids risk of major impacts* |
| 550 ppm $CO_2e$ | 1-3.5°C | $20-60 | 1.0-2.5% | *Consistent with low discounting benefit estimates* |
| 650 ppm $CO_2e$ | 1.5-5°C | $5-30 | 0.1-1.5% | *Consistent with conventional benefit estimates* |
| No limit | 3-8°C | | | |

# End

RESOURCES FOR THE FUTURE

# Comparison of Emissions Reduction Goals in Legislation in the 110th Congress (as of July 11, 2007)




RESOURCES FOR THE FUTURE

This graph depicts emissions targets from some of the major climate change bills in Congress. Targets are based on comparison with historical year emissions. Kerry-Snowe, Sanders-Boxer, and Waxman specify future emissions as a percentage of 1990 emissions. For Lieberman-McCain, Udall-Petri, and Bingaman-Specter, emissions targets for covered sectors are related to historical emissions for those sectors, and total emissions are assumed to match those in the corresponding historical year.

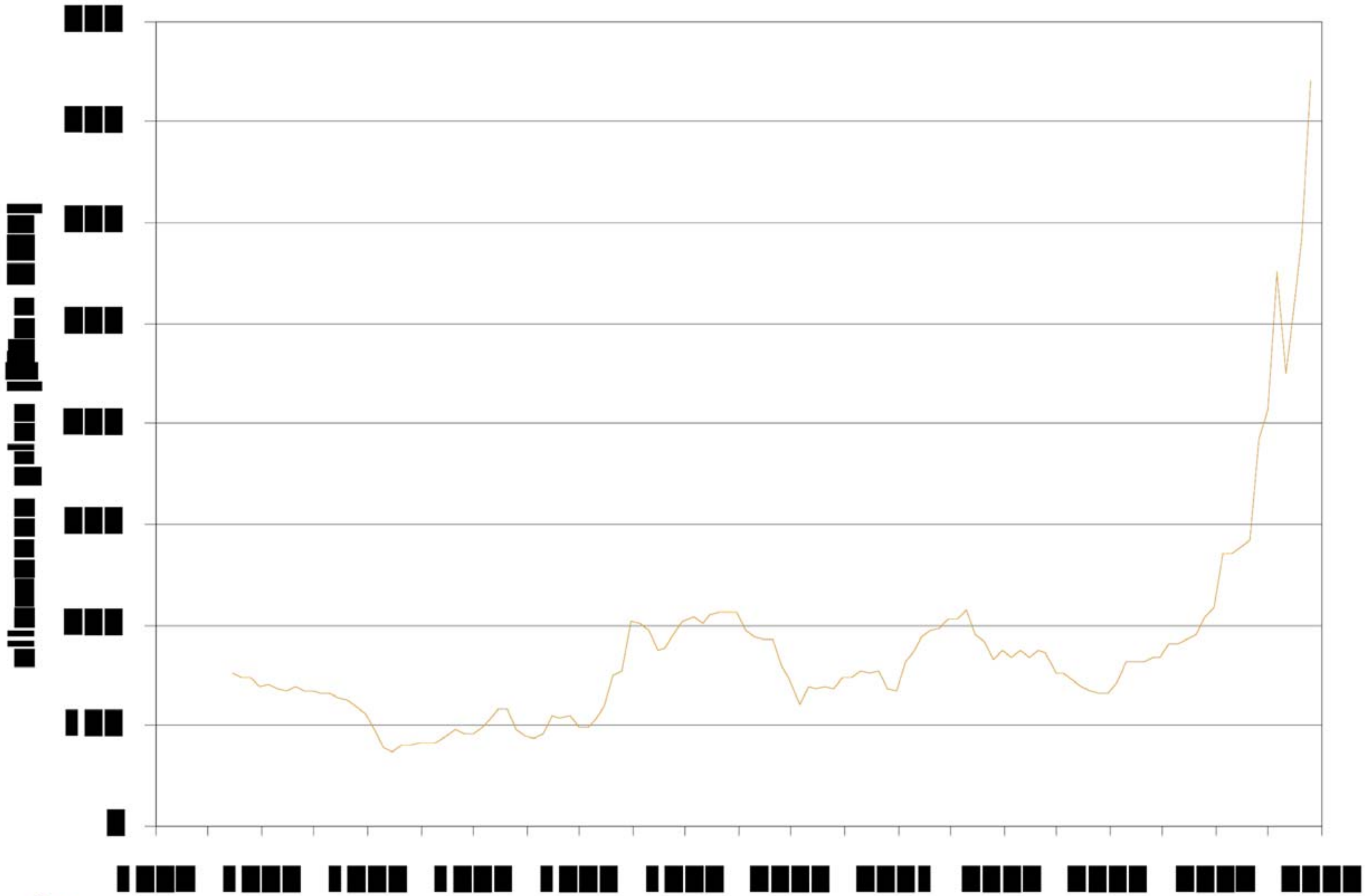
[1] Bill contains flexibility mechanisms which allow actual emissions to rise above the target.

## Summary of Market-Based Climate Change Legislation Introduced in the 110th Congress

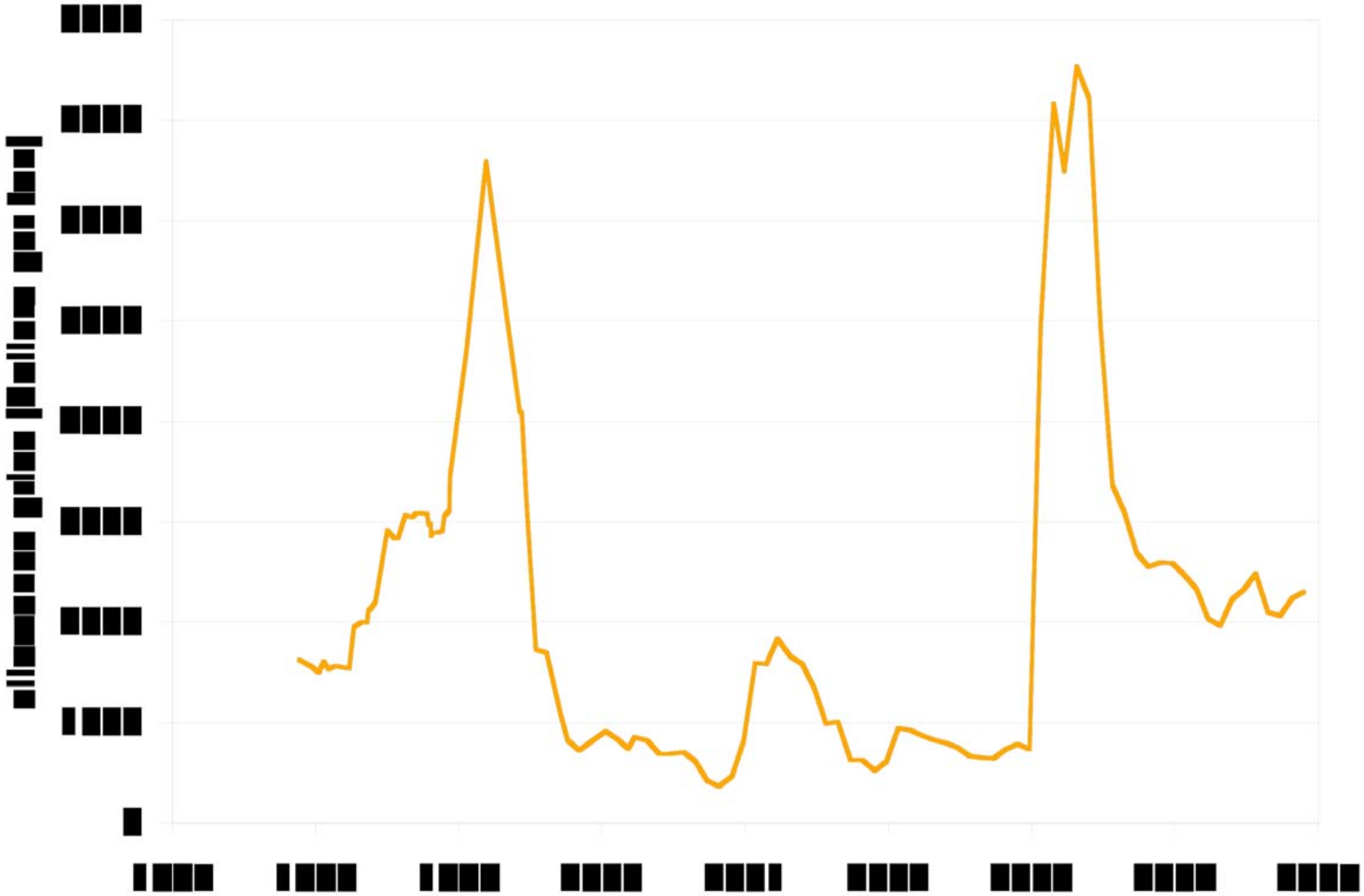
As of July 25, 2007

<table>
<tr><th></th><th>Who's Regulated</th><th>Allowance Allocation</th><th>Price Stability (Safety Valve & Borrowing)</th><th>Offsets</th><th>Technology</th></tr>
<tr><td>Bingaman-Specter (S. 1766)</td><td>Economy-wide emissions regulation: coal and process emissions at emitters; oil refiners, NG processors, and oil/NG importers; and F-gas producers and importers.</td><td>55% grandfathered to industry (phased out over time). 22% auctioned to support technology, transition assistance, and adaptation. 14% set aside for CCS and sequestration. 9% to states.</td><td>$12/metric ton $CO_2$ safety valve, rising at 5% per year above inflation.</td><td>Unlimited domestic offsets including methane and $SF_6$ reductions. Domestic agricultural sequestration offsets limited to 5% of cap. Use of international offsets limited to 10%.</td><td>Detailed technology development programs funded from allowance auction revenues (12% of allowances auctioned in 2012, steadily increased to 26% by 2043).</td></tr>
<tr><td>Udall-Petri (based on May draft and discussion with Udall-Petri staff)</td><td>Economy-wide emissions regulation: primarily upstream sources (e.g., producers and importers of fuels).</td><td>20% grandfathered to industry. 80% auctioned to support RD&D, developing-country engagement, adaptation and dislocation aid, sequestration, and debt reduction.</td><td>$12/metric ton $CO_2$ safety valve, rising at 2% above inflation in first 2 years, and 2%-8% thereafter.</td><td>Unlimited geological sequestration offsets. 5% of allowances set aside to fund biological sequestration and 1% for CCS projects.</td><td>Establishes Advanced Research Projects Agency-Energy to fund technology advancement and sequestration projects with 30% of allowances.</td></tr>
<tr><td>Lieberman-McCain (S. 280)</td><td>Economy-wide emissions regulation: large downstream at emitter; transport emissions regulated at refinery.</td><td>Some allowances given free to covered entities, others auctioned to fund transition assistance, adaptation measures, and technology support. Distribution at discretion of EPA.</td><td>Borrowing (with interest) – up to 25% of allowances, for no more than 5 years.</td><td>Up to 30% of obligation can be met with domestic sequestration projects and international offsets.</td><td>Revenues from some auctioned allowances used to finance advanced technology development, demonstration, and deployment.</td></tr>
<tr><td>Kerry-Snowe (S. 485)</td><td rowspan="2">Economy-wide emissions regulation: point of regulation at discretion of EPA Administrator.</td><td rowspan="2">Discretion of the President.</td><td rowspan="2">No provisions.</td><td>Secretary of Agriculture sets rules for domestic biological sequestration.</td><td rowspan="3">Each bill includes: vehicular emissions rules; energy efficiency & renewable standards for electric generation. All but Waxman have additional bill-specific mandates.</td></tr>
<tr><td>Waxman (H.R. 1590)</td><td>No provisions.</td></tr>
<tr><td>Sanders-Boxer (S. 309)</td><td colspan="4">Economy-wide cap on U.S. emissions. Discretion to implement a market-based allowance program to achieve this cap is left to the EPA Administrator.</td></tr>
<tr><td>Feinstein-Carper (S. 317)</td><td rowspan="2">Electricity-sector emissions regulated at the power plant. (S. 1168 also regulates $SO_2$, $NO_X$, and mercury emissions from power plants.)</td><td>85% grandfathered to industry, based on generation. Free allocation phased out by 2036.</td><td>Borrowing (with interest) – up to 10% of allowances, for no more than 5 years.</td><td>Up to 25% through int'l offsets; extensive domestic biological sequestration offsets.</td><td>Distributes auction revenues to multitude of technology programs.</td></tr>
<tr><td>Alexander-Lieberman (S. 1168)</td><td>75% grandfathered to industry, based on heat input.</td><td>No provisions.</td><td>Domestic offsets in five categories, including methane, $SF_6$, efficiency, and forest sequestration.</td><td>New source performance standard for $CO_2$ emissions from electric generation units.</td></tr>
<tr><td>Stark (H.R. 2069)</td><td>Economy-wide fossil fuel emissions regulated at the point of production.</td><td>Equivalent to 100% auction. (This legislation is an emissions tax.) Revenues to the general fund.</td><td>Tax on fuels of $3/metric ton of $CO_2$ emissions, rising by $3 each year.</td><td>Tax refunds for fuels used in processes which sequester carbons (e.g., CCS, or manufacture of plastics).</td><td>No provisions.</td></tr>
</table>

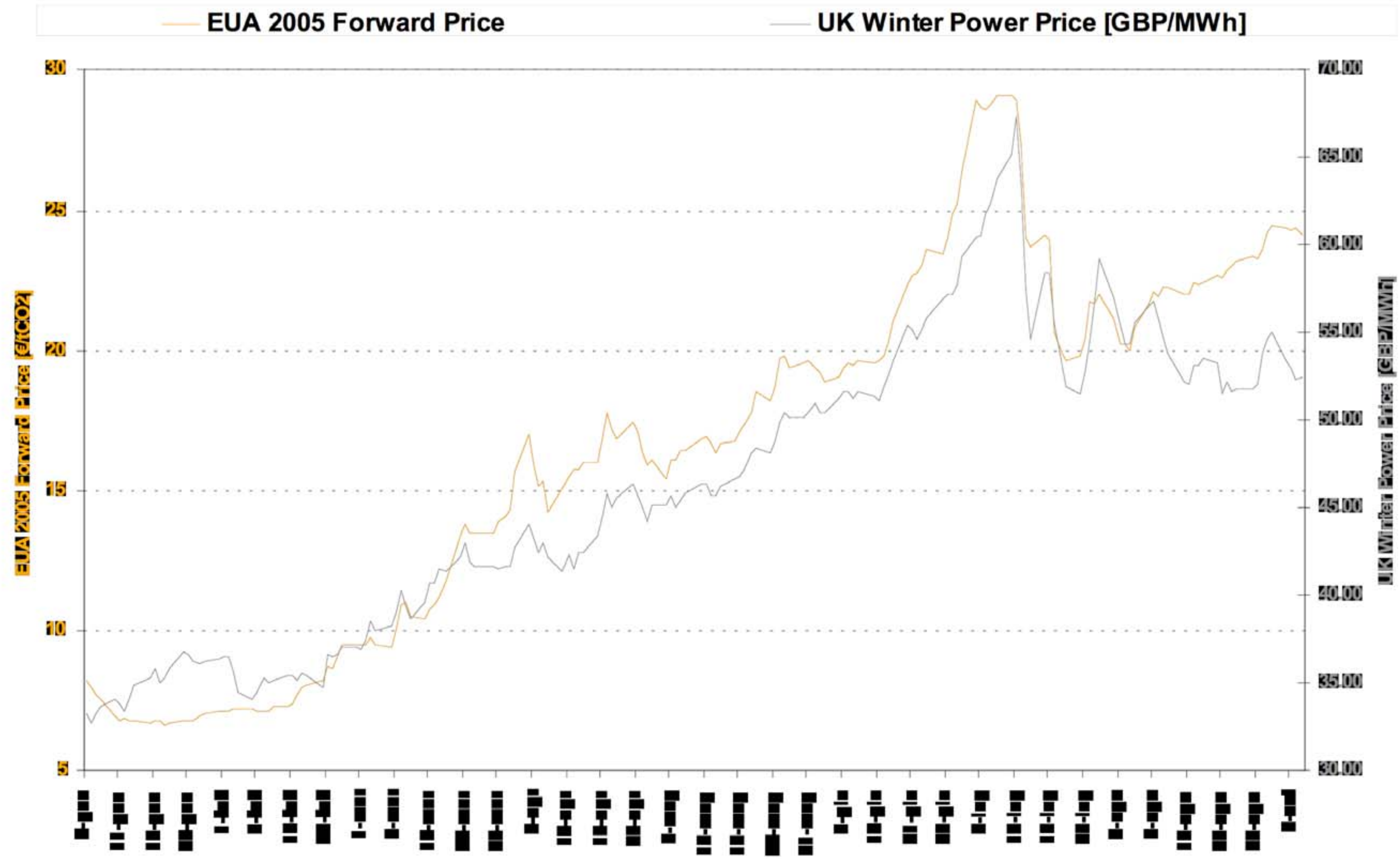
# $SO_2$ Market



# $NO_x$ OTC Current Vintage Price

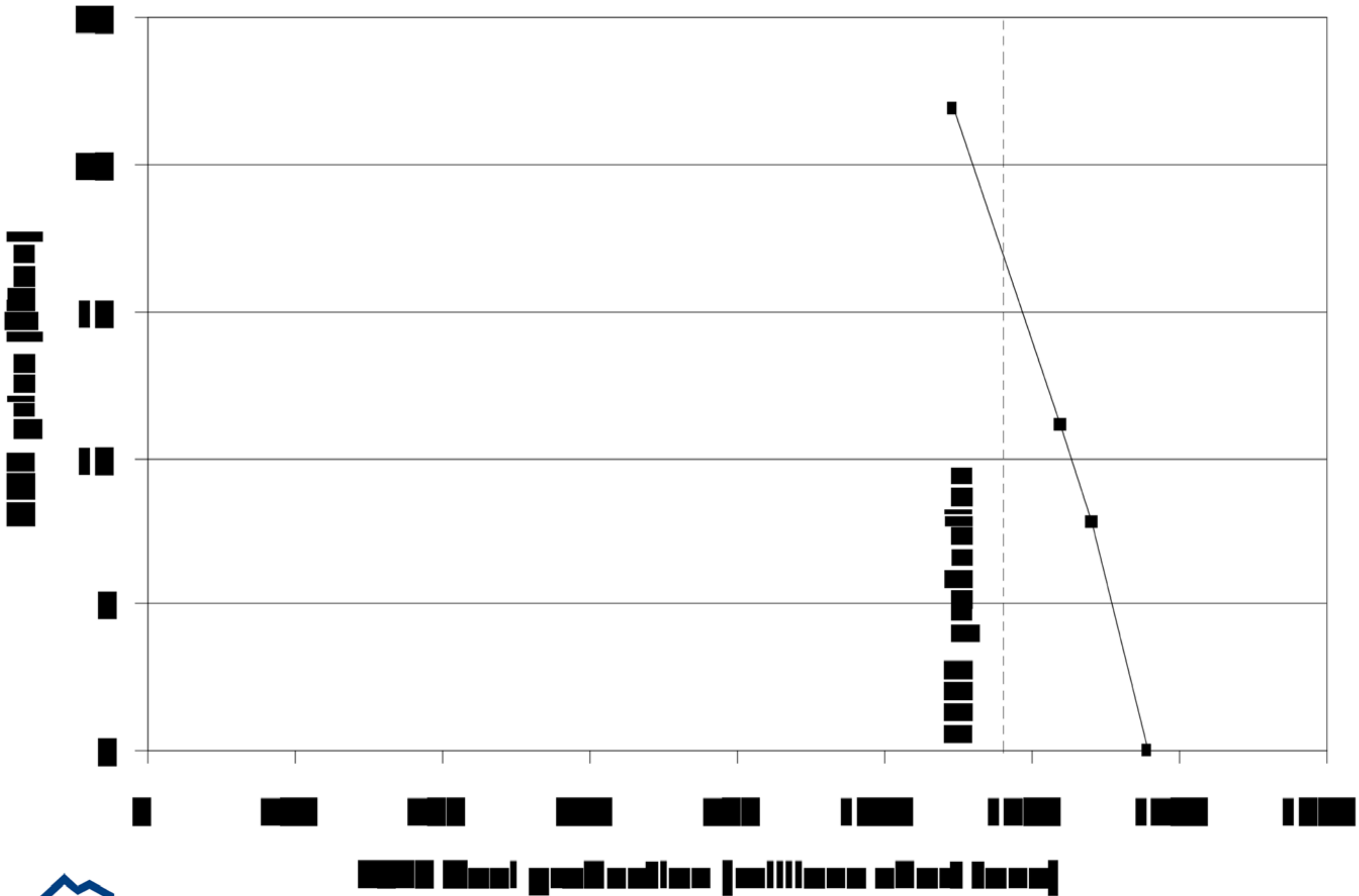


# Permit v. Electricity Price




RESOURCES FOR THE FUTURE

# Coal at different prices



# Household costs at different prices