The Use of Economic Modeling in the Climate Change Debate: Failures and Opportunities

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10th Anniversary Conference
on Global Economic Analysis
Purdue University

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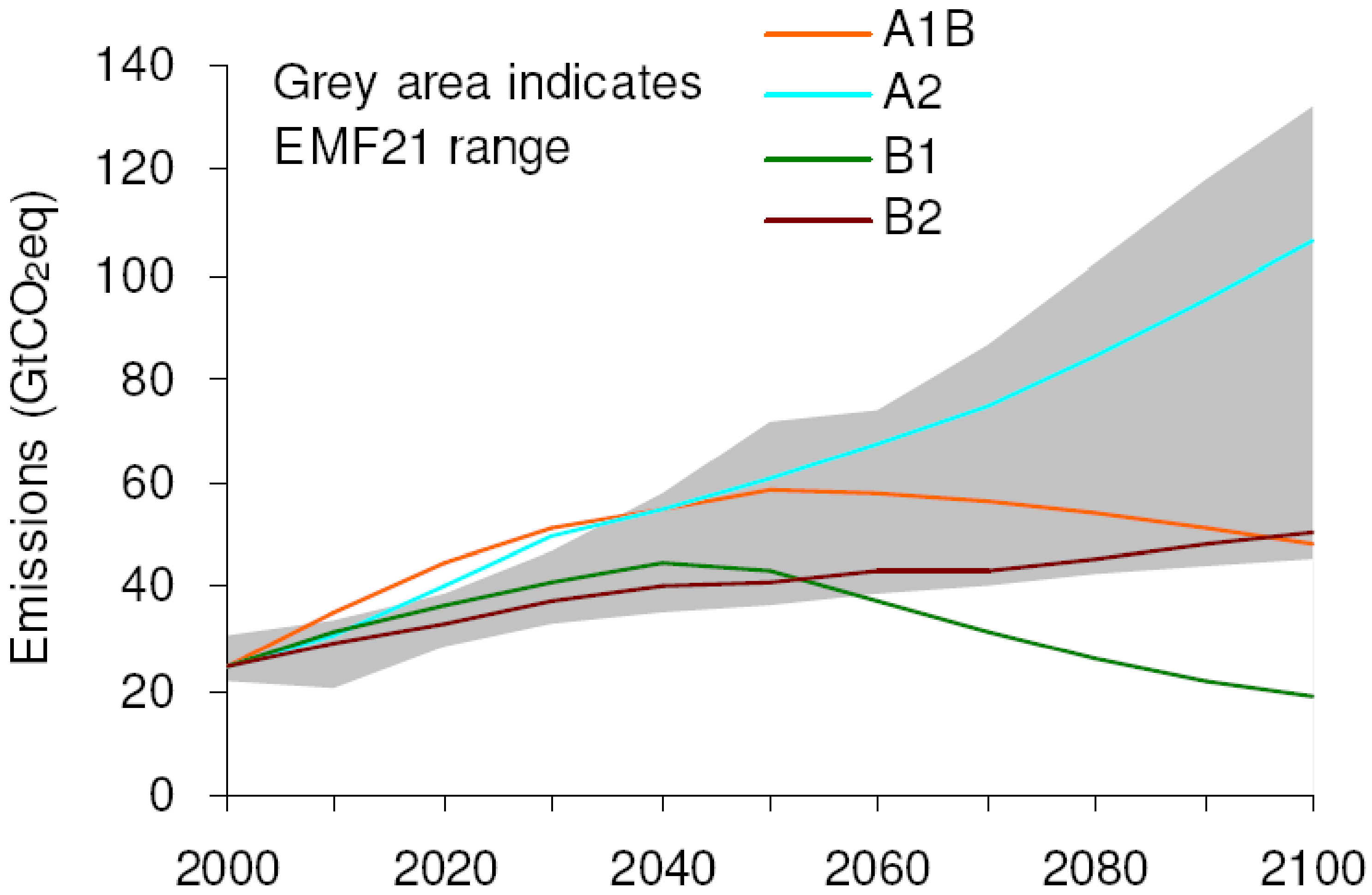
Baseline Global Emission Scenarios



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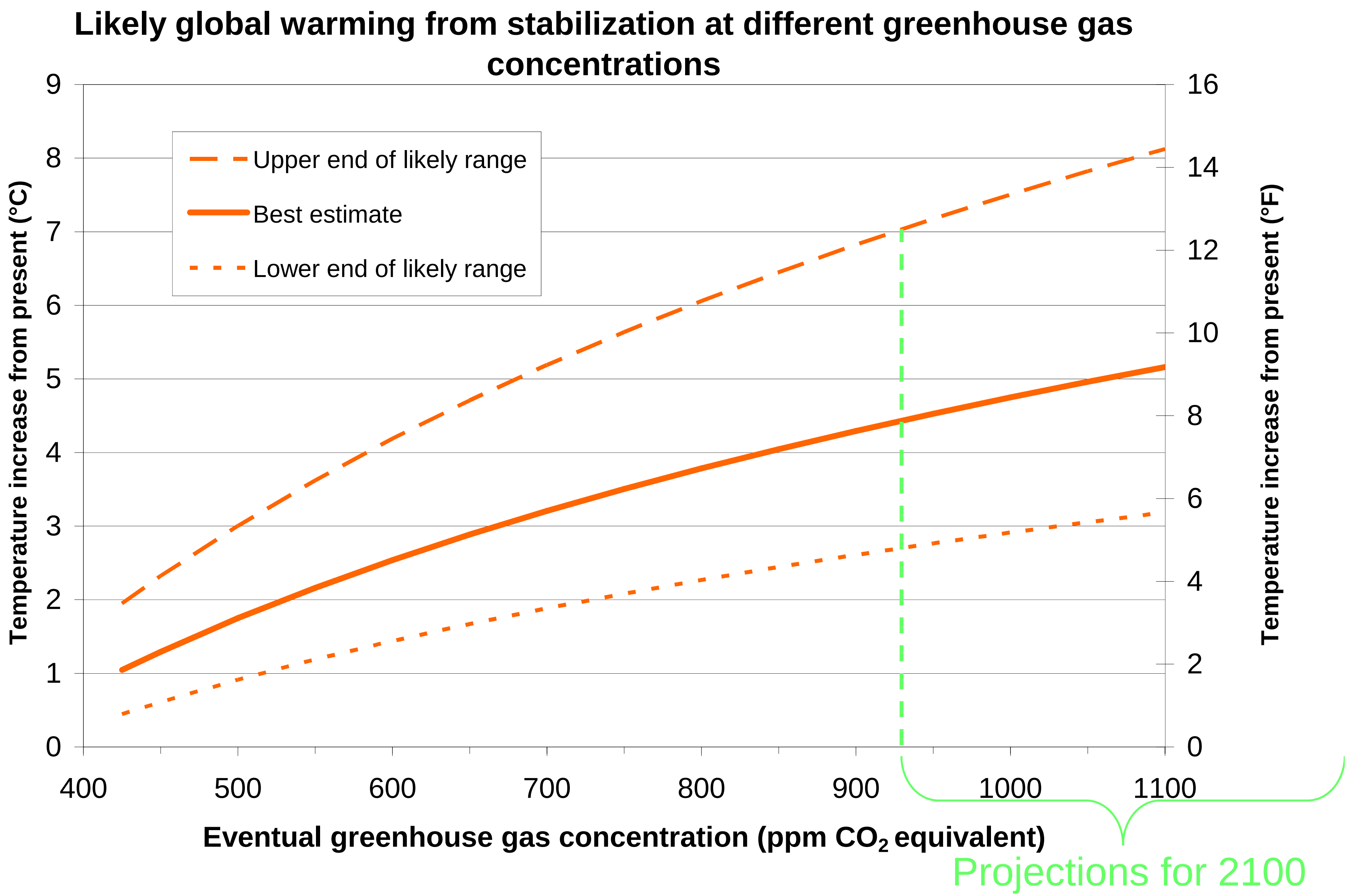

Note: "Likely" is defined as greater than a 66% probability of occurrence. Source: IPCC Fourth Assessment Report.

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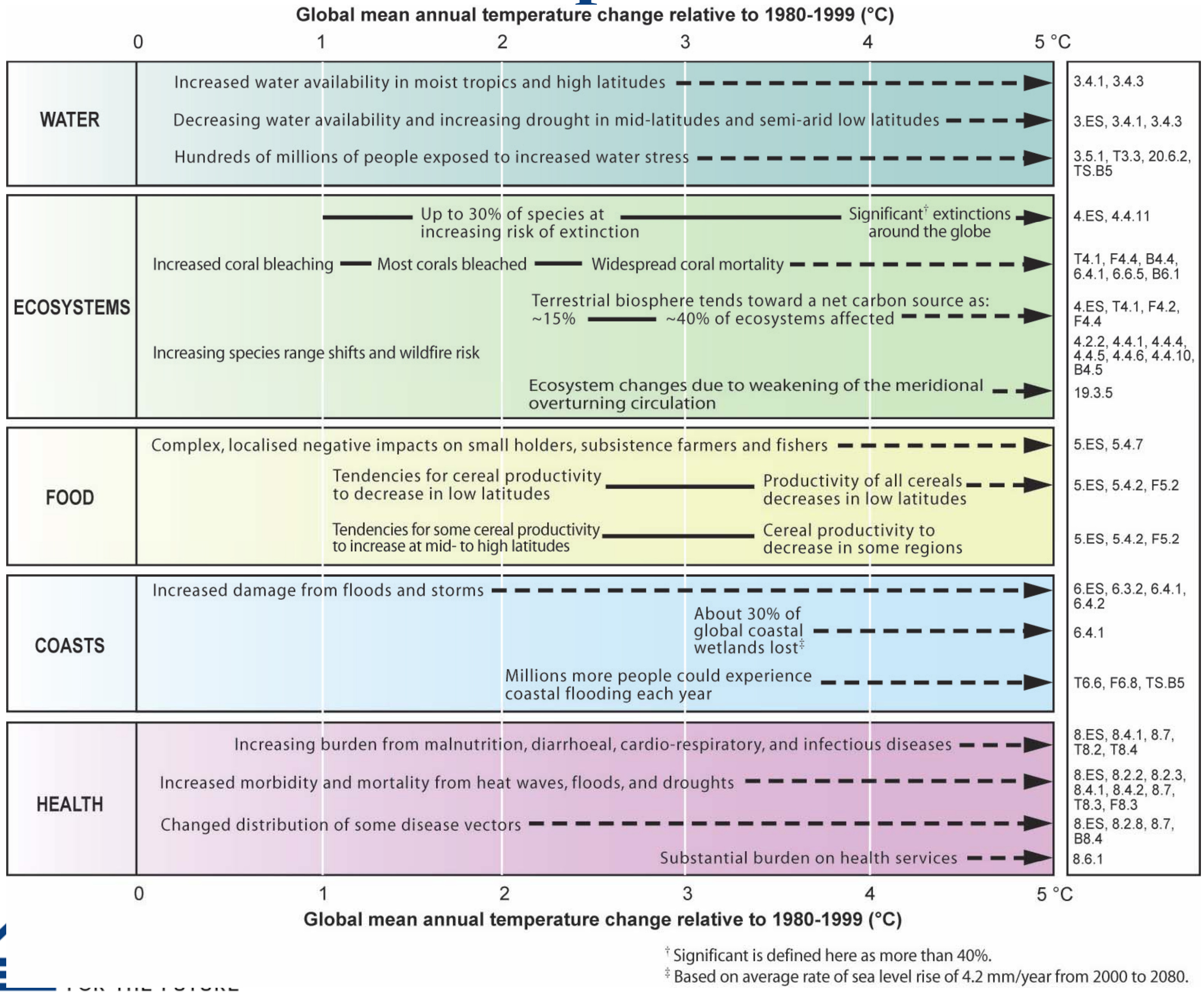
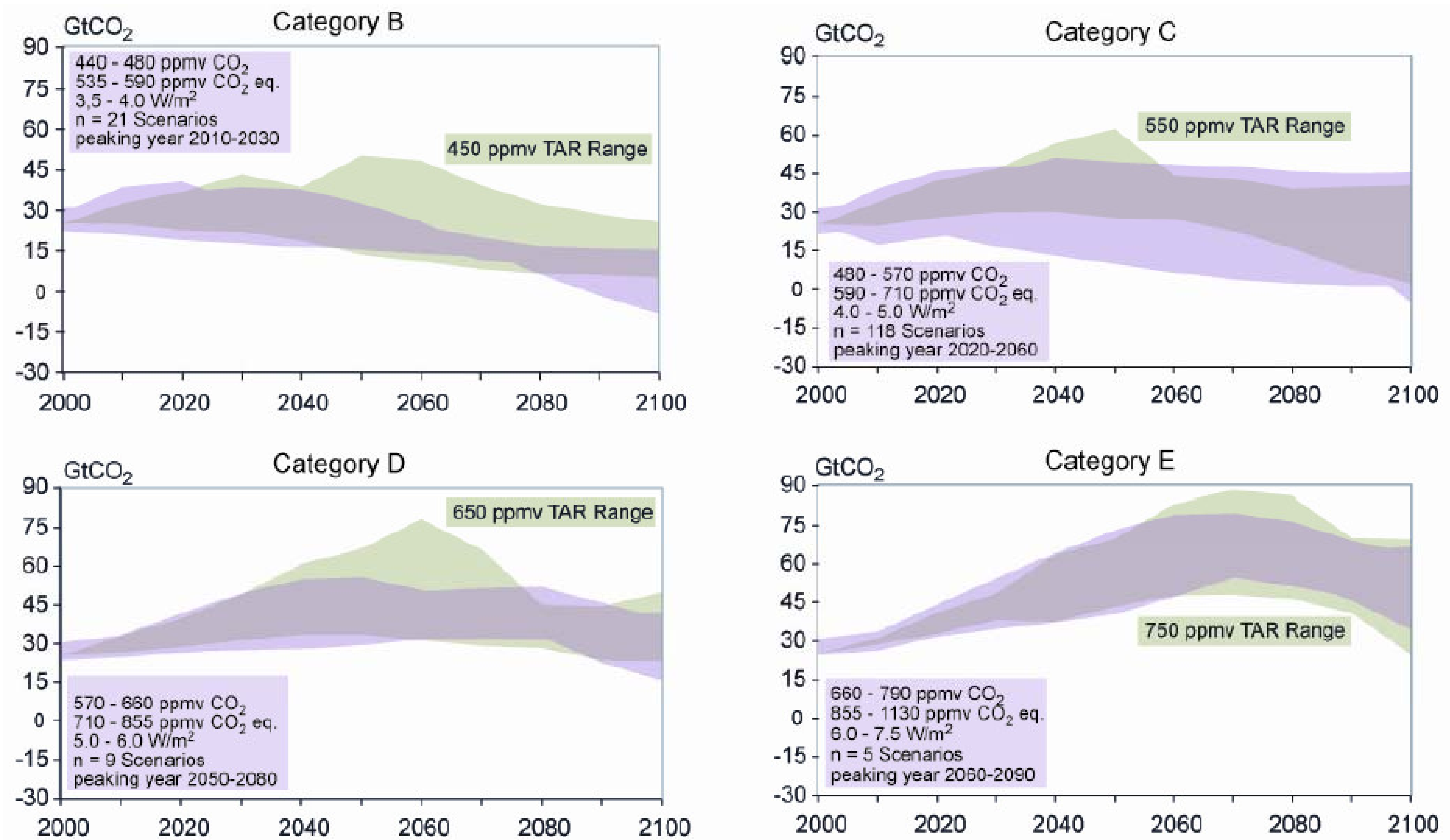
Impacts



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
Decreasing water availability and increasing drought in mid-latitudes and semi-arid low latitudes
Hundreds of millions of people exposed to increased water stress
3.4.1, 3.4.3
3.ES, 3.4.1, 3.4.3
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.

Stabilization Scenarios



Mitigation Cost - IPCC

"Both bottom-up and top-down studies indicate that there is substantial economic potential for the mitigation of global GHG emissions over the coming decades, that could offset the projected growth of global emissions or reduce emissions below current levels (*high agreement*, *much evidence*)"

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Top-down v. Bottom-up

***Table SPM 1**: Global economic mitigation potential in 2030 estimated from bottom-up studies.*

Carbon price (US$/$tCO_2$-eq)	Economic mitigation potential ($GtCO_2$-eq/yr)	Reduction relative to SRES A1 B (68 $GtCO_2$- eq/yr) %	Reduction relative to SRES B2 (49 $GtCO_2$- eq/yr) %
0	5-7	7-10	10-14
20	9-17	14-25	19-35
50	13-26	20-38	27-52
100	16-31	23-46	32-63

***Table SPM.2**: Global economic potential in 2030 estimated from top-down studies.*

Carbon price (US$/$tCO_2$-eq)	Economic potential ($GtCO_2$-eq/yr)	Reduction relative to SRES A1 B (68 $GtCO_2$ eq/yr) %	Reduction relative to SRES B2 (49 $GtCO_2$ eq/yr) %
20	9-18	13-27	18-37
50	14-23	21-34	29-47
100	17-26	25-38	35-53

Mitigation Cost - IPCC

"In 2030 macro-economic costs for multi-gas mitigation, consistent with emissions trajectories towards stabilization between 445 and 710 ppm CO2-eq, are estimated at between a 3% decrease of global GDP and a small increase, compared to the baseline (see Table SPM.4). However, regional costs may differ significantly from global averages (*high agreement*, *medium evidence*)"

Mitigation Cost

Table SPM.4: *Estimated global macro-economic costs in 2030*[16] *for least-cost trajectories towards different long-term stabilization levels.*[17, 18]

Stabilization levels (ppm CO_2-eq)	Median GDP reduction[19] (%)	Range of GDP reduction [19, 20] (%)	Reduction of average annual GDP growth rates (percentage points) [19, 21]
590-710 "C"	0.2	-0.6 – 1.2	< 0.06
535-590 "B"	0.6	0.2 – 2.5	<0.1
445-535[22] "A"	Not available	< 3	< 0.12

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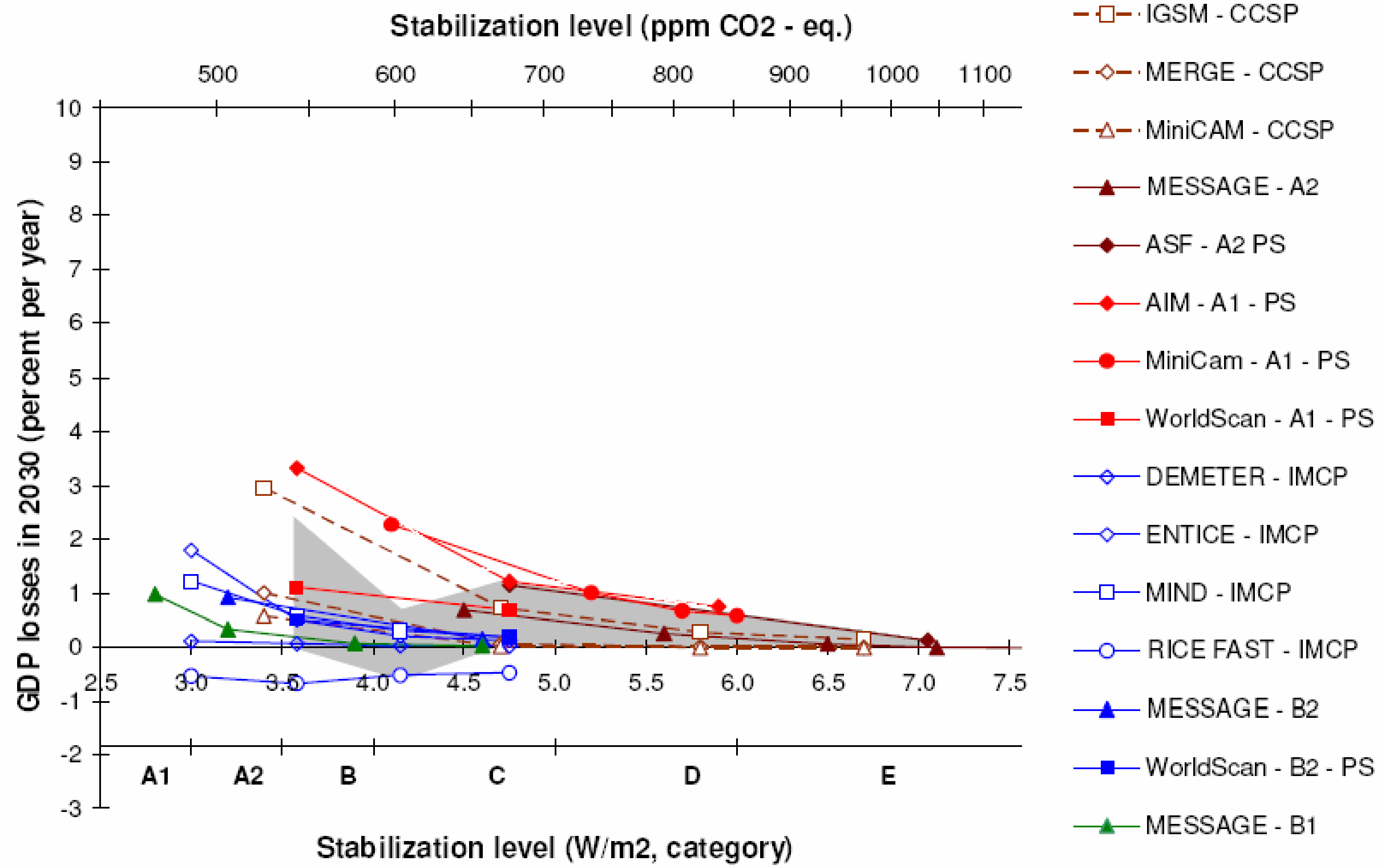
Costs



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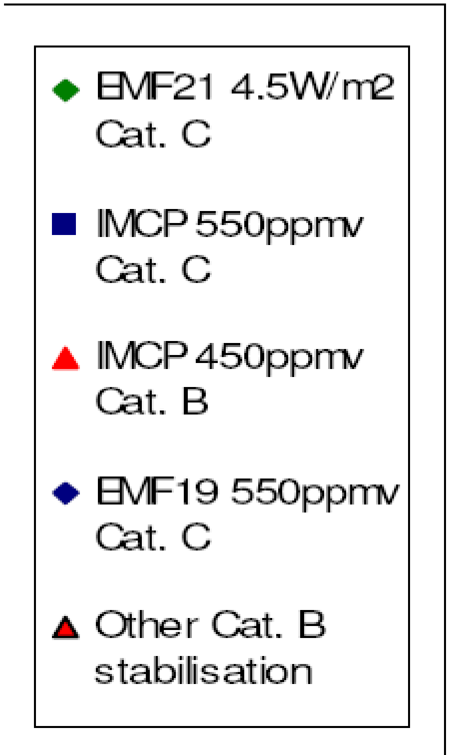
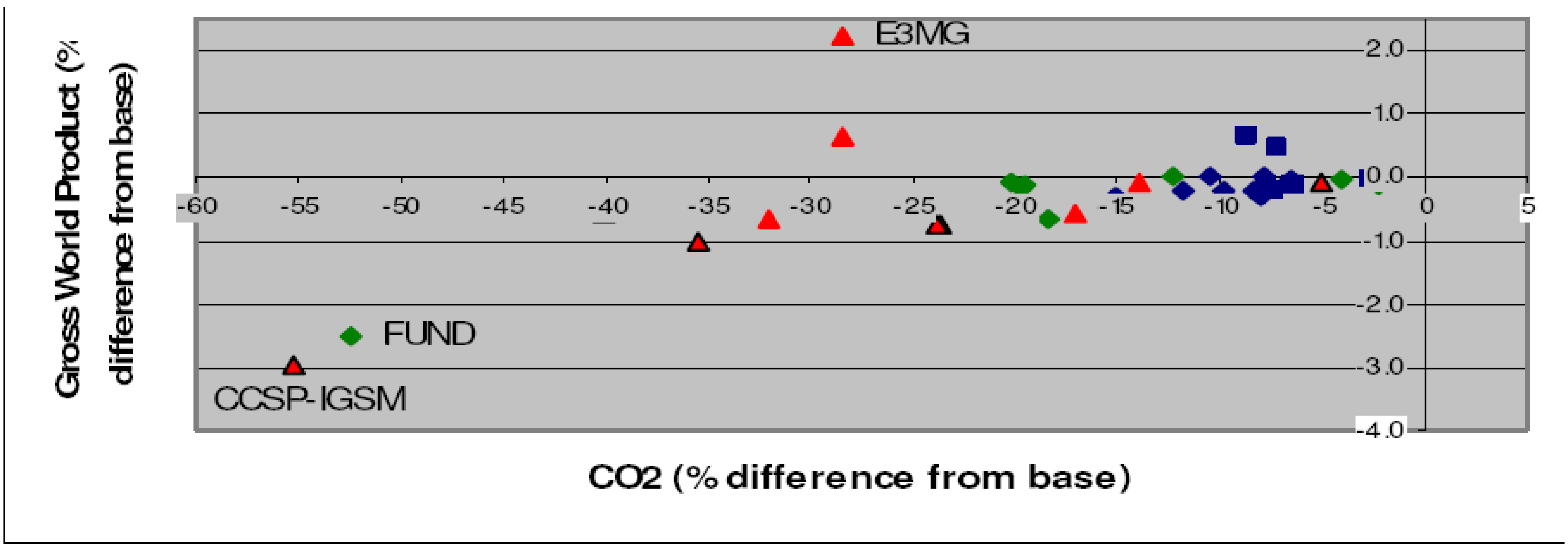
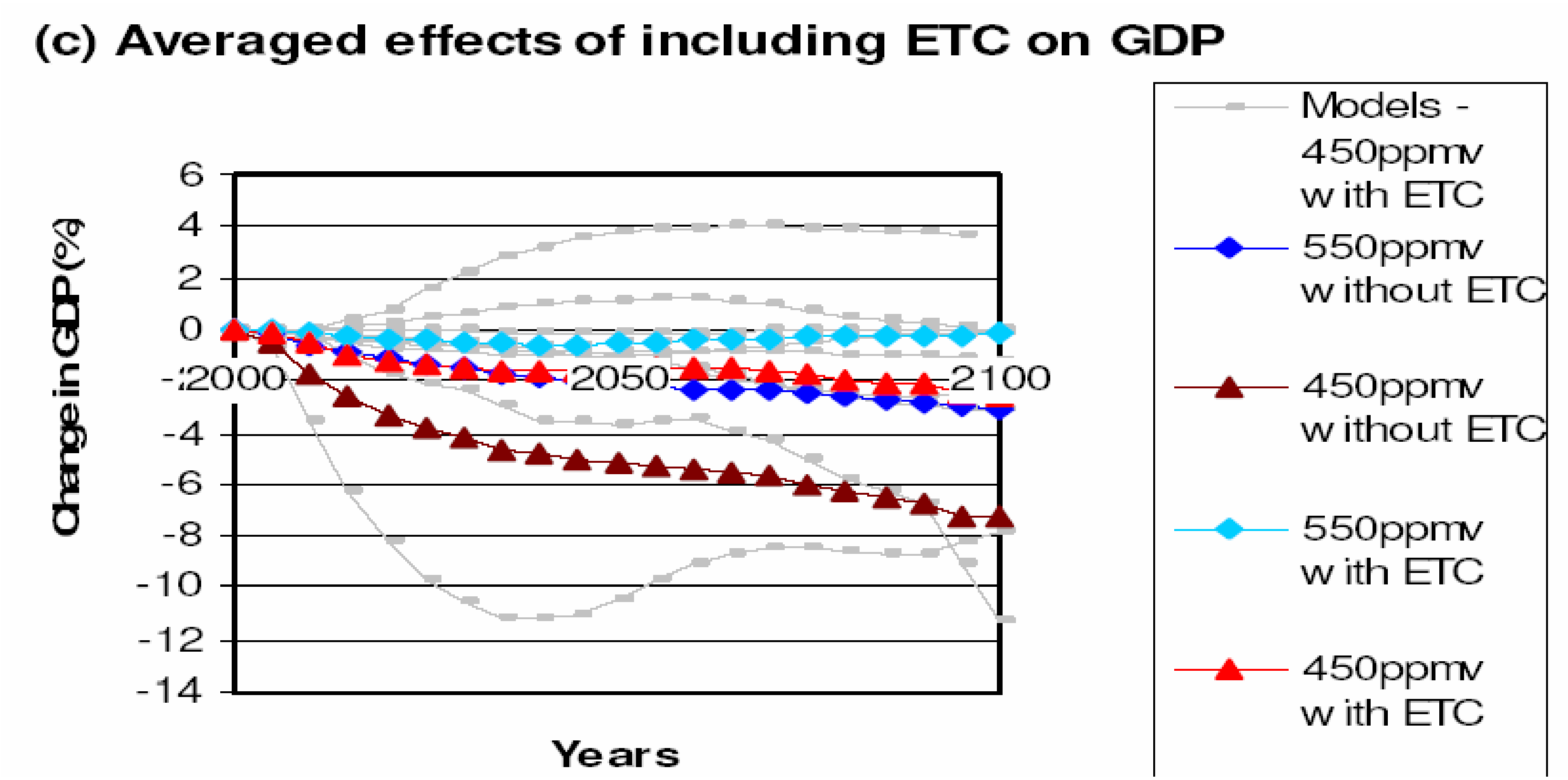
More costs



(b) Gross World Product and CO_2, year 2030



Endogenous Technological Change



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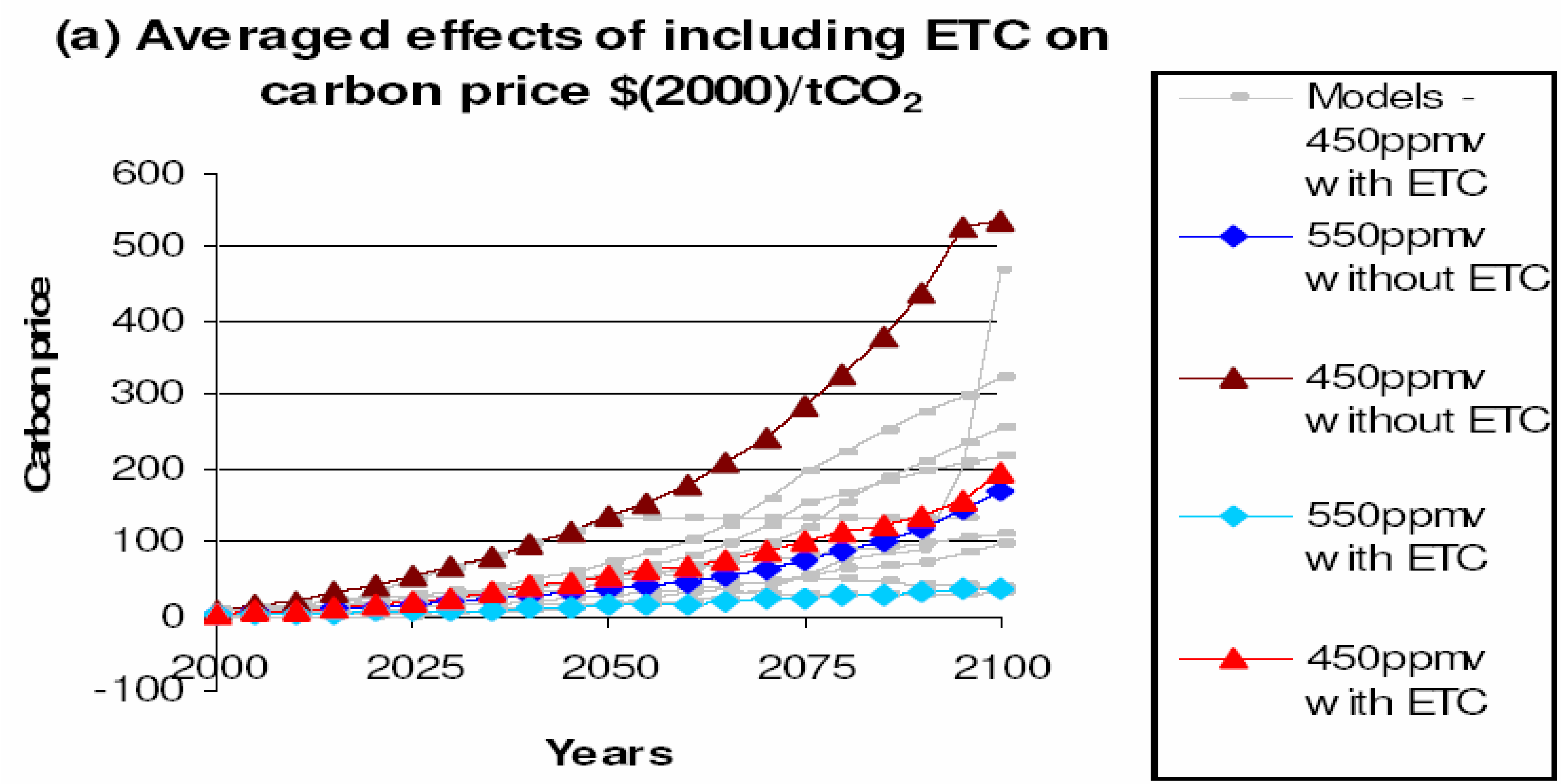
Endogenous Technological Change



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A look at RICE-FAST

The Dynamics of Carbon and Energy Intensity in a Model of Endogenous Technical Change

Valentina Bosetti, Carlo Carraro** and Marzio Galeotti**

We emphasize this fact by using two versions of the FEEM-RICE v.3, called FAST and SLOW FEEM-RICE. The two versions primarily differ in the value of the learning factor, δ_A, defined as the rate at which accumulation of past abatement becomes effective experience. Therefore, it represents the effectiveness of Learning by Doing. In particular the FAST version of the model assumes a 10% learning factor as opposed to the 5% learning factor of the SLOW version. In addition to this, the two versions of the model differ in the magnitude of the crowding out effect of investment in energy R&D on other research investments, which in turn controls for the profitability of R&D investments. Differences in

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A look at RICE-FAST

analysis of our optimization runs. Therefore, we will limit our analysis to the SLOW version of the model, which is less optimistic with respect to the future evolution of technical change.

The model has been used to assess the economic costs of achieving different stabilization targets. Our results suggest that these costs can be small, if adequate R&D investments can be financed and undertaken. Therefore, models in which technical change is exogenous and/or stabilization targets induce no change in the optimal trajectory of energy-related innovation are likely to over-estimate the actual stabilization costs.

Stern Costs

9 Identifying the Costs of Mitigation

Key Messages

Slowly reducing emissions of greenhouse gasses that cause climate change is likely to entail some costs. Costs include the expense of developing and deploying low-emission and high-efficiency technologies and the cost to consumers of switching spending from emissions-intensive to low-emission goods and services.

Fossil fuel emissions can be cut in several ways: reducing demand for carbon-intensive

An estimate of resource costs suggests that the annual cost of cutting total GHG to about three quarters of current levels by 2050, consistent with a 550ppm CO_2e stabilisation level, will be in the range –1.0 to +3.5% of GDP, with an average estimate of approximately 1%. This depends on steady reductions in the cost of low-carbon technologies, relative to the cost of the technologies currently deployed, and improvements in energy efficiency. The range is wide because of the uncertainties as to future rates of innovation and fossil-fuel extraction costs. The better the policy, the lower the cost.

- **Efficiency gains offer opportunities both to save money and to reduce emissions,** but require the removal of barriers to the uptake of more efficient technologies and methods.

- **A range of low-carbon technologies is already available, although many are currently more expensive than fossil-fuel equivalents.** Cleaner and more efficient power, heat and transport technologies are needed to make radical emission cuts in the medium to long term. Their future costs are uncertain, but experience with other technologies has helped to develop an understanding of the key risks. The evidence indicates that efficiency is likely to increase and average costs to fall with scale and experience.

- **Reducing non-fossil fuel emissions** will also yield important emission savings. The cost of reducing emissions from deforestation, in particular, may be relatively low, if appropriate institutional and incentive structures are put in place and the countries facing this challenge receive adequate assistance. Emissions cuts will be more challenging to achieve in agriculture, the other main non-energy source.

Main (bottom-up) cost analysis

Table 2.3 Global costs (sensitivity analysis of assumptions) % world product [a/]

Case	2015	2025	2050
(i) Central case	0.3	0.7	1.0
(ii) High costs of abatement (low rate of innovation and low future oil and gas prices)	0.4	0.9	3.3
(iii) Low costs of abatement (high rate of innovation and high future oil and gas prices)	0.2	0.2	-1.0
(iv) Low future oil and gas prices	0.4	1.1	2.4
(v) High future oil and gas prices	0.2	0.5	0.2
(vi) High costs of carbon capture and storage	0.3	0.8	1.9
(vii) A lower rate of growth of energy demand [b/]	0.3	0.5	0.7
(viii) A higher rate of growth of energy demand [b/]	0.3	0.6	1.0
(ix) Including incremental vehicle costs [c/]			
• Means	0.4	0.8	1.4
• Ranges	0.3 to 0.5	0.5-1.1	-0.6 to 3.5

a/ The world product in 2005 was approximately $35 trillion (£22 trillion at the ppp rate of $1.6/£). It is assumed to rise to $110 trillion (£70 trillion) by 2050, a growth rate of 2.5% per year, or 1 ½ -2% in the OECD countries and 4-4 ½% in the developing countries.

b/ Assuming central values of all other costs

c/ Assuming the incremental costs of a hydrogen fuelled vehicle using an internal combustion engine are £2,300 in 2025 and $1400 in 2050, and for a hydrogen fuelled fuel cell vehicle £5000 in 2025 declining to £1700 by 2050. (Ranges of ~± 30% are taken about these averages for the fuel cell vehicle.)

Supporting top-down analysis

Table 10.1 Meta-analysis estimates

Average impact of model assumptions on world GDP in 2030 for stabilisation at 450ppm CO_2 (approximately 500-550ppm CO_2e)
(% point levels difference from base model run)

	Full equation
Worst case assumptions	**-3.4**
Active revenue recycling[4]	1.9
CGE model	1.5
Induced technology	1.3
Non-climate benefit	1.0
International mechanisms	0.7
'Backstop' technology	0.6
Climate benefit	0.2
Total extra assumptions	**7.3**
Best-case assumptions	**3.9**

Source: Barker et al. 2006

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More on the meta-analysis

Table B4: Full Specification for WRI-post-SRES-IMCP Model Results for Changes in GWP

Table B4: Full Specification for WRI-post-SRES-IMCP Model Results for Changes in GWP with Model Characteristics and Model Dummies

gdp	Coef.	Robust Std. Err.	t	P>|t|	[95% Conf.	Interval]
co2	.0555702	.0079059	7.03	0.000	.0400613	.071079
co2square	-.0003844	.0000893	-4.31	0.000	-.0005596	-.0002093
with_itc_co2	-.0408368	.0040338	-10.12	0.000	-.0487499	-.0329238
recy_co2	-.0598588	.0073158	-8.18	0.000	-.07421	-.0455075
cben_co2	-.0075047	.0024388	-3.08	0.002	-.0122888	-.0027206
ncbens_co2	-.0302976	.0094481	-3.21	0.001	-.0488317	-.0117635
km_co2	-.022692	.0046201	-4.91	0.000	-.031755	-.0136289
cge_co2	-.0469216	.0065534	-7.16	0.000	-.0597773	-.0340659
bst_co2	-.019956	.0049227	-4.05	0.000	-.0296127	-.0102994
feemricef~o2	-.0545712	.0064325	-8.48	0.000	-.0671895	-.0419528
imaclim_co2	(dropped)					
demeter_co22	.0008902	.0000738	12.06	0.000	.0007454	.001035
imaclim_co22	.0041472	.0004992	8.31	0.000	.003168	.0051264
d450ppmv_co2	.0246745	.0035268	7.00	0.000	.017756	.031593
y2005	-.1651745	.3023866	-0.55	0.585	-.7583583	.4280093
y2085	-.4384904	.3513767	-1.25	0.212	-1.127777	.2507958
y2090	-.5525733	.2960954	-1.87	0.062	-1.133416	.0282691
y2095	-.7559423	.4294102	-1.76	0.079	-1.598305	.0864203
v2100	-.5955352	.3104269	-1.92	0.055	-1.204491	.0134209
e3mg	1.207555	.2482652	4.86	0.000	.7205401	1.69457
aimdynamic	.1299106	.164667	0.79	0.430	-.1931123	.4529334
feemricefast	-.120907	.214692	-0.56	0.573	-.5420627	.3002487
feemriceslow	1.065279	.2671142	3.99	0.000	.5412884	1.58927
enticebr	.5217119	.1655078	3.15	0.002	.1970396	.8463842
mind	-1.298386	.3255686	-3.99	0.000	-1.937046	-.659727
message	.550352	.1651815	3.33	0.001	.2263198	.8743842

What can you do?

- Be clear about what your model is designed to show:
  - Qualitative behavior
  - Quantitative, relative effects – this effect v. that effect.
  - Quantitative effects versus baseline.
  - Absolute levels.
- Be clear about key outputs you have confidence in:
  - Emissions
  - Energy use
  - Welfare
  - Regional effects
- Be clear about key assumptions and their implications
  - Perfect foresight v recursive behavior
  - Putty-putty v. putty-clay capital
  - Technology detail and assumptions
- When someone asks for more detailed, underlying results – share but ask to see the final product.

Comparison of Targets Proposed in 110th Congress and MIT Scenarios

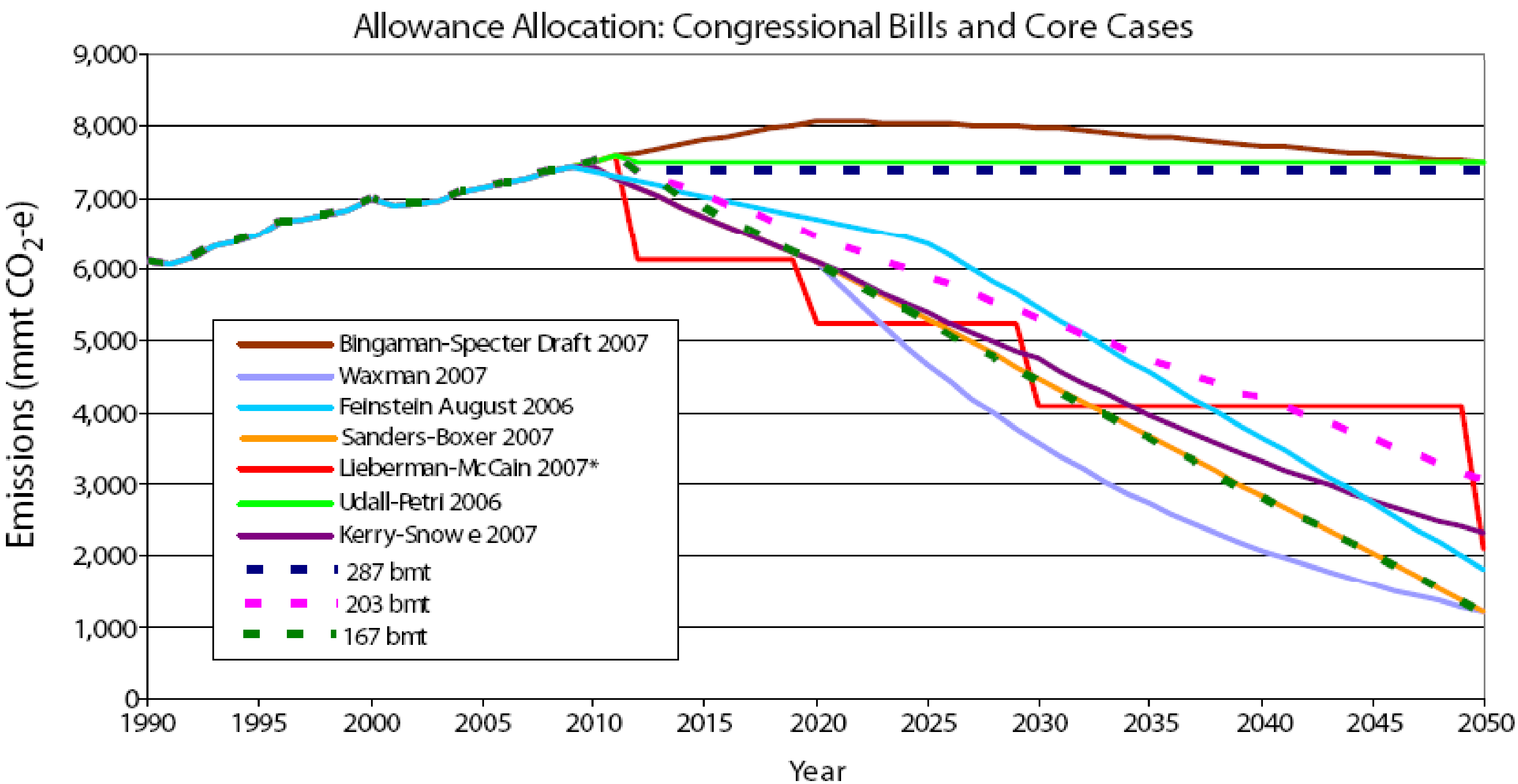

Figure 1. Scenarios of allowance allocation of Congressional Bills and core cases over time. [Note: for Lieberman-McCain, this is the allowance path for covered sectors only.]

MIT Costs Estimates

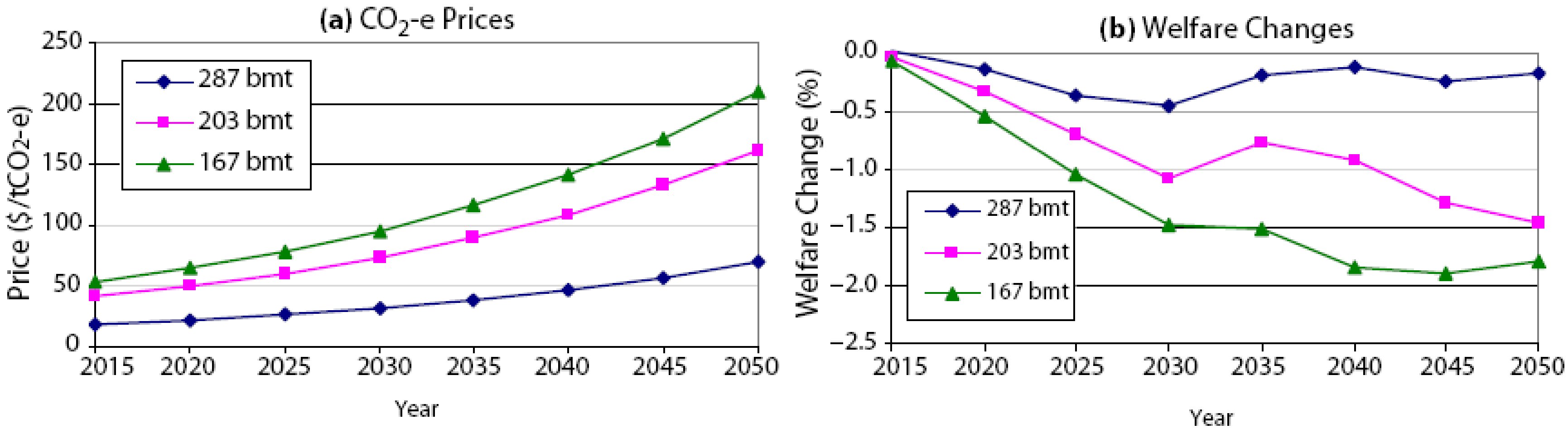

Figure 3. CO_2-e prices and welfare effects in the core scenarios: **(a)** CO_2-e prices, **(b)** welfare effects.

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Summary of Climate Change Bills Introduced in the 110th Congress

Draft as of May 9, 2007

<table>
<tr><th></th><th>Who's regulated</th><th>Allocation</th><th>Price limit / flexibility</th><th>Offsets</th><th>Technology</th></tr>
<tr><td>Bingaman-Specter (January draft)</td><td rowspan="2">Economy-wide energy-related CO_2 emissions regulated near point of fossil fuel production; process & non-CO_2 emissions regulated at source</td><td>55% directed to industry, declining 2% per year; 29-30% directed to states; remainder includes offsets, sequestration, adaptation, and technology</td><td>$7 / ton CO_2 safety valve, rising at 5% per year above inflation</td><td>Set-aside for offsets</td><td>Detailed technology provisions funded up to $50 billion from allowance sales</td></tr>
<tr><td>Udall (March draft)</td><td>20% directed to industry; 25% directed to technology; remainder includes adaptation, states, sequestration, developing countries, and general revenue</td><td>Unspecified safety valve, rising over time</td><td>Domestic offsets for sequestration</td><td>Establishes Advanced Research Project Agency for Energy (ARPA-E) with funding from allowance sales</td></tr>
<tr><td>Lieberman-McCain (S. 280)</td><td>Large downstream sources (more than 10,000 tons CO_2 per year) regulated at source; all transport emissions regulated at refinery</td><td>No more than 50% to industry; details unspecified</td><td>Borrowing (with interest)</td><td>Up to 30% of obligation can be met with sequestration and international offsets</td><td>Unspecified technology programs funded from allowance sales</td></tr>
<tr><td>Kerry-Snowe (S. 485)</td><td rowspan="3">Economy-wide emissions regulations left up to EPA</td><td rowspan="3">Unspecified</td><td rowspan="3">None</td><td rowspan="2">Domestic sequestration</td><td rowspan="3">Extensive specification of additional regulations and standards</td></tr>
<tr><td>Sanders-Boxer (S. 309)</td></tr>
<tr><td>Waxman (H.R. 1590)</td><td>None</td></tr>
<tr><td>Feinstein-Carper (S. 317)</td><td rowspan="2">Electricity-sector emissions regulated at the power plant</td><td>85% directed to industry, declining to zero by 2036, based on generation</td><td>Borrowing</td><td>Extensive agricultural offsets</td><td rowspan="2">Additional incentives for carbon capture and storage.</td></tr>
<tr><td>Alexander-Lieberman (S. 1168)</td><td>75% directed to industry based on heat input.</td><td>None</td><td>Domestic offsets in six categories</td></tr>
</table>

Summary

- Modelers need to be sure the message in their results is not getting confused before it reaches the policymaker. Clarity in exposition and follow-up with post-product users.
- Opportunities for future work
  - Technology, technology, technology
    - Models that match micro-knowledge & articulate key features
    - Empirical work to better parameterize models
  - Practical policy implementation
    - Effect of imperfect coverage across sectors, regions
    - Non-price policies
    - Burden & allocation

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