

Overview of EMF 22 International Scenarios

Thursday, July 30, 2009

Overview

- **The goal of EMF 22 is to put together, in a timely manner, a high-quality, coordinated set of transition policy scenarios using high-quality modeling to inform ongoing and upcoming climate policy discussions.**
- Moving from idealized scenarios to more realistic scenarios that don't satisfy perfect where, when, and what flexibility.
- Three focus areas:
 - International transition scenarios
 - U.S. transition scenarios
 - E.U. transition scenarios
- Modelers required to construct a common set of scenarios, but it is hoped that they will also include their own scenarios that inform particular facets of the issues being explored.

Introduction To The EMF 22 International Scenarios



The EMF 22 International Scenarios explore ten possible international approaches to mitigation.

- The ten scenarios are combinations of
 - Three concentration goals based on Kyoto gases
 - (1) 450 CO₂-e, (2) 550 CO₂-e, and (3) 650 CO₂-e
 - Two means of achieving concentration goals
 - (1) not-to-exceed this century and (2) overshoot through 2100
 - Two international policy regimes
 - (1) Full participation immediately and (2) delayed participation by non-Annex I regions and Russia

The Ten EMF 22 International Scenarios

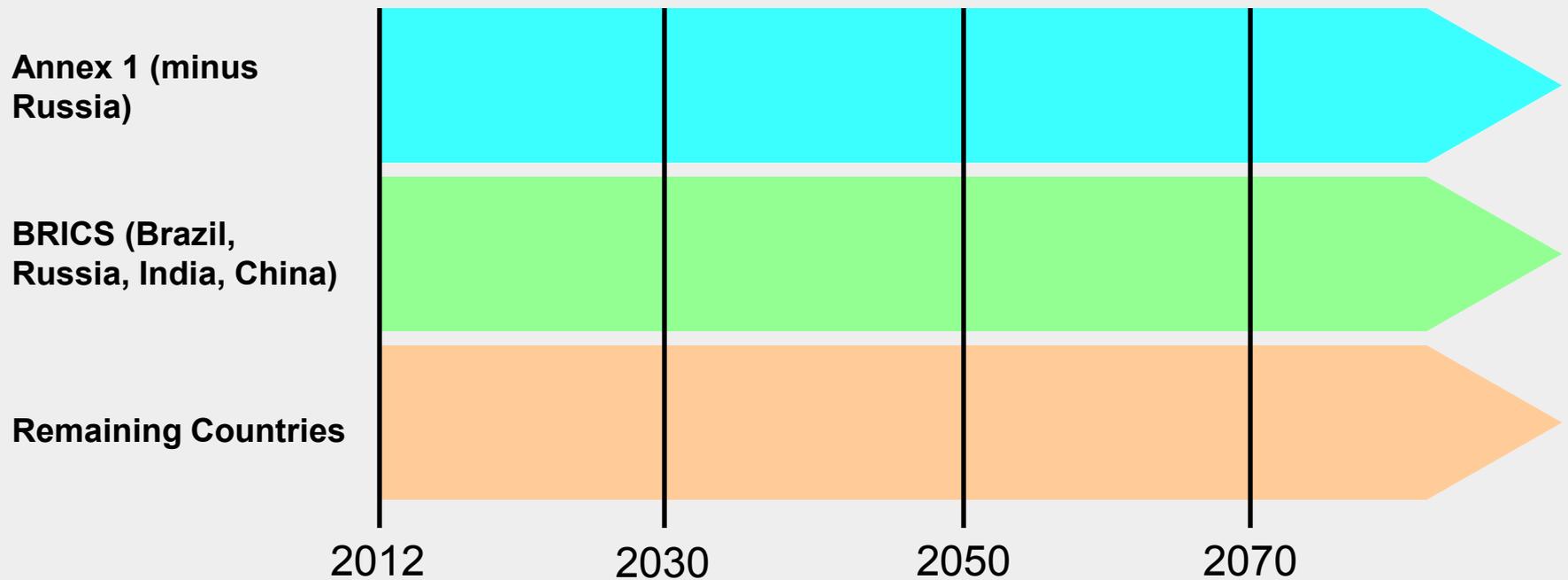
Model	650 CO ₂ -e		550 CO ₂ -e				450 CO ₂ -e			
	Full	Delay	Full		Delay		Full		Delay	
	Not-to-Exceed	Not-to-Exceed	Not-to-Exceed	Overshoot	Not-To-Exceed	Overshoot	Not-to-Exceed	Overshoot	Not-To-Exceed	Overshoot
	1	2	3	4	5	6	7	8	9	10

No overshoots were explored for the 650 CO₂-e target

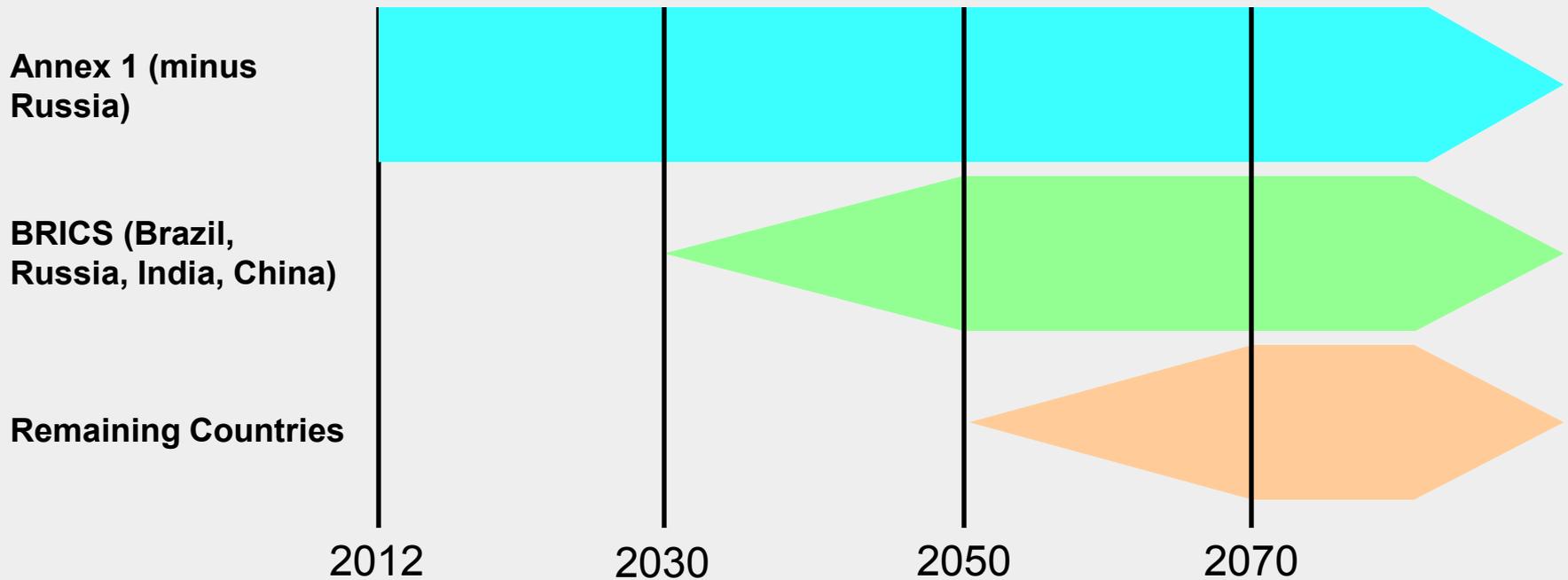
The Participating Models are From Europe, North America, and Australia

- ETSAP-TIAM (Canada)
- FUND (E.U.)
- GTEM (Australia)
- IMAGE (E.U.)
- MERGE (U.S.)
- MESSAGE (E.U.)
- MiniCAM (U.S.)
- POLES (E.U.)
- SGM (U.S.)
- WITCH (E.U.)

Full Participation: All Begin Reductions Immediately



Delayed Participation: Regions Enter the Global Coalition over Time



The delayed participation case explores the potential impacts of a one single possibility for delay in non-Annex I participation – it does not represent any real policy proposal. Mechanisms such as offsets may lead to policy structures that lie between the two cases explored in this study.

**This is not a cost-benefit
analysis.**

The Relationship Between Metrics Underlying Mitigation



The Three Long-Term Concentration Goals Considered In This Study

Targets	
Kyoto Gases Only	
Radiative Forcing (W/m ²)	CO ₂ -equivalent Concentration (ppmv)
2.6	450
3.7	550
4.5	650

Kyoto gases are CO₂, CH₄, N₂O, and non-CFC Halocarbons.

CO₂-only concentrations are lower than CO₂-e concentrations.

Targets		Results
Kyoto Gases Only		CO ₂ Only
Radiative Forcing (W/m ²)	CO ₂ -equivalent Concentration (ppmv)	CO ₂ Concentration in 2100 (ppmv)
2.6	450 	355 - 415
3.7	550 	425 - 484
4.5	650 	501 - 545

- CO₂-only in 2100 ranges represent the ranges from the participating models.

Full gas CO₂-e concentrations include the effects of other factors, such as aerosols.

Targets Kyoto Gases Only		Results CO ₂ Only	Full-Gas (IPCC Definition)	
Radiative Forcing (W/m ²)	CO ₂ -equivalent Concentration (ppmv)	CO ₂ Concentration in 2100 (ppmv)	2100 Radiative Forcing (W/m ²)	2100 CO ₂ -equivalent Concentration (ppmv)
2.6	450	335 - 415	2.5 - 2.7	427 - 460
3.7	550	425 - 481	3.5 - 3.8	535 - 566
4.5	650	501 - 545	4.2 - 4.6	610 - 657

- CO₂-only in 2100 ranges represent the ranges from the participating models.
- 2100 Non-Kyoto forcing is taken from three participating models – IMAGE, MESSAGE, and MiniCAM.

Every CO₂-e concentration is associated with a long-term equilibrium temperature.

Targets Kyoto Gases Only		Results CO ₂ Only	Full-Gas (IPCC Definition)		Equilibrium Temperature		
Radiative Forcing (W/m ²)	CO ₂ -equivalent Concentration (ppmv)	CO ₂ Concentration in 2100 (ppmv)	2100 Radiative Forcing (W/m ²)	2100 CO ₂ -equivalent Concentration (ppmv)	Low (CS = 2) (°C)	Medium (CS = 3) (°C)	High (CS = 4.5) (°C)
2.6	450	355 - 415	2.3 - 2.7	427 - 460	1.2 - 1.5	1.9 - 2.2	2.8 - 3.3
3.7	550	425 - 484	3.5 - 3.8	535 - 566	1.9 - 2.1	2.8 - 3.1	4.3 - 4.6
4.5	650	501 - 545	4.2 - 4.6	610 - 657	2.3 - 2.5	3.4 - 3.7	5.1 - 5.6

- CO₂-only in 2100 ranges represent the ranges from the participating models.
- 2100 Non-Kyoto forcing is taken from three participating models – IMAGE, MESSAGE, and MiniCAM.
- Climate sensitivity ranges from the IPCC Fourth Assessment Report.

Every CO₂-e concentration is associated with a long-term equilibrium temperature.

Key Results Radiative Forcing (W/m ²)	Targets		Full-Gas (IPCC Definition)		Equilibrium Temperature		
	2100 Radiative Forcing (W/m ²)	2100 CO ₂ -e Concentration (ppmv)	2100 Radiative Forcing (W/m ²)	2100 CO ₂ -e Concentration (ppmv)	Low (CS = 2) (°C)	Medium (CS = 3) (°C)	High (CS = 4.5) (°C)
Beyond 2100, CO ₂ -e concentrations and temperature could increase or decrease depending on post-2100 actions.	2.6	450	In overshoot pathways, temperatures could exceed the long-term equilibrium levels prior to 2100.		2 - 1.5	1.9 - 2.2	2.8 - 3.3
	3.7	550			9 - 2.1	2.8 - 3.1	4.3 - 4.6
	4.5	650			3 - 2.5	3.4 - 3.7	5.1 - 5.6

- CO₂-only in 2100 ranges represent the ranges from the participating models.
- 2100 Non-Kyoto forcing is taken from three participating models – IMAGE, MESSAGE, and MiniCAM.
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An Overview Of The Submitted Scenarios

Which scenarios were the modeling groups able to provide?

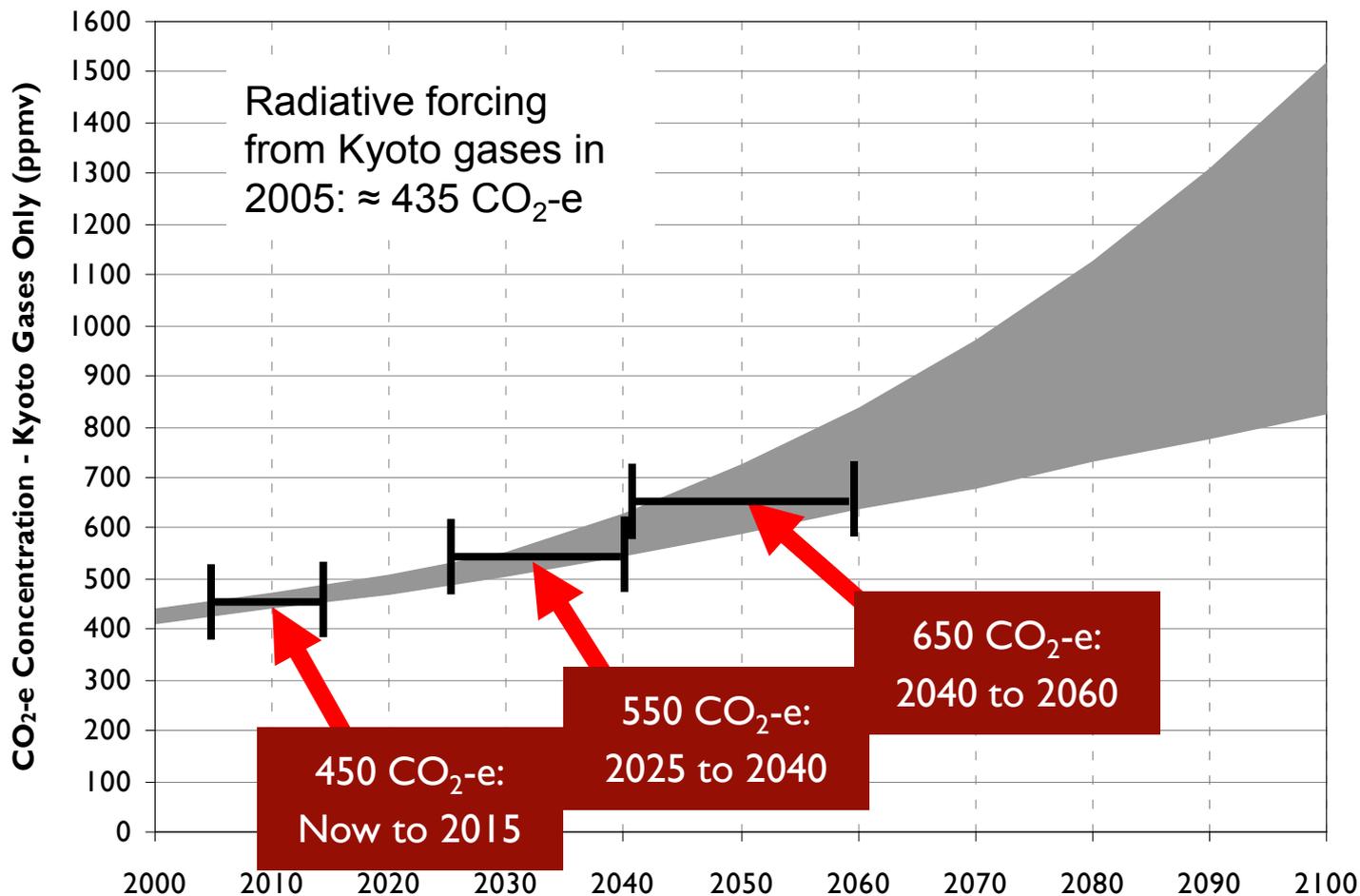
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	Full	Delay	Full		Delay		Full		Delay		
	Not-to-Exceed	Not-to-Exceed	Not-to-Exceed	Overshoot	Not-To-Exceed	Overshoot	Not-to-Exceed	Overshoot	Not-To-Exceed	Overshoot	
1 ETSAP-TIAM	+	+	+	+	+	+	+	+	+	XX	+
2 FUND	+	+	+	+	+	+	+	XX	+	XX	XX
3 GTEM	+	+	+	+	XX	+	XX	+	XX	XX	XX
4 IMAGE	+	+	+	+	+	+	XX	XX	XX	XX	XX
IMAGE-BC	+	+	+	+	+	+	XX	+	XX	XX	XX
5 MERGE Optimistic	+	+	+	+	XX	XX	XX	XX	XX	XX	XX
MERGE Pessimistic	+	+	+	+	+	+	XX	XX	XX	XX	XX
6 MESSAGE	+	+	+	+	XX	+	XX	+	XX	XX	XX
7 MiniCAM Base	+	+	+	+	XX	+	+	+	XX	XX	+
MiniCAM LoTech	+	+	+	+	XX	+	XX	+	XX	XX	XX
8 POLES	+	+	+	+	XX	+	XX	XX	XX	XX	XX
9 SGM	+	+	+	+	+	+	XX	XX	XX	XX	XX
10 WITCH	+	+	+	+	+	+	XX	XX	XX	XX	XX



Reasons That Models Were Not Able To Provide Particular Scenarios.

- Physically infeasible (e.g., RF exceeds target before full entry)
- Model could not solve because of the aggressiveness of the constraint (e.g., solution mechanism failed, decline constraints prevent solution, CO₂ price limits in model)
- Initial carbon price above \$1000/tCO₂

Without mitigation, CO₂-e concentrations will quickly pass the three long-term goals.



Which scenarios were the modeling groups able to provide?

Model	650 CO2-e		550 CO2-e				450 CO2-e				
	Full		Full		Delay		Full		Delay		
	Not-to-Exceed	Not-to-Exceed	Not-to-Exceed	Overshoot	Not-To-Exceed	Overshoot	Not-to-Exceed	Overshoot	Not-To-Exceed	Overshoot	
1 ETSAP-TIAM	+	+	+	+	+	+	+	+	+	XX	+
2 FUND	+	+	+	+	+	+	+	XX	+	XX	XX
3 GTEM	+	+	+	+	XX	+	XX	+	XX	XX	XX
4 IMAGE	+	+	+	+	+	+	XX	XX	XX	XX	XX
IMAGE-BC	+	+	+	+	+	+	XX	+	XX	XX	XX
5 MERGE Optimistic	+	+	+	+	XX	XX	XX	XX	XX	XX	XX
MERGE Pessimistic	+	+	+	+	+	+	XX	XX	XX	XX	XX
6 MESSAGE	+	+	+	+	XX	+	XX	+	XX	XX	XX
7 MiniCAM Base	+	+	+	+	XX	+	+	+	XX	XX	+
MiniCAM LoTech	+	+	+	+	XX	+	XX	+	XX	XX	XX
8 POLES	+	+	+	+	XX	+	XX	XX	XX	XX	XX
9 SGM	+	+	+	+	+	+	XX	XX	XX	XX	XX
10 WITCH	+	+	+	+	+	+	XX	XX	XX	XX	XX

The Challenge of 450 CO₂-e

The Challenges of 450 CO₂-e

(From the MiniCAM Paper: Calvin et al.)



	Not-to-Exceed	Overshoot
Immediate Accession	<ul style="list-style-type: none"> 1) Includes immediate participation by all regions 2) Includes 70% dramatic emissions reductions by 2020 3) Includes substantial transformation of the energy system by 2020, including the construction of 500 new nuclear reactors, and the capture of 20 billion tons of CO₂ 4) Includes a carbon price of \$100/tCO₂ globally in 2020 5) Includes a tax on land-use emissions beginning in 2020 6) Includes advanced technologies 	<ul style="list-style-type: none"> 1) Includes immediate participation by all regions 2) Includes the construction of 126 new nuclear reactors and the capture of nearly a billion tons of CO₂ in 2020 3) Includes negative global emissions by the end of the century, and thus requires broad deployment of bioCCS technologies 4) Carbon prices escalate to \$775/tCO₂ in 2095 5) Possible without a tax on land-use emissions, but would result in a tripling of carbon taxes and a substantial increase in the cost of meeting the target.
Delayed Accession		<ul style="list-style-type: none"> 1) Includes dramatic emissions reductions for Groups 2 and 3 at the time of their accession, 2) Includes negative emissions in Group 1 by 2050 and negative global emissions by the end of the century, and thus requires broad deployment of bioCCS technologies 3) Carbon prices begin at \$50/tCO₂, and rise to \$2000/tCO₂ 4) Results in significant land-use leakage, where crop production is outsourced to non-participating regions resulting in a substantial increase in land-use change emissions in these regions

The Challenges of 450 CO₂-e

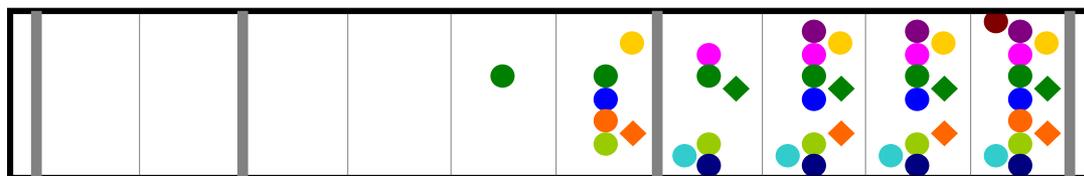
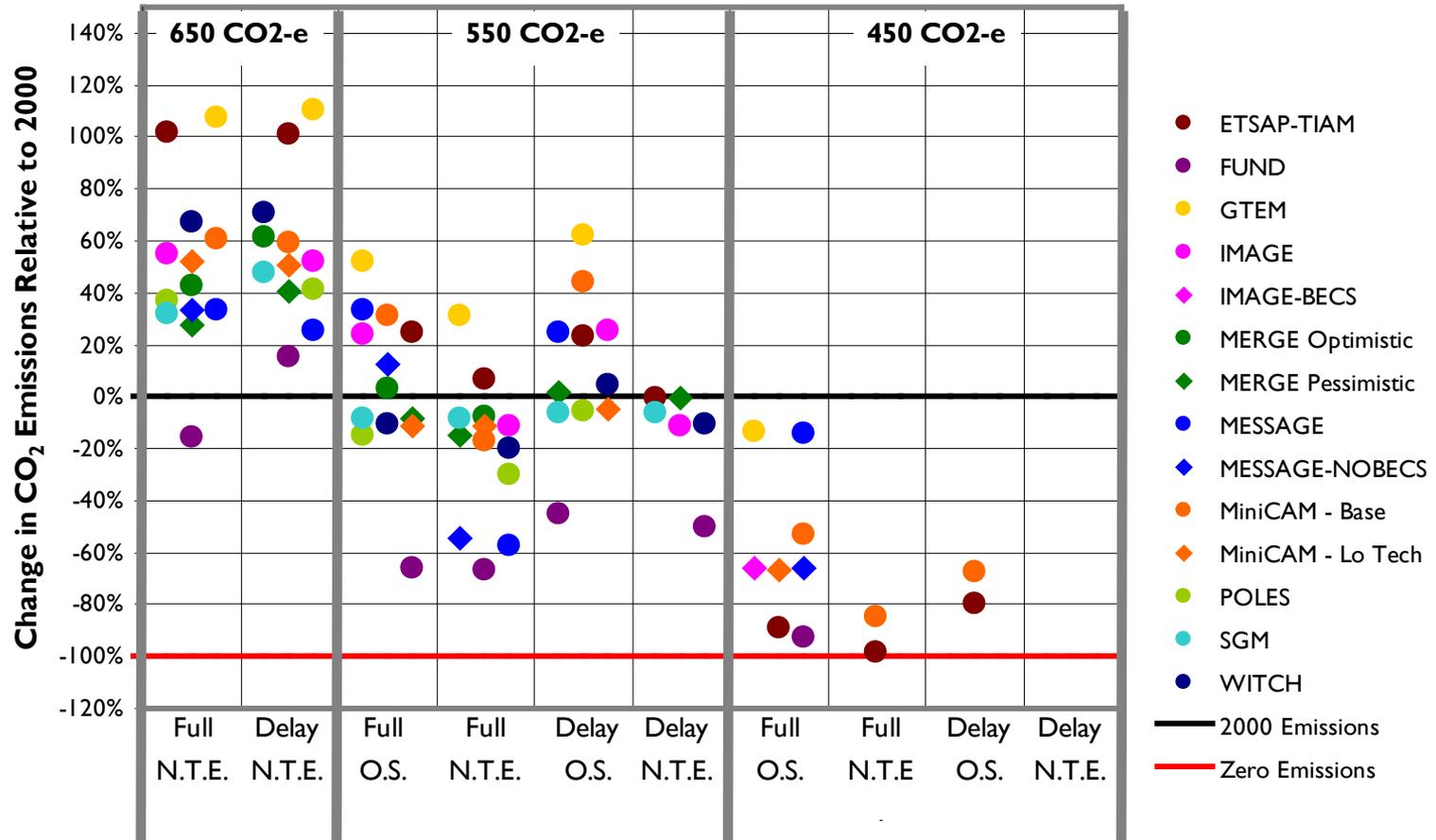
(From the MiniCAM Paper: Calvin et al.)



	Not-to-Exceed	Overshoot
Immediate Accession	<p>2) Includes 70% emissions reductions by 2020</p> <p>3) Includes substantial transformation of the energy system by 2020, including the construction of 500 new nuclear reactors, and the capture of 20 billion tons of CO₂</p> <p>5) Includes a tax on land-use emissions beginning in 2020</p>	<p>2) Includes the construction of 126 new nuclear reactors and the capture of nearly a billion tons of CO₂ in 2020</p> <p>3) Requires broad deployment of bioCCS technologies</p> <p>4) Requires a tripling of carbon taxes and a substantial increase in the cost of meeting the target.</p>
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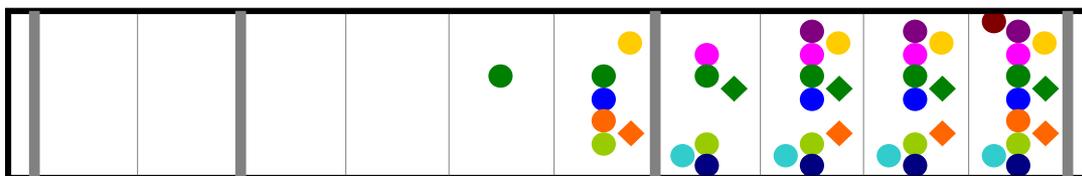
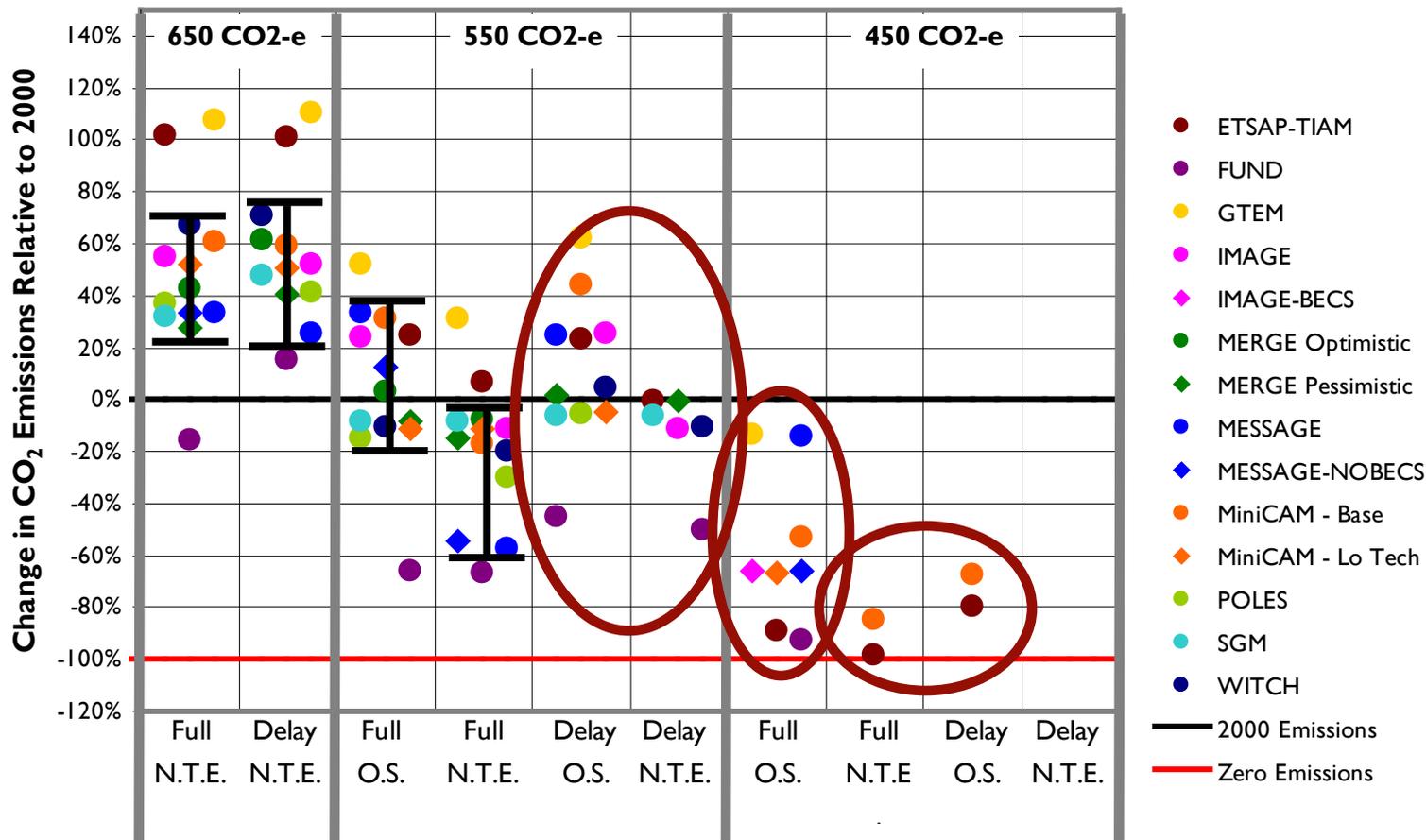
Global Emissions Across Scenarios

Global Emissions Reductions: 2050



Scenarios that could not be modeled under criteria of study.

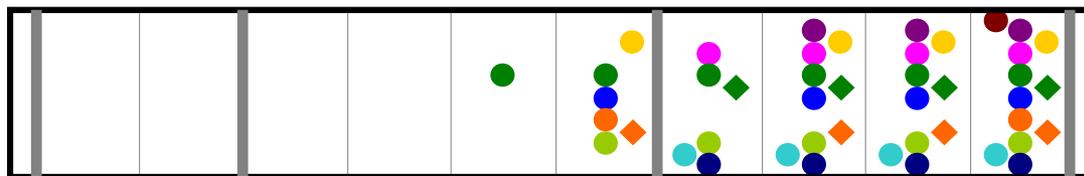
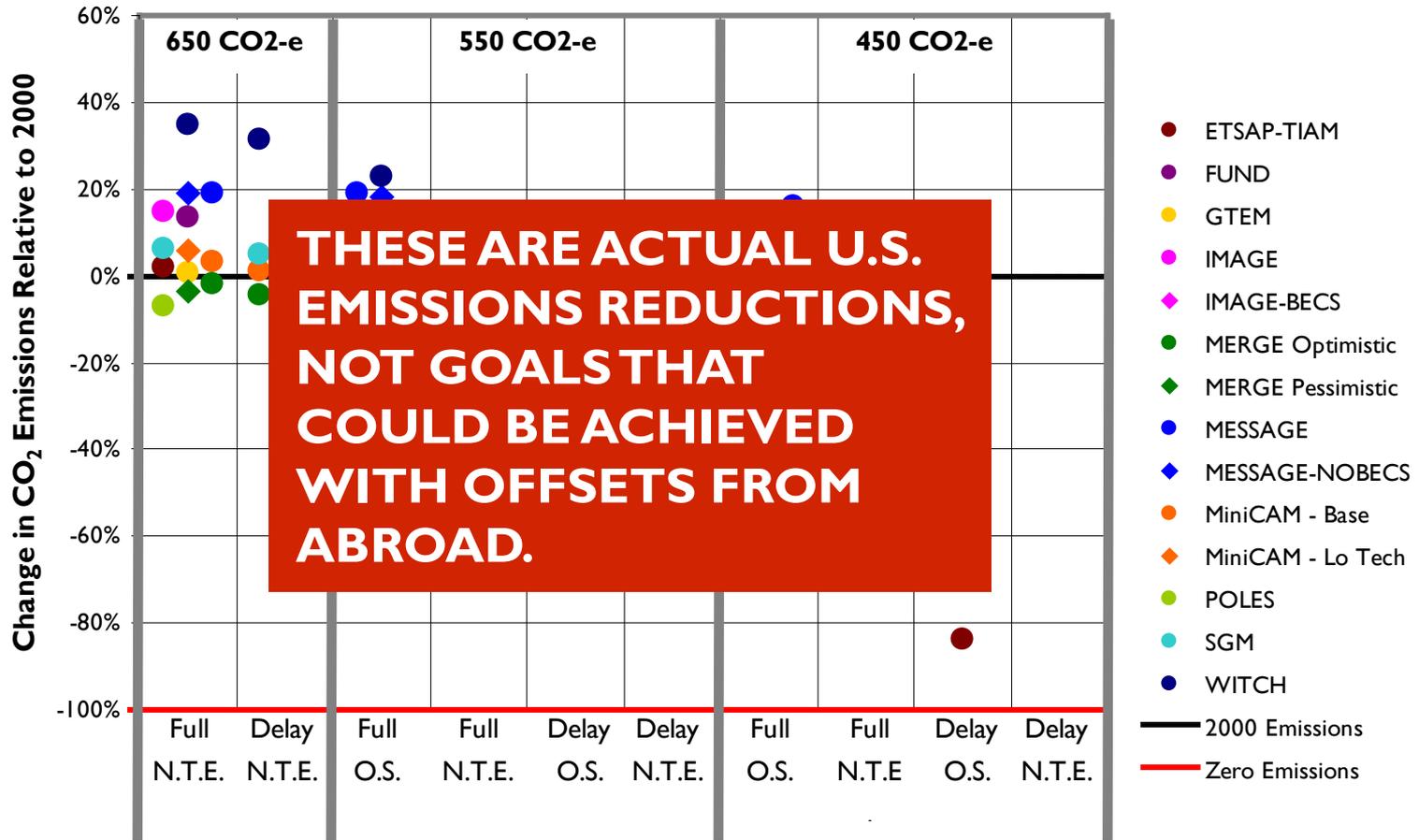
Global Emissions Reductions: 2050



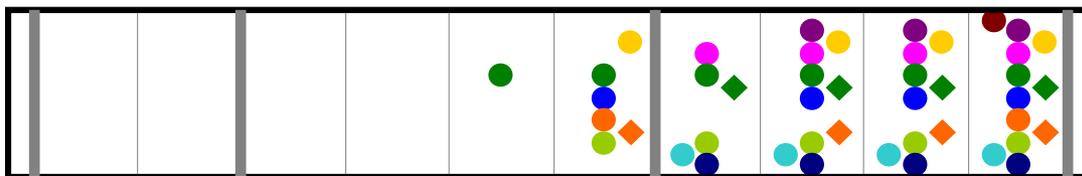
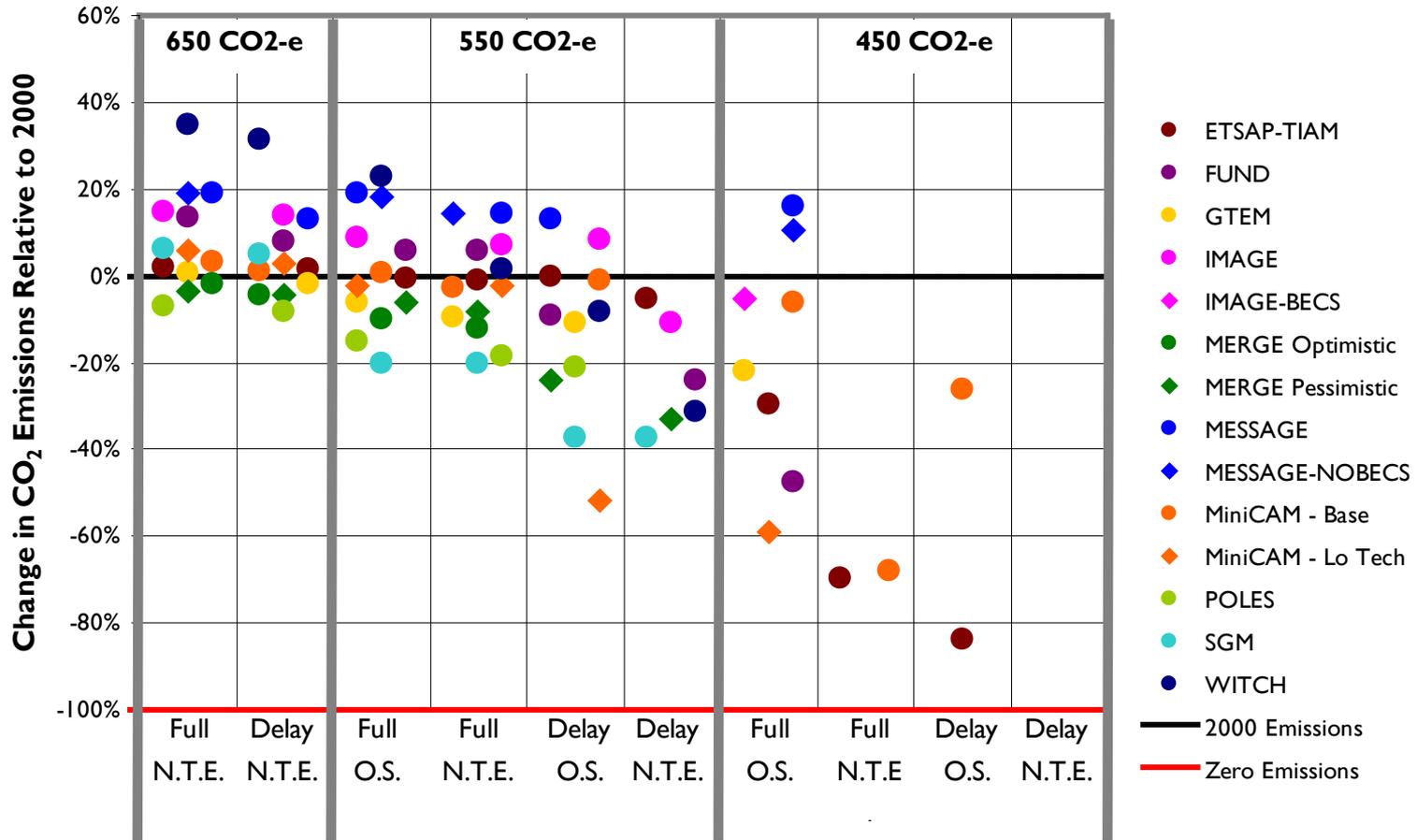
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Global and Regional Emissions Across Scenarios

U.S. Emissions Reductions: 2020

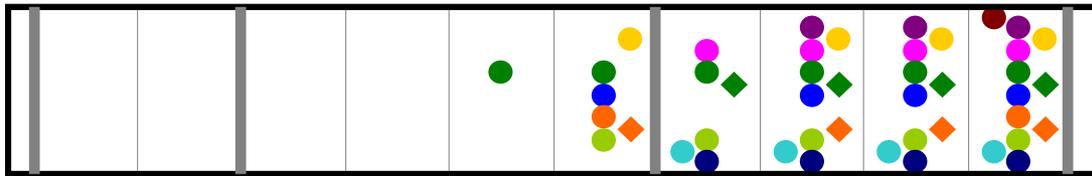
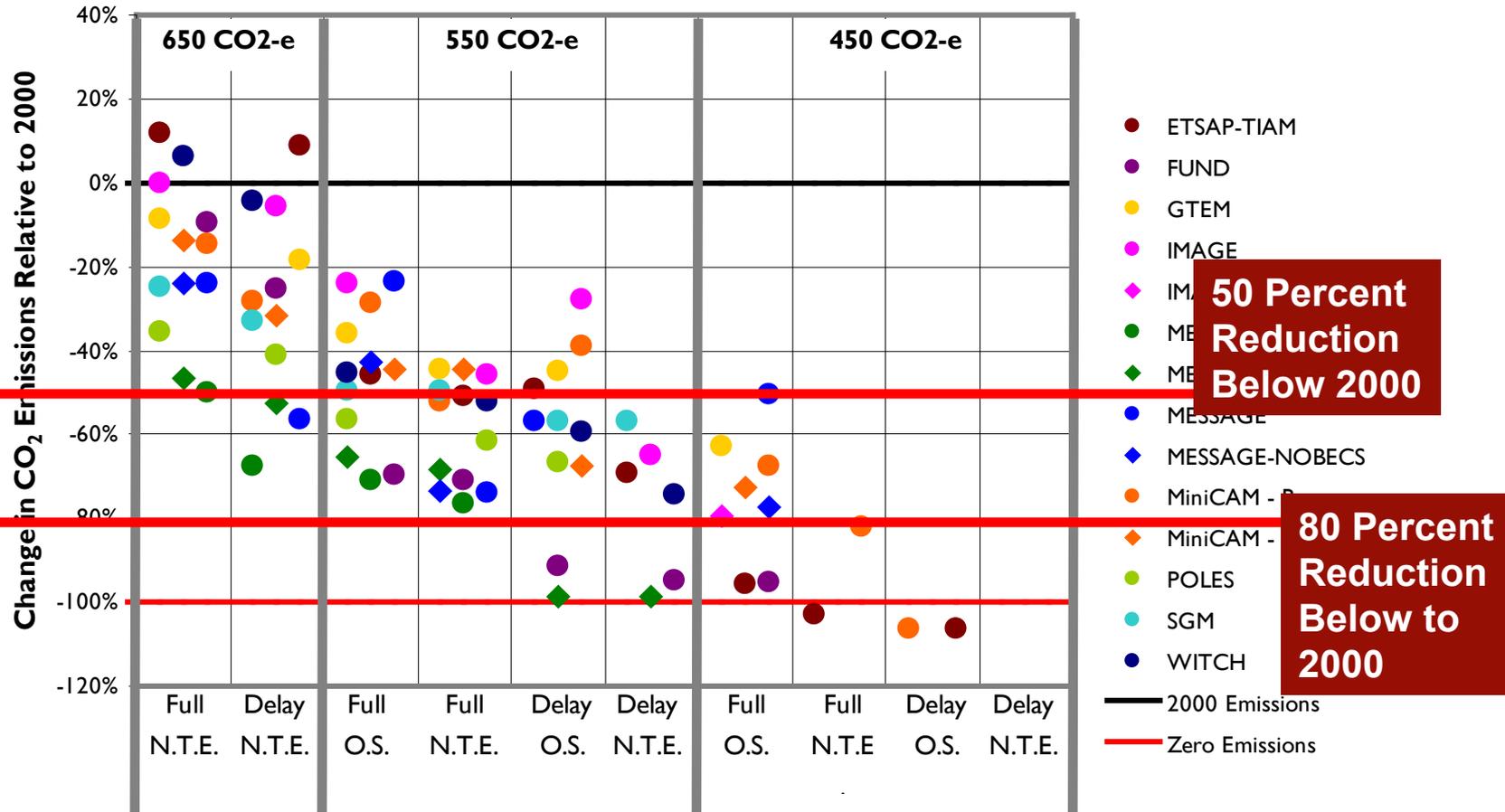


U.S. Emissions Reductions: 2020



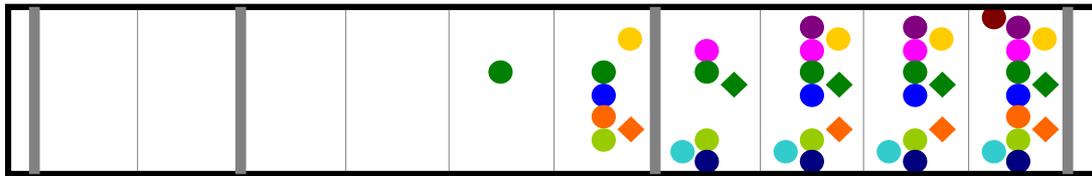
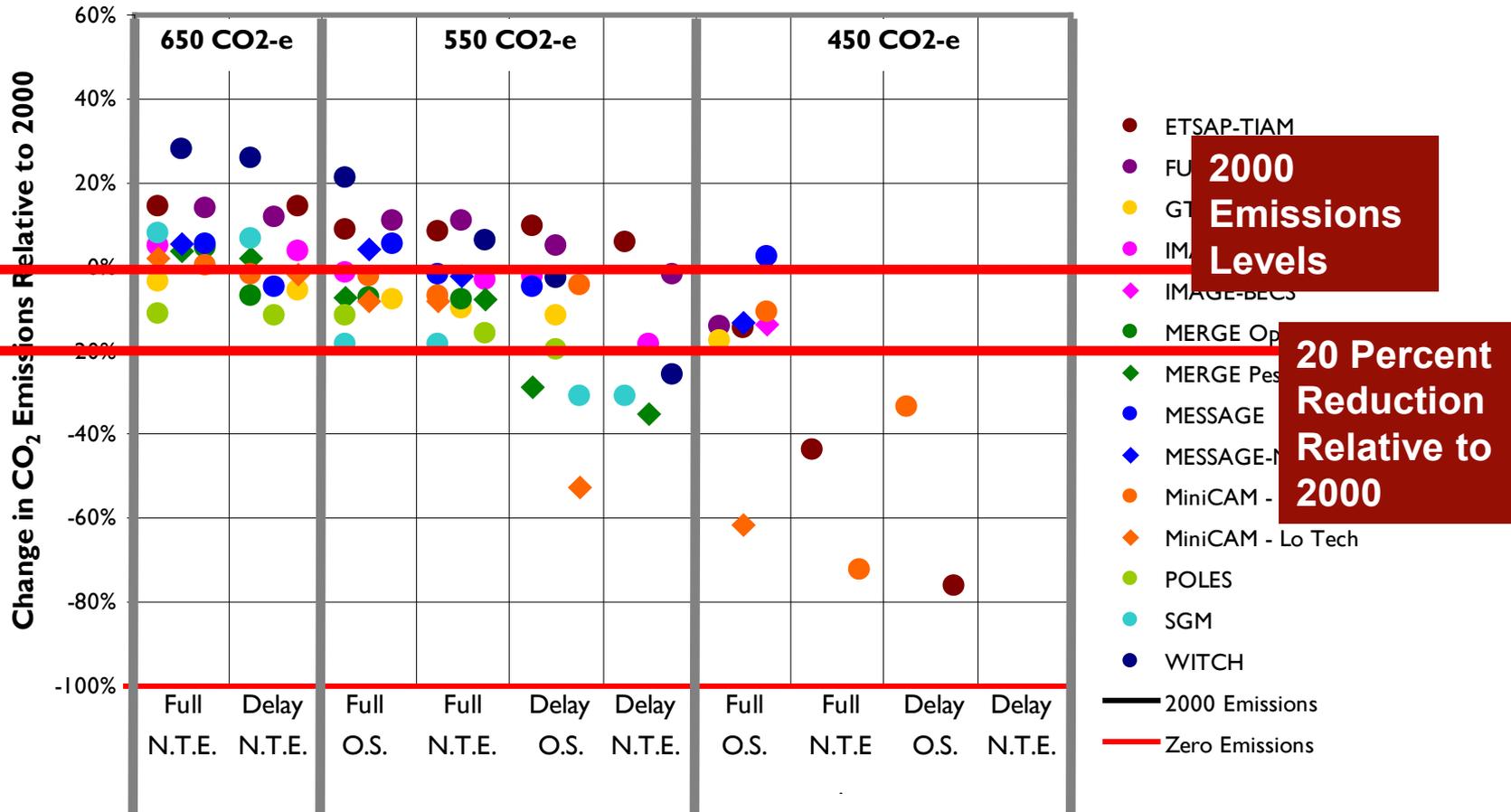
Scenarios that could not be modeled under criteria of study.

U.S. Emissions Reductions: 2050



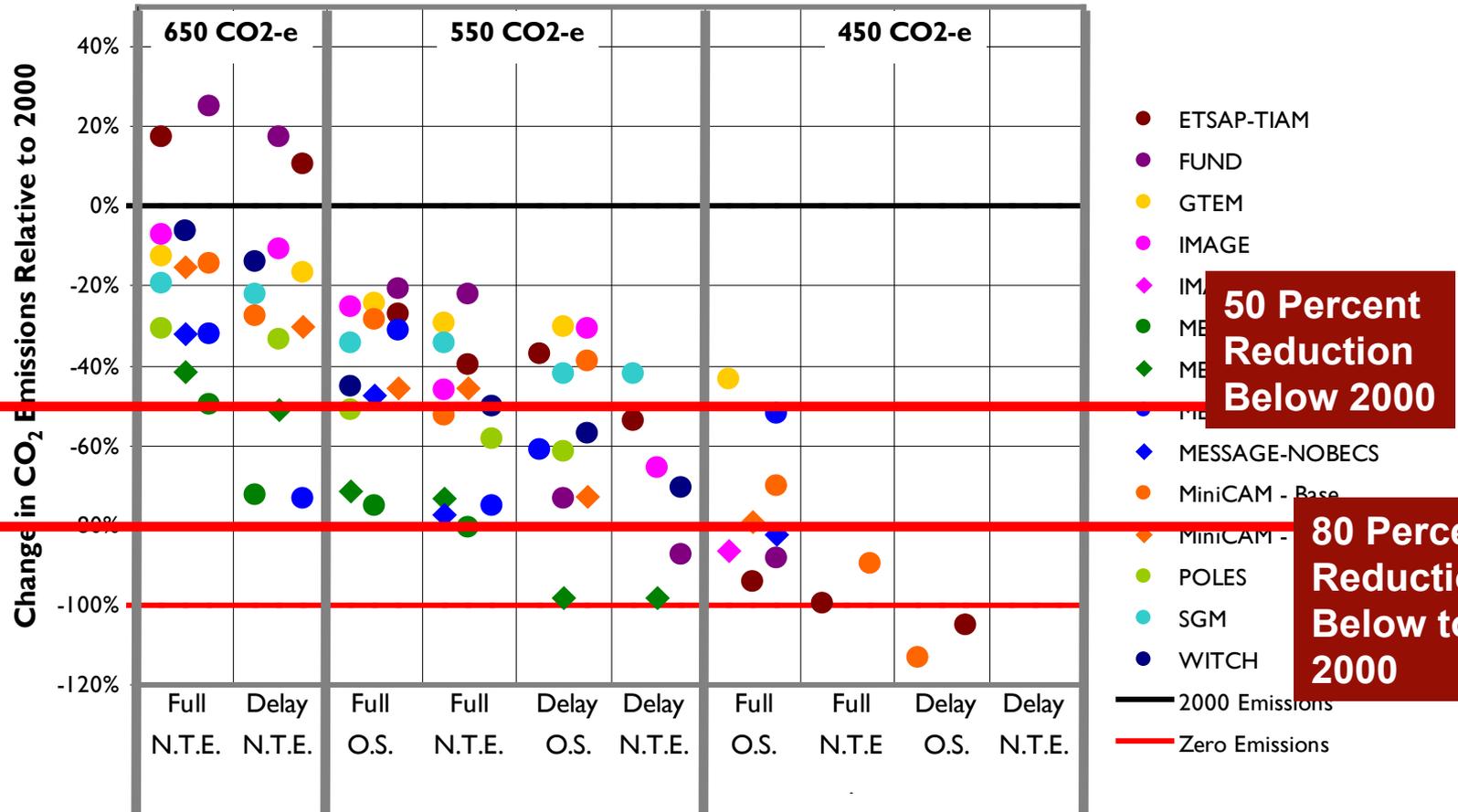
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E.U. Emissions Reductions: 2020



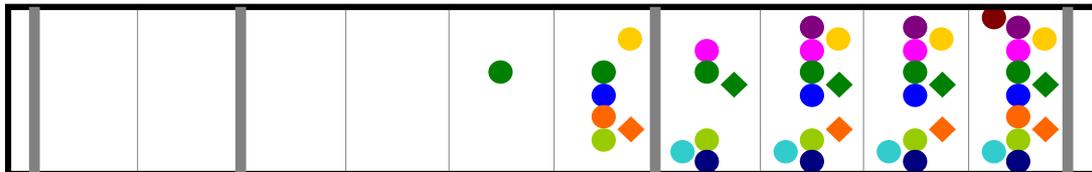
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E.U. Emissions Reductions: 2050



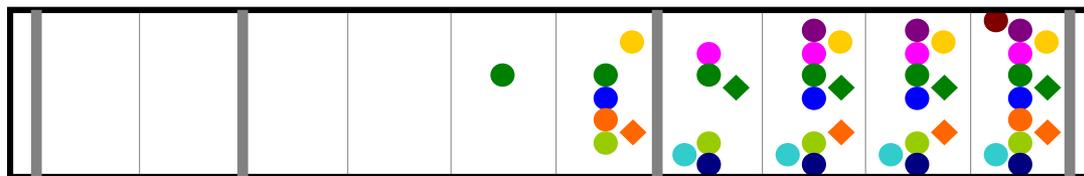
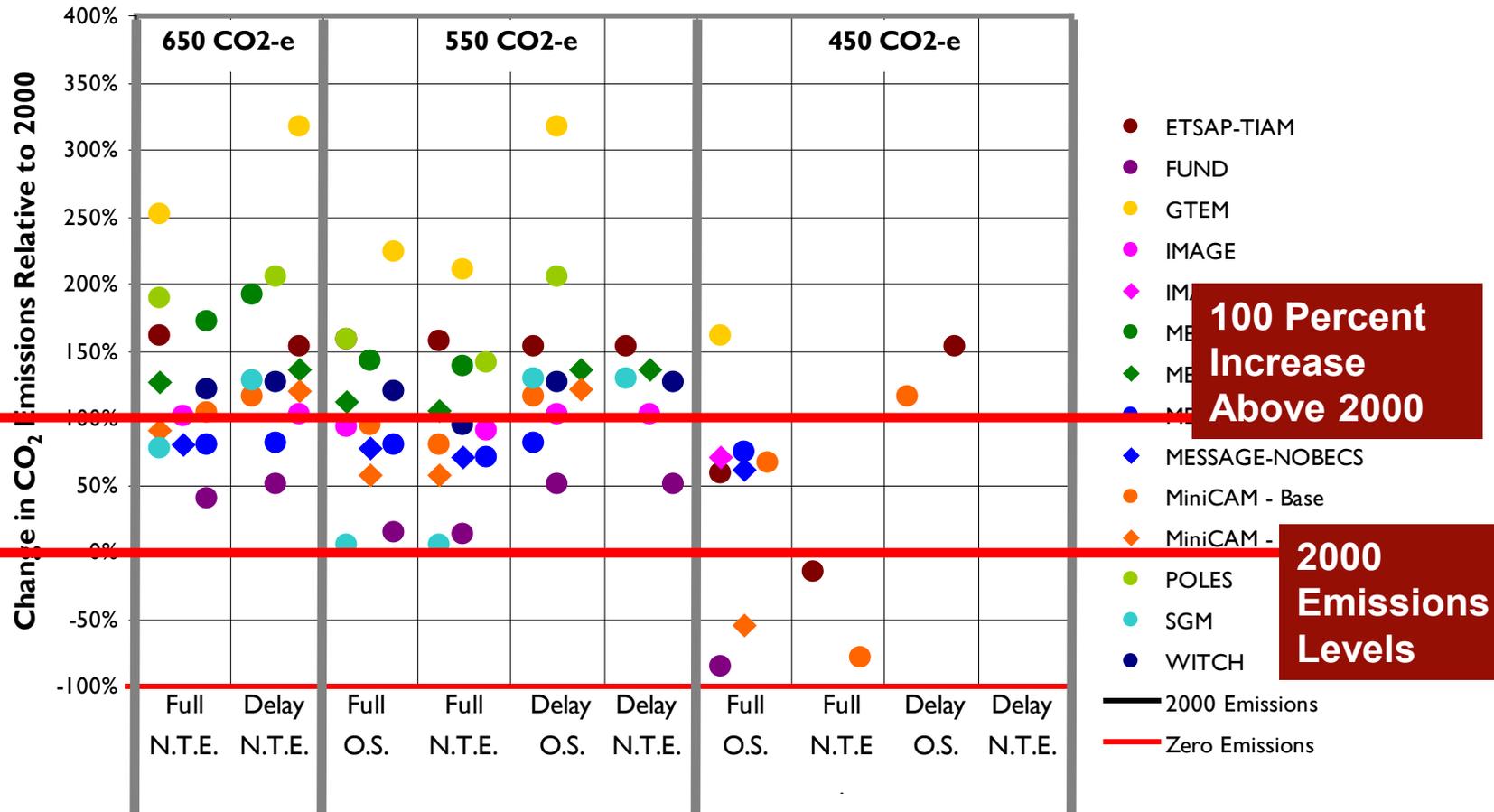
50 Percent Reduction Below 2000

80 Percent Reduction Below to 2000



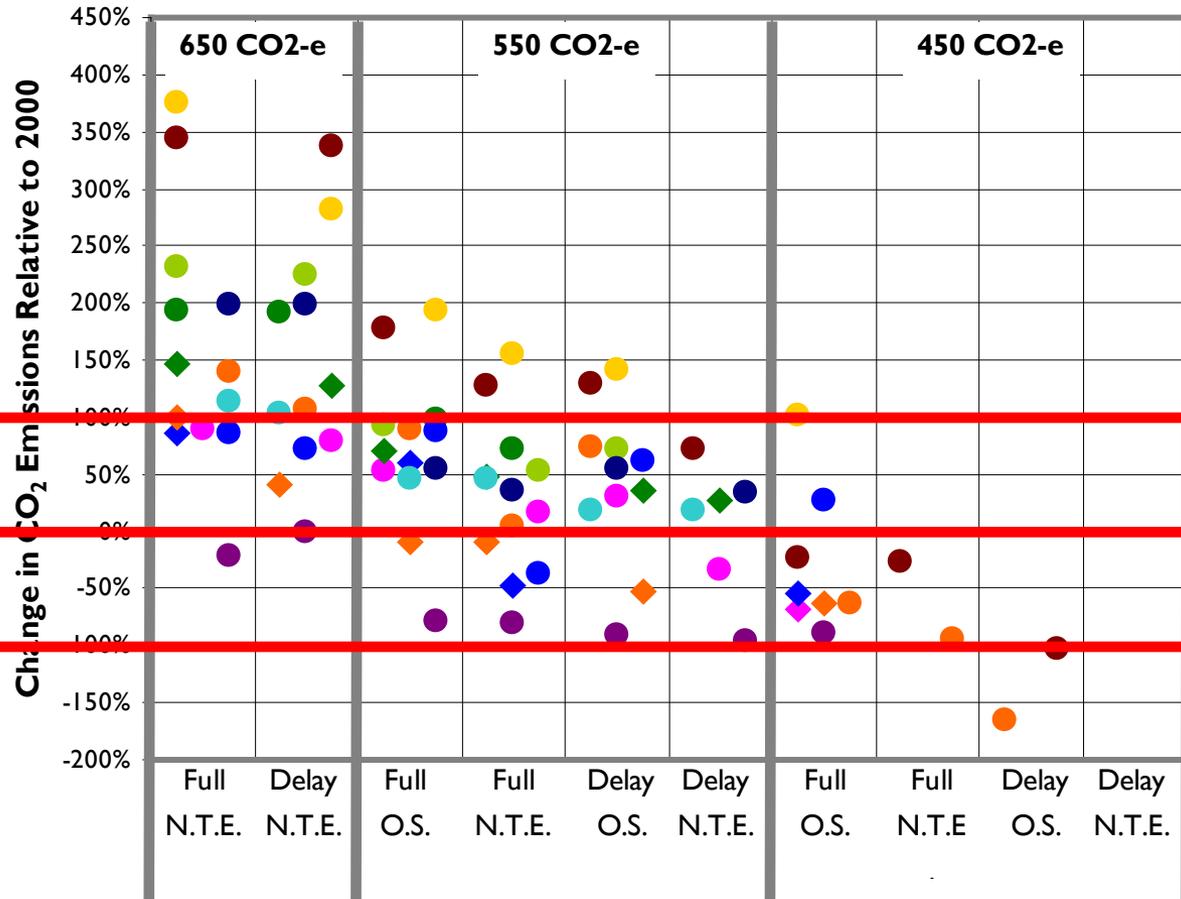
Scenarios that could not be modeled under criteria of study.

China Emissions Reductions: 2020



Scenarios that could not be modeled under criteria of study.

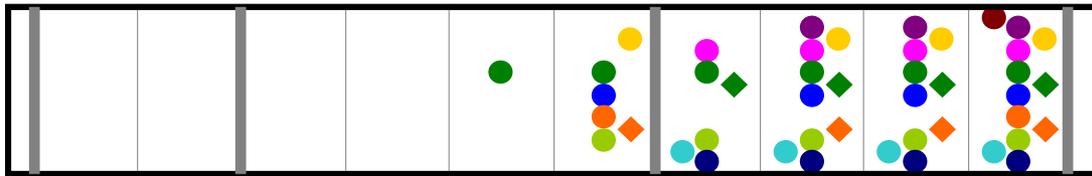
China Emissions Reductions: 2050



100 Percent Increase Above 2000

2000 Emissions Levels

100 Percent Reduction Below to 2000



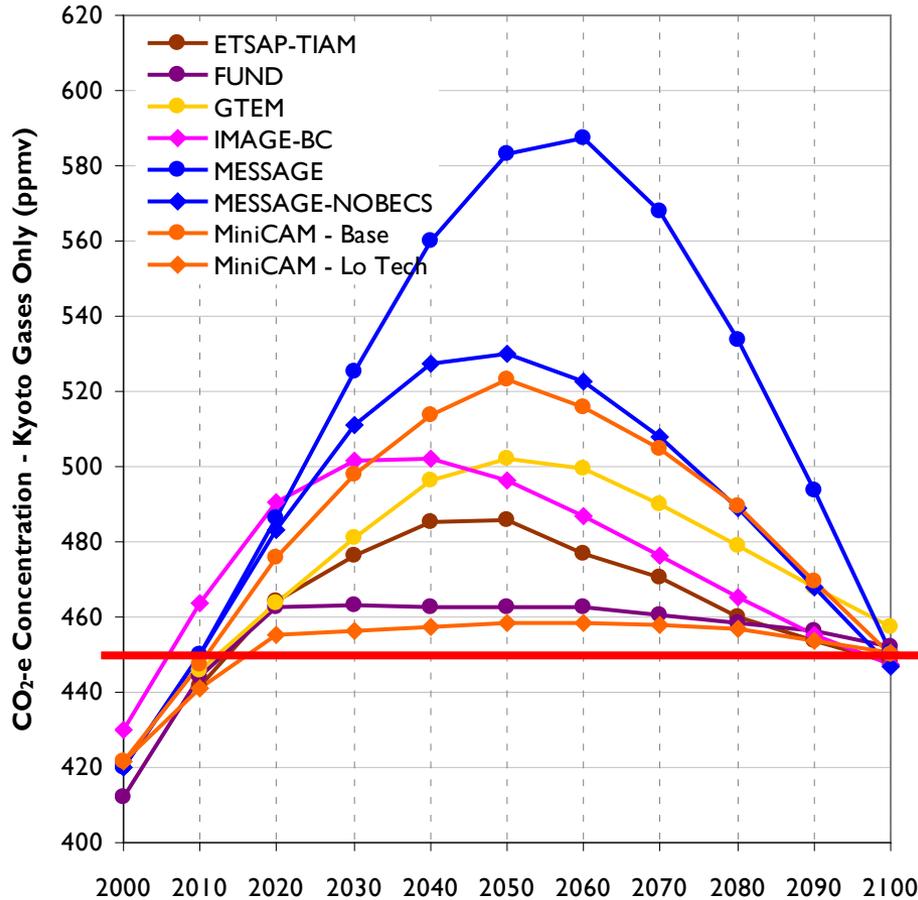
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A Word On Overshoot

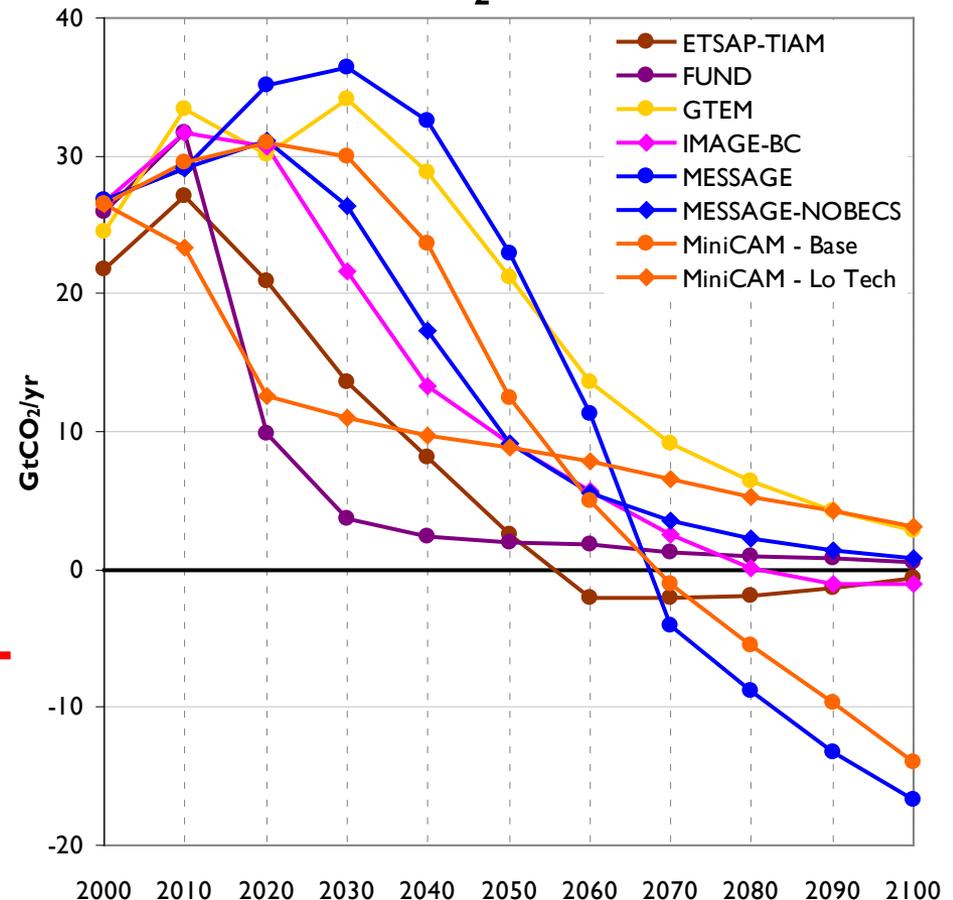
A Word on Overshoot

450 CO₂-e Overshoot: Full Participation

Concentrations



CO₂ Emissions

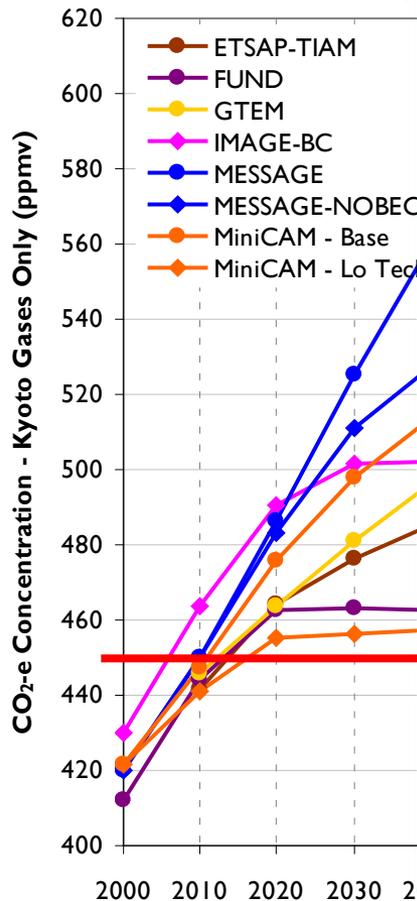


A Word on Overshoot

450 CO₂-e Overshoot: Full Participation

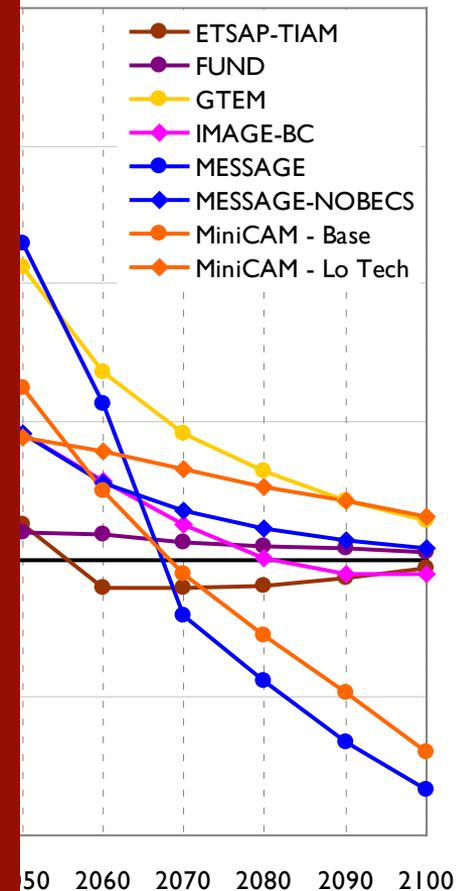
Concentrations

CO₂ Emissions



Overshoot scenarios

- Allow for flexibility in emissions reductions through mid-century
- Raise the possibility of lower concentrations beyond 2100
- Exceed the target concentration prior to 2100, with implications for temperature
- Can require dramatic emissions reduction beyond mid-century.



A Summary Of Issues Addressed In This Study

Issues Addressed In This Study

- The challenges associated with meeting different targets
- The relationship between U.S. emissions reductions and global goals
- The emissions and economic implications of delayed participation
- The costs and benefits of overshoot pathways
- **The economic costs of the scenarios**
- **Physical requirements of different scenarios (e.g., energy systems)**
- **Effects of economic growth on difficulty of meeting targets**
- **Leakage effects**
- **The role of land use policies**
- **Uncertainty**
- **The role and benefits of technology**
- **Intermediate targets**
- **The implications of anticipation for policy architectures**

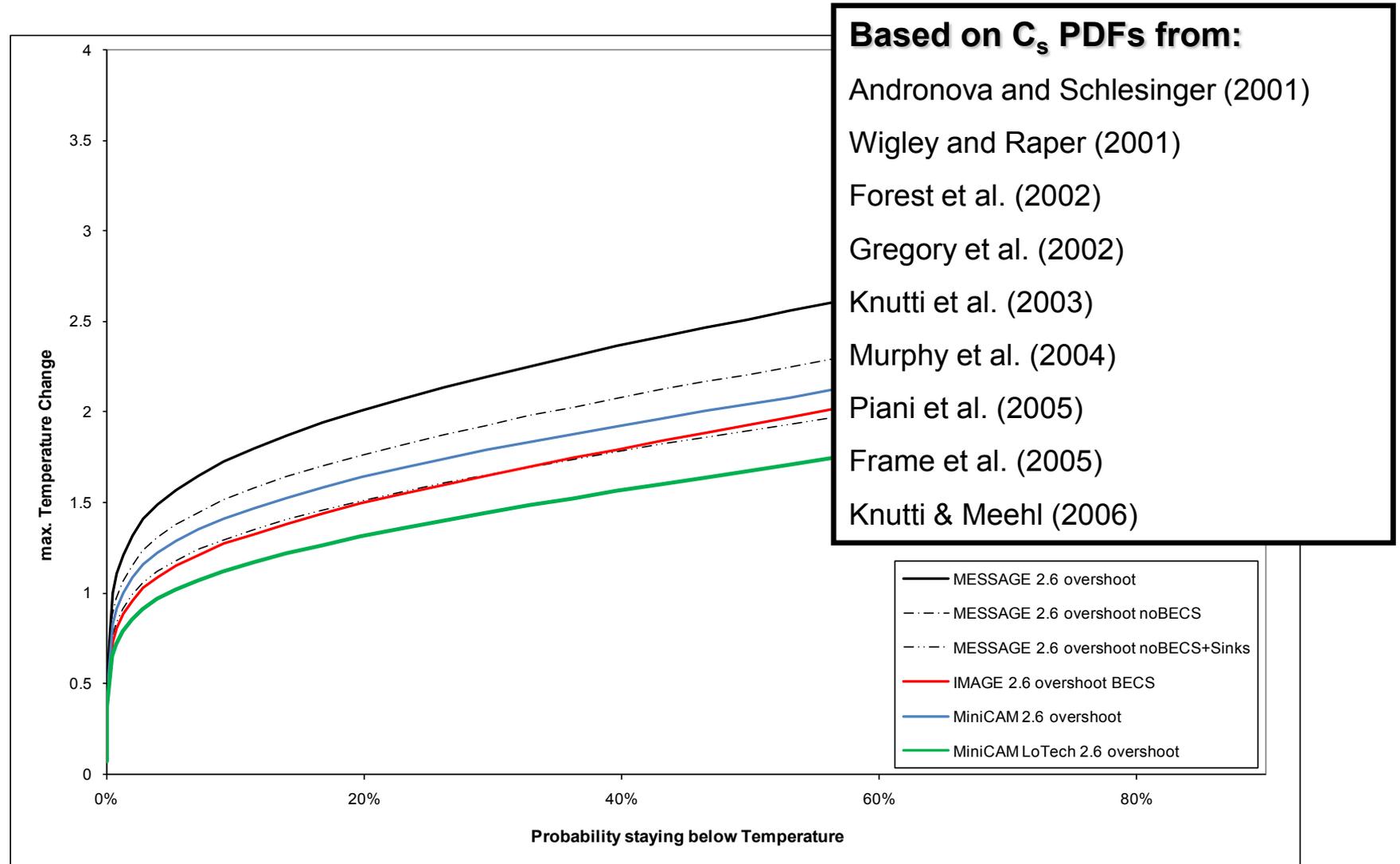
END

The Temperature Implications of Overshoot

Probability Of Staying Below Temperature

Target: 450 CO₂-e Overshoot

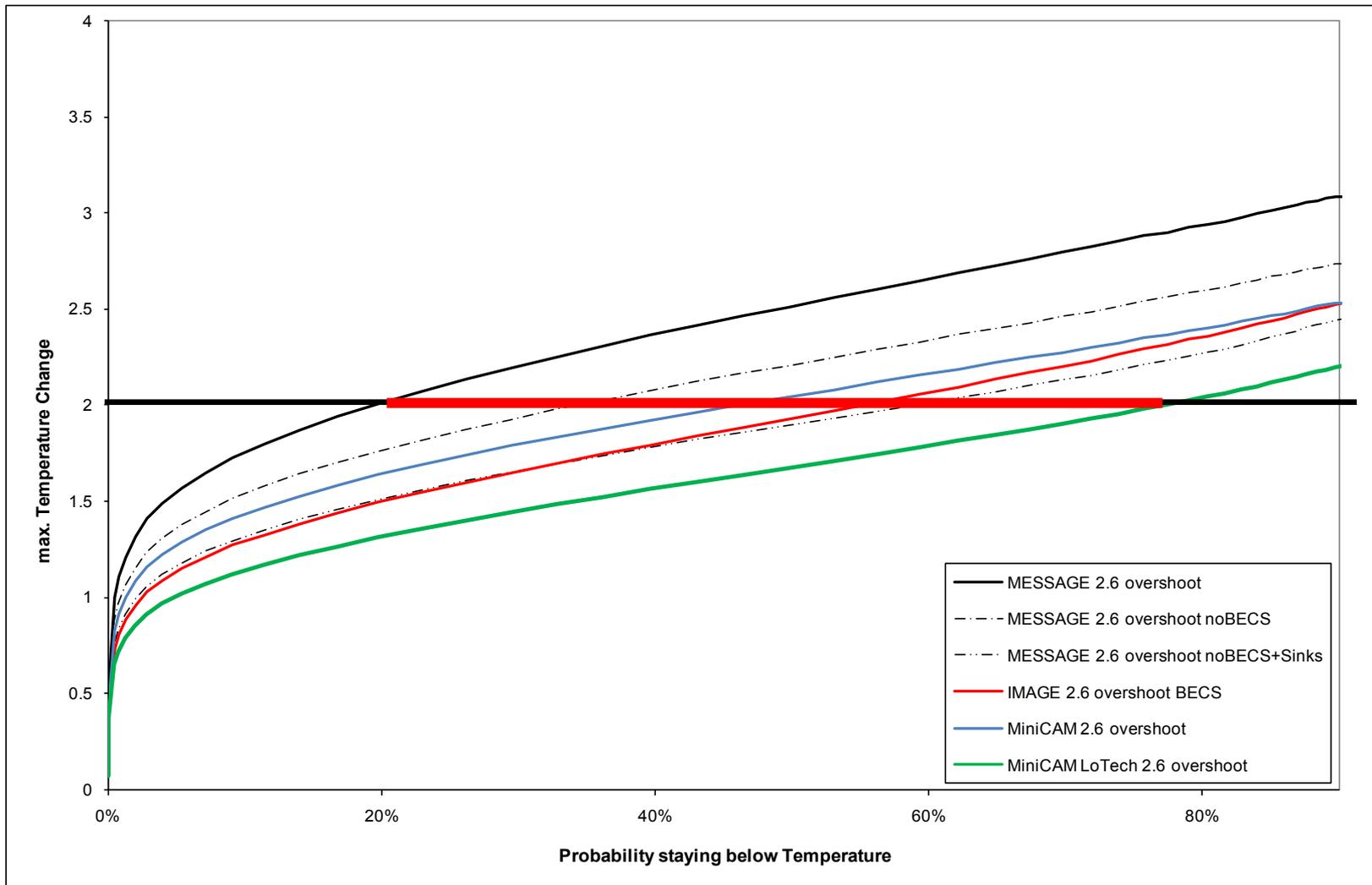
[From the MESSAGE paper: Krey et al.]



Probability Of Staying Below Temperature

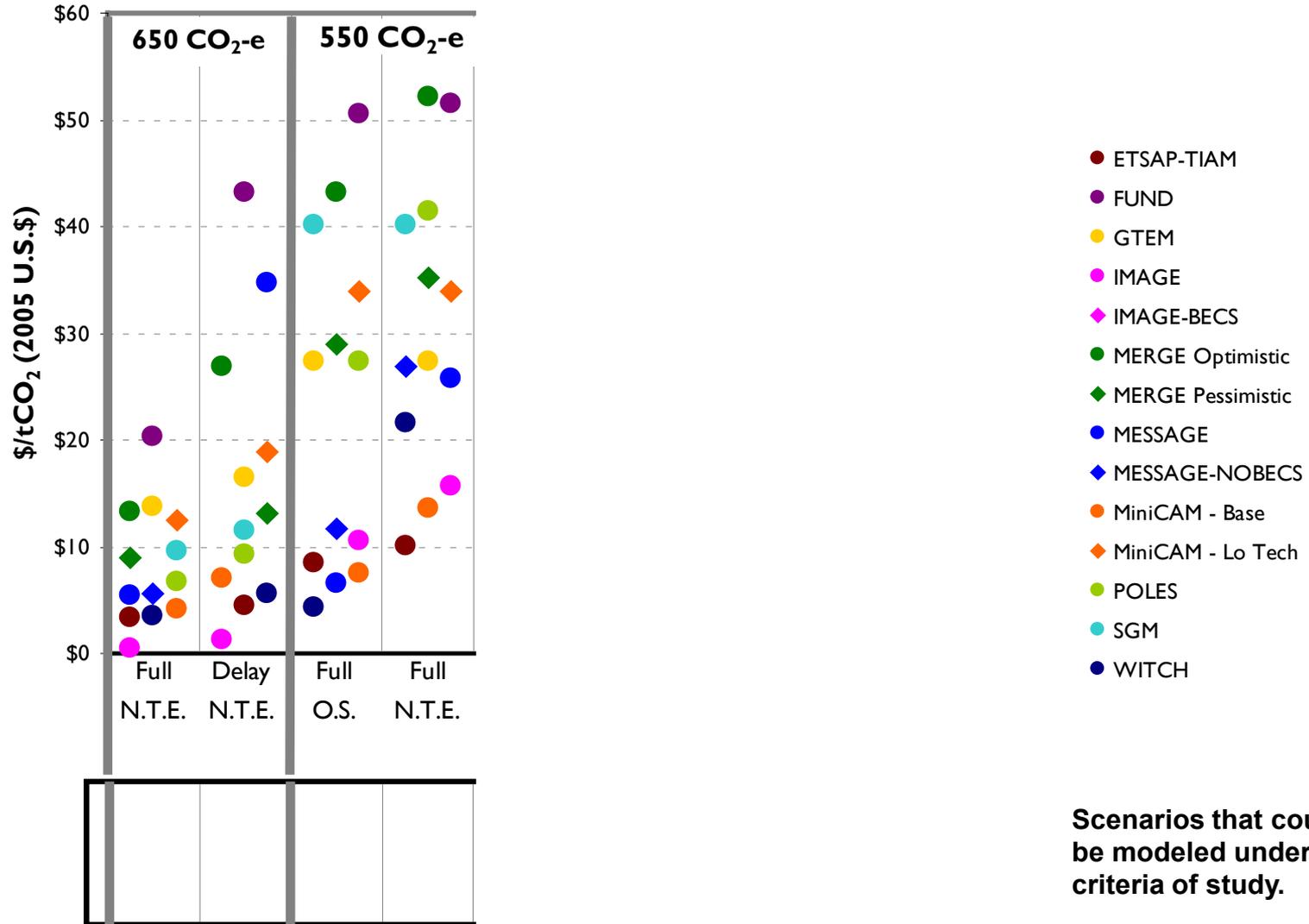
Target 450 CO₂-e Overshoot

[From the MESSAGE paper: Krey et al.]

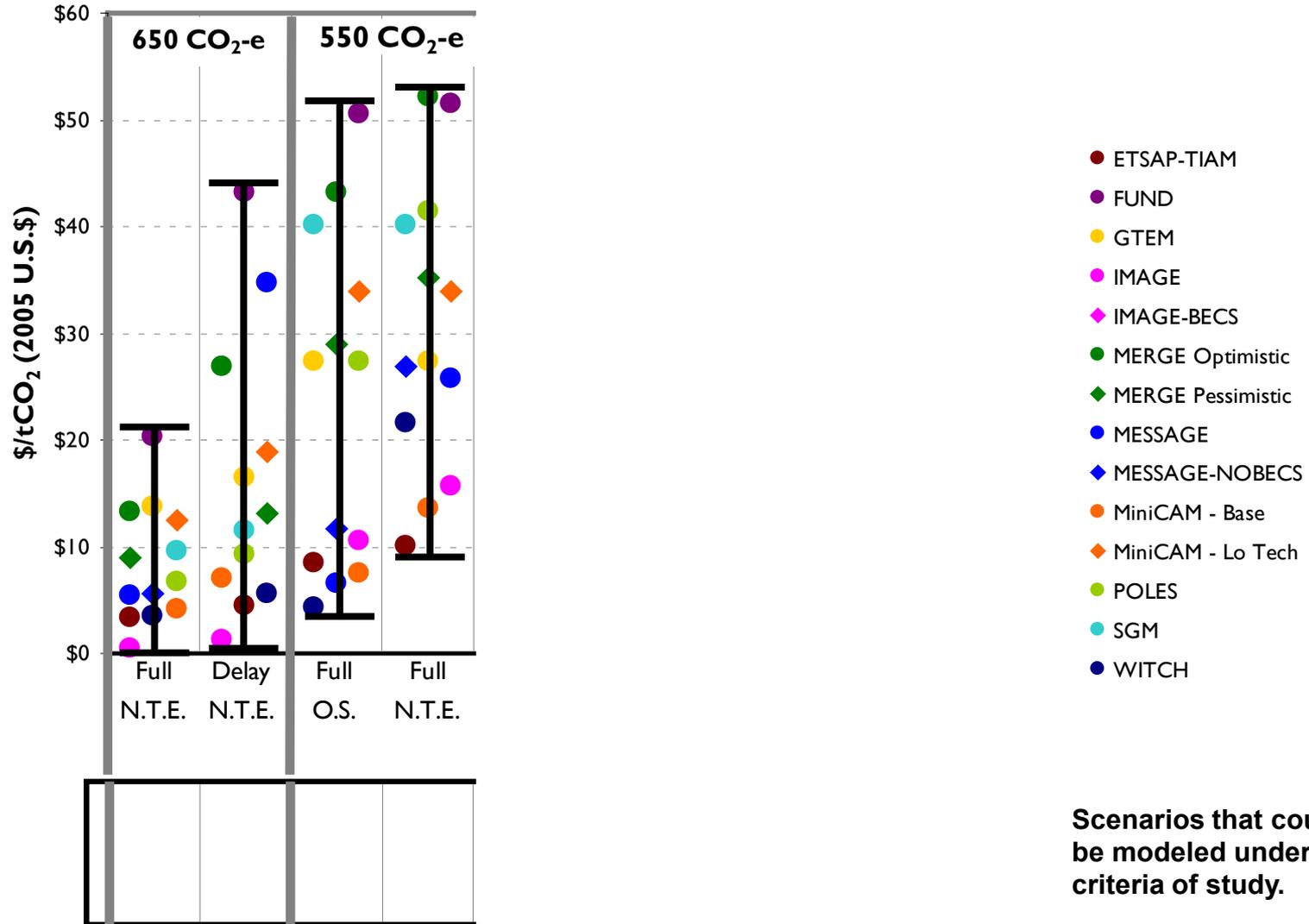


Carbon Prices In 2020 Across Scenarios

Annex I 2020 Carbon Prices

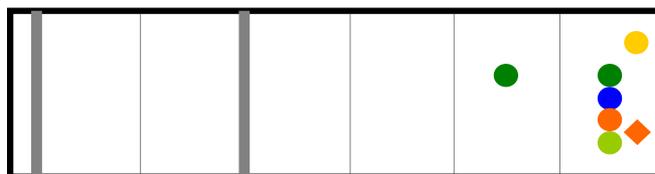
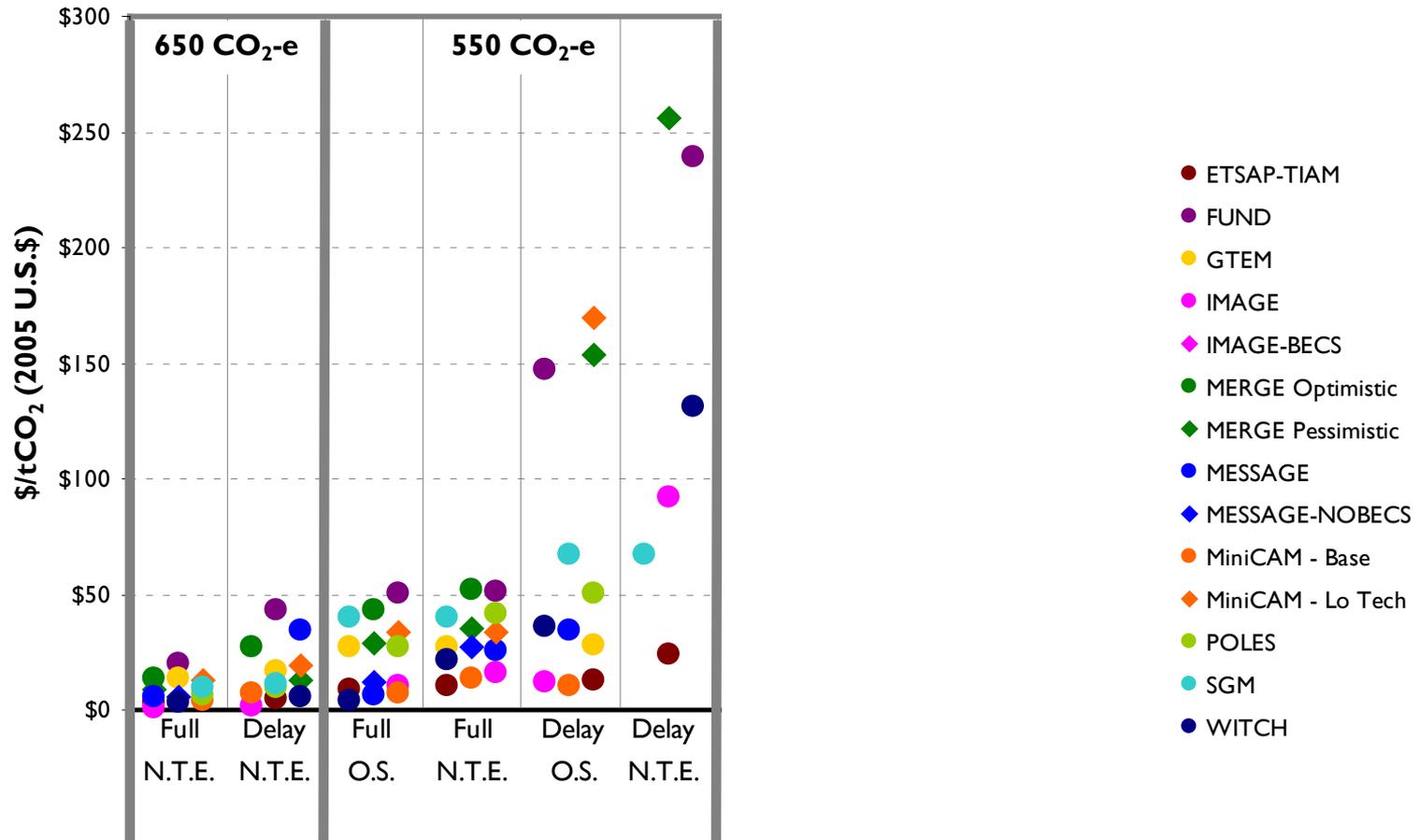


Annex I 2020 Carbon Prices



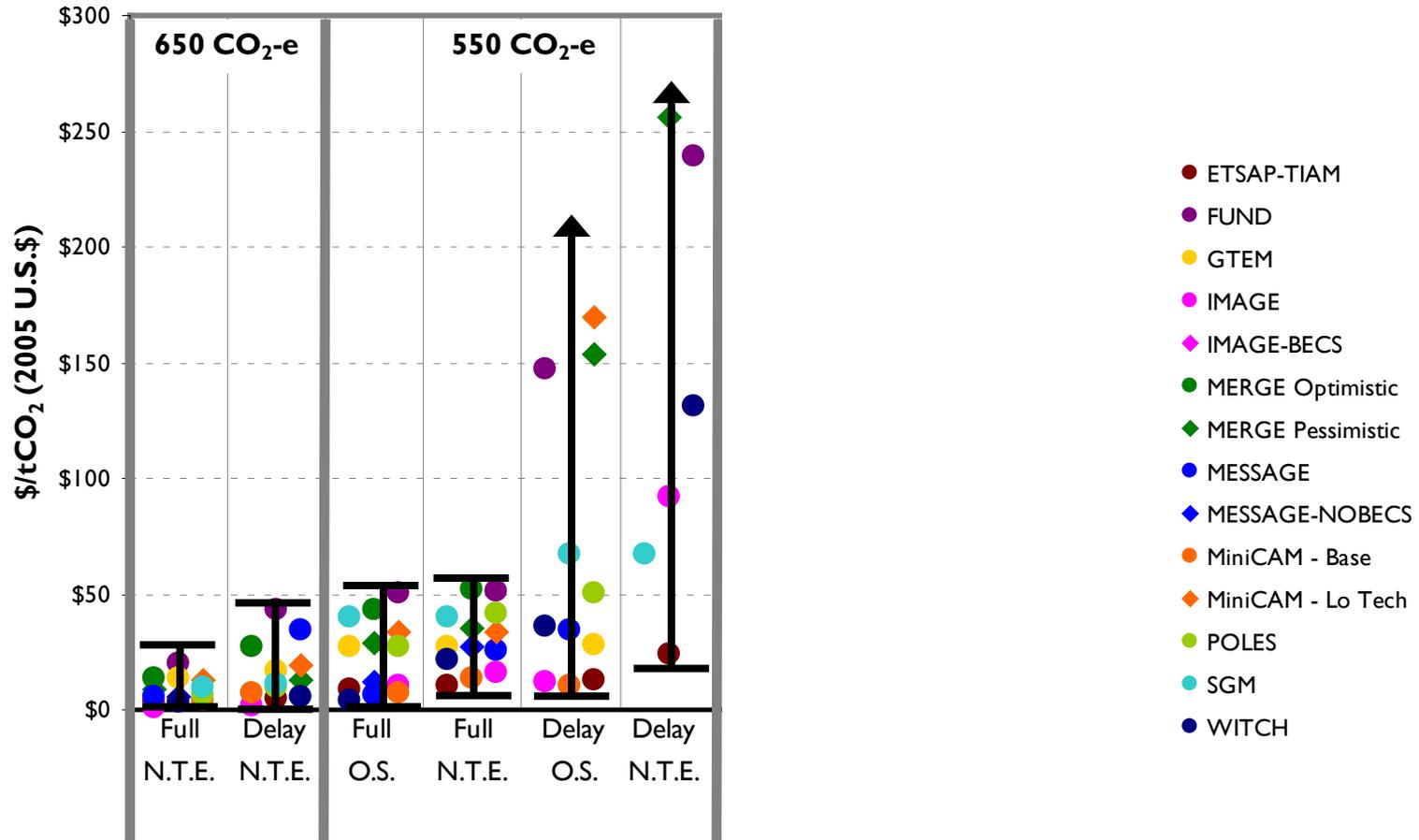
Scenarios that could not be modeled under criteria of study.

Annex I 2020 Carbon Prices



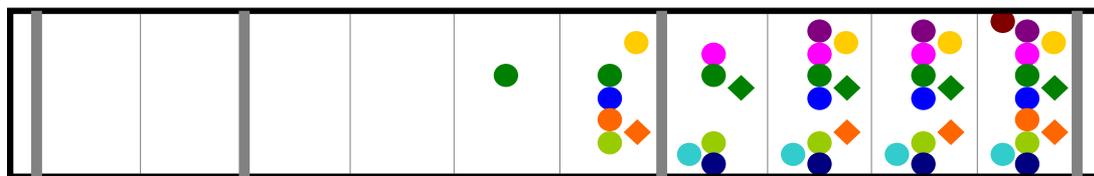
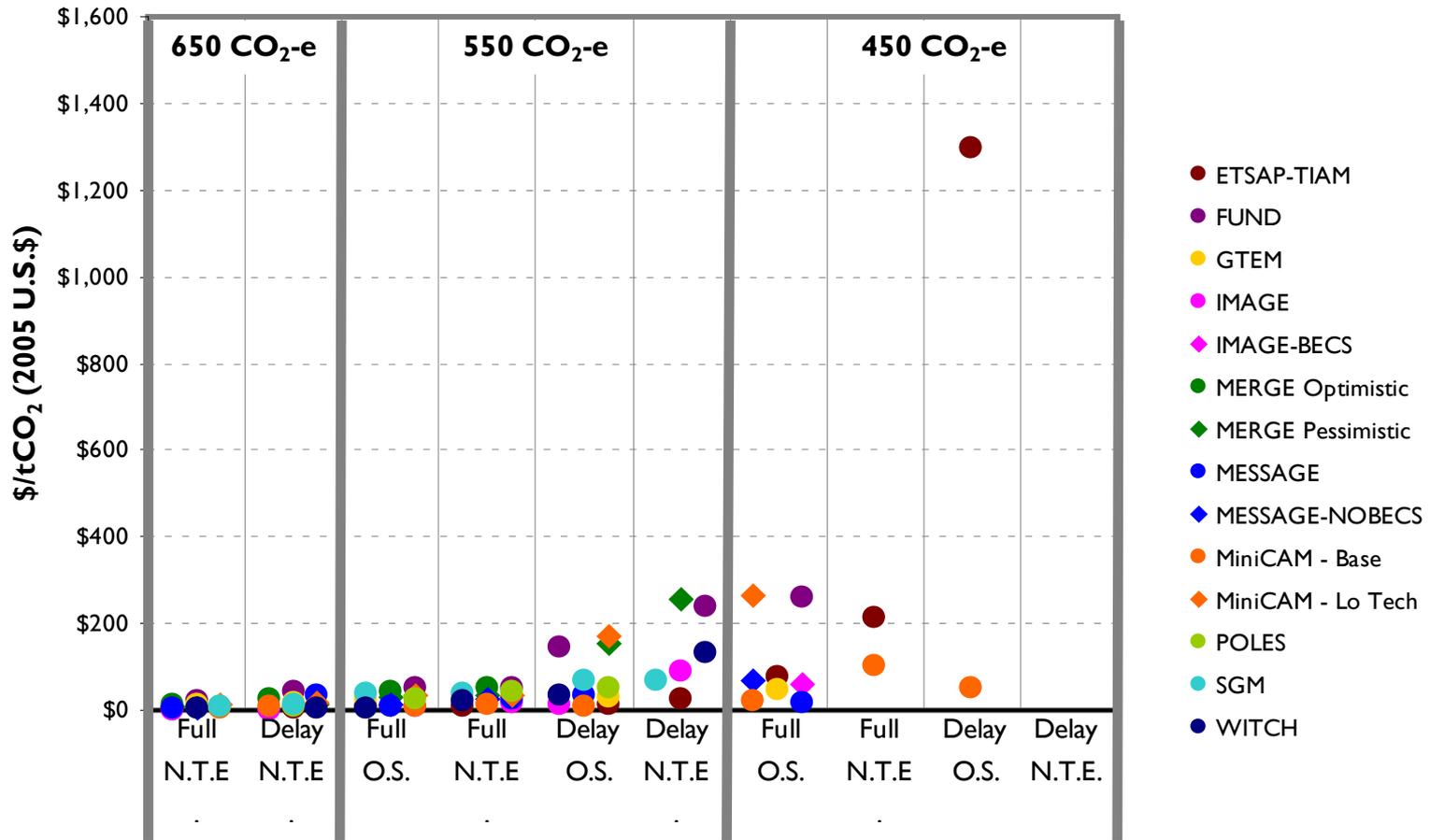
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Annex I 2020 Carbon Prices



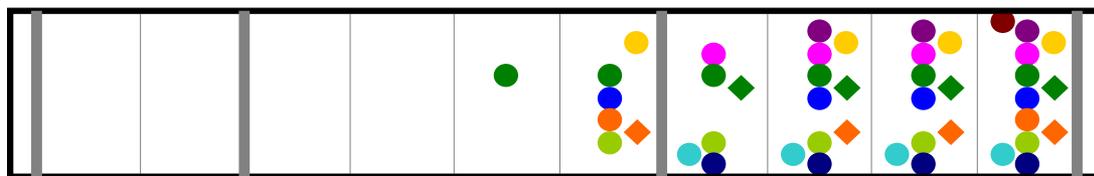
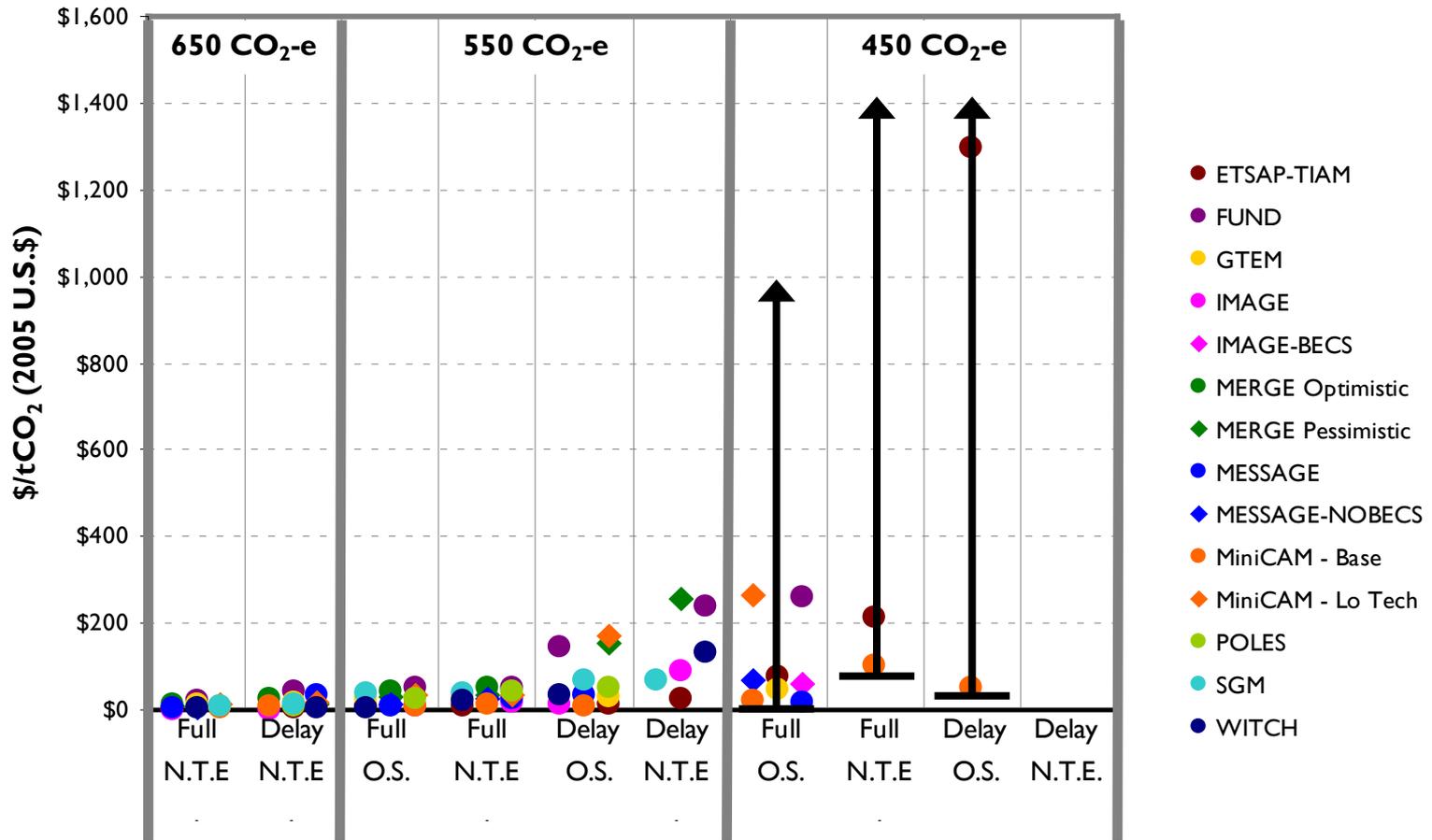
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Annex I 2020 Carbon Prices



Scenarios that could not be modeled under criteria of study.

Annex I 2020 Carbon Prices



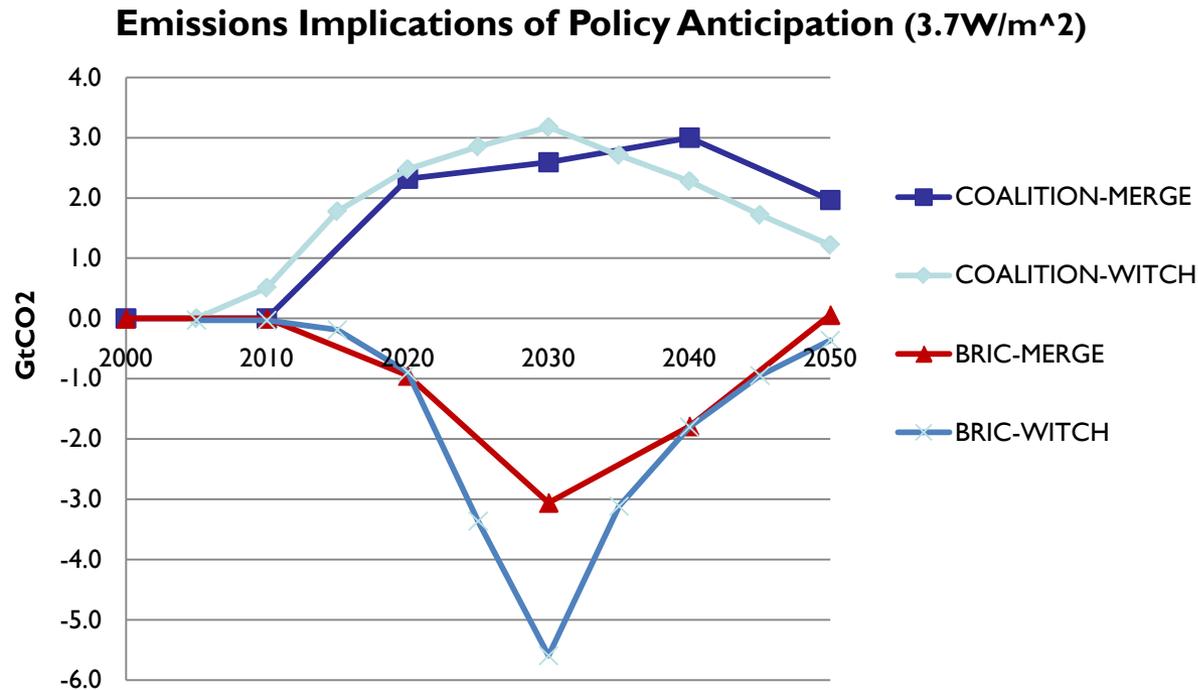
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The Benefits of Anticipation

The Benefits of Negotiating Future Targets



[From the MERGE paper, Blanford et al.
and the WITCH paper, Bosetti et al.]



Scenario: 550 CO₂-e (pessimistic baseline for MERGE). Difference in emissions between with and without anticipation.

- BRICs substantially reduce their emissions when they foresee the coming policy. They build more efficient capital so that emissions are lower even after 2030.
- Policy anticipation is visible from 2020, e.g. with a 10 years get-ahead. WITCH finds that R&D investments are anticipated by an additional 5 years.
- The higher mitigation by BRIC gives the Coalition more emission head-room.

The Benefits of Negotiating Future Targets



*[From the MERGE paper, Blanford et al.
and the WITCH paper, Bosetti et al.]*

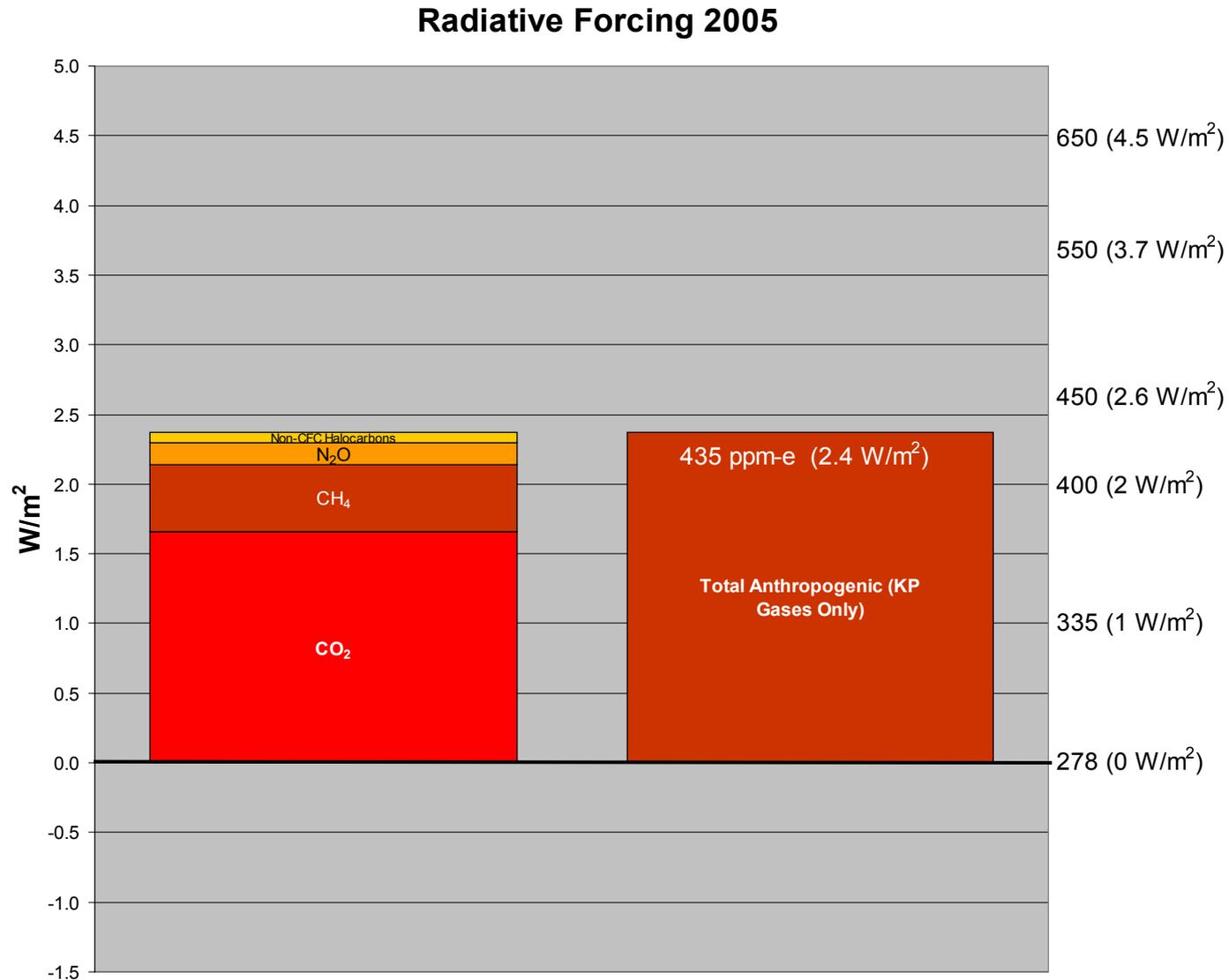
Cost savings due to policy anticipation			
Coalition		BRICs	
MERGE	WITCH	MERGE	WITCH
51%	46%	31%	23%

Scenario: 550 CO₂-e (pessimistic baseline for MERGE). Relative differences in costs (expressed as NPV GDP losses) between with and without anticipation cases.

- Sizeable cost savings due to policy anticipation.
- Policy anticipation roughly halves the Coalition macroeconomic losses, as its mitigation target is relaxed by the higher effort of developing countries seen in the previous slide
- BRICs also gain, reducing costs by 1/4 to 1/3, because they are free to build more efficient capital than the one that would have been optimal in a never climate concerned world.

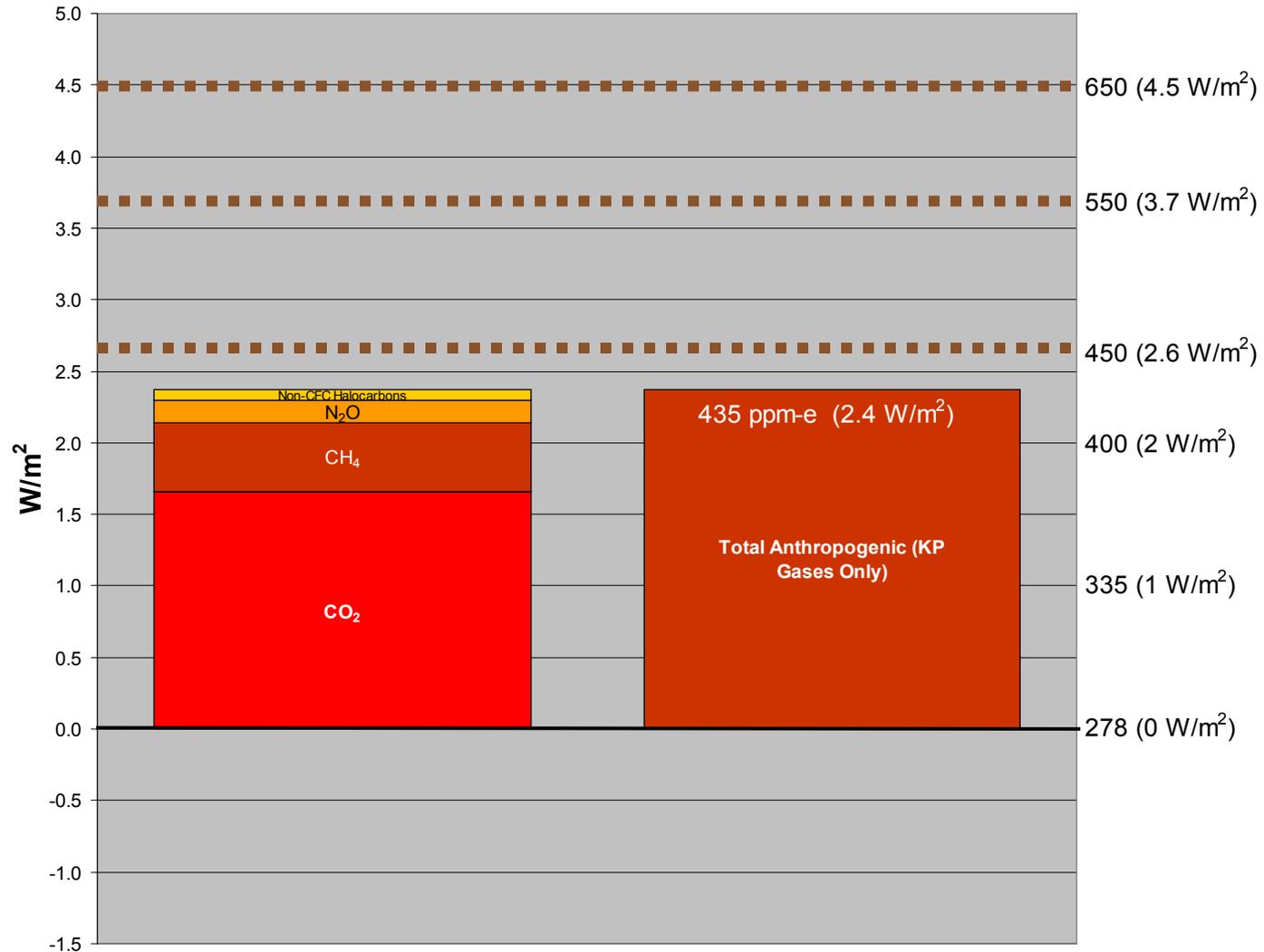
Understanding Kyoto and Full-Gas Forcing

Radiative Forcing: Kyoto Protocol Gases Only



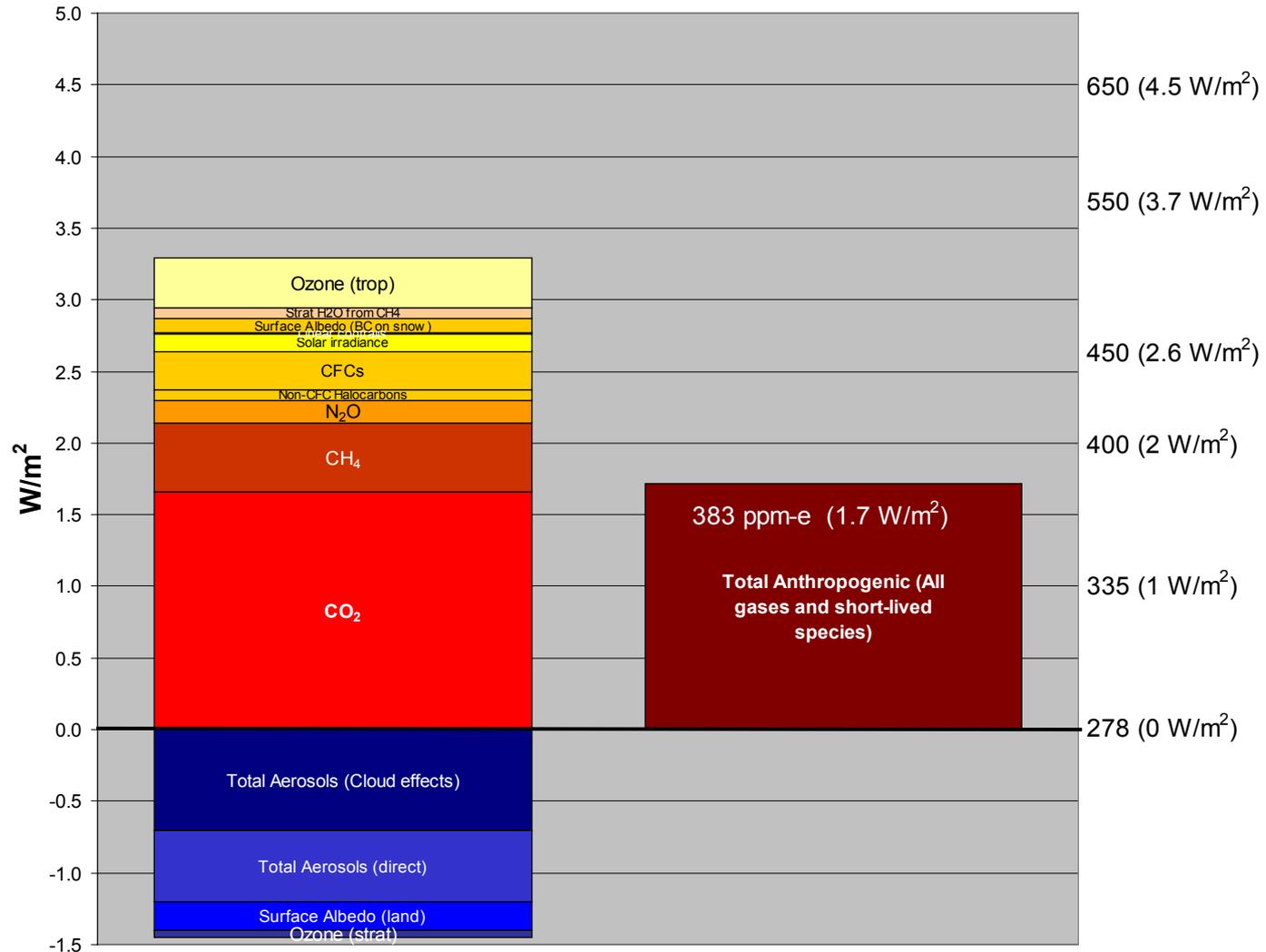
Radiative Forcing: Kyoto Protocol Gases Only

Radiative Forcing 2005



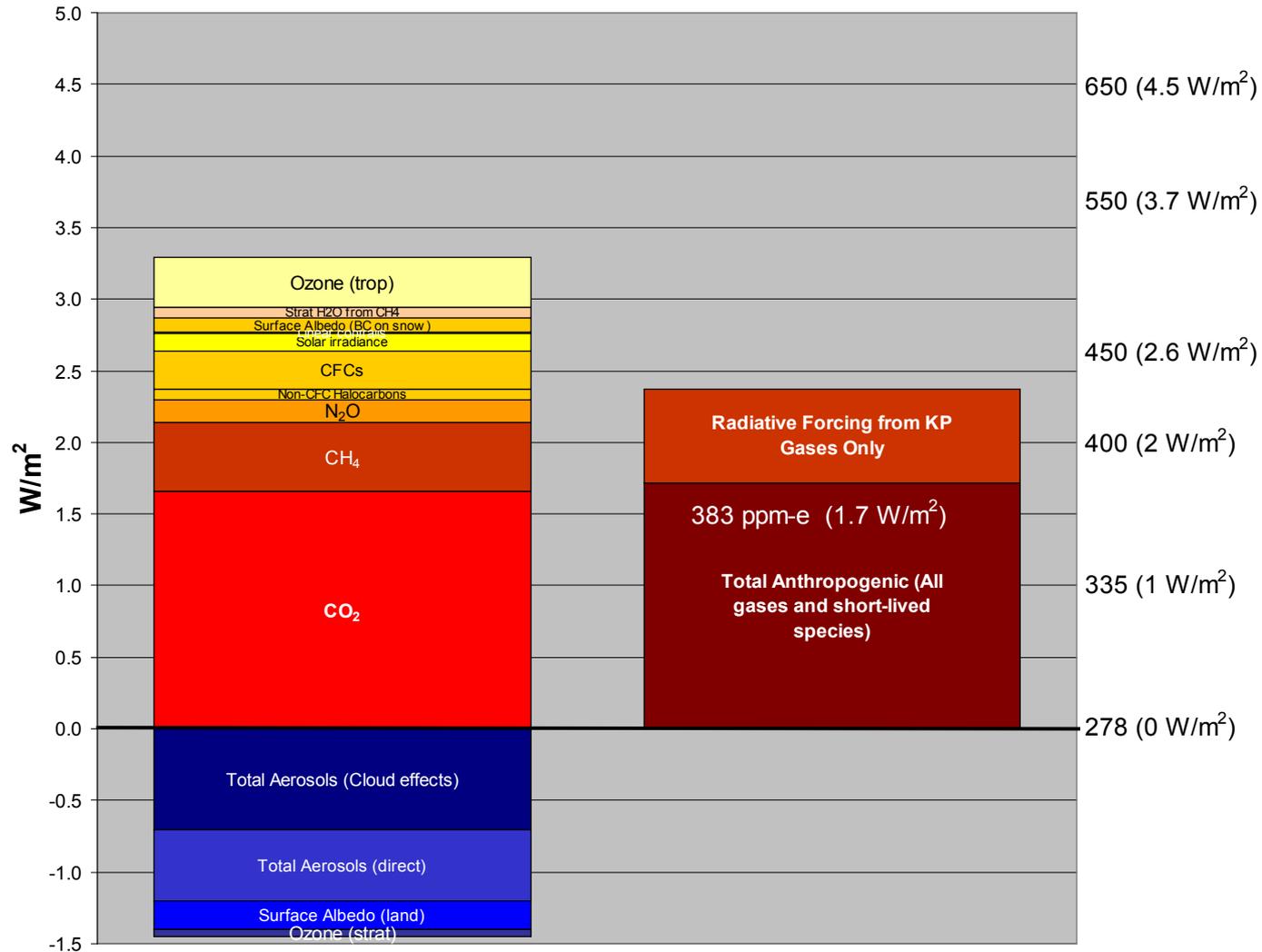
Radiative Forcing: All GHG's and SLS's

Radiative Forcing 2005



Radiative Forcing: All GHG's and SLS's

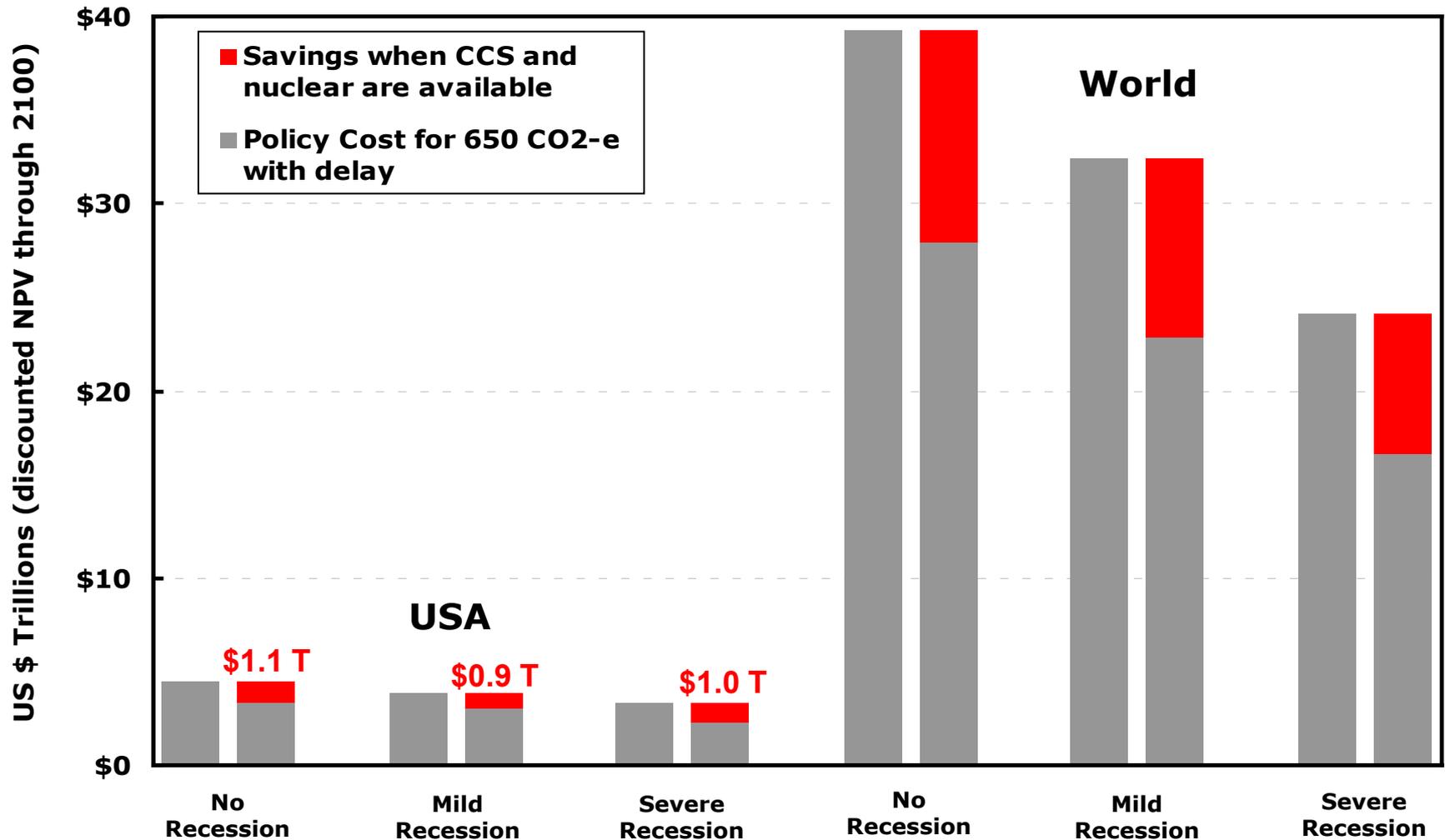
Radiative Forcing 2005



The Importance of Technology

The Benefits of Technology Availability

[From the MERGE paper: Blanford et al.]



Leakage in Terrestrial Systems

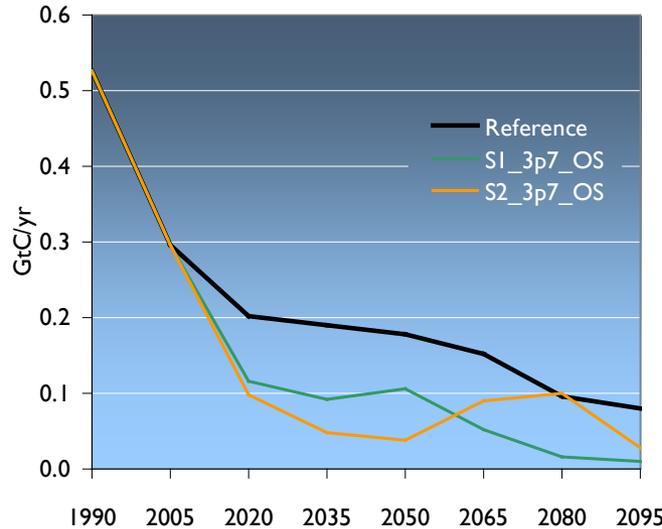
Land Use Leakage 3.7 Scenario, Overshoot



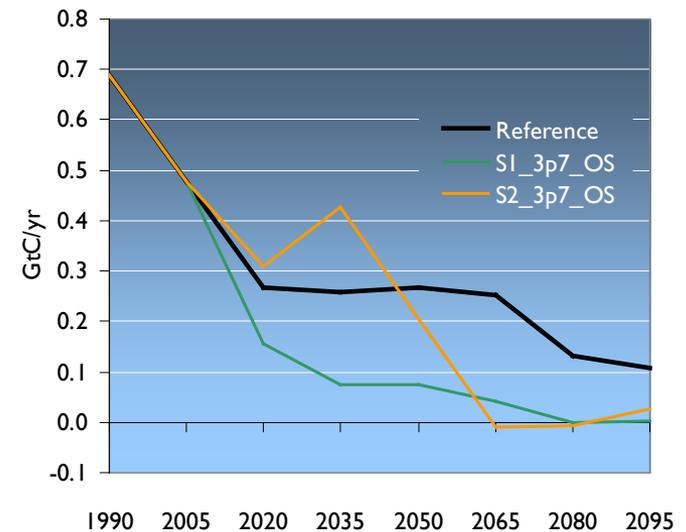
(From the MiniCAM Paper: Calvin et al.)

- **S1 = Immediate Accession**
- **S2 = Delay**

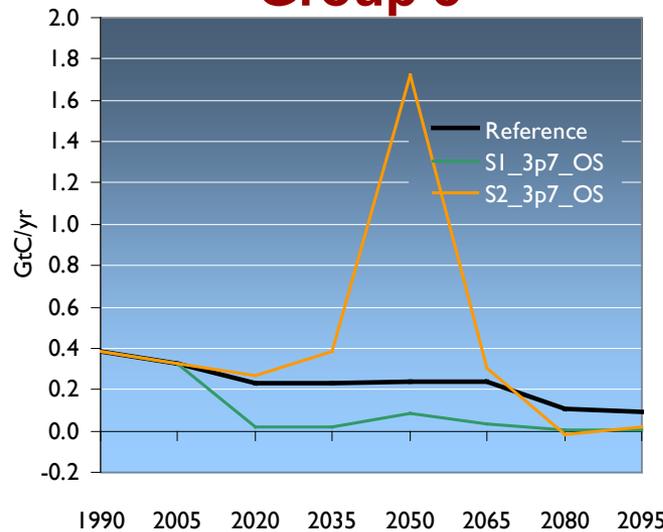
Group 1



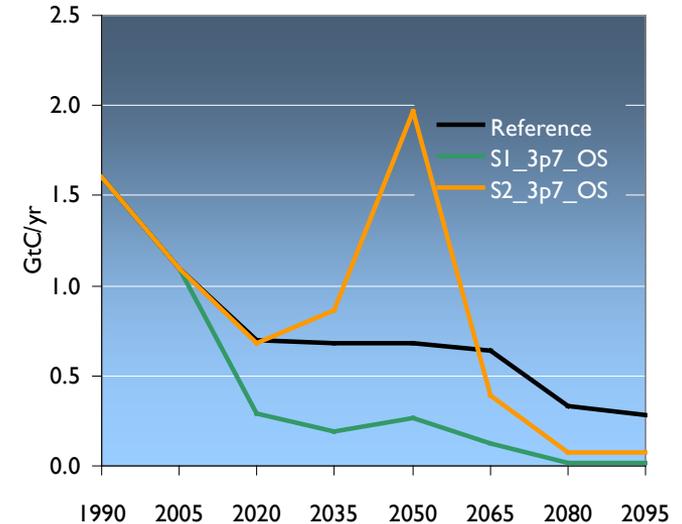
Group 2



Group 3



Global



- Leakage—offsetting increases in non-mitigating regions.
- Measuring leakage: *Mitigation by those reducing domestic emissions less total reductions in Global emissions.*

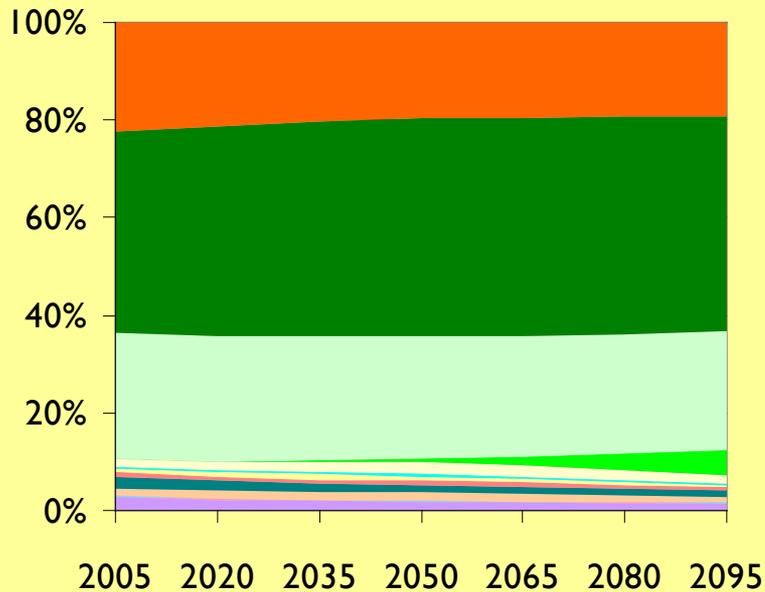
Land Allocation: 3.7 W/m² Overshoot



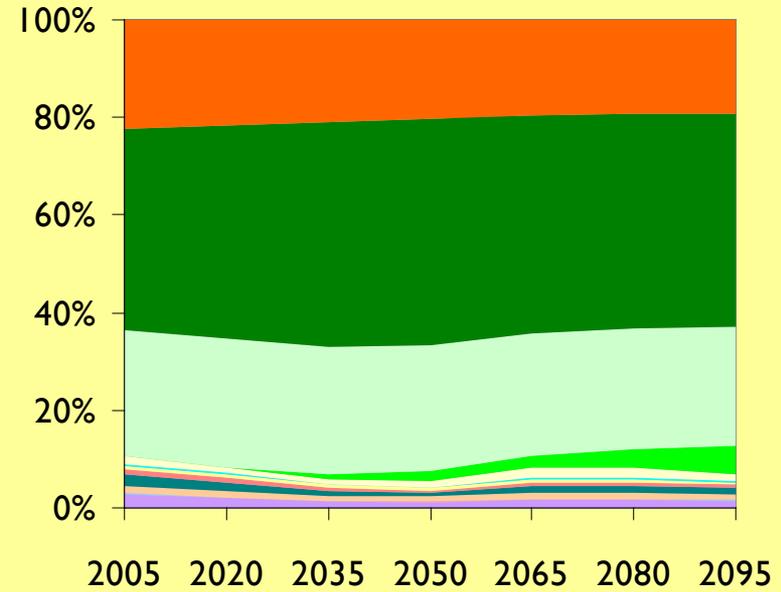
(From the MiniCAM Paper: Calvin et al.)

GROUP 1

Immediate Accession



Delayed Accession



- Grass/Shrub
- Forest
- Pasture
- biomass
- Corn
- FiberCrop
- FodderCrop
- MiscCrop
- OilCrop
- OtherGrain
- Rice
- SugarCrop
- Wheat

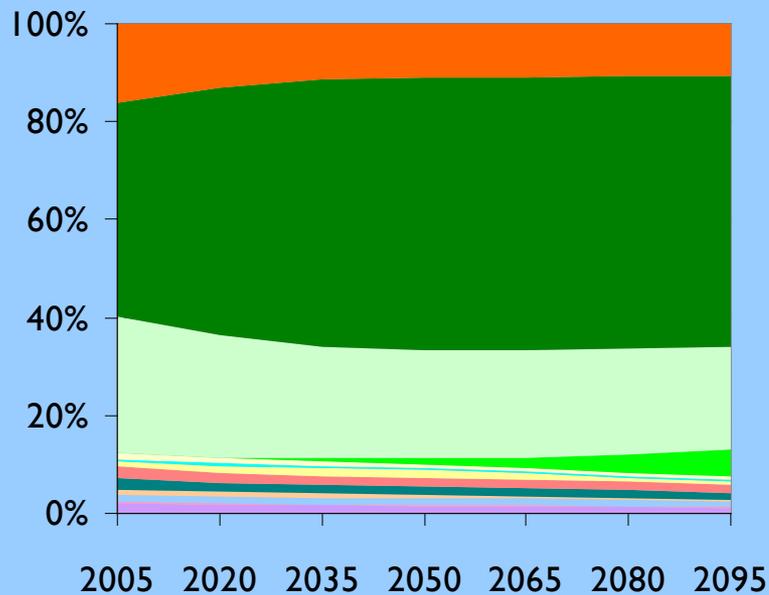
Land Allocation: 3.7 W/m² Overshoot



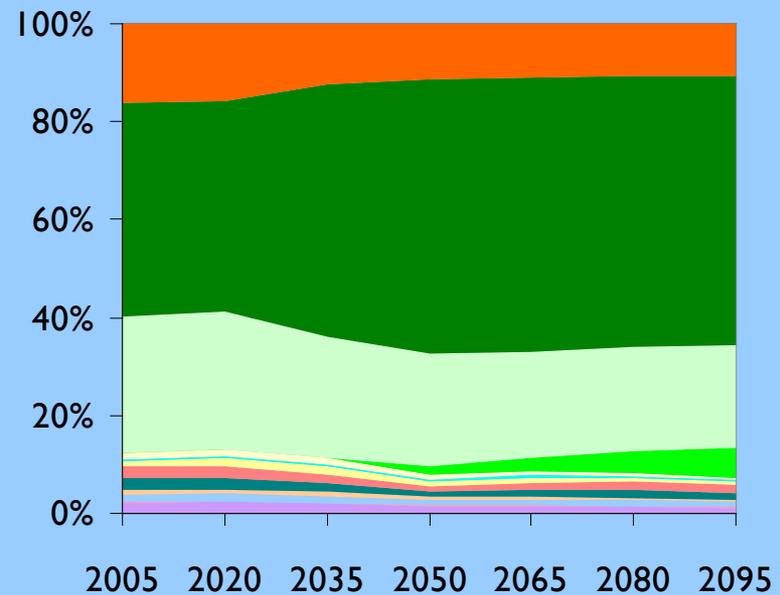
(From the MiniCAM Paper: Calvin et al.)

GROUP 2

Immediate Accession



Delayed Accession



- Grass/Shrub
- Forest
- Pasture
- biomass
- Corn
- FiberCrop
- FodderCrop
- MiscCrop
- OilCrop
- OtherGrain
- Rice
- SugarCrop
- Wheat

