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EMF22 Transition Scenarios

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GTSP
Global Energy Technology Strategy Program

Office of Science
U.S. DEPARTMENT OF ENERGY

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Acknowledgements

- Thanks to EMF-22 and to John Weyant in particular for making this happen and for the opportunity to participate.
- Thanks to the team: Leon, Marshall and Josh.
- Thanks to the sponsors of the Global Energy Technology Strategy Program (GTSP) for research support.

Background

- Most of the work that we have all done has been to explore the implications of simple, idealized regimes that stabilize greenhouse gas concentrations and/or climate.
- The real world is unlikely to be so neat and tidy.
- To the extent that the idealized stabilization scenarios are exploring a world with perfect where, when, and what flexibility, reported costs are minimized.
- **By definition of an optimum, to the extent that the world is non-optimal, costs will be higher.**

Background (2)

- There is only one idealized world.
- There are an infinite number of possible inefficient worlds. Which to choose?
- Two interesting questions arise:
  1. What are the physical, energy, agriculture-land-use, and economic implications of emissions mitigation **proposals under serious consideration?**
  2. What are the physical, energy, agriculture-land-use, and economic implications of **general “second-best” emissions mitigation measures**?
- Our work in support of the Pocantioc process explored the first type of issue. (Hugh Pitcher’s presentation to EMF-22 in Seville.)

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Policies and Measures *Trading Cases*

Regions	2005 to 2020	2020 to 2035	post 2035
EMISSIONS TRADING CASES			
Absolute Targets 1 (1% reductions)			
US/Australia	Stabilize @ 2005	reduce 1%/yr after 2020	reduce 1%/yr after 2020
Other Annex I	-10% from 2005	reduce 1%/yr after 2020	reduce 1%/yr after 2020
DCs w GDP/cap < poorest Annex I	No Limit	No limit	No limit
DCs w GDP/cap > poorest Annex I	No Limit	Stabilize emissions 1 period; reudce 1%/yr after	Stabilize emissions 1 period; reudce 1%/yr after
Absolute Targets 2 ($^{1}/_{2}$% reductions)			
US/Australia	Stabilize @ 2005	reduce $^{1}/_{2}$ %/yr after 2020	reduce $^{1}/_{2}$ %/yr after 2020
Other Annex I	Stabilize @ 2005	reduce $^{1}/_{2}$ %/yr after 2020	reduce $^{1}/_{2}$ %/yr after 2020
non-Annex I w GDP/cap < poorest Annex I	No Limit	No limit	No limit
non-Annex I w GDP/cap > poorest Annex I	No Limit	Stabilize emissions 1 period; reudce $^{1}/_{2}$ %/yr after	Stabilize emissions 1 period; reudce $^{1}/_{2}$ %/yr after
Intensity Targets			
Annex I	Reduce GHG/GDP 2%/yr	Reduce GHG/GDP 2%/yr	Reduce GHG/GDP 2%/yr
non-Annex I	Reduce GHG/GDP $^{2}/_{3}$ %/yr	Reduce GHG/GDP $1^{1}/_{3}$ %/yr	Reduce GHG/GDP 2%/yr
Mixed Targets (1% reductions; non-Annex I BAU)			
US/Australia	Stabilize @ 2005	reduce 1%/yr after 2020	reduce 1%/yr after 2020
Other Annex I	-10% from 2005 by 2020	reduce 1%/yr after 2020	reduce 1%/yr after 2020
non-Annex I w GDP/cap < poorest Annex I	No Limit	No limit	No limit
non-Annex I w GDP/cap > poorest Annex I	BAU	reduce GHG/GDP 2%/yr	reduce GHG/GDP 2%/yr

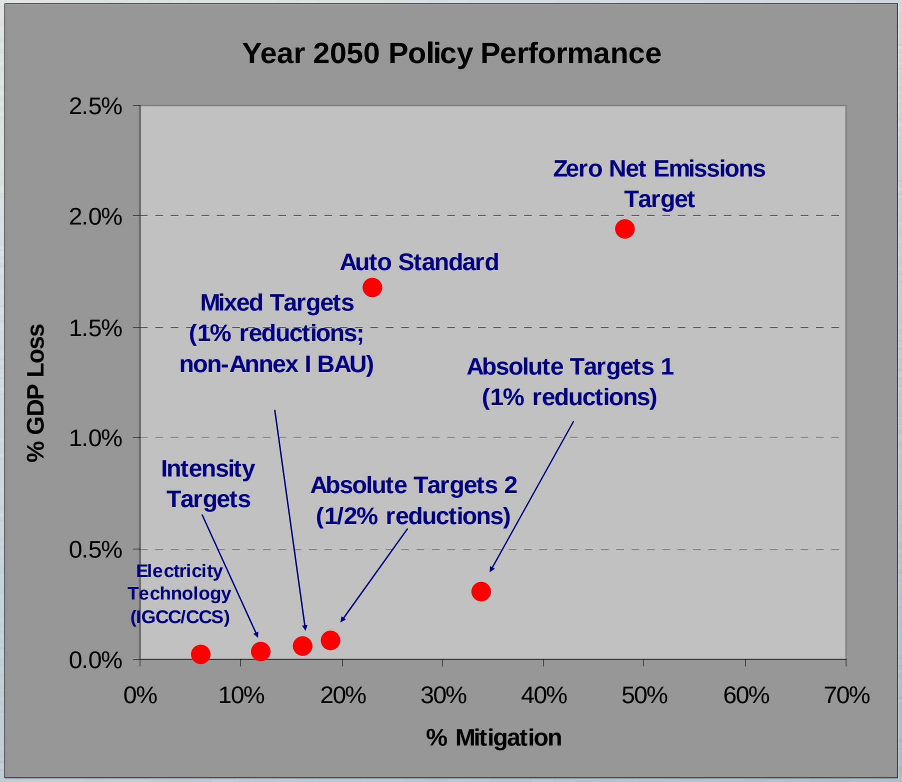
Order of Regional Participation

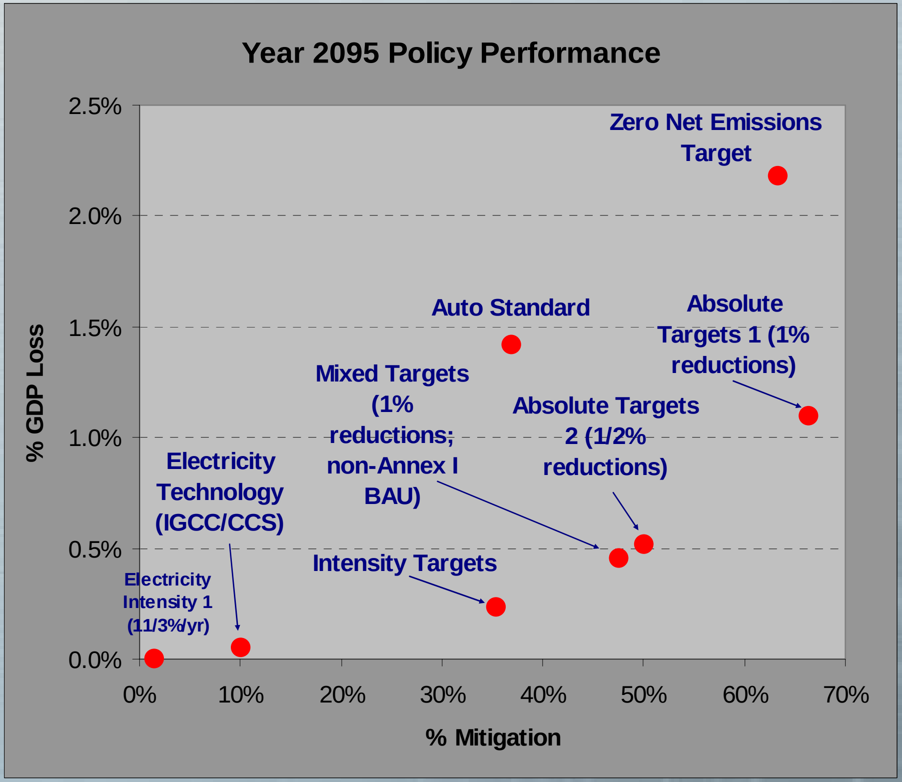
2005	2020	2035	2050	2065	2080	2095
USA	USA	USA	USA	USA	USA	USA
Canada	Canada	Canada	Canada	Canada	Canada	Canada
W. Europe	W. Europe	W. Europe	W. Europe	W. Europe	W. Europe	W. Europe
E. Europe	E. Europe	E. Europe	E. Europe	E. Europe	E. Europe	E. Europe
FSU	FSU	FSU	FSU	FSU	FSU	FSU
Japan	Japan	Japan	Japan	Japan	Japan	Japan
Australia & NZ	Australia & NZ	Australia & NZ	Australia & NZ	Australia & NZ	Australia & NZ	Australia & NZ
		Korea	Korea	Korea	Korea	Korea
		China	China	China	China	China
		Latin America	Latin America	Latin America	Latin America	Latin America
		Mideast	Mideast	Mideast	Mideast	Mideast
			Other SE Asia	Other SE Asia	Other SE Asia	Other SE Asia
			India	India	India	India
				Africa	Africa	Africa

Policies and Measures
Regulatory Cases

Regions	2005 to 2020	2020 to 2035	post 2035
REGULATORY CASES			
Electricity Intensity 1 ($1^1/_3$%/yr)			
Annex I	Reduce GHG/kWh $1^1/_3$ %/yr	Reduce GHG/kWh $1^1/_3$ %/yr	Reduce GHG/kWh $1^1/_3$ %/yr
non-Annex I w GDP/cap < poorest Annex I	No Limit	No Limit	No Limit
non-Annex I w GDP/cap > poorest Annex I	BAU	reduce GHG/kWh 1%/yr after 2020	reduce 1%/yr after 2020
Electricity Intensity 2 (2%/yr)			
Annex I	Reduce GHG/kWh 2 %/yr	Reduce GHG/kWh 2 %/yr	Reduce GHG/kWh 2 %/yr
non-Annex I w GDP/cap < poorest Annex I	No Limit	No Limit	No Limit
non-Annex I w GDP/cap > poorest Annex I	BAU	reduce GHG/kWh 2%/yr after 2020	reduce GHG/kWh 2%/yr after 2020
Electricity Technology (IGCC/CCS)			
All	50% of new coal elec. IGCC or better	All new coal elec. IGCC or better; 50% CCS	All new coal elec. IGCC or better; 100% CCS
Auto Standard			
All	EU standard (140gCO_2/km)	Reduce CO_2/km 2%/y)	Reduce CO_2/km 2%/y)
Zero Net Emissions Targets			
Transport sector	No Limit	No Limit	All vehicles non-emitting by 2080
Power generation sector	No Limit	No Limit	All power non-emitting by 2065

Putting the Policies Together





Background (3)

This presentation begins to explore **general "second-best" emissions mitigation measures.**

WARNING!

THIS WORK IS PRELIMINARY AND SUBJECT TO CHANGE

Outline of the Research

- We know that inefficient “second best” emissions mitigation measures are more expensive than optimal measures—this work has sought to provide some quantitative insights on how expensive several different types of inefficiency might be.
- We looked at 4 stabilization scenario sets

  Set 1: **Idealized**—perfect global where, when, and who flexibility

  Set 2: **Graduated accession of nations**—the cost of delay

  Set 3: **Parallel regimes**—the cost of delay and uncoordinated measures

  Set 4: **Inefficient markets**—the cost of inefficient

- We will talk about the first **3** of these.

The Reference Scenario

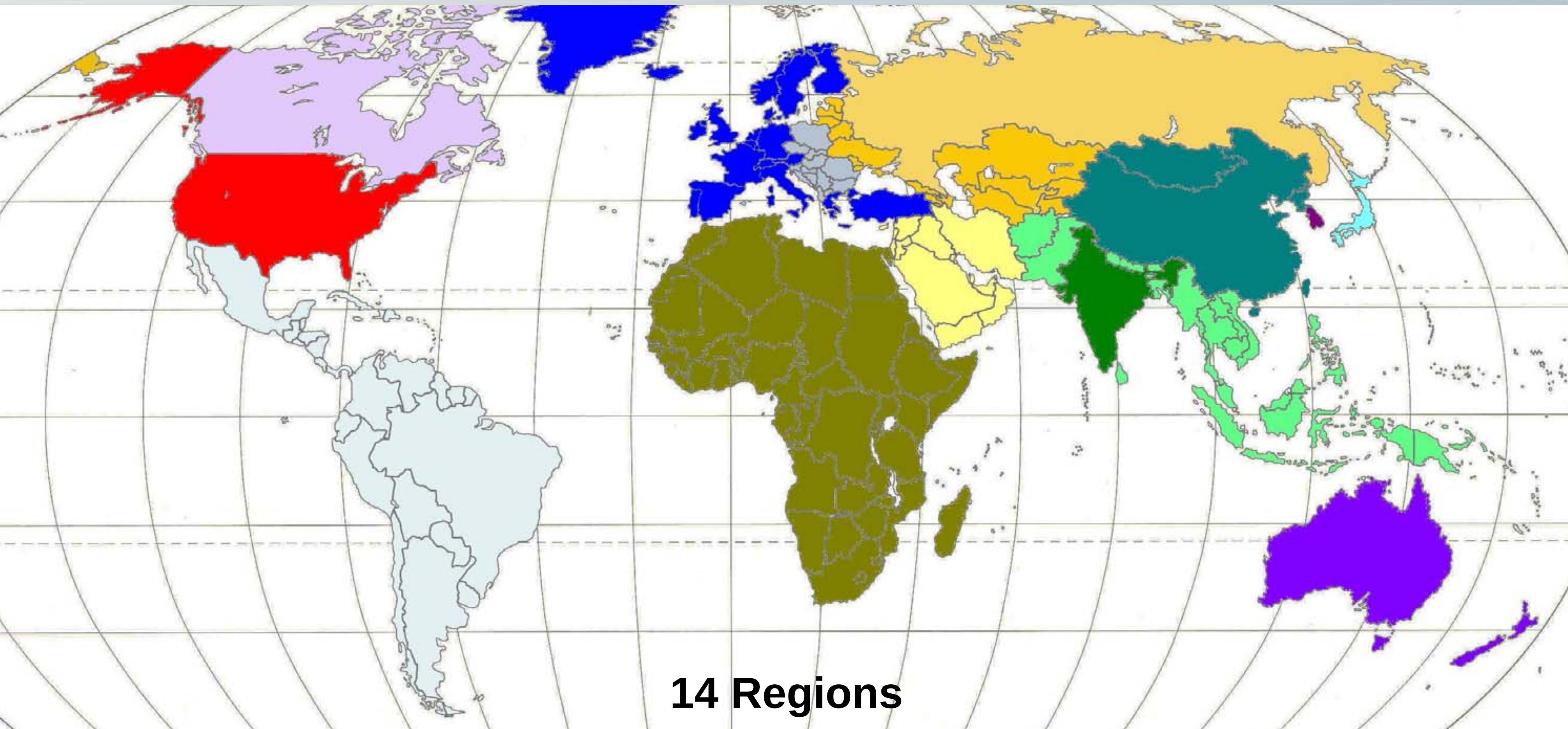
MiniCAM
An Integrated Assessment Model

Emissions, Atmosphere, Climate

Emissions: Energy-economy-agriculture-land-use model

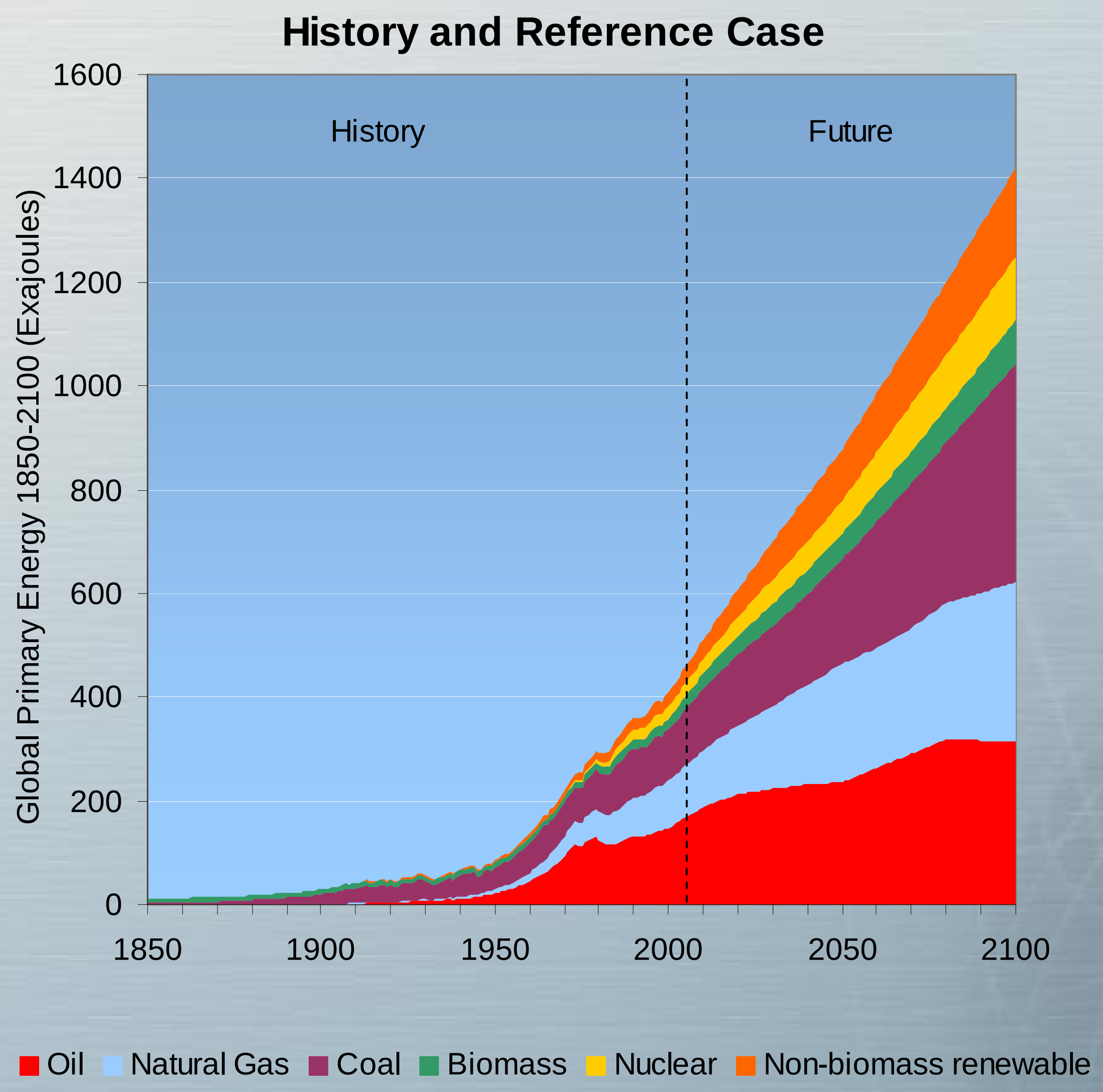
15 gaseous emissions—linked to associated human activities

2095 time horizon

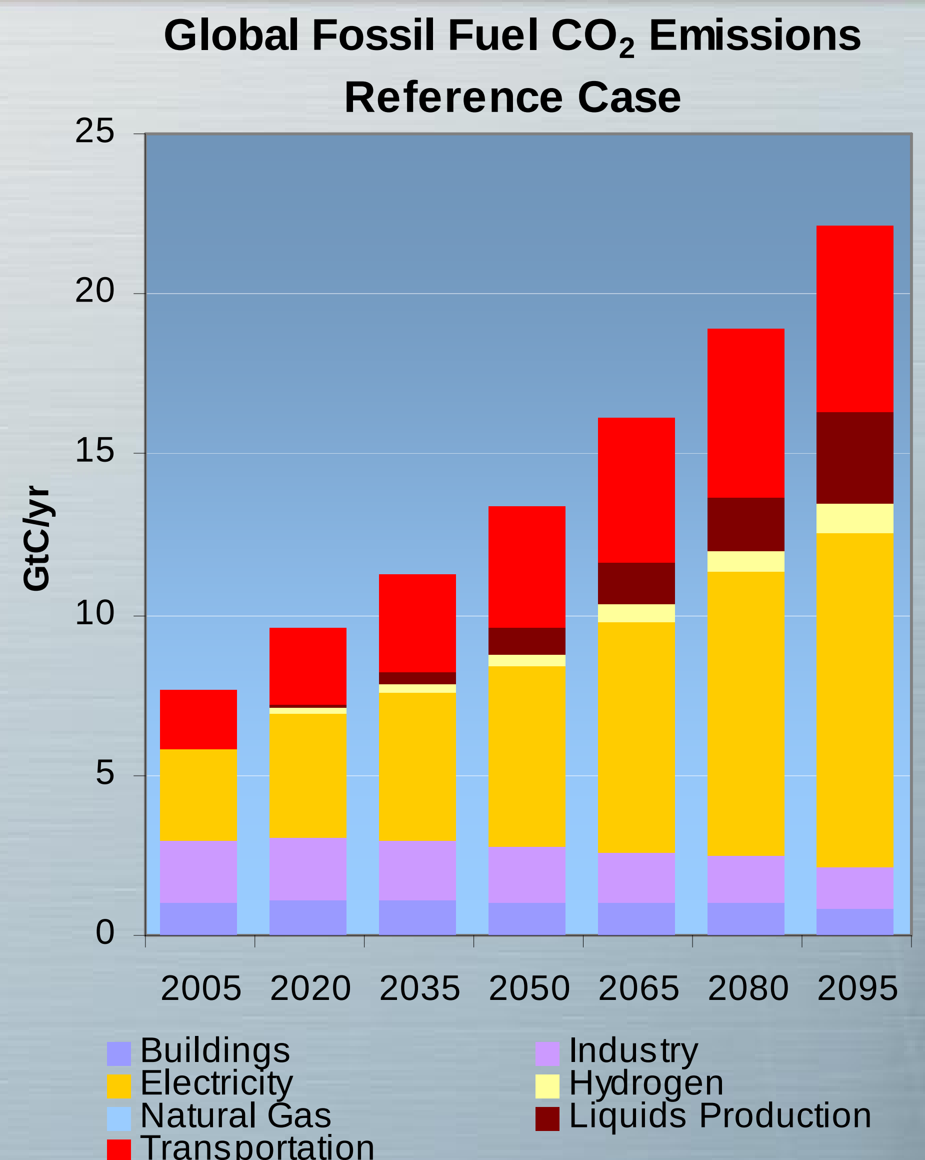


14 Regions

The Reference Scenario
Global Energy



The Reference Scenario Global Fossil CO_2 Emissions



Idealize Stabilization Scenario Set 1

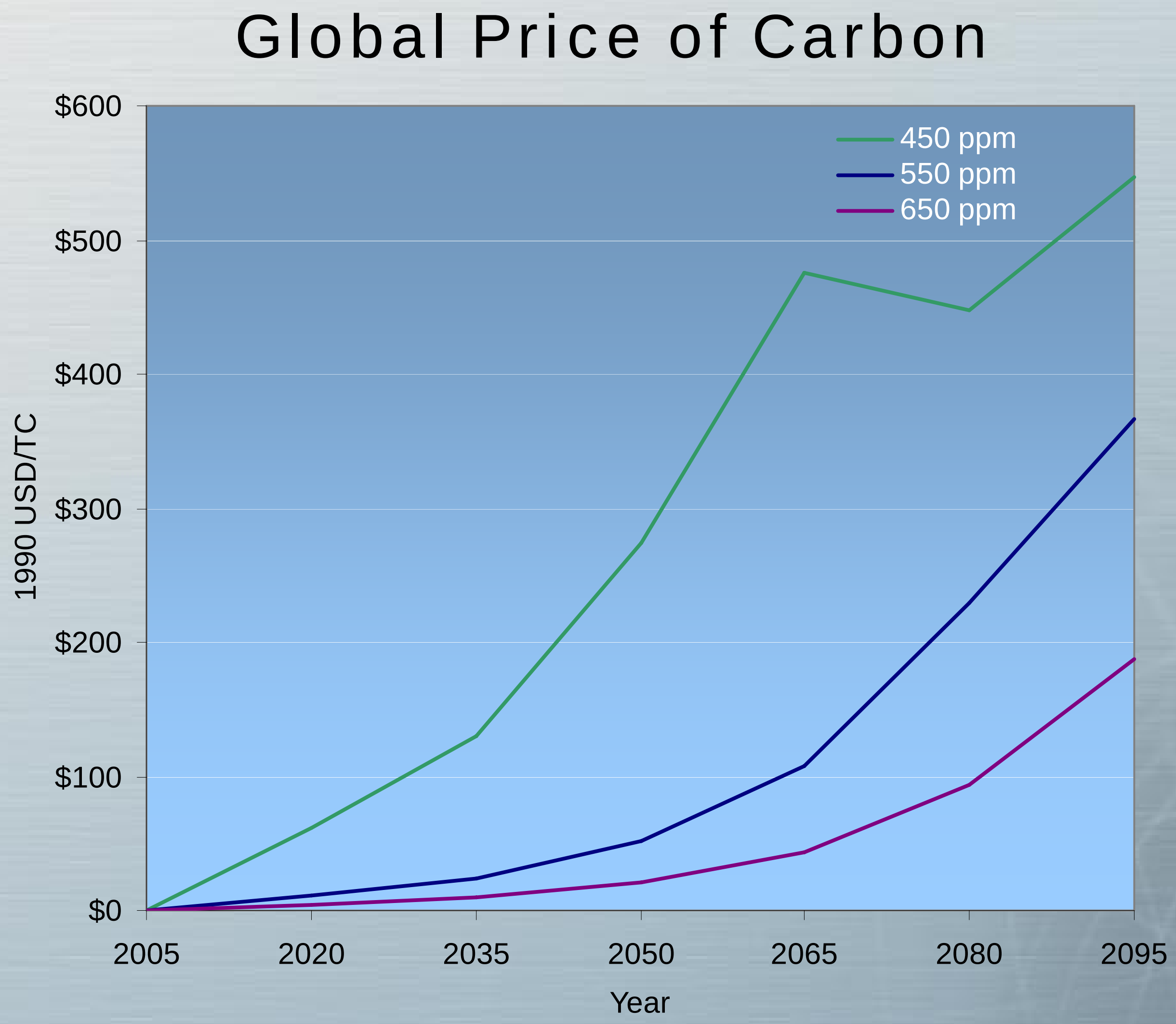
The Emissions Mitigation Measures
Idealized Stabilization Scenario Set 1

- Stabilize CO_2 concentrations
  - –450 ppm, 550 ppm, 650 ppm.
  - –Sectoral carbon prices—All EQUAL.
  - –Regional carbon prices—All EQUAL.
  - –Time path of carbon prices—Peck-Wan-Hotelling.
- Notes:

We have chosen CO_2 rather than radiative forcing for simplicity. We have further simplified the analysis by assuming a fixed agriculture-land-use emissions path. Unmanaged ecosystem extent and composition is fixed.

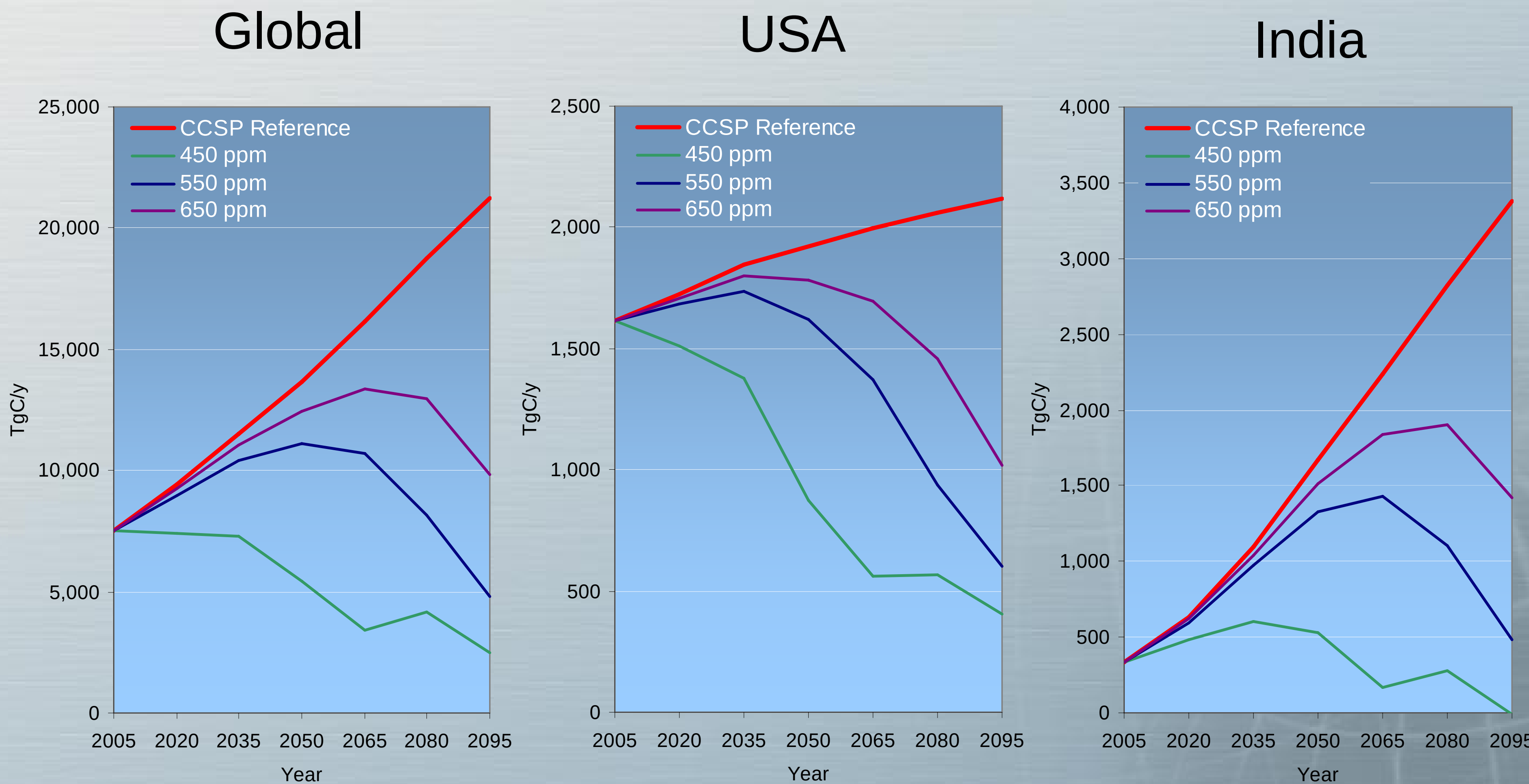
This case sets an economically efficient benchmark for comparison with other cases.

The Emissions Mitigation Measures
Idealized Stabilization Scenario Set 1



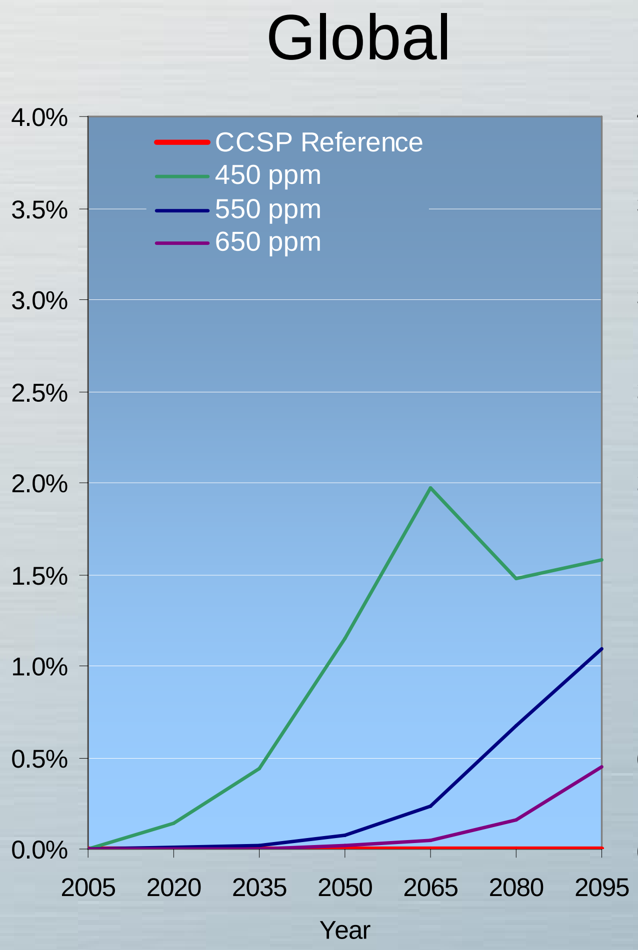
The Emissions Mitigation Measures
Idealized Stabilization Scenario Set 1

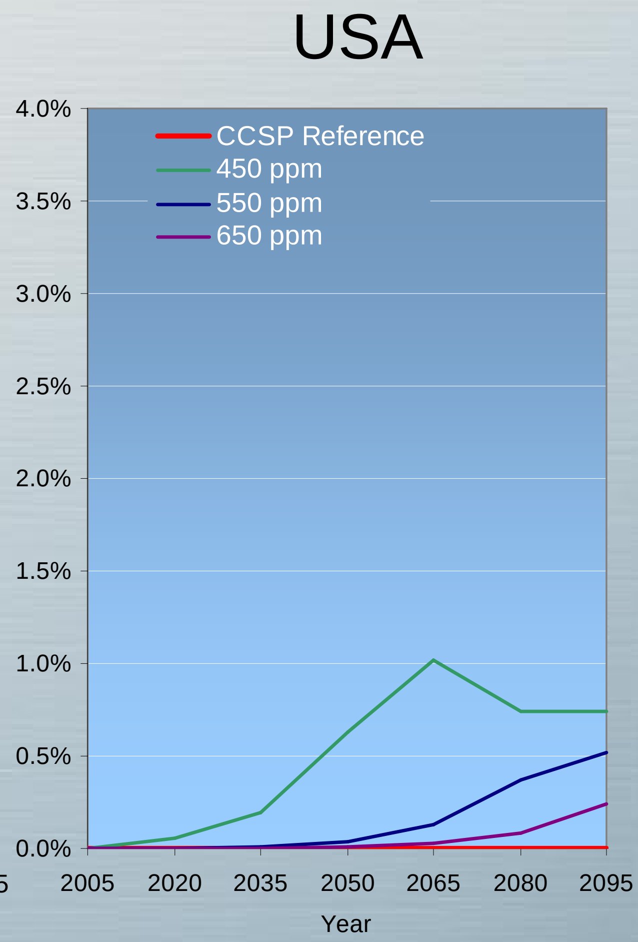
Fossil Fuel CO_2 Emissions

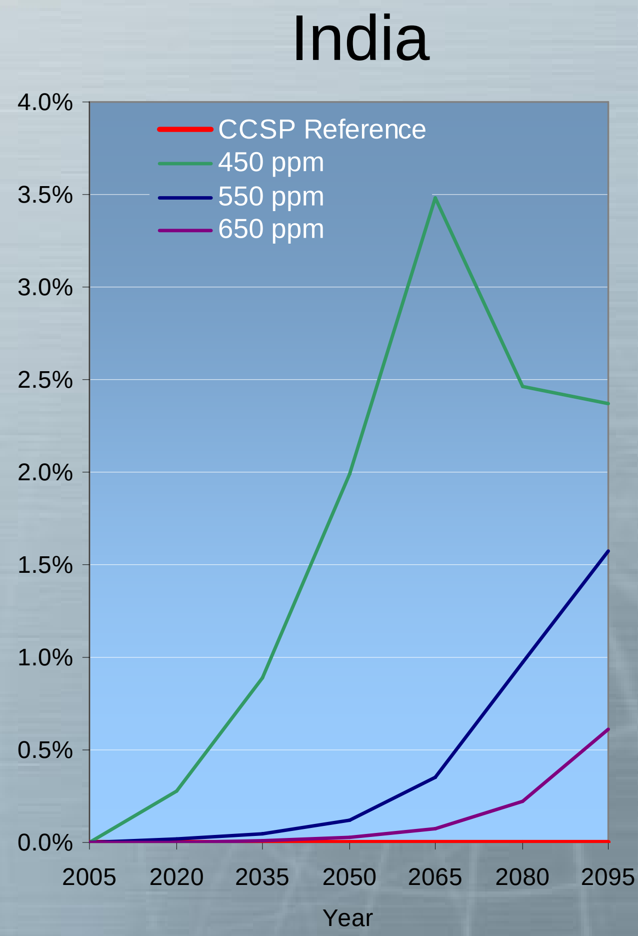


The Emissions Mitigation Measures
Idealized Stabilization Scenario Set 1

Emissions Mitigation Costs Per GDP







Graduated Accession Scenario Set 2

The Emissions Mitigation Measures
Graduated Accession Scenario Set 2

- Stabilize CO_2 concentrations
  - 450 ppm, 550 ppm, 650 ppm.
  - Sectoral carbon prices—All EQUAL.
  - Regional carbon prices—All EQUAL.
  - Time path of carbon prices—Peck-Wan-Hotelling.
  - **Staggered accession based on per capita income.**
    - **Alternative accession cases—first group enters: 2020-2035, 2035-2050, 2050-2065**
- Notes:

We assume that all Annex 1 nations participate in an international protocol by 2020 and that others join at different times based on per capita income. Non-Annex 1 participation is keyed to China's entry date.

Order of Regional Participation
(1st NA1 Group Enters 2020-2035)

2005-2020	2020-2035	2035-2050	2050-2065	2065-2080	2080-2095
USA	USA	USA	USA	USA	USA
Australia & NZ	Australia & NZ	Australia & NZ	Australia & NZ	Australia & NZ	Australia & NZ
Canada	Canada	Canada	Canada	Canada	Canada
W. Europe	W. Europe	W. Europe	W. Europe	W. Europe	W. Europe
E. Europe	E. Europe	E. Europe	E. Europe	E. Europe	E. Europe
Japan	Japan	Japan	Japan	Japan	Japan
FSU	FSU	FSU	FSU	FSU	FSU
	Korea	Korea	Korea	Korea	Korea
	China	China	China	China	China
	Latin America	Latin America	Latin America	Latin America	Latin America
	Mideast	Mideast	Mideast	Mideast	Mideast
		Other SE Asia	Other SE Asia	Other SE Asia	Other SE Asia
		India	India	India	India
			Africa	Africa	Africa

NA1 1st Group Enters 2020-2035

Order of Regional Participation
(1st NA1 Group Enters 2035-2050)

2005-2020	2020-2035	2035-2050	2050-2065	2065-2080	2080-2095
USA	USA	USA	USA	USA	USA
Australia & NZ	Australia & NZ	Australia & NZ	Australia & NZ	Australia & NZ	Australia & NZ
Canada	Canada	Canada	Canada	Canada	Canada
W. Europe	W. Europe	W. Europe	W. Europe	W. Europe	W. Europe
E. Europe	E. Europe	E. Europe	E. Europe	E. Europe	E. Europe
Japan	Japan	Japan	Japan	Japan	Japan
FSU	FSU	FSU	FSU	FSU	FSU
		Korea	Korea	Korea	Korea
		China	China	China	China
		Latin America	Latin America	Latin America	Latin America
		Mideast	Mideast	Mideast	Mideast
			Other SE Asia	Other SE Asia	Other SE Asia
			India	India	India
				Africa	Africa

NA1 1st Group Enters 2035-2050

Order of Regional Participation
(1st NA1 Group Enters 2050-2065)

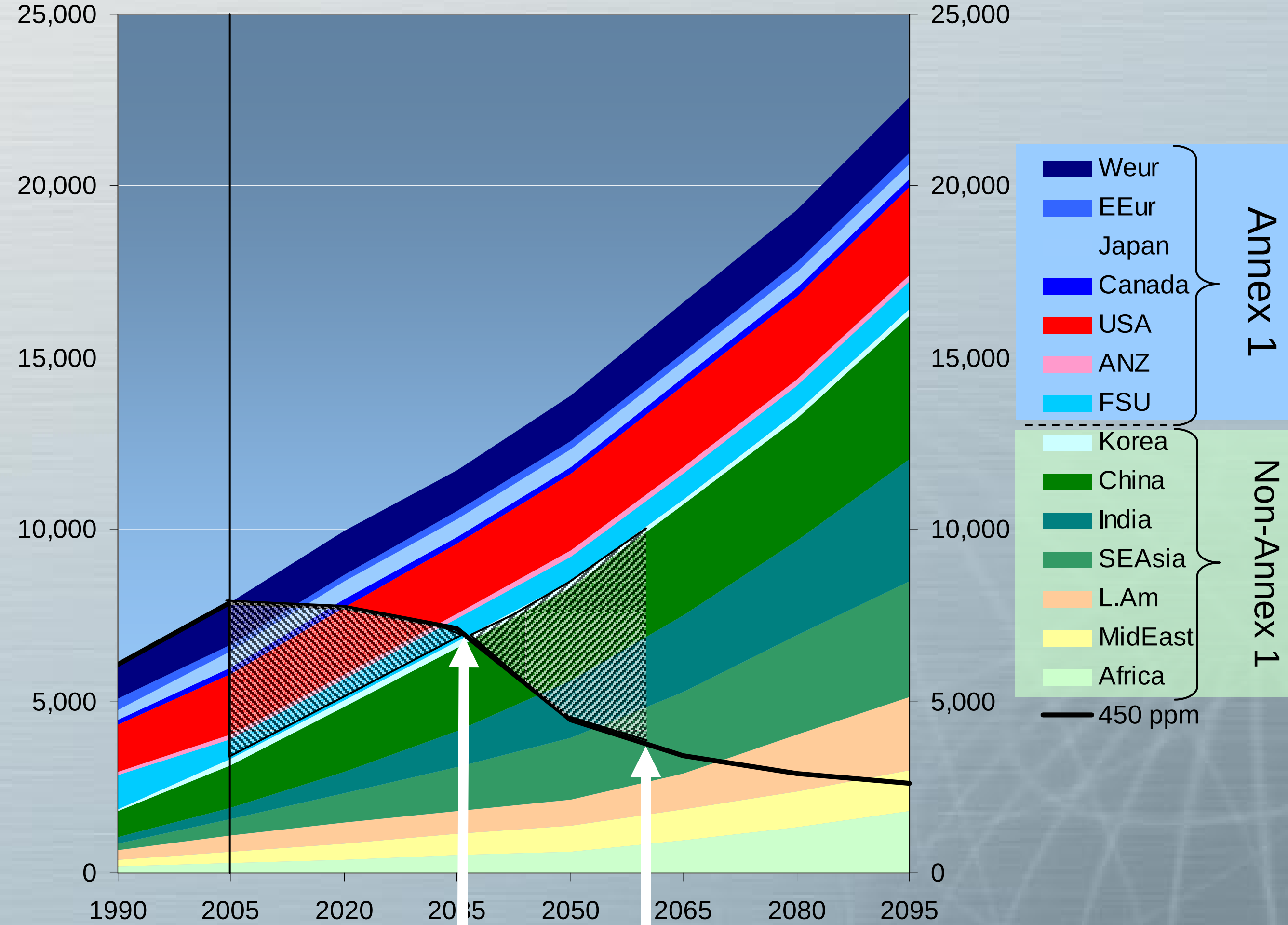
2005-2020	2020-2035	2035-2050	2050-2065	2065-2080	2080-2095
USA	USA	USA	USA	USA	USA
Australia & NZ	Australia & NZ	Australia & NZ	Australia & NZ	Australia & NZ	Australia & NZ
Canada	Canada	Canada	Canada	Canada	Canada
W. Europe	W. Europe	W. Europe	W. Europe	W. Europe	W. Europe
E. Europe	E. Europe	E. Europe	E. Europe	E. Europe	E. Europe
Japan	Japan	Japan	Japan	Japan	Japan
FSU	FSU	FSU	FSU	FSU	FSU
			Korea	Korea	Korea
			China	China	China
			Latin America	Latin America	Latin America
			Mideast	Mideast	Mideast
				Other SE Asia	Other SE Asia
				India	India
					Africa

NA1 1st Group Enters 2050-2065

Point of No Return: Regional Participation (The Richels Effect)

The point of no return for regional participation is the date after which even if Annex 1 emissions fall to zero, CO_2 concentrations cannot be held below a given concentration.

The point of no return is later than one might think. Time can be bought by dramatically cutting emissions quickly in participating countries and shifting those emissions to non-participants, but costs rise rapidly to participants, and to the world.



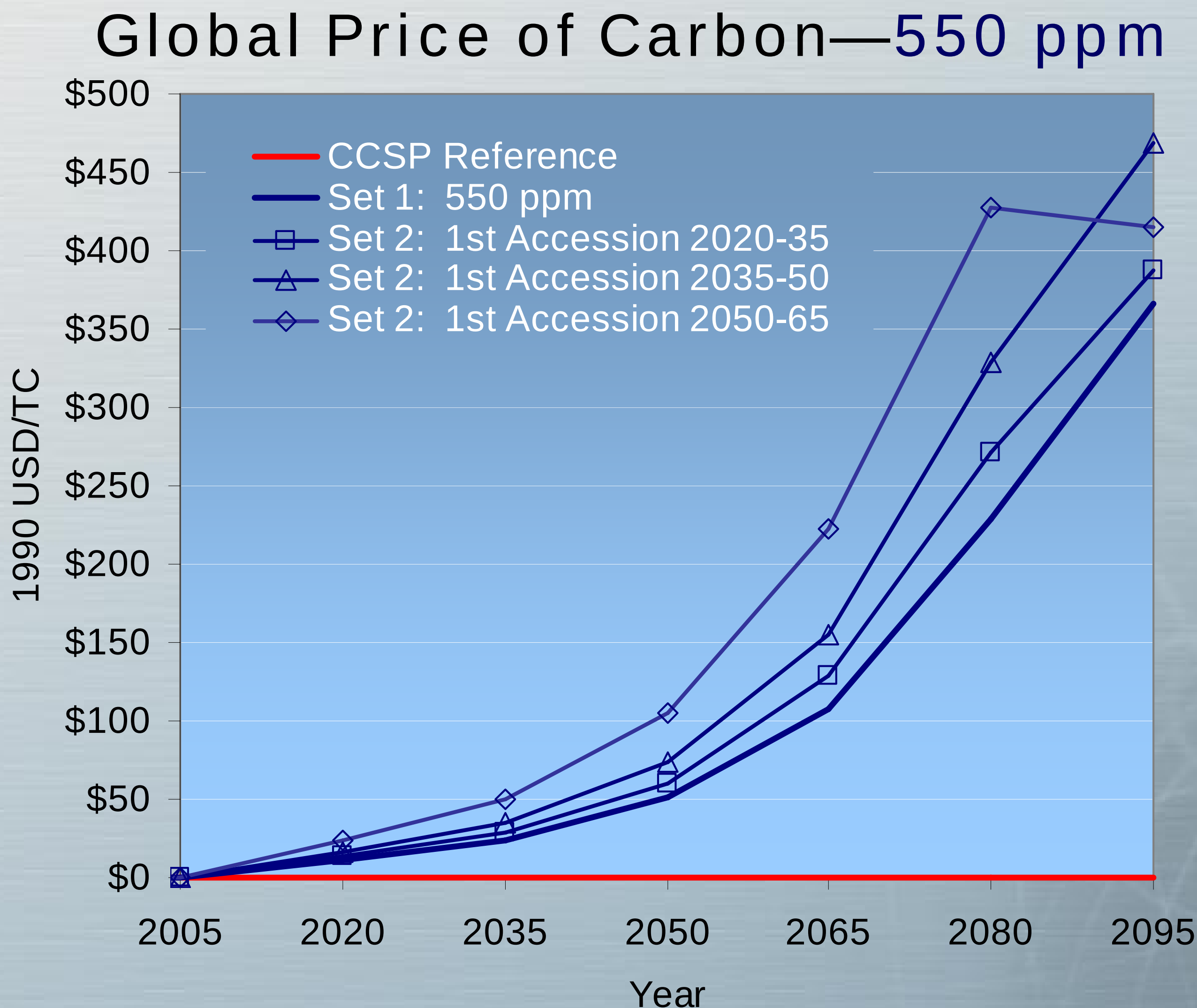
450 Annex 1 Alone
Emissions phase down

450 Annex 1 Alone
Immediate deep cuts

Graduated Accession Scenario Set 2
550 ppm

The Emissions Mitigation Measures

Graduated Accession Scenario Set 2



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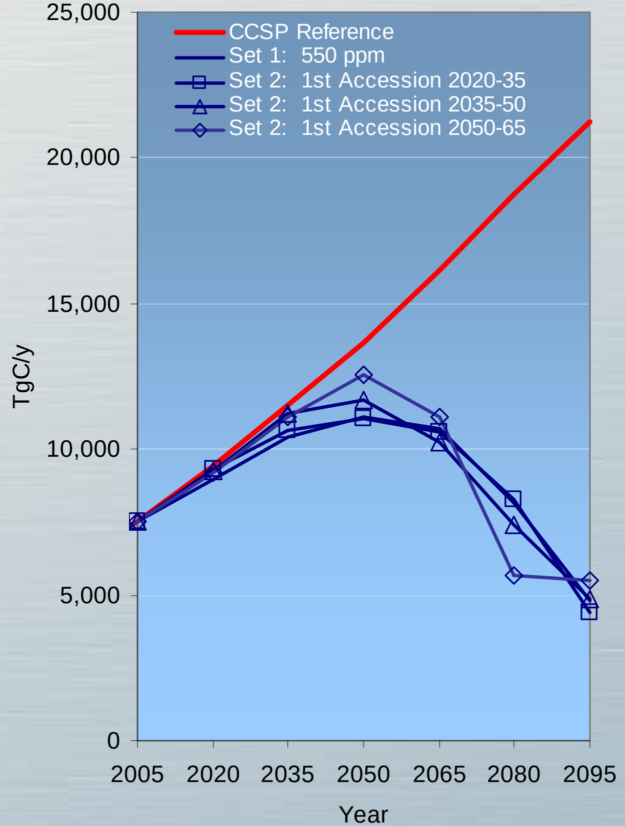
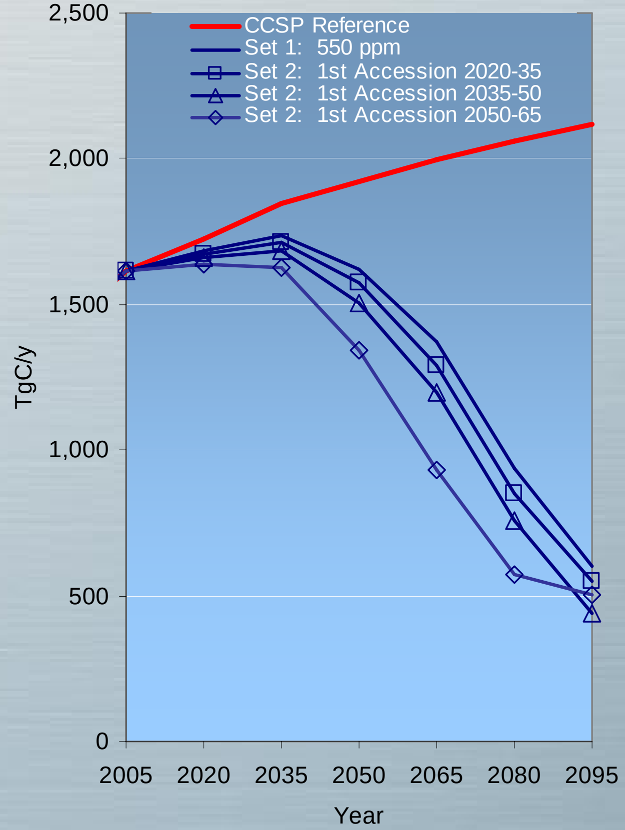
The Emissions Mitigation Measures
Graduated Accession Scenario Set 2

Fossil Fuel CO_2 Emissions—550 ppm

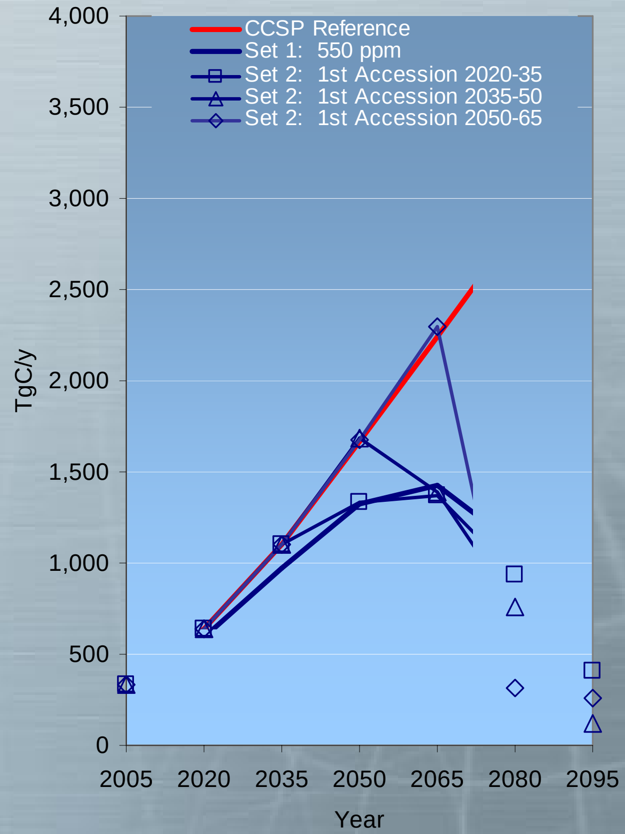
Global



USA

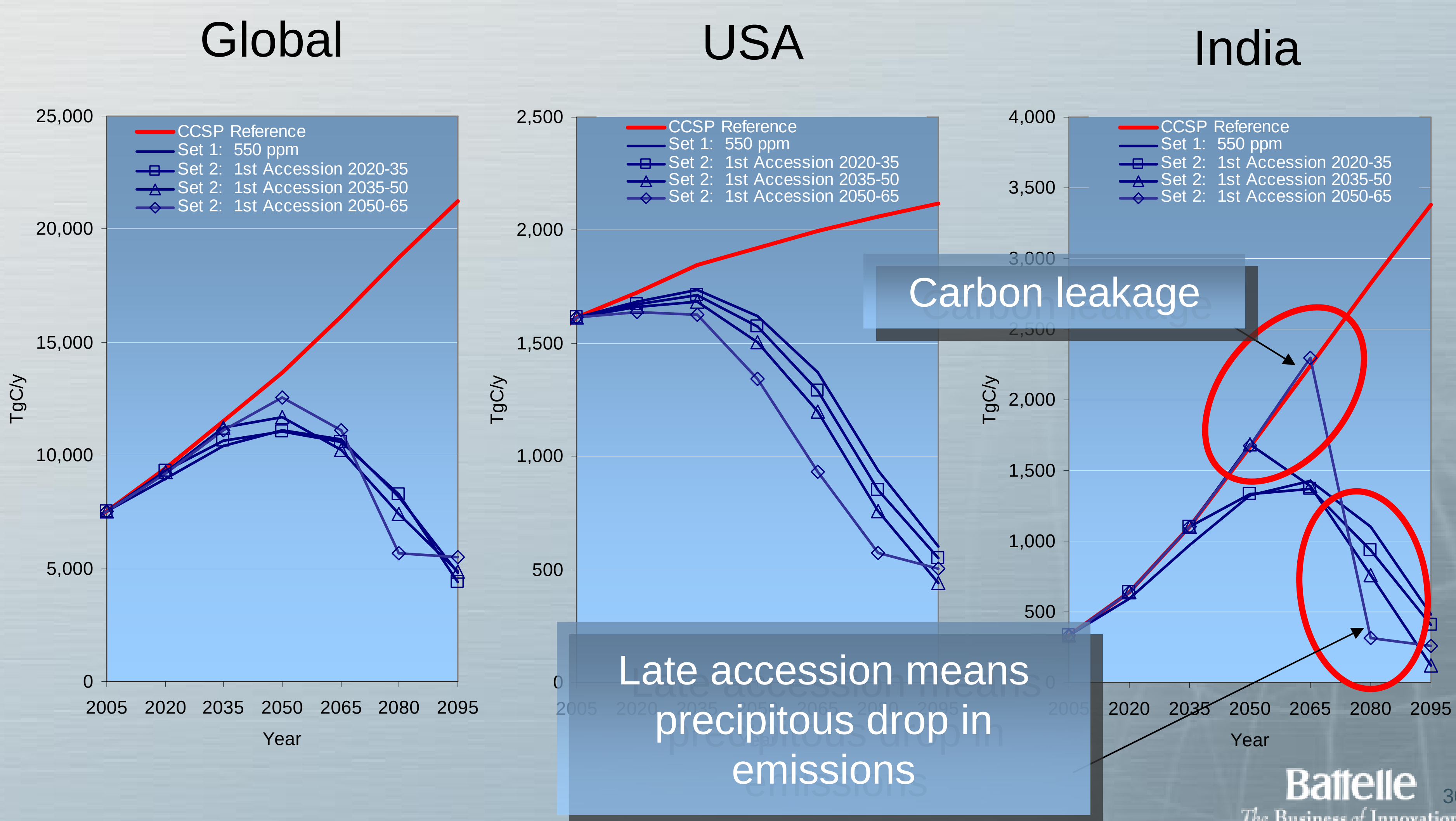


India



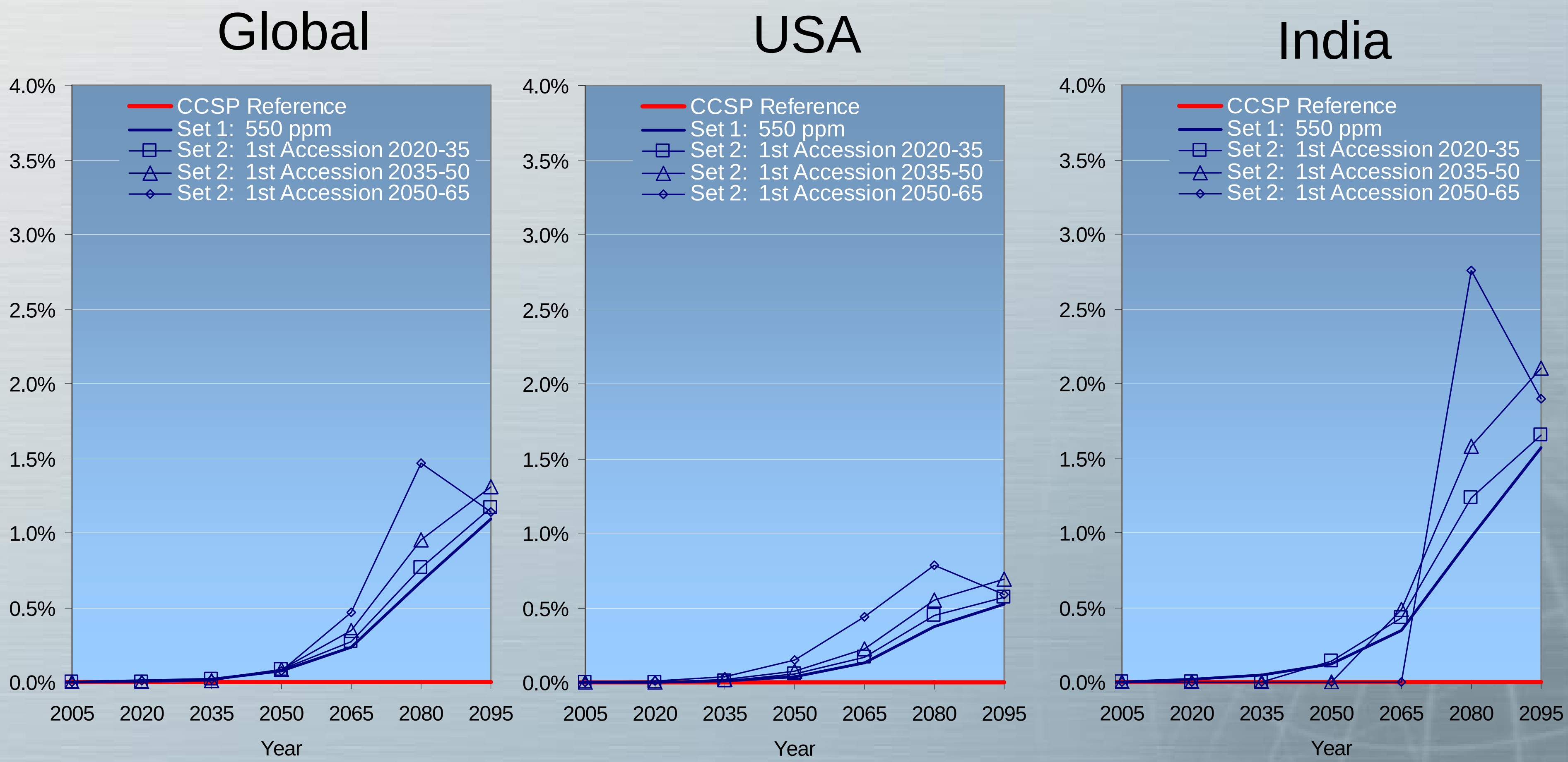
The Emissions Mitigation Measures
Graduated Accession Scenario Set 2

Fossil Fuel CO_2 Emissions—550 ppm



The Emissions Mitigation Measures
Graduated Accession Scenario Set 2

Emissions Mitigation Costs Per GDP—550 ppm



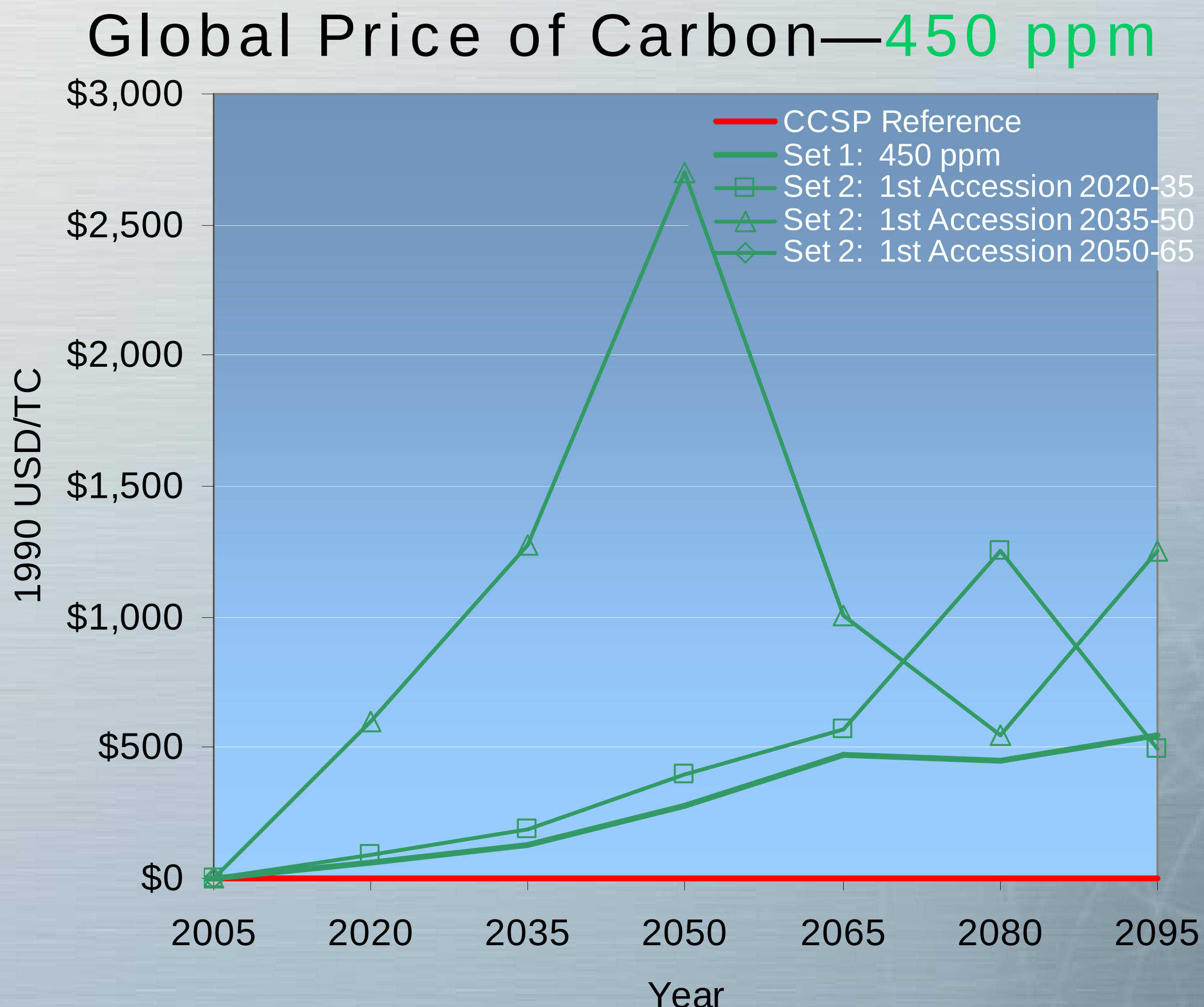
Late accession leads to cost spikes.

Graduated Accession Scenario Set 2
450 ppm

Set 2 1st Accession 2050-65 is infeasible!

The Emissions Mitigation Measures

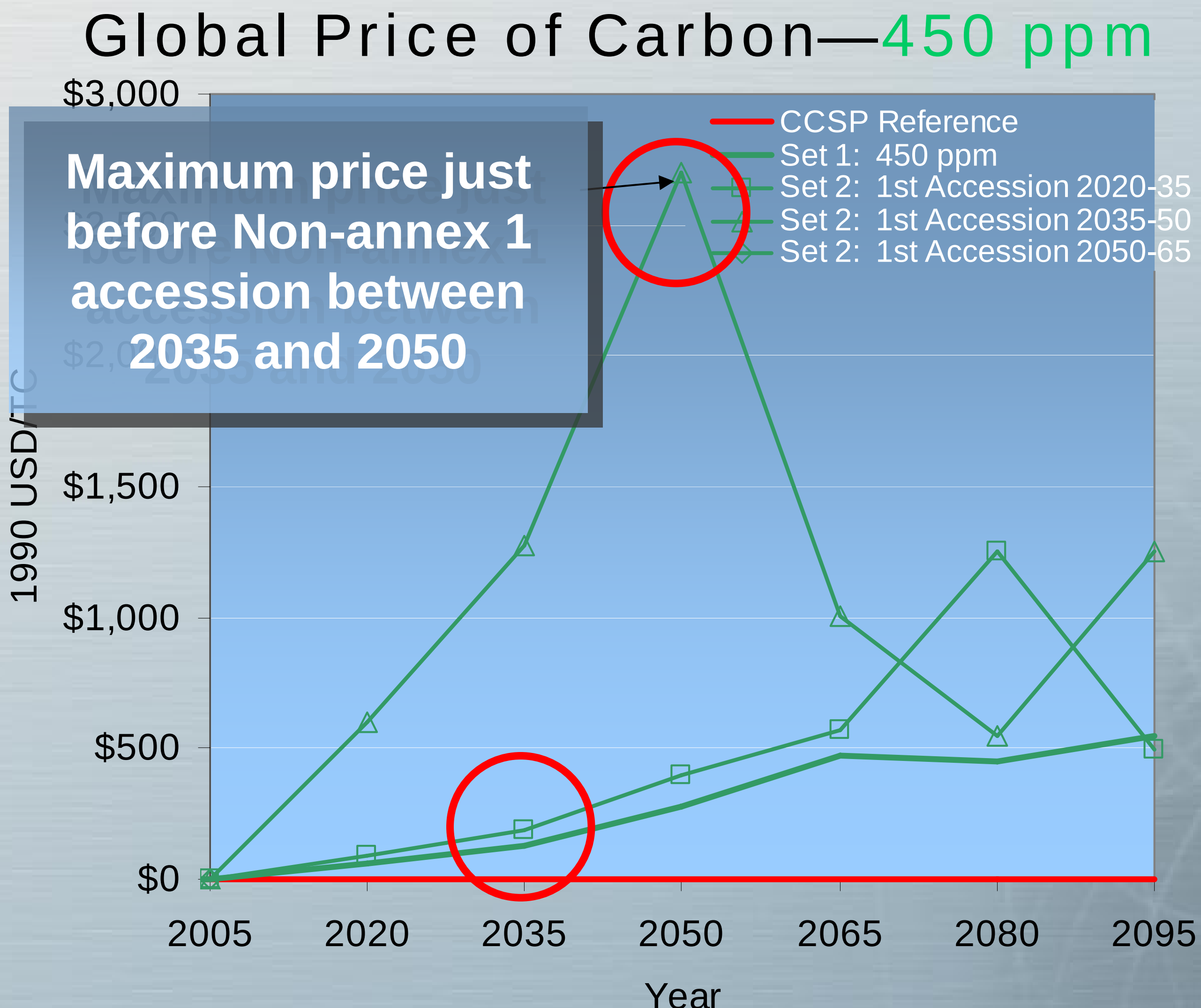
Graduated Accession Scenario Set 2



Set 2 1st Accession 2050-65 is infeasible!

The Emissions Mitigation Measures

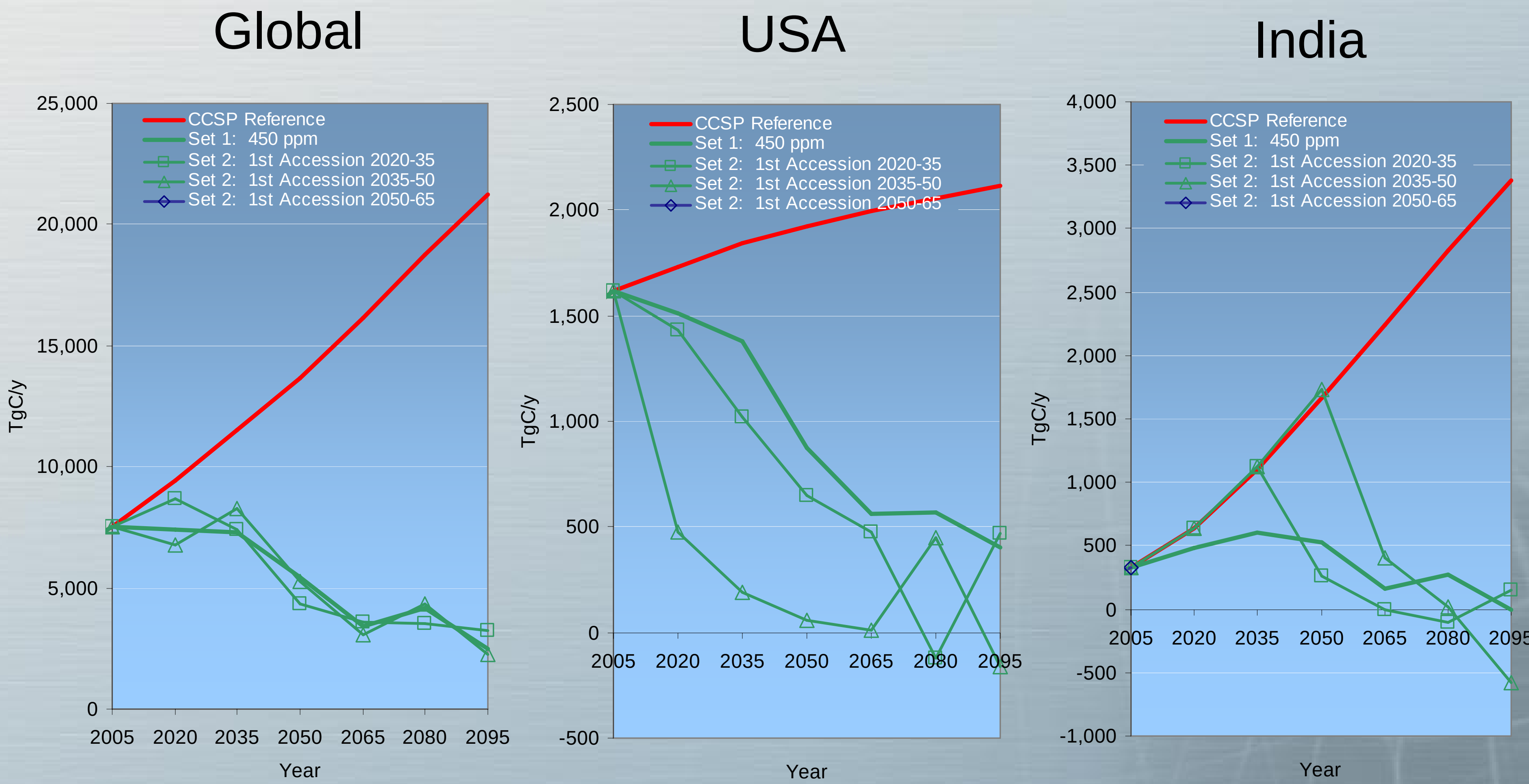
Graduated Accession Scenario Set 2



Set 2 1st Accession 2050-65 is infeasible!

The Emissions Mitigation Measures
Graduated Accession Scenario Set 2

Fossil Fuel CO_2 Emissions—450 ppm



Set 2 1st Accession 2050-65 is infeasible!

The Emissions Mitigation Measures

Graduated Accession Scenario Set 2

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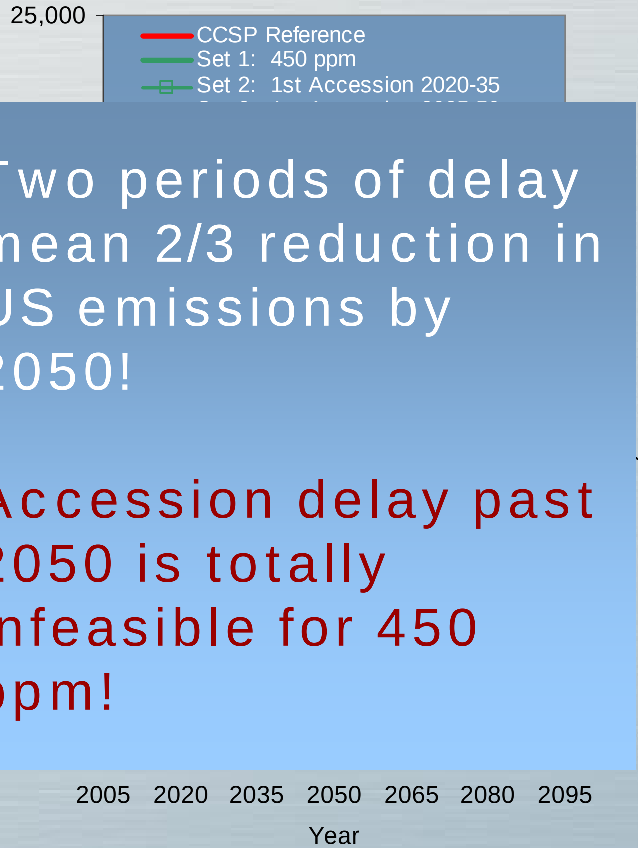
Fossil Fuel CO_2 Emissions—450 ppm

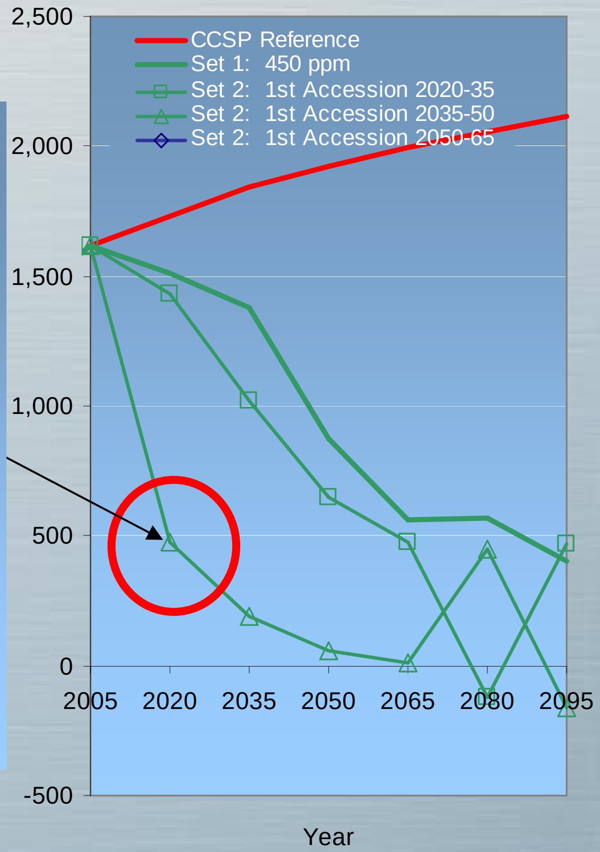
Global



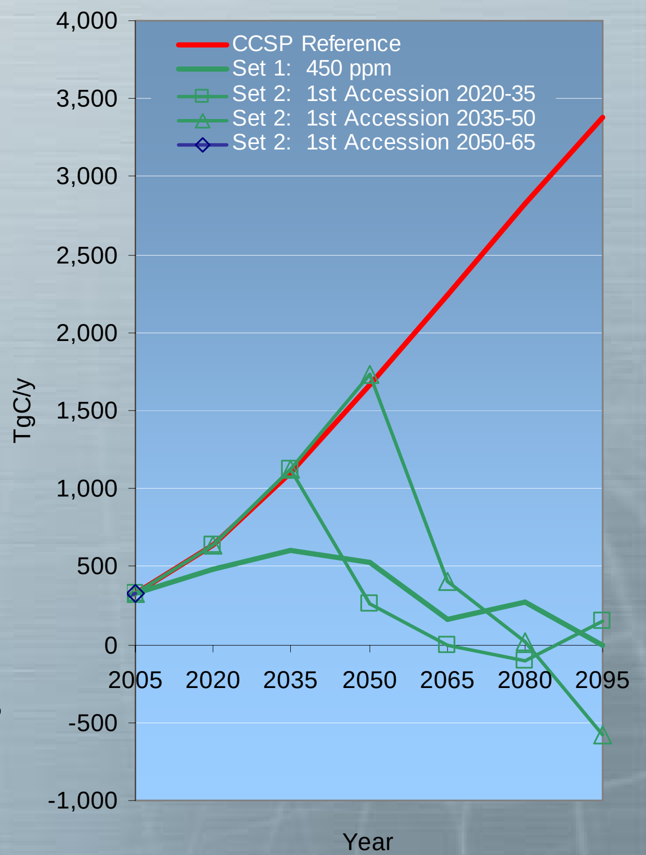
Two periods of delay mean 2/3 reduction in US emissions by 2050!

Accession delay past 2050 is totally infeasible for 450 ppm!

USA



India



Set 2 1st Accession 2050-65 is infeasible!

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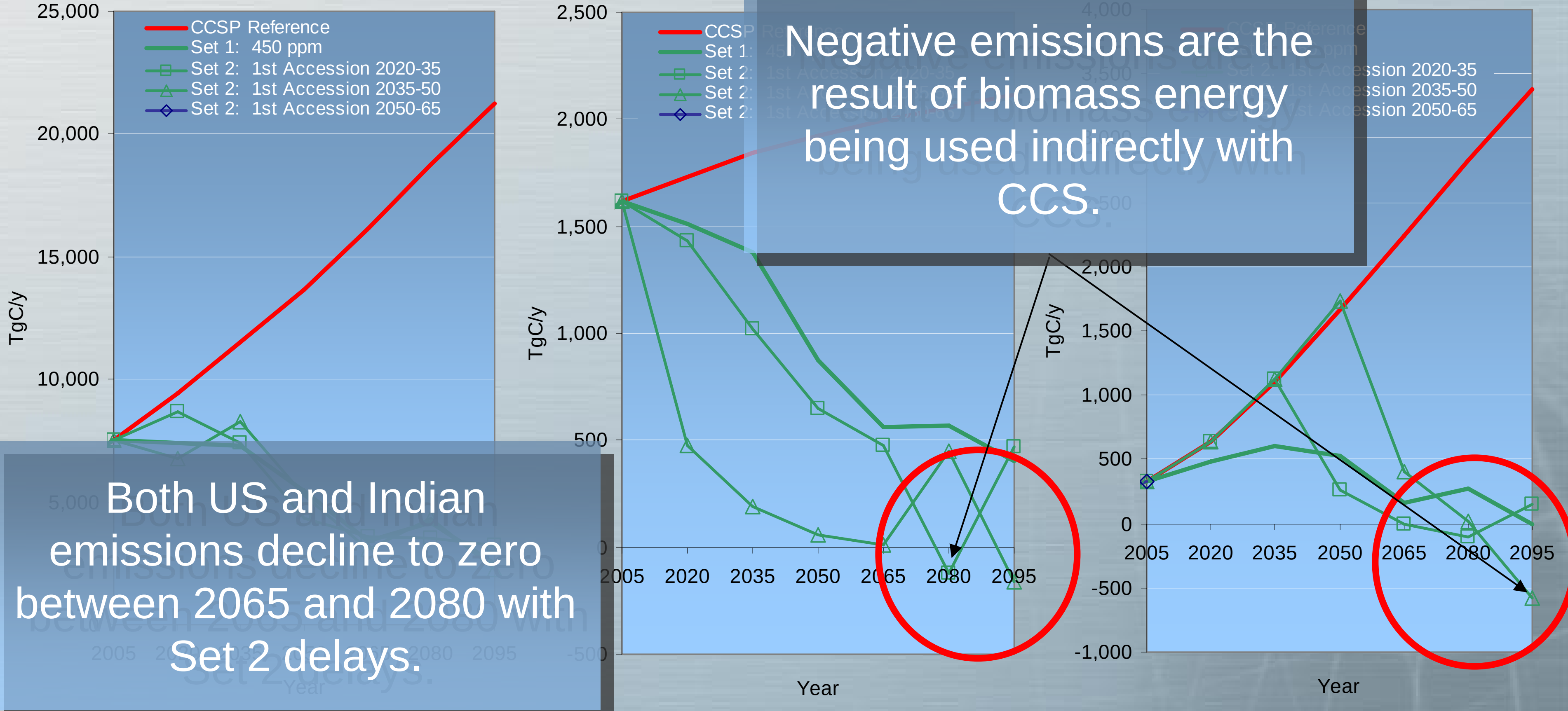
The Emissions Mitigation Measures
Graduated Accession Scenario Set 2

Fossil Fuel CO_2 Emissions—450 ppm

Global USA India



Negative emissions are the result of biomass energy being used indirectly with CCS.

Both US and Indian emissions decline to zero between 2065 and 2080 with Set 2 delays.

Set 2 1st Accession 2050-65 is infeasible!

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The Emissions Mitigation Measures
Graduated Accession Scenario Set 2

Emissions Mitigation Costs Per GDP—450 ppm

Set 2 1st Accession 2050-65 is infeasible!

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Parallel Regimes Scenario Set 3

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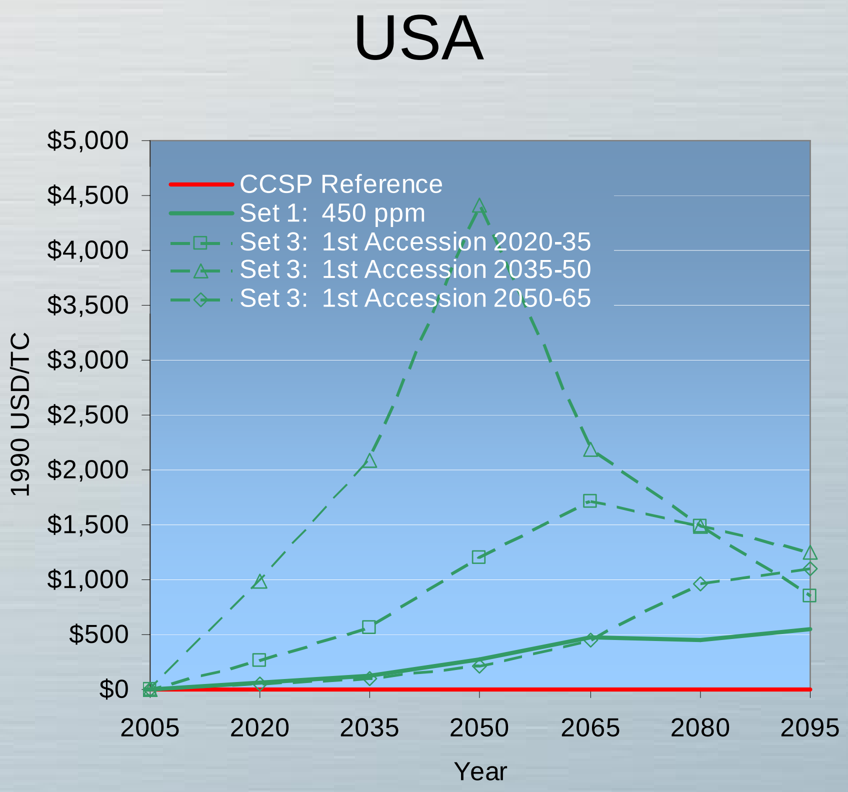
The Emissions Mitigation Measures
Parallel Regimes Scenario Set 3

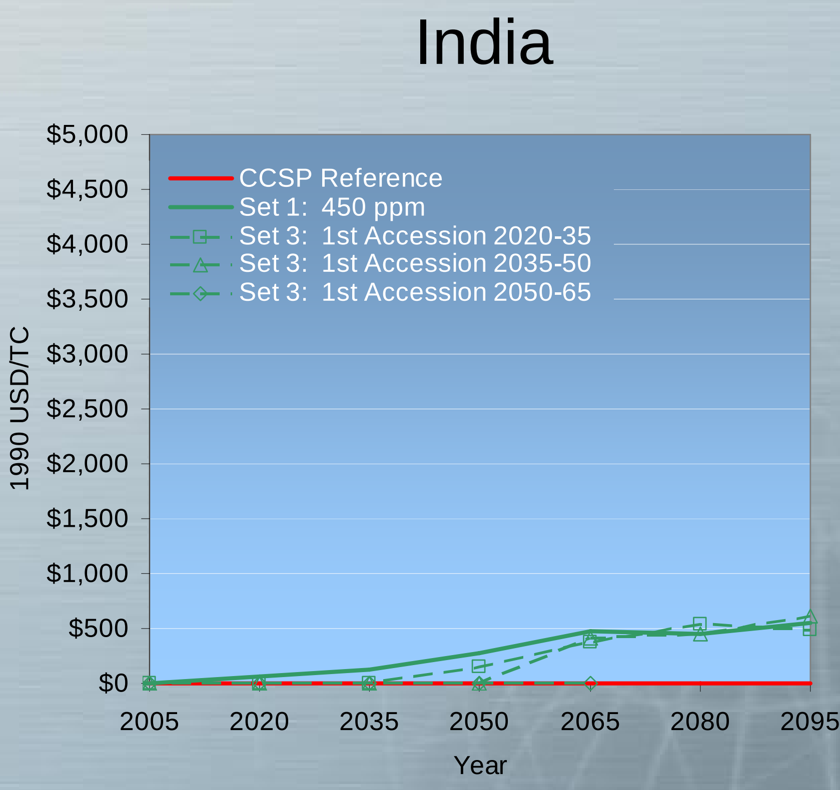
- Stabilize CO_2 concentrations
  - –450 ppm, 550 ppm, 650 ppm.
  - –Sectoral carbon prices—All EQUAL.
  - –**Regional carbon prices—each region separate.**
  - –**Time path of carbon prices**
    - **Annex 1 follows Peck-Wan-Hotelling.**
    - **Other regions carbon price proportional to relative per capita income.**
  - –Staggered accession based on per capita income.
    - Alternative accession cases—first group enters: 2020-2035, 2035-2050, 2050-2065

Parallel Regimes Set 3
450 ppm

The Emissions Mitigation Measures
Parallel Regimes Scenario Set 3

Prices of Carbon—450 ppm



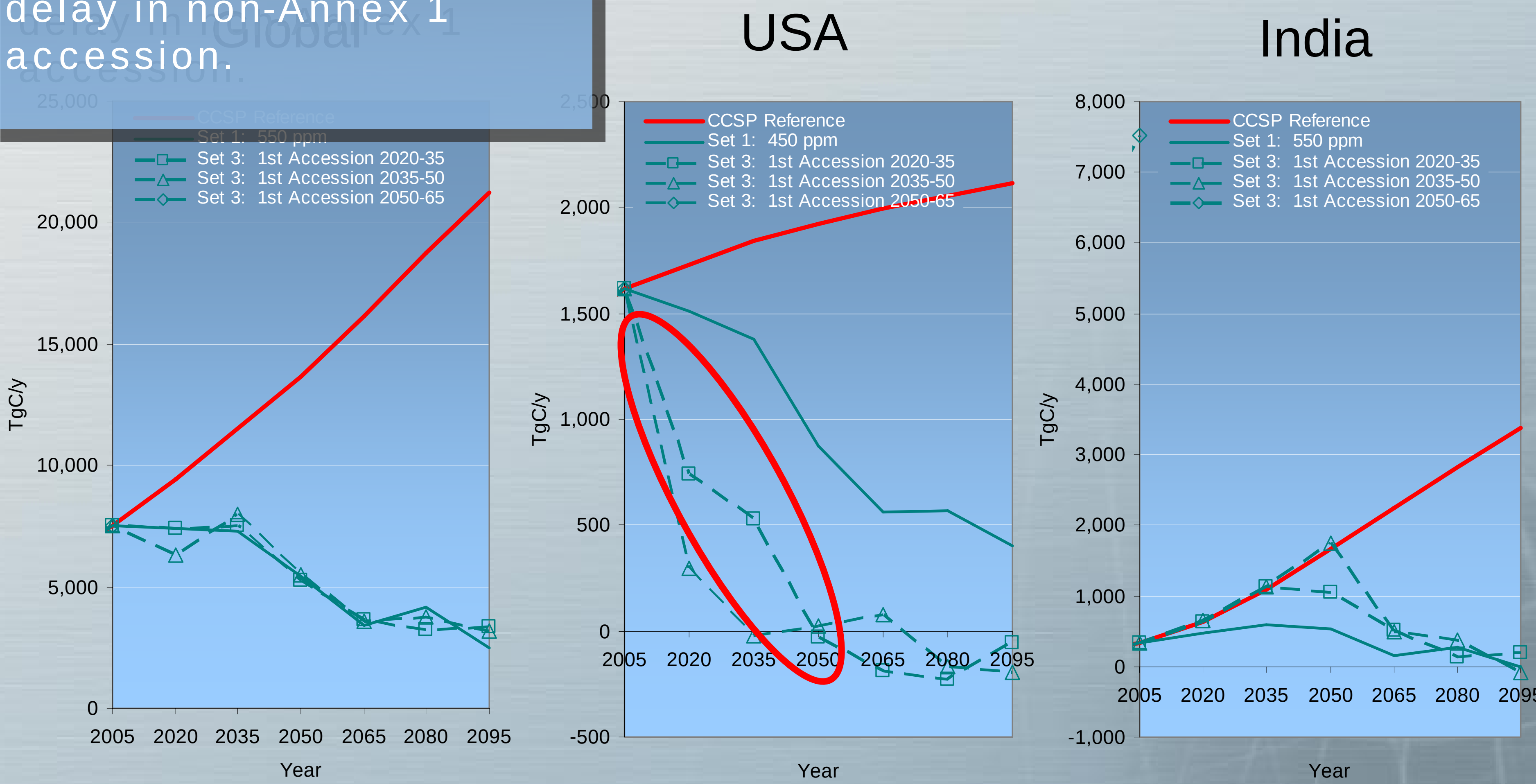


There is little difference in the Set 3 global emissions path from Set 1, however USA emissions must be much lower with ANY delay in non-Annex 1 accession.

...ns Mitigation Measures

Parallel Regimes Scenario Set 3

Fossil Fuel CO_2 Emissions—450 ppm



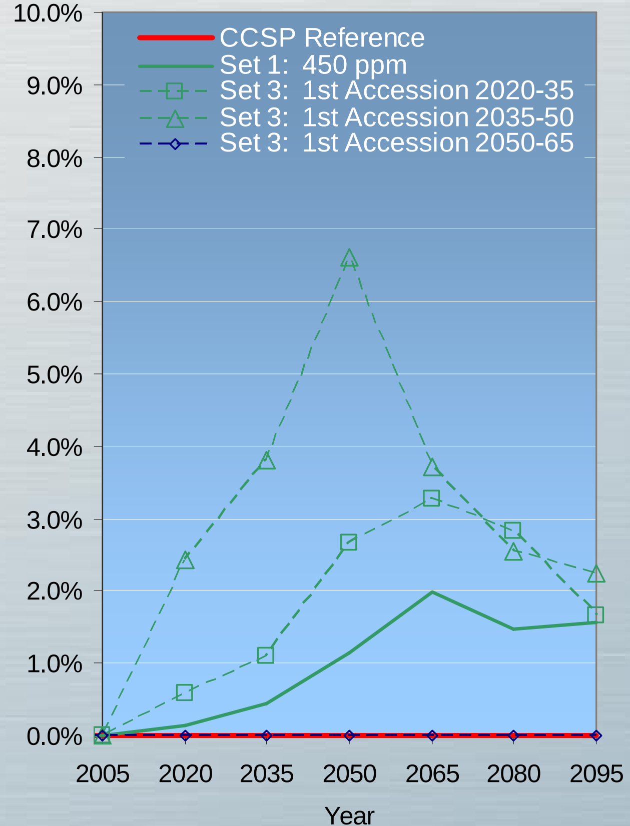
Set 3 scenarios require radical reductions in US emissions.

The Emissions Mitigation Measures

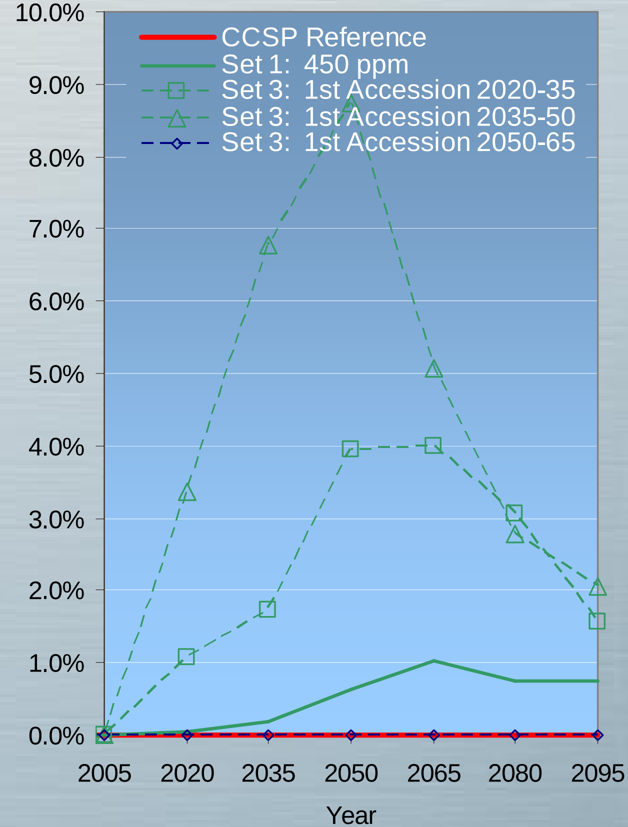
Parallel Regimes Scenario Set 3

Emissions Mitigation Costs Per GDP—450 ppm

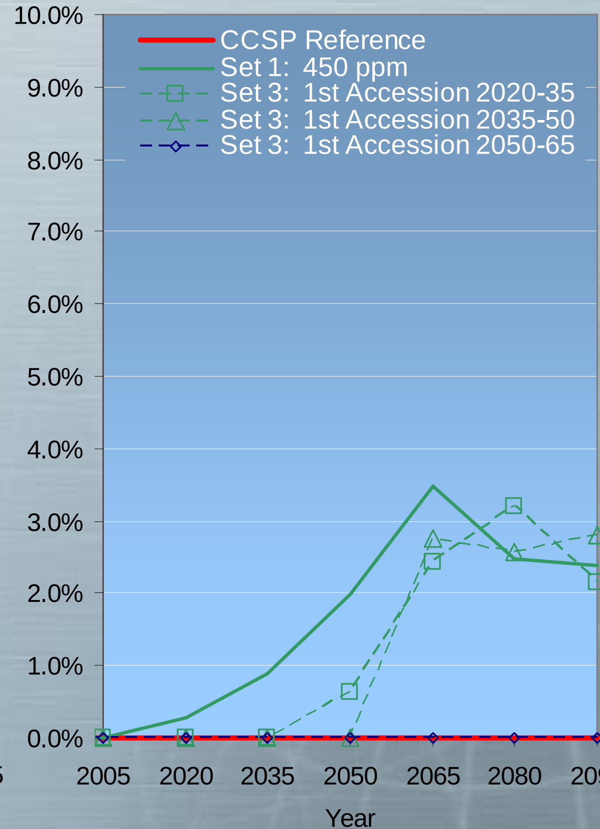
Global



USA



India



Set 3 with 1st Accession in 2050-65 is infeasible!

The Emissions Mitigation Measures

Parallel Regimes Scenario Set 3

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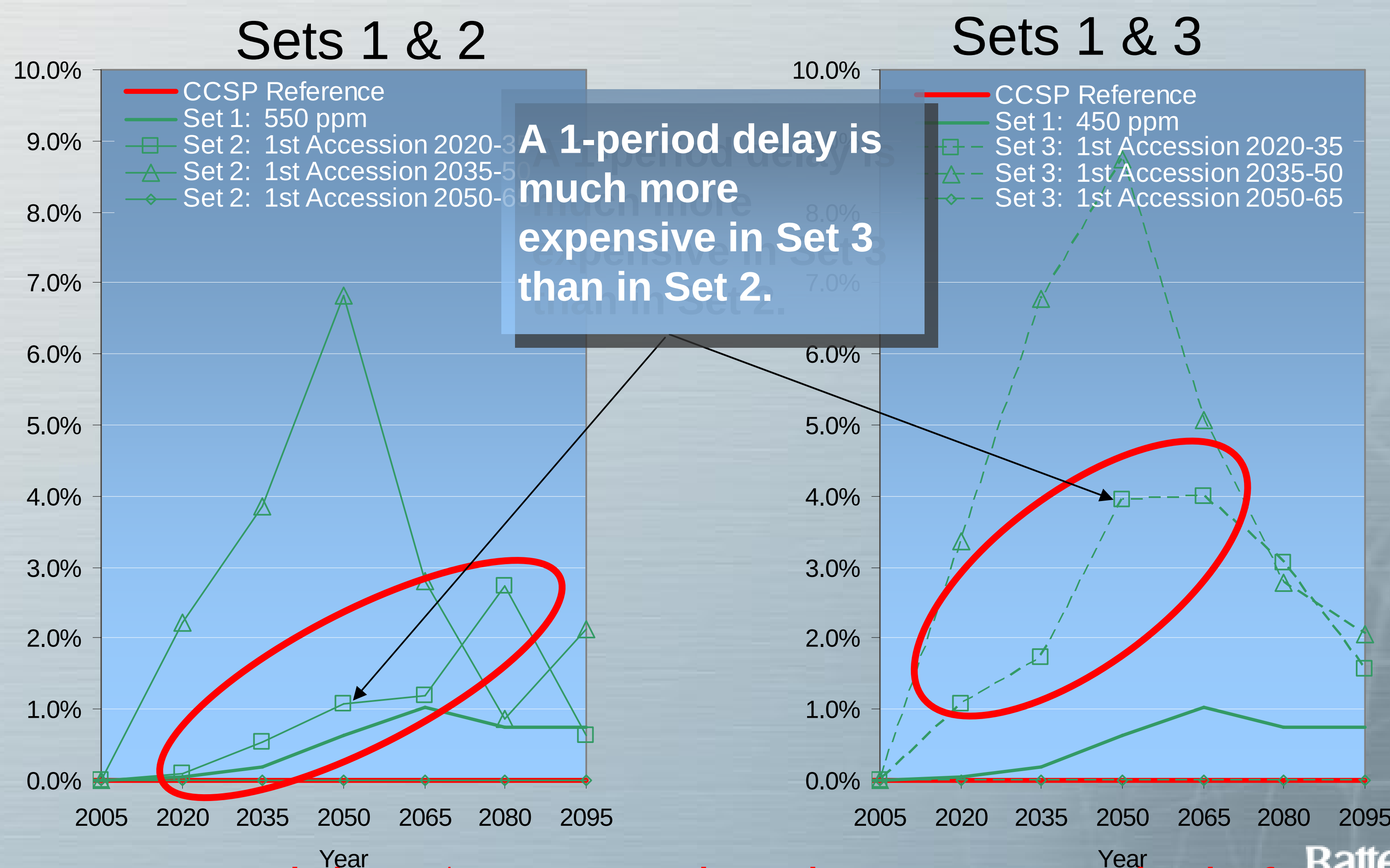
USA Emissions Mitigation Costs Per GDP—450 ppm



Sets 2 & 3 with 1st Accession in 2050-65 is infeasible!

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Final Observations

WARNING!

THIS WORK IS PRELIMINARY AND SUBJECT TO CHANGE

Final Observations

- We know that inefficient "second best" emissions mitigation measures are more expensive than optimal measures—this work has sought to provide some quantitative insights on how expensive several different types of inefficiency might be.
- We looked at 4 stabilization scenario sets

  Set 1: **Idealized**—perfect global where, when, and who flexibility

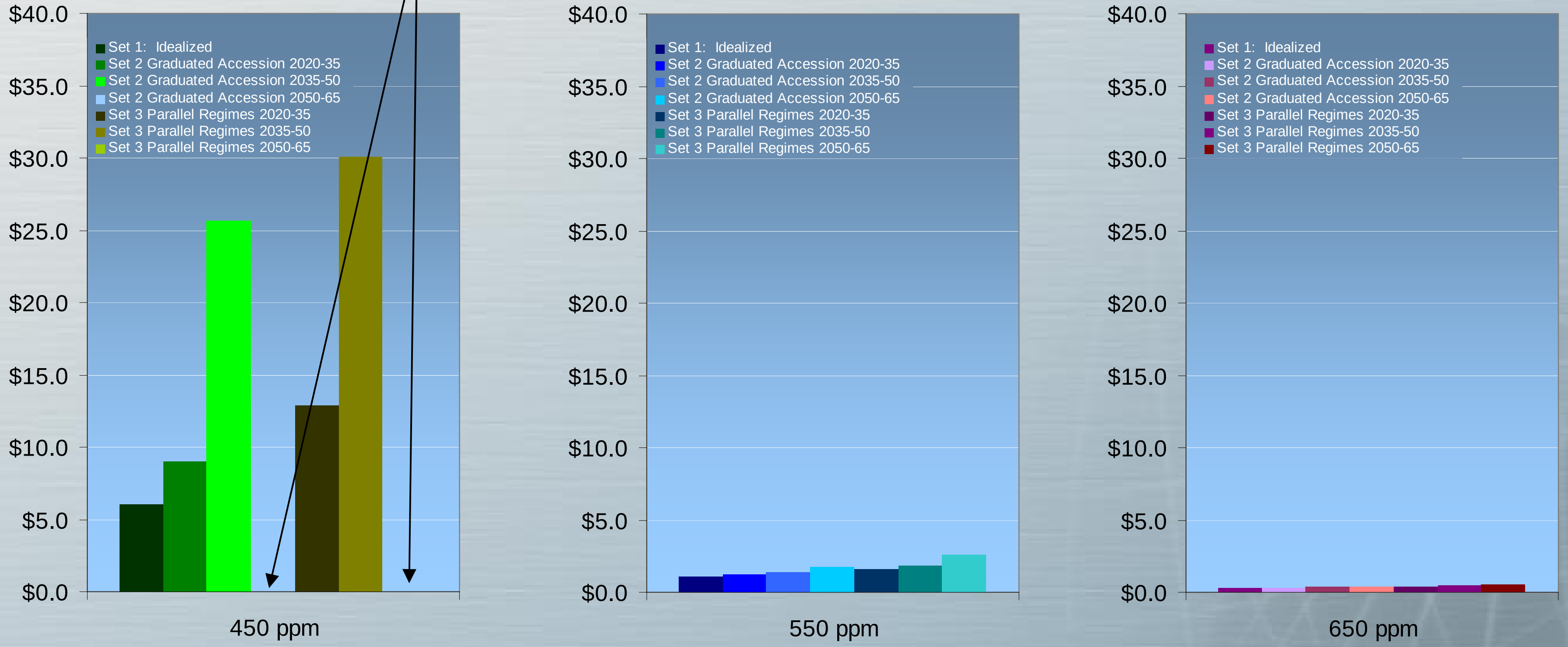
  Set 2: **Graduated accession of nations**—the cost of delay

  Set 3: **Parallel regimes**—the cost of delay and uncoordinated measures

  Set 4: **Inefficient markets**—the cost of inefficient

The effect of inefficiencies on present discounted costs (1990 USD)

Post 2050 non-Annex 1 accession: MiniCAM can't get to 450 ppm from here!



The dominant determinant of cost is the stabilization level.

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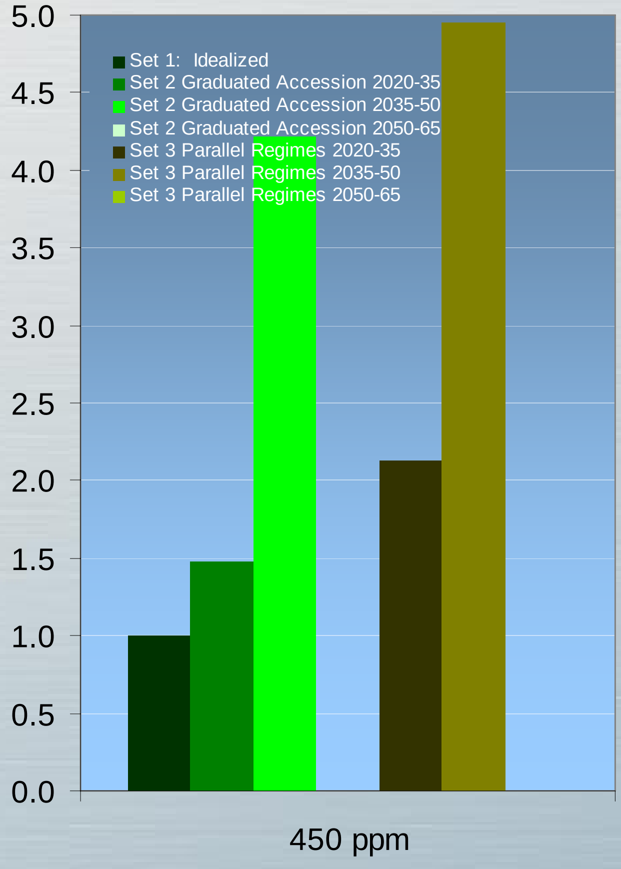
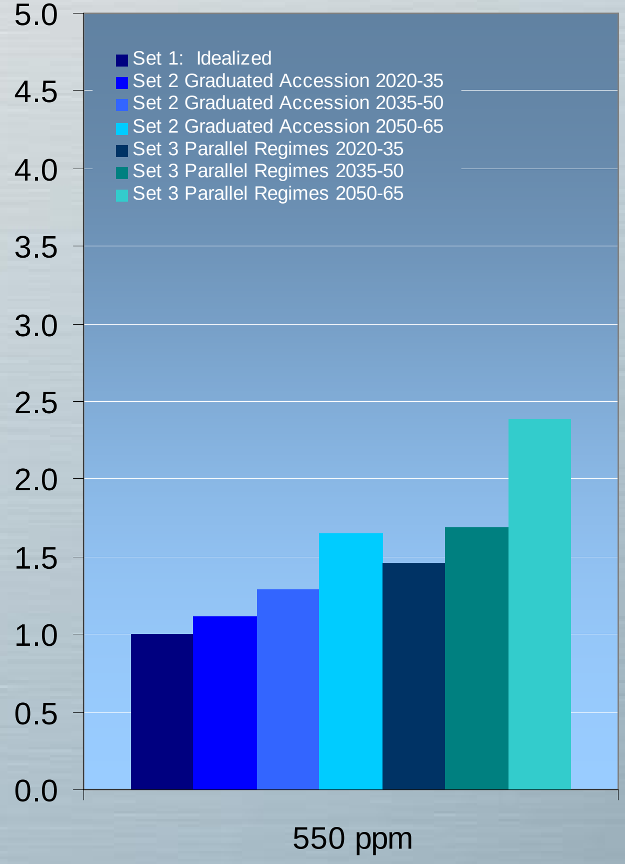
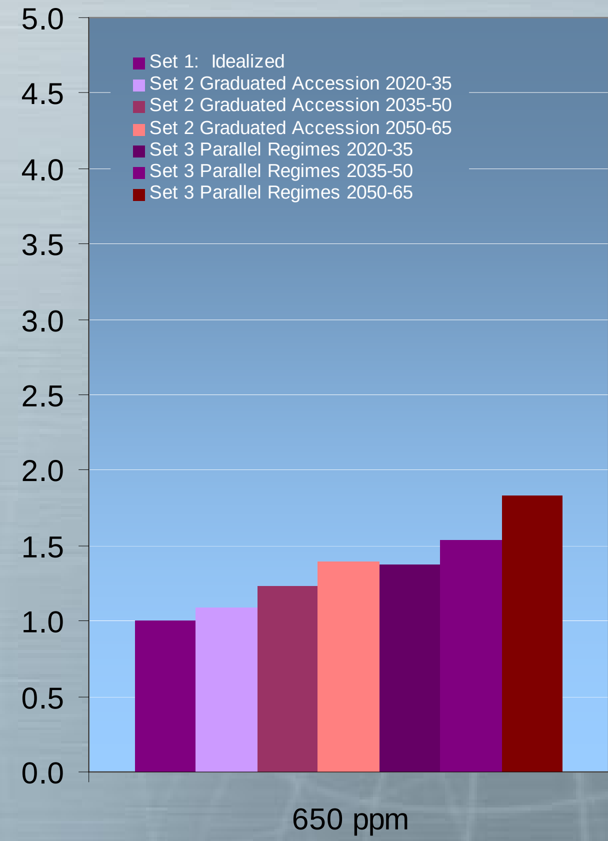
The effect of inefficiencies on present discounted costs

The relative effect on cost increases as the stringency of the limitation rises.

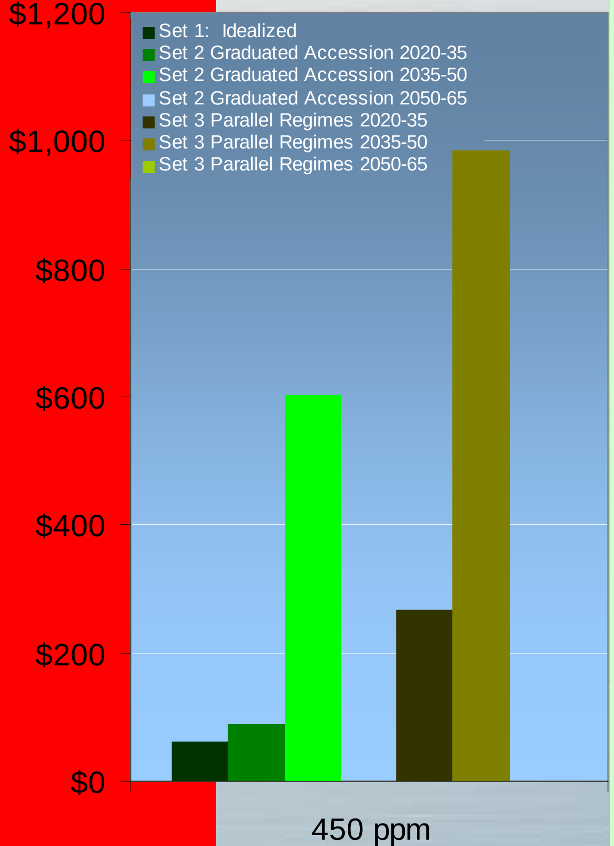


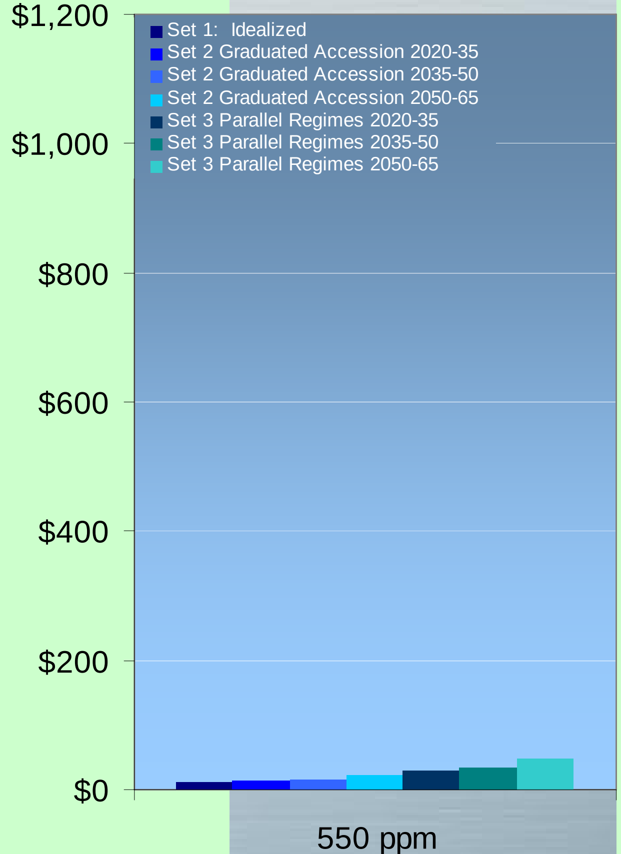


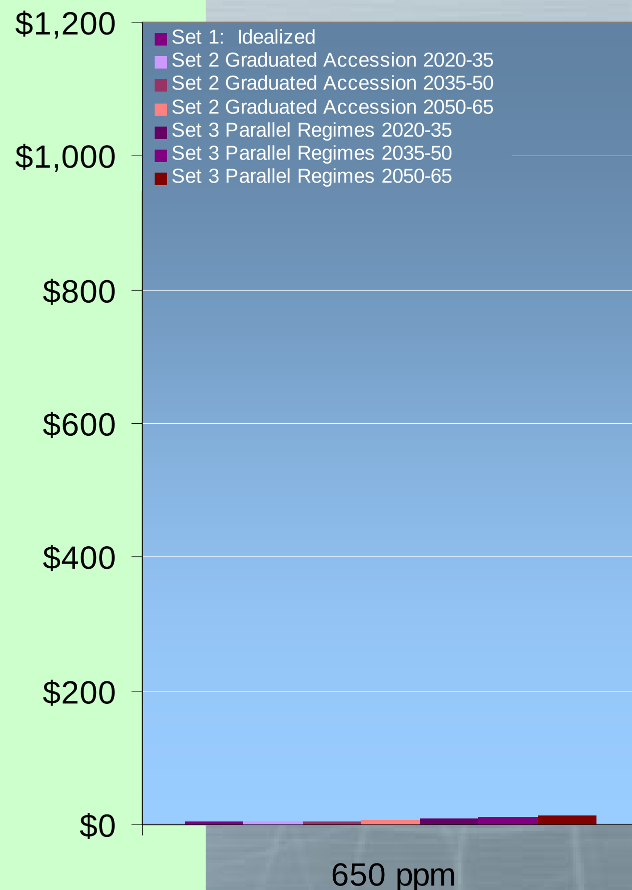


All costs normalized to the idealized cost at the concentration.

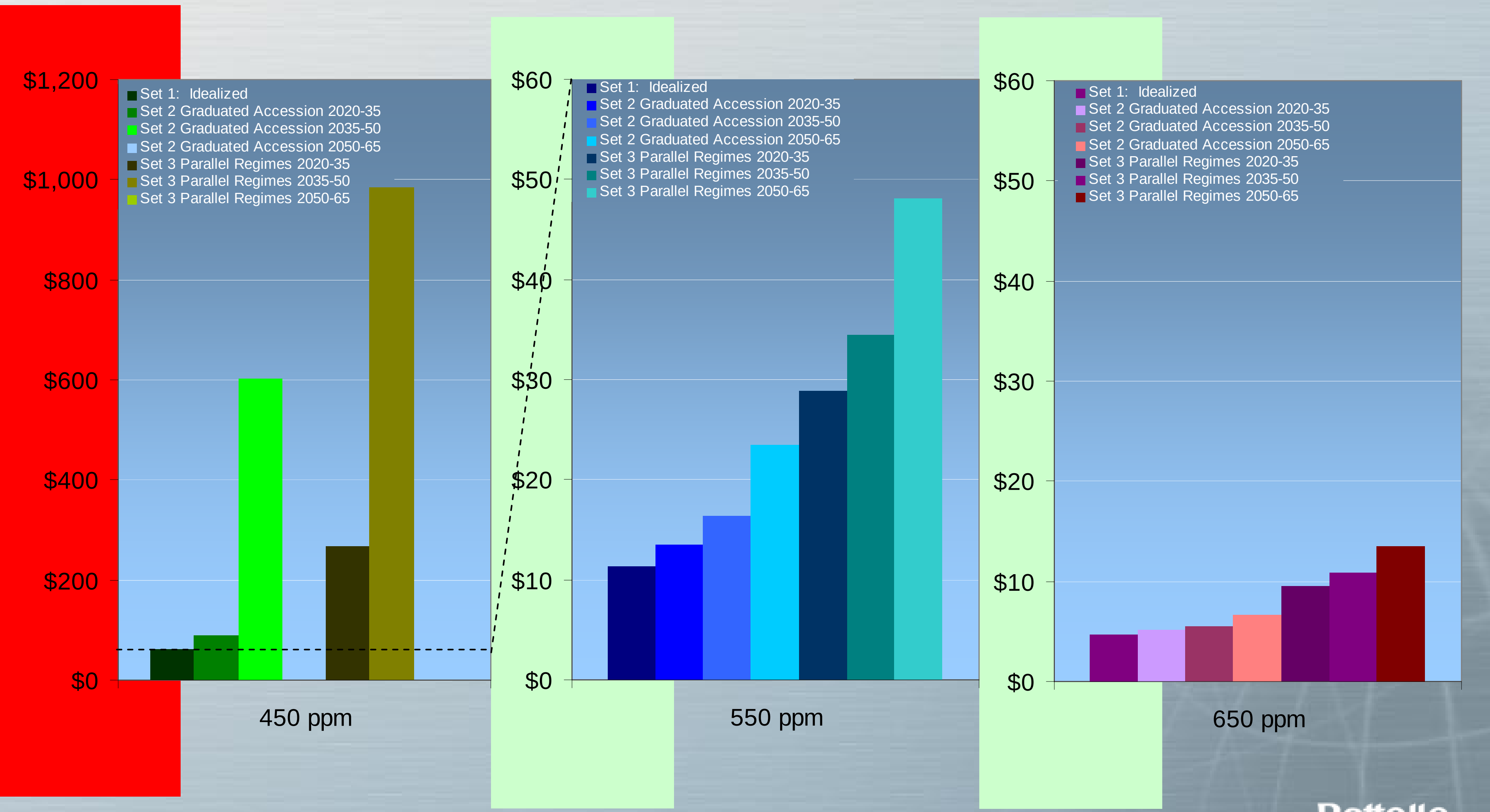
2020 prices of carbon (1990 USD) in the USA







2020 prices of carbon (1990 USD) in the USA (rescaled)



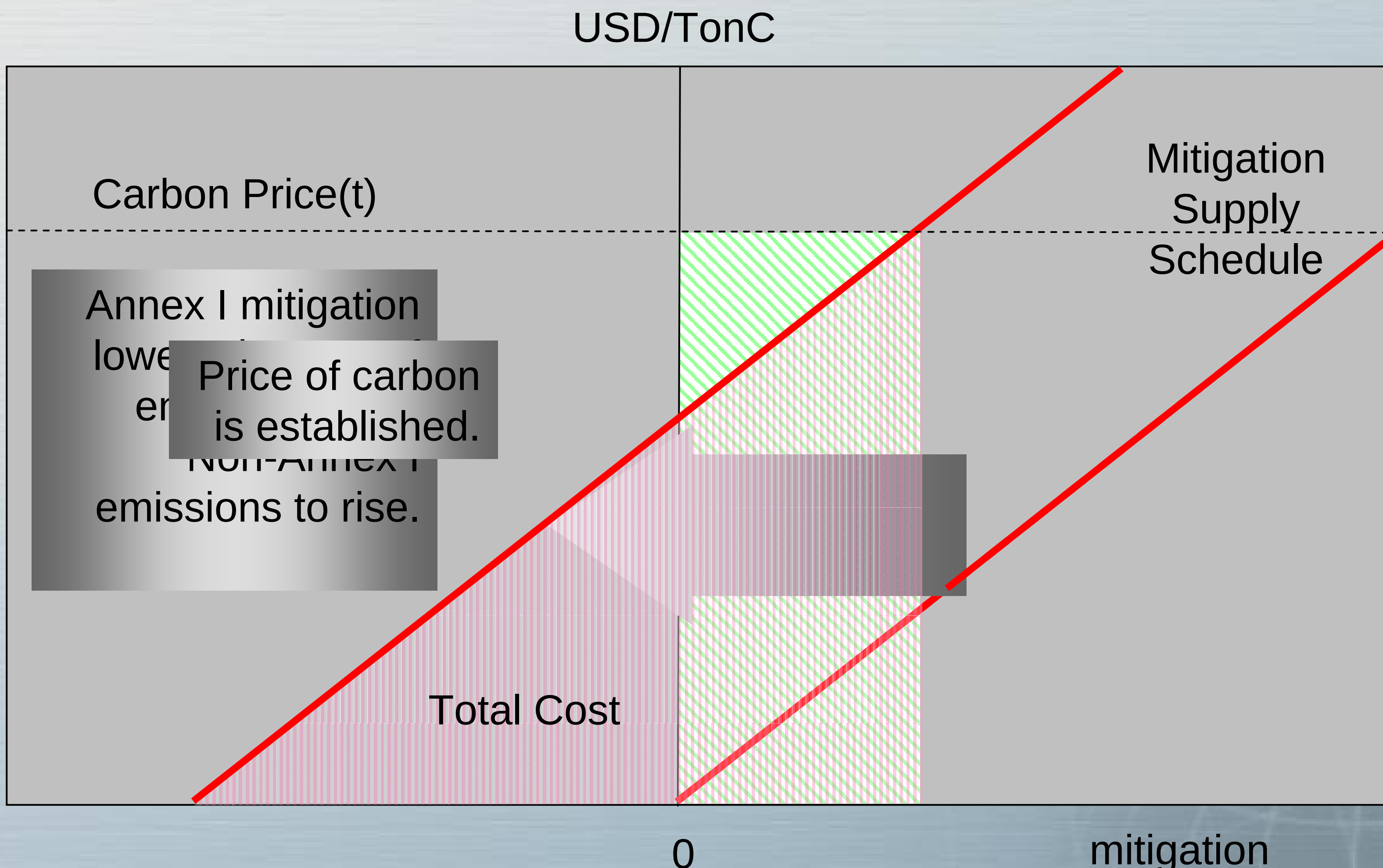
GTSP Global Energy Technology Strategy Program

Final Observations

- "Second best" is just that, second best
- Near-term prices of carbon depend in part on expectations about the future—including international emissions mitigation architectures and long-term stabilization goal.
- Carbon prices are strongly linked to the long-term stabilization objective.
  - The difference between an idealized 450 ppm stabilization and a 650 ppm stabilization is a factor of 6.
- Carbon prices are also linked to long-term emissions mitigation architectures, particularly as the stabilization level declines.
  - At 450 ppm the difference between an idealized regime and parallel emissions architecture with late non-annex 1 accession regime is a factor of 5.
  - At 650 expectations about the future regimes implies something less than a factor of 2 difference with the idealized regime.

END

The Effect of Annex I Mitigation on Non-Annex I Emissions Mitigation and BAU Allowances



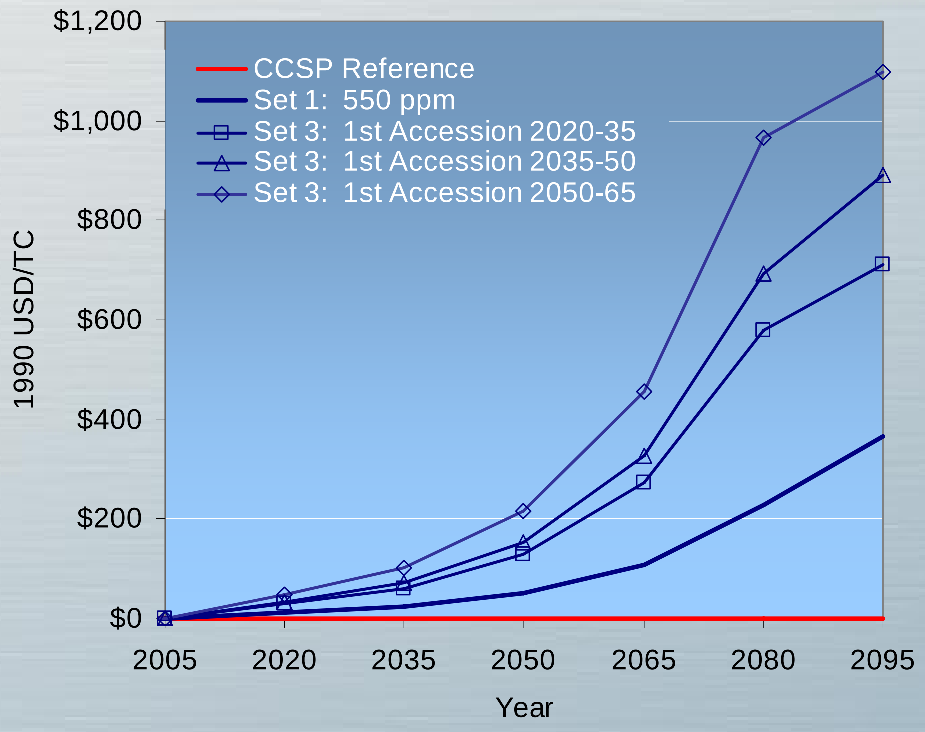
Parallel Regimes Set 3
550 ppm

The Emissions Mitigation Measures

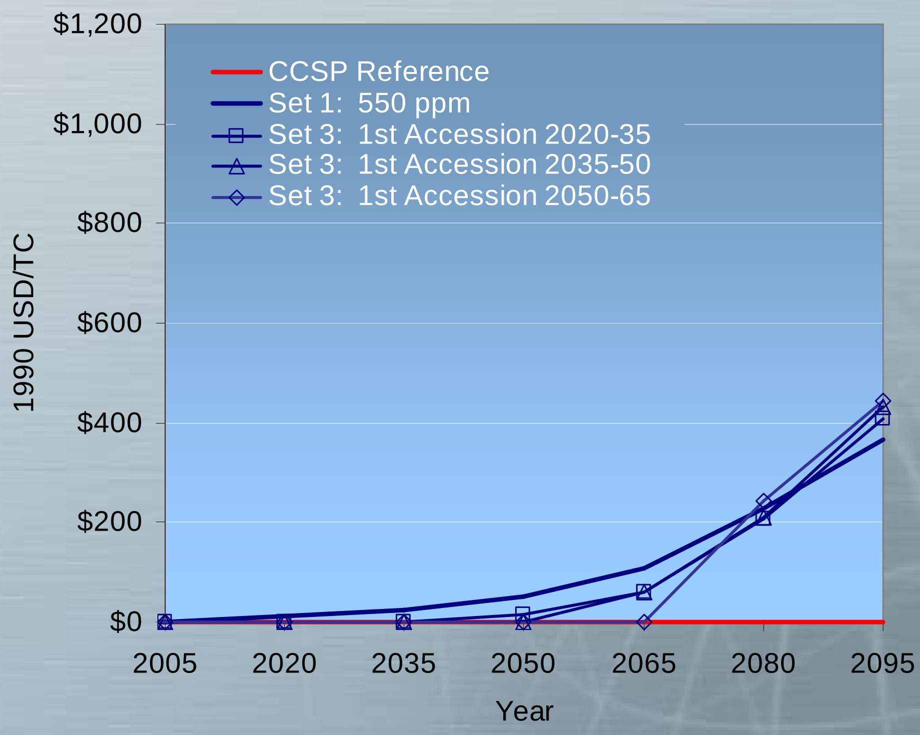
Parallel Regimes Scenario Set 3

Price of Carbon—550 ppm

USA



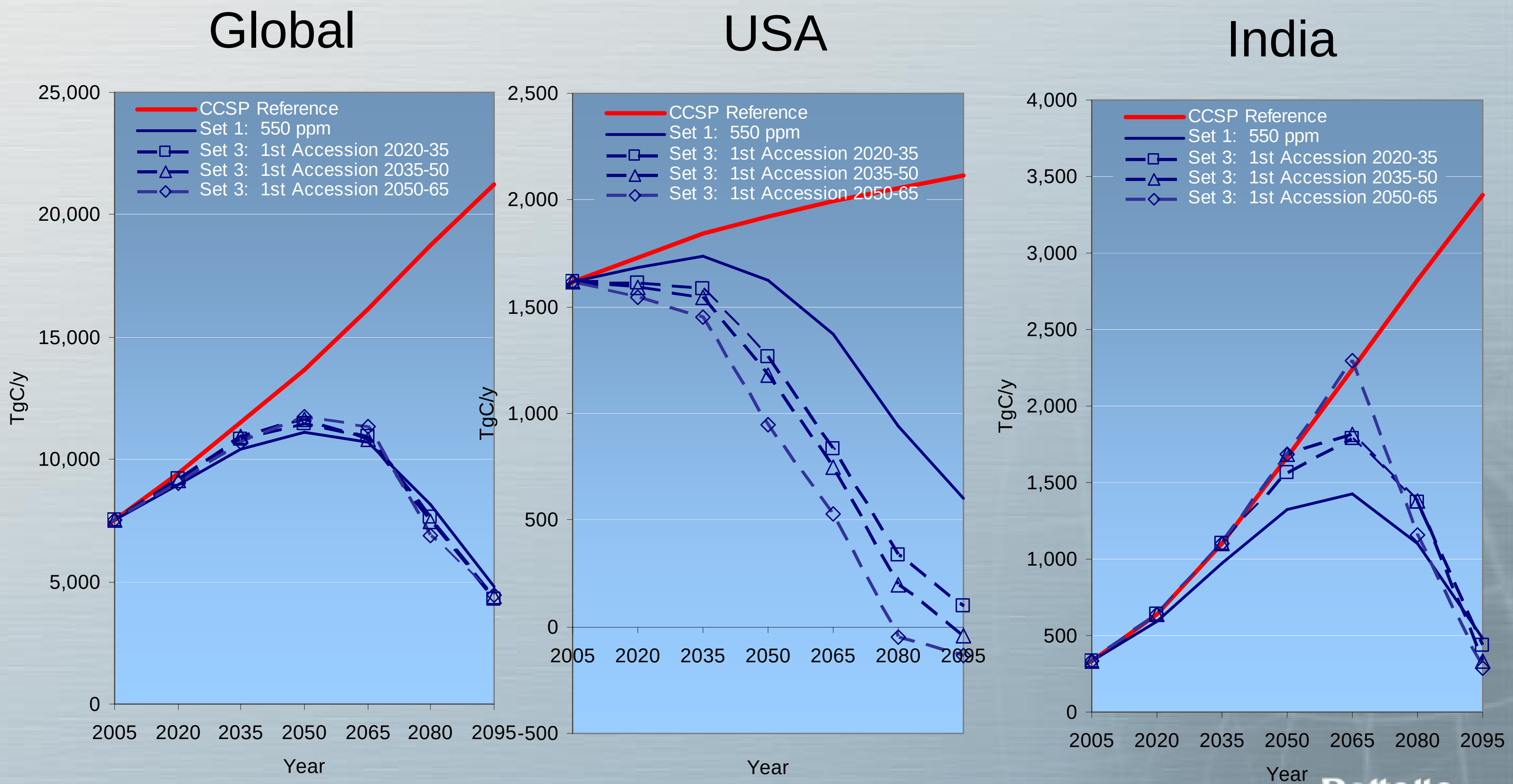
India



The Emissions Mitigation Measures

Parallel Regimes Scenario Set 3

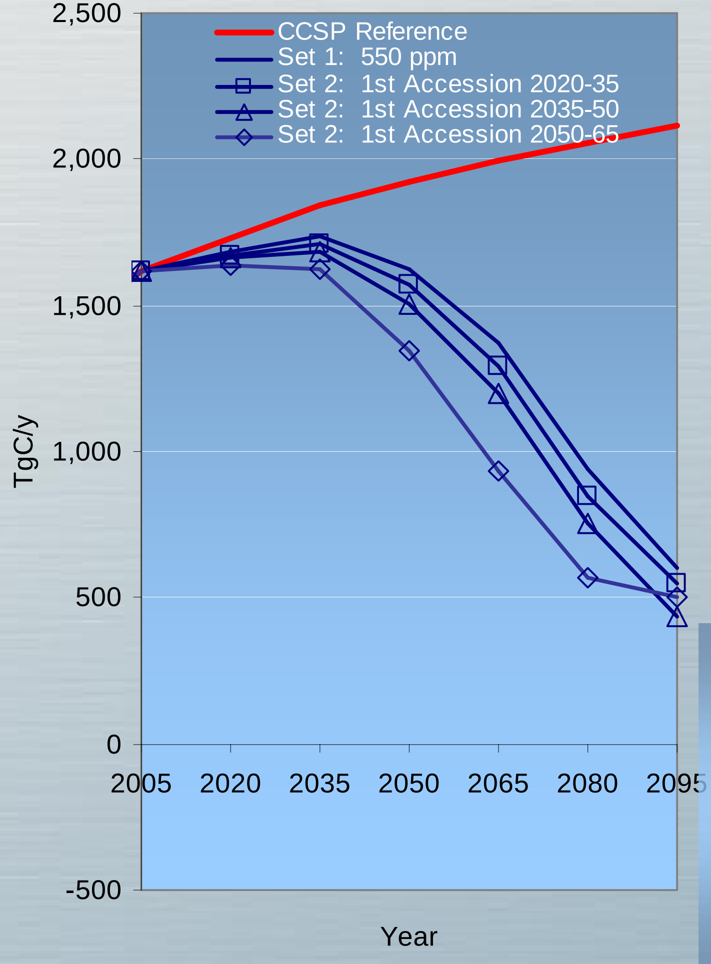
Fossil Fuel CO_2 Emissions—550 ppm



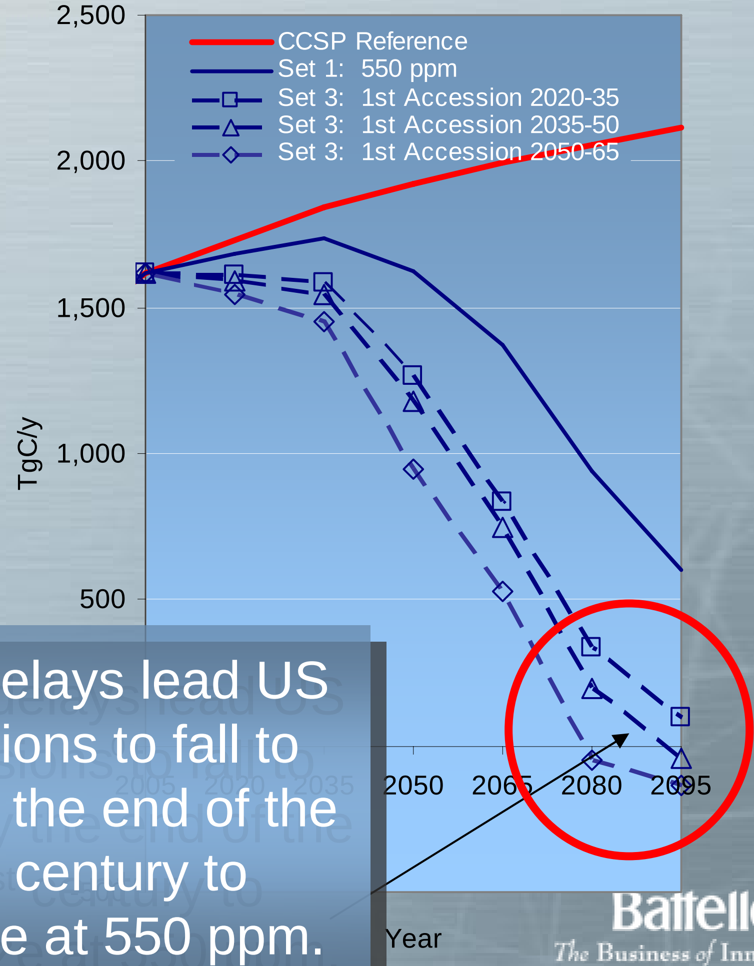
The Emissions Mitigation Measures
Parallel Regimes Scenario Set 3

Fossil Fuel CO_2 Emissions—550 ppm

USA Sets 1 & 2



USA Sets 1 & 3



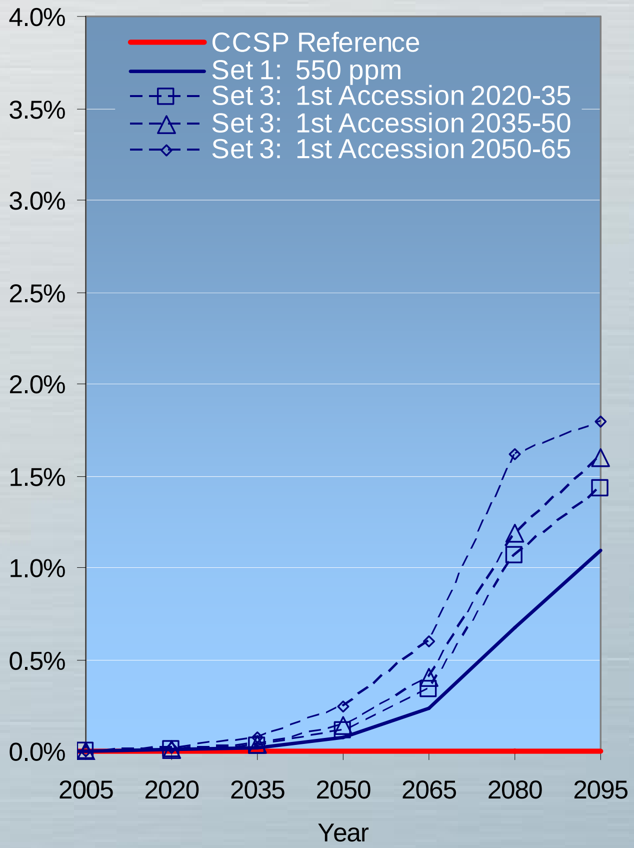
Set 3 delays lead US emissions to fall to zero by the end of the 21st century to stabilize at 550 ppm.

The Emissions Mitigation Measures

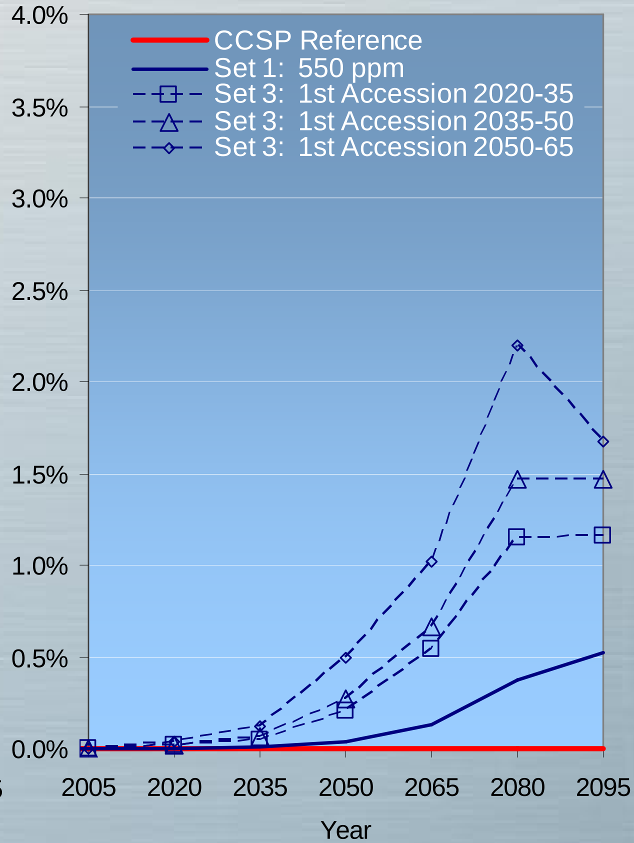
Parallel Regimes Scenario Set 3

Emissions Mitigation Costs Per GDP—550 ppm

Global



USA



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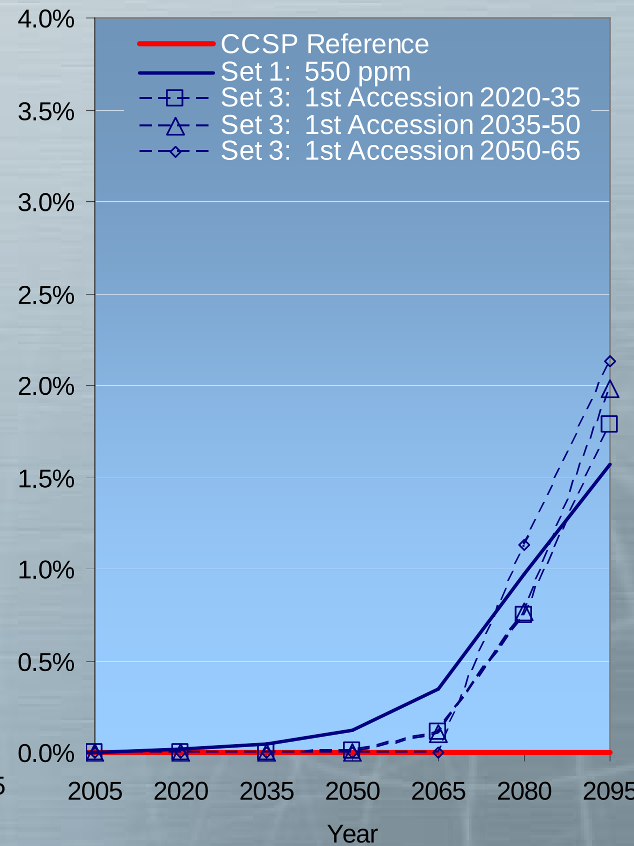
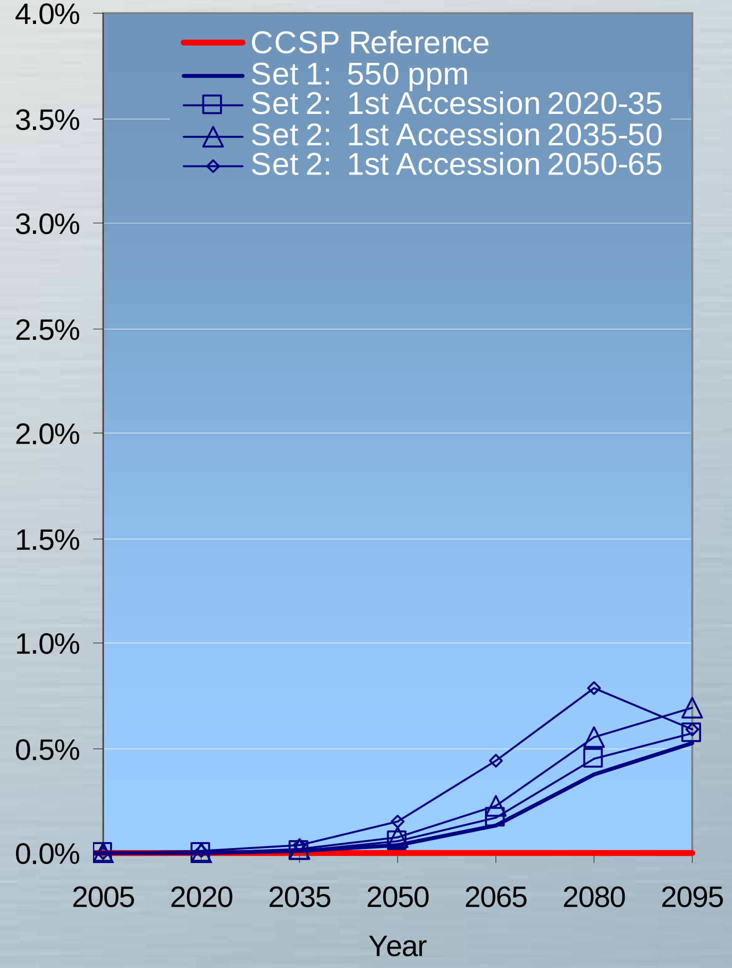


The Emissions Mitigation Measures

Parallel Regimes Scenario Set 3

USA Emissions Mitigation Costs Per GDP—550 ppm

Sets 1 & 2



Sets 1 & 3