Addressing Non-CO_2 Gases & Sinks in GHG Scenarios: Experience from Energy Modeling Forum 21

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Outline

- Introduction to the EMF 21 Study
- Data Development on Non-CO_2 GHG and Sinks
- Results part A: Non-CO_2 GHGs
- Areas for further work

- Results part B: Recent EMF 21 Scenario Runs

EMF 21 Working Group Objectives

1) Conduct a new comprehensive, multi-gas policy assessment to improve the understanding of the affects of including non-CO_2 GHGs (NCGGs) and sinks (terrestrial sequestration) into short- and long-term mitigation policies. Answer the question: *How important are NCGGs & Sinks in climate policies?*.
2) Advance the state-of-the-art in integrated assessment / economic modeling
3) Strengthen collaboration between NCGG and Sinks experts and modeling teams
4) Publish results in a special issue of the *Energy Journal*

Economy, Technology, & Integrated Assessment Models (18)

Asia / Australia

ABARE (Guy Jakeman & Brian Fisher) with GTEM
Energy Research Institute China (Jiang Kejun) with IPAC
IAE Japan (Atsushi Kurosawa) with GRAPE
Indian Institute of Management (P. Shukla) with SGM-India
National Institute for Environmental Studies, Japan (Junichi Fujino) with AIM

Europe

CEA - IDEI (Marc Vielle) with GEMINI-E3
CICERO - University of Oslo (H.A. Aaheim) with COMBAT
Cntr for European Econ Research-(C. Boehringer & A. Loschel) with EU PACE
Copenhagen Economics (Jesper Jensen) with the EDGE Model
Hamburg Univ. (Richard Tol) with FUND
IIASA (Shilpa Rao) with MESSAGE
Oldenburg University, Germany (Claudia Kemfert) with WIAGEM
RIVM (Detlef van Vuuren, Tom Kram, & Bas Eickhout) with IMAGE
UPMF (Patrick Criqui) & CIRAD (Daniel Deybe) with POLES/AGRIPOL

US

Argonne Nat Lab (Don Hanson) & EPA (Skip Laitner) with AMIGA
EPRI (Rich Richels) & Stanford Univ (Alan Manne) with MERGE
MIT (John Reilly) with EPPA
PNNL-JGCRI (Jae Edmonds, Hugh Pitcher, & Steve Smith) with SGM & MiniCAM

Non-CO_2 GHG Experts
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Methane & N_2O
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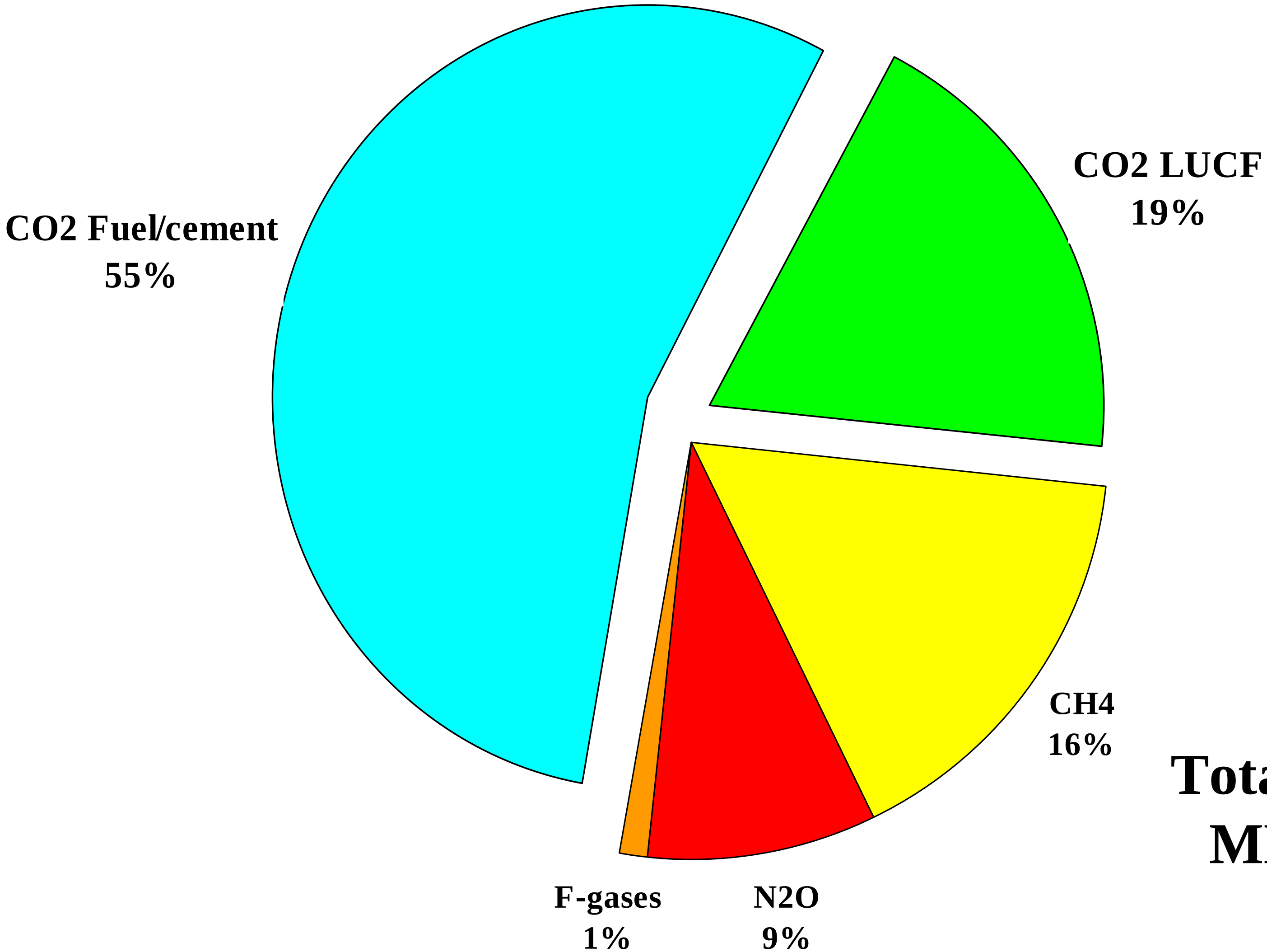
Fluorinated (HGWP) Gases
Jochen Harnish, Ecofys, Germany
Deborah Ottinger and Dave Godwin, USEPA

Sinks (Terrestrial Sequestration)
Bruce McCarl, Texas A&M
Ken Andrasko, USEPA & Jayant Sathaye, LBNL
Roger Sedjo, RFF & Brent Sohngen, Ohio State Univ
Ron Sands, PNNL-JGCRI

2000 Global Net GHG Emissions



Total 11,100 MMTCE

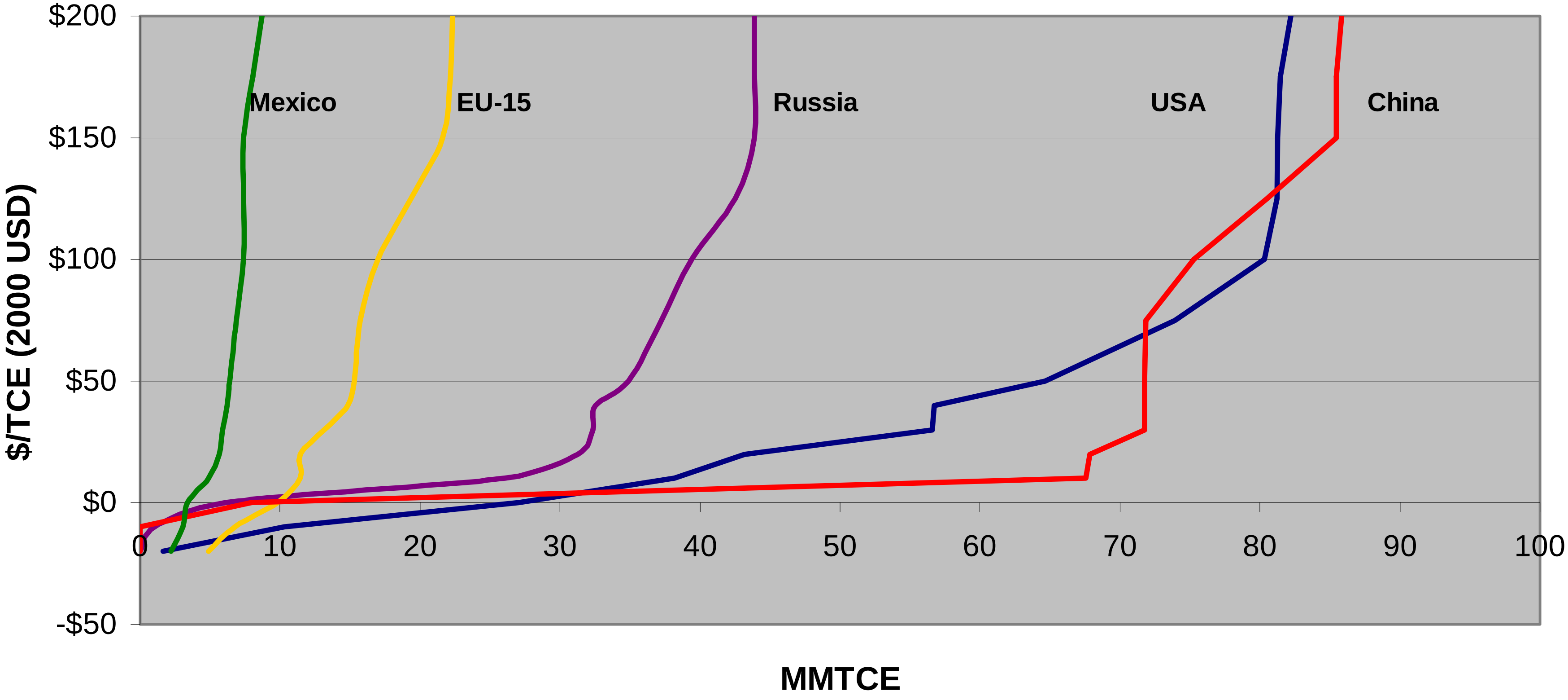
Non-CO_2 GHG & sequestration data requirements

- Global, consistent non-CO_2 GHG emission baselines for 2000 and projections 2020 by region. And key emissions drivers.
- Comparable marginal abatement curves
  - by region, by gas, and by sector
  - sensitivities to energy, material prices
  - in MMTCE w/ 100-yr GWP & gas specific units
  - Various discount and tax rates
- Assessment of how marginal abatement curves vary over time, from 2010 to 2100 by decade.

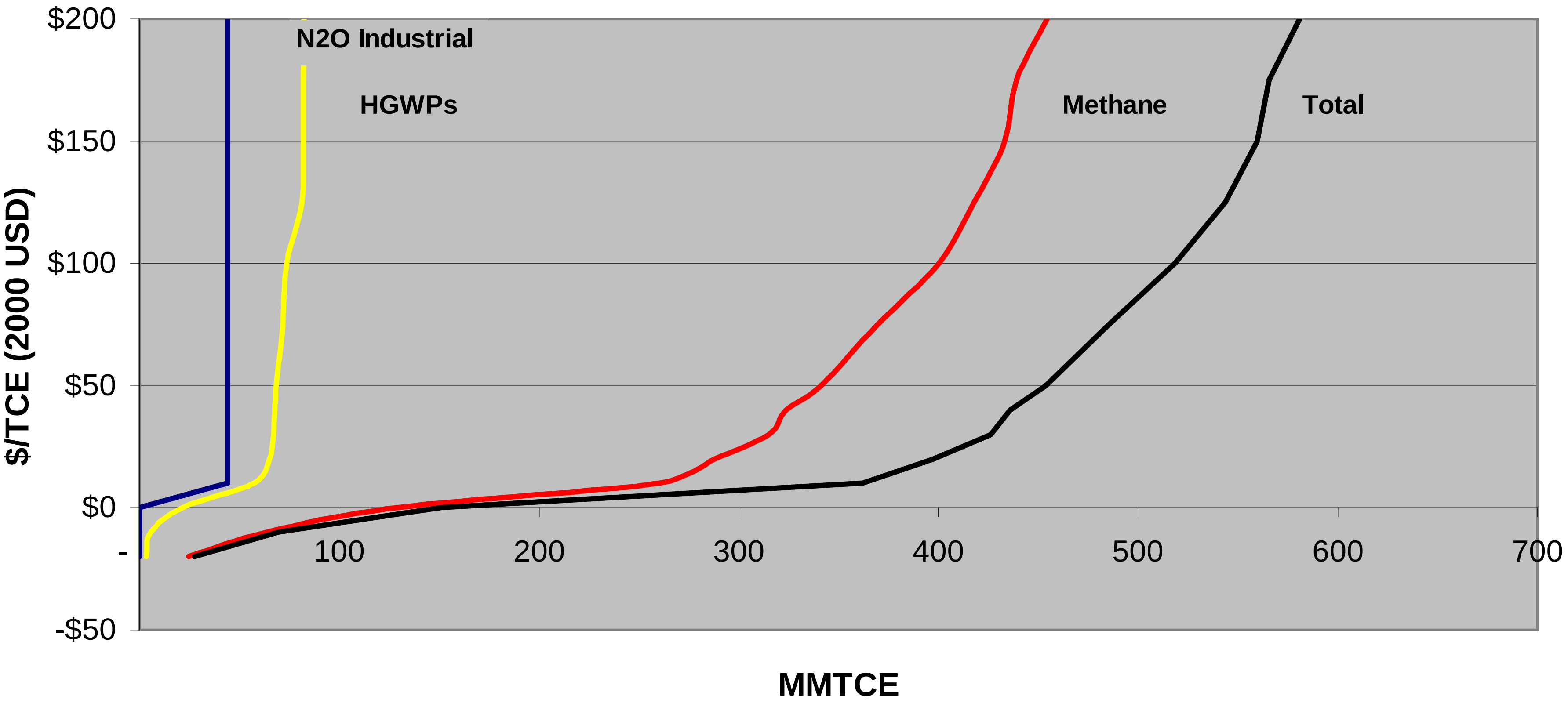
Global Non-CO2 GHG Emissions for 2000 in MMTCE

Sectors	Sub-sectors	Methane	N2O	F-gases
ENERGY 459 17%	Coal	123		
	Nat Gas	244		
	Petroleum Syst	17		
	Stationary/Mobile	16	59	
INDUSTRY 182 7%	Adipic & Nitric Acid Prd		60	
	HFCs			26
	PFCs			29
	SF6			15
	Substitution of ODS			52
AGRICULTURE 1610 61%	Biomass	134	51	
	Soils		656	
	Enteric Fermentation	476		
	Manure Management	61	55	
	Rice	177		
WASTE 388 15%	Landfills	213		
	Wastewater	154	21	
TOTAL NCGG	2,639	1,615 61%	902 34%	122 5%

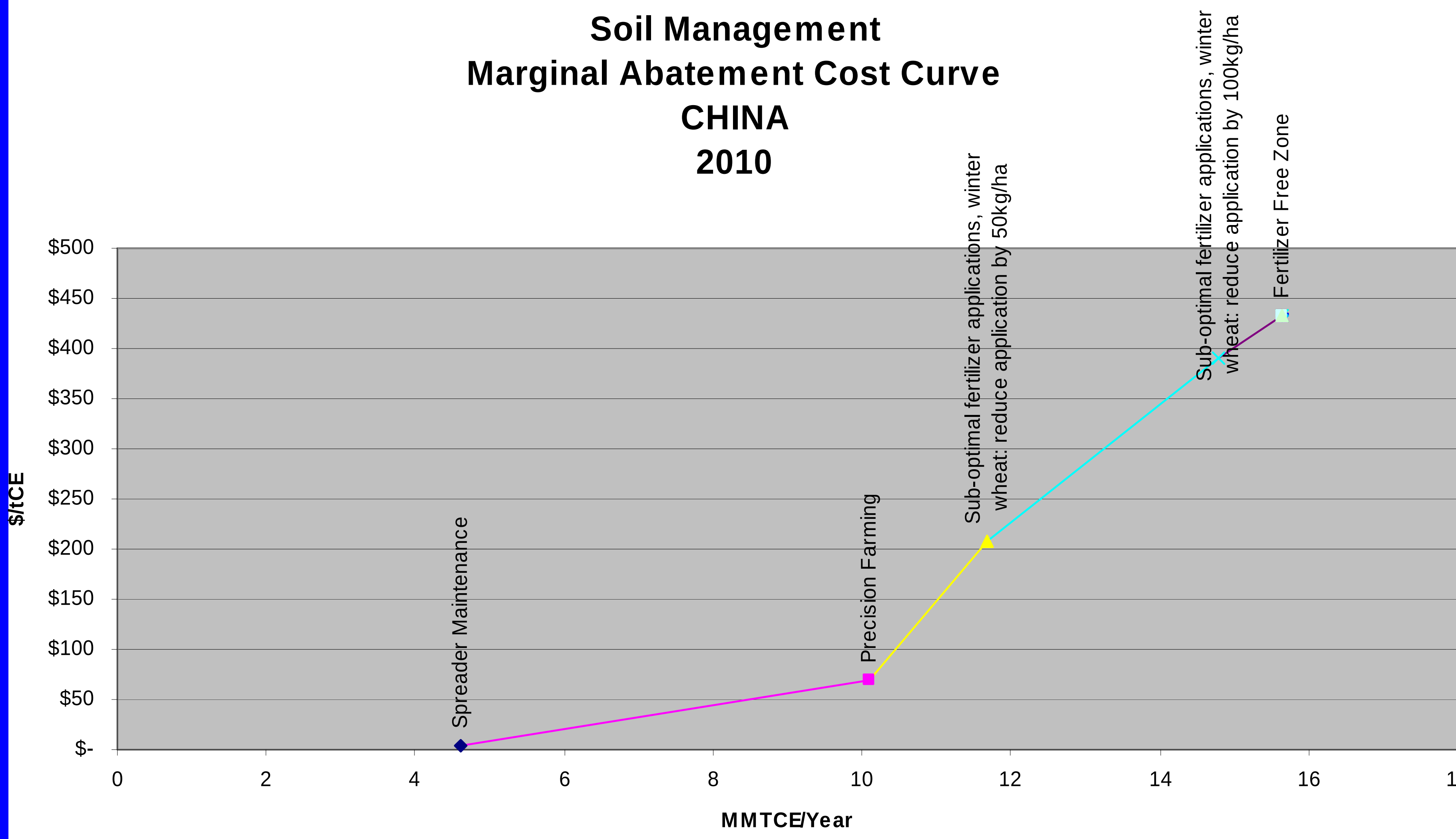
Regional Methane Marginal Abatement Curves for Energy & Waste Sectors: 2010



Global Non-CO_2 Marginal Abatement Curves for Energy, Industry & Waste Sectors: 2010



Soil Management
Marginal Abatement Cost Curve
CHINA
2010



EMF 21 Scenarios:

1) Modeler's Reference Case

2) Long-term, Cost-minimizing

Case A - achieved through CO_2 mitigation only, and

Case B - achieved through multi-gas mitigation.

- <u>Climate Change Target:</u> Stabilize radiative forcing at 4.5 W/m^2 relative to pre-Industrial times by 2150.
- <u>Time frame:</u> 2000 to 2100. From 2002 to 2012, KP is *NOT* in reference scenario.
- <u>Emissions:</u> Based on meeting climate target at lowest global cost.

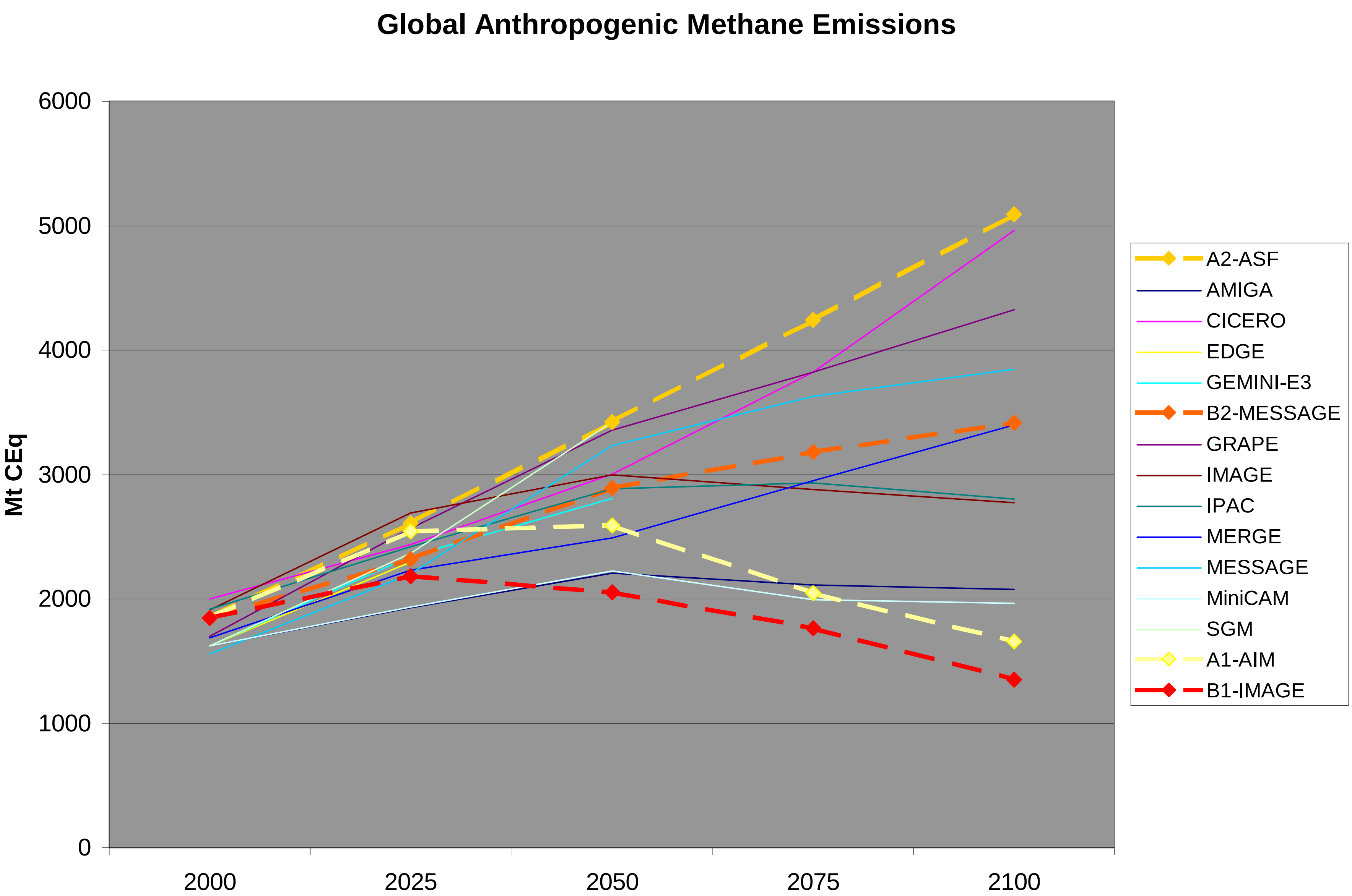
EMF 21 Scenarios:

3) Combined Decadal Rate of Change and Long-Term Cost-minimizing

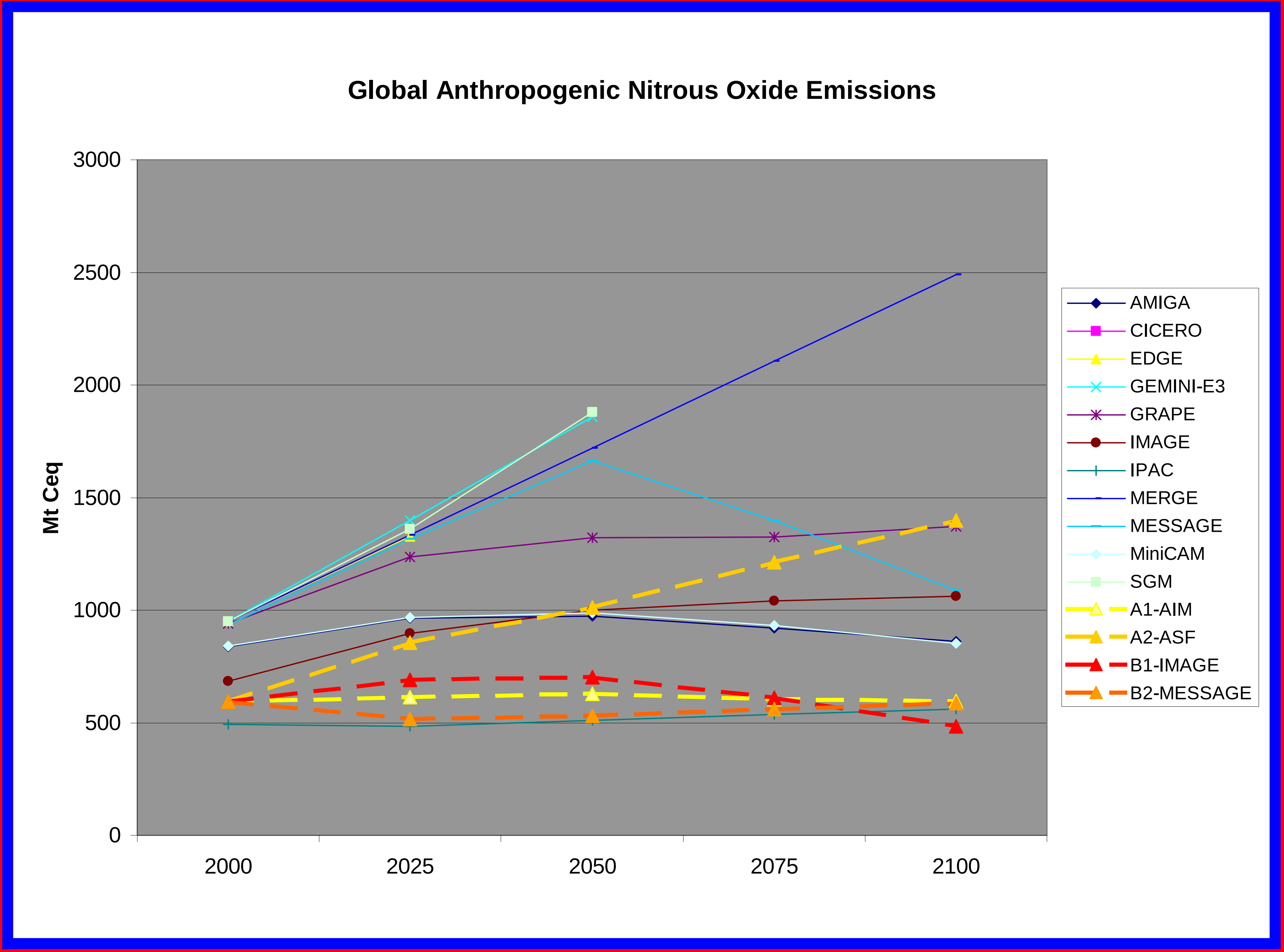
Achieved through multi-gas mitigation.

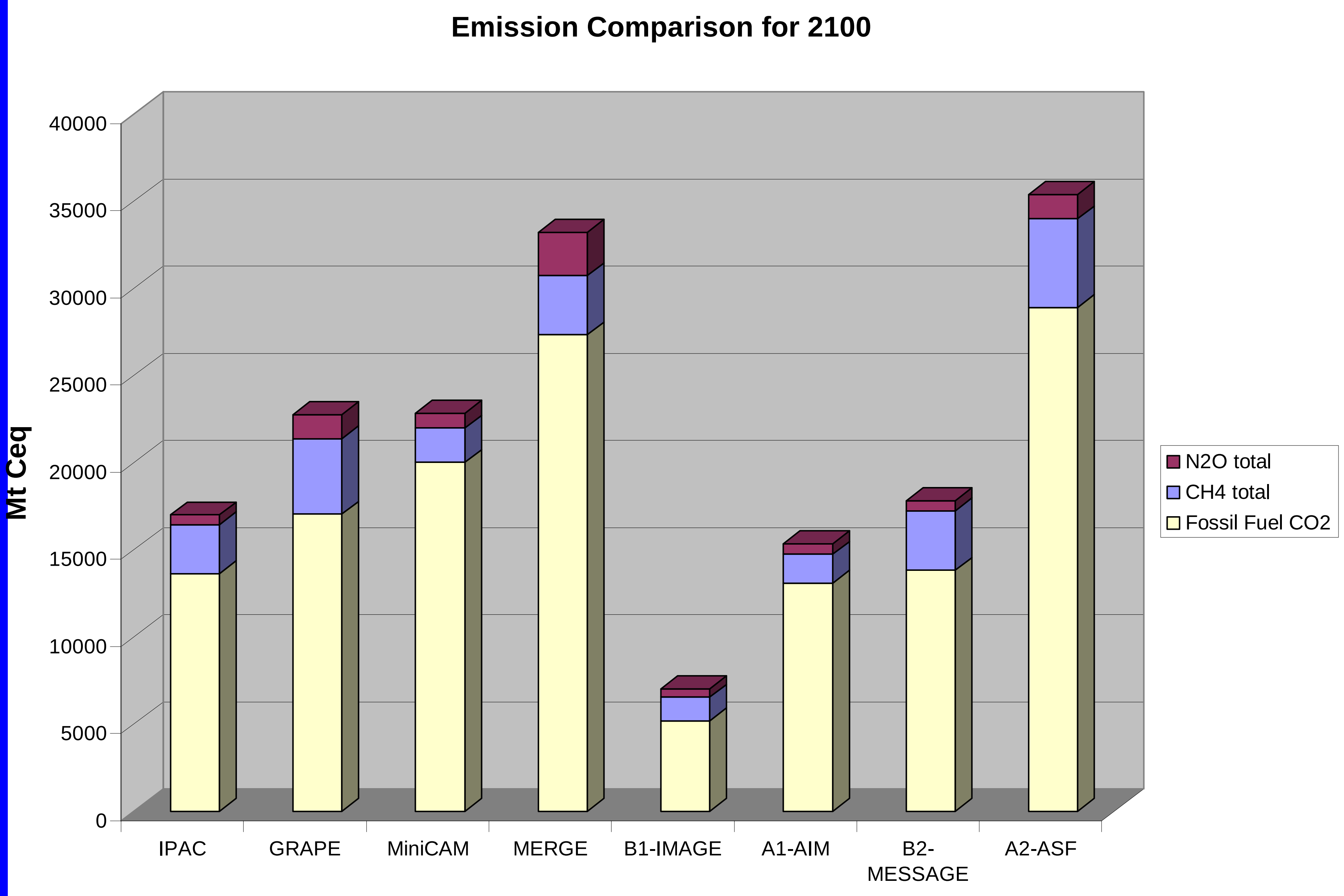
- Climate Change Target: Hold global mean decadal rate of temperature change from 2010 to 2100 at 0.2ºC. (starting in 2030) and meet LT at 4.5 W/m2 by 2150.
- Time frame: 2000 to 2100. From 2002 to 2012, KP is *NOT* in reference scenario.
- Emissions: Based on meeting climate target at lowest global cost.

4) CO_2, Multigas + Sinks with selected price path(s)



Global Anthropogenic Methane Emissions
Mt CEq
6000
5000
4000
3000
2000
1000
0
2000
2025
2050
2075
2100
A2-ASF
AMIGA
CICERO
EDGE
GEMINI-E3
B2-MESSAGE
GRAPE
IMAGE
IPAC
MERGE
MESSAGE
MiniCAM
SGM
A1-AIM
B1-IMAGE


Global Anthropogenic Nitrous Oxide Emissions
Mt Ceq
3000
2500
2000
1500
1000
500
0
2000
2025
2050
2075
2100
AMIGA
CICERO
EDGE
GEMINI-E3
GRAPE
IMAGE
IPAC
MERGE
MESSAGE
MiniCAM
SGM
A1-AIM
A2-ASF
B1-IMAGE
B2-MESSAGE



Emission Comparison for 2100
Mt Ceq
40000
35000
30000
25000
20000
15000
10000
5000
0
IPAC
GRAPE
MiniCAM
MERGE
B1-IMAGE
A1-AIM
B2-MESSAGE
A2-ASF
N2O total
CH4 total
Fossil Fuel CO2

Further work on Non-CO_2 GHGs

- Improve coverage of Non-CO_2 sources, principally agriculture
- Evaluation of Non-CO_2 GHG as offsets (agriculture & waste), including transactions costs
- Estimate rates of technical change in mitigation options, especially for the long-run type, 2100 analysis
- Improve estimates of emissions factors for long-term emissions projections, i.e., across space and time
- Conduct uncertainty analysis for both emissions (activity drivers, emission factors) and mitigation estimates

EMF 21 Sinks Subgroup

- Conduct comparison of land use data across models, both climate economic and Ag/Forestry.
- Compare key drivers and dynamics in future use and expansion of land for agriculture, forestry, & biofuels.
- Evaluate paired prices in models, i.e., timber-carbon, agriculture-carbon, biofuels-carbon.
- How does all this affect competition for land use in the reference and mitigation scenarios ?
- How do we match up the sinks mitigation scenarios with the climate scenarios ?
- How best to incorporate the results from the sinks models into the climate economic models and how to handle the price interactions?

EMF 21 Sinks Subgroup

- Models including sinks in reference and/or mitigation cases, in some form:

  AIM EPPA ABARE

  IMAGE 2.2 IPAC POLES/Agripol

  MERGE MiniCAM

- Forest and/or agric. sector models:

  GCOMAP GTM

  FASOM-GHG (US)

Comparison of Reference Cases: 3 LT, global models --GCOMAP, GTM, IMAGE

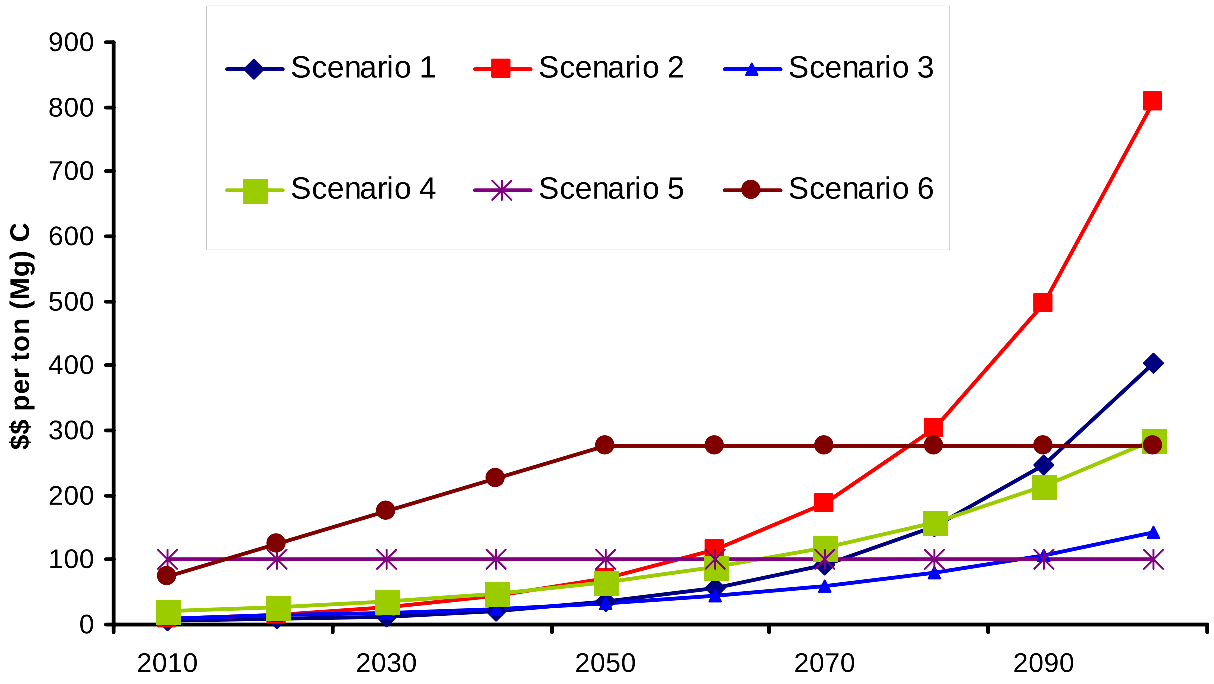
- Land Area in forest varies:
    - across regions, and totals
    - GTM has managed vs. unmanaged, inaccessible forest
    - GTM has age classes for existing & new forest; allows forest mgmt. option. GCOMAP only new forest.
- LUCF Activities included vary:
- Assumptions about land -use change & C cycling vary:
    - Makes <u>annual</u> time-slice hard to compare across models
    - Thus: best to use <u>cumulative</u> C gain by a date

Actions That Affect Carbon

- Land Use
  - Reduce deforestation or increase afforestation
  - Change inaccessible margin.
- General Management of Forest Stands
  - Replant rather than naturally regenerate
  - Enhance stocking density: fertilize, chemical weed suppression, thinning (remove dead or slow growing stock and replace with faster growing stock).
- Rotation ages
  - Generally, longer rotations enhance carbon storage.
- Harvest Quantity (storage in markets)

Sequestration Scenarios

Scenario 1	♦	$5 in 2010, rising by 5% per year
Scenario 2	■	$10 in 2010, rising by 5% per year
Scenario 3	▲	$10 in 2010, rising by 3% per year
Scenario 4	■	$20 in 2010, rising by 3% per year
Scenario 5	X	$100 Constant Price
Scenario 6	●	$75 in 2010, rising by $5 per year through 2050



Scale

Results for 2100

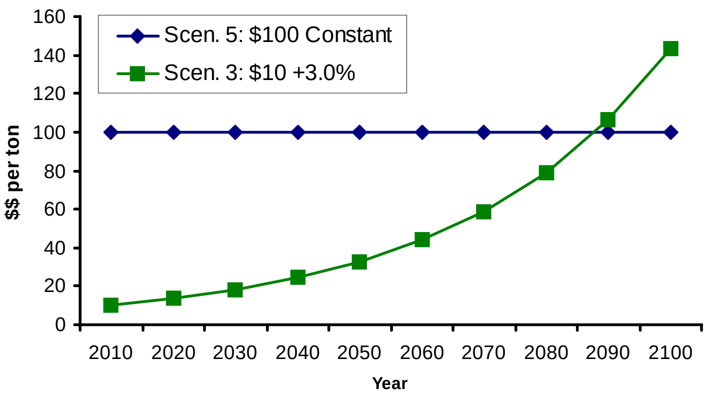
	Price	Cum. C	Land	Temp.	Trop.
	$$ per ton	Pg	Million ha	%	%
Scenario 5	$100.00	66.7	593	38%	62%
Scenario 3	$143.00	56.5	726	36%	64%
Scenario 6	$275.00	150.1	1,004	40%	60%
Scenario 4	$286.01	98.9	1,022	41%	59%
Scenario 1	$403.65	93.2	1,109	44%	56%
Scenario 2	$807.30	138.9	1,403	50%	50%

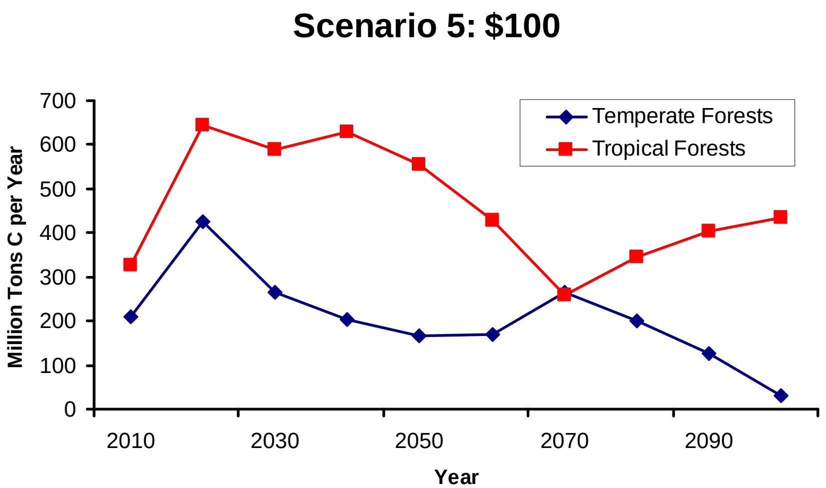
- Higher long term C prices, generally increase cumulative carbon.
- Higher C prices increase the importance of temperate forests.

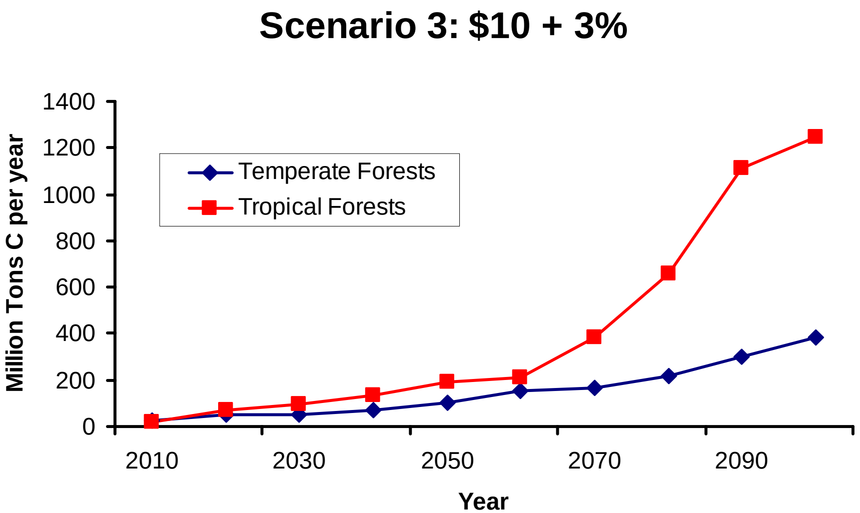
From Sohngen & Sedjo, EMF21

Compare Scenarios 5 & 3

[$100 Constant] VS [$10 + 3% ($143)]

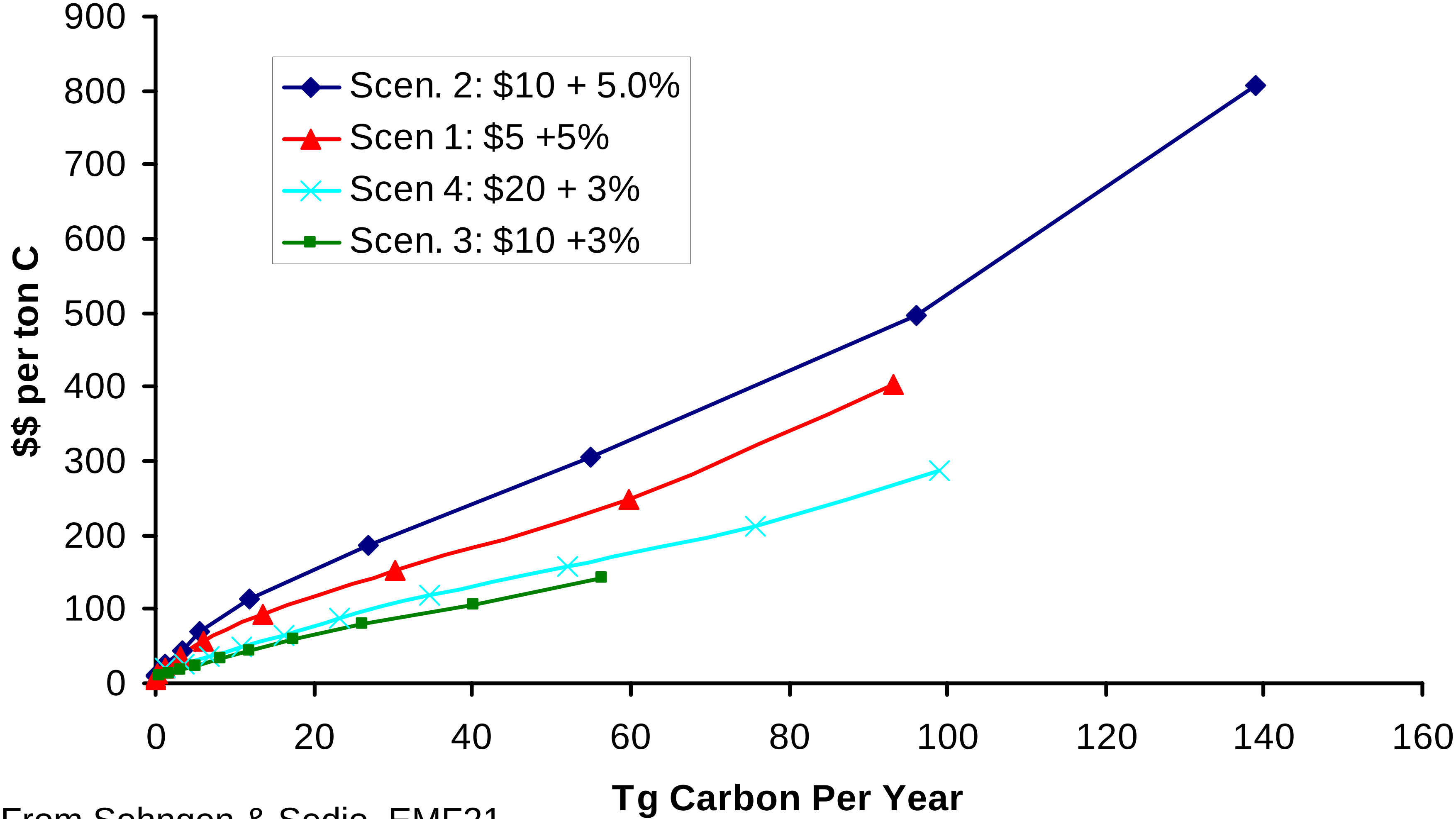






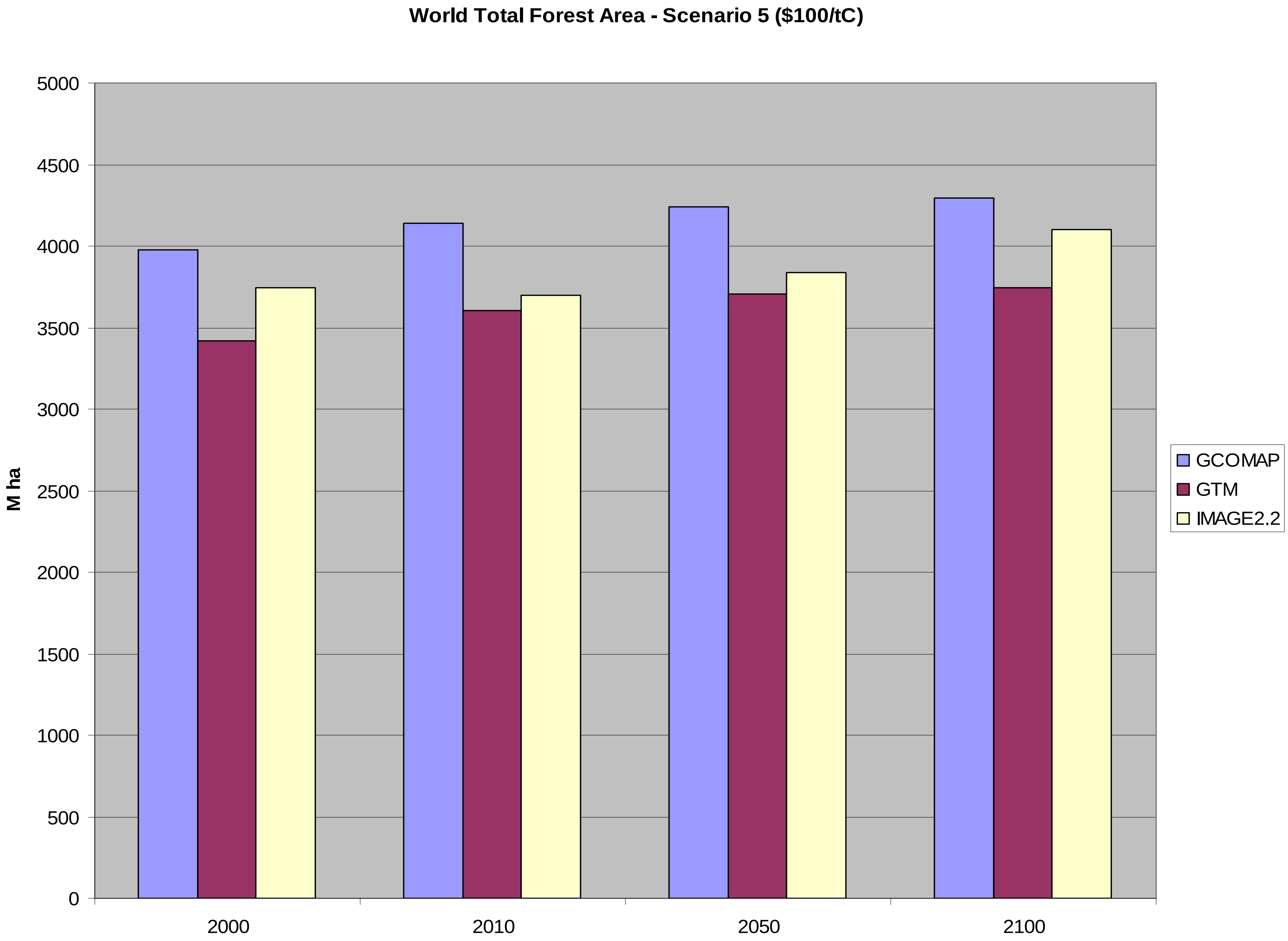
From Sohngen & Sedjo, EMF21

Faster Price Increases Delay Carbon

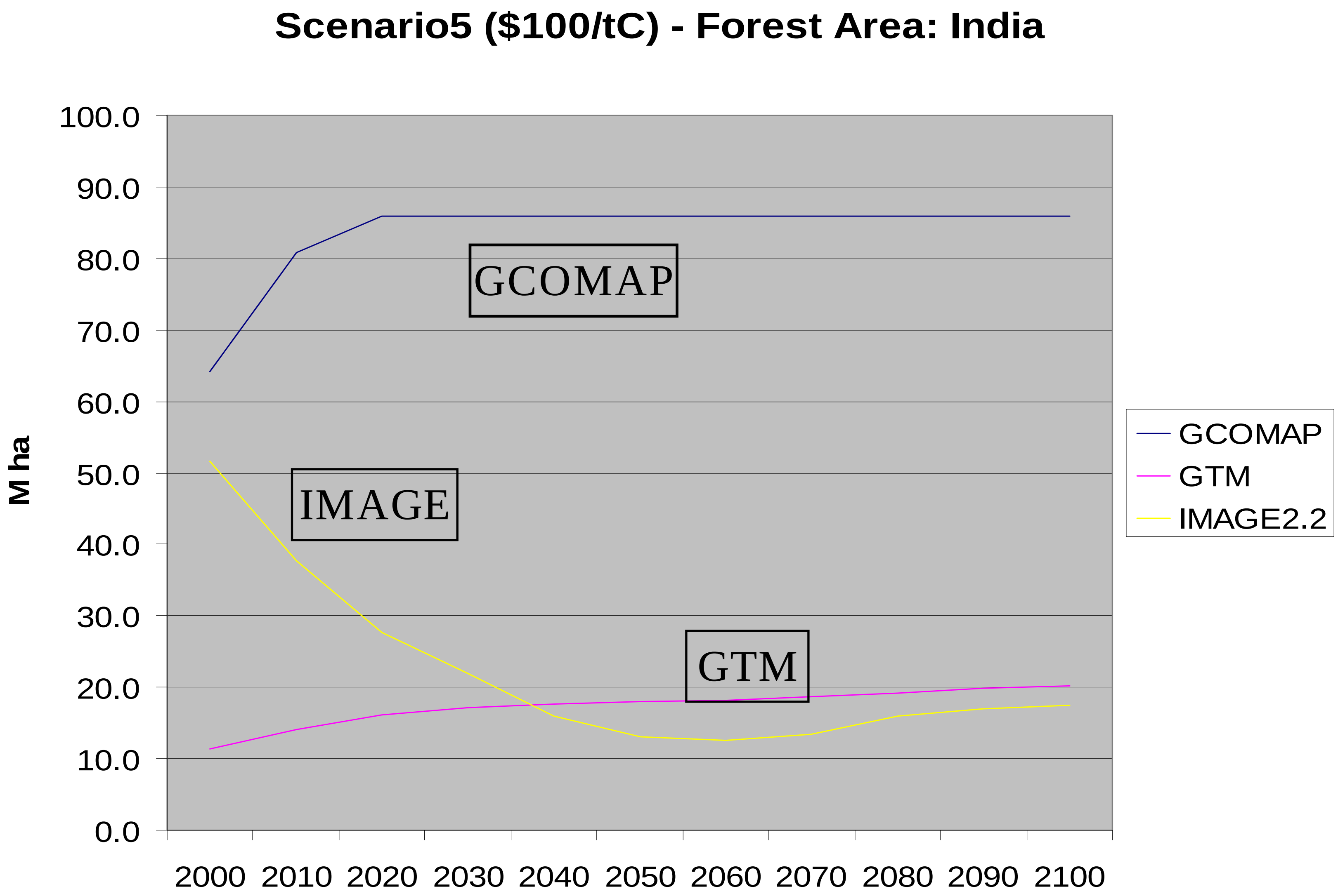


From Sohngen & Sedjo, EMF21

Scenario 5: World Forest Area Increases in 3 Models



But, Forest Area and C Partitioning by Region Varies.
Scenario 5 Good Agreement: NAM, LAM, EUR.. Less Good: Rest of Regions.



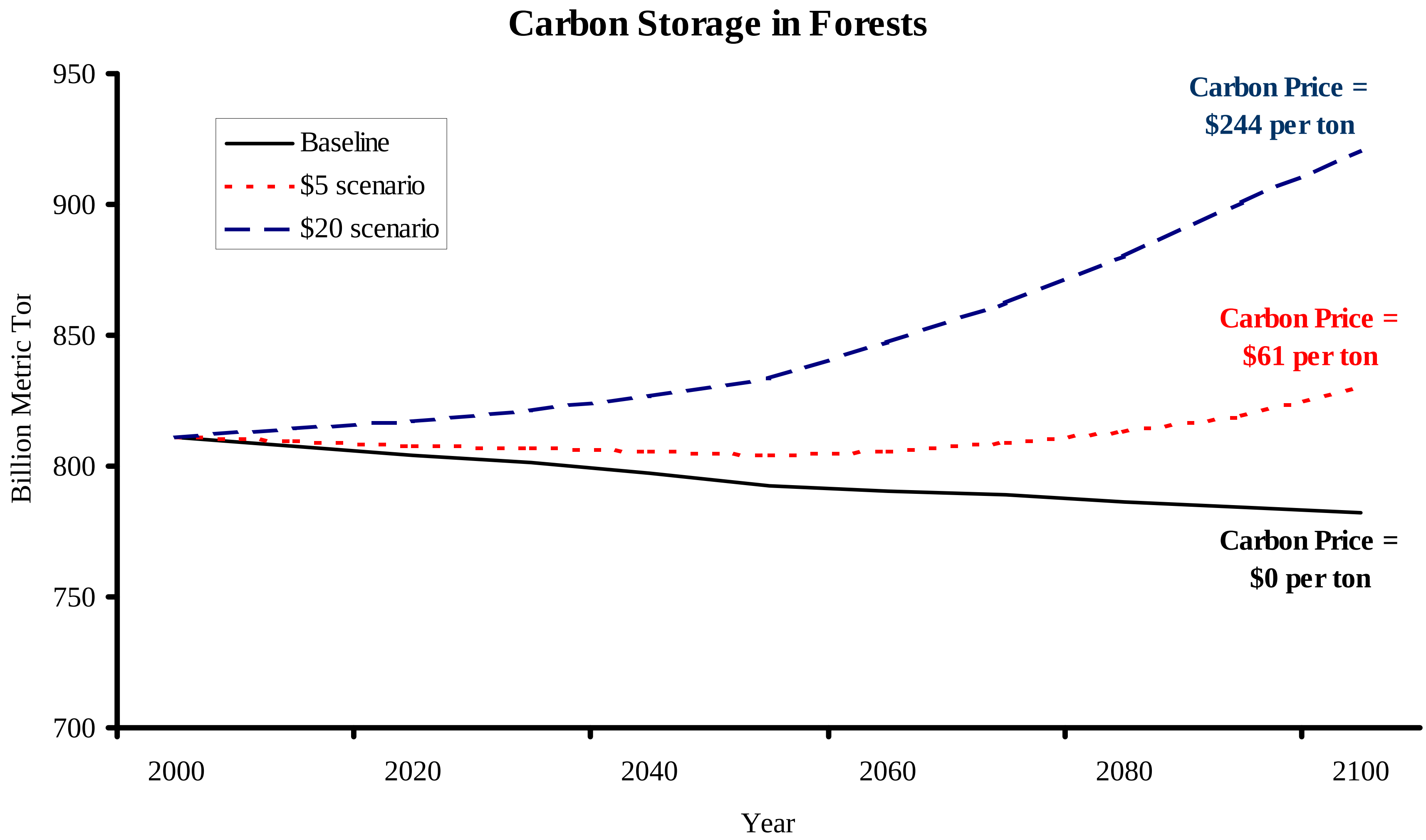
Preliminary Conclusions

- Lower prices and slower growth in prices favors actions in tropics and subtropics.
- Faster price growth delays carbon sequestration, particularly in tropics and subtropics.
- Profile of annual sequestration heavily dependent on price path
  - Simple functional forms seem to work for slower price growth scenarios, but are less reliable for fast growth scenarios.
- Rotations matter at the beginning and at the end…
  - Early strategy for lower cost species.
  - Long run strategy for setting aside timberland from production.
- Management ~ 5-10%; Rotations ~ 7-8%.
  - Most Important in temperate zones.
  - Just looking at land use could miss 35% of carbon in temperate or 9% in tropics

Sinks Sub-group: Continuing Issues

- How to report results in roughly comparable way?
  - Report by activity? (eg, forestation only, biofuels only, etc.)
  - Report <u>cumulative C stock change</u> by date, since C cycling
- Avoided deforestation is significant option: 2 models include
- Land availability assumptions vary & drive some mitigation options.
  - Eg, what historic & projected afforestation rate to use?
- How to estimate market potential, vs. technical potential?
  - Decision rules (IMAGE), econ. response, barriers analysis
- Boundary bet. Sinks & other sectors: eg, biofuels
- How best to incorporate the results from sinks models into climate economic models? ISSUE: Sinks price paths different from economic models.

Planned Landuse and Integrated Assessment Workshop in Spring/Summer with ABARE & RIVM.


Carbon Storage in Forests
Baseline
$5 scenario
$20 scenario
Carbon Price =
$244 per ton
Carbon Price =
$61 per ton
Carbon Price =
$0 per ton
Billion Metric Ton
950
900
850
800
750
700
2000
2020
2040
2060
2080
2100
Year

How Deforestation Handled Critical for Reference& Scenarios

- Global deforestation: c. 17 million ha/yr 2000 (FAO)
- IMAGE: DEFOR in baseline & scenarios, but not as mitigation option
- GTM: DEFOR baseline & as mitigation option (not reported)
- GCOMAP: DEFOR in baseline & avoided deforestation as mitigation:

Scenario GCOMAP	**Avoid DEFOR Cum. C, 2050**	**% of Total Mitigation 2050**	**Avoid DEFOR Cum. C, 2100**	**% of Total Mitigation 2100**
Scen. 2	10.9 Pg	48%	40 Pg	41%
Scen. 5	28.8 Pg	55%	52 Pg	64%