Battelle
The Business of Innovation

The Role of Technology in a Low Carbon Society

Expert Workshop on Developing Visions of a Low-Carbon Society Through Sustainable Development

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Joint Global Change Research Institute

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Office of Science
JGCRI Joint Global Change Research Institute
UNIVERSITY OF MARYLAND
GTSP Global Energy Technology Strategy Program

Acknowledgements

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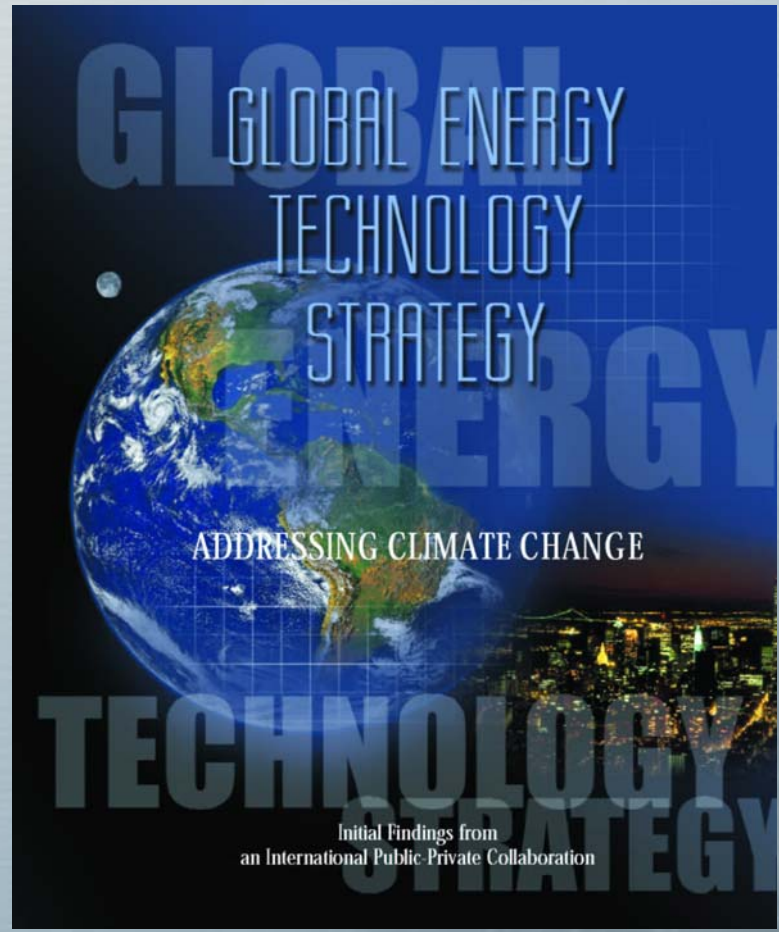
  - US Department of Energy—Office of Fossil Energy

GTSP Phase I

- The GTSP started in 1998.
- GTSP has conducted research to assess the role that technology can play in addressing the long-term risks of climate change
- Argued that technology was a core response to managing the risks of climate change on a par with improving the climate science, adapting to climate change, and emissions mitigation.



Some Points

- New Scenarios—*an oil market transition story.*
- The challenge of climate change—*a long term problem with implications for today.*
- Stabilization of climate change—*means big changes in the global energy system in both the near term and the long term.*
- CO_2 prices that stabilize climate cost-effectively are rise with time.
- Energy and greenhouse gas emissions—*non-energy policy and technology matter to energy*
  - *Non-CO_2 gases*
  - *Agriculture and land use*

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Development along a reference path

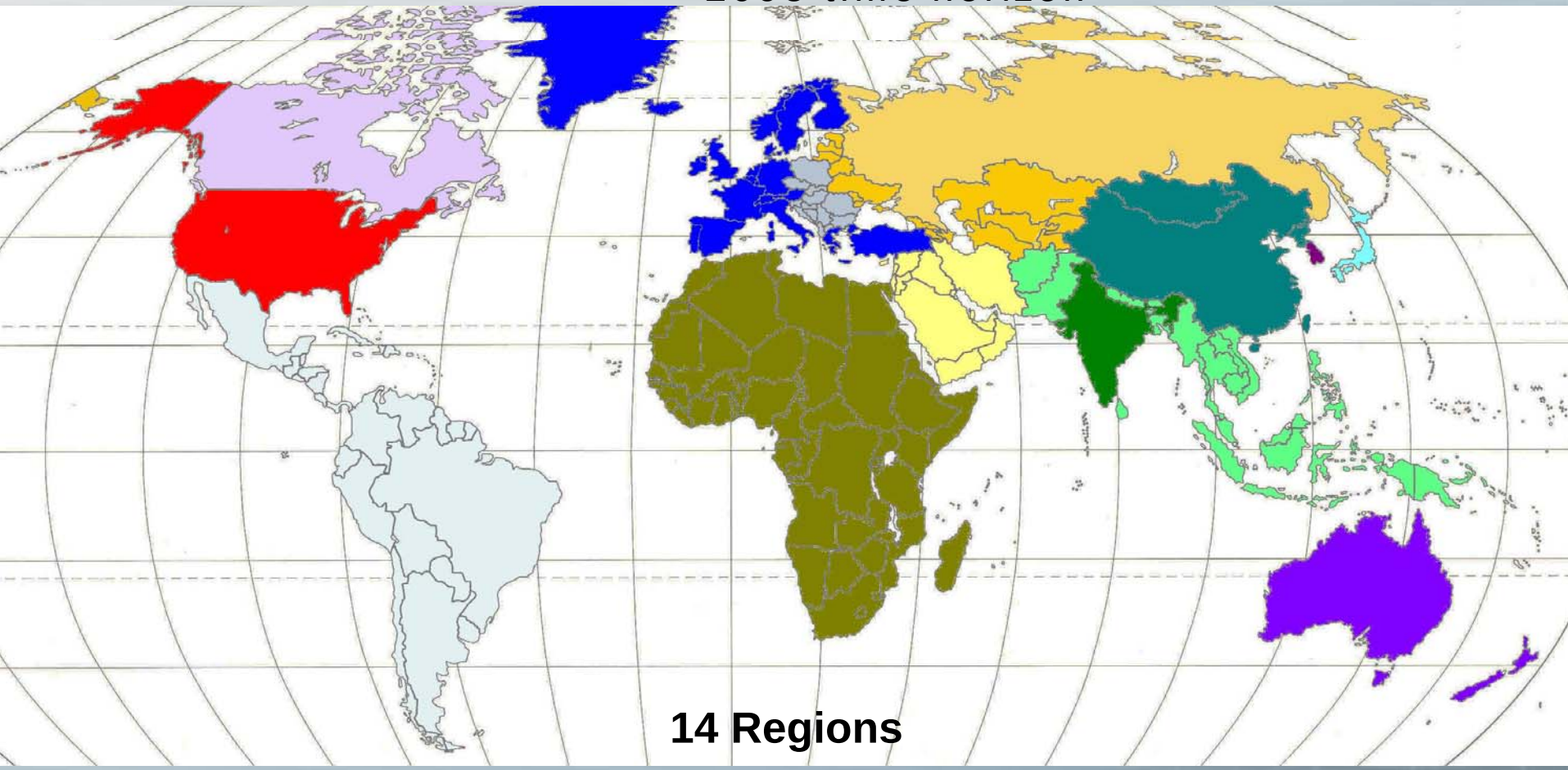
MiniCAM—An Integrated Assessment Model

Emissions, Atmosphere, Climate

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

15 gaseous emissions—linked to associated human activities

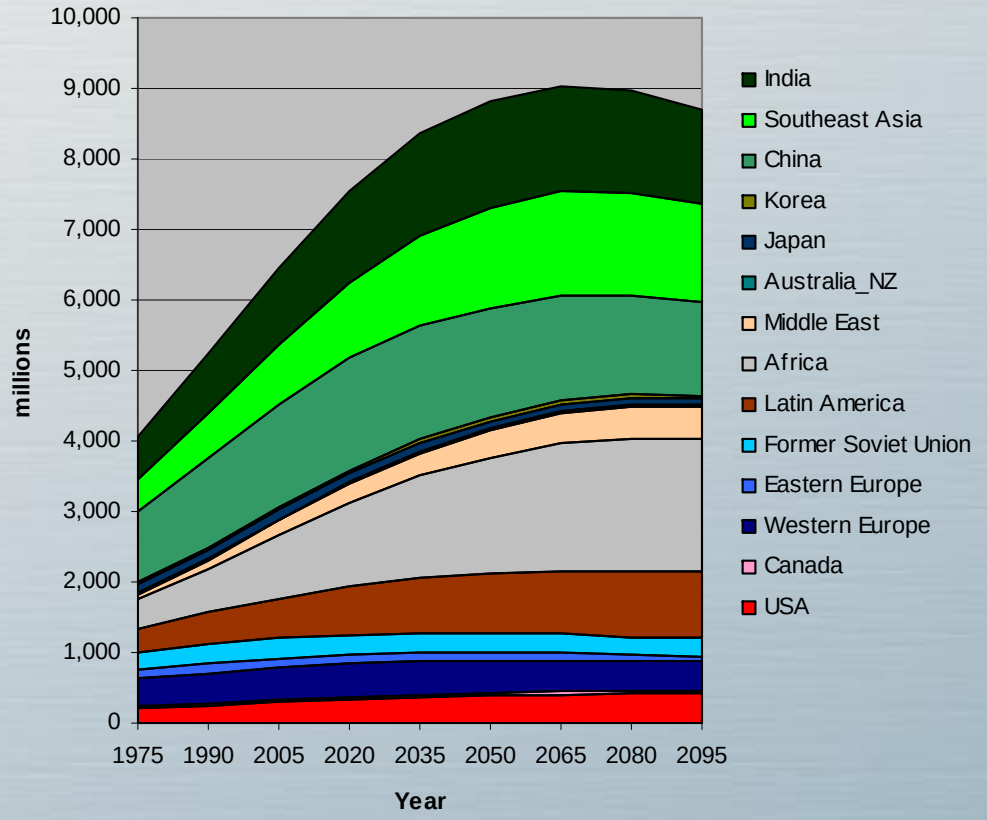
2095 time horizon

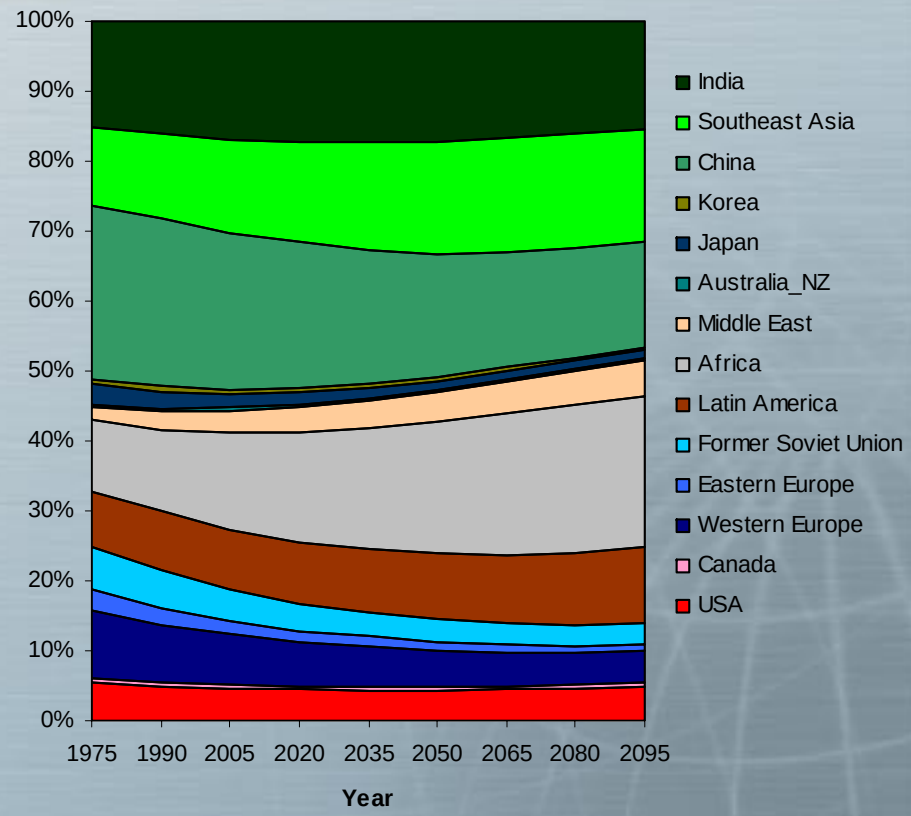


14 Regions

Demographics

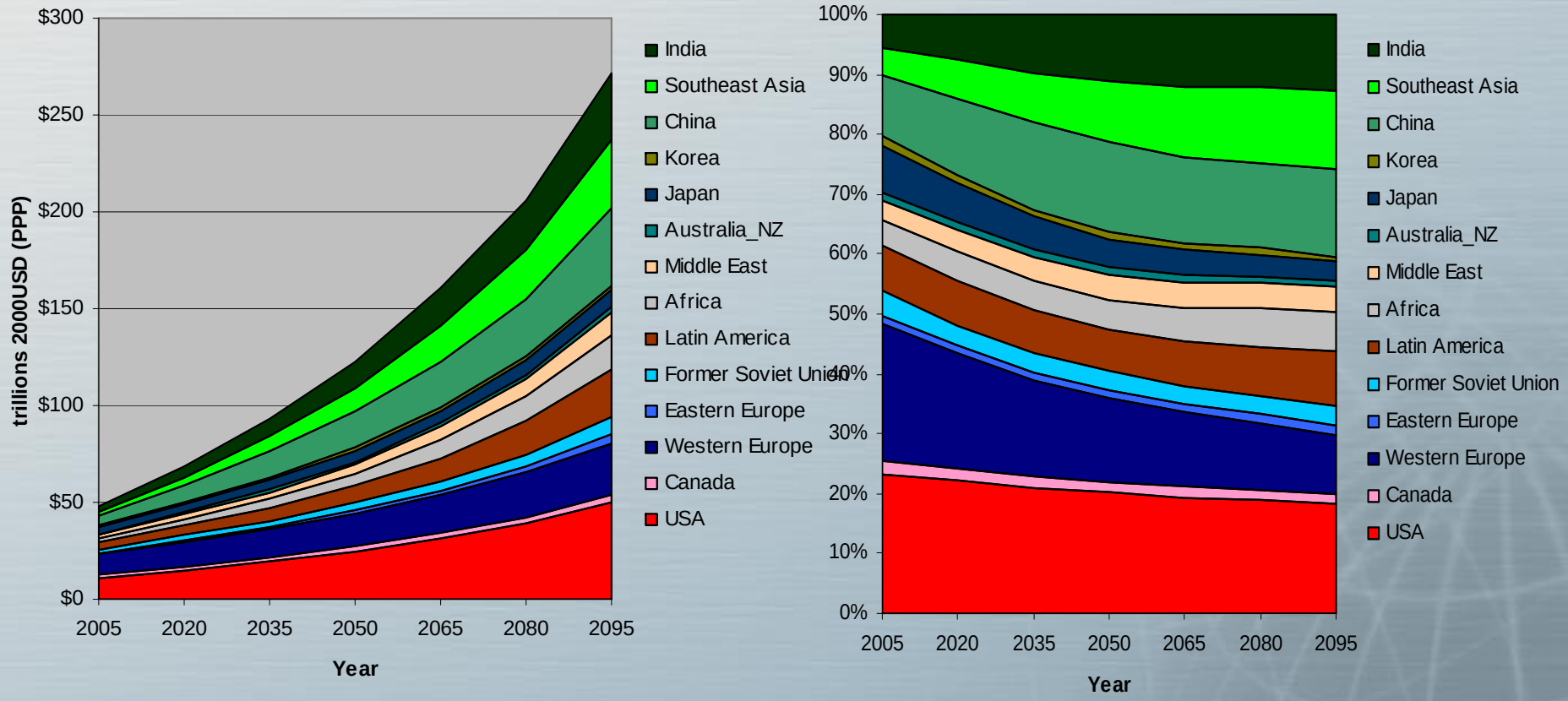
A world of 8.5 billion people & demographic transitions





Economics

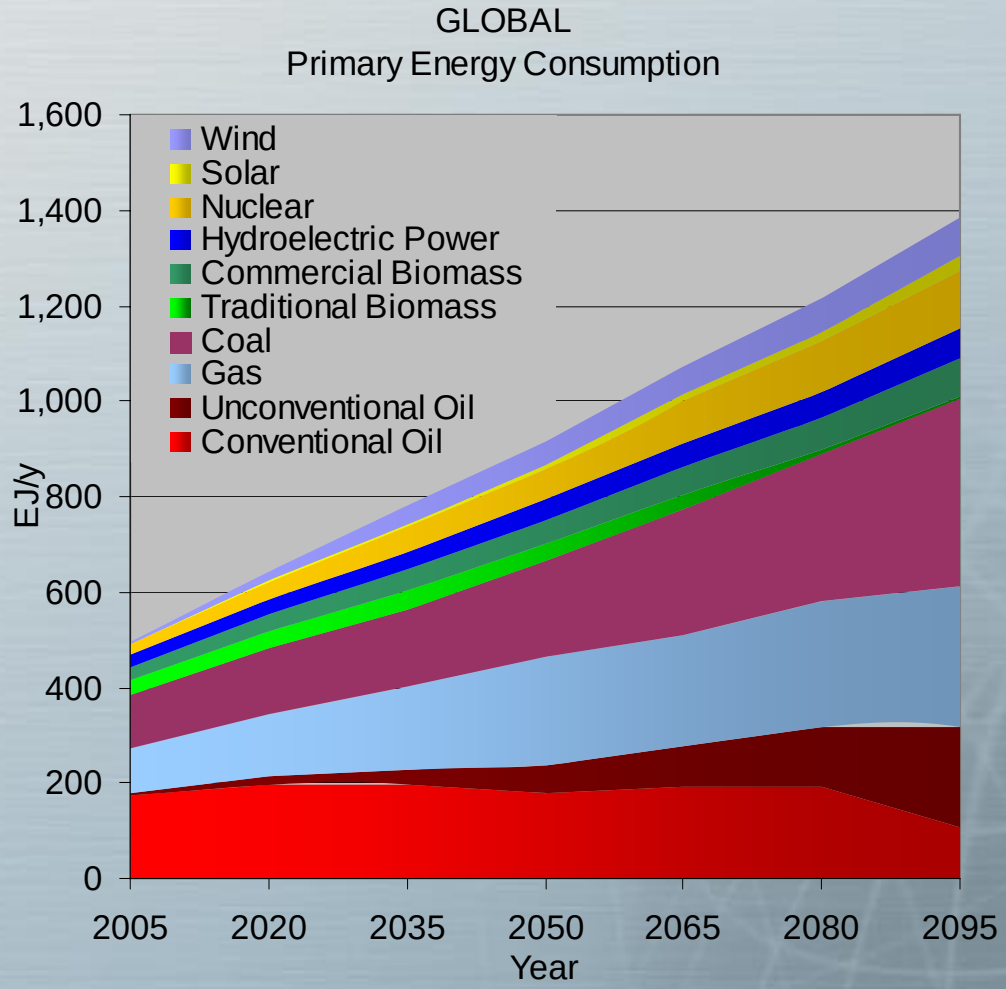
A $250+ trillion world with a changing economic balance



2005=48 trillion 2000$ U.S.
2050=122 trillion 2000$ U.S.

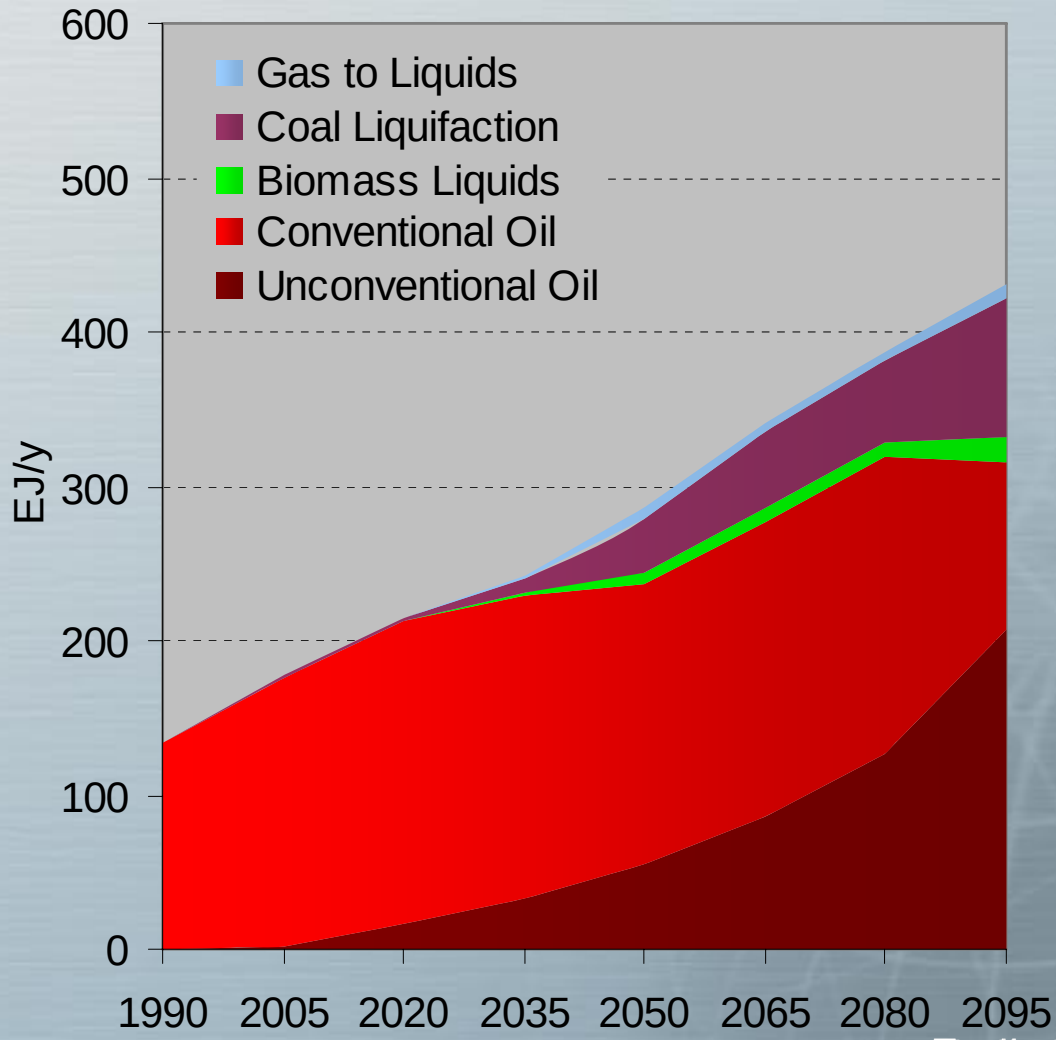
Primary Energy

A 1,400 EJ/y world, dominated by fossil fuels, but with increasingly disperse sources



The Oil Market—global

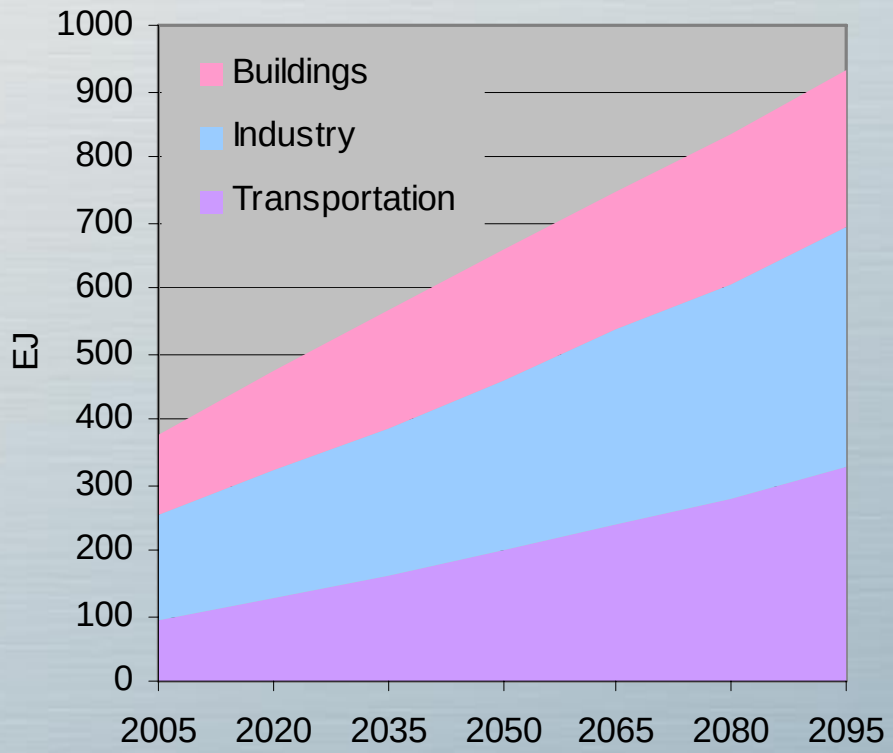
- Conventional oil production is limited.
- Shale oil and synfuels become the dominant forms of liquid fuels in the second half of the century.
- Implication—higher CO_2 emissions.



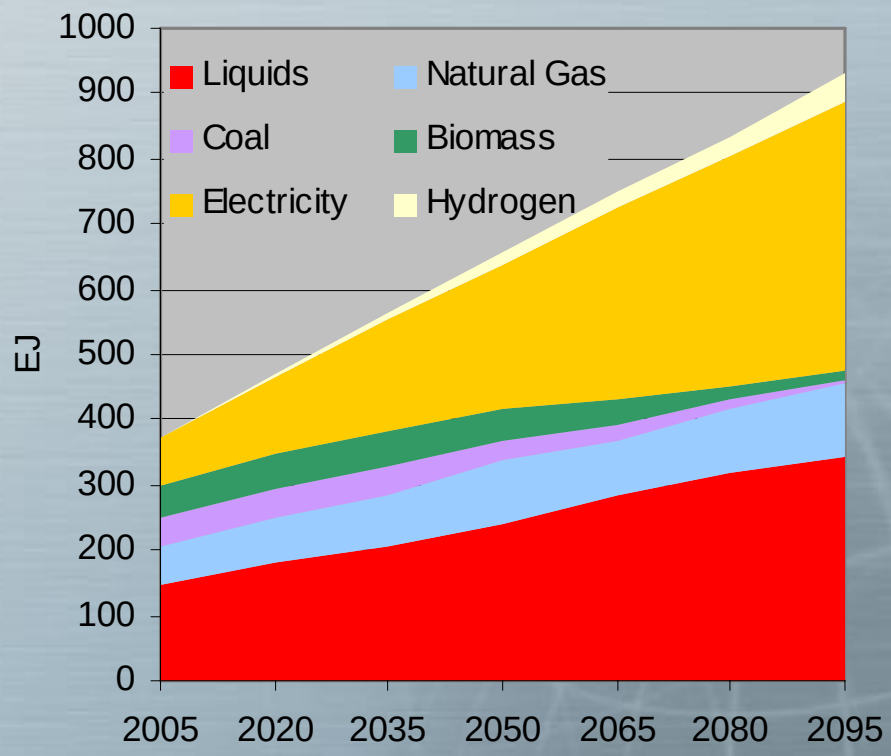
End-use Energy

A 900+ EJ world with rapidly growing transport demand

Global Final Energy by Sector

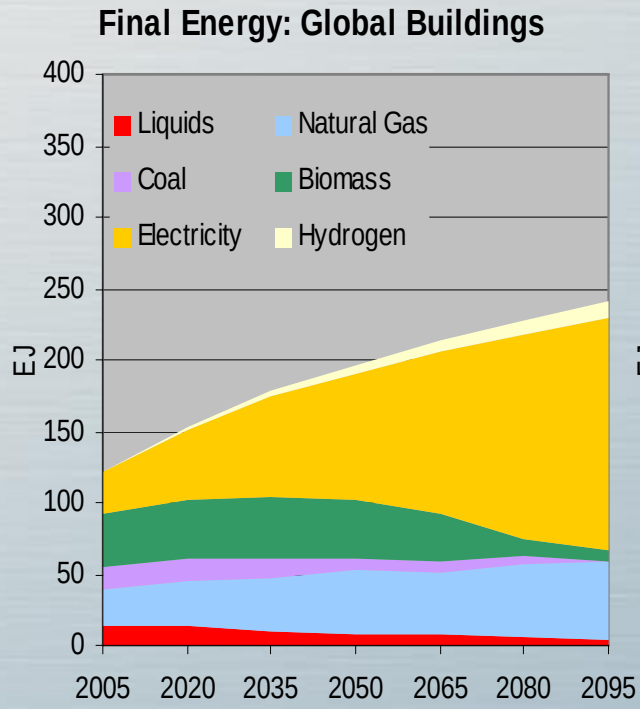


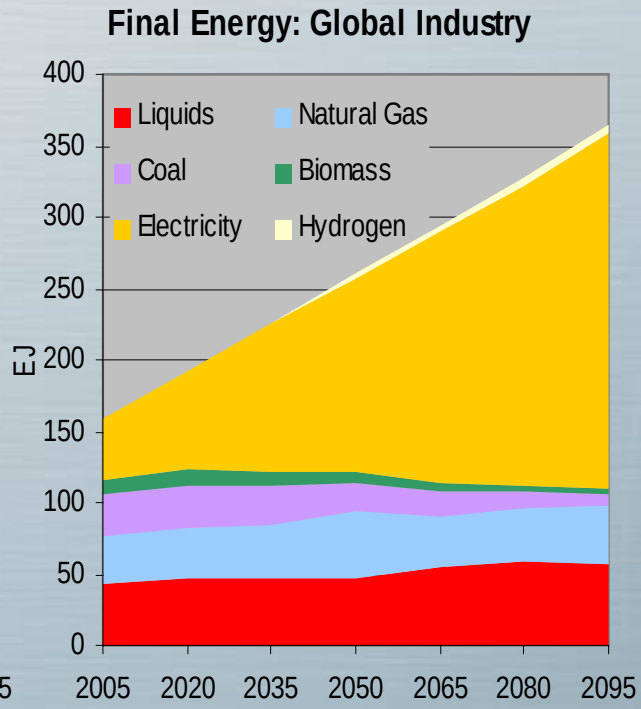
Global Final Energy by Fuel

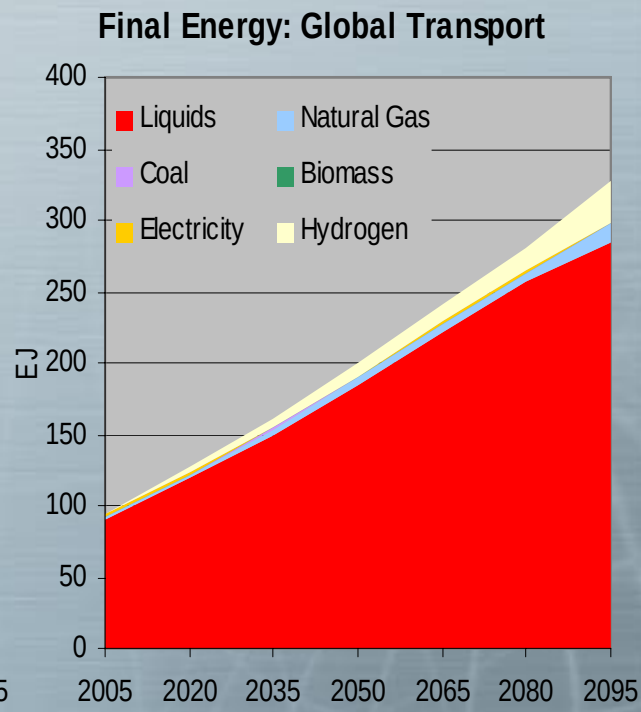


End-use energy by sector—Global

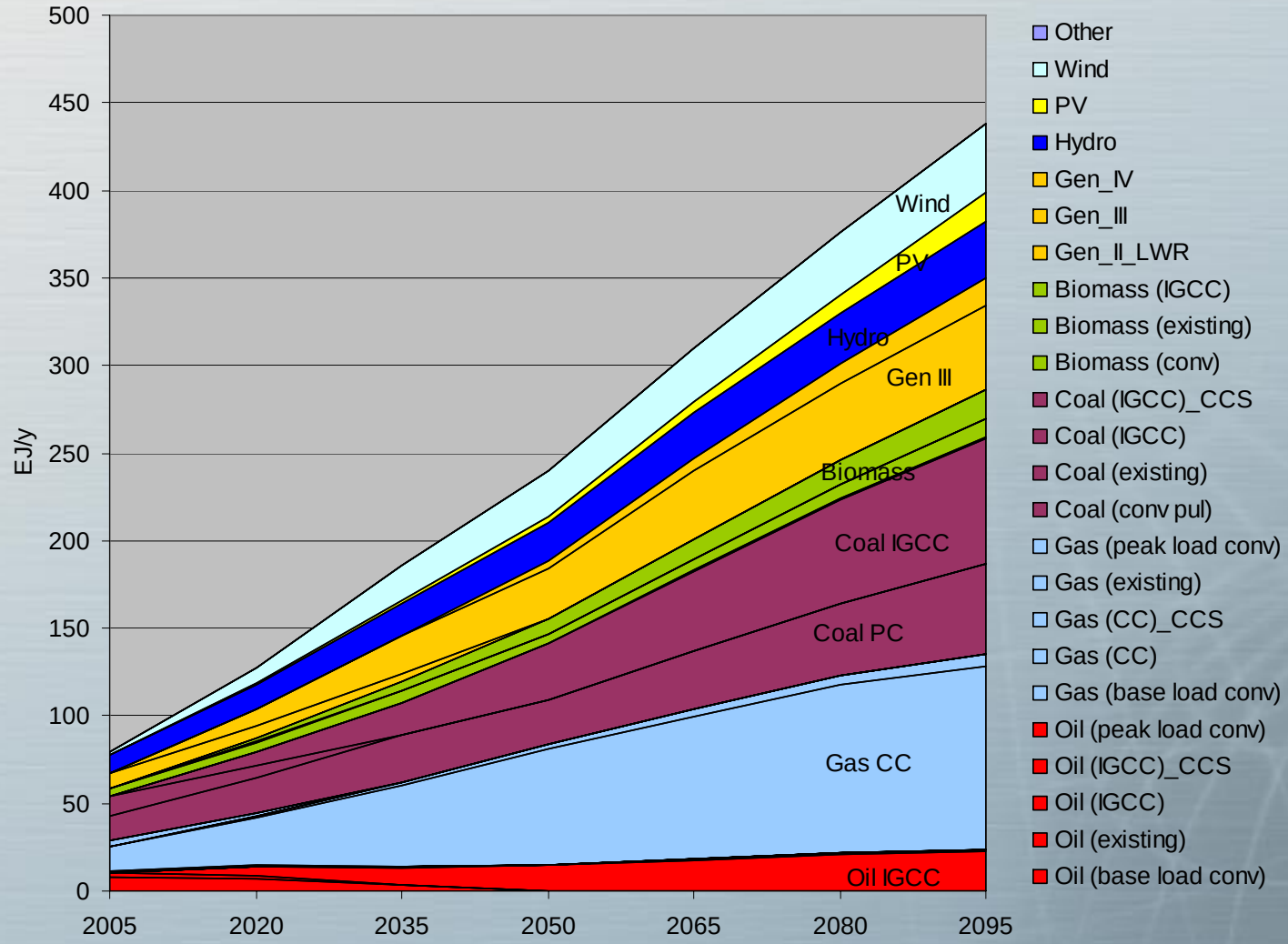
A 900+ EJ world with rapidly growing transport demand





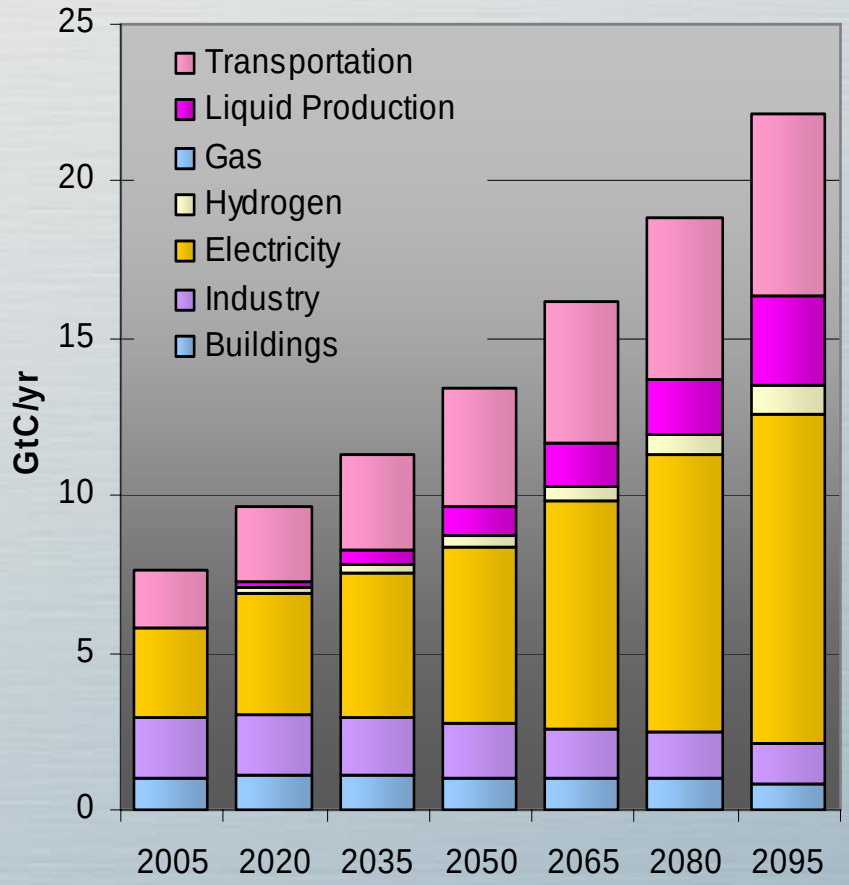


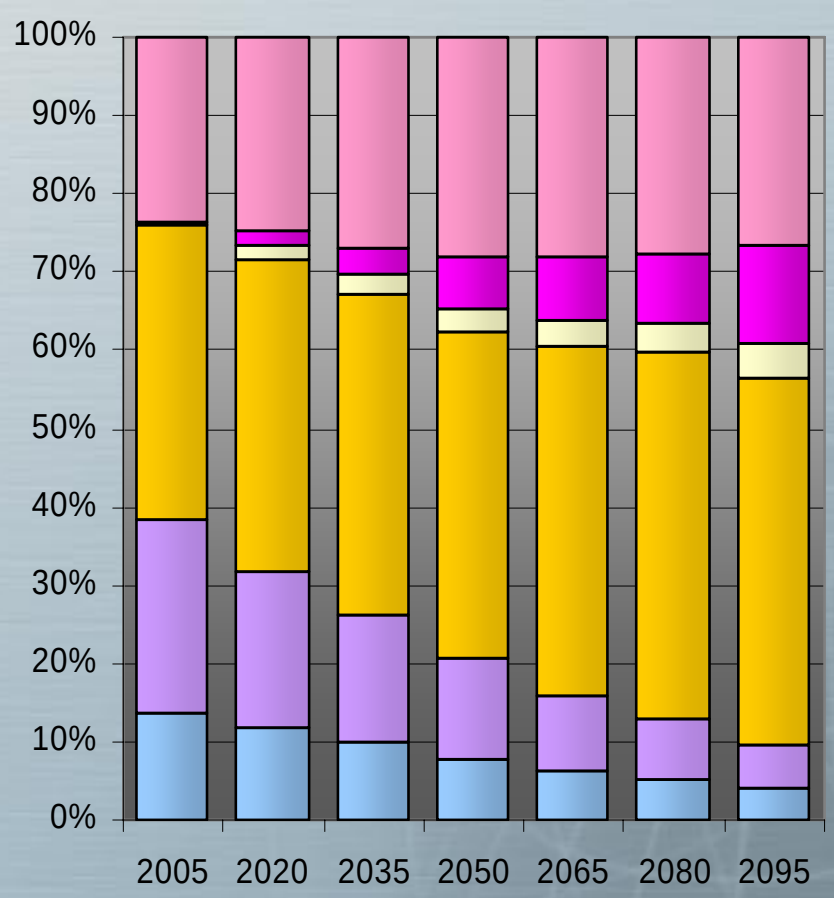
Electric Power



Fossil Fuel CO_2 by Sector of Origin

Global





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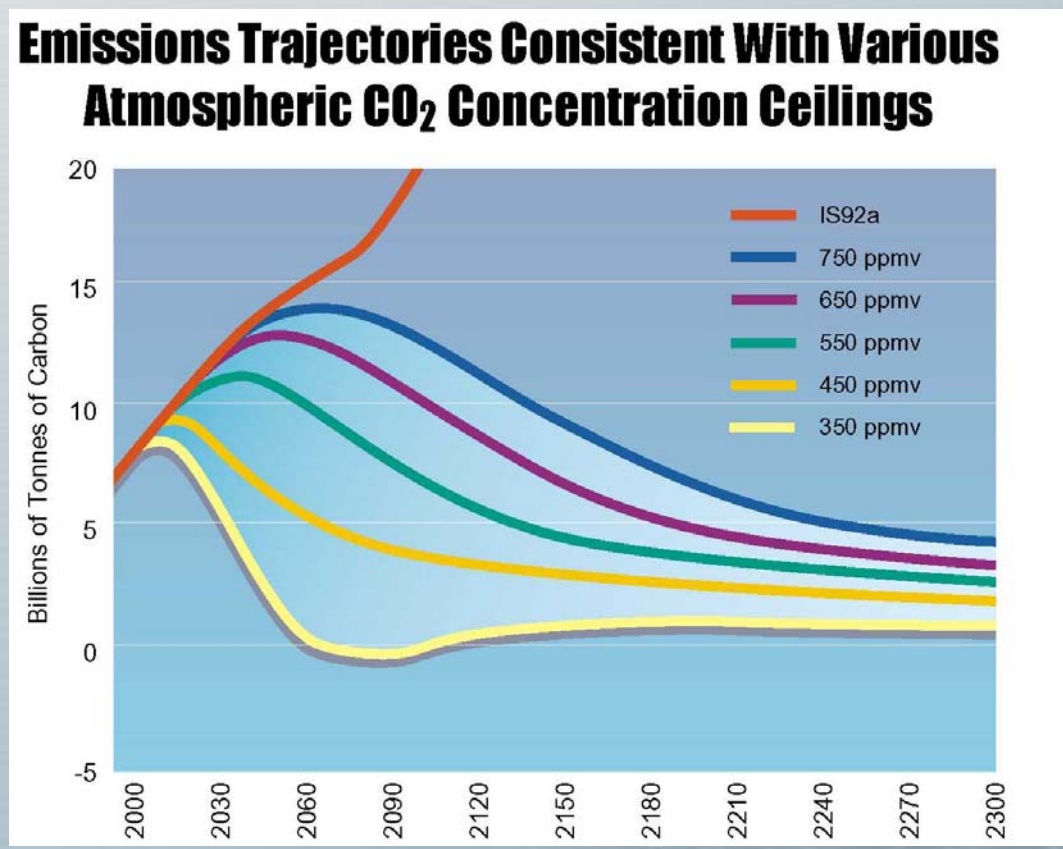
The challenge of climate change

Stabilizing CO_2 Concentrations

- Stabilization of greenhouse gas **concentrations** is the goal of the Framework Convention on Climate Change.

- Stabilization means that **GLOBAL** emissions must peak in the decades ahead and then decline indefinitely thereafter.



- Climate change is a **long-term**, century to millennial problem—**with implications for today**. It will not be solved with a single treaty, single technology, by a single country, or by a quick fix.

Scenario Architecture

Level	Radiative Forcing From Preindustrial (Wm^{-2})	Approximate 2100 CO_2 Level (ppmv)
Level 1	3.4	450
Level 2	4.7	550
Level 3	5.8	650
Level 4	6.7	750

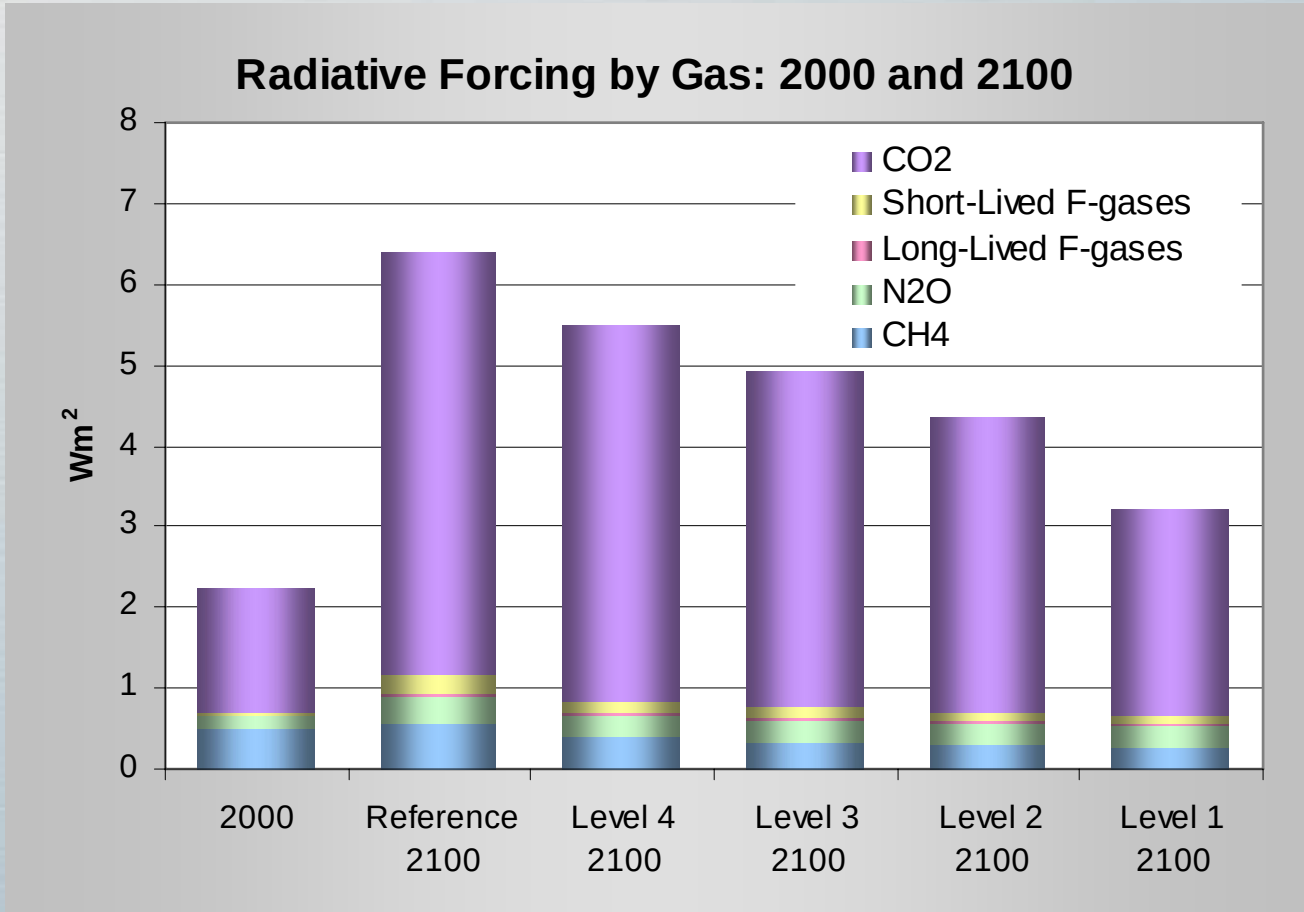
The Gases

CO_2, CH_4, N_2O, HFCs, PFCs, SF_6

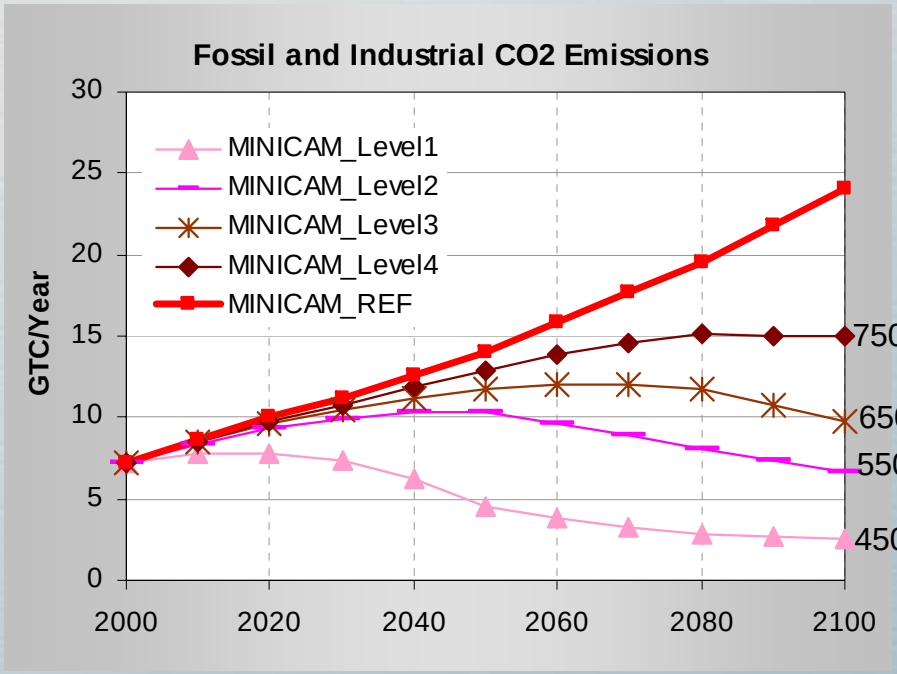
Implementing Stabilization

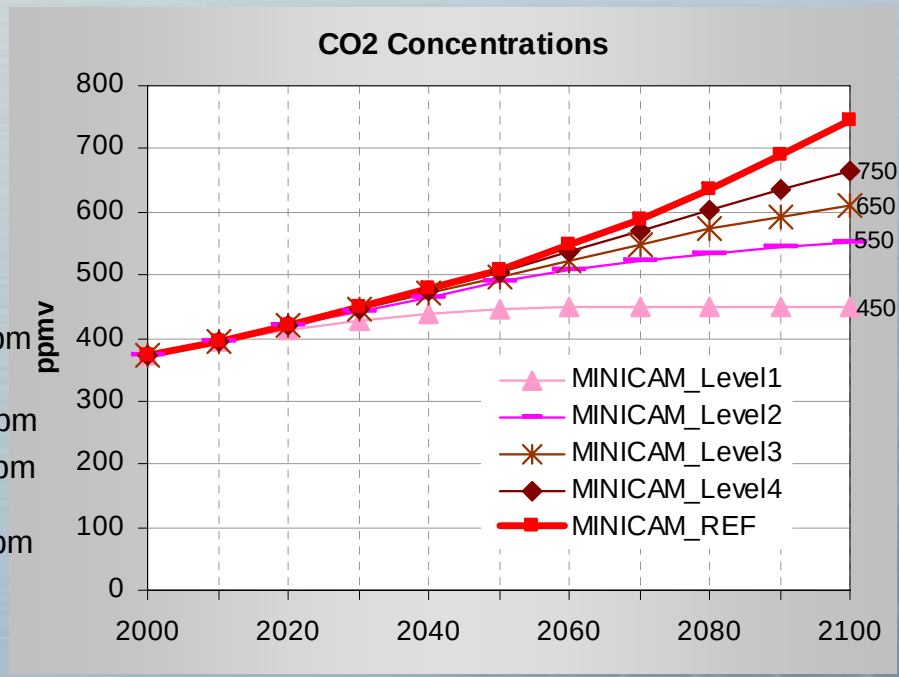
- Assume current policies are effective
  - U.S. 18% reduction in GHG/GDP by 2012
  - Kyoto Protocol
- Assume all nations participate in supplementary programs to achieve stabilization of radiative forcing
  - Perfect “Where Flexibility”;
  - Use WRE methodology to limit fossil fuel CO_2 emissions;
  - Use GWPs to compute prices for non-CO_2 GHGs.

Composition of Radiative Forcing

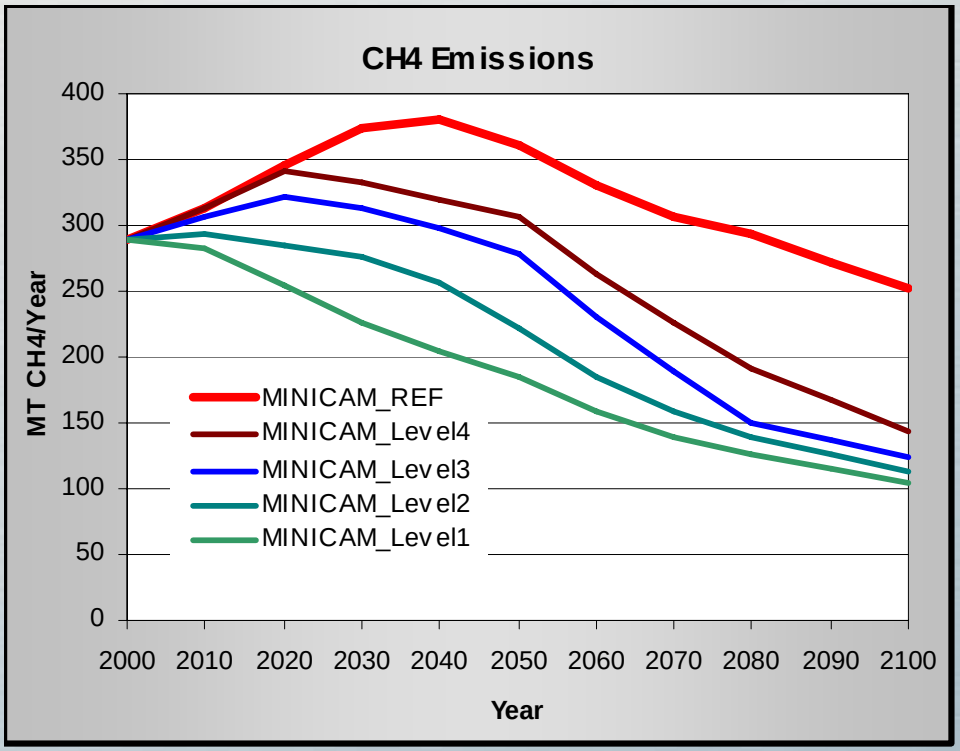


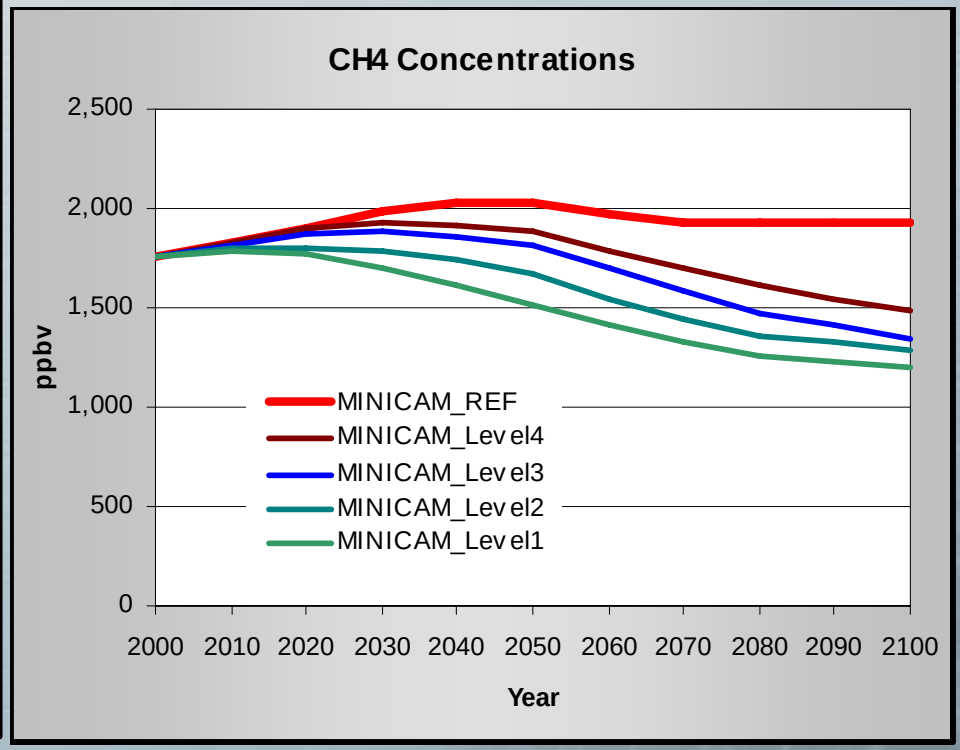
Greenhouse Gases—CO_2





Greenhouse Gases—CH_4





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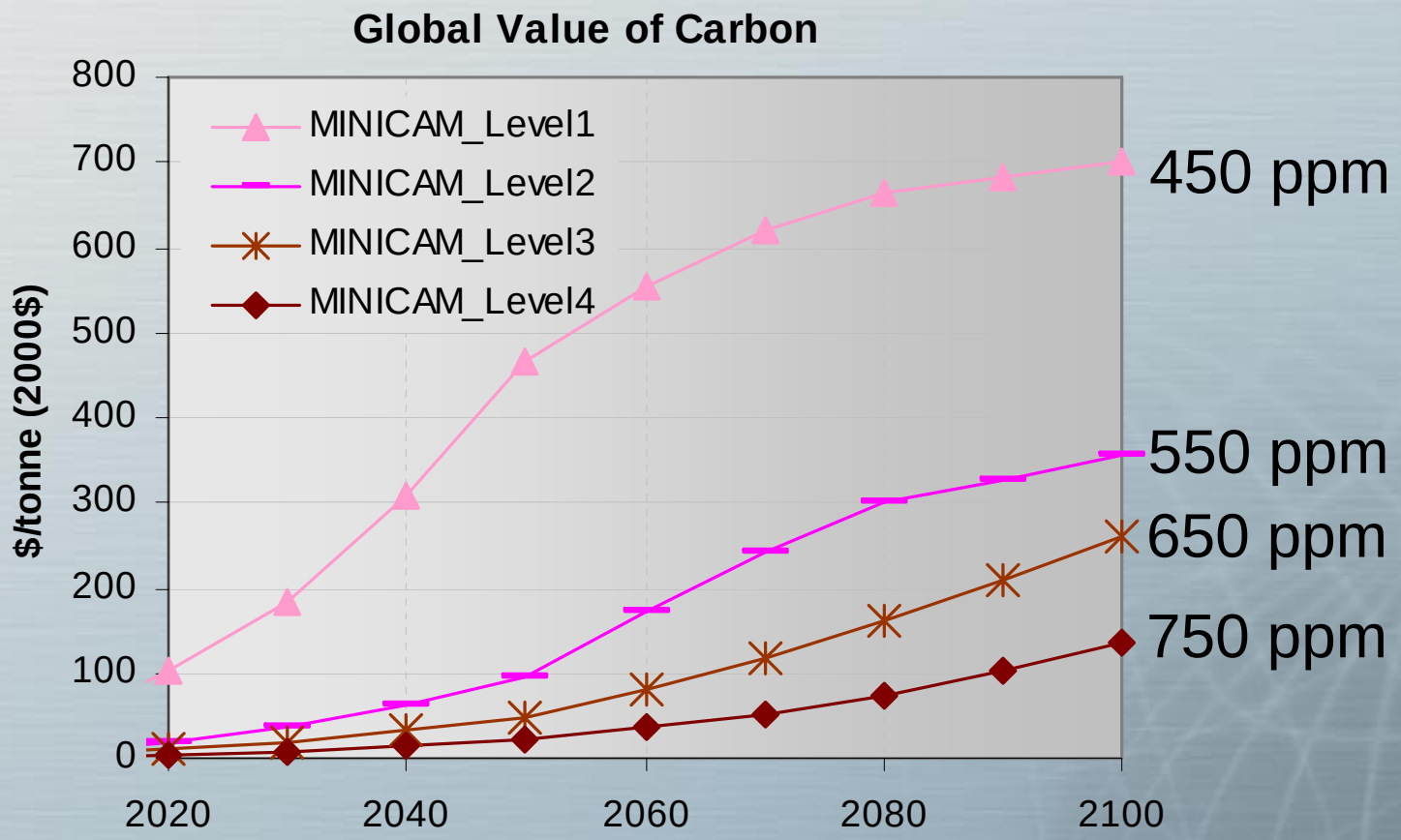
Implications for energy and technology

The Carbon Price

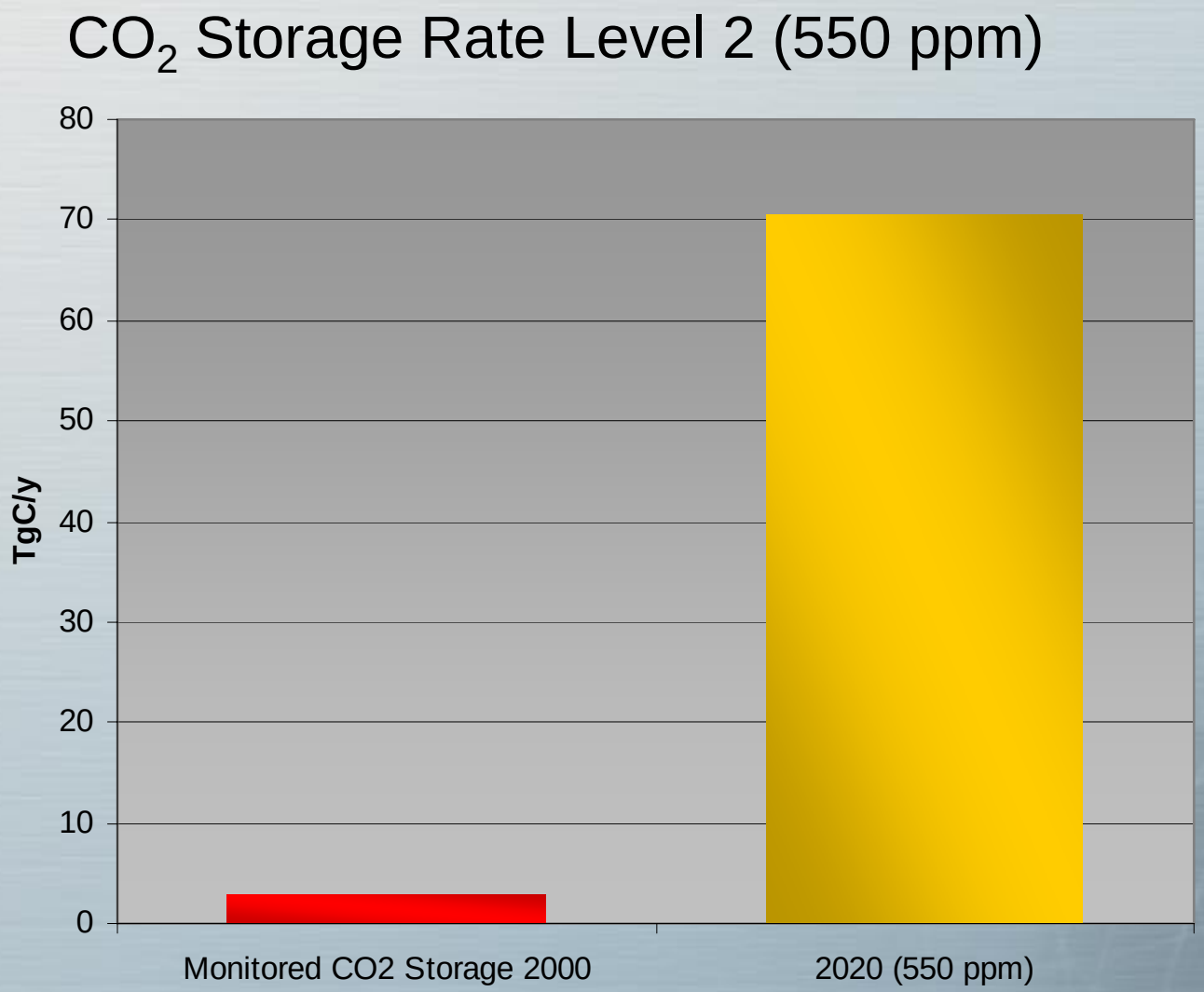


Effect on consumers

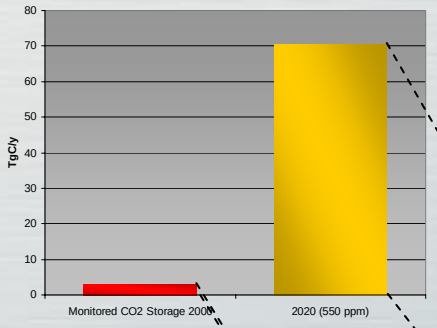
Impact of $100/tonne C on fuel prices

Fuel	Added Cost ($)
Crude Oil ($/bbl)	**$12.19**
Gasoline ($/gal)	**$0.26**
Heating Oil ($/gal)	**$0.29**
Wellhead Natural Gas ($/tcf)	**$1.49**
Residential Natural Gas ($/tcf)	**$1.50**
Minemouth Coal ($/short ton)	**$55.33**
Utility Coal ($/short ton)	**$55.33**
Electricity (c/kWh)	**1.76**

Major near-term changes in the energy system occur in stabilization



In the long-term the challenge grows



CO_2 Storage Rate Level 2 (~550 ppm)

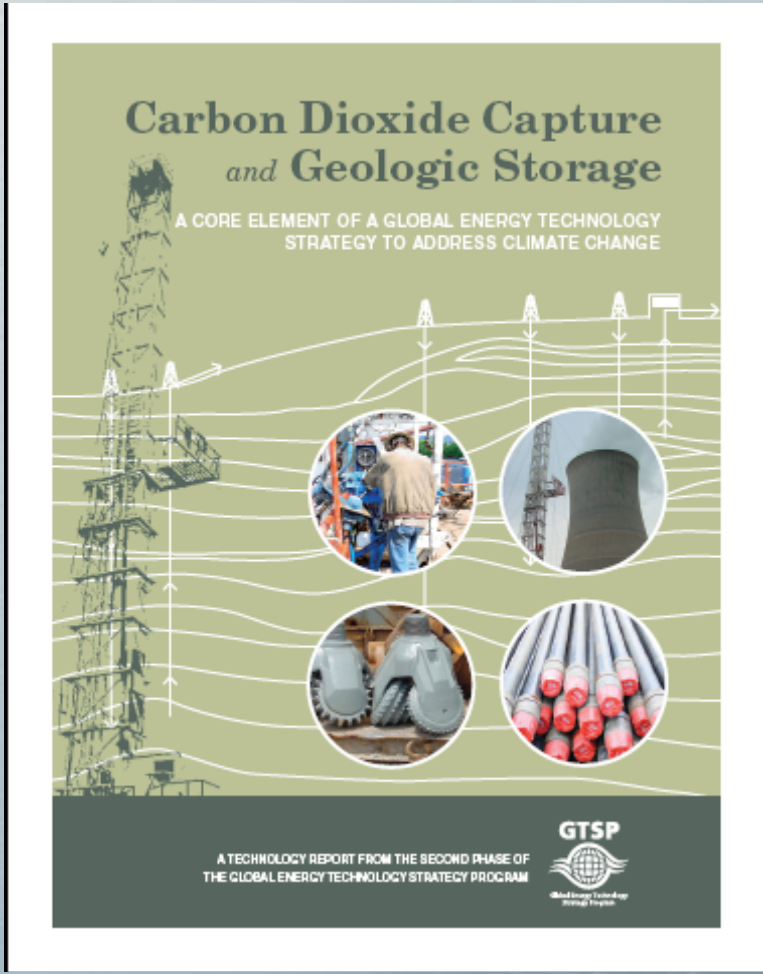
TgC/y

7,000
6,000
5,000
4,000
3,000
2,000
1,000
0

Monitored CO2 Storage 2000
2020 (550 ppm)
2050 (550 ppm)
2095 (550 ppm)

For more information on CCS see the GTSP special report on CCS

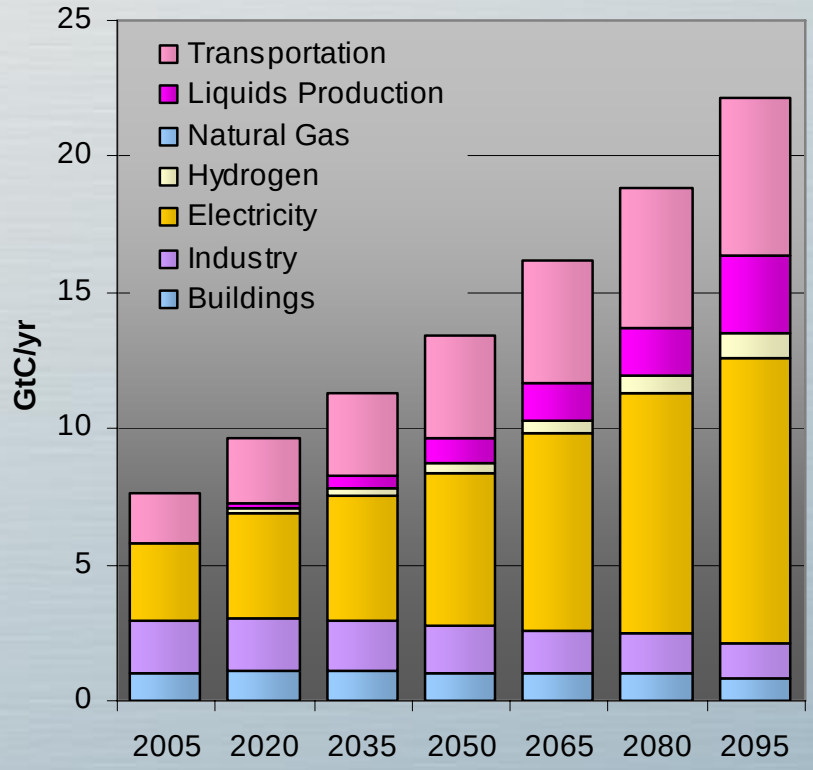
- Released May 10, 2006.
- Jim Dooley gave a keynote speech on the same day at the ***Fifth Annual Conference on Carbon Capture and Sequestration*** to introduce the CCS report.



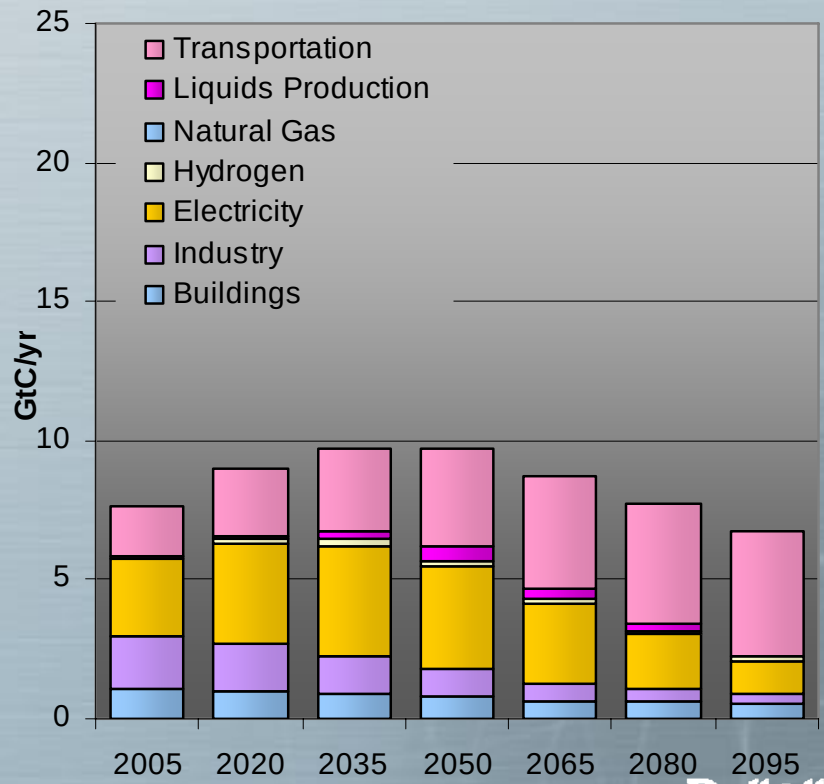
Fossil CO_2 Emissions—Global

Stabilization changes the sources of fossil CO_2 emissions. Utility emissions drop to virtually zero. Transportation emissions dominate.

Reference

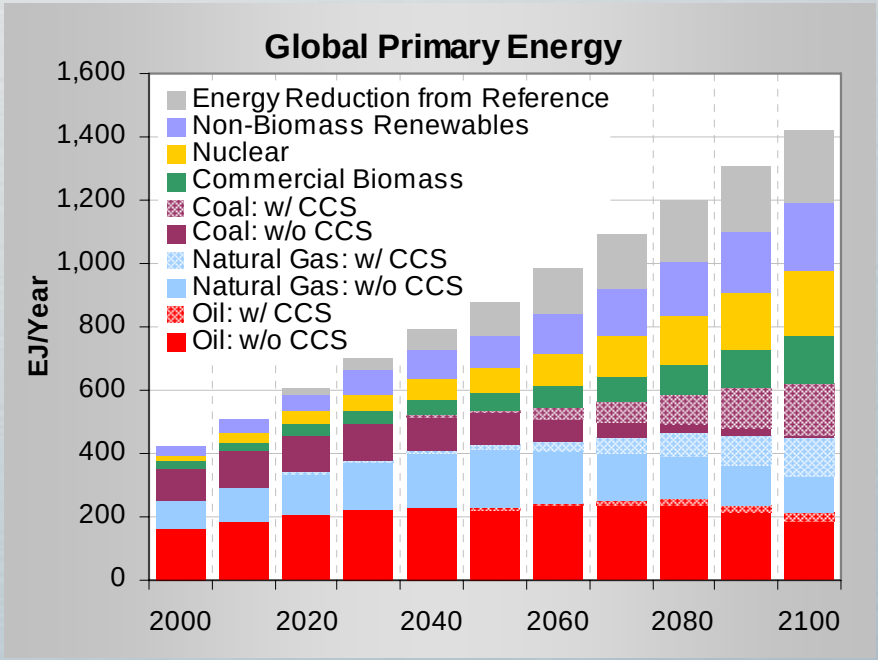


Level 2 (550 ppm CO_2)



The energy system—Global
4.7 W/m² (~550 ppm CO_2)

Level 2 (550 ppm CO_2)



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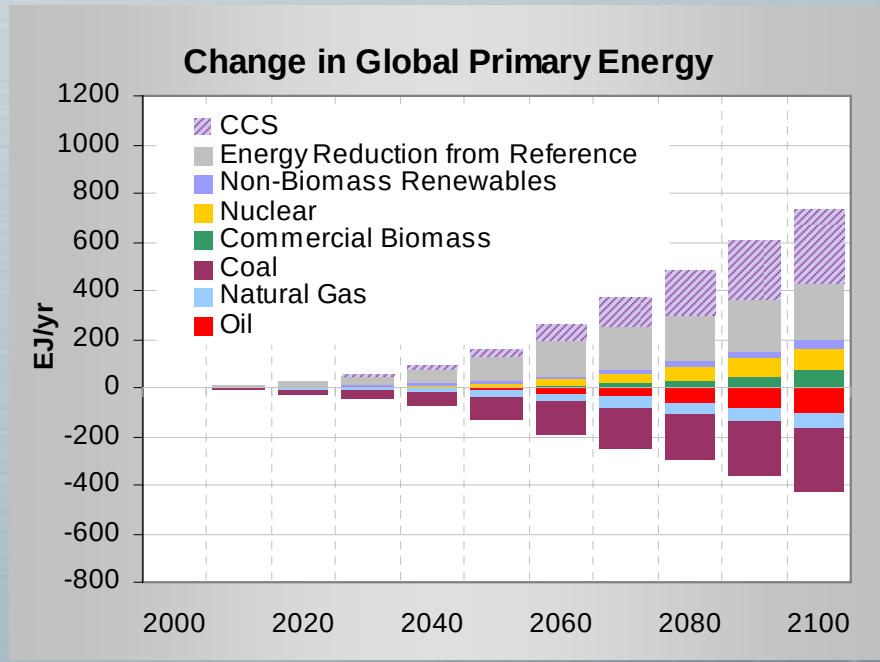
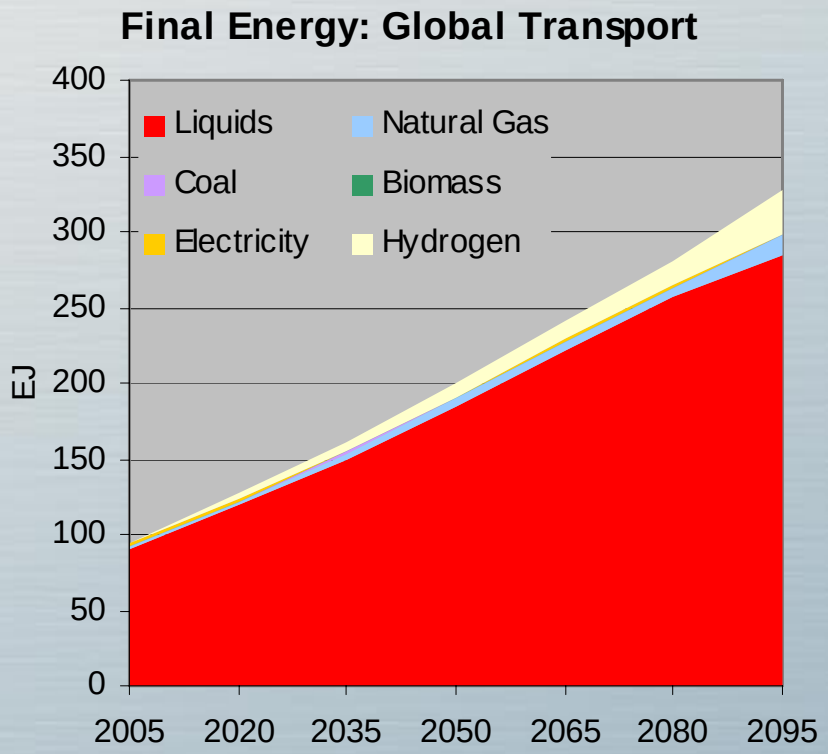


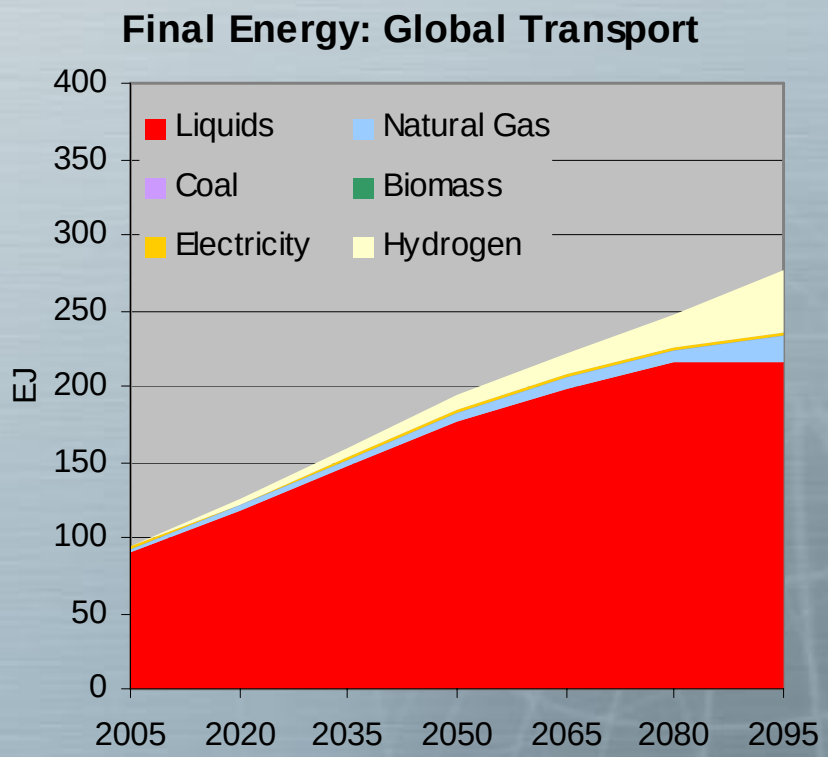
Transport Energy Use—Global

Remains dominated by liquid fuels, but …

Reference



Level 2 (550 ppm CO_2)



Oil Supply—Global

Stabilization extends the life of conventional oil, reduces shale oil production, eliminates coal liquefaction and promotes bioenergy.

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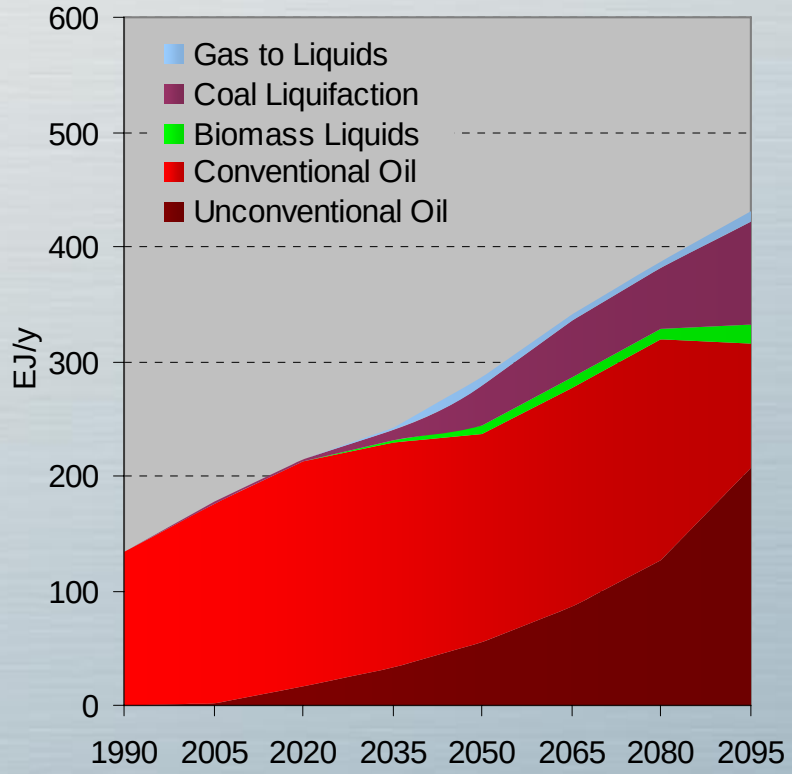

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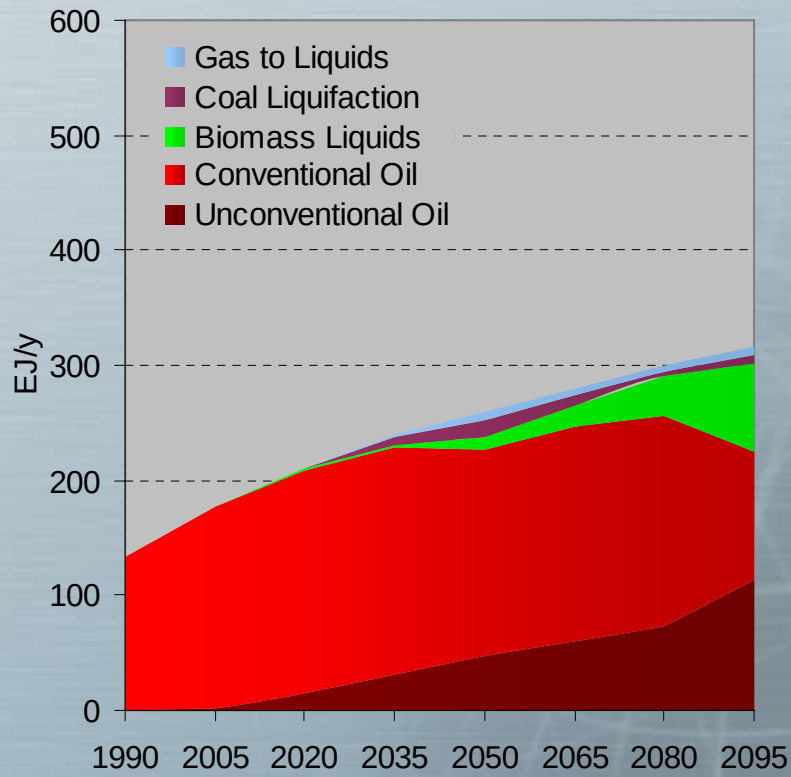
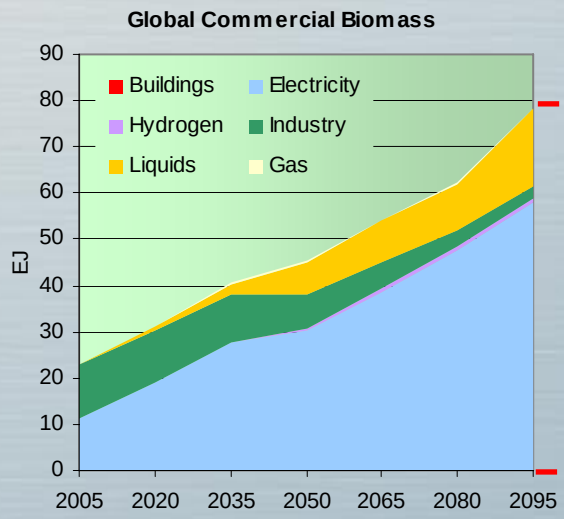


Commercial Bioenergy Consumption—Global

The scale of bioenergy changes under stabilization.

Reference



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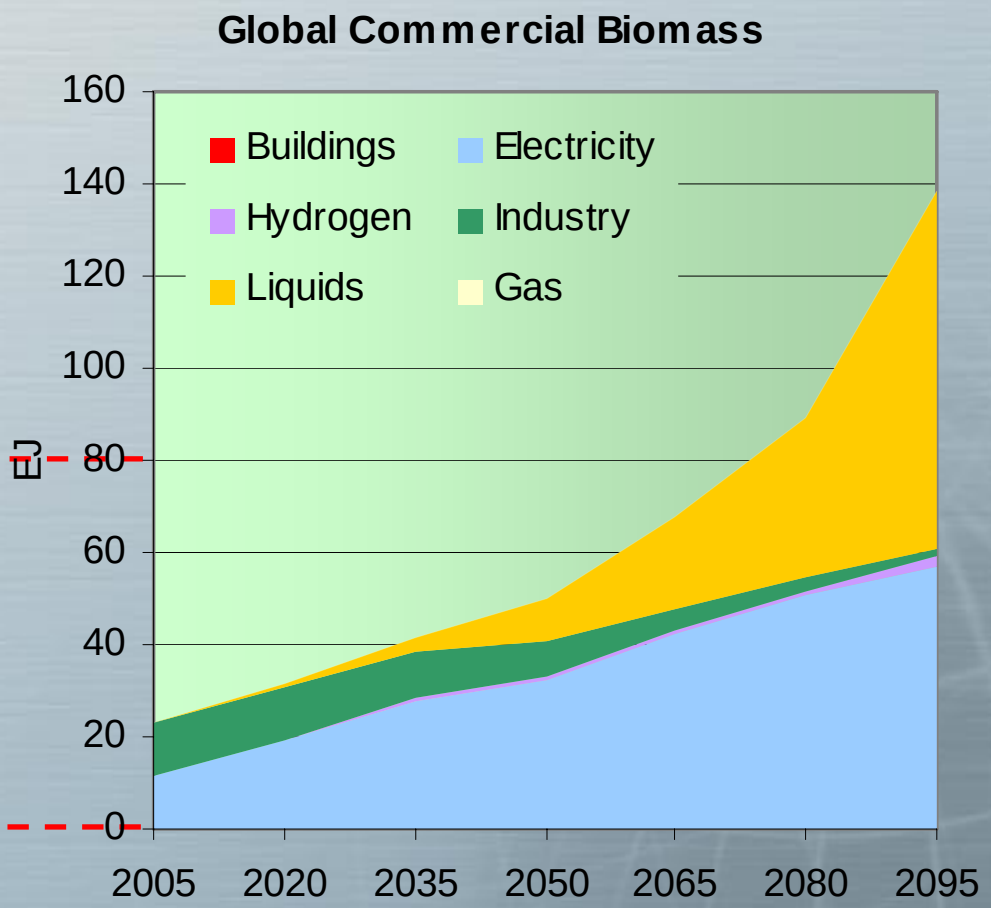
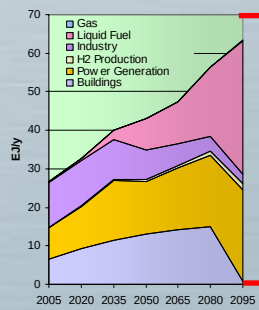


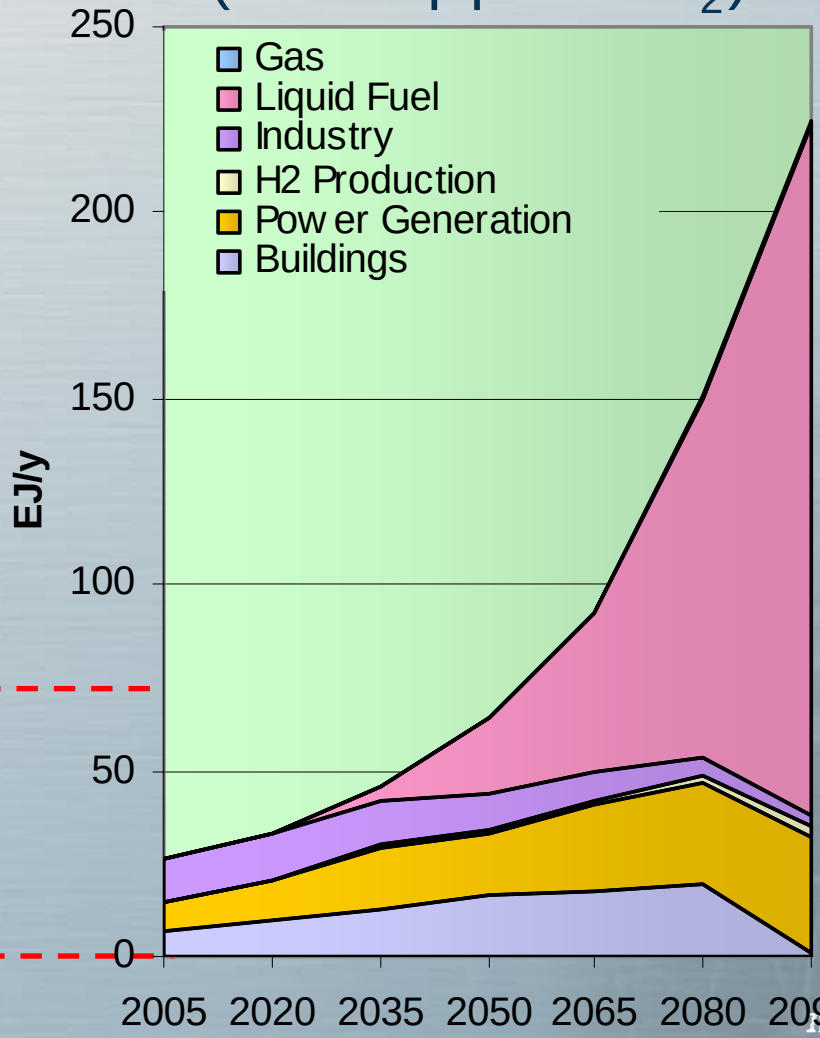
Bioenergy: Implications of Policy Regime

From an earlier scenario exercise without valuation of terrestrial carbon stocks

Reference



4.7 W/m^2
(~550 ppm CO_2)



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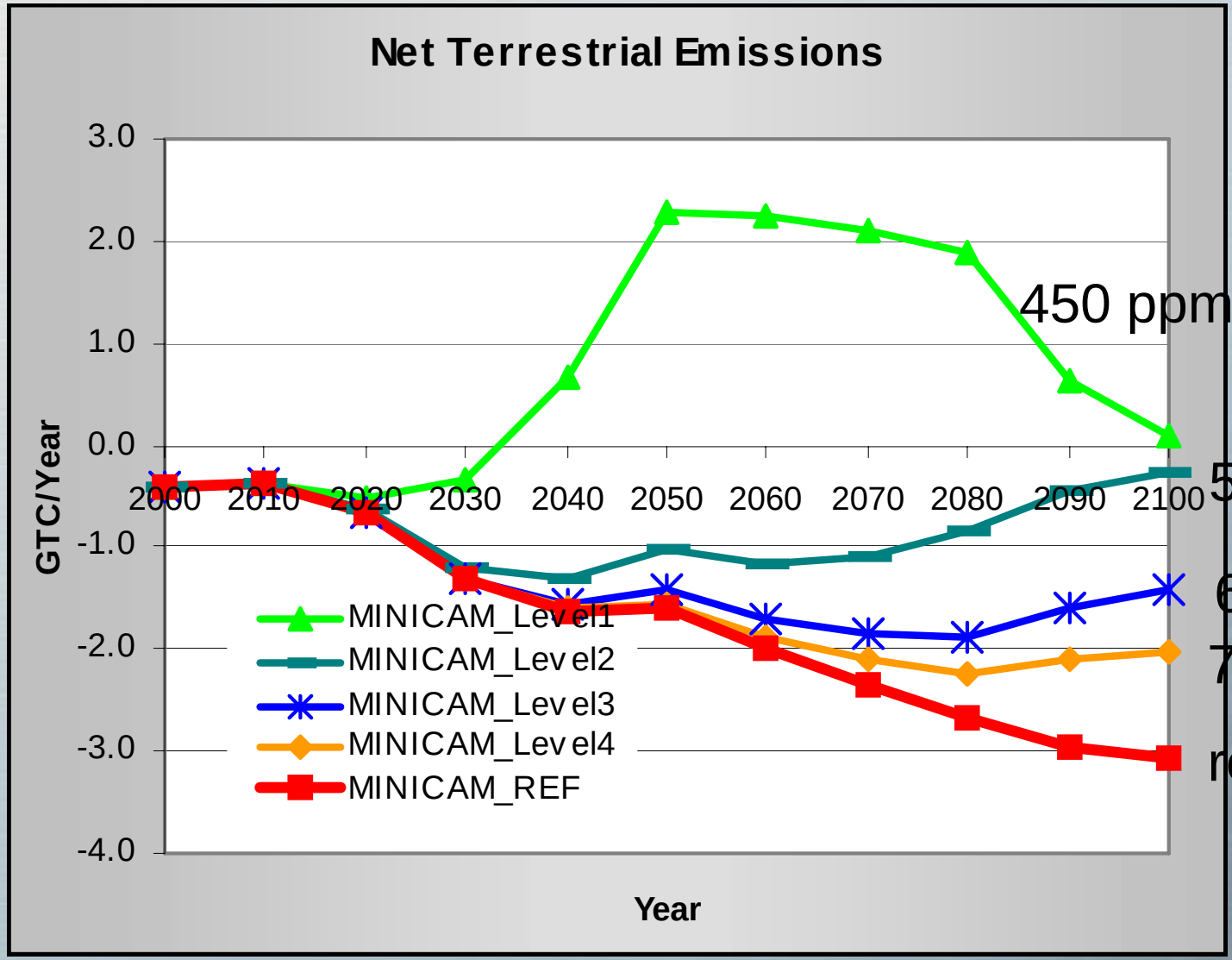
Implications for agriculture & land use—no terrestrial carbon valuation



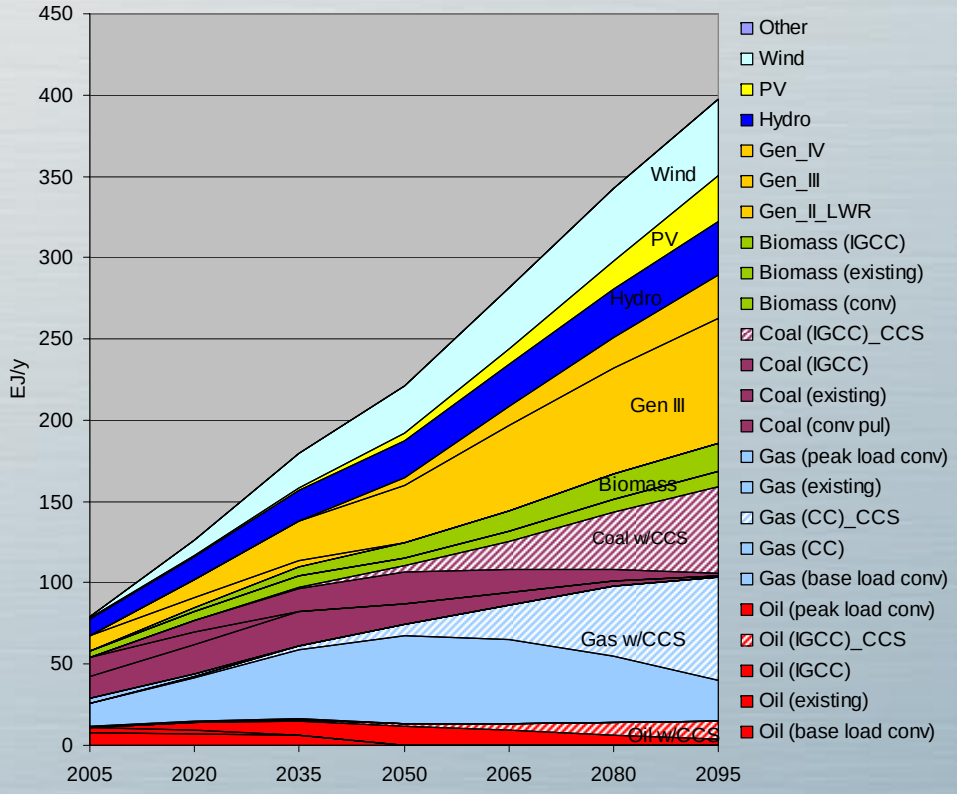
Implications for policy

- Land-use change emissions are accelerated by the imposition of a limit on fossil fuel CO_2.
- **The reason is that terrestrial carbon is not valued!**
- The implication for policy is that terrestrial carbon needs to be valued just as much as fossil fuel carbon.

Electric power—Level 2 Global 4.7 W/m² (~550 ppm CO_2)

Non-emitting technologies expand market share and fossil generation deploys CCS.

Technology Mix



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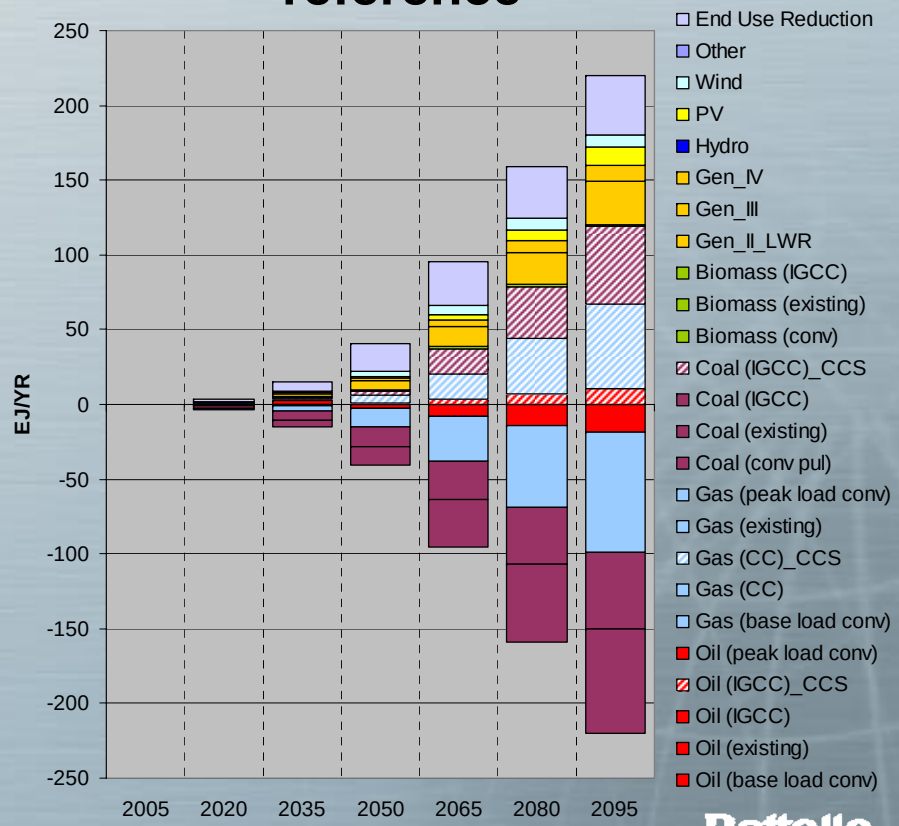
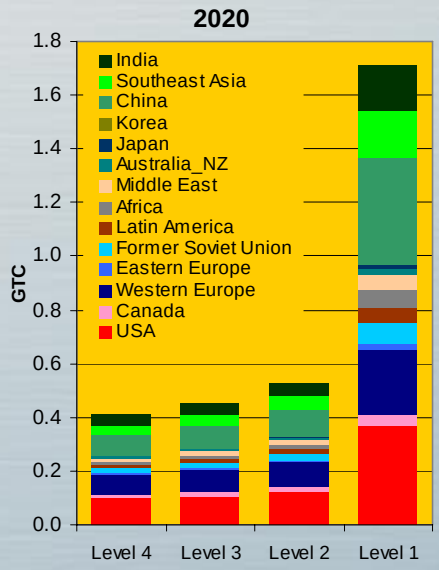
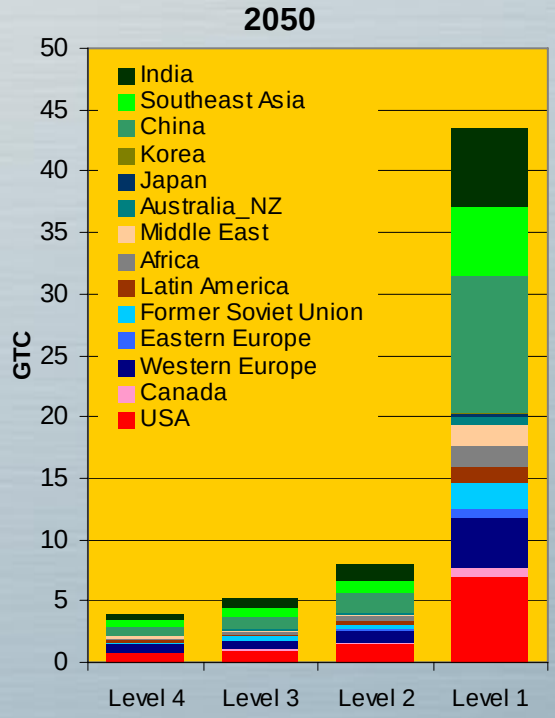
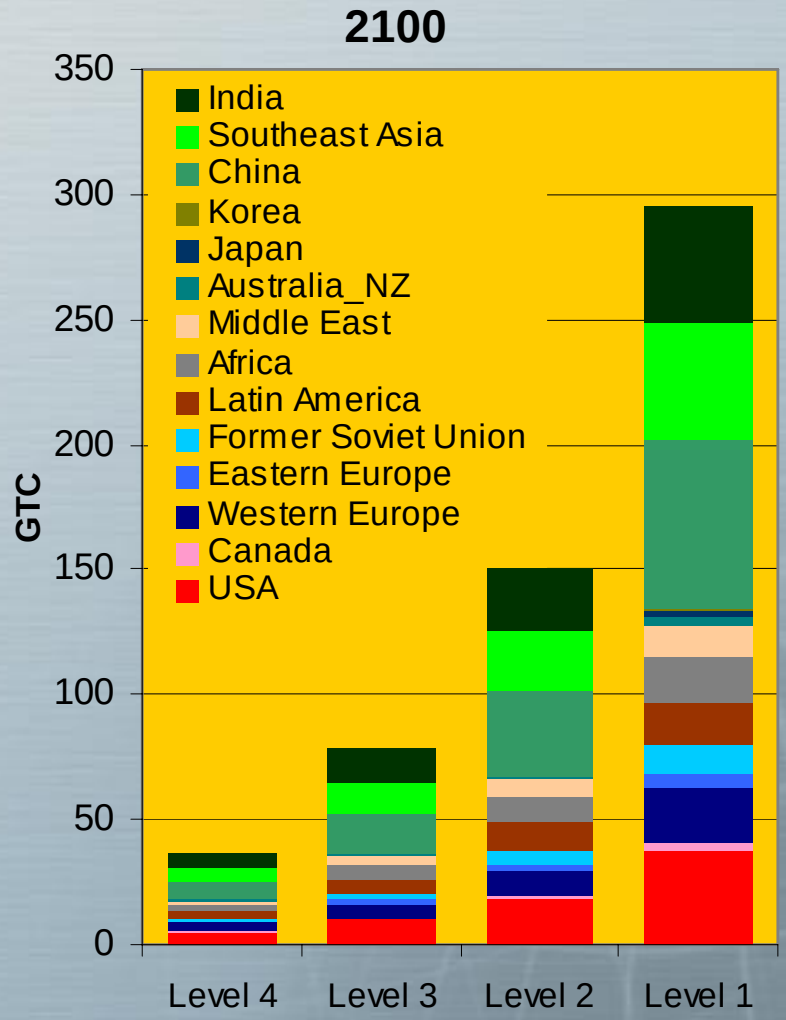


Cumulative CO_2 Capture and Storage







Summary

- New scenarios are a story of changing demographics and heterogeneous economic growth.
  - Shift in the economic center of gravity of the world toward Asia and the Pacific
- New scenarios are a story about the transition from a world dominated by conventional oil.
  - The competition among liquid fuel options
    - Unconventional oil
    - Coal to liquids
    - Biofuels

Summary

- New scenarios of energy, economy, and greenhouse gas emissions have been developed using the PNNL MiniCAM.
  - Higher transportation demands
  - Higher fossil fuel demands
  - Higher CO_2 emissions
  - Lower CH_4 emissions (a technology story)
- New stabilization scenarios based on radiative forcing
- Implications for energy technology and the economy
  - Dramatic changes are ultimately required in all sectors of the economy
  - Changes need to begin in the near term to meet any stabilization goals, and are more dramatic for stringent scenarios.

Summary

- In stabilization cases, the price of carbon and other greenhouse gases is positive and rising.
  - There is no evidence that the world will run out of fossil fuels and transition to non-emitting technologies.
  - Because cumulative emissions of CO_2 are limited over the course of a century, the challenge of emissions mitigation grows with time.
- When land-use carbon is not valued at the same rate as fossil fuel and industrial carbon
  - Large land-use change emissions of CO_2 can occur, and
  - The cost of stabilizing radiative forcing is unnecessarily high.