Energy Sector Evolutions: A Scenario Perspective from MiniCAM

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Modeling the Oil Transition: A DOE/EPA Workshop on the Economic and Environmental Implications of Global Energy Transitions

Battelle
Pacific Northwest National Laboratory

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Today's Discussion

- Brief Overview of MiniCAM
- Energy Sector Evolution in a Reference Scenario
- The Implications of Stabilization and a Move to Alternative Fuels

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Overview of MiniCAM

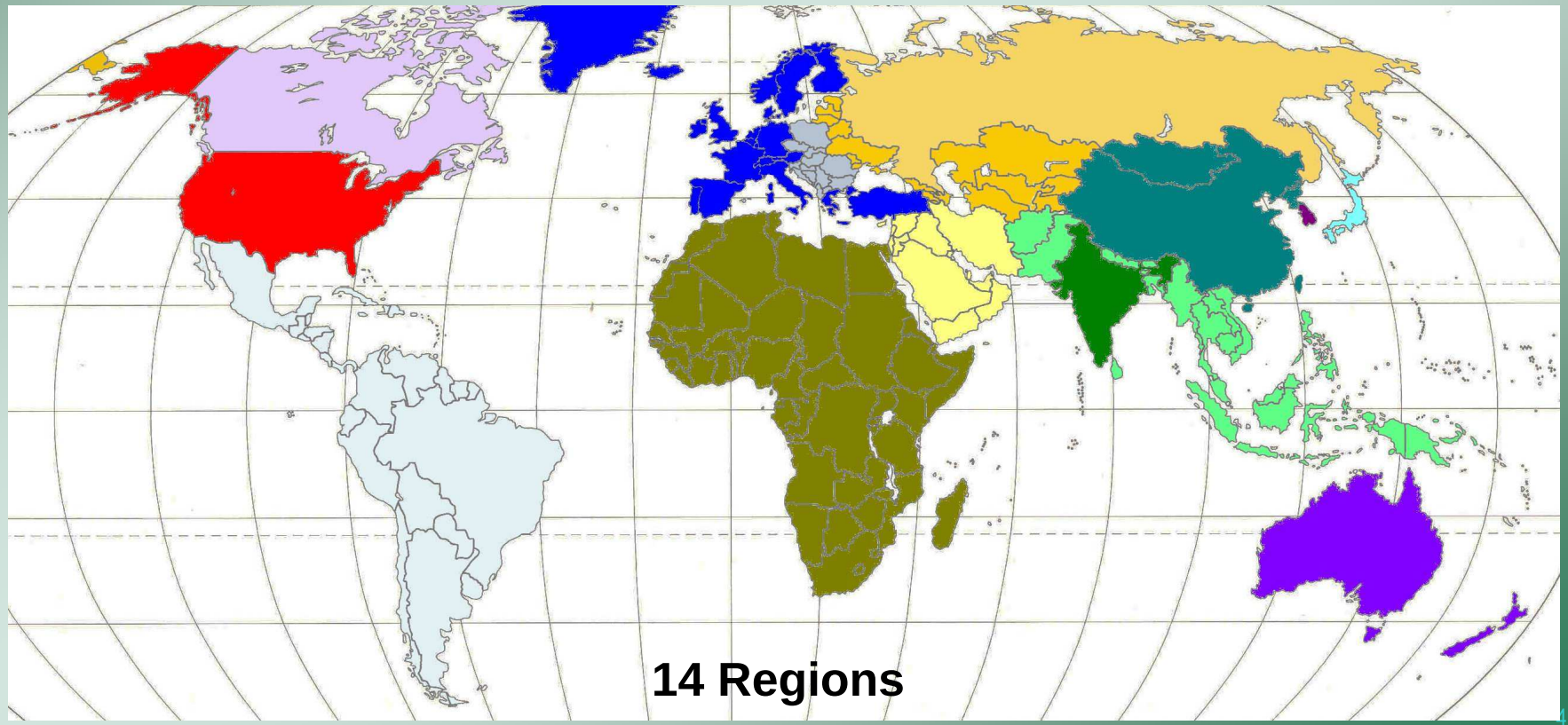
MiniCAM—An Integrated Assessment Model

Emissions, Atmosphere, Climate

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

15 gaseous emissions—linked to associated human activities

2095 time horizon

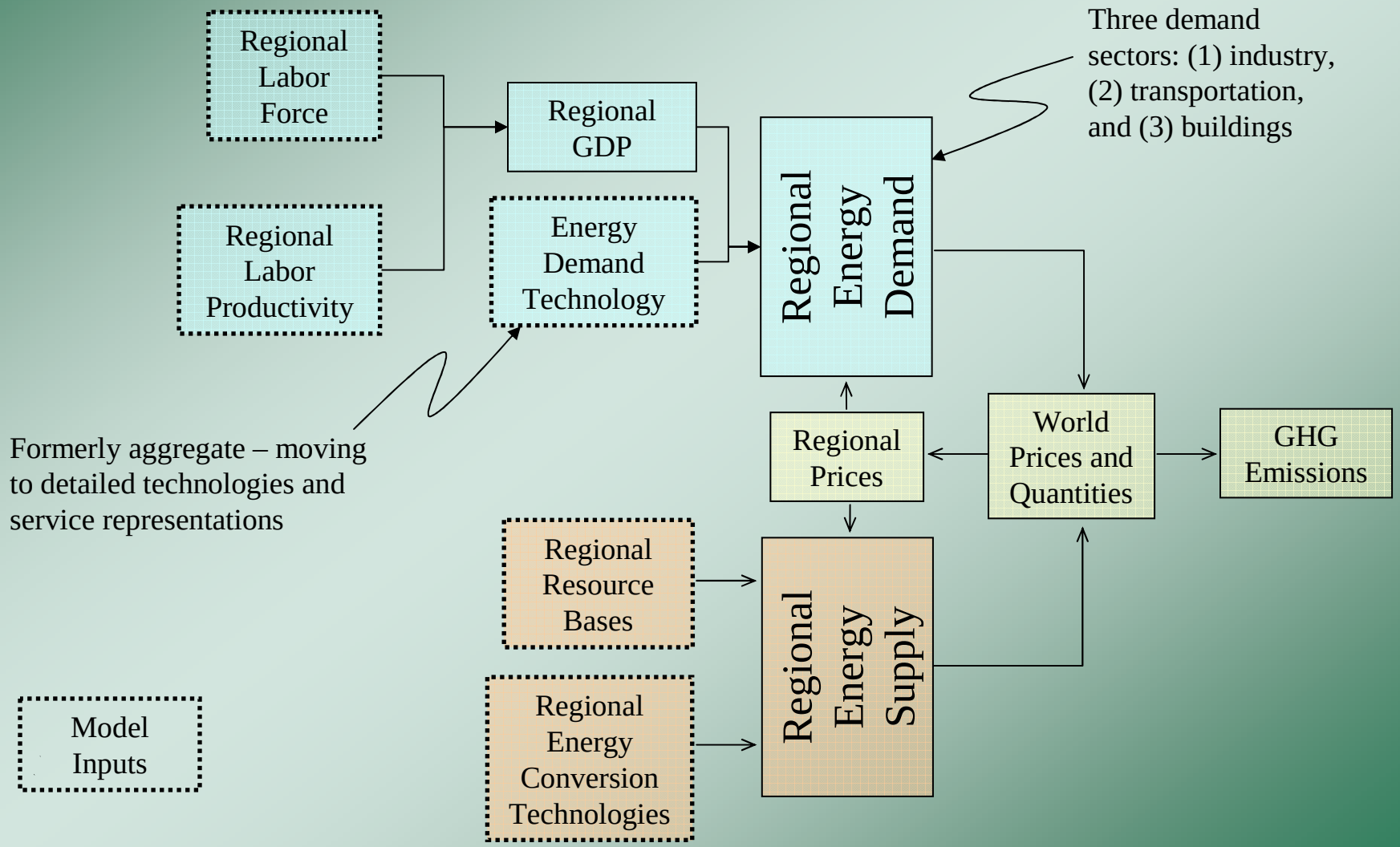


14 Regions

MiniCAM Model: Key Characteristics

- Energy-Agriculture-Economy Market Equilibrium
  - Partial rather than general equilibrium
- Explicit Energy Technologies: “Relatively Technologically Detailed”
- Exogenous assumptions regarding technological advance.
- Fossil resources explicitly represented through discrete grades.
- Fully Integrated Agriculture and Land Use Model
- Typically Runs to 2095 in 15-year time steps
  - Meant for analysis of long-term evolution, not short-term fluctuations.
- Includes an Integrated Climate Assessment Model (MAGICC)
- Recently (2003) moved to object-oriented modeling platform in C++ (O^{bj}ECTS) from Fortran.

Top Level View of MiniCAM Energy Markets Core Elements



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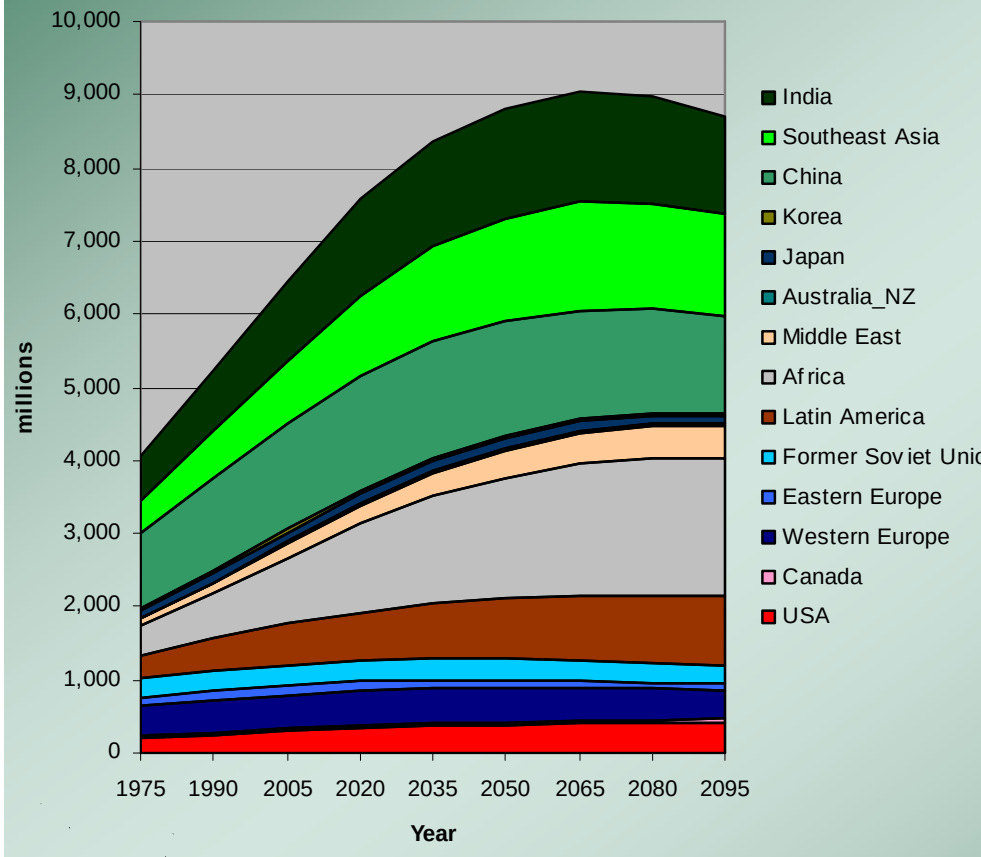
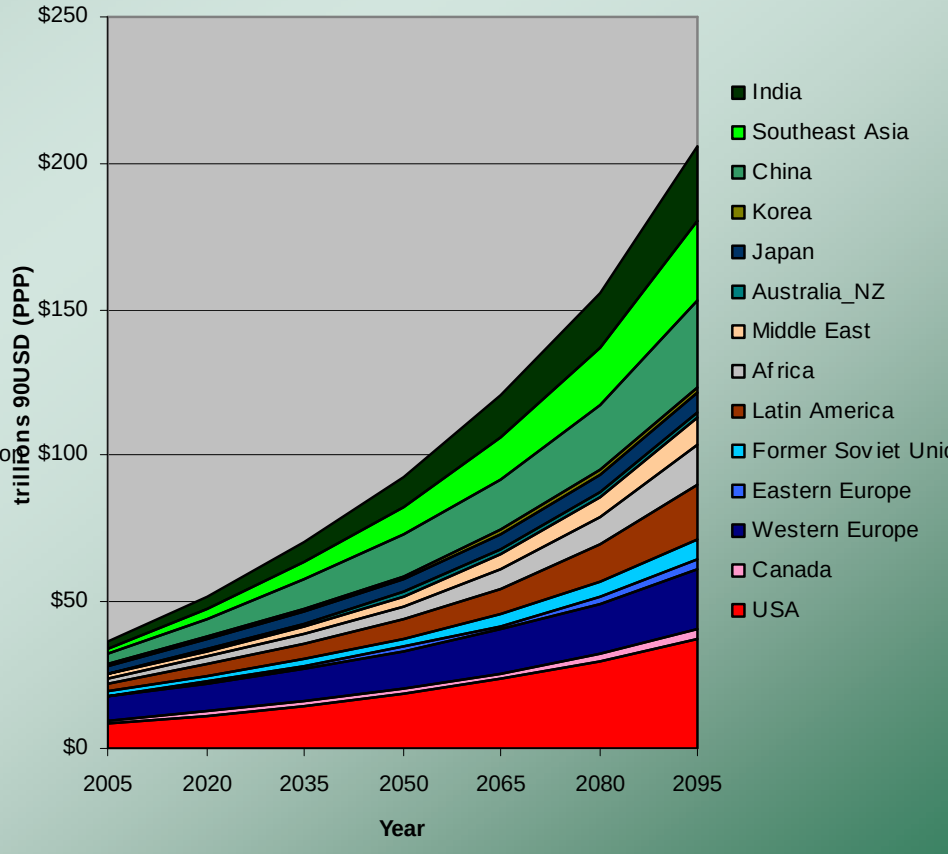
Drivers and Evolution: A Reference Scenario

The result of several ongoing scenario processes (CCSP, CCTP, GTSP)

Demographics & Economics

Developing and transition economies take on an increasing share of increasing global economic activity

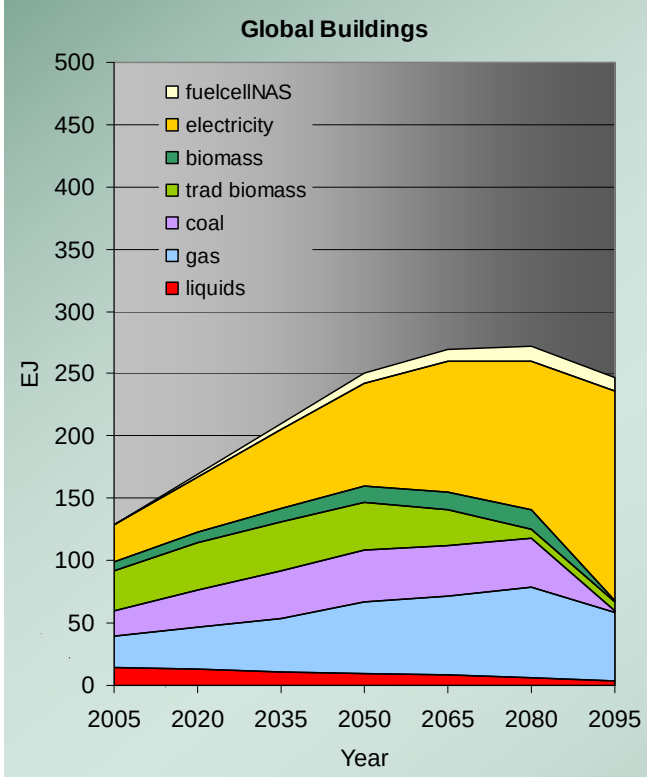


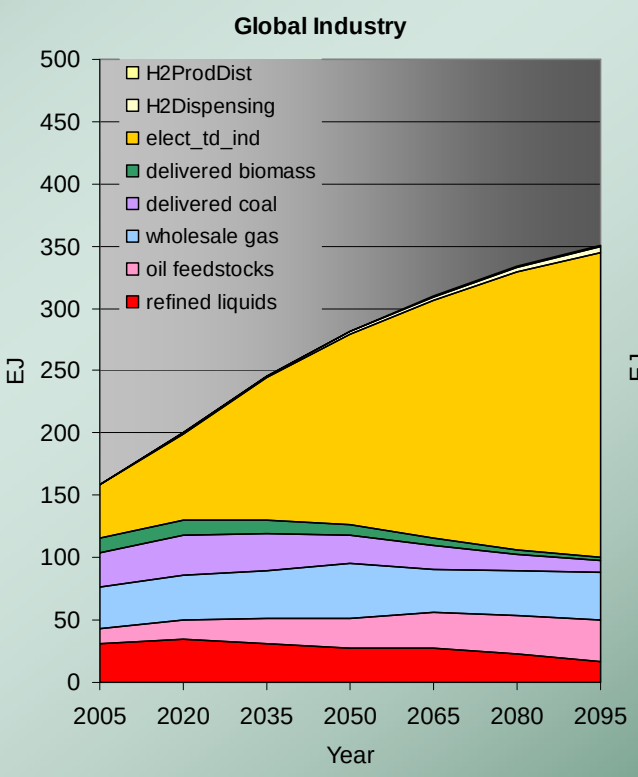


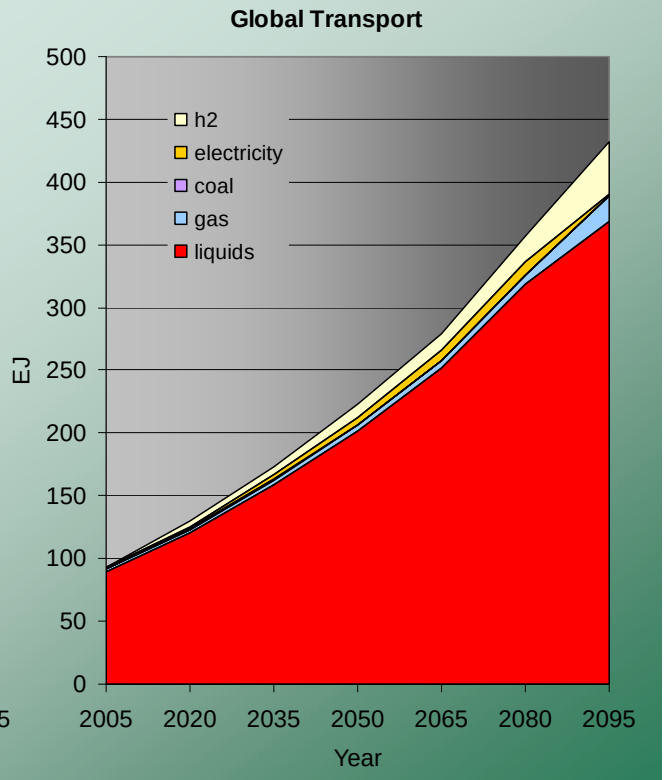
Combines the United Nations medium scenario and the Millennium Assessment Techno-Garden (MATG) scenario from IIASA (O'Neill, 2005).

Global End-Use Energy by Sector

- A 1,000 EJ final energy world
- Differential rates of demand growth relative to economic activity and population growth.

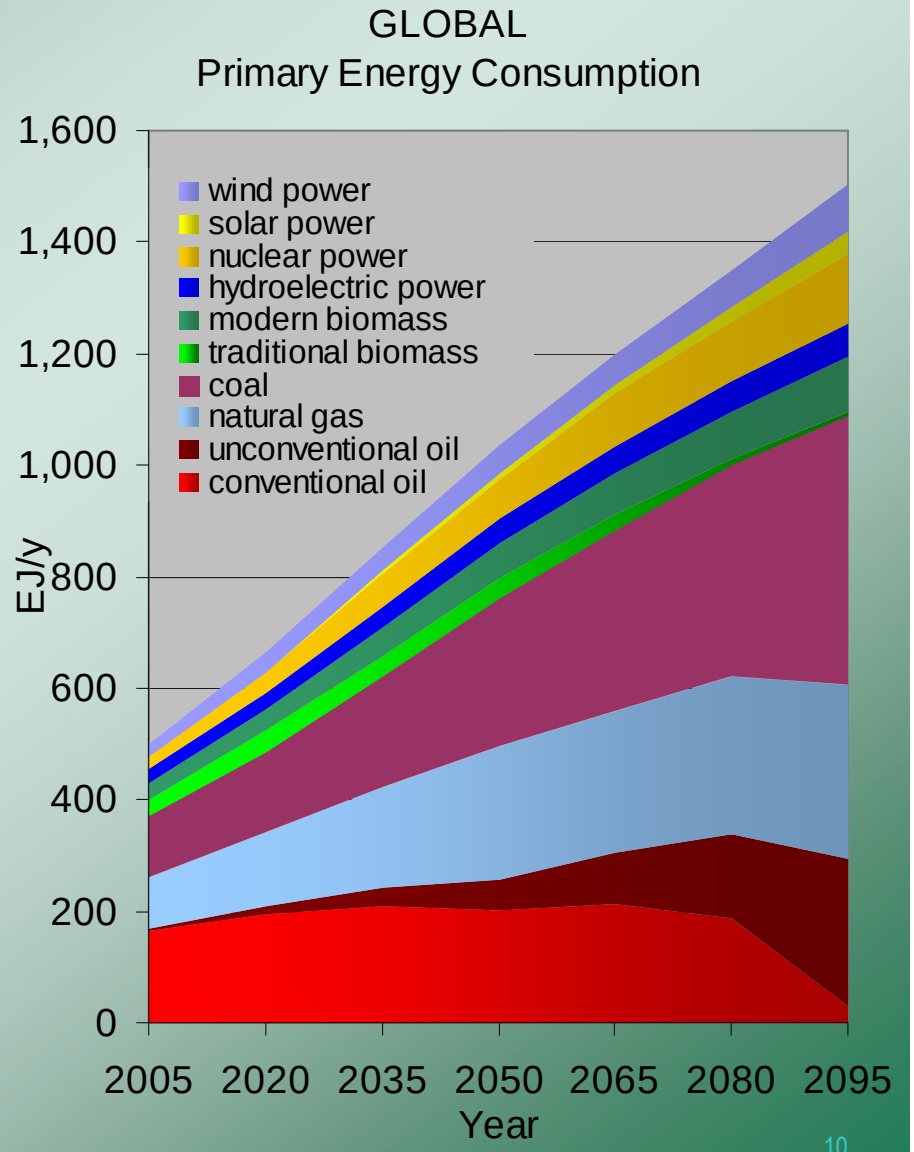






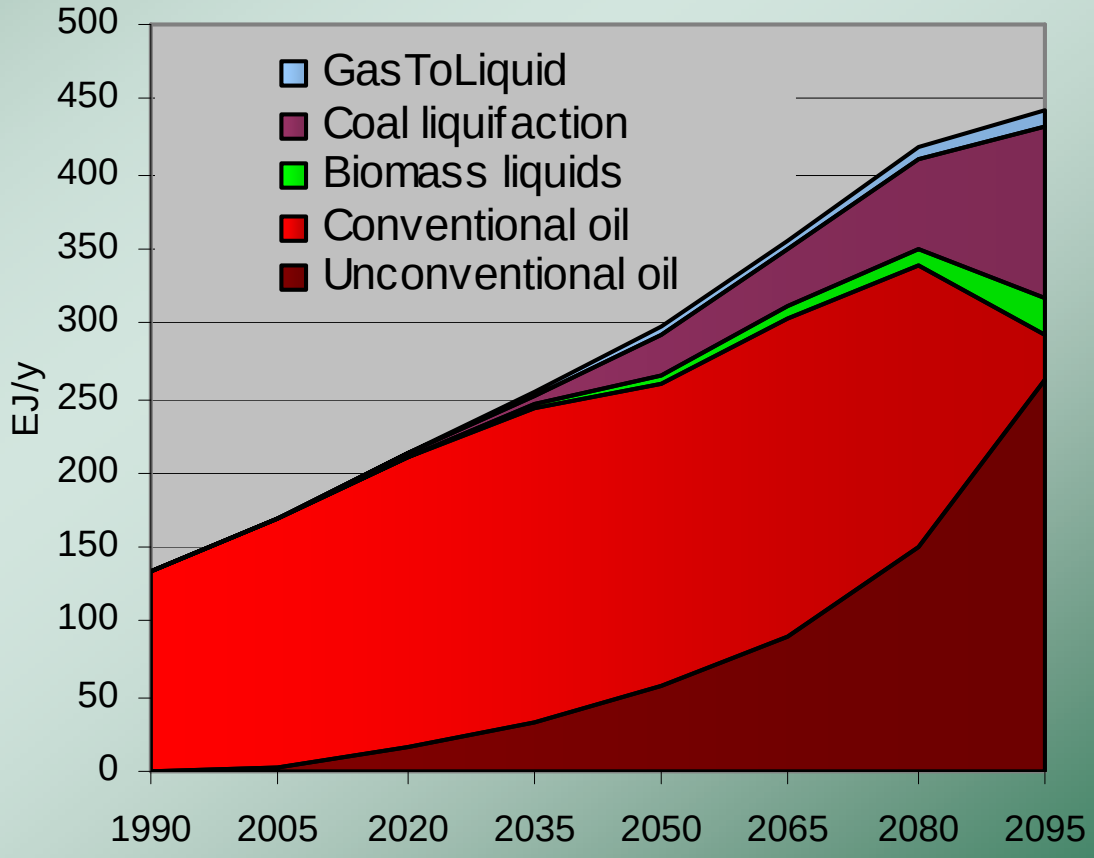
Primary Energy

- A 1,500 EJ/Yr world by the end of the century.
- The growth in non-fossil resources is substantial, but
- fossil fuels remain the dominant source of energy.
  - There is no shortage of fossil fuels.



The Global Evolution of Liquid Fuels

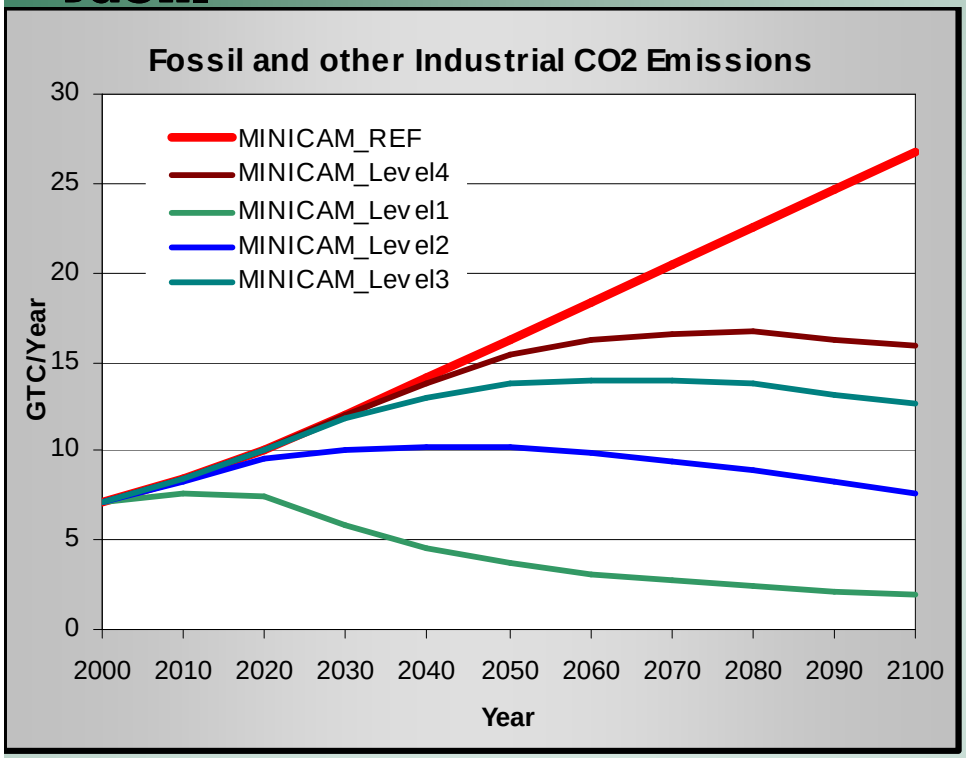
- Conventional oil production is ultimately limited, but this does not provide a substantive brake on the use of liquid fuels.
- Unconventional oil and synfuels become the dominant forms of liquid fuels in the second half of the century.
- Implication—higher CO_2 emissions.

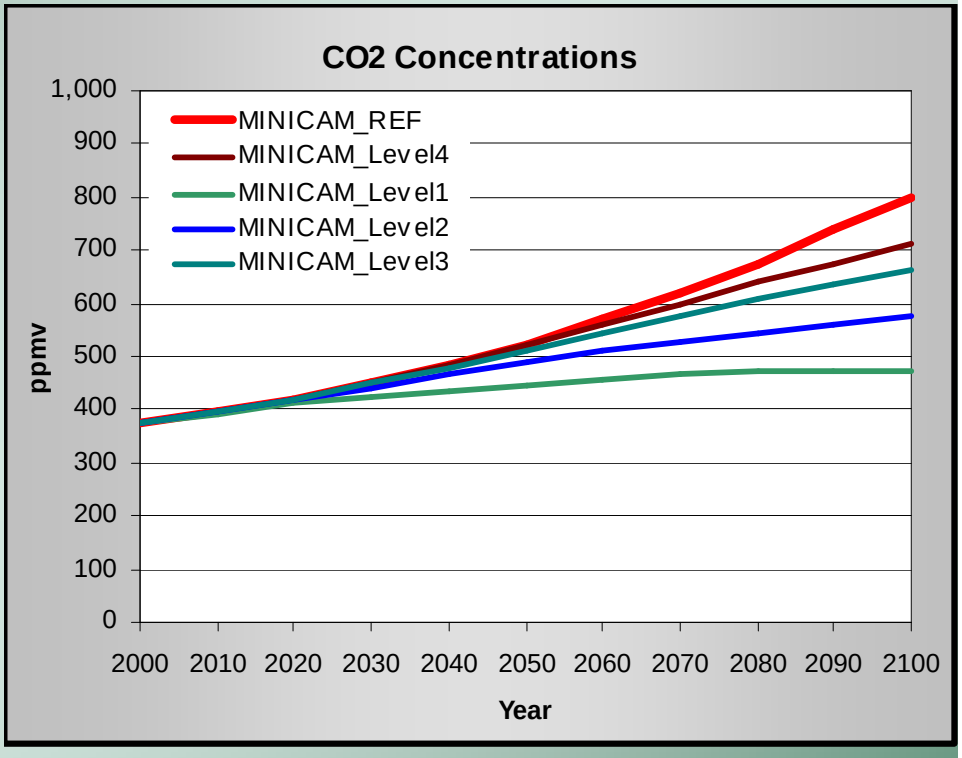


There is no Shortage of Fossil Fuels in this Scenario

- Resource Bases for this Scenario
  - ~18,000 EJ (~3000 billion barrels) of conventional oil, much more unconventional oil starting around $55-70/bbl.
  - About 6000 EJ proved natural gas, 13,500 EJ estimated additional sources, another 16,000 EJ unconventional
  - Over 250,000 EJ of coal
- Coal to liquids technology becomes economic in the future at costs around $60 to $75/bbl oil.

Greenhouse Gases—CO_2





- Fossil and other industrial carbon emissions exceed 25 GTC/year by the end of the century.
- CO_2 concentrations reach 800 ppmv by the end of the century, and are still rising.

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Implications of Stabilization

Scenario Architecture: Stabilization of Radiative Forcing

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

WARNING: **We have not considered chemically active gases such as CO, NOx, or VOCs, nor the aerosols and dark particles.**

The Global Energy System: 4.7 W/m2 (~550 ppm CO2)

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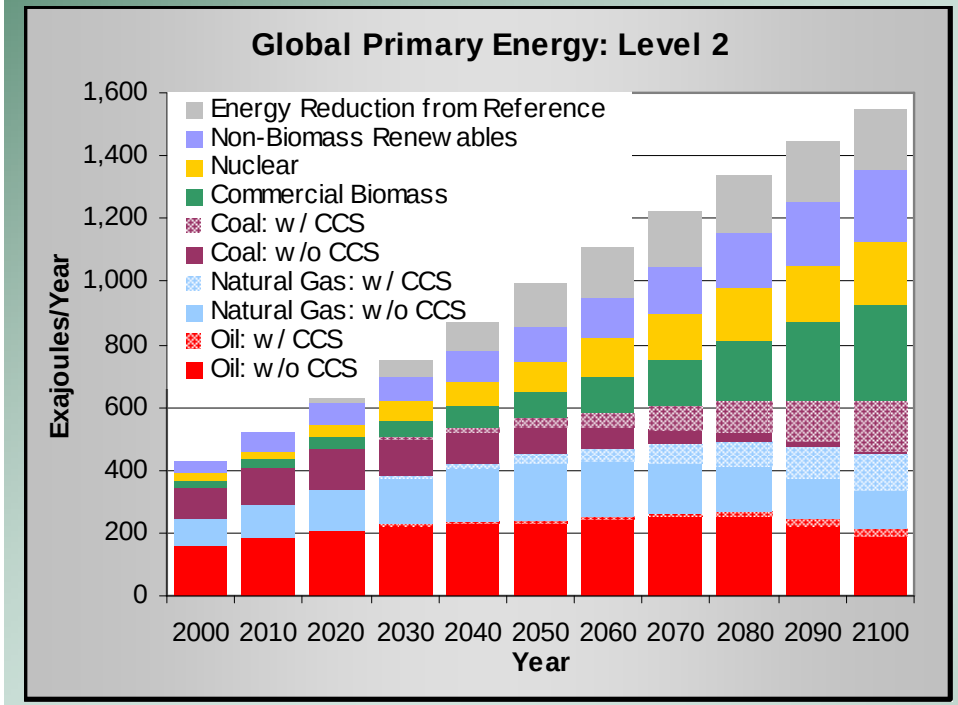
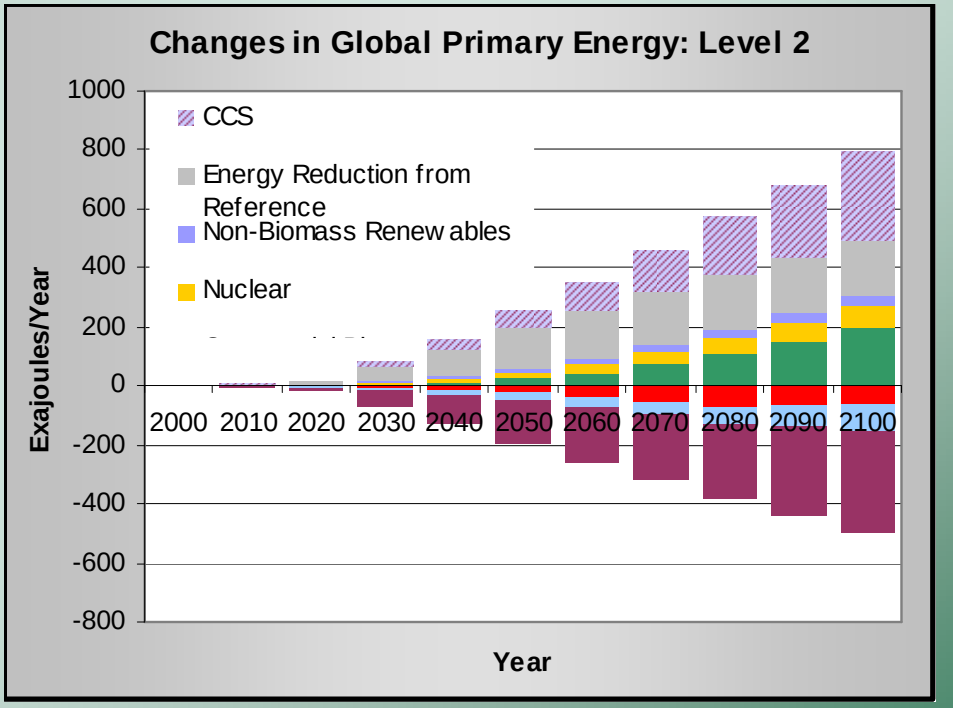


Change relative to reference

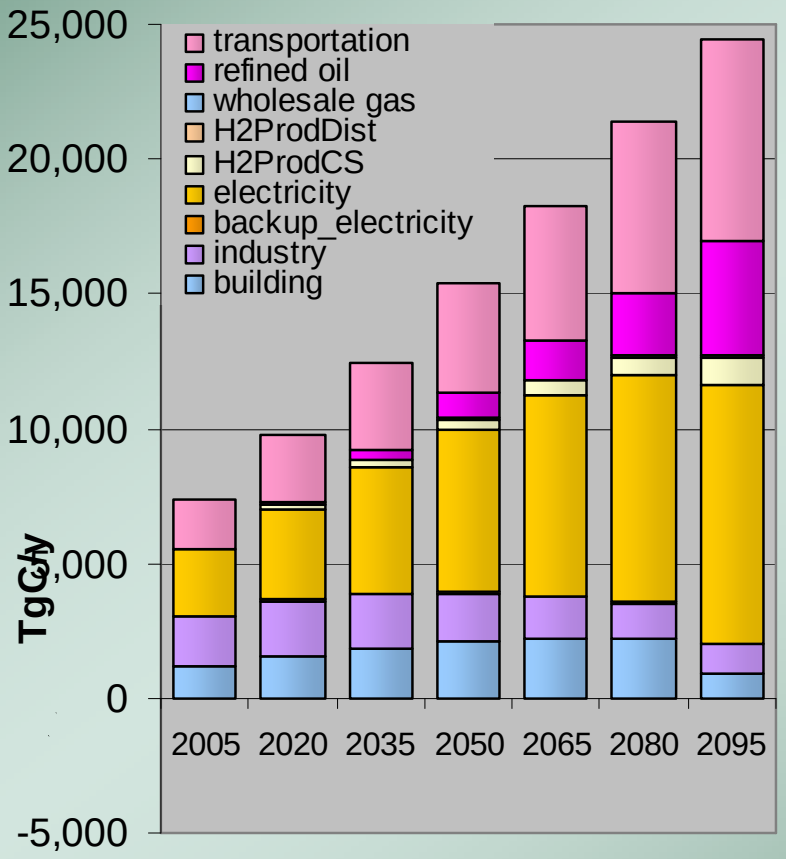


- Increasing proportion of the energy system is supplied by low-CO2 emissions technologies, accompanied by energy demand reductions.

CO_2 Emissions—Global

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

Reference



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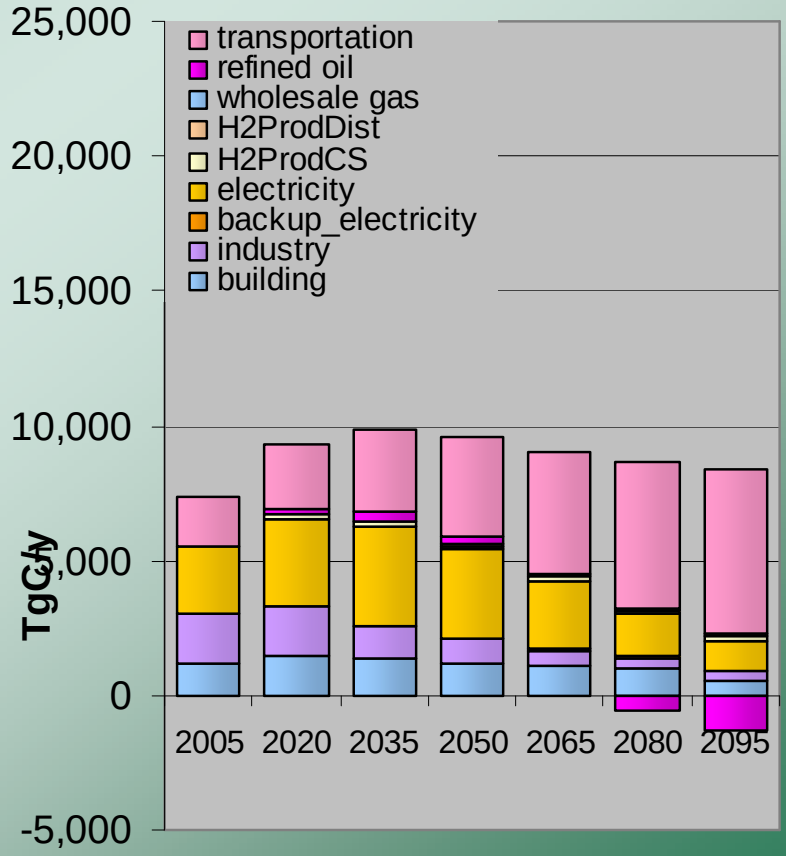

Transport Energy Use—Global

Remains dominated by liquid fuels, but …

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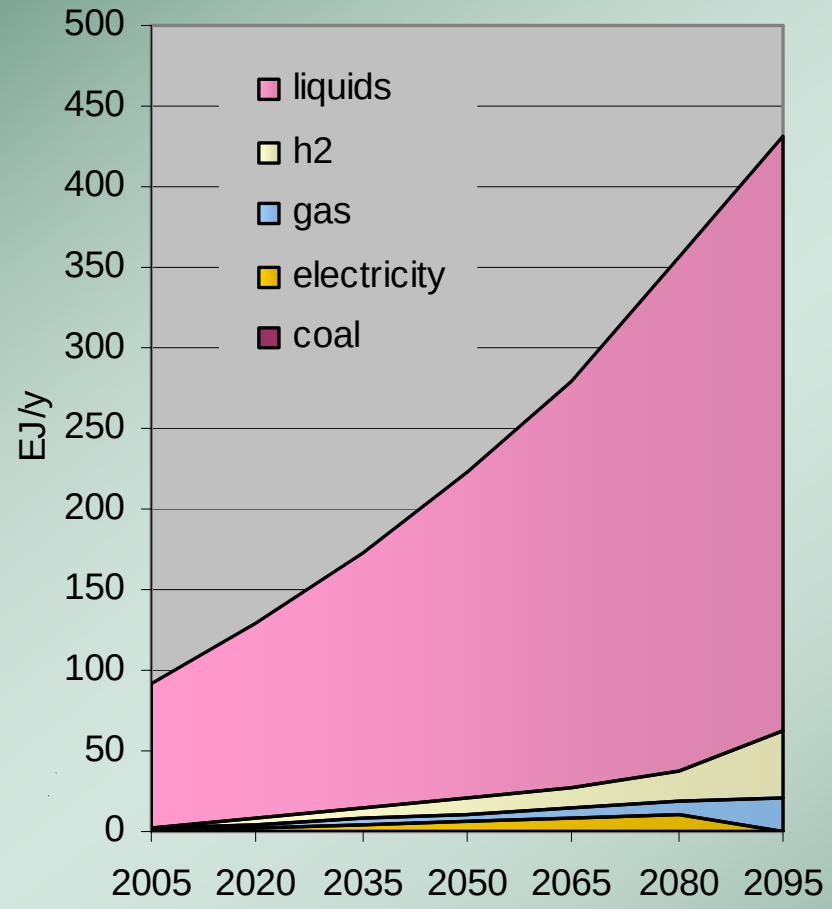

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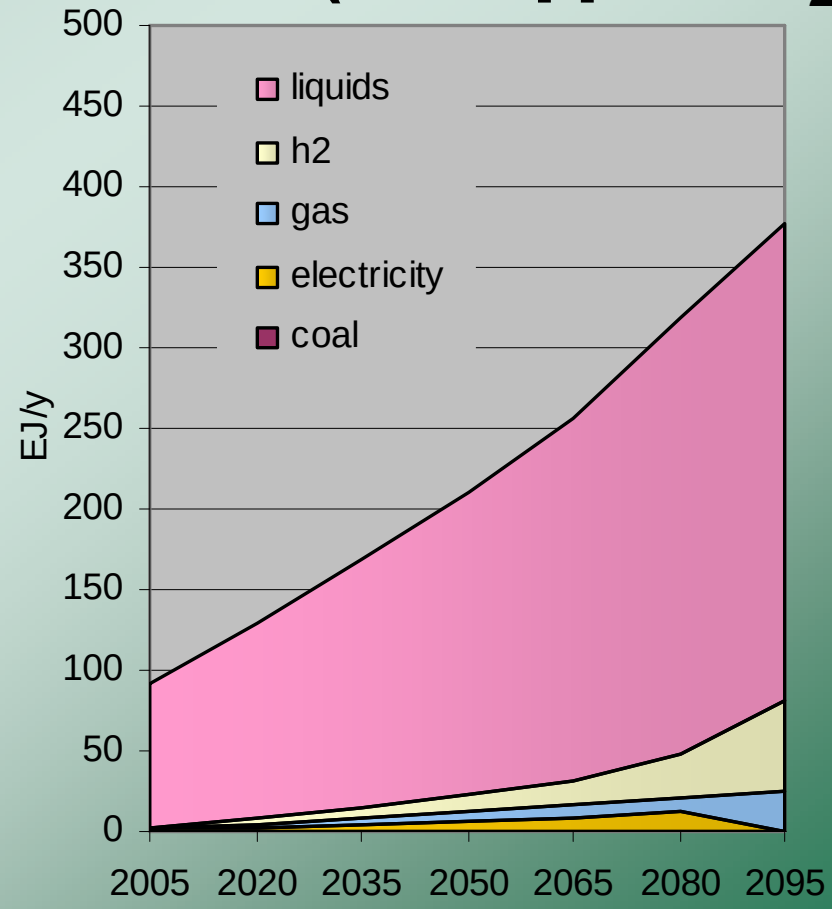

Global Liquids Supply

Stabilization in this scenario reduces shale oil production, eliminates coal liquefaction and promotes bioenergy.

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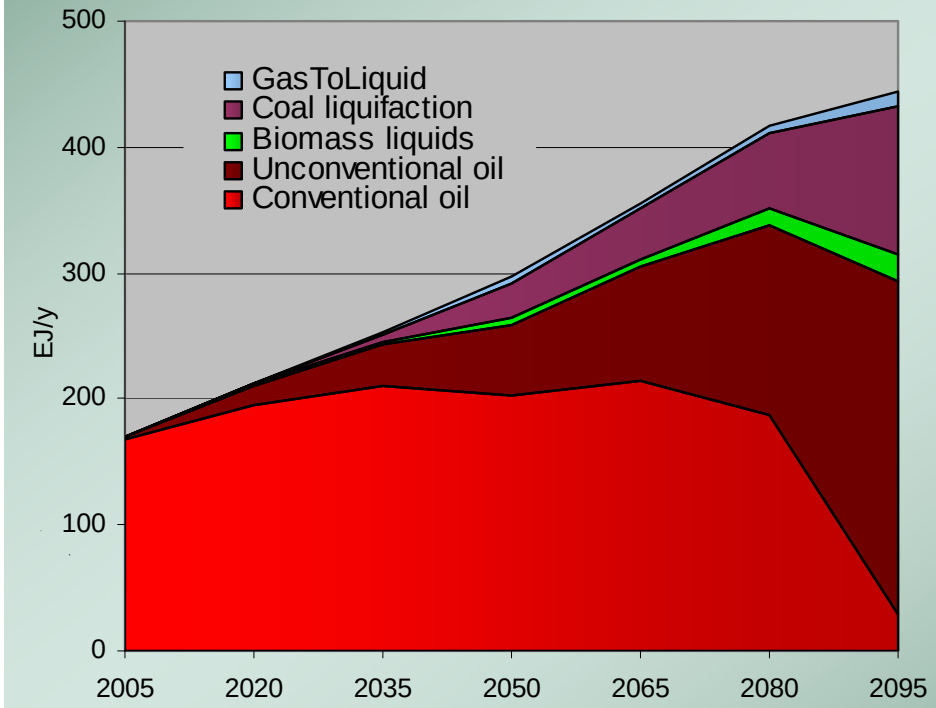

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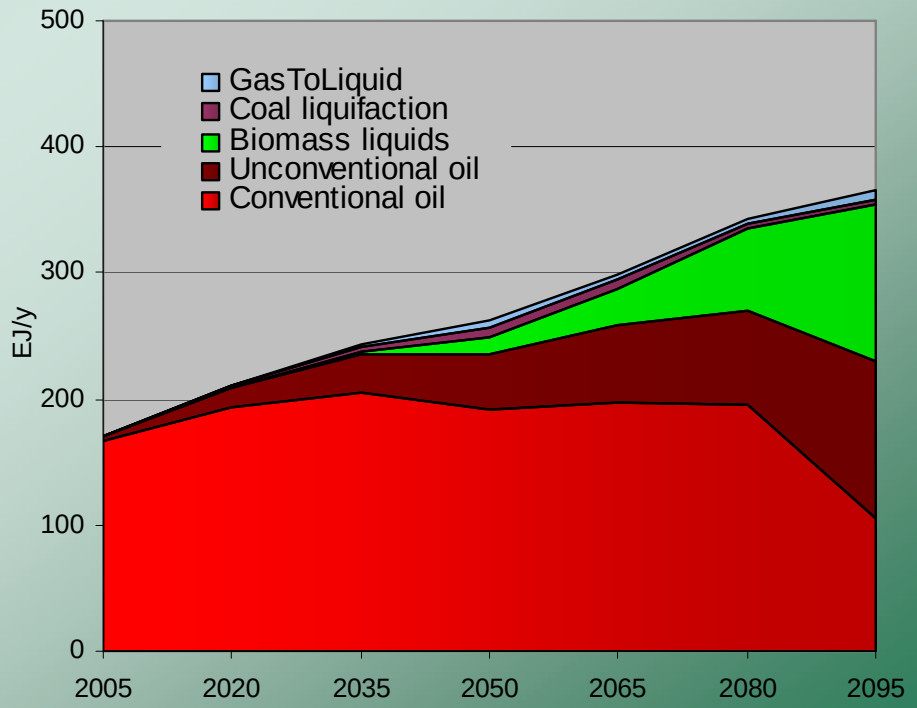
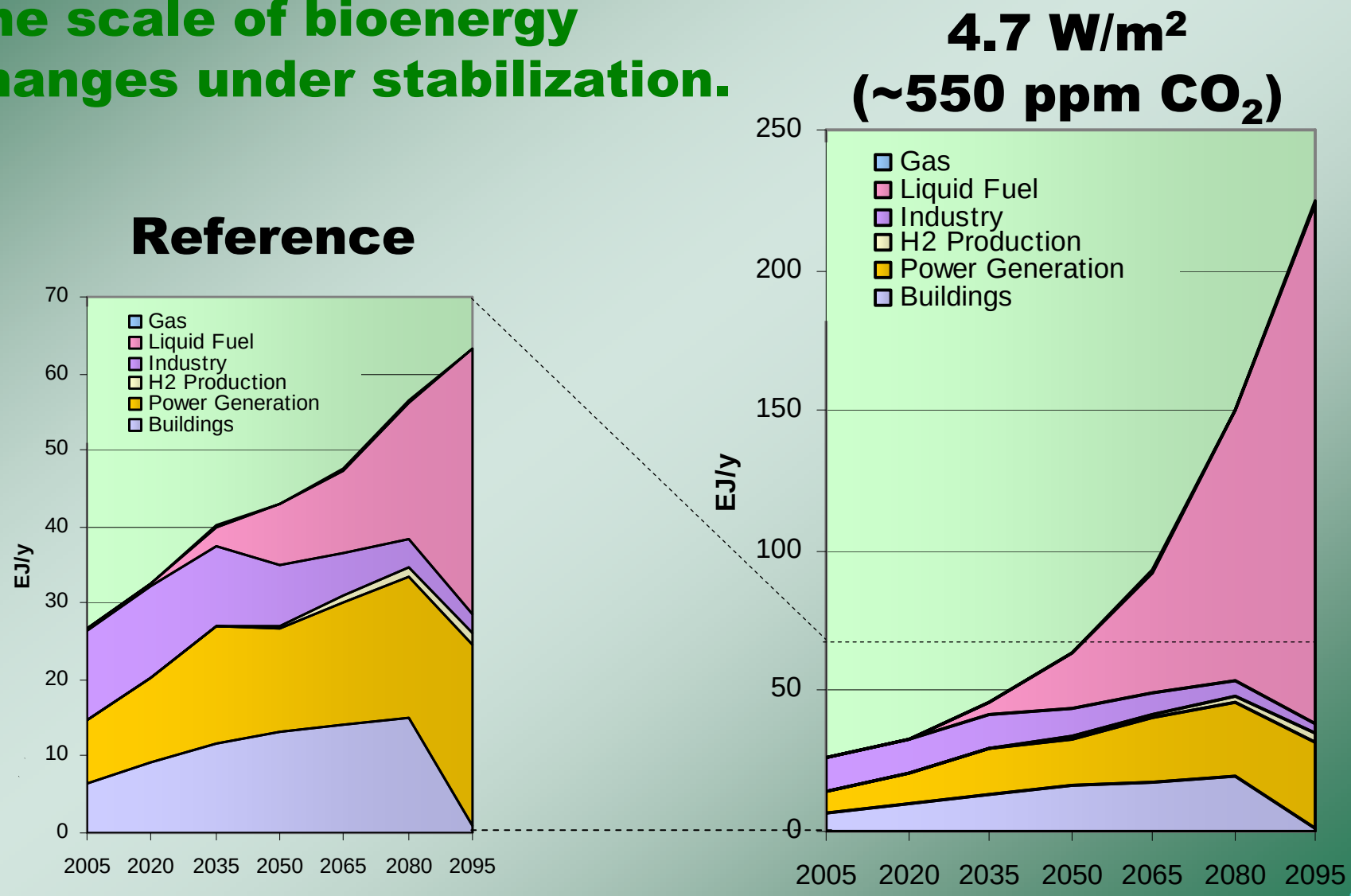
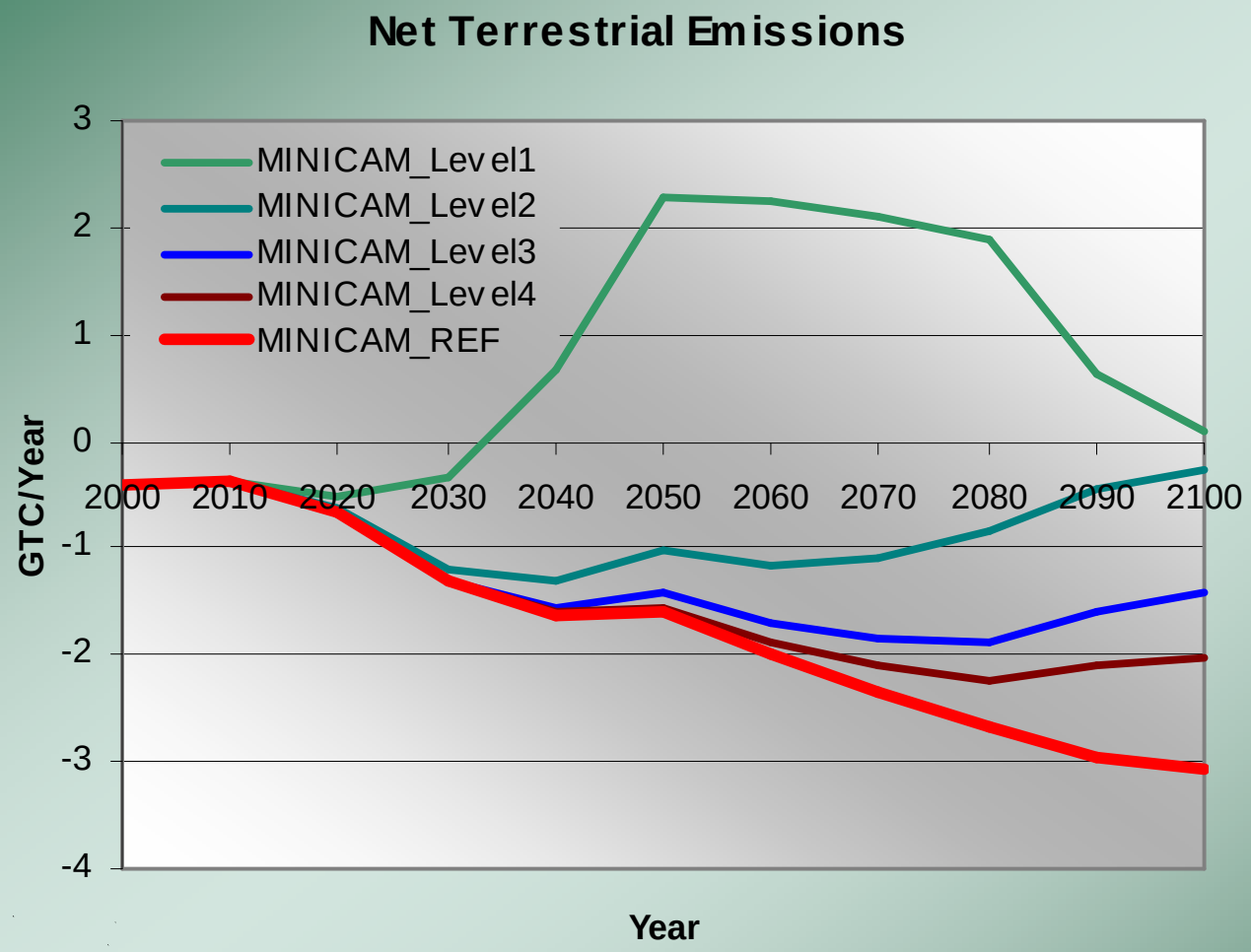


Bioenergy Consumption—Global

The scale of bioenergy changes under stabilization.



Implications for Agriculture & Land Use



- Land-use change emissions are accelerated by the imposition of a limit on fossil fuel CO_2.
- Terrestrial carbon is not valued in these scenarios.
- Implication: the valuation of terrestrial carbon is not independent of the valuation of carbon in fossil fuels.

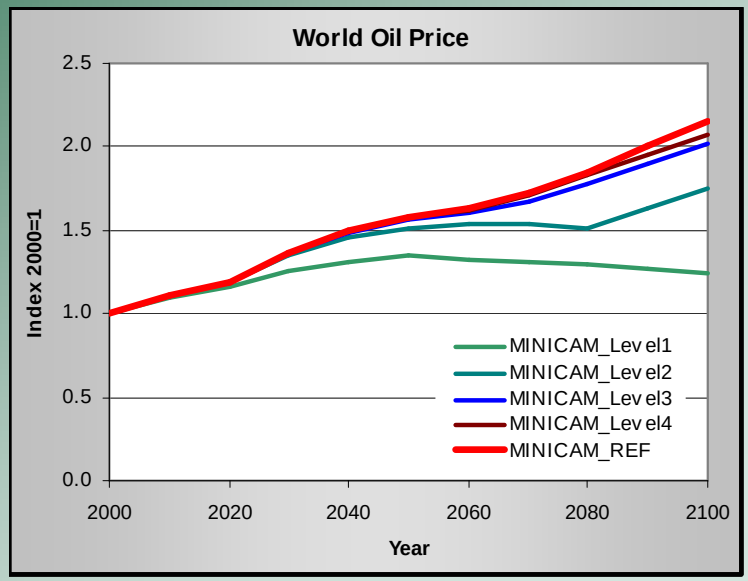
The Value of Carbon

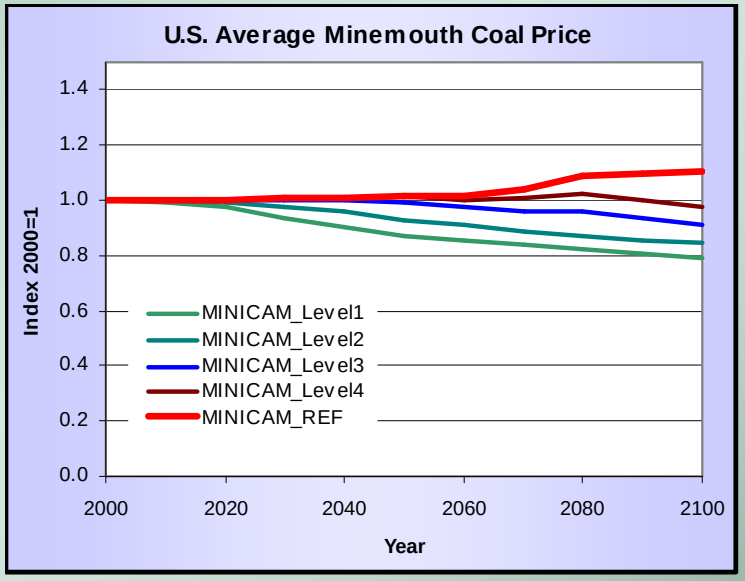
Value of Carbon in $2000/tonneC

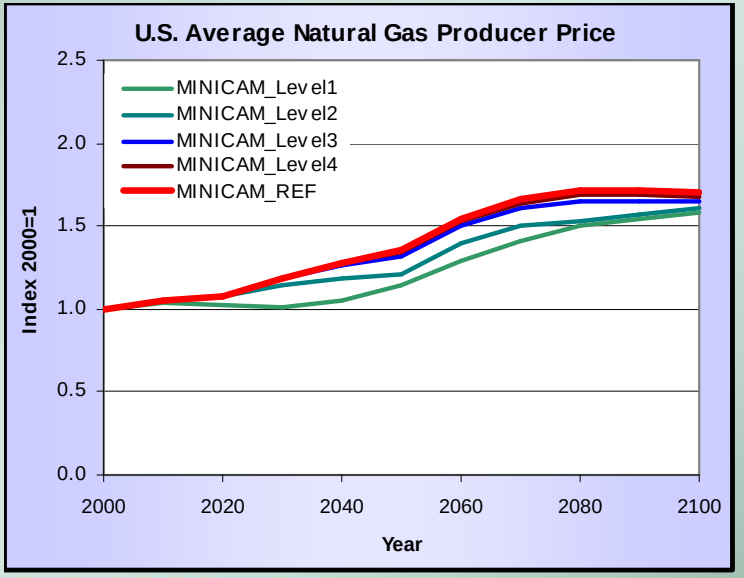
Stabilization Level	Year 2050	Year 2100
450	$500	$800
550	$150	$350
650	$50	$200
750	$10	$150

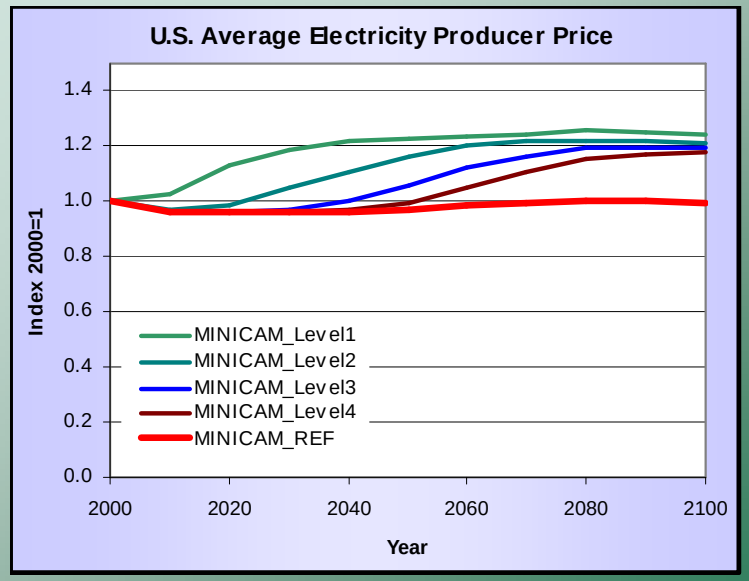
- There is substantial variability between scenarios and models regarding the potential value of carbon.
- These numbers assume perfect when and where flexibility; they may substantially underestimate the economic implications that might be associated with real-world policies.

Effect of stabilization on producer prices









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**

Summary

- MiniCAM is a century-scale energy-economy-agriculture-land-use IAM.

- A scenario was presented based on MiniCAM:
  - Ample fossil alternatives to conventional oil are available;
  - Stabilization requires differential treatment of different sectors – decarbonization of electricity proceeds more quickly than transportation;
  - Substantial use of bioenergy as an alternative transportation fuel raises important issues regarding the valuation of terrestrial carbon stocks.

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END