Battelle
The Business of Innovation

Energy Implications of Stabilizing Greenhouse Gas Concentrations

Jae Edmonds
Joint Global Change Research Institute

March 12, 2007

Office of Science

PNNL-SA-51961

GTSP
Global Energy Technology Strategy Program

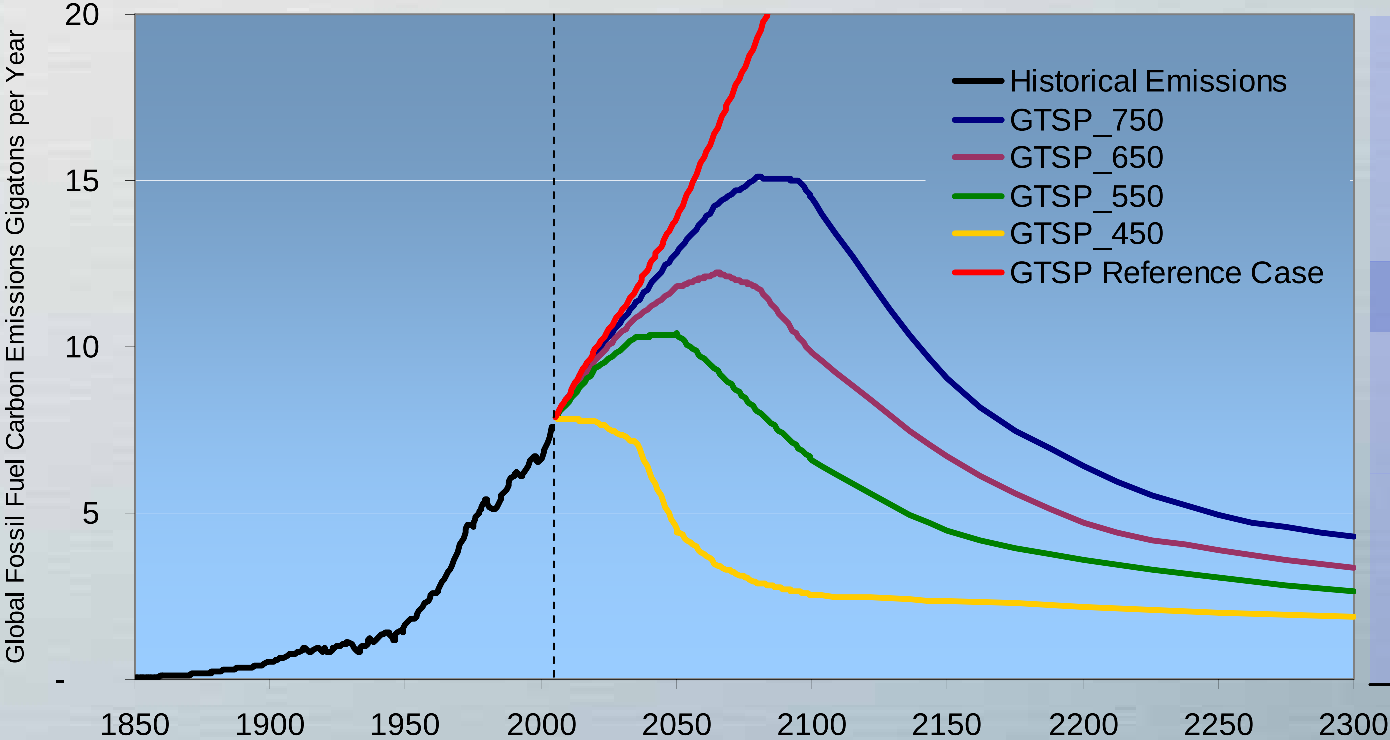
GTSP
Global Energy Technology Strategy Program

Acknowledgements

- Thanks to RITE and to IIASA for the opportunity to participate.
- Thanks to the sponsors of the Global Energy Technology Strategy Program (GTSP) for research support.
- Particularly, the U.S. Department of Energy's Office of Science.

Office of Science

Climate change is a long-term strategic problem with implications for today

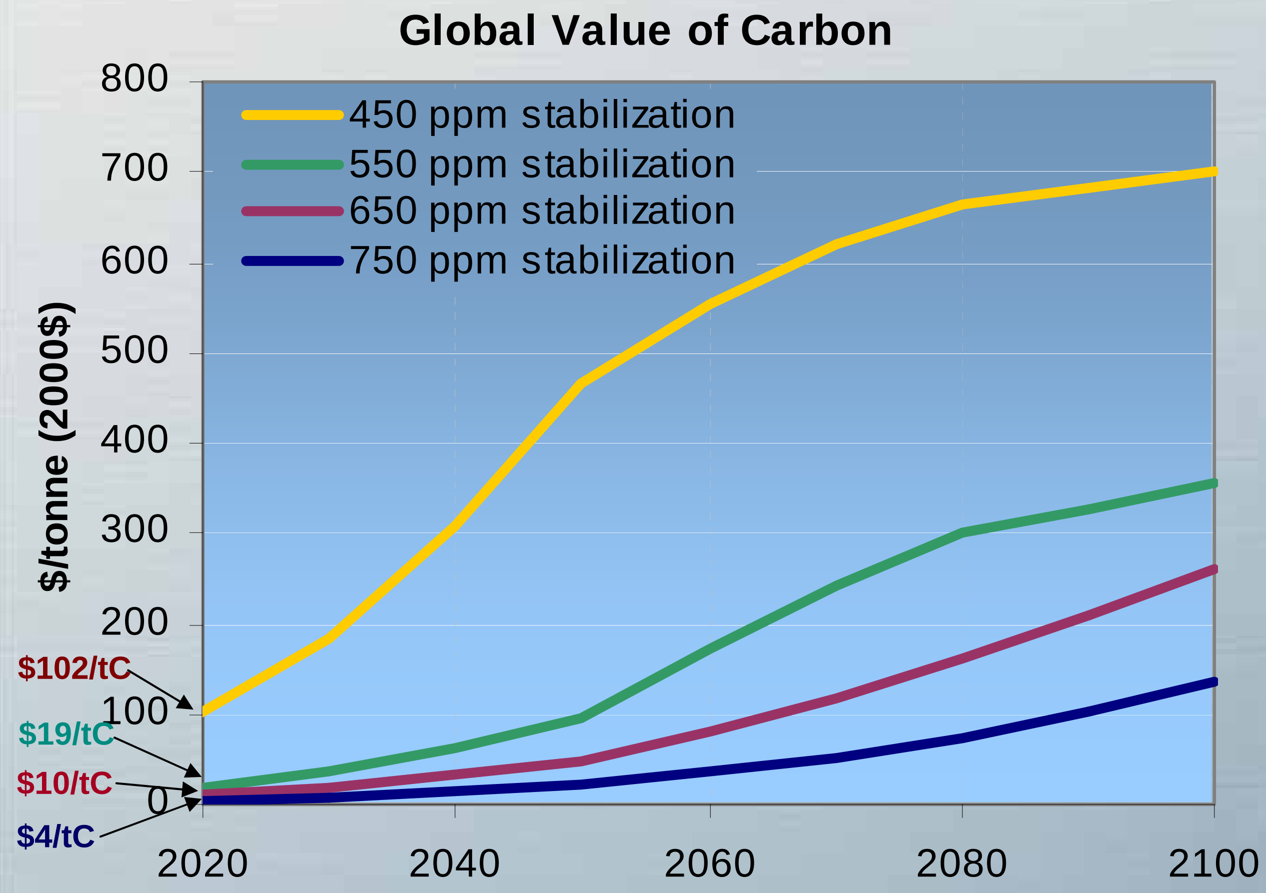


Fossil Fuel Carbon Emissions
Historic & 2005 to 2100

1750-2005	300 GtC
GTSP Ref	**1430 GtC**
750 ppm	**1200 GtC**
650 ppm	**1040 GtC**
550 ppm	**862 GtC**
450 ppm	**480 GtC**

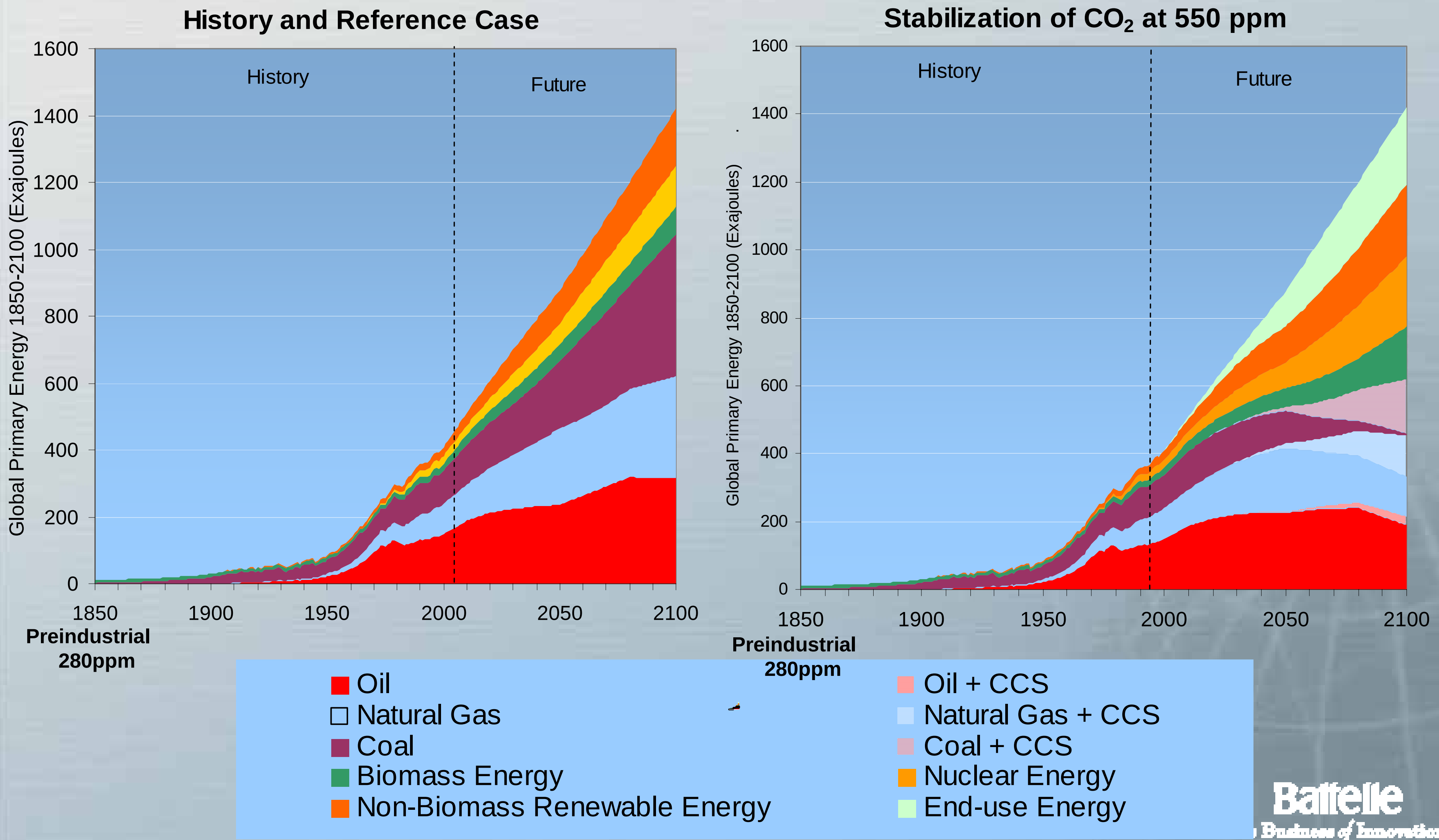
- Stabilization of greenhouse gas **concentrations** is the goal of the Framework Convention on Climate Change.
- Stabilizing CO_2 **concentrations** at any level means that **global**, CO_2 emissions must peak and then decline forever.

A global commitment to stabilizing CO_2 concentrations requires a carbon price that escalates over time



- Price of carbon should start low and rise steadily to minimize society's costs.
- Eventually all nations and economic sectors need to be covered as the atmosphere is indifferent as to the source of CO_2 emissions.
- The response to this escalating price of carbon will vary across economic sectors and regions.

Stabilization of CO_2 concentrations means fundamental change to the global energy system

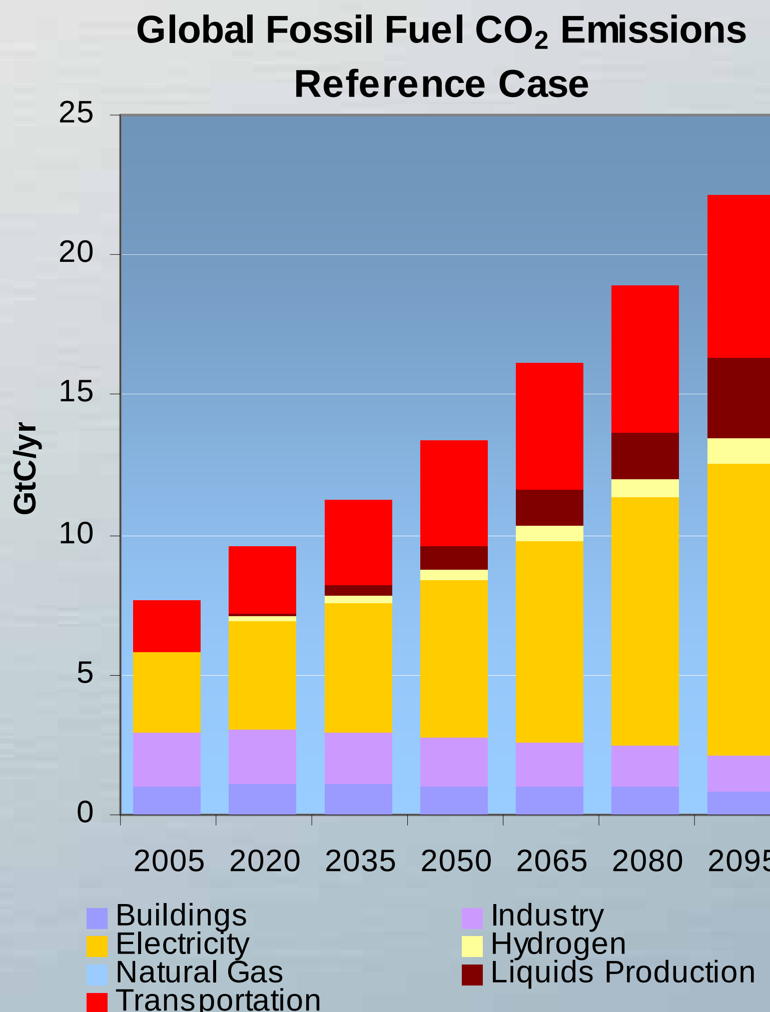


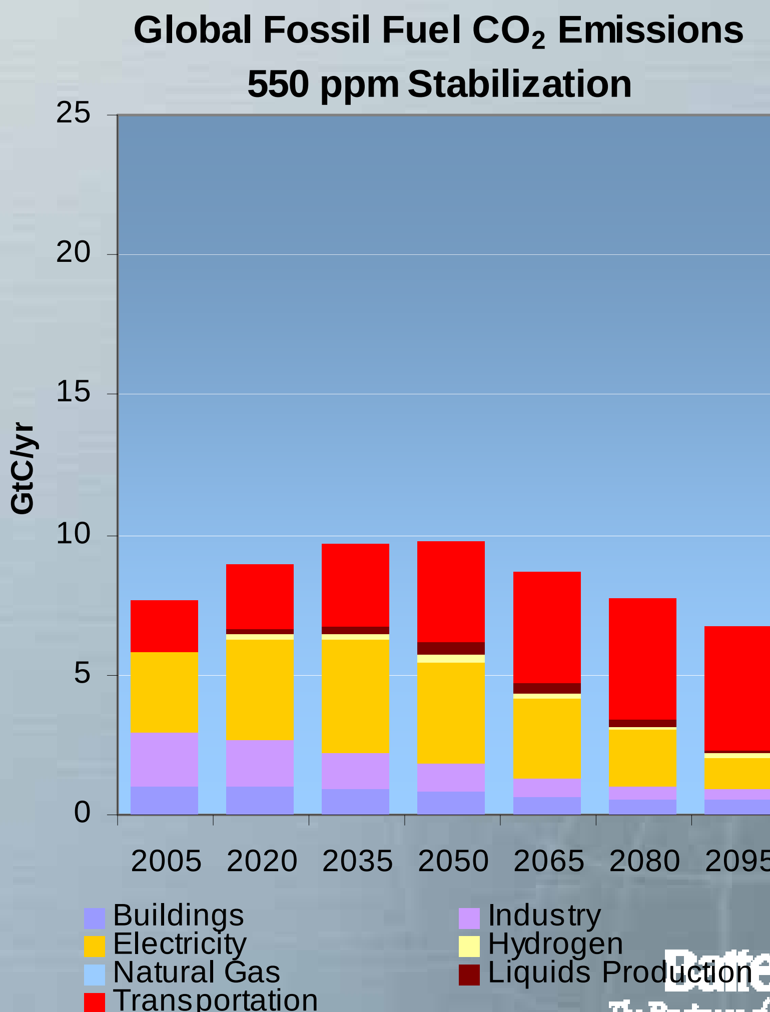
GTSP Global Energy Technology Strategy Program

Battelle The Business of Innovation

The response to this escalating price of carbon will vary across economic sectors and regions.

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

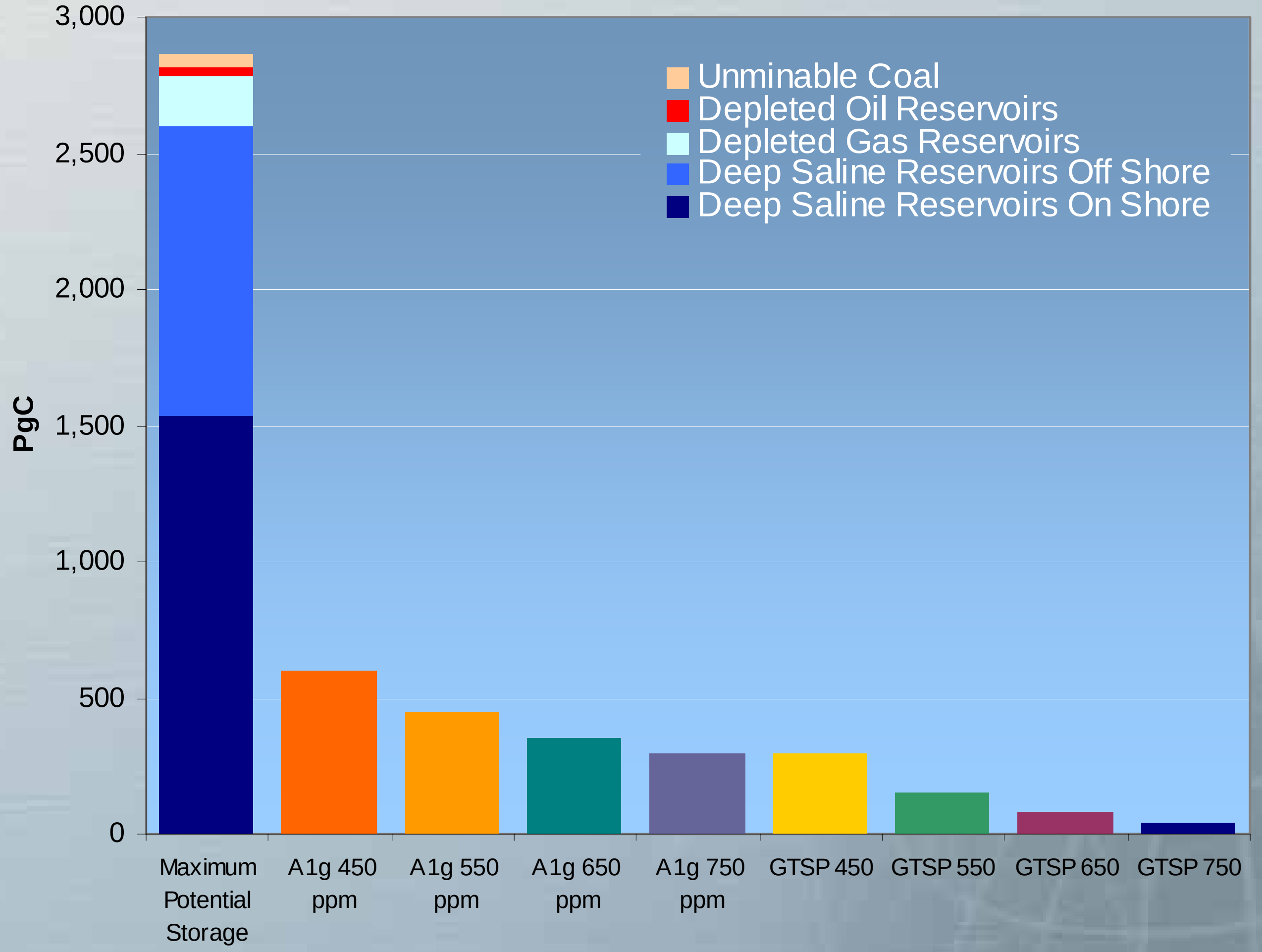




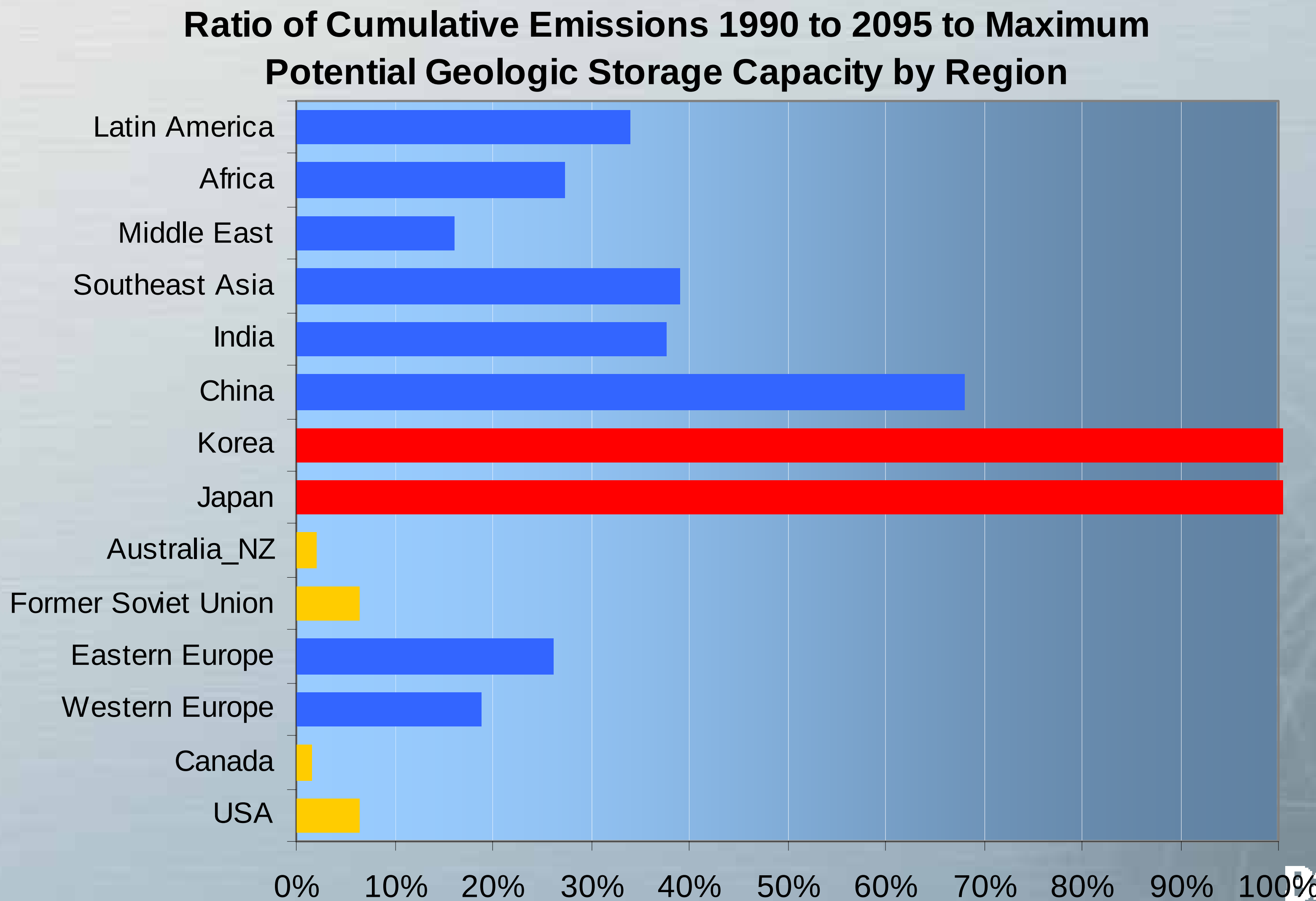
CO_2 Capture and Storage

Projection of CO_2 Storage Demand *Global 2000-2100*

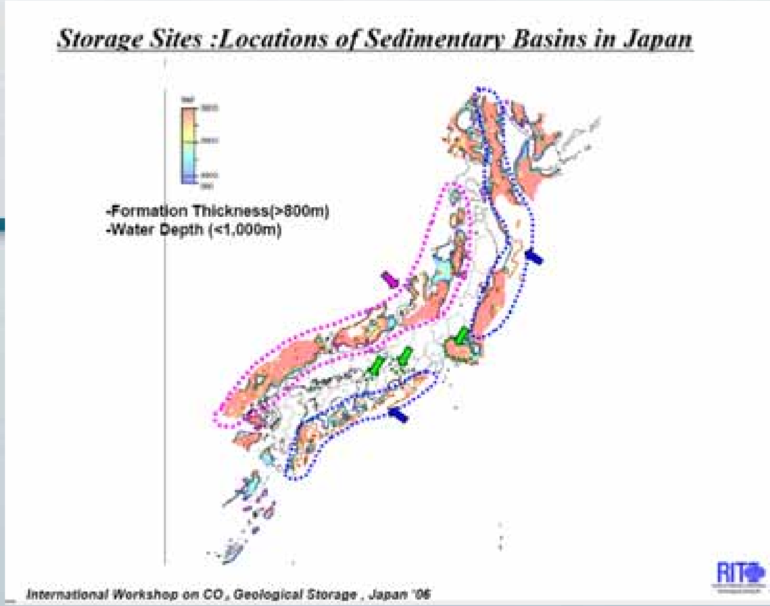
- For stabilization scenarios from 450-750ppmv, most integrated assessment models show a demand for no more than 600 GtC (2,220 $GtCO_2$) storage over the course of this century.
- Published estimates of potential storage capacity place the potential global geologic CO_2 storage capacity at approximately 3,000 GtC (11,000 $GtCO_2$).
- A broad portfolio of carbon management technologies will be needed to fulfill the UNFCCC stabilization goal.



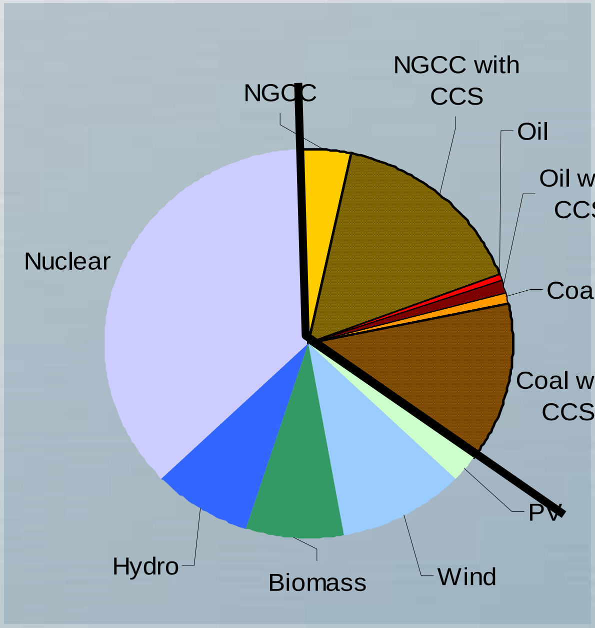
Potential geologic storage reservoirs are distributed heterogeneously



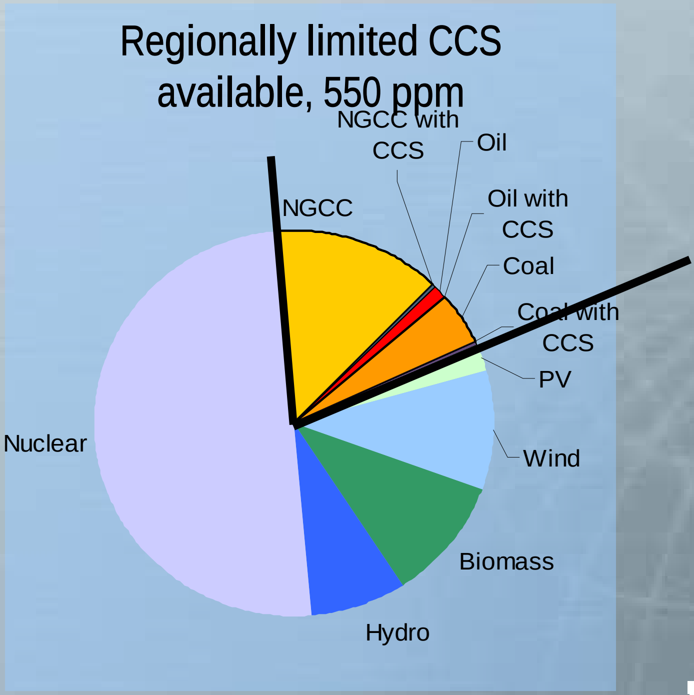
Japan: Is There Enough CO_2 Storage Capacity?



Composition of Power Generation in Japan, 2095



Regionally unlimited CCS assumed available, 550 ppm



Japan CO_2 Storage Capacity*

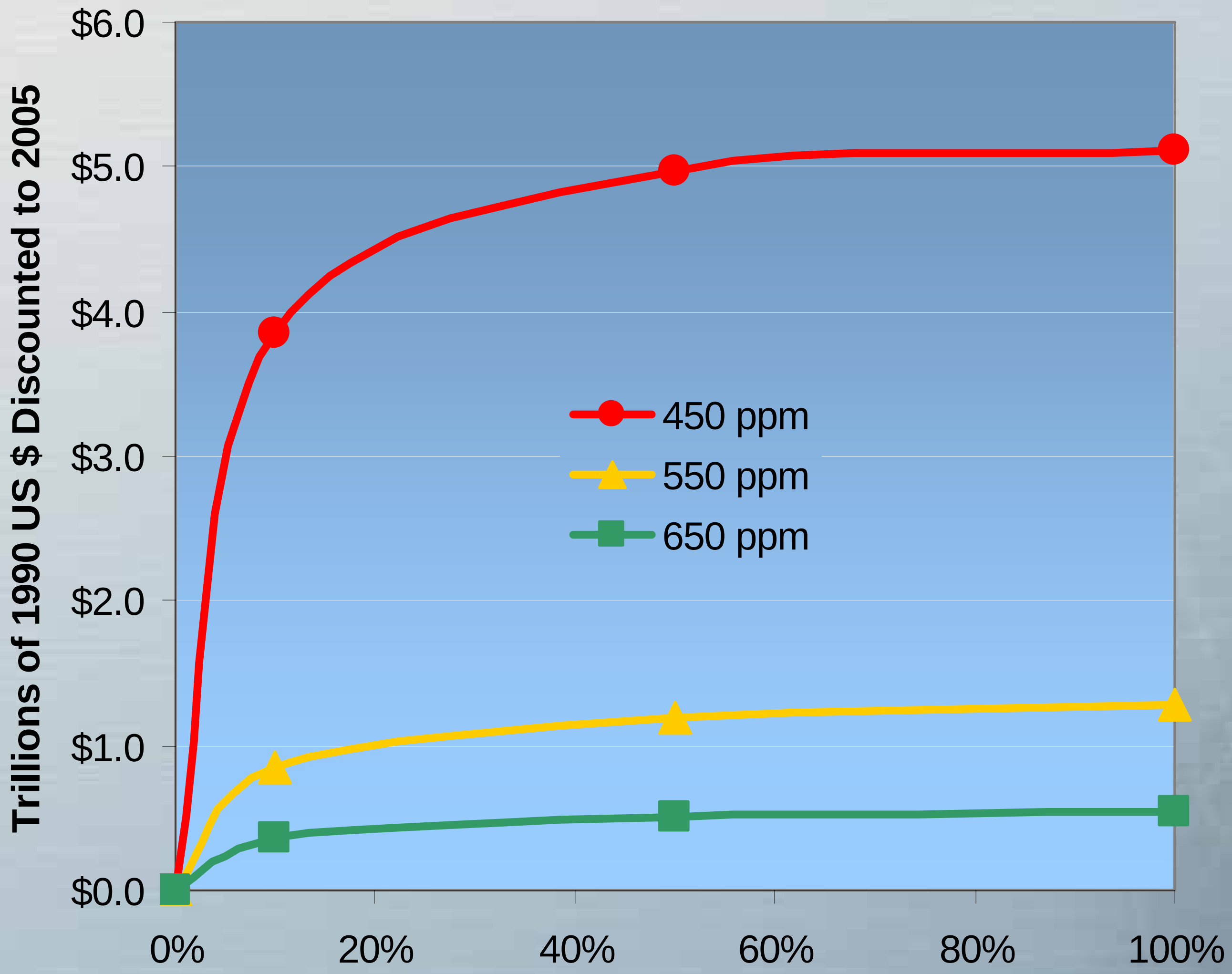
- Japan total onshore CO_2 storage capacity = 19.5 billion tonnes (Gt CO_2) (5.3 PgC).
- Japan total offshore capacity = 72 Gt CO_2 (20 PgC).

Target	CO_2 Storage Capacity* (Gt CO_2)
Onshore Oil and Gas	2
Onshore Deep Saline Anticlines	1.5
Onshore Deep Saline Monoclines	16
Offshore Deep Saline Monoclines	72

In 2003 - total annual Japanese CO_2 emissions were 1.2 Gt – 14% from Natural Gas (US-EIA estimate).

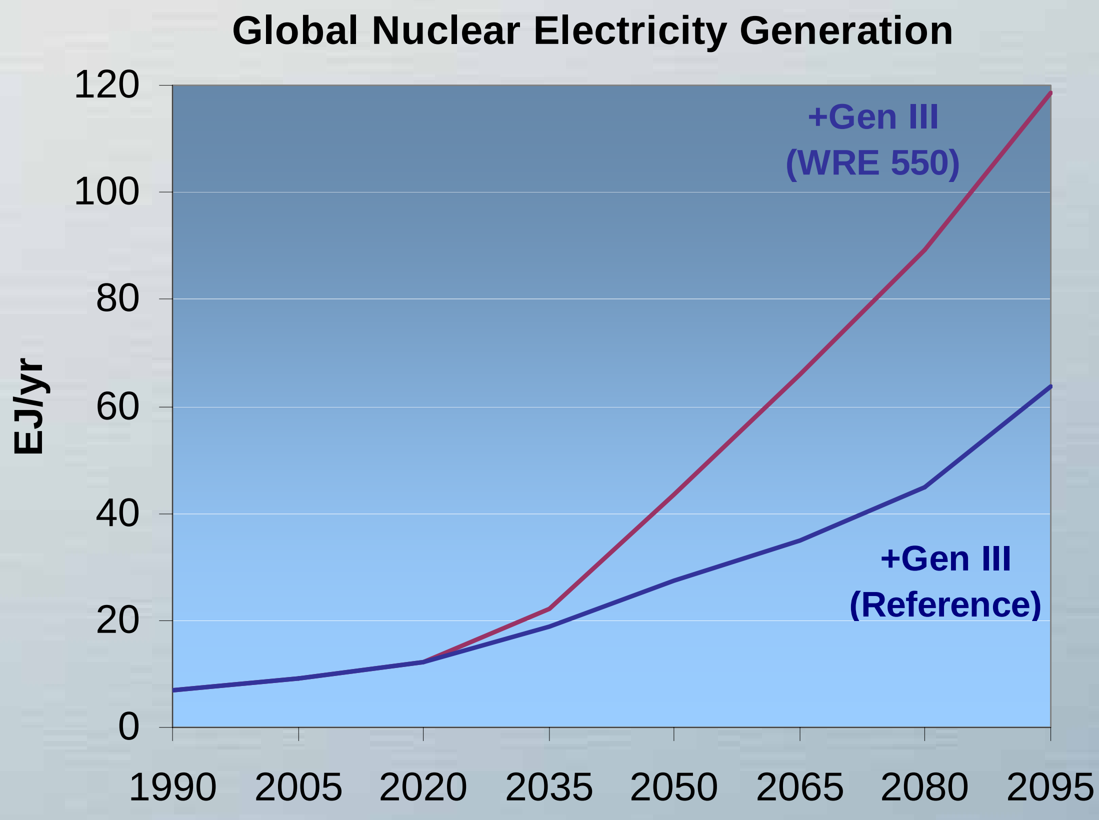
*Tanaka, S, Koide, H., and Sasagawa, A. 1995. Possibility of underground CO_2 storage in Japan. Energy Convers. Mgmt., 36(6-9): 527-530. [Note: the estimates in this report are unconfirmed]

Even if potential storage is limited, there is substantial economic value in deploying CCS



Nuclear energy

Climate policy accelerates the expansion of the market for nuclear power…



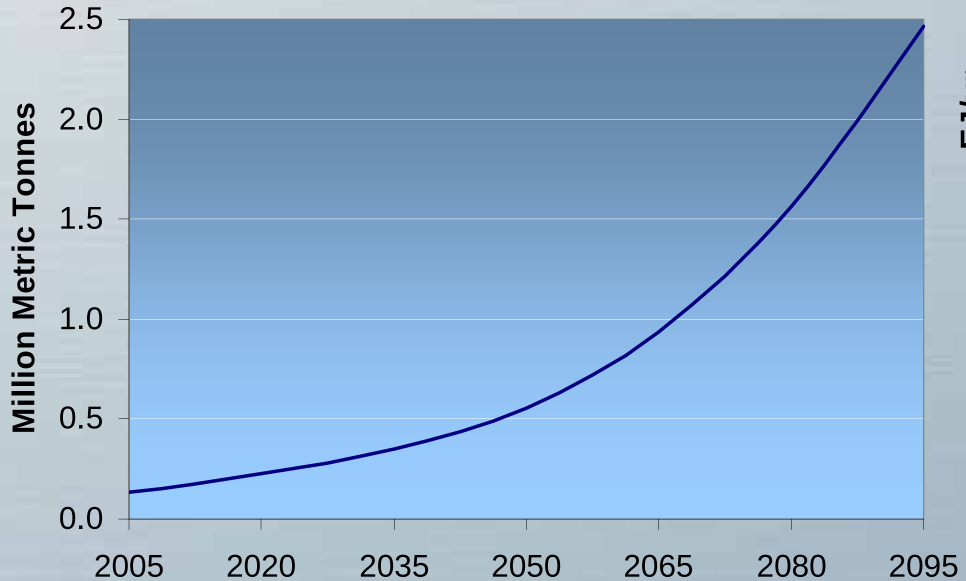
- Regardless of whether there is a global climate policy that seeks to stabilize atmospheric concentrations of greenhouse gases, nuclear energy is already an important energy supplier and is expected to continue to expand throughout this century.
- The market for nuclear power to generate hydrogen for the transportation sector is a small portion of the market for electricity.

Issues that while difficult to quantitatively model, might impact the projected growth of nuclear power in the 21st century.

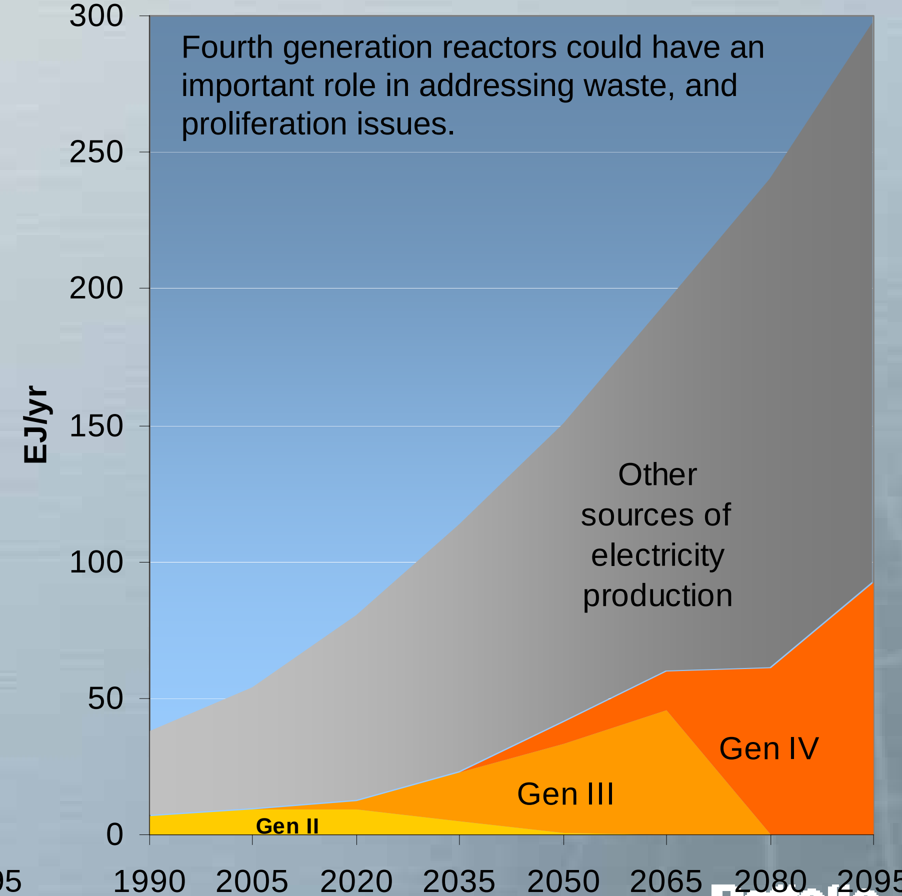
GTSP
Global Energy Technology Strategy Program

- Public policies designed to address proliferation concerns
- Inability to deal with nuclear waste

Global Nuclear Spent Fuel Waste Third Generation Reactors Under a 550 ppm Stabilization Scenario



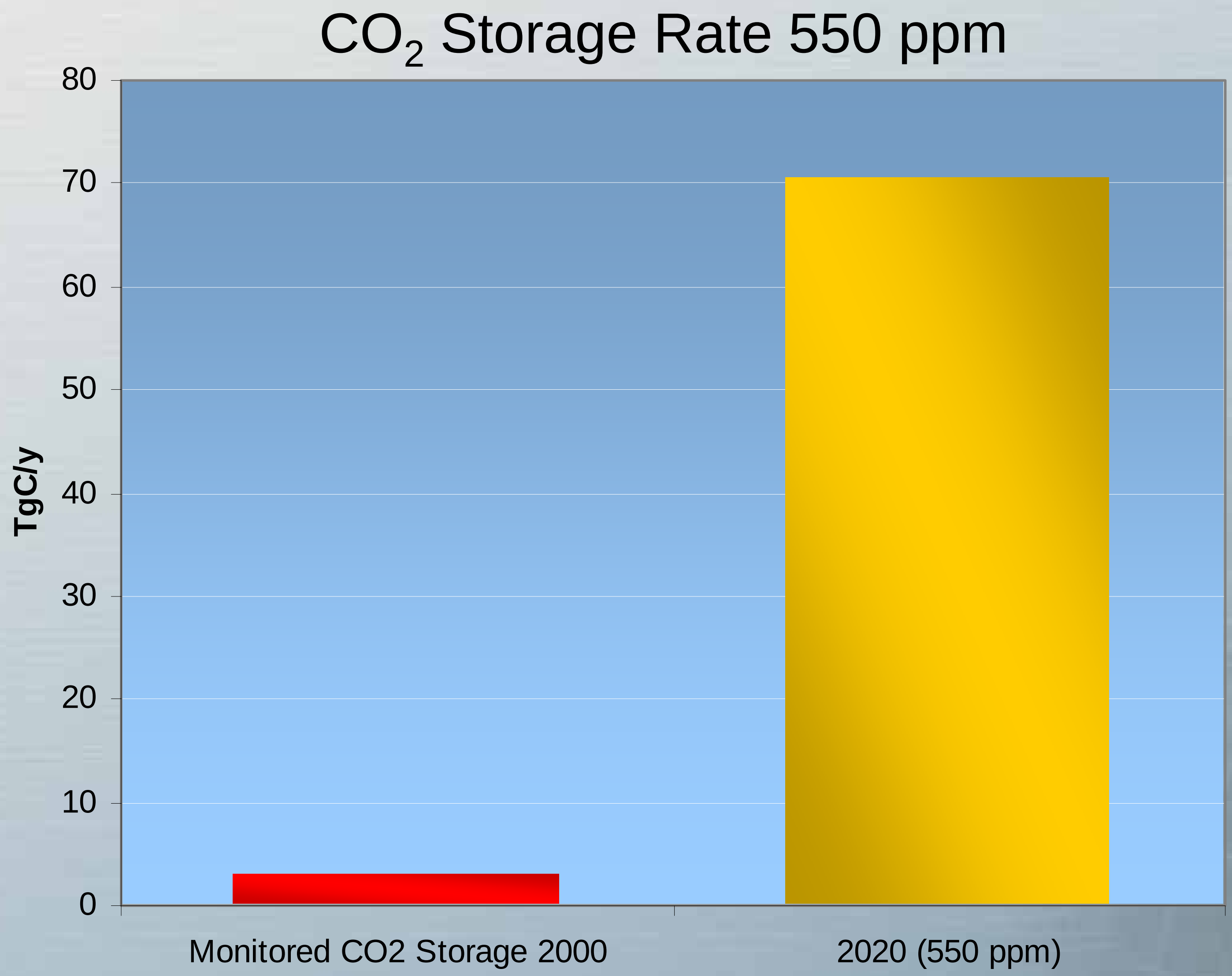
Nuclear Power Production by Technology 550 ppm Stabiilization Scenario



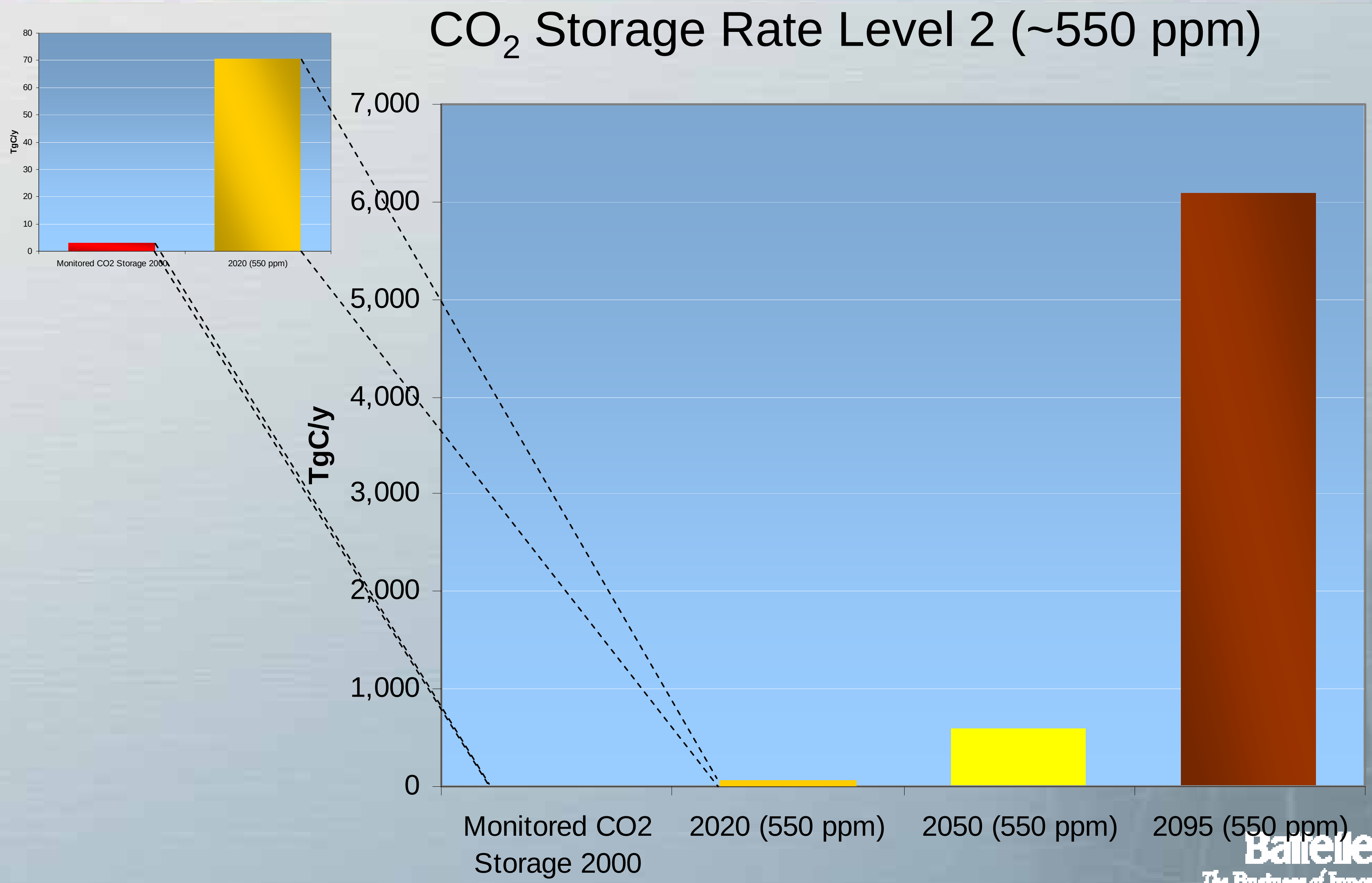
Battelle
The Business of Innovation

The challenge of scale

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



In the long-term the challenge grows

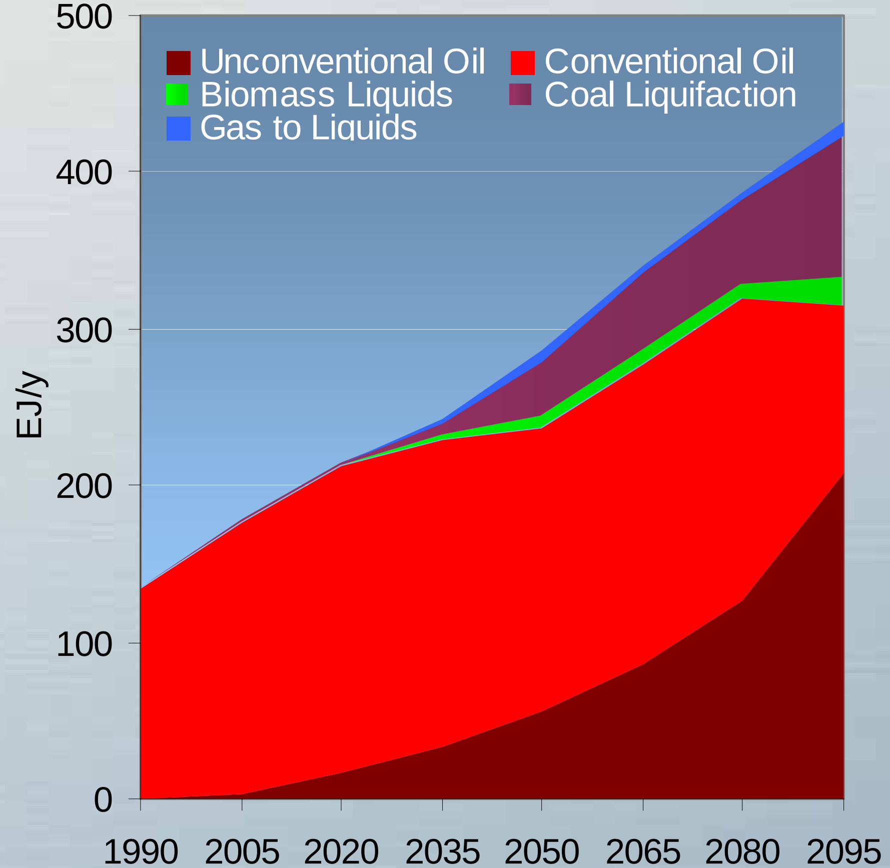


Bioenergy and Land use

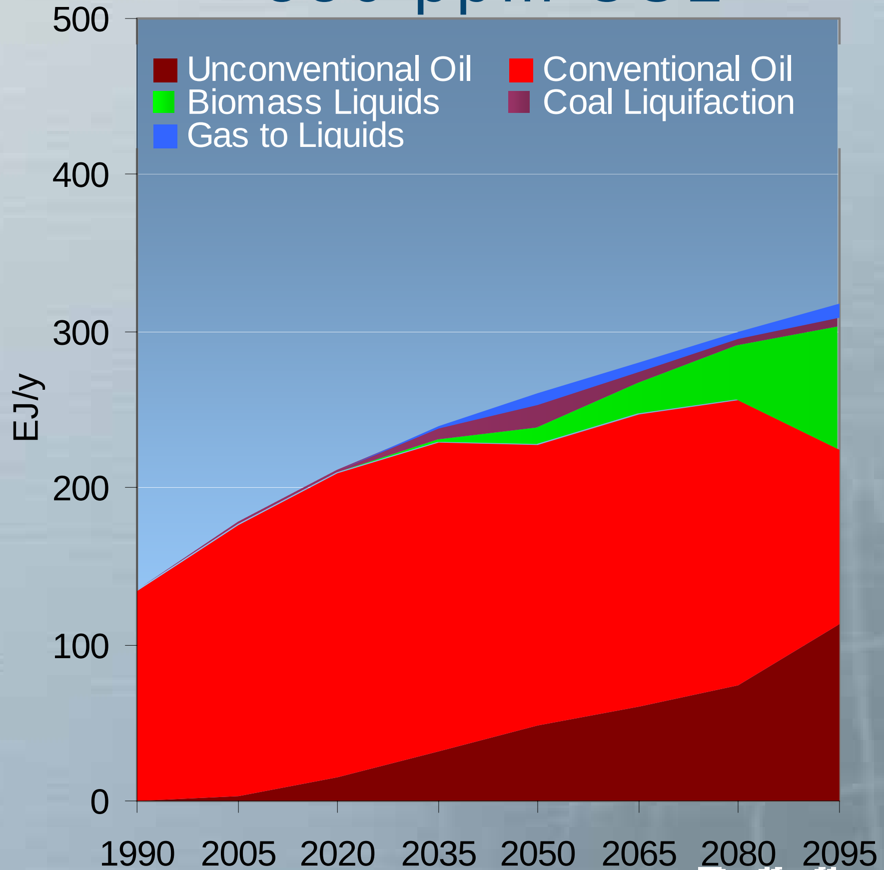
Oil Supply—Global

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

Reference



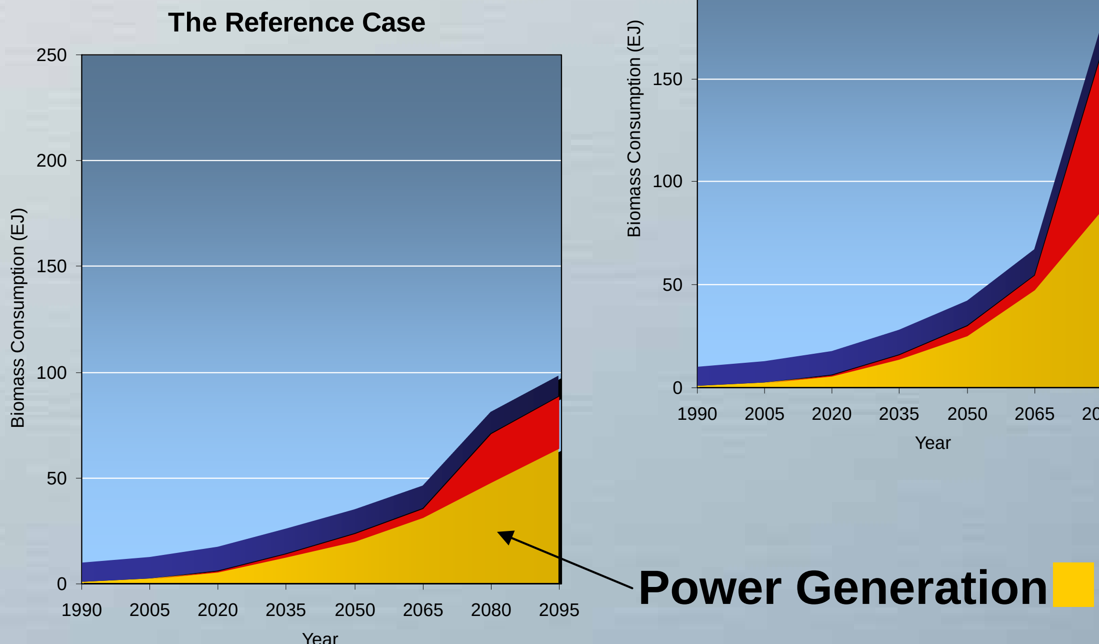
550 ppm CO2

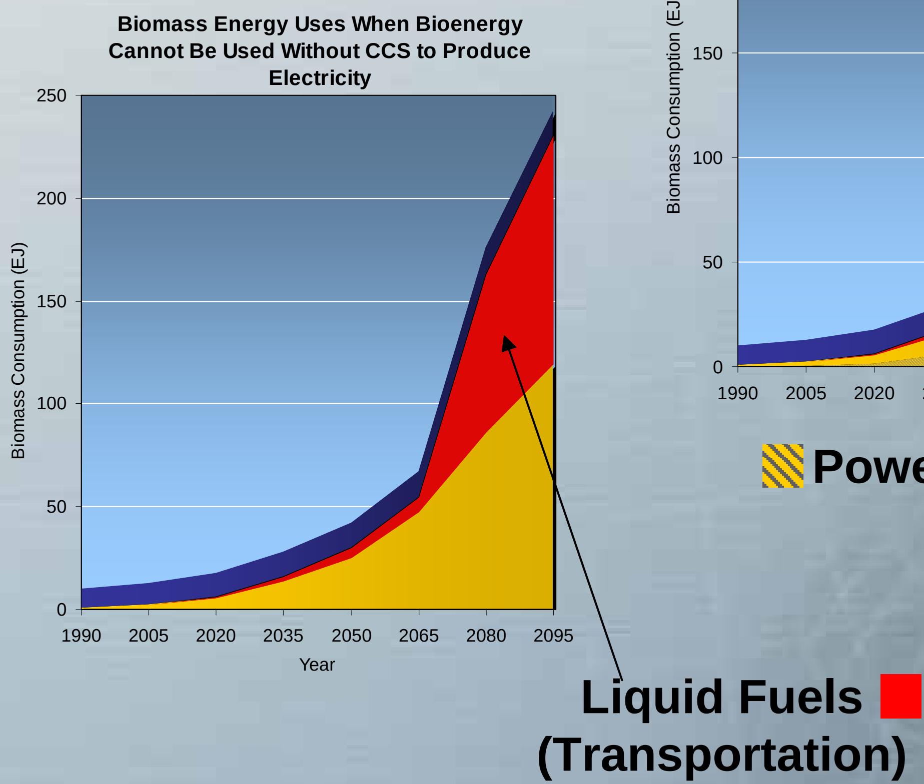


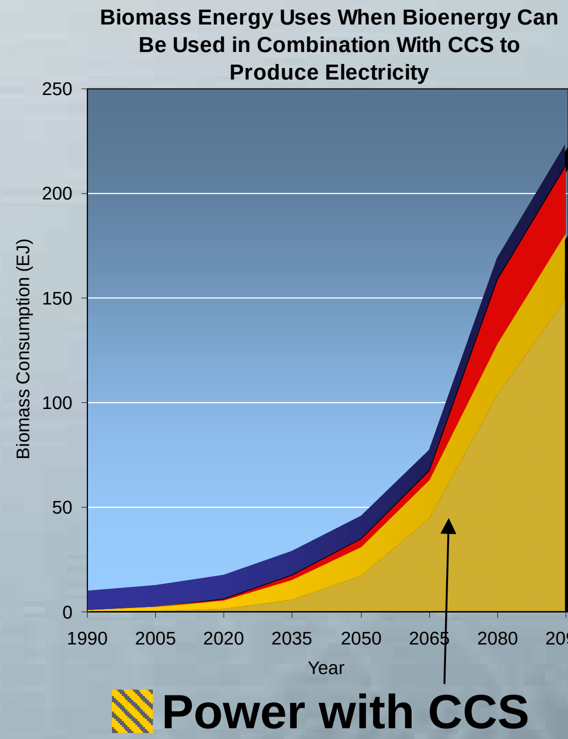
Battelle
The Business of Innovation

The Flexible Role of Bioenergy

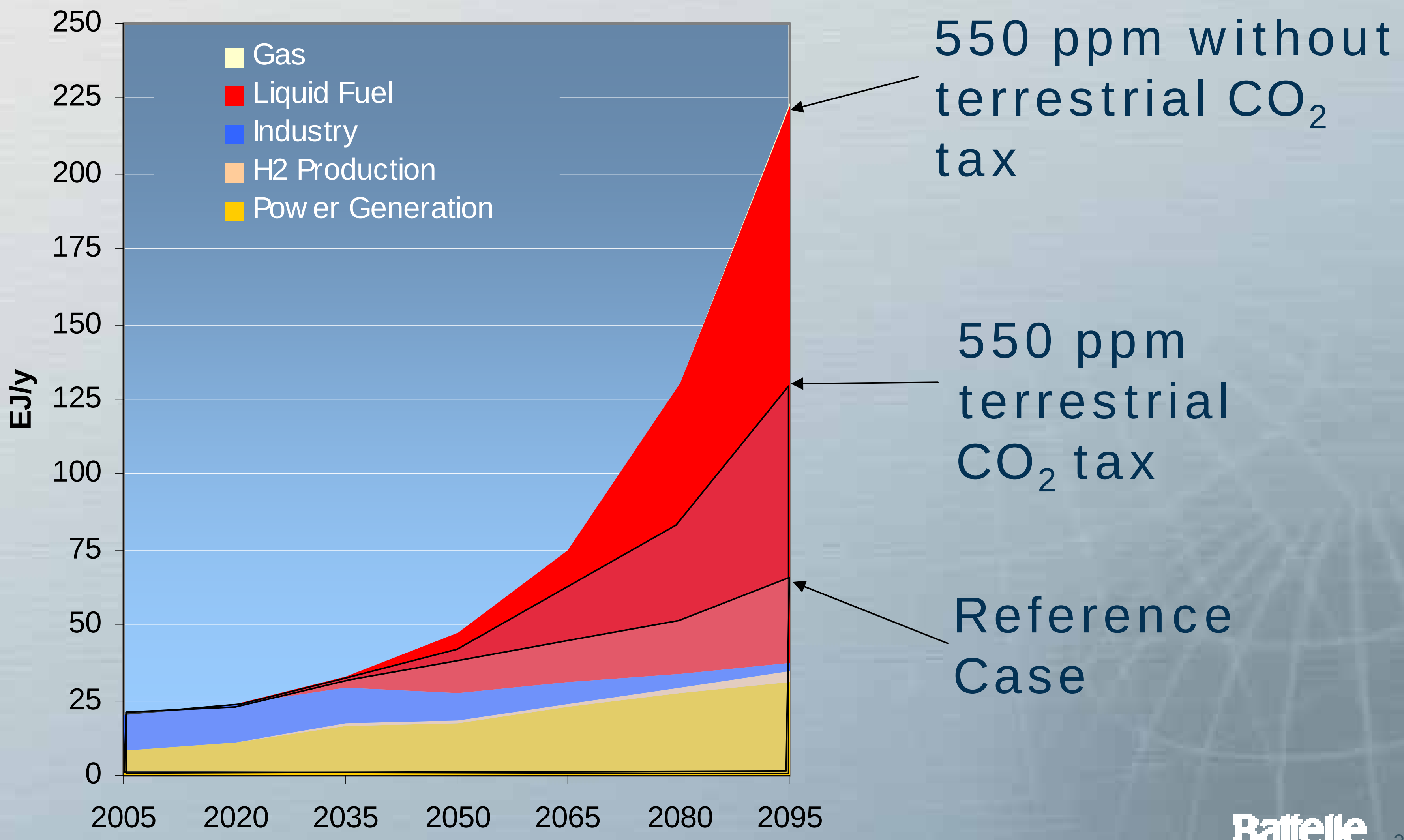
Reference and two 500 ppm stabilization scenarios



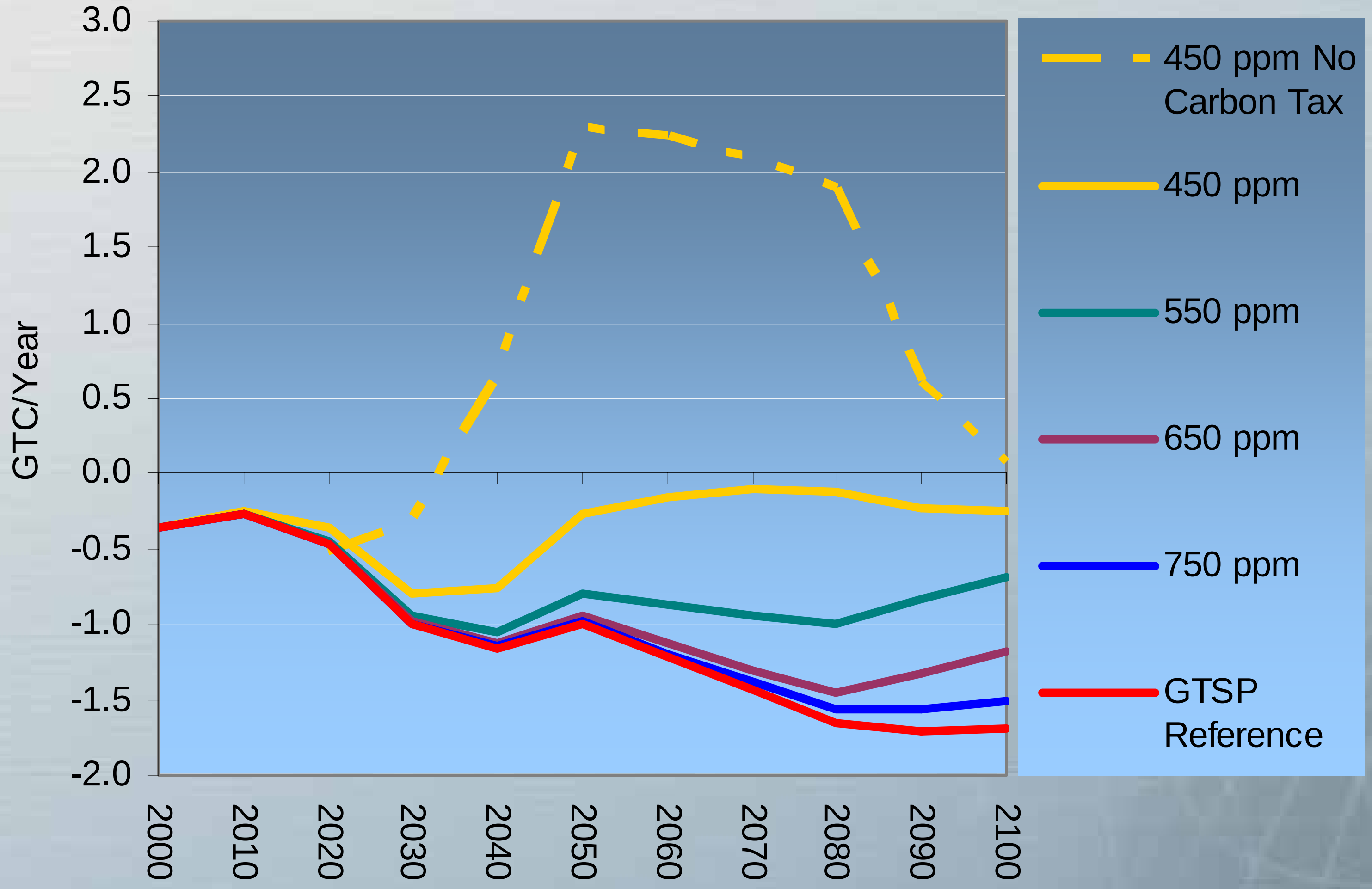




Commercial bioenergy with and without a value on terrestrial carbon



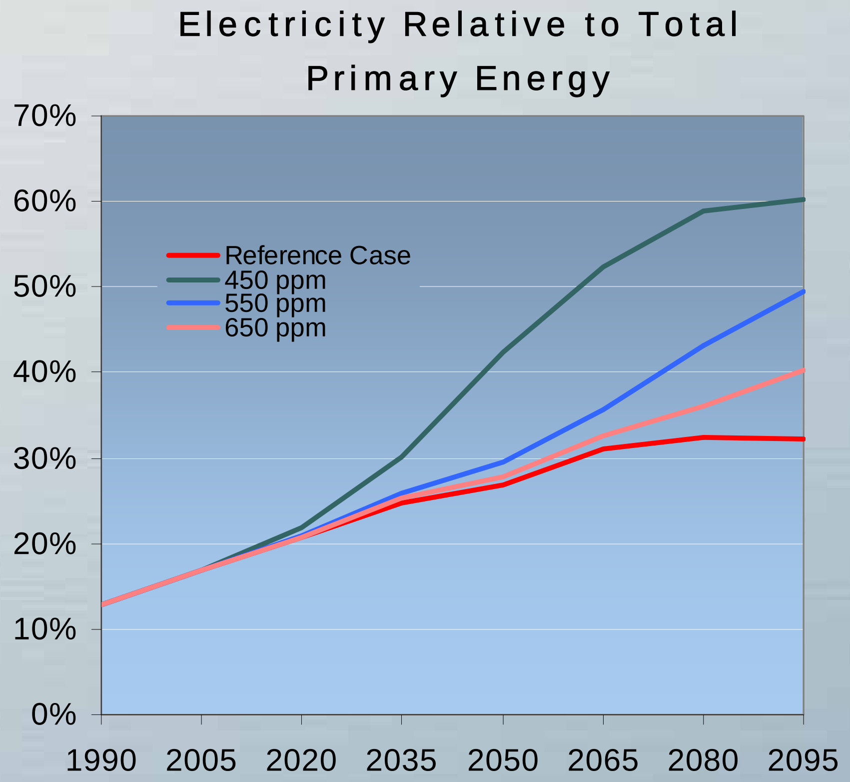
Carbon cycle implications of valuing terrestrial carbon emissions

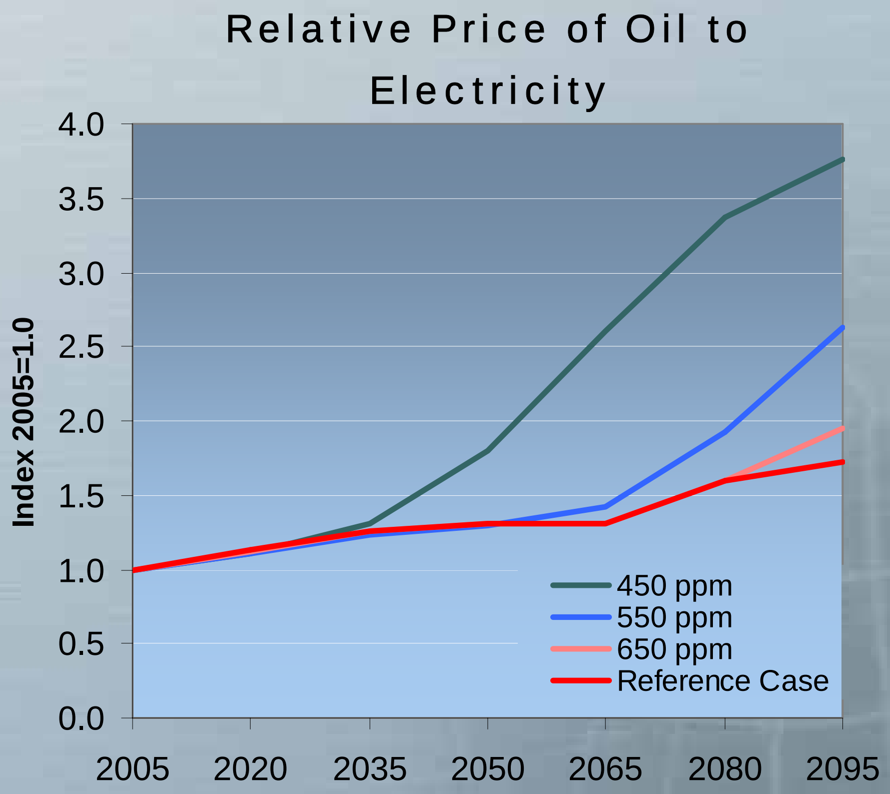


End use energy efficiency and fuel choice

Electrification

- The world is electrifying.
- Emissions mitigation increases the relative role of electricity.
- Electricity prices rise relatively less than fuel prices.

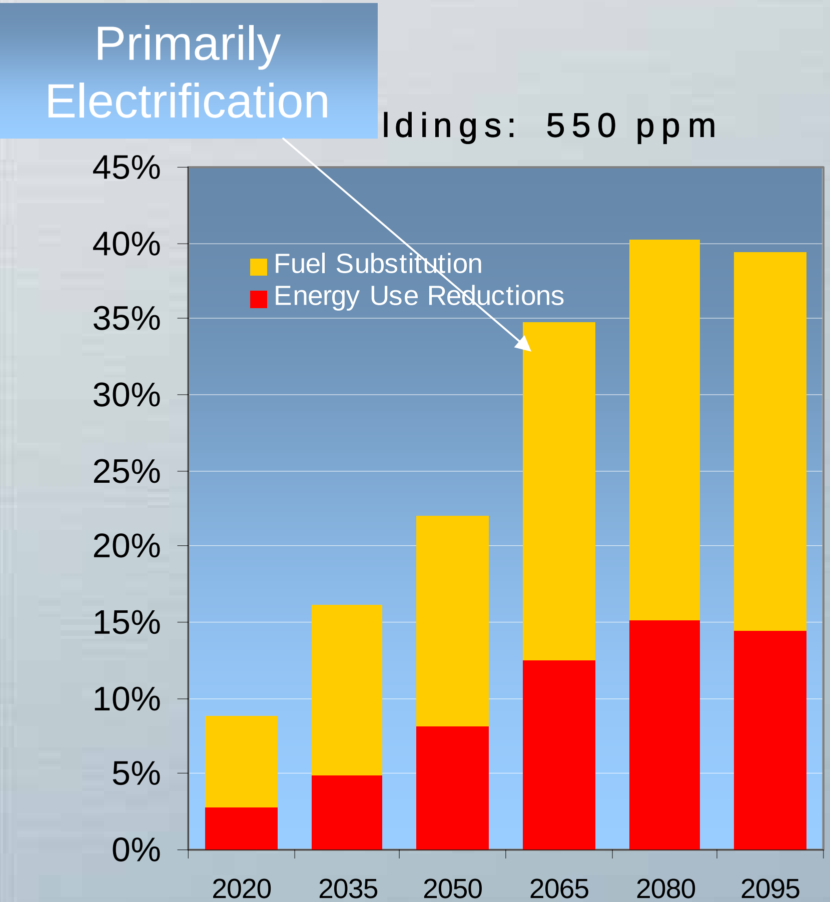


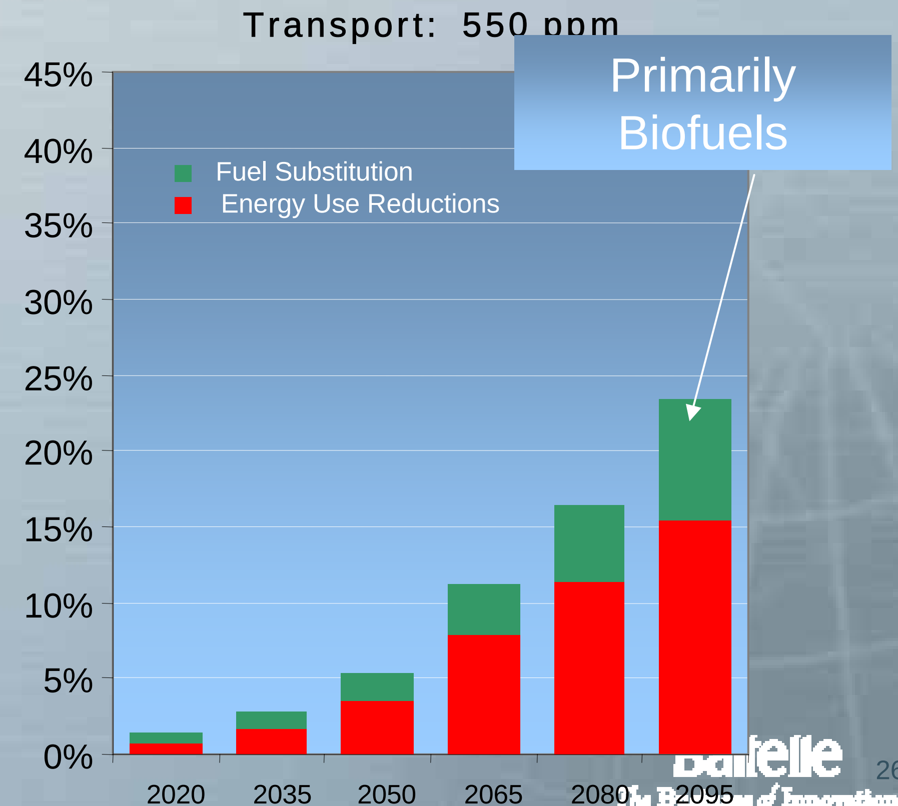


End-use Energy Technologies

- Three sectors
  - Buildings
  - Industry
  - Transportation

- Emissions reductions come from two sources
  - Energy efficiency improvements
  - Fuel substitution

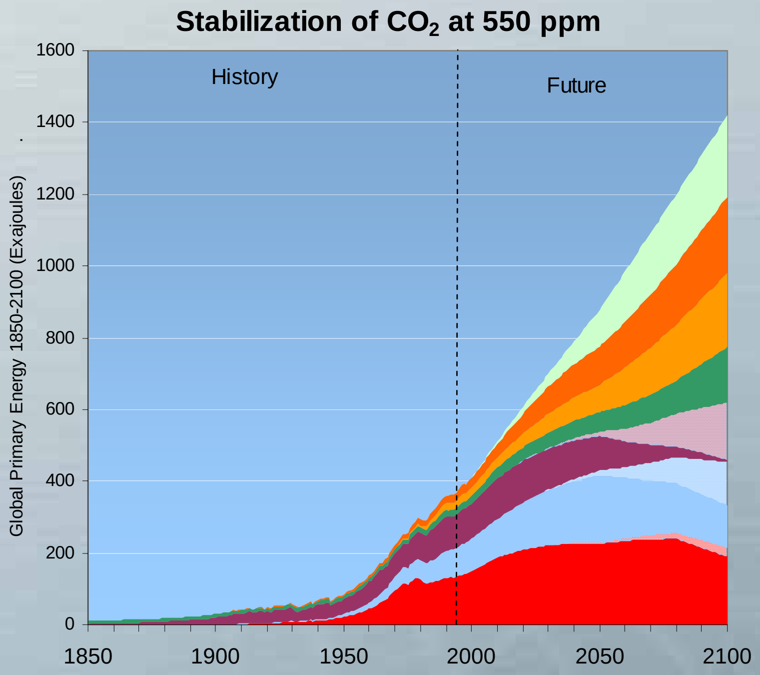




Stabilization of CO_2 concentrations means fundamental change to the global energy system

… but the character of the global energy system will depend on technology developments:

- CO_2 capture and storage (CCS) plays a potentially large role assuming that the institutions make adequate provision for its use.
- Biotechnology has dramatic potential, but important land-use implications.
- Hydrogen could be a major new energy carrier, but requires important technology advances in fuel cells and storage.
- Nuclear energy could deploy extensively throughout the world but public acceptance, institutional constraints, waste, safety and proliferation issues remain.



- Wind & solar could accelerate their expansion particularly if energy storage improves.
- End-use energy technologies that improve efficiency and/or use energy carriers with low emissions, e.g. electricity deploy more extensively.`

Battelle
The Business of Innovation

END