Long-Term Technological Options

Nebojsa Nakicenovic

International Institute for

Applied Systems Analysis (IIASA)

naki@iiasa.ac.at

UNFCCC Workshop on the IPCC Third Assessment Report

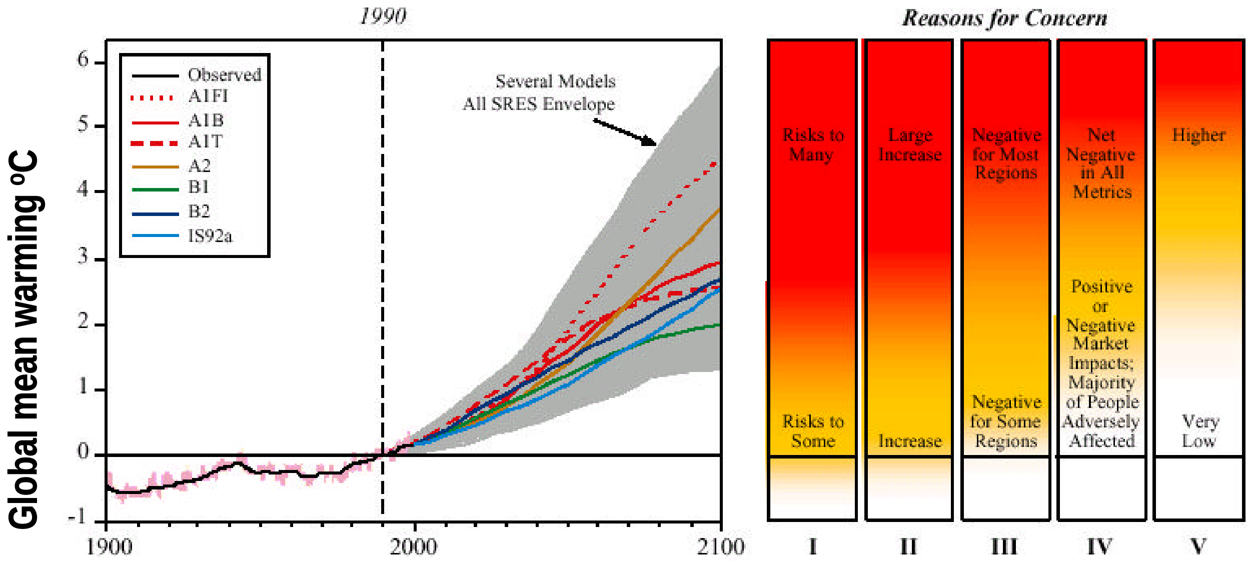
Wissenschaftszentrum Bonn, Germany – 4-6 April 2002

WMO

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

UNEP

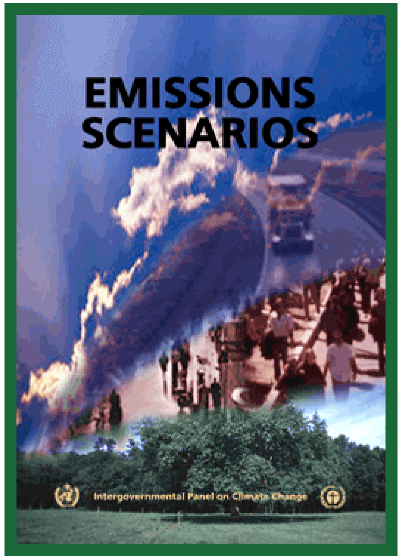
Comparing Reasons for Concern



Year

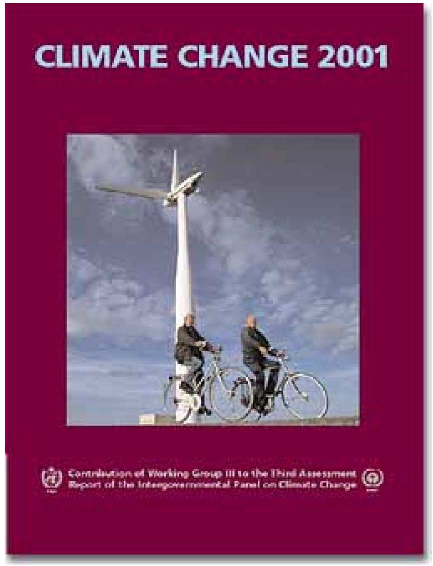
I Risks to Unique and Threatened Systems
II Risks from Extreme Climate Events
III Distribution of Impacts
IV Aggregate Impacts
V Risks from Future Large-Scale Discontinuities

IPCC SRES and TAR

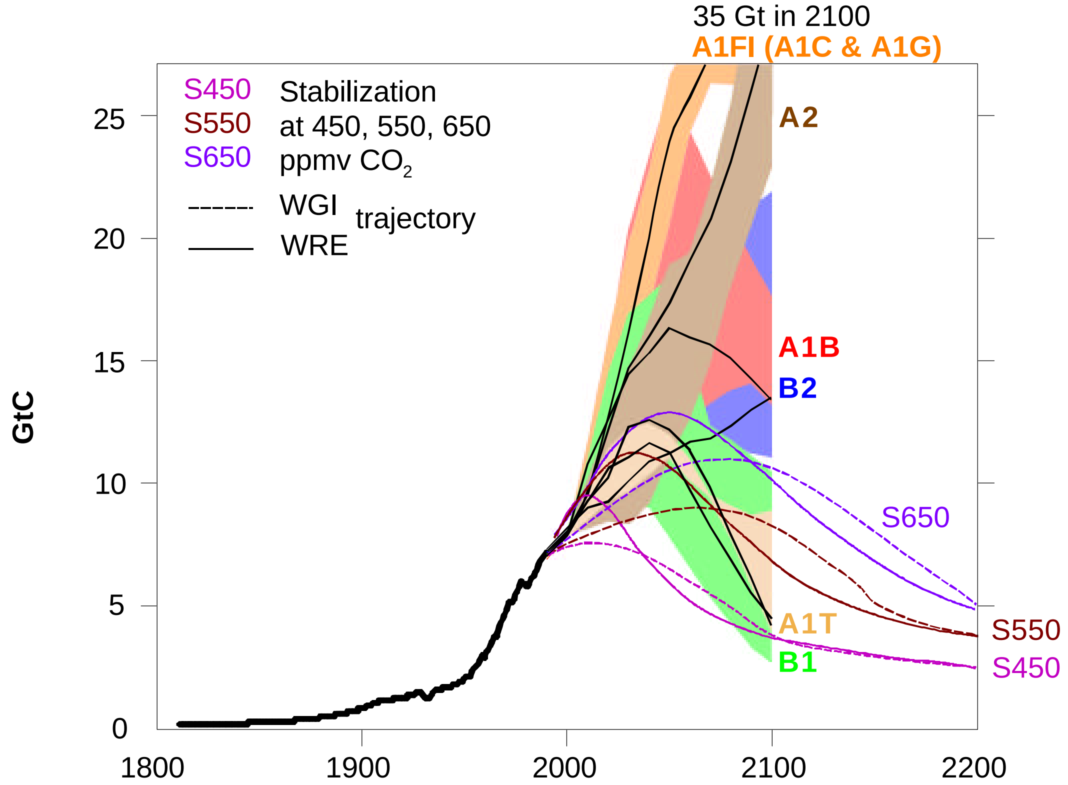


Technology is at least as important driving force of GHG emissions as population and economic growth (SRES).

Innovative technology is an important driving force of a broad range of GHG atmospheric stabilization levels over the next 100 years or more (TAR).



Emissions Scenarios and Stabilization Profiles



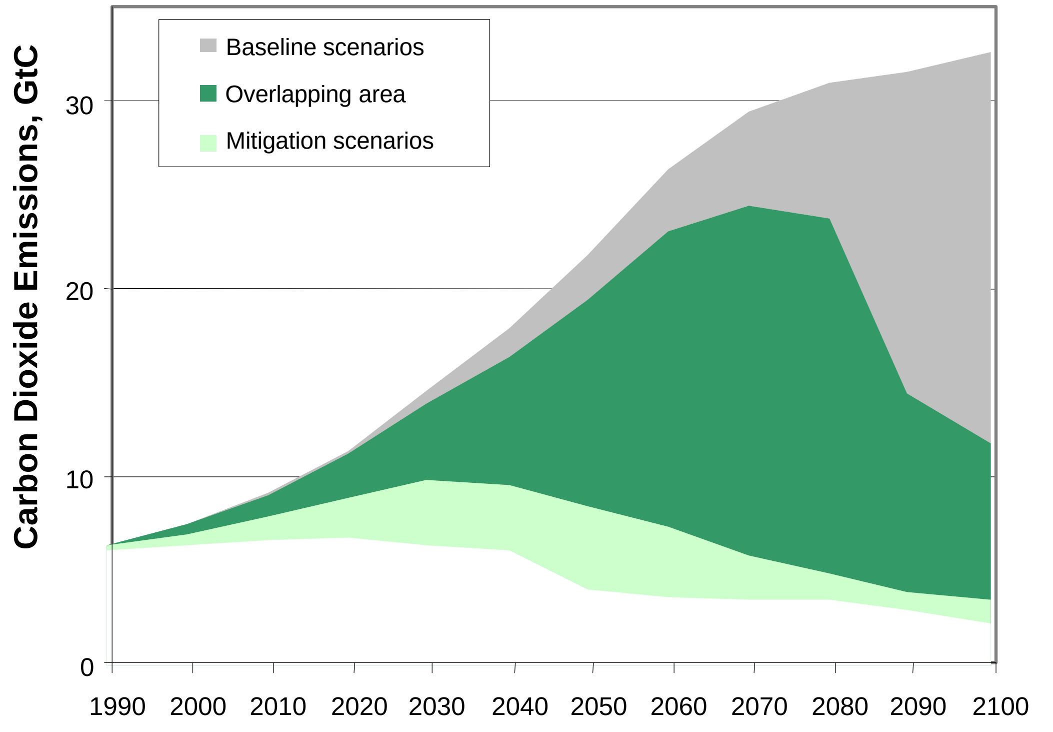
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

WMO

UNEP

Carbon Dioxide Emissions

of the IPCC SRES and TAR Scenarios



Nakicenovic

IIASA 2002

Stabilization Strategies

Reduce net carbon emissions close to zero

- Improve energy efficiencies & end-use
- Introduce zero-carbon technologies
- Decarbonize hydro-carbon sources

Store carbon over geological time <0.1%/$_{yr}$

Develop electricity & hydrogen economy

Stabilization Strategies

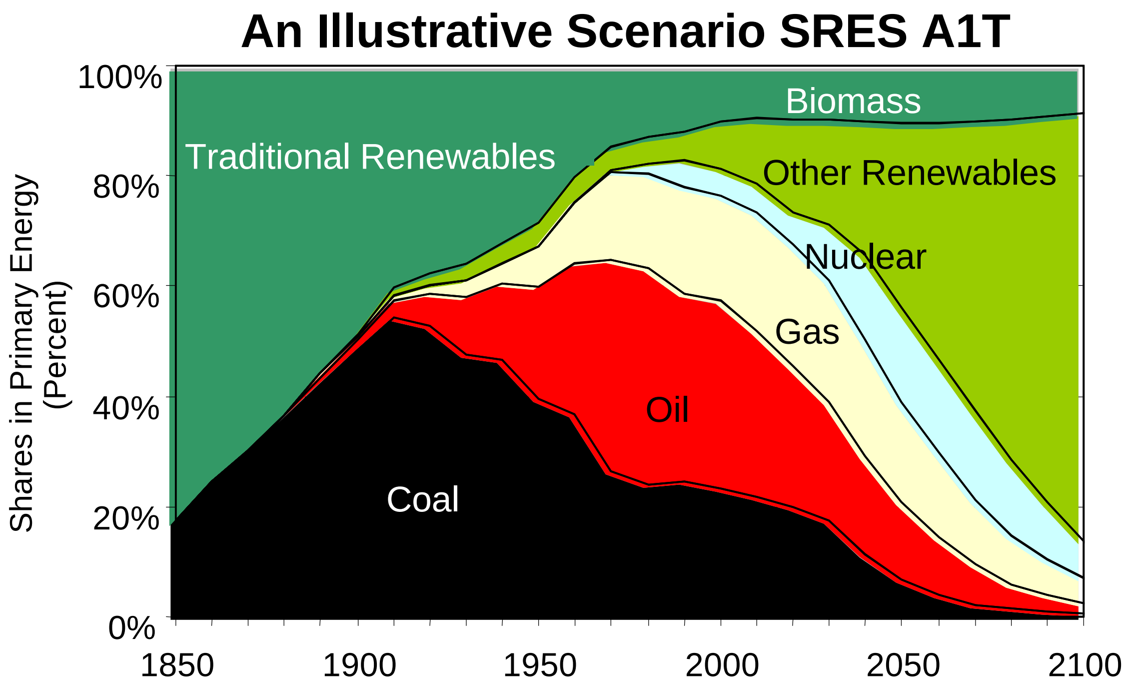
Reduce net carbon emissions to zero

- Improve energy efficiencies & end-use;
- Diffuse biomass & other renewables;
- Diffuse nuclear energy;
- Substitute among hydro-carbon sources;
- Decarbonize hydro-carbon sources; and
- Diffuse afforestation

Store carbon over geological time <0.1$^{\%}/_{yr}$

Develop electricity & hydrogen economy

Evolution of Global Primary Energy

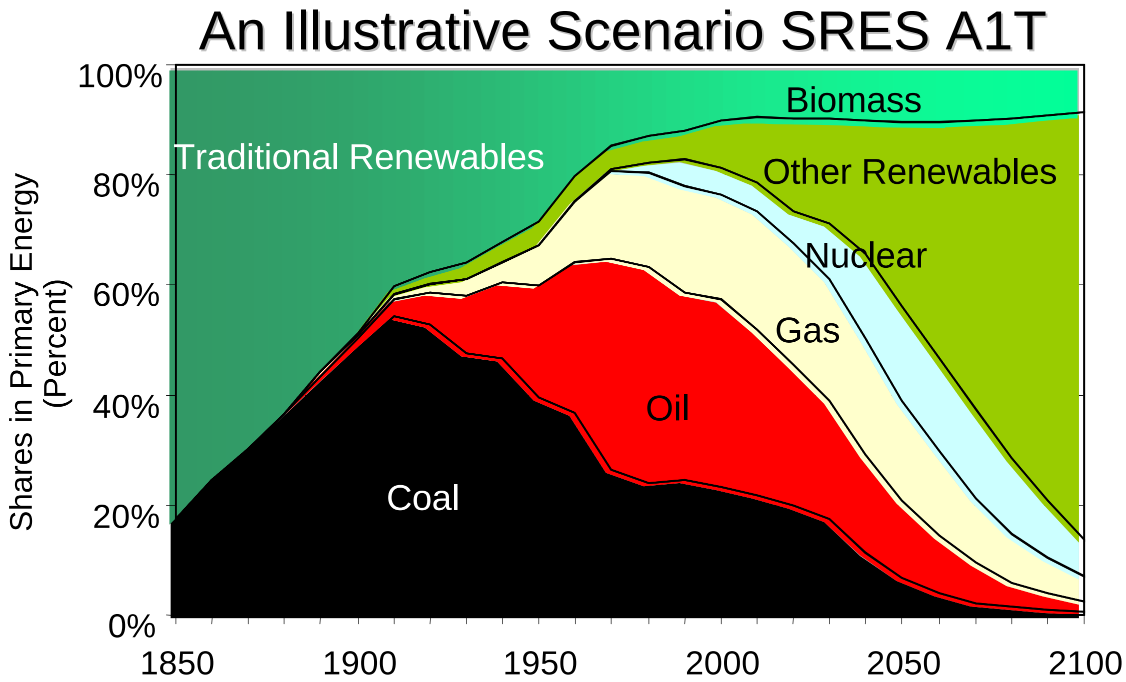


WMO

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

UNEP

Evolution of Global Primary Energy



WMO

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

UNEP

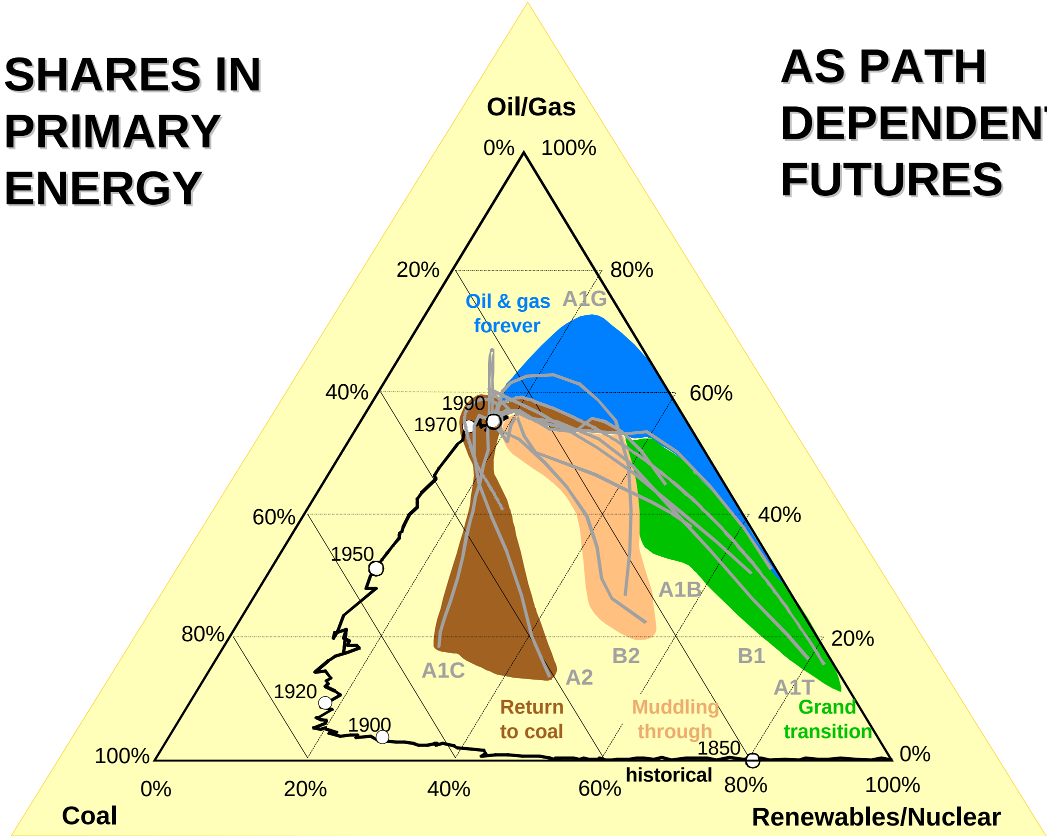
Sources of Emissions Reduction for 550ppmv Stabilization Across the 9 Post-SRES Models. Minimum-Maximum and (Median) in 2100 (GtC)

	A1B	A1FI	A1T	A2	B1	B2
Substitution among fossil fuels	-0.1 – 2.2 (0.97)	0.2 – 11.8 (1.82)	0.1 – 0.1 (0.09)	2.4 – 5.4 (2.95)	0.0 – 0.2 (0.09)	0.6 – 2.7 (1.35)
Switch to nuclear	0.3 – 6.4 (0.55)	-2.4 – 1.9 (1.20)	0.0 – 2.0 (1.03)	0.3 – 1.7 (1.18)	0.0 – 3.1 (0.02)	-0.2 – 5.1 (2.28)
Switch to biomass	-0.8 – 1.5 (1.03)	-0.2 – 5.5 (2.50)	-0.2 – 0.3 (0.07)	1.1 – 3.8 (1.84)	0.0 – 4.3 (0.04)	-1.9 – 1.5 (0.63)
Switch to other renewables	0.1 – 2.5 (1.51)	0.6 – 15.1 (2.70)	-0.1 – 0.0 (-0.05)	2.2 – 6.7 (3.33)	0.1 – 0.3 (0.28)	0.1 – 3.2 (2.07)
CO_2 scrubbing and removal	0.0 – 4.7 (0.00)	0.0 – 23.8 (0.39)	0.5 – 1.6 (1.06)	0.0 – 5.8 (0.00)	0.0 – 1.1 (0.00)	0.0 – 3.0 (0.63)
Demand reduction & end use	0.5 – 6.6 (0.94)	1.9 – 17.7 (10.4)	0.0 – 0.2 (0.11)	5.2 – 15.6 (10.21)	0.1 – 0.3 (0.08)	0.7 – 3.5 (1.64)
TOTAL reduction	7.1 – 11.9 (9.16)	21.7 – 30.5 (21.1)	0.3 – 4.4 (2.31)	21.7 – 26.9 (22.81)	0.2 –9.6 (0.39)	6.0 – 10.6 (8.14)

Note: Emission reductions are estimated by subtracting the mitigation value (in GtC) from the baseline value (in GtC) of each scenario.

SHARES IN PRIMARY ENERGY

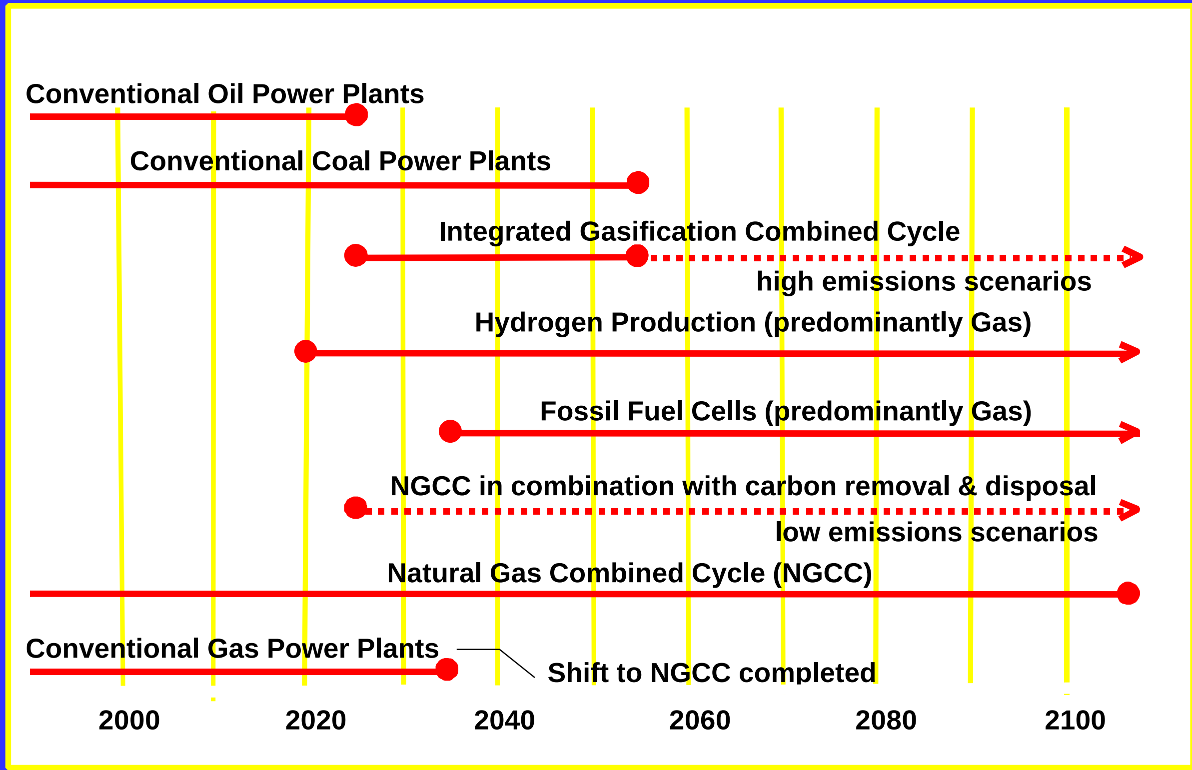
AS PATH DEPENDENT FUTURES



INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

WMO UNEP

Diffusion of Fossil Technologies



Nakicenovic IIASA 2001

CO_2-Capture
Technological Options

- Separation through CO_2 scrubbing
  - Solvent absorption
  - Absorption on a sold
  - Membrane separation
  - Cryogenic separation
- Separation through CH_4 steam reforming and shift reaction
- Separation through oxy-fuel combustion

  (CH_4 with O_2 in recycled CO_2)

Main actions

- Capacity building and learning
- Enabling environment for private and public technology transfer activities
- Mechanisms for technology diffusion and transfer

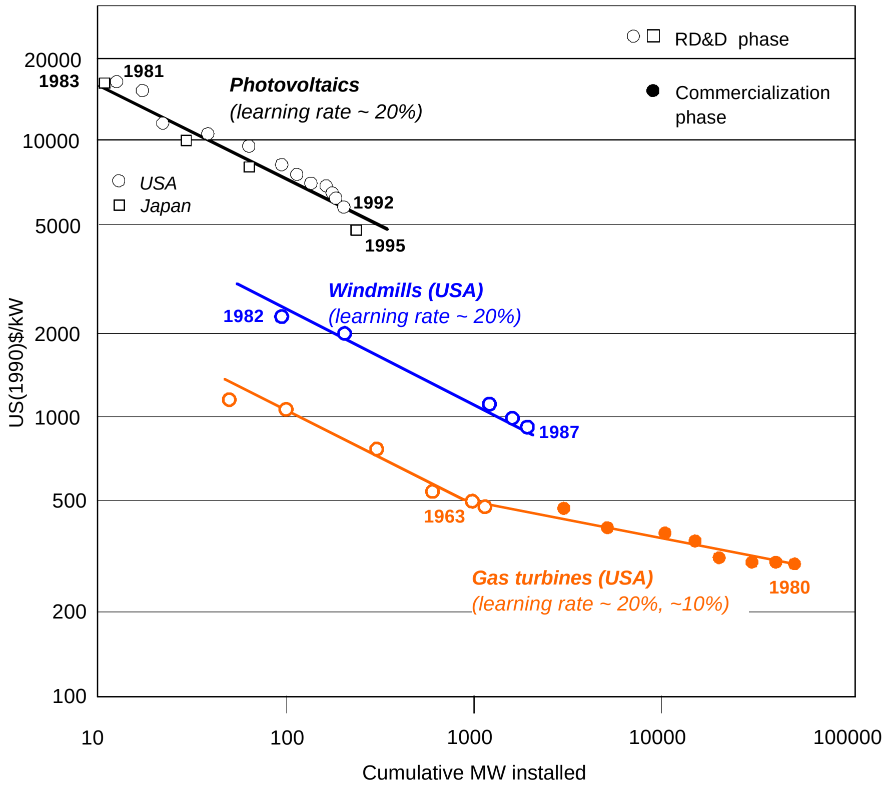
Three Major Elements to Increase Technology Diffusion and Improve its Transfer

- Bulild adequate capacity and learning
- Create an appropriate enabling environment
- Establish effective mechanisms for diffusion and transfer

Three Major Elements to Increase Technology Diffusion and Improve its Transfer

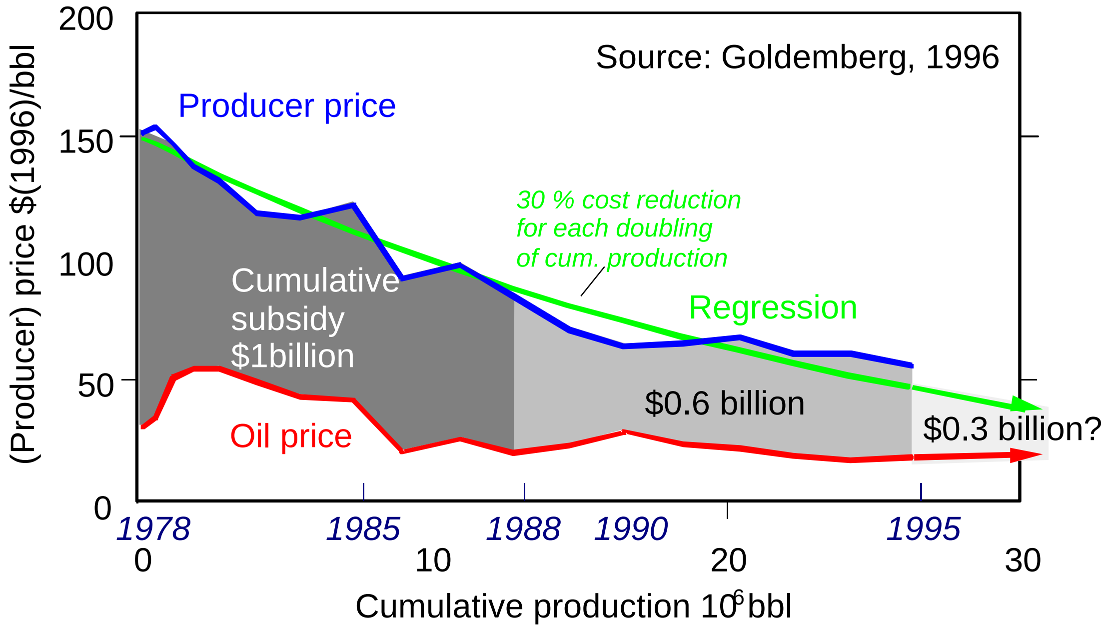
- Develop adequate human and organizational capacity
- Create an appropriate enabling environment
- Establish effective mechanisms

Learning Curves



Nakicenovic *et al.* IIASA 1998

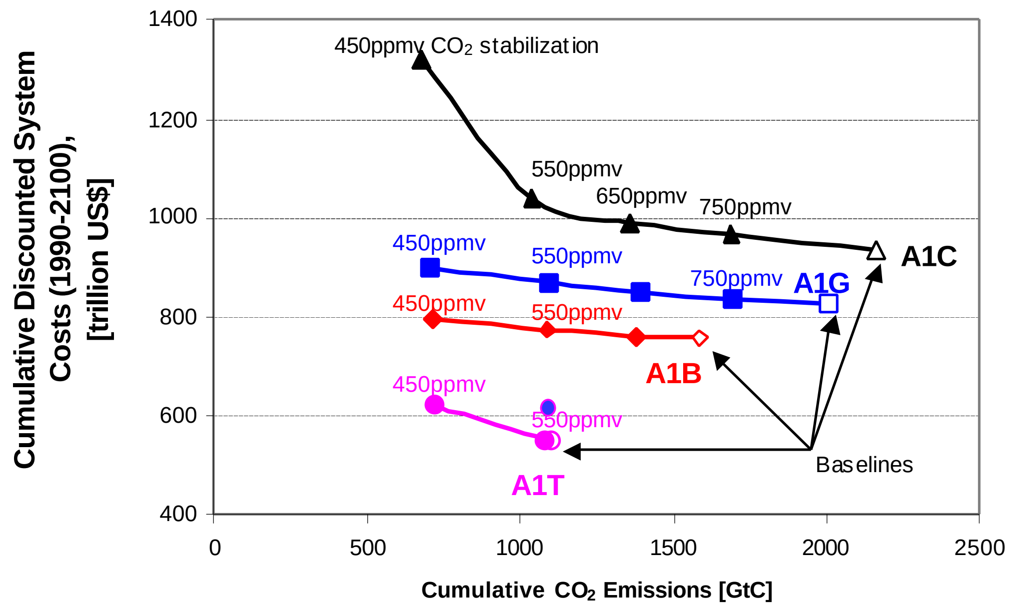
Brazil – Ethanol Learning Curve



Grübler

IIASA 2001

ENERGY SYSTEMS COSTS OF ALTERNATIVE BASELINES AND STABILIZATION SCENARIOS



Nakicenovic

IIASA 2002

Some Key Findings in the TAR Related to Long-Term Innovative Technological Options

- **Technological options could achieve a broad range of atmospheric stabilization levels over the next 100 years or more, but implementation would require associated socio-economic and institutional changes.**
- **No single technology option will provide all of the emissions reductions needed.**
- **Lower emissions scenarios require different patterns of energy resource development**
- **Diffusion and transfer of technologies between countries and regions will widen the choice of options at the regional level and economies of scale and learning will lower the costs of their adoption.**

http://www.ipcc.ch/

http://sres.ciesin.columbia.edu/

http://www.iiasa.ac.at/Research/TNT/

naki@iiasa.ac.at

The Innovation Chain

- Research and development
- Demonstration projects
- Early deployment (cost buy-down)
- Widespread dissemination

Definition of Long-Term Scenarios I

A scenario is not a prediction. It is a coherent, internally consistent and plausible description of a possible future state of the world (Carter *et al*., IPCC 1994).

CO_2-Capture and Disposal Technological Opportunities

- **Initial markets** – storage of separated CO_2 (e.g. from refineries, power plants) in deep aquifers and use of CO_2 to offset emissions (e.g. through EOR or CH_4 from coal)
- **Long-term markets** – integrated and closed system cycles (e.g. $CH_4 + H_2O$? $CO_2 + H_2$; $CH_4 + O_2$? $CO_2 + H_2O$); clathrates as source of CH_4 and storage medium for CO_2
- **New opportunities** – transition from methane to hydrogen economy during the 21st century

SOME OTHER KEY FINDINGS IN THE TAR RELEVANT FOR INNOVATIVE TECHNOLOGICAL OPTIONS

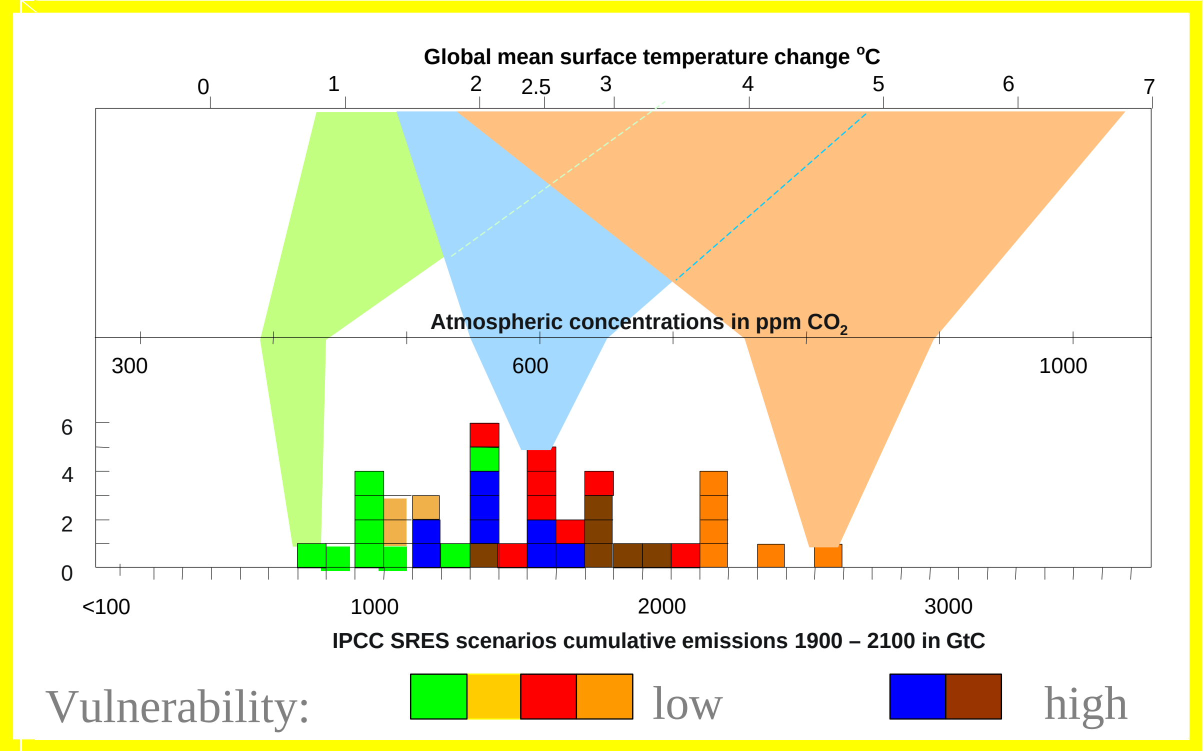
•Climate change mitigation will both be affected by, and have impacts on, broader socio-economic policies and trends, such as those relating to development, sustainability and equity.

•Social learning and innovation, and changes in institutional structure could contribute to climate change mitigation.

• Forests, agricultural lands, and other terrestrial ecosystems offer significant carbon mitigation potential. Although not necessarily permanent, conservation and sequestration of carbon may allow time for other options to be further developed and implemented.

MAJOR CLIMATE CHANGE UNCERTAINTIES

Cumulative CO_2 of IPCC SRES scenarios and resulting CO_2 concentrations and climate sensitivity in ^oC temperature change based on MAGICC model



Grübler

IIASA 2002

DYNAMICS OF TECHNOLOGY

- **Uncertainty:**

  Limited knowledge on feasibility and costs of future technologies

- **Technological Learning:**

  Improvements are a function of accumulated experience (learning curve)

TIME FOR A CHANGE

- Typical diffusion time constraints for replacing 80% of energy capital stock are 20 to > 50 years
- Premature replacement of capital by new technologies is too costly
- Start experimentation and technological learning now to prepare for future capital replacement

How can the technology transfer debate be assisted?

- Broader view of technology transfer can bridge North South gap
- Role of private sector should be acknowledged
- Many options available for government action that fit in UNFCCC framework

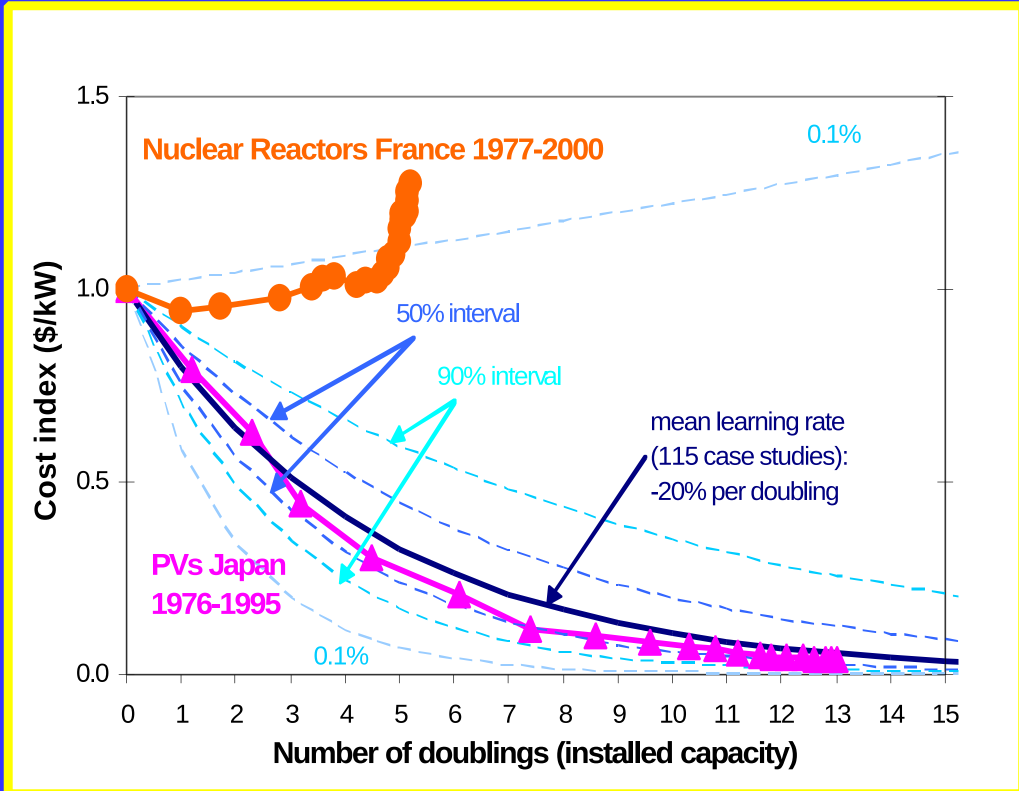
Costs to address enegy issues

billion/year over 20 years

- Efficient stoves to 2 billion ~$10
- Modern fuels for cooking ~$15
- PV costs until competitive >$10
- FC costs until competitive >$20
- Electrification of rural areas ~$50

Technological Uncertainties

Learning rates (push) and market growth (pull)



Nakicenovic IIASA 2002