Tables & Figures chapter 2

***Table 2.4.4.** A simple typology of uncertainties*

Type	Indicative examples of sources	Typical approaches and considerations
Unpredictability	Projections of human behaviour not easily amenable to prediction (e.g. evolution of political systems). Chaotic components of complex systems.	Use of scenarios spanning a plausible range, clearly stating assumptions, limits considered, and subjective judgments. Ranges from ensembles of model runs.
Structural uncertainty	Inadequate models, incomplete or competing conceptual frameworks, lack of agreement on model structure, ambiguous system boundaries or definitions, significant processes or relationships wrongly specified or not considered.	Specify assumptions and system definitions clearly, compare models with observations for a range of conditions, assess maturity of the underlying science and degree to which understanding is based on fundamental concepts tested in other areas.
Value uncertainty	Missing, inaccurate or non-representative data, inappropriate spatial or temporal resolution, poorly known or changing model parameters.	Analysis of statistical properties of sets of values (observations, model ensemble results, etc); bootstrap and hierarchical statistical tests;comparison of models with observations.

Source: reproduced from Table 2 in IPCC Guidance Notes (2005).

***Table 2.4.5.** Qualitatively defined levels of understanding*

consensus →	*High agreement limited evidence*	…	*High agreement much evidence*
agreement or	…	…	…
Level of	*Low agreement limited evidence*	…	*Low agreement much evidence*

Amount of evidence (theory, observations, models) →

Source: reproduced from Table 2 in IPCC (2005)

***Table 2.4.6.** Qualitatively calibrated levels of confidence*

Terminology	Degree of confidence in being correct
Very high confidence	At least 9 out of 10 chance of being correct
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

Source: reproduced from Table 3 in IPCC Guidance Notes (2005)

Table 2.4.7. *Qualitatively defined likelihood scale*

Terminology	**Likelihood of the occurrence/outcome**
Virtually certain	> 99% probability of occurrence
Very likely	> 90% probability
Likely	> 66% probability
About as likely as no	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Exceptionally unlikely	< 1% probability

Source: reproduced from Table 4 in IPCC Guidance Notes (2005)

Table 2.2.7. *Relationship between MDG's, Energy-, Food-, and Water Access, and climate change*

1. **MDG Goals**	2. **Sectoral Themes**	3. **Climate Change Links**
To halve between 1990 and 2015, the proportion of the worlds population whose income is below 1US$ a day	Energy: Energy for local enterprises Lighting to facilitate income generation Energy for machinery Employment related to energy provision Food/water: Increased food production Improved water supply Employment	Energy: GHG emissions. Adaptive capacity increase due to higher income levels and decreased dependence on natural resources. production costs etc. Food/water: GHG emissions Increased productivity of agriculture can reduce climate change vulnerability. Improved water management can help adaptation
To halve between 1990 and 2015, the proportion of people who suffer from hunger	Energy: Energy for machinery and irrigation in agriculture Food/water: More efficient production processes that increases production and reduces waste Distribution of land and food	Energy: GHG emissions. Food/water: Increased GHG emissions from some agricultural activities but partly offset by more carbon sequestration and improved waste management. Adaptive capacity of farmers depend on income and land ownership.
To ensure that, by 2015, children everywhere will be able to complete a full course of primary schooling	Energy: Reduce time spent by children on energy provision. Lighting for reading Energy for educational media including TV and computers Food/water: Reduced time spend in this sector enables children to spend more time on education Improved health increases childrens capacity to read	Energy: Education can support adaptive and mitigative capacity. Food/water: Education can support adaptive and mitigative capacity

Ensuring that girls and boys have equal access to primary and secondary education, preferably by 2005, and to all levels of education no later than 2015	Energy: Modern energy services free girls and young women's time spend on energy provision New electronic educational media makes it easier for girls to get information from home Food/water: Modern production practices in agriculture and improved water supply free girls and young women's time spend on energy.	Energy: Education can support adaptive and mitigative capacity Food/water: Education can support adaptive and mitigative capacity
5. To reduce by two-thirds, between 1990 and 2015, the death rate for children under the age of five years	Energy: Energy supply can support health clinics Reduced air pollution from tradional fuels Reduced time spend on fuel collection can increase the time spend on childrens health care Food/water: Improved health due to increased supply of high quality food and clean water Reduced time spend on food and water provision can increase the time spend on childrens health care	Energy: GHG emissions Food/water: Health improvements will decrease vulnerability to climate change and the adaptive capacity
To reduce by three-quarters between 1990 and 2015 the rate of maternal mortality	Energy: Energy provision for health clinics Reduced air pollution from tradional fuels and other health improvements. Food/water: Improved health due to increased supply of high quality food and clean water Time savings on food and water provision can increase the time spend on childrens health care	Energy: GHG emissions Food/water: Health improvements will decrease vulnerability to climate change and the adaptive capacity

6 HIV/AIDS, malaria and other major diseases	Energy: Energy for health clinics Cooling of vaccines and medicine Food/water Health improvements from cleaner water supply Food production practices that reduces malaria potential	Energy: GHG emissions from increased health clinic services, but health improvements can also reduce the health service demand Food/water: Health improvements will decrease vulnerability to climate change and the adaptive capacity
To stop the unsustainable exploitation of natural resources	Energy: Deforestation caused by woodfuel collection Use of exhaustible resources Food/water: Land degradation	Energy: GHG emissions Carbon sequestration Food/water: Carbon sequestration Improved production conditions for land use activities will increase the adaptive capacity
To halve, between 1990 and 2015, the proportion of people who are unable to reach and afford safe drinking water	Energy: Energy for pumping and distribution systems, and for desalination and water treatment Water: Improved water systems	Energy: GHG emissions Water: Reduced vulnerability and enhanced adaptive capacity
Develop a global partnership for development		

Table 2.2.8. *Development goals, targets and climate change*

Millennium development goals and global targets[1]	India's 10th plan (2002-2007) and beyond targets[2, 3, 4]	How these address climate change concerns?
Goal 1: Eradicate extreme poverty and hunger *Target 1: Halve, between 1990 and 2015, the proportion of people whose income is less than $1 a day* *Target 2: Halve, between 1990 and 2015, the proportion of people who suffer from hunger*	Double the per capita income by 2012 Reduction of poverty ratio by 5 percentage points by 2007 and by 15 percentage points by 2012 Reduce decadal population growth rate to 16.2% between 2001-2011 (from 21.3% during 1991-2001)	Enhanced adaptation capacity due to improved food security, health security and resilience to cope with risks from uncertain and extreme events
Goal 2: Achieve universal primary education *Target 3: Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling*	All children in school by 2003; all children to complete 5 years of schooling by 2007 Increase in literacy rates to 75% by 2007 (from 65% in 2001)	Enhanced adaptation capacity due to improved skills, flexibility to shift vocations/locations
Goal 3: Promote gender equality and empower women *Target 4: Eliminate gender disparity in primary and secondary education, preferably by 2005 and in all levels of education no later than 2015*	At least halve, between 2002 and 2007, gender gaps in literacy and wage rates	Enhanced capacity of women to deal with added social risks from climate change
Goal 4: Reduce child mortality *Target 5: Reduce by two-thirds, between 1990 and 2015, the under-five mortality rate*	Reduction of Infant mortality rate (IMR) to 45 per 1000 live births by 2007 and to 28 by 2012 (115 in 1980, 70 in 2000)	Enhanced resilience of children to health effects of climate change due to improved access to health services
Goal 5: Improve maternal health *Target 6: Reduce by three-quarters, between 1990 and 2015, the maternal mortality ratio (MMR)*	Reduction of MMR to 2 per 1000 live births by 2007 and to 1 by 2012 (from 3 in 2001)	Enhanced resilience of women to health effects of climate change due to improved access to health services

Goal 6: Combat HIV/AIDS, malaria and other diseases *Target 7: Have halted by 2015 and begun to reverse the spread of HIV/AIDS* *Target 8: Have halted by 2015 and begun to reverse the incidence of malaria and other major diseases*	Have halted by 2007; 80 to 90% coverage of high risk groups, schools, colleges and rural areas for awareness generation by 2007 25% reduction in morbidity and mortality due to malaria by 2007 and 50% by 2010	Higher resilience of the population due to enhanced capacity to deal with epidemics Enhanced resilience to added risk of Malaria and other vector borne diseases
Goal 7: Ensure environmental sustainability *Target 9: Integrate the principles of sustainable development into country policies and programmes and reverse the loss of environmental resources* *Target 10: Halve by 2015 the proportion of people without sustainable access to safe drinking water* *Target 11: Have achieved by 2020 a significant improvement in the lives of at least 100 million slum dwellers*	Increase in forest and tree cover to 25% by 2007 and 33% by 2012 (from 23% in 2001) Sustained access to potable drinking water to all villages by 2007 Commission 14.4 GW hydro and 3 GW by other renewables in a total power generation capacity additions of 41.1 GW between 2002-2007 Electrify 62,000 villages by 2007 through conventional grid expansion, remaining 18,000 by 2012 through decentralized non-conventional sources like solar, wind, small hydro and biomass. Cleaning of all major polluted rivers by 2007 and other notified stretches by 2012	Lower GHG emissions and local emissions; lower fossil fuel imports; reduced pressure on land, resources and ecosystems Higher adaptive capacity to climate variability due to enhanced water supply Resilience to cope with health impacts of climate change due to access to clean water and electricity Higher adaptive capacity due to enhanced reach of health/education facilities dependent on electrical equipments and flexibility of economic activities in rural areas
Goal 8: Develop a global partnership for development *Target 12: Develop further an open, rule-based, predictable, non-discriminatory trading and financial system (includes a commitment to good governance, development, and poverty reduction - both nationally and internationally)*	Expeditious reformulation of the fiscal management system to make it more appropriate for the changed context Tenth plan includes state-wise break up of the broad developmental targets. Higher integration with the global economy Create 50 million employment opportunities by	Higher resilience to climate change due to enhanced supply of social infrastructure Higher mitigative and adaptive capacity from access to global resources and technologies Enhanced flexibility of jobs and migra-

Target 16: In cooperation with developing countries, develop and implement strategies for decent and productive work for youth *Target 17: In cooperation with pharmaceutical companies, provide access to affordable essential drugs in developing countries* *Target 18: In cooperation with the private sector, make available the benefits of new technologies, especially information and communications technologies*	2007 and 100 million by 2012 (current backlog of unemployment is around 9%, equivalent to 35 million persons)	tion Improved capacity to deal with health risks due to access to advanced medicine and health services Enhanced adaptive capacity to deal with extreme events from access to advanced information and communication systems

Note: Millennium targets13 and 14 refer to special needs of least developed, land locked and small island countries. India is party to several international conventions and programmes assisting these countries. India is also implementing policies in line with target 15 that exhorts amelioration of debt of developing countries, including own debt, under global cooperation.

Source: Shukla et al., 2003

Table 2.4.5.3. *Examples of Implementation Policies Related to Climate Change Mitigation*

	Specific policy example
Market oriented policies	
Market creation, possibly with public sector involvement in the transition period	Temporary support to specific demonstration projects
Privatisation for example through the establishment of well-defined property rights and enforcement.	Land property rights
Regulate competition by introducing more market actors.	Information campaigns, soft loans to developers of renewable technologies
Environmental taxes	Carbon taxes
Support efficiency in savings and investment decisions by deepening financial markets.	Support financing mechanisms
Launch technical standards to be met in a given time frame.	Efficiency standards for electricity appliances
Price liberalisation, support international competition	Exchange rate devaluation, subsidy removal
Policies targeting in-flexibility and constraints of established technical systems	
Timing of infrastructure investments	Long term planning of power production and transmission, transportation facilities
Subsidy to capital turnover projects	Specific capital grants
Subsidised credit to support research, development and learning processes	Demonstration and research programmes
Co-ordination and integration of specific climate change mitigation efforts in general investment policies	Information, capital subsidies
Institutional policies	

Establish monitoring and enforcement systems	Reporting systems
Establish and enforce property rights	Land reforms
Institutional set-up for the reduction of risks and/or risk pooling (notably capital market)	Offset market
Establishment of specific organisations to reduce uncertainty and transmit information.	Insurance schemes
Establish international mechanism for technology transfer.	CDM
Human capacity policies	
Training and education activities.	Capacity development programmes
Improvement of decision making processes	Participation, local governance
Educational programmes	Energy and transport provision to schools

Table 2.5.6.. *Input assumptions in energy sector mitigation studies (the table can be supplemented with assumptions for other sectors)*

Input assumptions	Meaning and relevance
Population	All else being equal, high growth increases GHG emissions.
Economic growth	Increased economic growth increases energy-using activities and also leads to increased investment, which speeds the turnover of energy-using equipment. Various assumptions on GHG emissions and resource intensities can be used foralternative scenarios.
Energy demand • Structural change • Technological change • Lifestyle	Different sectors have different energy-intensities; structural change therefore has a major impact on overall energy use. This “energy-efficiency” variable influences the amount of primary energy needed to satisfy given energy services required by a given economic output. Innovation and penetration of new technologies. Explaines structural changes in consumer behaviour
Energy supply • Technology availability and cost • Backstop technology • Learning	Potential for fuel and technology substitution. The cost at which an infinite alternative supply of energy becomes available; this is the upper bound of cost estimates. Technology costs related to time, market scale, and institutional capacity. Innovation and penetration of new technologies.
Price and income elasticities of energy demand	Relative changes in energy demand through changes in price or income, respectively; higher elasticities result in larger changes in energy use
Implementation and transaction costs	Implementation scale, regulatory framework, institutional capacity, administration
Discount rates	Time perspective Opportunity cost of capital

	Social time preference Risk assumptions Uncertainty
Policy instruments and regulation • Instruments • Barriers	Economic versus regulatory measures Implementation costs, including costs of overcoming barriers either in the form of institutional aspects or improvements in markets (including capacity building and institutional reforms); behavioral assumptions.
Existing tax systems and tax recycling	Recycling of carbon taxes; substitution of distortionary taxes decreases costs
Ancillary benefits	Integration of local and regional environmental policies in most cases generates Secondary benefits. Social policy goals, like income distribution and employment, can result indifferent policy rankings.

Table 2.7.2 *Measures of Inter-country Equity*

	GNI *Per Capita* $USD		Life Expectancy (LE) Years		Literacy (ILL) %	
	Average	C.Var	Average	C.Var	Average	C.Var
1980/90	3,764	4,915	61.2	0.18	72.5	25.3
2001	7,350	10,217	65.1	0.21	79.2	21.4
% Change Average		95%		6%		9%
% Change Co. Var.		6%		14%		-22%

Source: WB, 2005 (World Development Indicators)

Notes: Literacy Rates are for 1990 and 2001. GNI and LE data are for 1980, 1990, and 2001. 99 countries are included in the sample.

Coefficient of variation is the standard deviation of a series divided by the mean. The standard deviation is given by the formula:

$s = \sqrt{\sum_{i=1}^{i=n}(x_i - \bar{x})^2 \Big/ (n-1)}$ Where ‘x’ refers to the value of a particular observation, $\bar{x}$ is the mean of the sample and ‘n’ is the number of observations.

Table 2.7.3. *Impacts of Climate Change on Different Dimensions of Equity*

Dimension of Equity	Effect of Climate Change	
	Within a Country	Across Countries
Economic	Increased vulnerability of agricultural practices that are undertaken by poor people will increase inequality	With greater negative impacts in developing countries, inequality will increase
Health	Poorer people suffer from lower general health standard and less access to health services and can therefore be more impacted, although some impacts will affect all sections	Major impacts of flooding, vector borne diseases etc. will be in developing countries

Economic and Social Security	Probably affects all sections, but those more dependent on natural resources will be hurt more.	Bigger effects will be in developing countries
Gender	As major users of natural resources e. g firewood for wood fuel and as contributors to subsistence agriculture, women will be severely affected by climate change	Economic disparity along gender lines will increase
Access to Public Goods	Cuts in government expenditure to cope with climate change will affect all, but could fall disproportionately on the poor.	Costs of adaptation will be greater in poor countries, making them less able to maintain provision of other public goods.
Political and Social Freedoms	With possible social disruptions, freedoms could be eroded.	Effects of migration and could be felt in all countries, including the more well-to-do ones, affecting traditional liberties.

1 ***Table 2.8.1.*** *Examples of Disaggregating the World.*

Classifying Variable/s	**Units**	**Examples of Analytical Interest**
UN Membership	Annex-1, non-Annex-1	Burden sharing, International climate change cooperation
	Permanent, temporary, and non-members of UNSC	?
	Various Groupings such as G-4, G-7, G-8, G-19, G-77 Voluntary Associations	Burden sharing, International climate change cooperation

Per Capita Income	Stage of Development (Least developed, developing, economies in transition, developed)	Vulnerability of climate change, Mitigative and adaptive
	Consumption	Emission projections, equity
Population Density	Urbanization	Infrastructure investments and land use policies
Pop. Density as a proxy	Light Pollution ?why that	Good proxy
Altitude above MSL	Areas at risk for inundation from sea level rise	CC impact analysis--
Grid (formed by latitude and longitude)	Global Circulation Models to study climate change and impacts	General global cc projections, difficult to link to link to more detailed studies e.g. since sea and land in the same cell
Oil production, trade and consumption	Producing, exporting, importing, consuming	CO_2 taxes and other policy options
Temperature and Precipitation zones	Biomes, forestry and agriculture	CC impacts

Figures

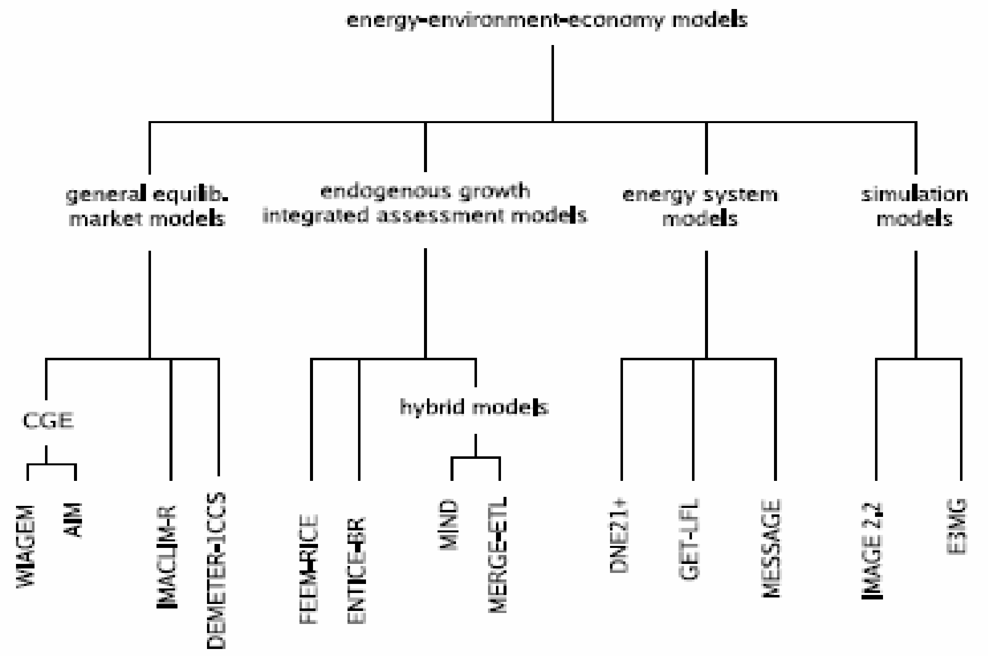


Figure 1: Classification of models in the IMCP

Figure 2.2.1 A schematic and simplified representation of an integrated assessment framework for considering anthropogenic climate change.

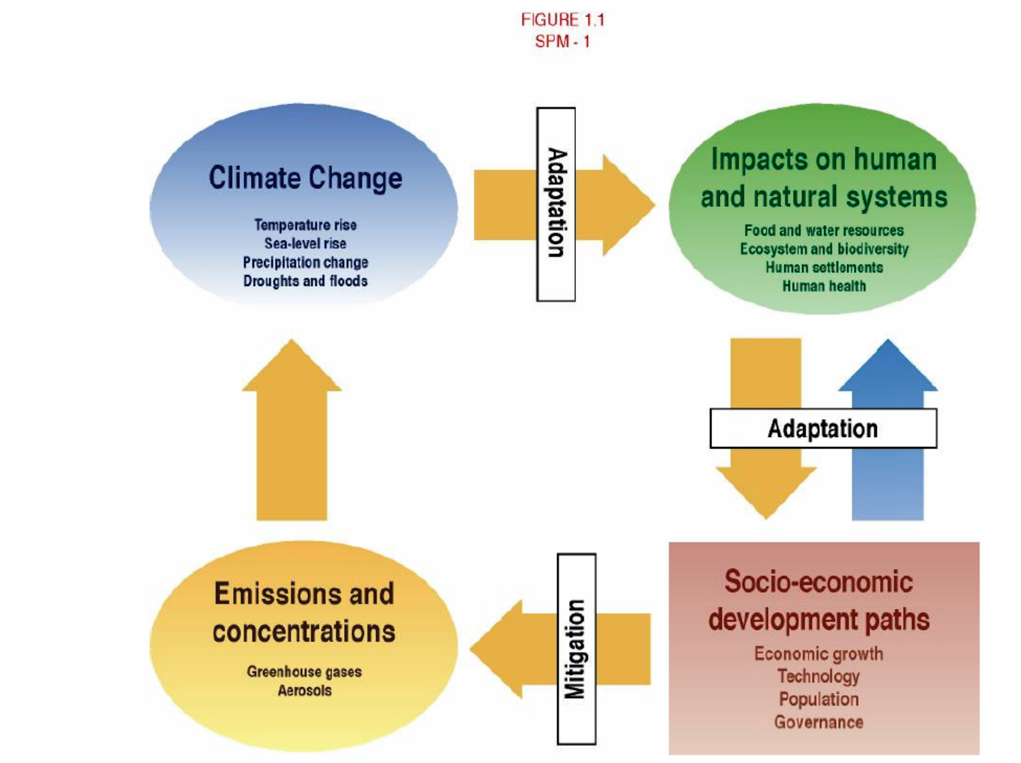
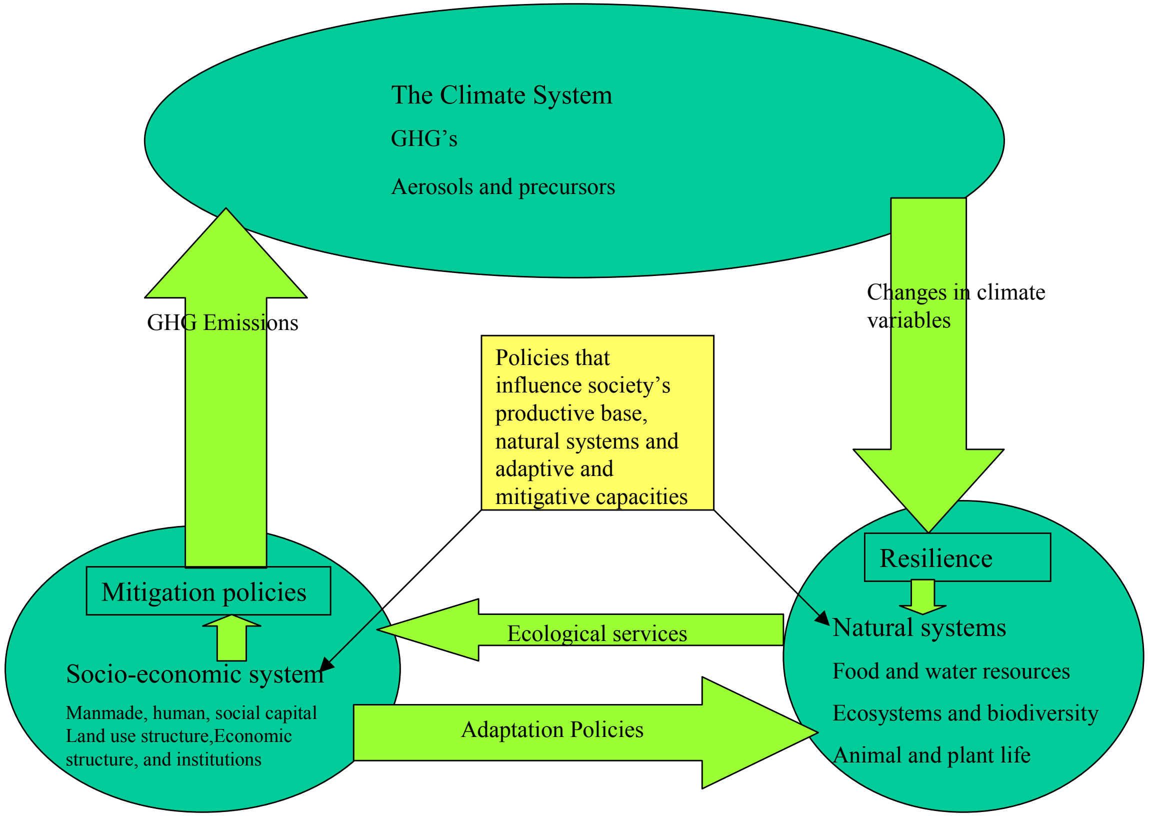
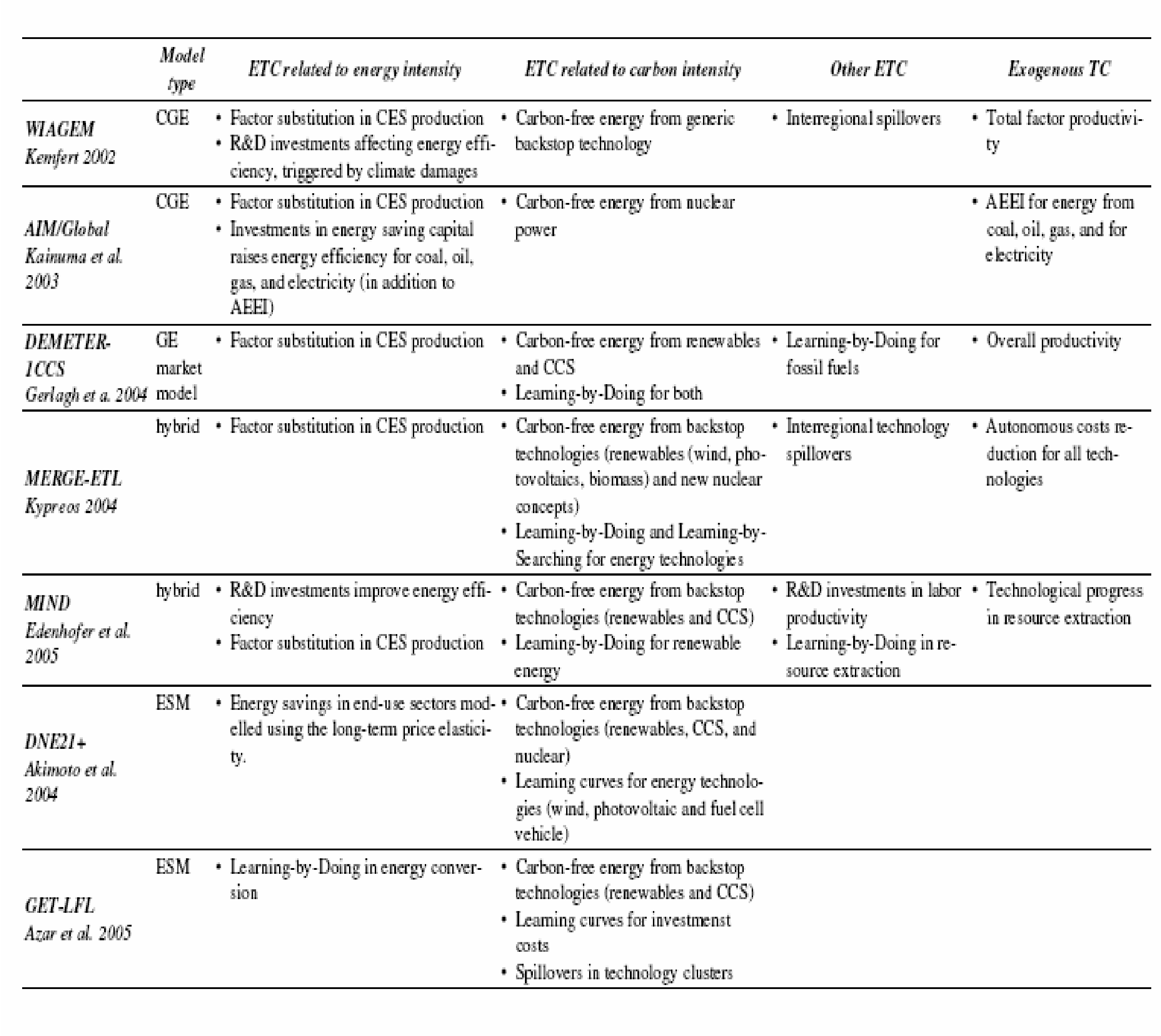


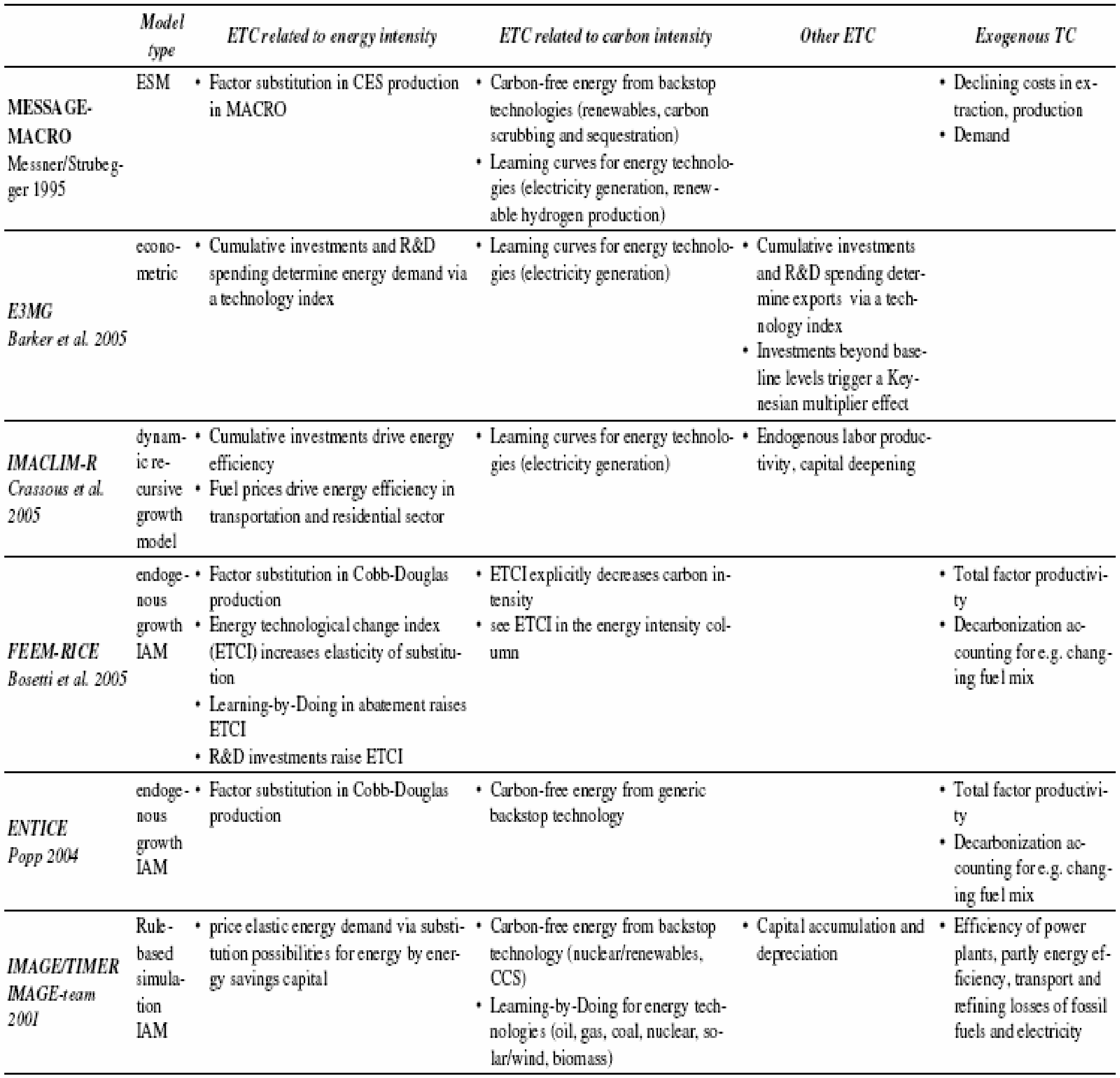
Figure 2.2.2. *TAR figure on SD, adaptation and mitigation interactions*



1
2 ***Figure 2.2.3.*** *Interactions between the climate system, nature, and the socio-economic system and the relationships to SD and adaptation-mitigation*



	Model type	*ETC related to energy intensity*	*ETC related to carbon intensity*	*Other ETC*	*Exogenous TC*
WIAGEM *Kemfert 2002*	CGE	• Factor substitution in CES production • R&D investments affecting energy efficiency, triggered by climate damages	• Carbon-free energy from generic backstop technology	• Interregional spillovers	• Total factor productivity
AIM/Global *Kainuma et al. 2003*	CGE	• Factor substitution in CES production • Investments in energy saving capital raises energy efficiency for coal, oil, gas, and electricity (in addition to AEEI)	• Carbon-free energy from nuclear power		• AEEI for energy from coal, oil, gas, and for electricity
DEMETER-1CCS *Gerlagh et a. 2004*	GE market model	• Factor substitution in CES production	• Carbon-free energy from renewables and CCS • Learning-by-Doing for both	• Learning-by-Doing for fossil fuels	• Overall productivity
MERGE-ETL *Kypreos 2004*	hybrid	• Factor substitution in CES production	• Carbon-free energy from backstop technologies (renewables (wind, photovoltaics, biomass) and new nuclear concepts) • Learning-by-Doing and Learning-by-Searching for energy technologies	• Interregional technology spillovers	• Autonomous costs reduction for all technologies
MIND *Edenhofer et al. 2005*	hybrid	• R&D investments improve energy efficiency • Factor substitution in CES production	• Carbon-free energy from backstop technologies (renewables and CCS) • Learning-by-Doing for renewable energy	• R&D investments in labor productivity • Learning-by-Doing in resource extraction	• Technological progress in resource extraction
DNE21+ *Akimoto et al. 2004*	ESM	• Energy savings in end-use sectors modelled using the long-term price elasticity.	• Carbon-free energy from backstop technologies (renewables, CCS, and nuclear) • Learning curves for energy technologies (wind, photovoltaic and fuel cell vehicle)		
GET-LFL *Azar et al. 2005*	ESM	• Learning-by-Doing in energy conversion	• Carbon-free energy from backstop technologies (renewables and CCS) • Learning curves for investmenst costs • Spillovers in technology clusters		



	Model type	*ETC related to energy intensity*	*ETC related to carbon intensity*	*Other ETC*	*Exogenous TC*
MESSAGE-MACRO Messner/Strubegger 1995	ESM	• Factor substitution in CES production in MACRO	• Carbon-free energy from backstop technologies (renewables, carbon scrubbing and sequestration) • Learning curves for energy technologies (electricity generation, renewable hydrogen production)		• Declining costs in extraction, production • Demand
E3MG *Barker et al. 2005*	econometric	• Cumulative investments and R&D spending determine energy demand via a technology index	• Learning curves for energy technologies (electricity generation)	• Cumulative investments and R&D spending determine exports via a technology index • Investments beyond baseline levels trigger a Keynesian multiplier effect	
IMACLIM-R *Crassous et al. 2005*	dynamic recursive growth model	• Cumulative investments drive energy efficiency • Fuel prices drive energy efficiency in transportation and residential sector	• Learning curves for energy technologies (electricity generation)	• Endogenous labor productivity, capital deepening	
FEEM-RICE *Bosetti et al. 2005*	endogenous growth IAM	• Factor substitution in Cobb-Douglas production • Energy technological change index (ETCI) increases elasticity of substitution • Learning-by-Doing in abatement raises ETCI • R&D investments raise ETCI	• ETCI explicitly decreases carbon intensity • see ETCI in the energy intensity column		• Total factor productivity • Decarbonization accounting for e.g. changing fuel mix
ENTICE *Popp 2004*	endogenous growth IAM	• Factor substitution in Cobb-Douglas production	• Carbon-free energy from generic backstop technology		• Total factor productivity • Decarbonization accounting for e.g. changing fuel mix
IMAGE/TIMER *IMAGE-team 2001*	Rule-based simulation IAM	• price elastic energy demand via substitution possibilities for energy by energy savings capital	• Carbon-free energy from backstop technology (nuclear/renewables, CCS) • Learning-by-Doing for energy technologies (oil, gas, coal, nuclear, solar/wind, biomass)	• Capital accumulation and depreciation	• Efficiency of power plants, partly energy efficiency, transport and refining losses of fossil fuels and electricity

Figure 2.3.2 The scientific decision model goes from left to right

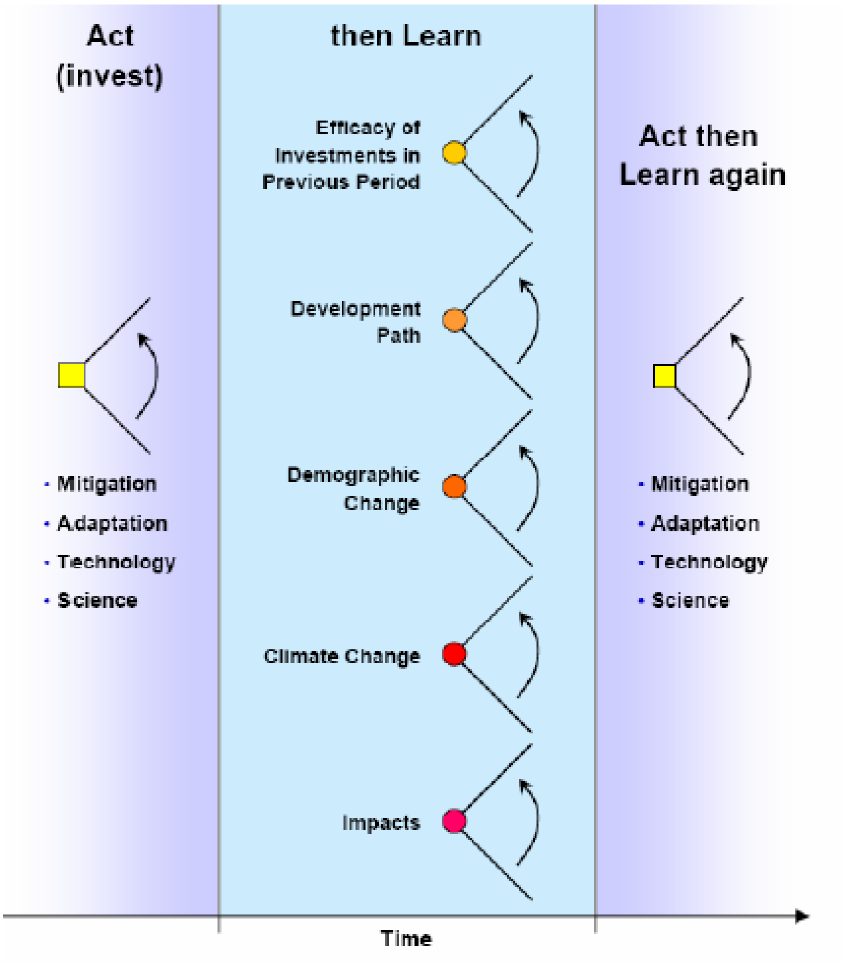
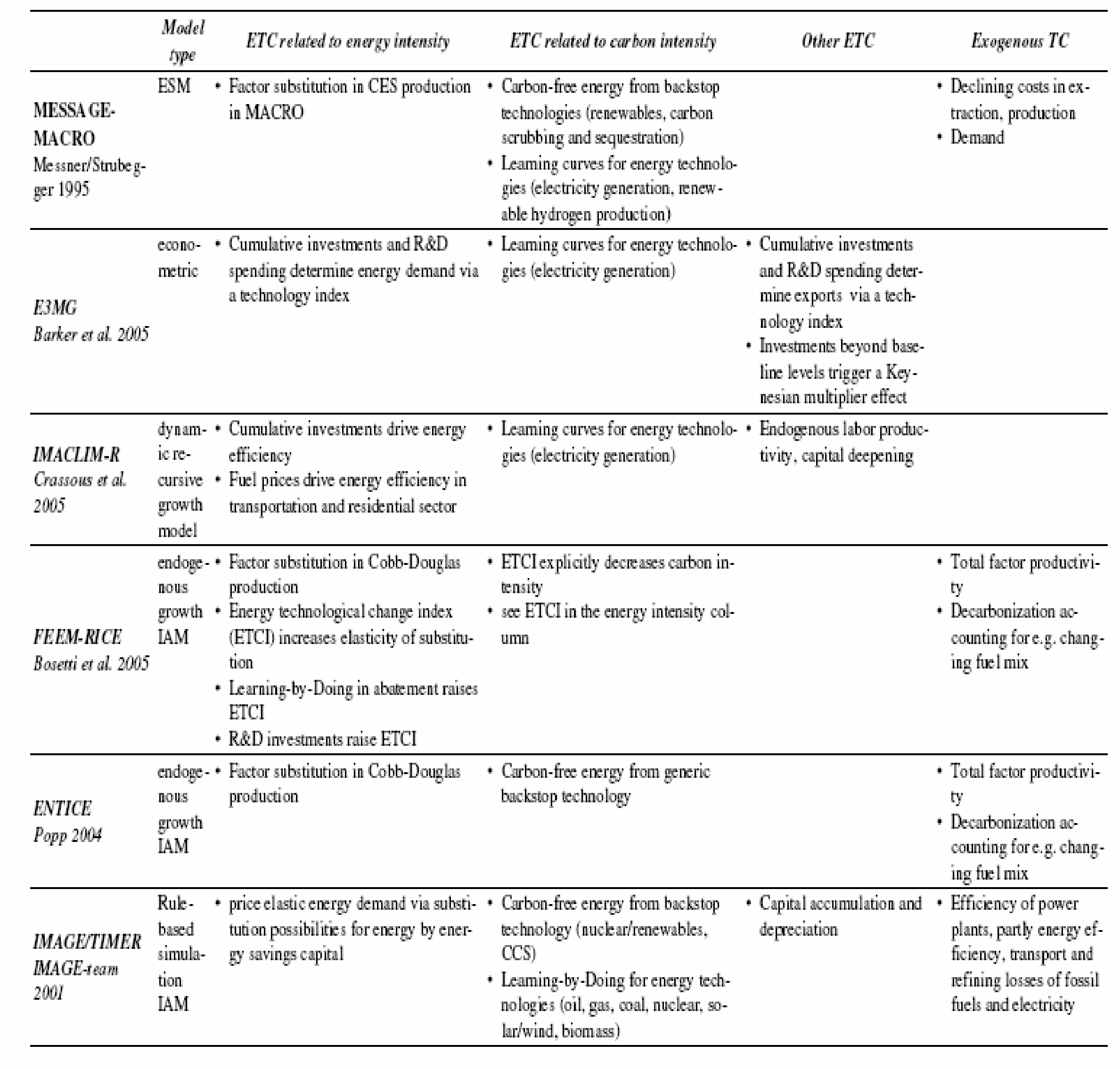


Figure 2.3.1 The dynamic nature of the climate change process. The squares are decision nodes, with arrows indicating the wide range of actions. The circles are outcome nodes, with wide range of potential consequences



	Model type	*ETC related to energy intensity*	*ETC related to carbon intensity*	*Other ETC*	*Exogenous TC*
MESSAGE-MACRO Messner/Strubegger 1995	ESM	• Factor substitution in CES production in MACRO	• Carbon-free energy from backstop technologies (renewables, carbon scrubbing and sequestration) • Learning curves for energy technologies (electricity generation, renewable hydrogen production)		• Declining costs in extraction, production • Demand
E3MG *Barker et al. 2005*	econometric	• Cumulative investments and R&D spending determine energy demand via a technology index	• Learning curves for energy technologies (electricity generation)	• Cumulative investments and R&D spending determine exports via a technology index • Investments beyond baseline levels trigger a Keynesian multiplier effect	
IMACLIM-R *Crassous et al. 2005*	dynamic recursive growth model	• Cumulative investments drive energy efficiency • Fuel prices drive energy efficiency in transportation and residential sector	• Learning curves for energy technologies (electricity generation)	• Endogenous labor productivity, capital deepening	
FEEM-RICE *Bosetti et al. 2005*	endogenous growth IAM	• Factor substitution in Cobb-Douglas production • Energy technological change index (ETCI) increases elasticity of substitution • Learning-by-Doing in abatement raises ETCI • R&D investments raise ETCI	• ETCI explicitly decreases carbon intensity • see ETCI in the energy intensity column		• Total factor productivity • Decarbonization accounting for e.g. changing fuel mix
ENTICE *Popp 2004*	endogenous growth IAM	• Factor substitution in Cobb-Douglas production	• Carbon-free energy from generic backstop technology		• Total factor productivity • Decarbonization accounting for e.g. changing fuel mix
IMAGE/TIMER *IMAGE-team 2001*	Rule-based simulation IAM	• price elastic energy demand via substitution possibilities for energy by energy savings capital	• Carbon-free energy from backstop technology (nuclear/renewables, CCS) • Learning-by-Doing for energy technologies (oil, gas, coal, nuclear, solar/wind, biomass)	• Capital accumulation and depreciation	• Efficiency of power plants, partly energy efficiency, transport and refining losses of fossil fuels and electricity

Figure 2.3.2. *The scientific decision model goes from left to right*

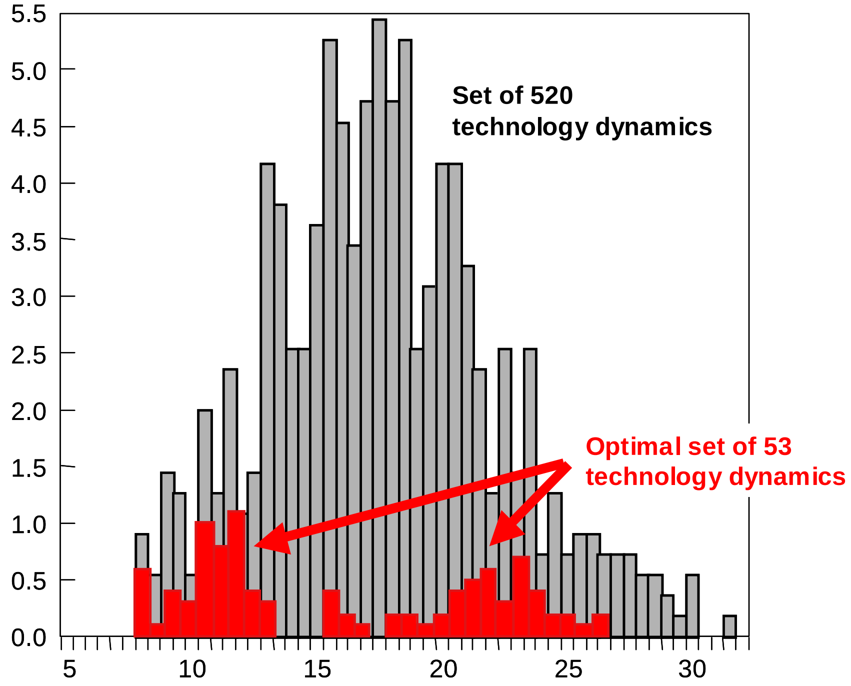


Figure 2.9.1. *Emissions impacts of exploring the full spectrum of technological uncertainty in a given scenario without climate policies. Relative frequency (percent) of 130,000 scenarios of full technological uncertainty regrouped into 520 sets of technology dynamics with their corresponding carbon emissions (GtC) by 2100 obtained through numerical model simulations for a given scenario of intermediary population, economic output, and energy demand growth. Also shown is a subset of 13,000 scenarios grouped into 53 sets of technology dynamics that are all "optimal" in the sense of statisfying a cost minimization criterion in the objective function. The corresponding distribution function is bi-modal, illustrating "technological lock-in" into low or high emissions futures respectively that arise from technological interdependence and spillover effects. Baseline emissions are an important determinant for the feasibility and costs of achieving particular climate targets that are ceteris paribus cheaper with lower baseline emissions. Source: Adapted from Gritsevskyi and Nakicenovic, 2000.*

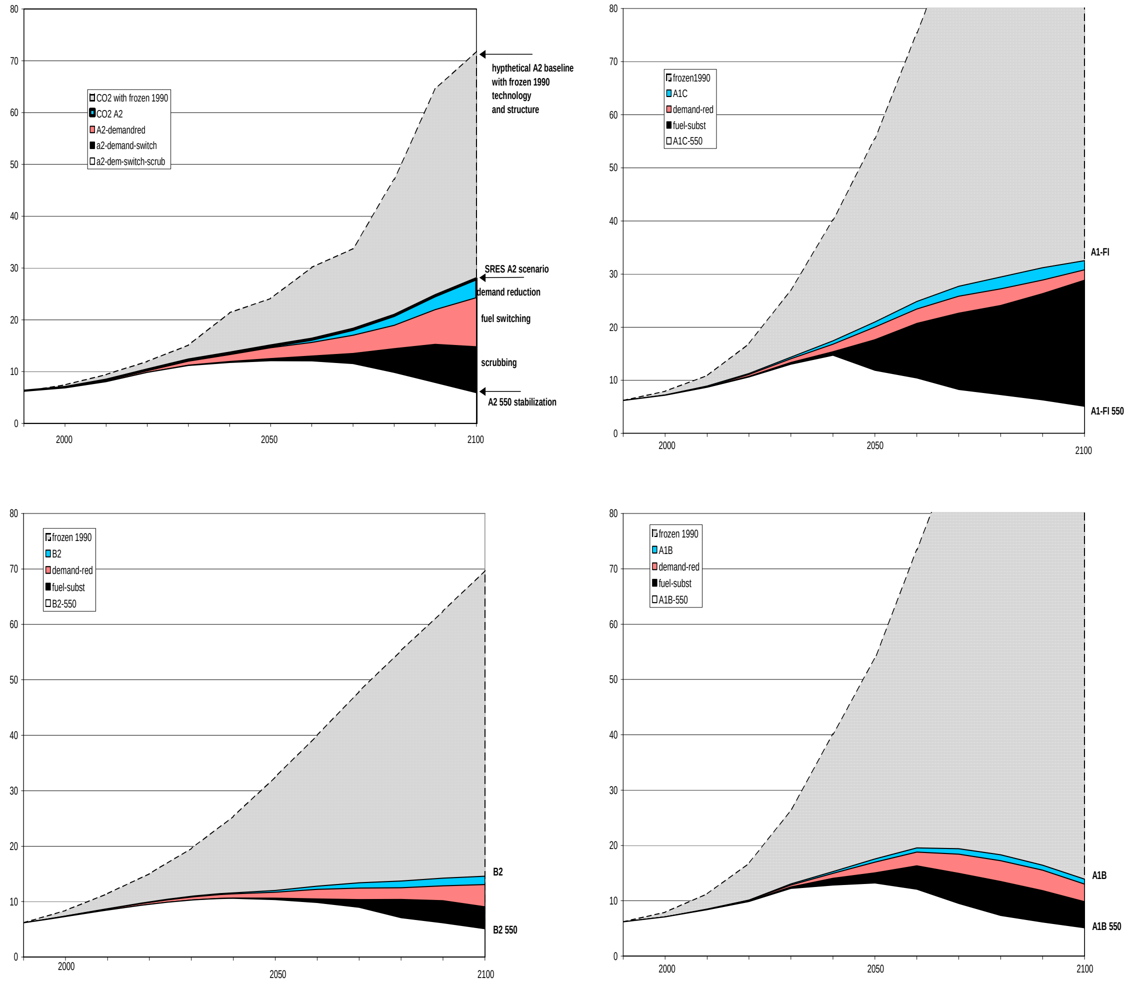


Figure 2.9.2. *Impact of technology on global carbon emissions in reference and climate mitigation scenarios. Global carbon emissions (GtC) in four scenarios developed within the IPCC SRES and TAR (A2, B2 top and bottom of left panel; A1FI and A1B top and bottom of right panel). Grey shaded area indicated the difference in emissions between the original no-climate policy reference scenario compared with a hypothetical scenario assuming frozen 1990 energy efficiency and technology, illustrating the impact of technological change incorporated already into the reference scenario. Color shaded areas show the impact of various additional technology options deployed in imposing a 550 ppmv CO2 stabilization constraint on the respective reference scenario including energy conservation (blue), substitution of high-carbon by low- or zero-carbon technologies (orange), as well as carbon capture and sequestration (black). Of particular interest are the two A1 scenarios shown on the right hand side of the panel that share identical (low) population and (high) economic growth assumptions making thus differences in technology assumptions more directly comparable. Source: Adapted from SRES (2000), TAR (2001), Riahi and Roehrl (2001), and Edmonds (2004).*

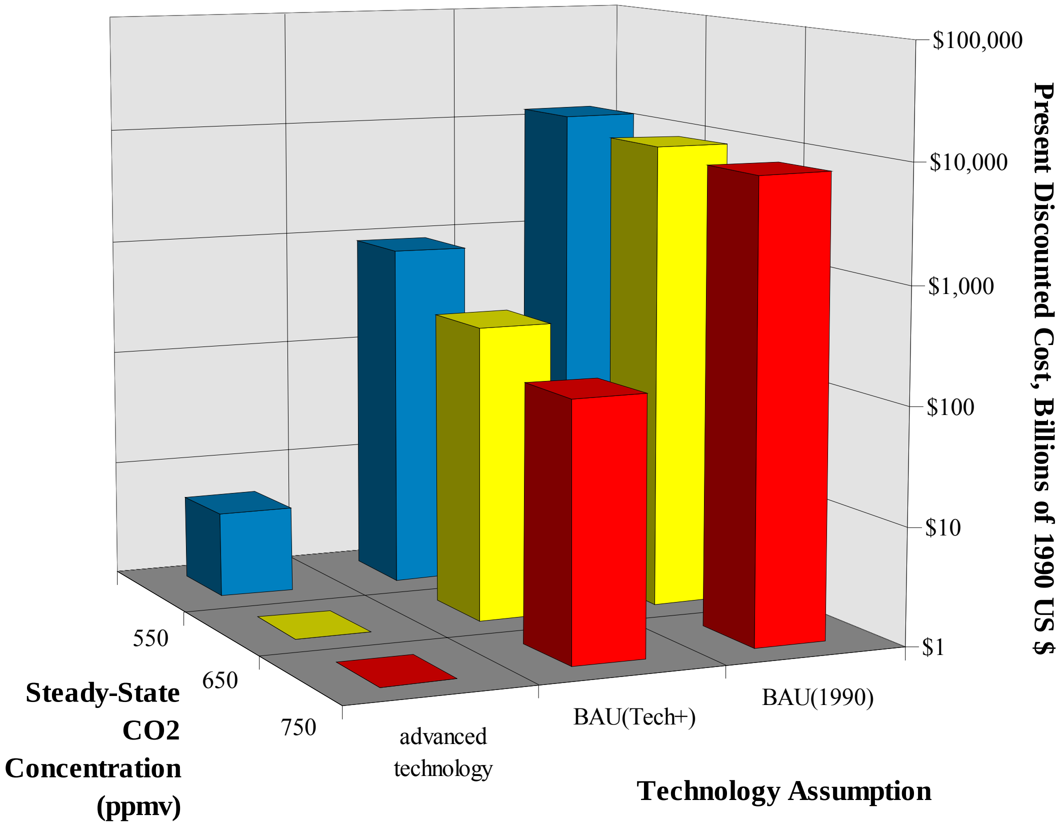


Figure 2.9.3. *Impact of technological change assumptions on costs of alternative stabilization (750, 650, and 550 ppmv) scenarios. Costs are total discounted (at XX percent) systems costs over the period 1990 to 2100. For each of the three stabilization targets, three alternative technology scenarios are shown. Two reference (BAU) scenarios one with frozen 1990 technologies (BAU-1990), one with "business as usual" rates of technological change (BAU-Tech+) and one scenario assuming accelerated development and deployment of low emissions and carbon capture technologies ("advanced technology" scenario). The results confirm the critical importance of technological change in determining future costs of energy supply and of climate stabilization that emerge as robust finding from a number of scenario and modeling studies). While feasibility and costs of future technologies remain inherently uncertain, modeling studies help to assess the relative importance for costs and for emissions reduction of new technologies that can guide technology development strategies and subsequent niche market deployment strategies that are important preconditions for subsequent improvements in economics and for large-scale diffusion. Source: adapted from Edmonds et al. (1997).*

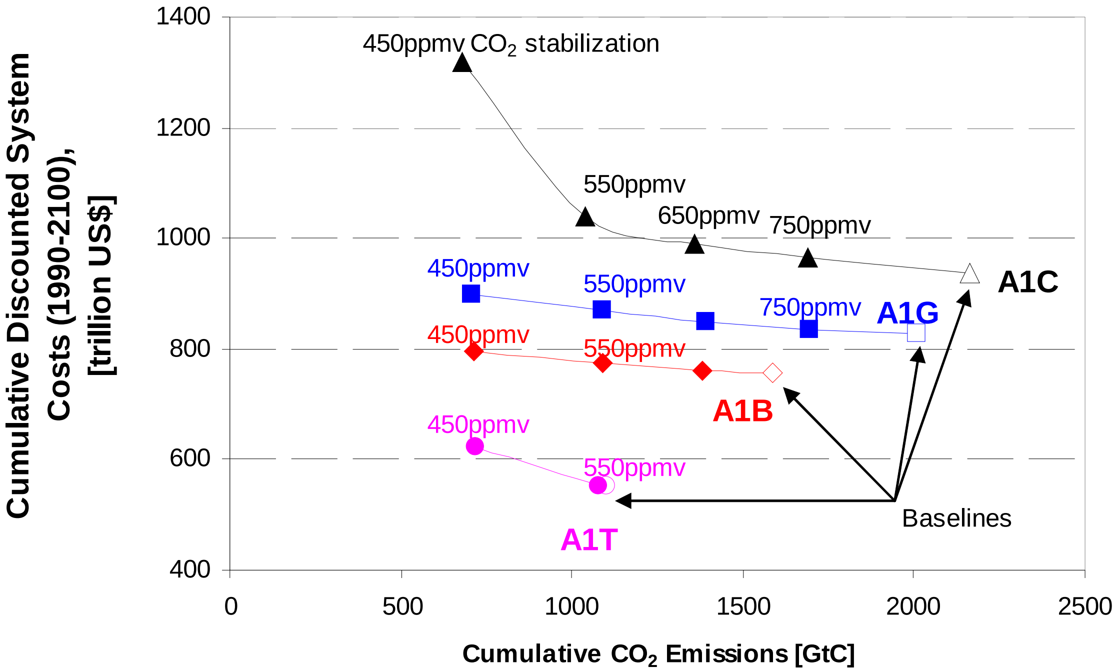


Figure 2.9.4. *The impacts of different technology assumptions on energy systems costs on emissions (cumulative 1990-2100 CO2 emissions in GtC) in no-climate policy baseline (reference) scenarios and on the costs of alternative stabilization targets. Total cumulative (1990-2100) undiscounted total energy systems costs (in trillion 1990$) in four scenario based on the SRES A1 scenario family, shown here for better comparability as sharing identical assumption concerning future population and economic growth. Also shown are corresponding total cumulative costs of scenarios meeting increasingly stringent stabilization targets (at 750, 650, 550 and 450 ppmv respectively). For comparison: the total cumulative (undiscounted) GDP of the scenarios is around 30,000 trillion US$ over the 1990-2100 time period. The cost difference across the scenarios are dominated by baseline uncertainties. Compared to that the cost differences between alternative stabilization targets (with exception of the A1C-450 stabilization scenario) is much smaller. Costs of stabilization increase also non-linearly with the stringency of the stabilization target adopted. Ceteris paribus, the higher the rates of technological change particularly in low-carbon technologies are in any particular scenario, the lower future emissions even in absence of climate policies and the lower the costs of achieving any given stabilization target. These results suggest the importance of technology policies in lowering future "baseline" emissions in order to enhance feasibility, flexibility, and economics of meeting alternative stabilization targets that due to persistent uncertainty cannot be determined at the present. Source: Roehrl and Riahi (2002).*

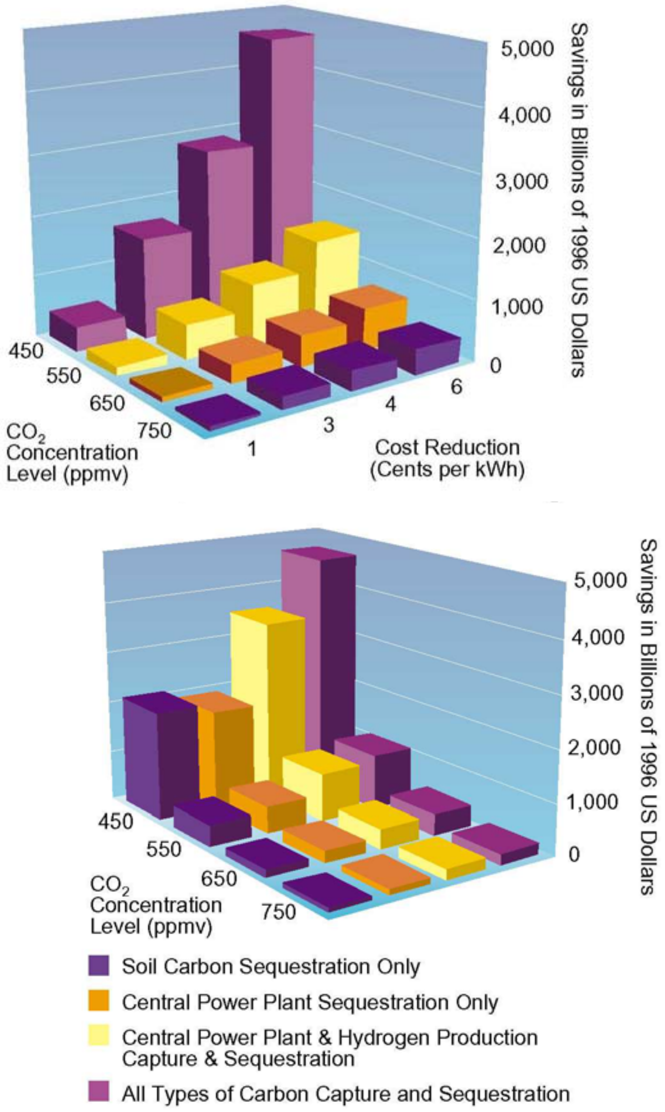


Figure 2.9.5. *The value of improved technology. Modeling studies enable to calculate the economic value of technology improvements that increase particularly drastically with increasing stringency of stabilization targets (750, 650, 500, and 450 ppmv respectively) imposed upon a reference scenario (modeling after the IS92a scenario in this particular modeling study). Detailed model representation of technological interdependencies and competition and substitution is needed for a comprehensive assessment of the economic value of technology improvements. Top panel: cost savings (billions of 1990 US$) compared to the reference scenario when lowering the costs of solar photovoltaic from a reference value of 9 US cents per kWh (top) by 1, 3, 4, and 6 cents/kWh respectively. For instance the value of reducing PV costs from 9 to 3 cents per kWh could amount to up to 1.5 trillion Dollars in an illustrative 550 ppmv stabilzation scenario compared to the reference scenario in which costs remain at 9 cents/kWh). Bottom panel: cost savings resulting from availability of an ever larger and diversified portfolio of carbon capture and sequestration technologies. For instance, adding soil carbon sequestration to the portfolio of carbon capture and sequestration technology options reduces costs by 1.1 trillion Dollars in an illustrative 450 ppmv stabilization scenario. Removing all carbon capture sequestration technologies would triple the costs of stabilization for all concentration levels analyzed. Source: GETS (2001).*

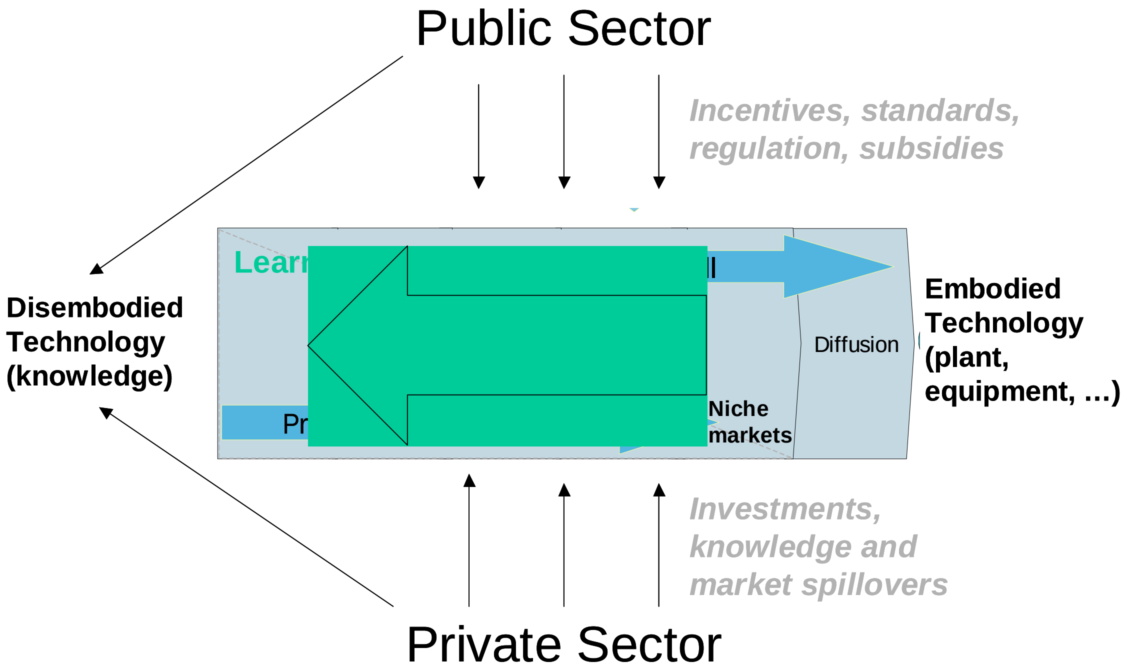


Figure 2.9.6. Describing the technology development cycle and its main driving forces. Note that important overlaps and feedbacks exist between the stylized technology life-cycle phases illustrated here and therefore the Figure does not suggest a "linear" model of innovation. It is important to recognize the need for finer terminological distinction of "technology", particularly when discussion different mitigation and adaptation options. Source: Adapted from Foxon (2003) and Grubb (2005).

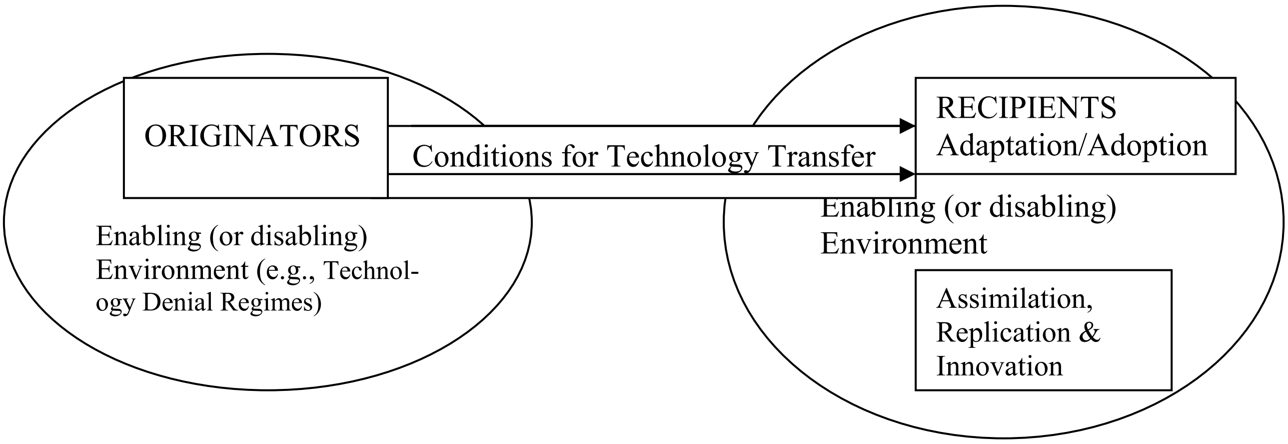


***Figure 2.9.7**. A General Framework for Technology Transfer*