

Integrating Climate Change Policies into Sustainable Development Strategy - Applying the Sustainomics Framework

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WHY ? is climate important for future development
Climate Change undermines Sustainable
Development and unfairly penalizes the poor



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Study long term CC-SD circular interaction using
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HOW ? do we trace CC-SD links and make development
more sustainable (MDMS)
Study CC-SD circular interaction using the
Sustainomics framework

WHAT? are the practical analytical tools and policy
options to integrate CC responses into SD
strategy (from global to local levels)
Many case studies and examples of good
practice are available

Why CC is important for SD

Key Motivations for Seeking More Sustainable Development Paths

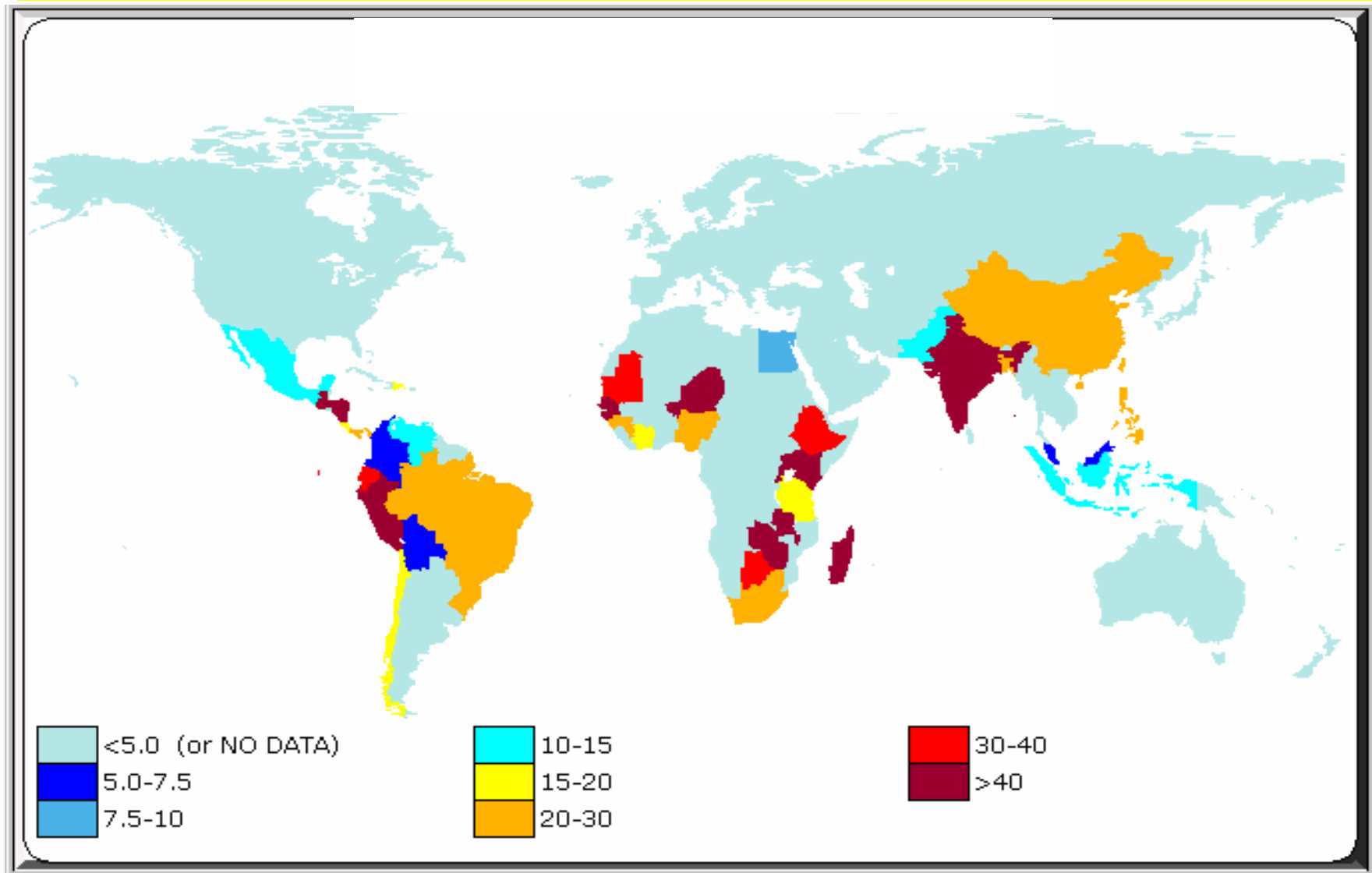


Motivation 1: Sustainable Development will be harmed by Climate Change, especially in Developing Countries

The **sustainable development challenge** is to:

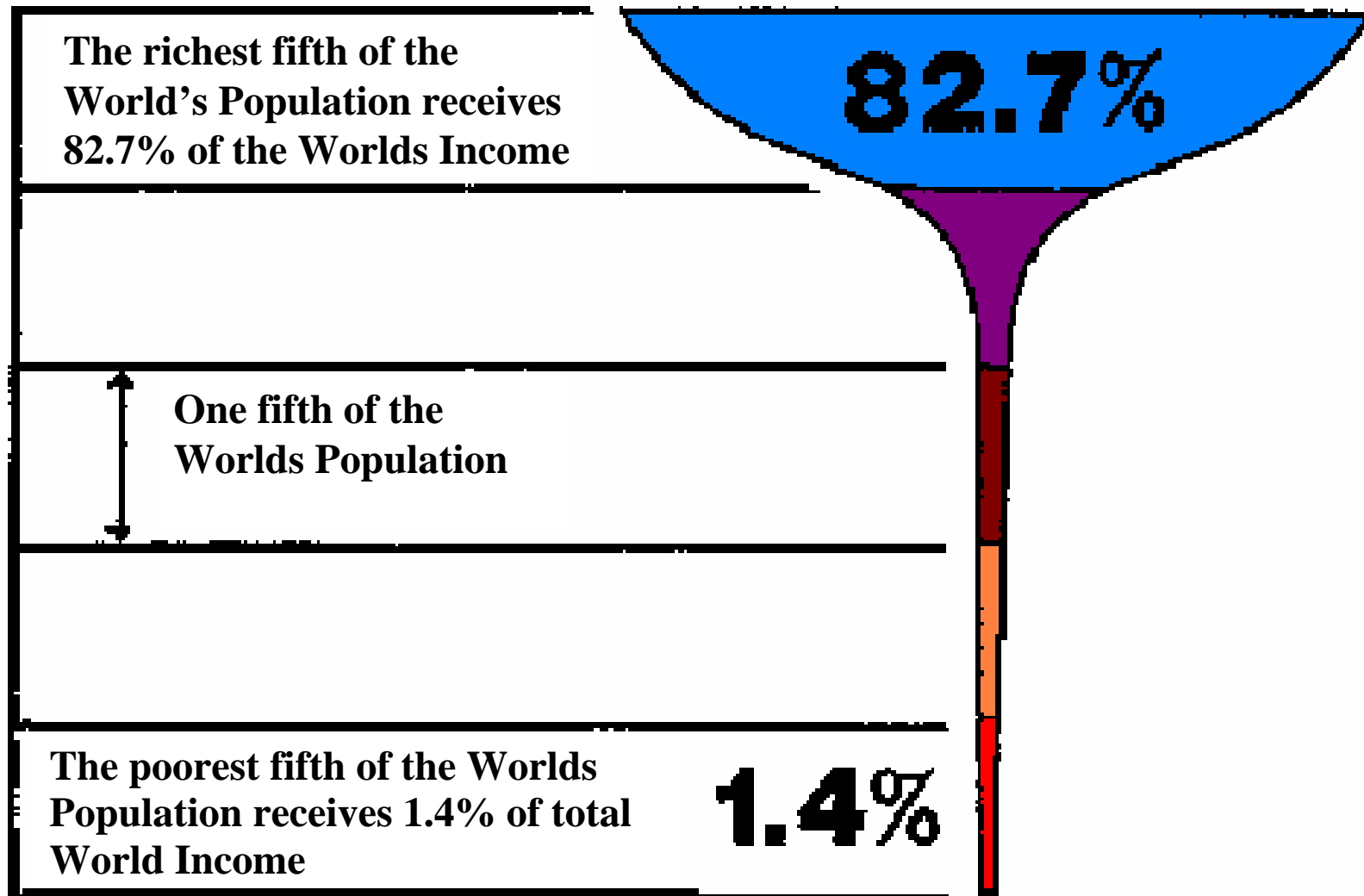
- **alleviate poverty** for the 1.3 billion people who live on less than \$1 per day and the 3 billion people who live on less than \$2 per day
- provide adequate **food**, especially for the 800 million people who are malnourished today—this will require food production to double in the next 35 years without further environmental degradation, e.g., deforestation
- provide **clean water** for the 1.3 billion people who live without clean water and provide sanitation for the 2 billion people who live without sanitation
- provide **energy** for the 2 billion people who live without electricity
- provide a **healthy environment** for the 1.4 billion people who are exposed to dangerous levels of *outdoor pollution* and the even larger number exposed to dangerous levels of *indoor air pollution and vector-borne diseases*
- provide **safe shelter** for those that live in areas susceptible to civil strife due to environmental degradation and those vulnerable to natural disasters

POVERTY: Poor living on < \$1 per day



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EQUITY: World Income Distribution - Champagne Glass



Motivation 2:

CC & SD Major agreements: Poverty/Equity focus

1. UNCED 1992: Rio Earth Summit

- Rio Declaration of Principles
- Agenda 21
- UNFCCC

2. Millennium Development Goals 2000: UN

3. WSSD Goals 2002: Johannesburg Summit

4. Millennium Development Summit 2006: UN



Millennium Development Goals (MDG)

United Nations Millennium Declaration, 2000

- Eradicate extreme poverty and hunger
- Achieve universal primary education
- Promote gender equality and empowerment
- Reduce child mortality
- Improve maternal health
- Combat HIV/AIDS, malaria and other diseases
- Ensure environmental sustainability
- Develop a global partnership for development

Commendable targets, but most are unlikely to be achieved



Motivation 3:

UN Framework Convention on Climate Change 1992

Article 2

Stabilize atmospheric GHG concentrations to prevent ‘dangerous’ anthropogenic interference in the climate system:

- enable **economic development** to proceed in a sustainable manner
- ensure **food production** is not threatened
- allow **ecosystems** to adapt naturally

UNFCCC also speaks of “**common but differentiated responsibilities**”

Adaptation Burden & Equity: CC → SD

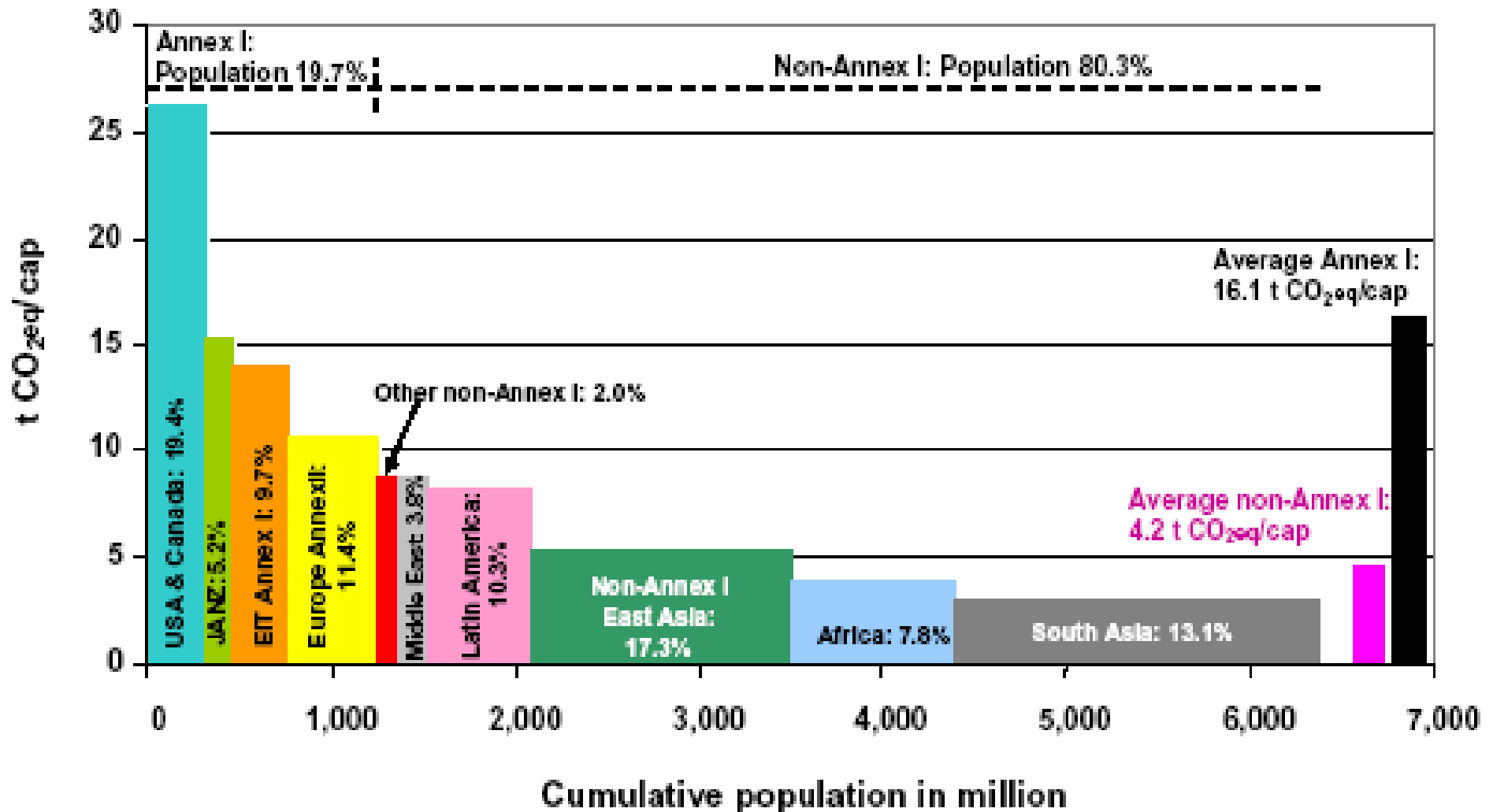
Developing countries are most vulnerable to climate change

- **Climate change is likely to impact disproportionately upon the poorest countries and the poorest persons within all countries**, exacerbating inequities in health status and access to adequate food, clean water and other resources.
- **Net economic effects will be negative in most developing countries**
- **Impacts will be worse** - many areas are already flood and drought prone, and economic sectors are climate sensitive
- **Lower capacity to adapt** because of a lack of financial, institutional and technological capacity, and access to knowledge



Mitigation Responsibility & Equity: SD → CC

Per capita GHG emissions and population 2004



Motivation 4:

Global Long Term Perspectives

- **Lessons of History**
- **Future Scenarios**



Sustainability & Resource Use: Historical view

DURABLE USE OF RESOURCES

- Nile Basin (Egypt)
Pharaonic system lasted over 4000 years, with sustainable resource use and reasonable quality of life
- Yellow River Basin (China)
Imperial system was stable for many millenia, and supported flourishing society
- Saraswati River (India)
Hosted a flourishing civilisation for 4000 years. River eventually dried up due to tectonic activity, climate change and desertification, and water piracy.

OVEREXPLOITATION OF RESOURCES

- Sahara Desert
Once green with many animals and hunters. Over-exploitation led to a drier habitat which could no longer sustain these populations



Recent lesson of late 19th century holocausts - relevance to Globalization & Climate Change

- 18th century – Brazil, China and India had quality of life comparable with Europe.
- 19 century – Colonial rule trapped developing country small farmers were into exporting cash crops at ever decreasing terms of trade. Growing trade led to falling grain output and rising food insecurity.
- Late 19th century – Two El Nino draughts 1876-78 & 1898-1901 killed tens of millions due to food vulnerability and famine. The developing world is still unable to catch up after this setback.
- **Future globalization and climate change could interact like colonial trade expansion and El Nino, BUT on a worldwide scale** – Potential for future starvation and death on global scale due to vulnerability of the poor, unless a new vision based on SD emerges.



Some Long Term Global Scenarios

MAIN SCENARIOS

1. Barbarization

2. Conventional

3. Transition

**Likely Actual Future
(BAU)**

VARIANTS

**Breakdown
Fortress World**

**Market Driven
Policy Reform**

**New Sustainability
Eco-Communalism**

Mix of above scenarios

Source: Adapted from Global Scenario Group (2000)



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Barbarization

Unrestrained market forces increase risk of conflict (erosion of ethical & moral underpinnings of civilization)

Climate Change

Environmental degradation
Social polarization
Terrorism

Break-down

Conflict and rivalry
overwhelms all efforts
to impose order

Fortress World

Regional and international actors
respond to protect their interests
and create alliances

Introduction to Climate Change

Brief Overview of IPCC

AR4 Main Findings:

**Risk to Sustainable
Development**



IPCC Assessment Process

IPCC was created in 1988 by WMO and UNEP

Three assessment reports have been prepared already, and progressively improved our understanding of climate change:

1. Climate Change 1990
2. Climate Change 1995
3. Climate Change 2001

IPCC reports review the **most recent and critical scientific information**. They are policy relevant but not policy prescriptive.



IPCC Fourth Assessment Report (AR4)

Three Main Working Groups:

I. Science of Climate Change

II. Impacts, Adaptation and Vulnerability

III. Mitigation

Synthesis Report

Task Force on National Greenhouse Gas Inventories

Several hundred lead authors write the report, while over 2000 leading scientists worldwide, are involved in reviewing and editing the AR4.



IPCC AR4 – Summary of Main Findings

- **Global warming is unequivocal. Total radiative forcing of the climate now is unprecedented in several thousand years, due to rising concentrations of GHG (CO₂, CH₄ & NO₂).**
- **Humans activities since the 18th century are very likely to have caused net warming of Earth's climate, dominating over the last 50 years. Further climate change is inevitable without actions to reduce GHG emissions**
- **There is confidence that models provide useful projections of future climate change, especially at global scales. They explain observed features of recent and past climate changes.**
- **Poor countries and poorest groups will be the most vulnerable to climate change impacts. Most socio-economic sectors, ecological systems and human health will be adversely affected.**
- **Adaptation measures are available, but must be systematically developed**
- **Mitigation technologies are also available but better policies and measures (PAM) are needed to realize their potential.**
- **Making development more sustainable (MDMS) by integrating climate change policy into sustainable development strategy is an effective strategy**

Main Findings: Changes in Climate, Effects & Causes

- **Unequivocal warming of climate system** – including increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level. {WGI, SPM}
- **Regional changes** in many physical and biological systems on all continents and in some oceans are consistent with warming. {WGII 1.3}
- **During 1970-2004, global total annual anthropogenic GHG emissions have grown 70%.** Atmospheric concentrations of CO₂, CH₄ and N₂O now far exceed pre-industrial values spanning many thousands of years. {WGI SPM; WGIII 1.3}
- **Anthropogenic GHG increases *very likely* the cause of most of global average warming over past 50 years,** and it is *likely* that there is **discernible human induced warming** averaged over every continent except Antarctica. {WGI 9.4, SPM}
- Over the past 30 years, global scale anthropogenic warming has *likely* discernibly influenced observed **changes in many physical and biological systems.** {WGII 1.4, SPM}

Main Findings: CC Drivers, Projections & Impacts - 1

- **Global GHG emissions will grow, and temperature rise of $\sim 0.2^{\circ}\text{C}$ per decade is projected for next 20 years**, for range of SRES emission scenarios. { WGIII 3.2, WGI 10.3, 10.7, SPM }
- Many changes in global climate system during the 21st century would *very likely* be larger than 20th century changes, with continued GHG emissions at or above current rates. {WGI 10.3, 11.1, SPM}
- All future scenarios predict **more warming of land** than adjacent oceans and more in **northern high latitudes**. {WGI 10.3, 11.1, SPM}
- More anthropogenic emissions will remain in the atmosphere, since warming tends to reduce terrestrial ecosystem and ocean uptake of atmospheric CO₂. {WGI 7.3, 10.4, 10.5, SPM}
- Under any scenario, **warming and sea level rise would continue for centuries**, due to lags and feedbacks in climate processes. {WGI 10.7, SPM}
- Equilibrium climate sensitivity is *very unlikely* less than 1.5°C . {WGI 8.6, 9.6, Box 10.2, SPM}



Main Findings: CC Drivers, Projections & Impacts - 2

- **Vulnerable people** are especially the poor, children and elderly, worldwide.
- **Vulnerable sectors** are low-lying coasts, water resources in dry tropics and subtropics, agriculture in low-latitude regions, some ecosystems, and human health in areas with low adaptive capacity.
- **Vulnerable regions** are the Arctic, sub-Saharan Africa, small islands and Asian megadeltas. Within other regions, some people, areas and activities can be particularly at risk. {WGII TS.4.5}
- Greater frequencies and intensities of **extreme weather events** are *very likely* to increase impacts. Some sectors and regions (including developed countries) are vulnerable to **heat waves and tropical cyclones**. {WGII Table SPM.2, 19.3}



Main Findings: Adaptation & Mitigation Responses - 1

- **Present adaptation levels must improve** to reduce vulnerability to higher levels and rates of warming. {WGII 17.ES, 20.5, Table 20.6, SPM}
- Long term unmitigated climate change would be *likely* to exceed the capacity of natural managed and human systems to adapt. {WGII 20.7, SPM}
- Over the coming decades, **global emissions can be reduced below current levels using a wide range of mitigation options** available (currently or by 2030) in all sectors, at **costs from net negative up to 100 US\$/tCO₂-equivalent** {WGIII 11.3, SPM}
- **CO₂ stabilisation can be achieved** through currently available technologies or those that are to be commercialised through effective incentives. The lower the stabilisation levels, the greater the need for investment in new technologies and more R&D to improve technical performance, reduce costs, and achieve social acceptability. {WGIII 3.3, 3.4}



Main Findings: Adaptation & Mitigation Responses - 2

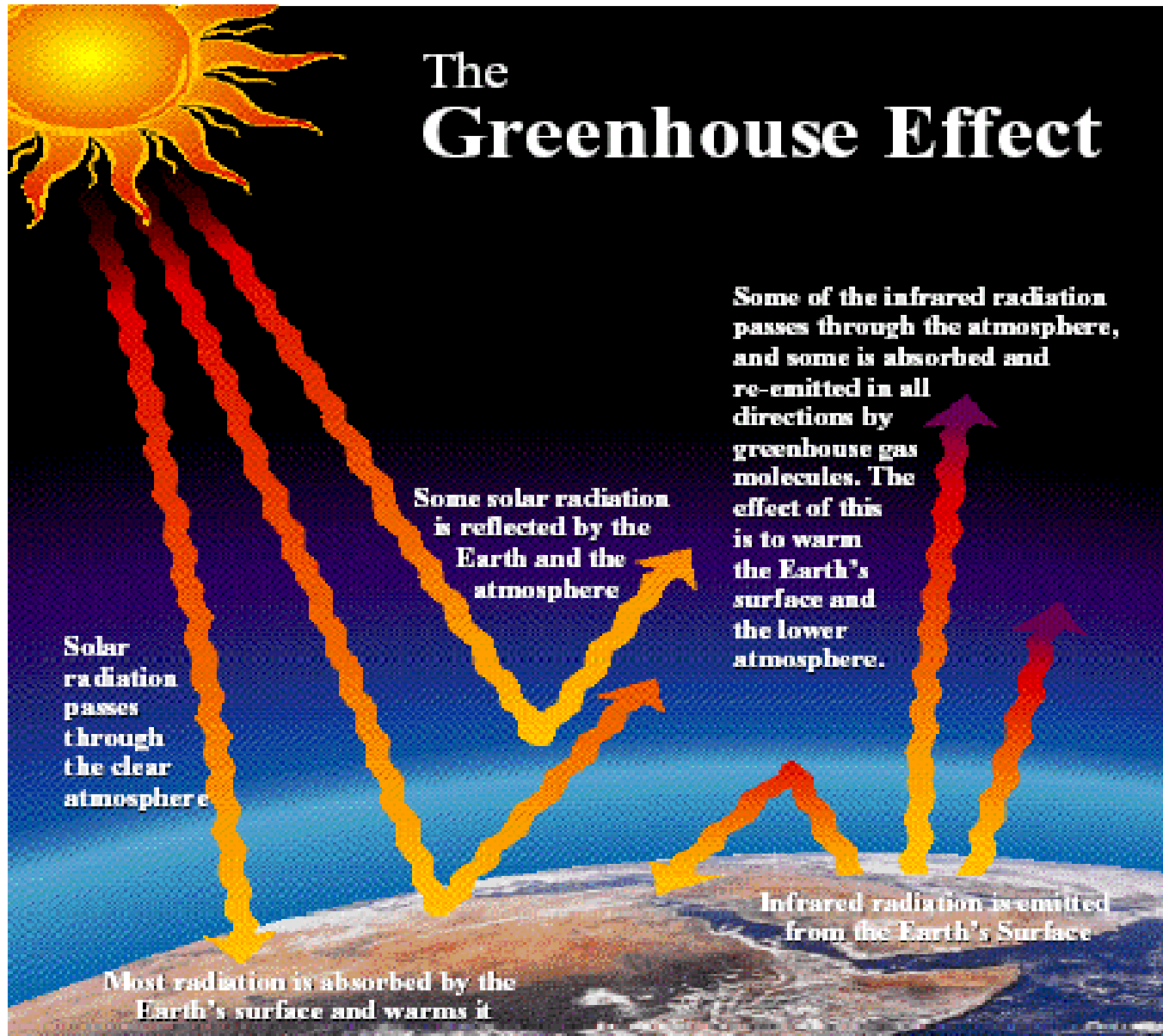
- **Risks of many major impacts on vulnerable systems significantly reduced with lowest stabilisation scenarios: 445-490 ppm, and equilibrium temperature increase of 2-2.4°C above pre-industrial. In these scenarios, global emissions must peak over the next decade and fall below 50% of current levels by 2050. {WGII Table 20.6; WGIII 3.3}**
- **Making development more sustainable (MDMS) by changing development paths can make a major contribution to climate change mitigation and adaptation and to reducing vulnerability. {WGII 18.7, 20.3, SPM; WGIII 13.2, SPM}**
- **Appropriate macro-economic and other policies that seem unrelated to climate change can significantly affect emissions. {WGIII 12.2}**



Evidence of Past and existing Climate Change



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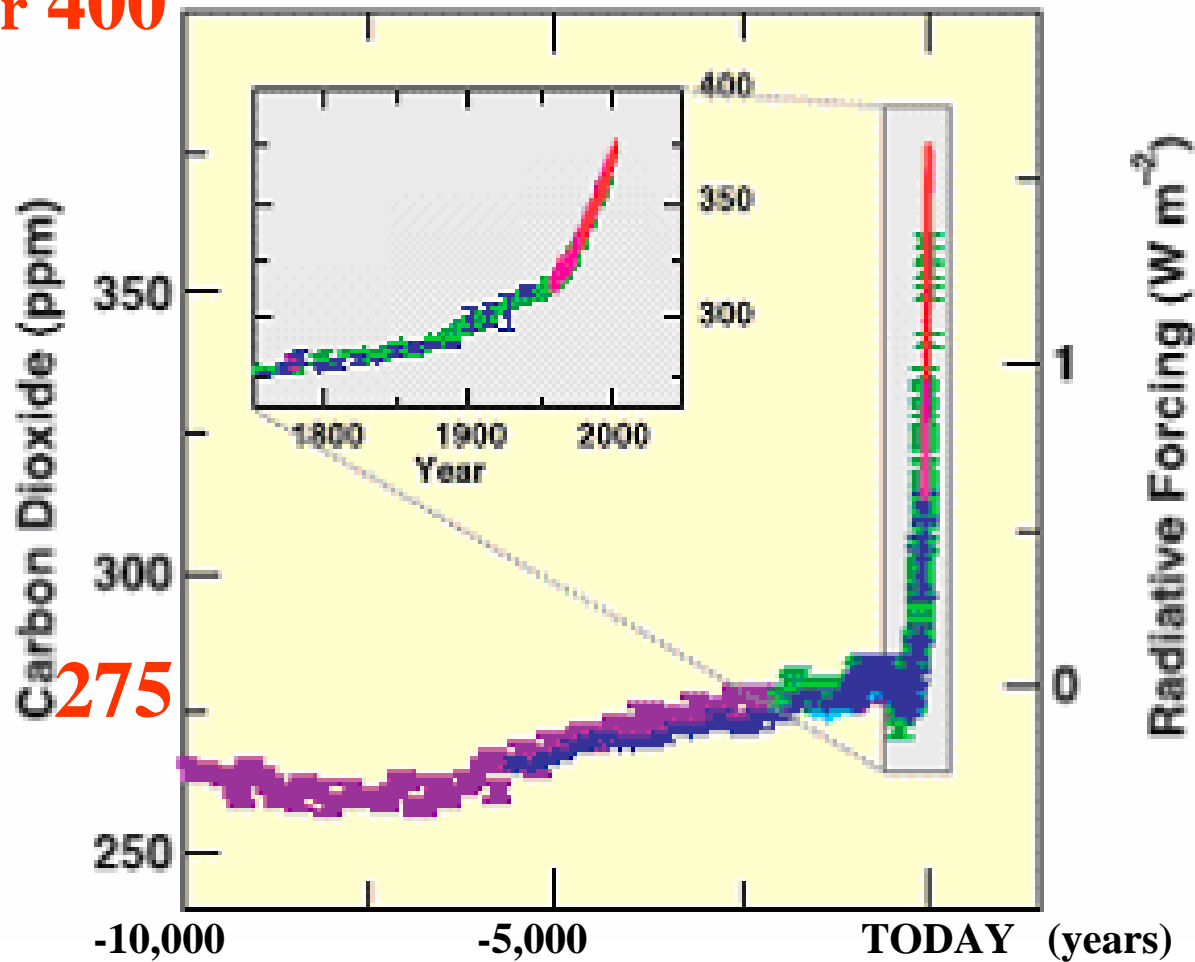


MAIN DRIVER

Changes in CO₂ from ice core and modern data

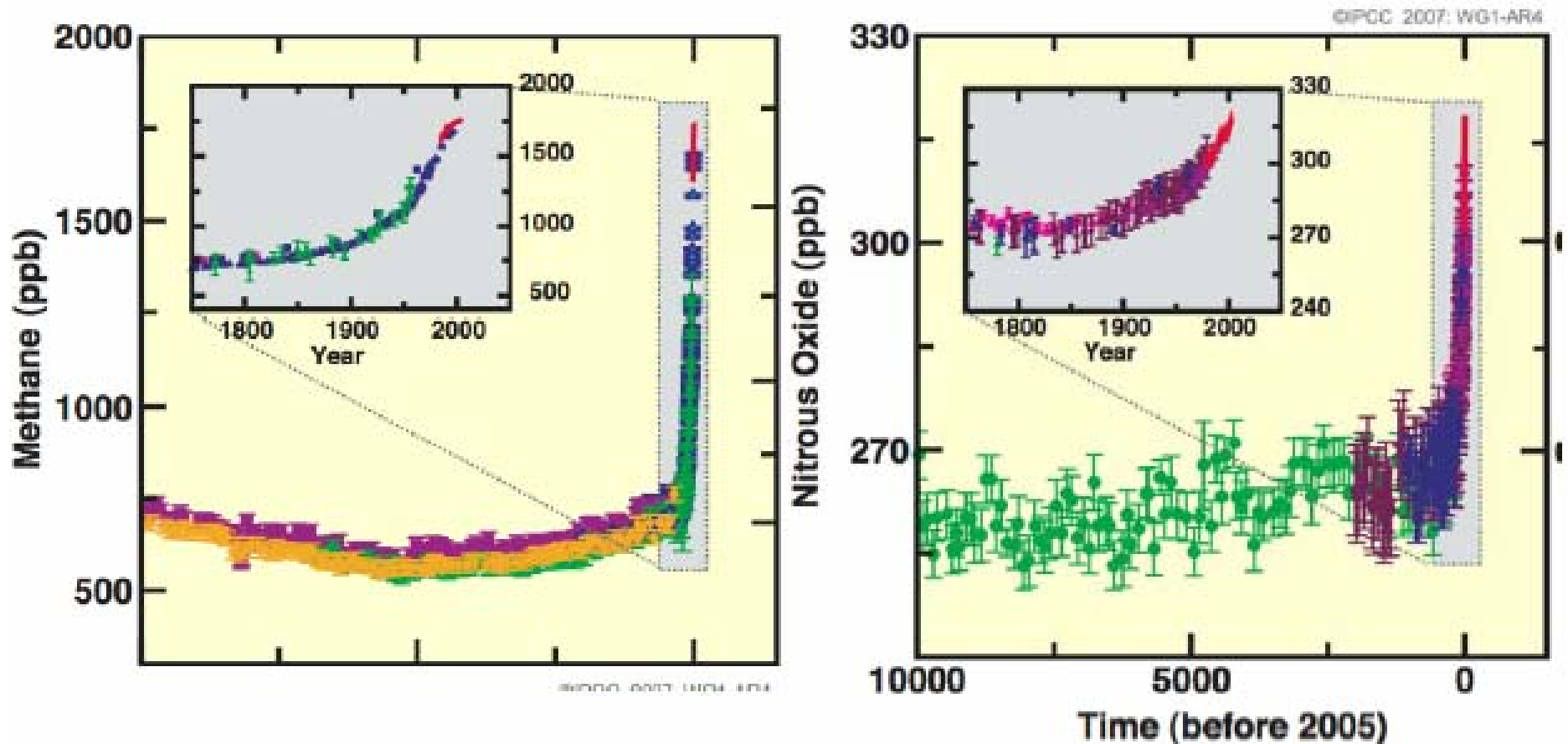
Now: near 400

Pre-ind: 275



OTHER DRIVERS

Changes in Methane, Nitrous Oxide & Aerosols



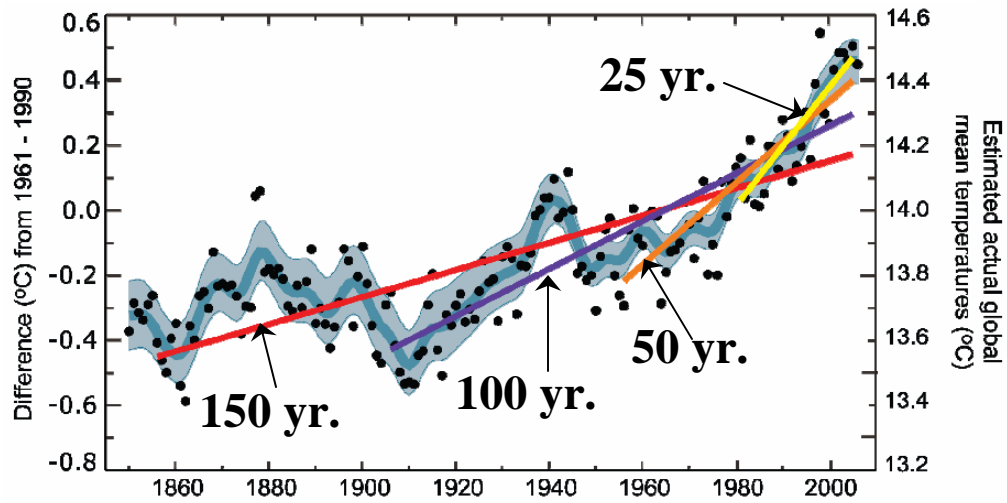
Note: Aerosols provide short term cooling effect

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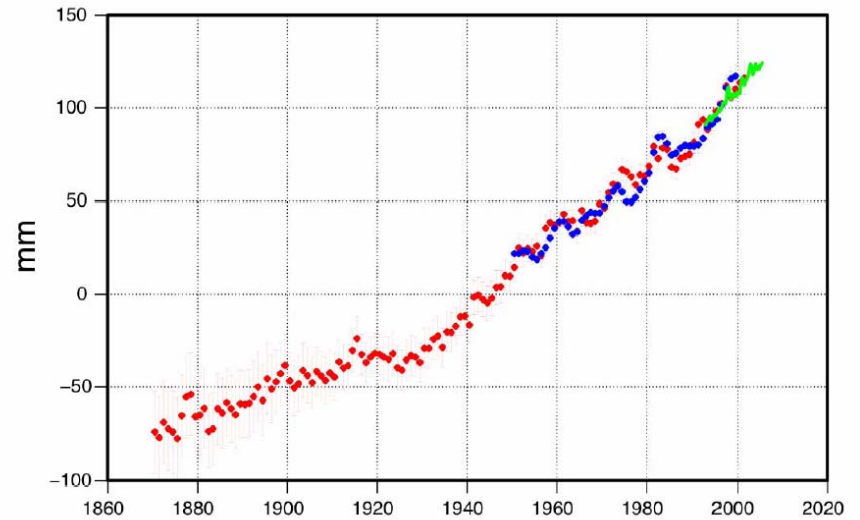
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RESULT: Mean temp, sea level and arctic ice cover

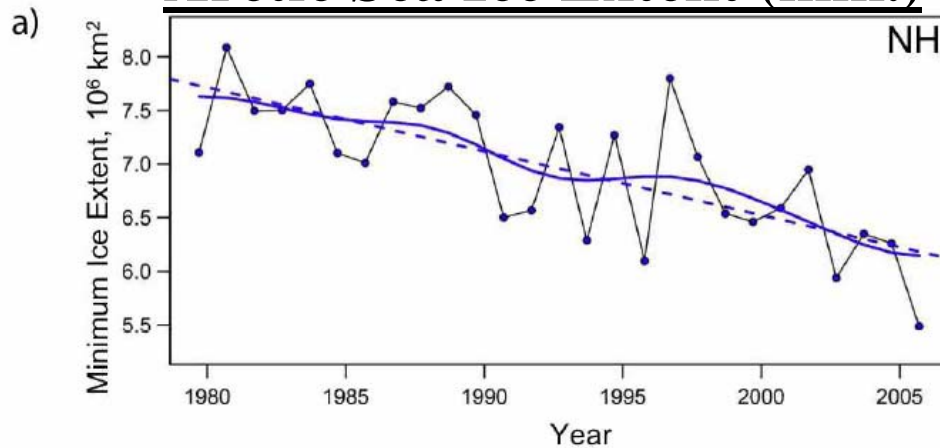
Mean Temperature



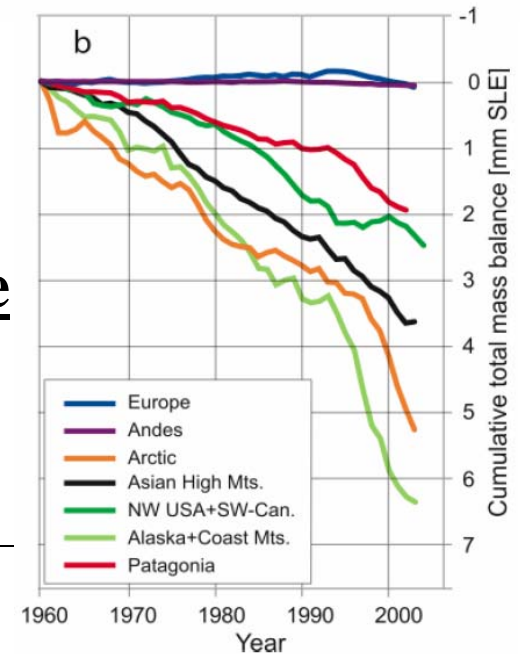
Mean Sea Level



Arctic Sea Ice Extent (min.)



Glacier Mass Balance



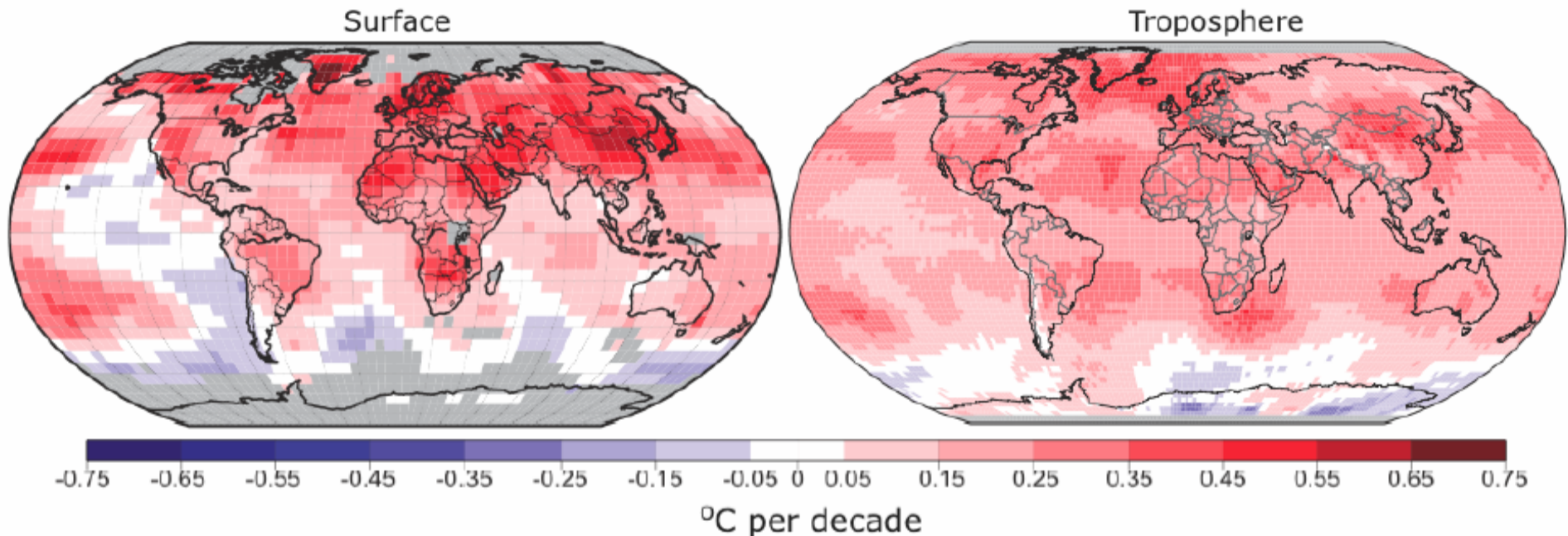
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Warming is Worldwide (2005)

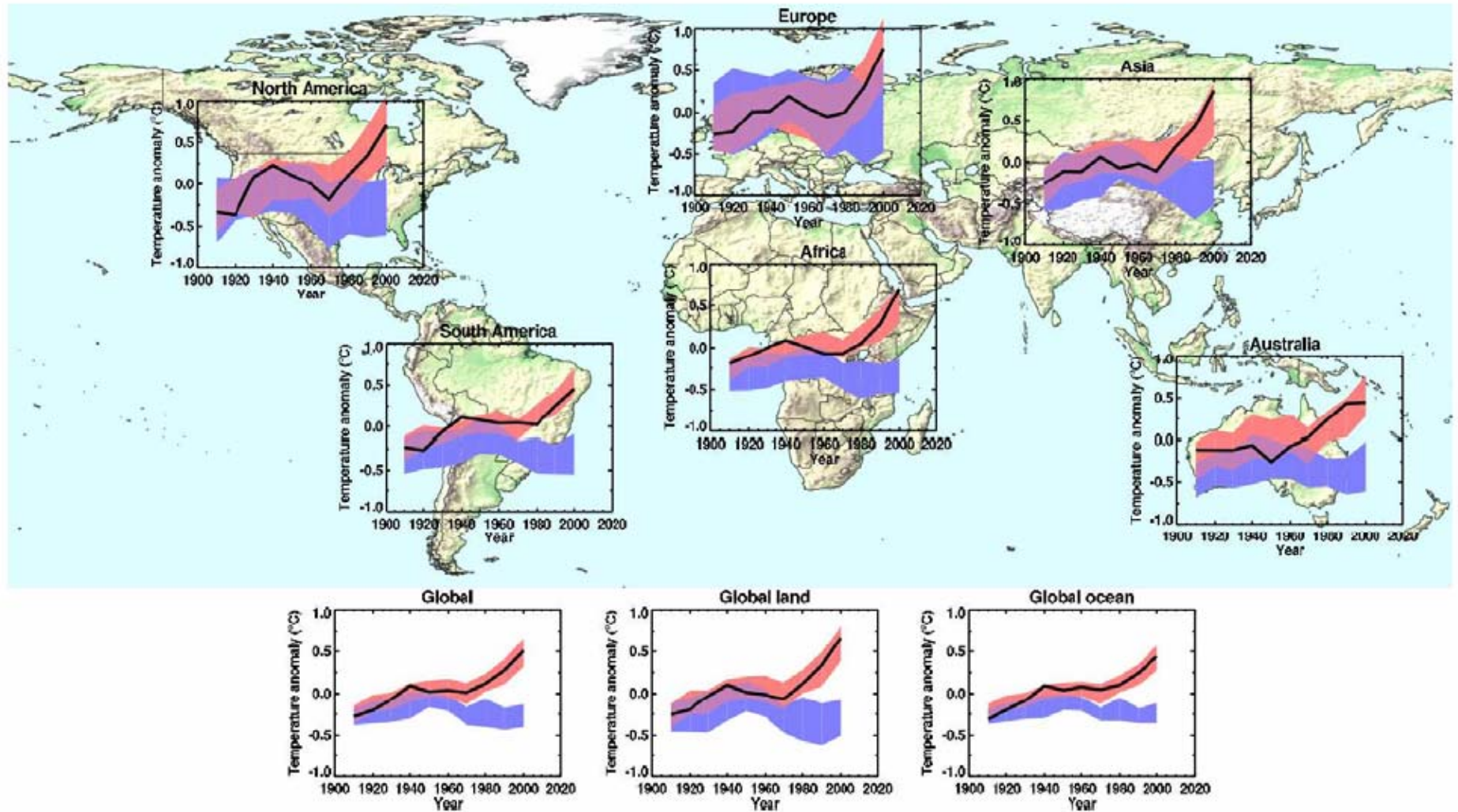
Warming trends since 1979 (when satellite measurements started) show:

- Warming everywhere at surface except in eastern Pacific, Southern Ocean and parts of Antarctica;
- Land warming significantly faster than ocean over last 20 years;
- Mid-troposphere warming consistent with that at surface.

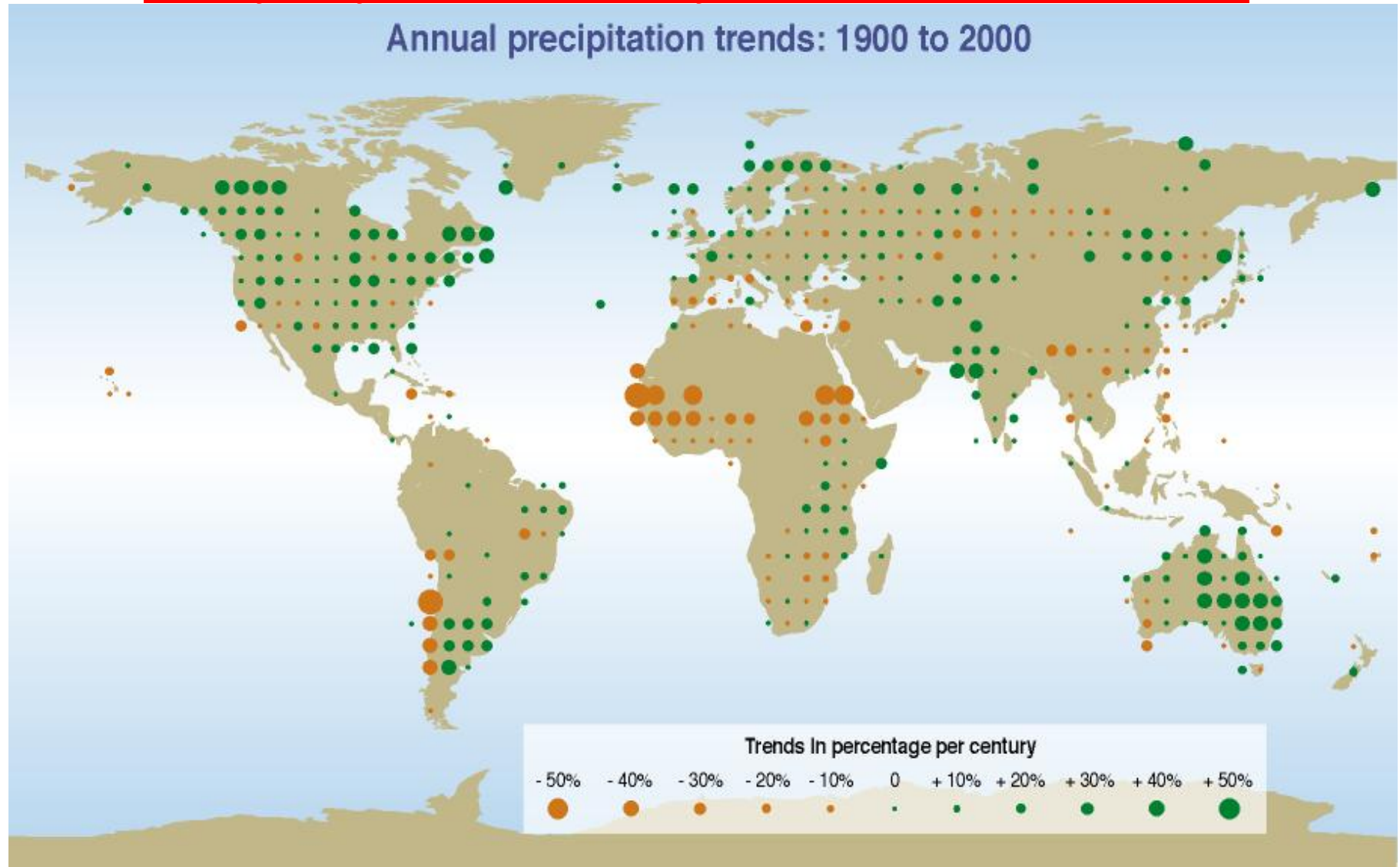


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Model results (red) accurately track worldwide actual temperature changes (black)

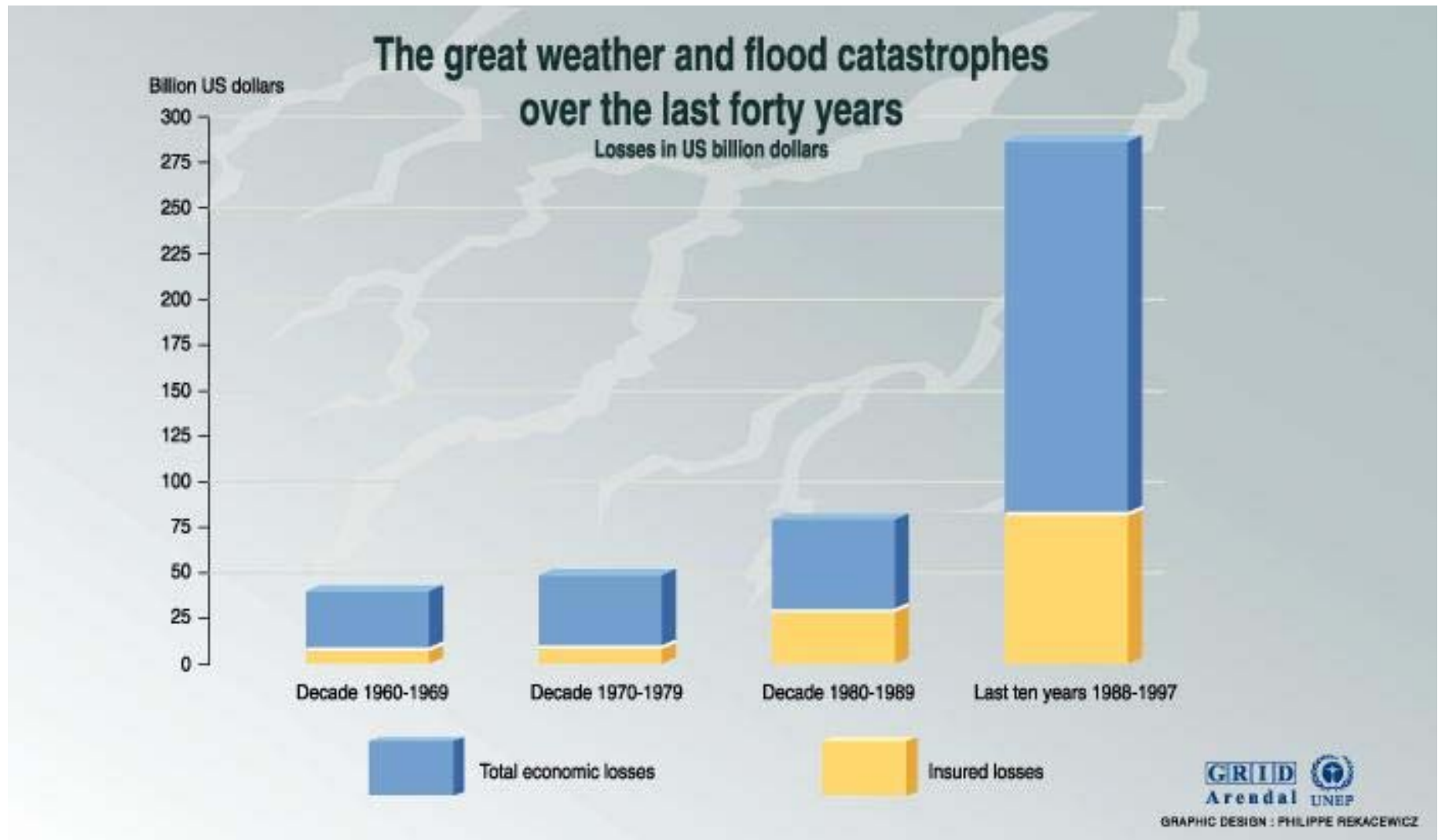


Precipitation patterns have changed many dry areas are dryer & wet areas wetter



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Extreme Weather Events – Economic Damage has Increased



Observed regional changes in climate, and in physical and biological systems

Examples include:

- non-polar glacier retreat
- reduction in Arctic sea ice extent and thickness in summer
- earlier flowering and longer growing and breeding season for plants and animals in N. Hemisphere
- poleward and upward (altitudinal) migration of plants, birds, fish and insects; earlier spring migration and later departure of birds in N. Hem.
- increased incidence of coral bleaching



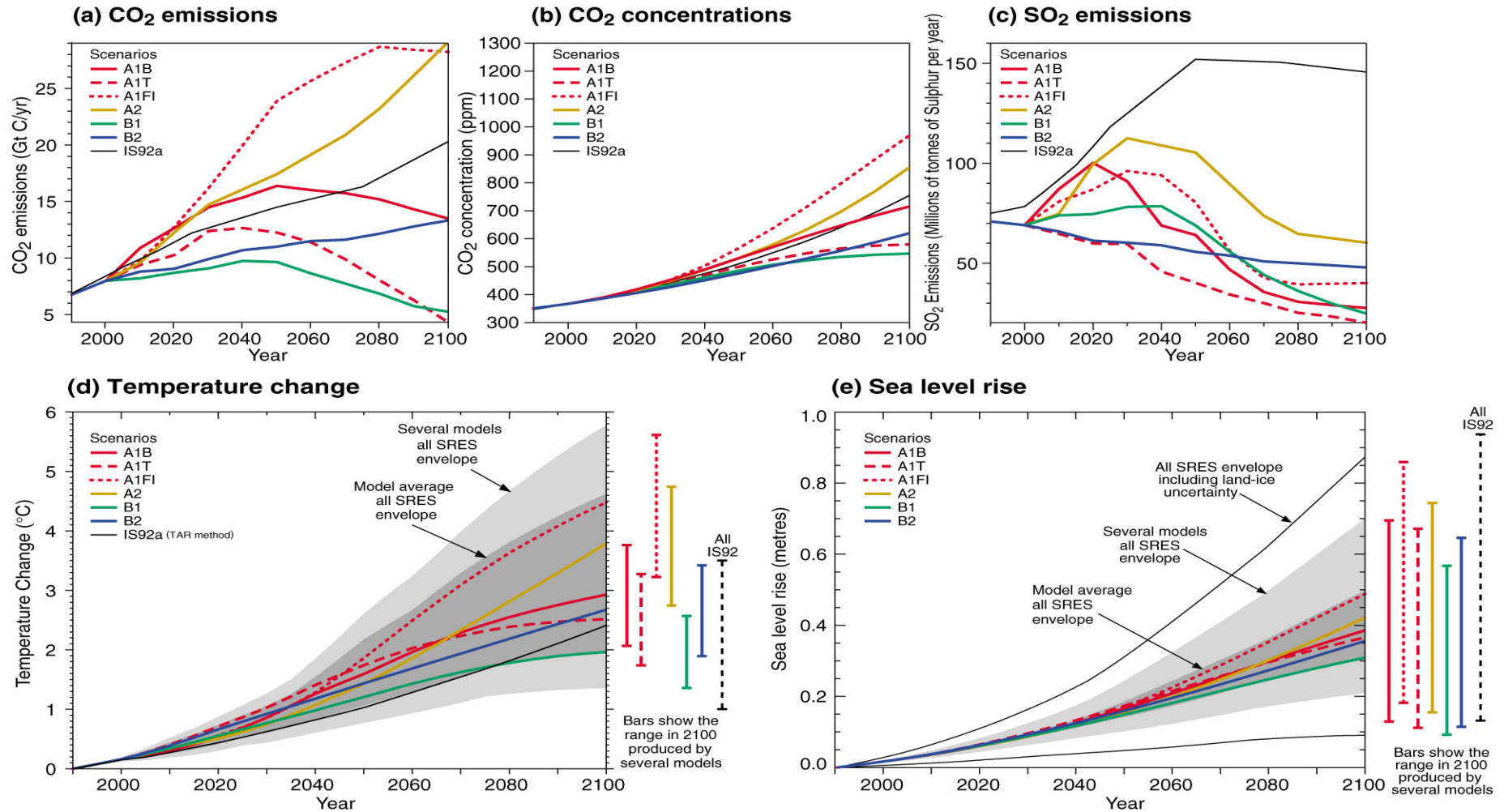
Predicting Future Climate Change



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The Global Climate of the 21st Century

GHG conc. 2-3 times pre-ind. level (275 ppmv) by 2100



Temp. rise ~3C (1.8 to 4) by 2100

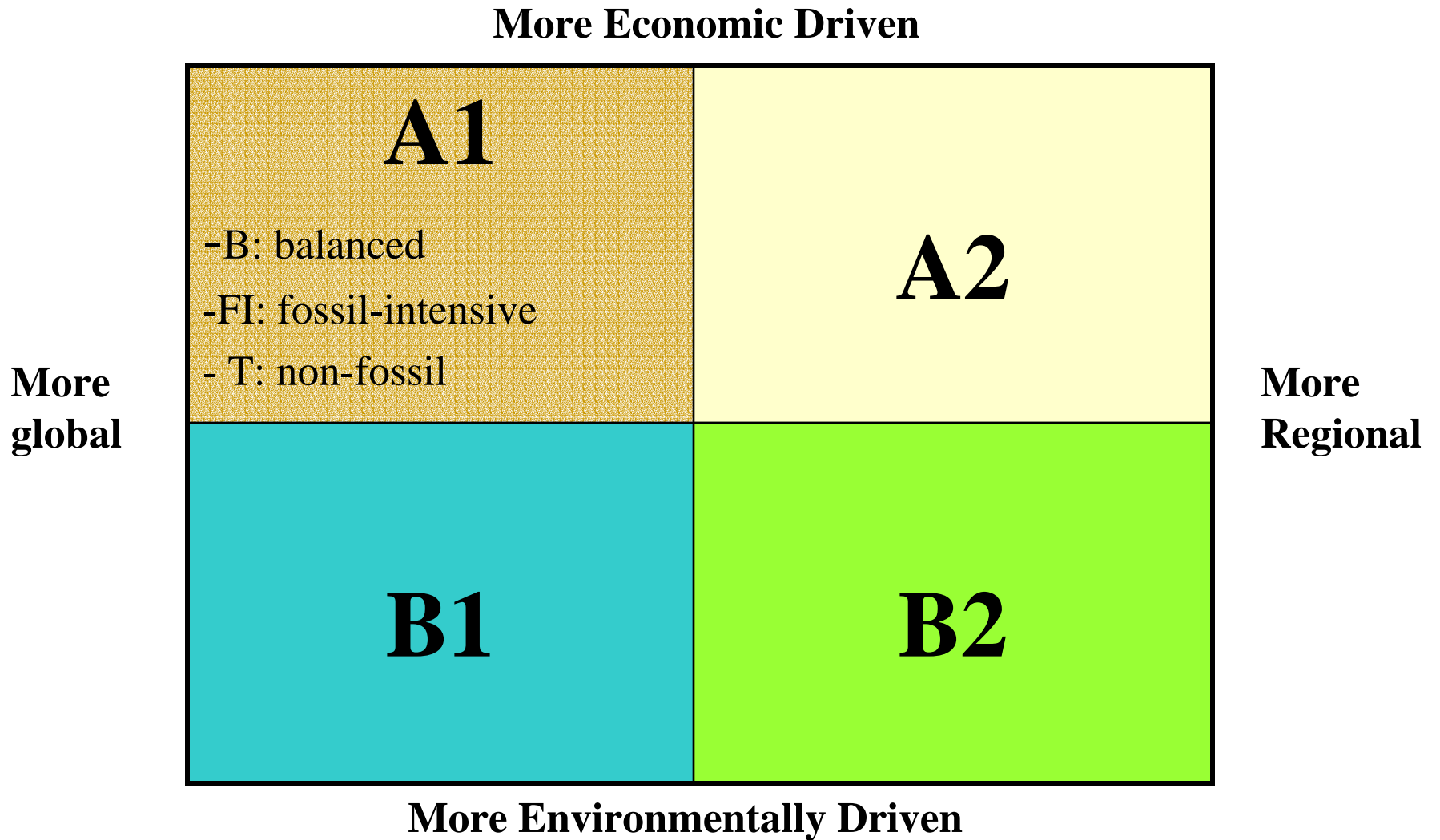
Sea level rise ~0.4m (0.2 to 0.6)

by 2100



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IPCC-SRES Scenarios of World Development



Scenario Assumptions

	1990	2100
• Population (billion)	5.3	7.0 - 15.1
• World GDP (10^{12} 1990US\$/yr)	21	235 - 550
• Per capita income ratio: developed countries to developing countries	16.1	1.5 - 4.2
• Final energy intensity (10^6 J/US\$) ^a	16.7	1.4 - 5.9
• Primary energy (10^{18} J/US\$)	351	514 - 2226
• Share of coal in primary energy (%) ^a	24	1 - 53
• Share of zero carbon in primary energy (%) ^a	18	28 - 35



Temp. (C) and Sea Level (m) Rise - 1990 to 2100

Case	Temperature Change (°C at 2090-2099 relative to 1980-1999) ^a		Sea Level Rise (m at 2090-2099 relative to 1980-1999)
	Best estimate	<i>Likely</i> range	Model-based range excluding future rapid dynamical changes in ice flow
Constant Year 2000 concentrations ^b	0.6	0.3 – 0.9	NA
B1 scenario	1.8	1.1 – 2.9	0.18 – 0.38
A1T scenario	2.4	1.4 – 3.8	0.20 – 0.45
B2 scenario	2.4	1.4 – 3.8	0.20 – 0.43
A1B scenario	2.8	1.7 – 4.4	0.21 – 0.48
A2 scenario	3.4	2.0 – 5.4	0.23 – 0.51
A1FI scenario	4.0	2.4 – 6.4	0.26 – 0.59

Range: 2 – 4 C

Range: 0.2 – 0.6 m



CC → SD

Developing countries are most vulnerable to climate change

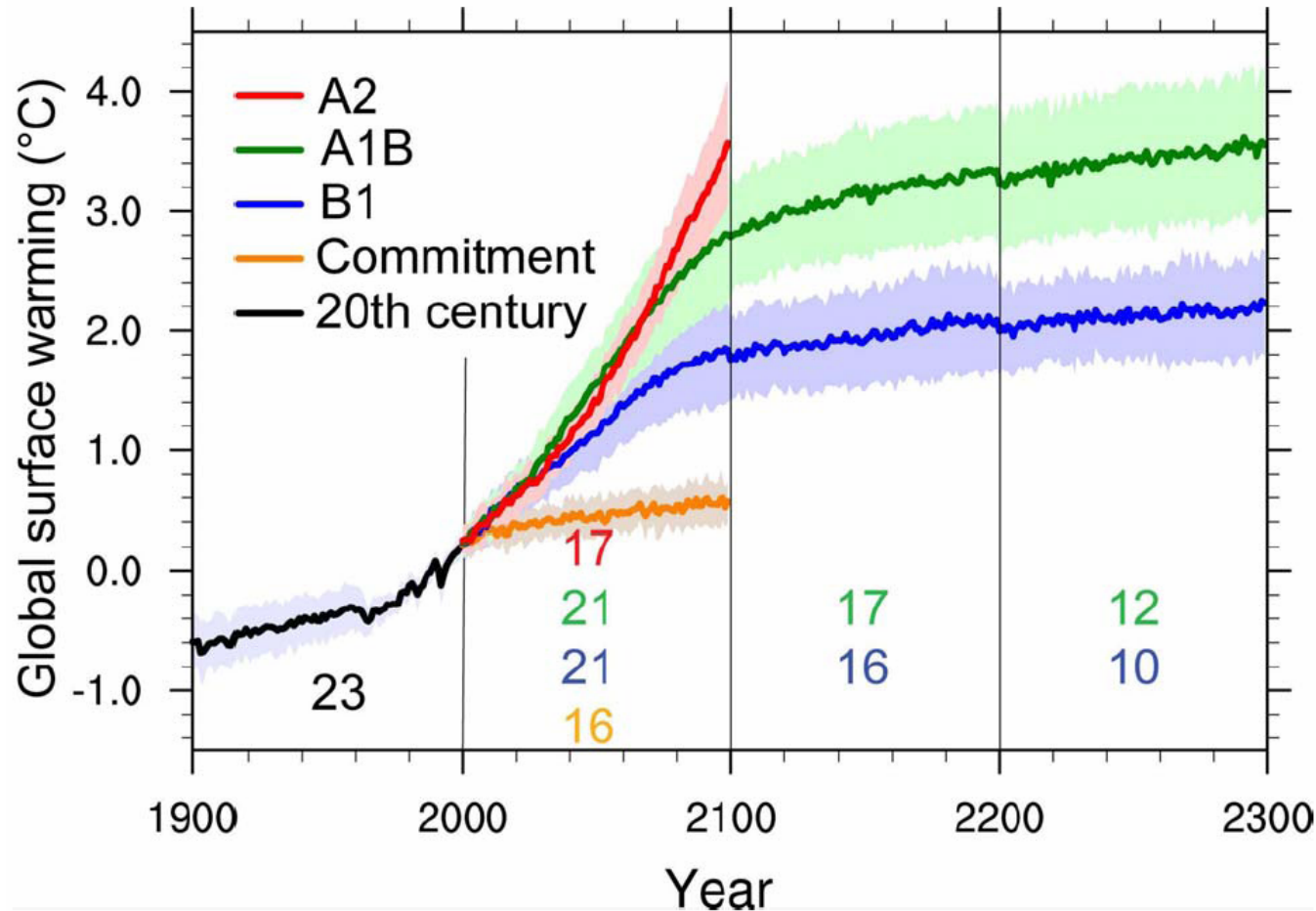
- **Climate change is likely to impact disproportionately upon the poorest countries and the poorest persons within countries**, exacerbating inequities in health status and access to adequate food, clean water and other resources.
- **Net market sector effects are expected to be negative in most developing countries**
- **Impacts will be worse** - many areas already flood and drought prone, and economic sectors are climate sensitive
- **Lower capacity to adapt** because of a lack of financial, institutional and technological capacity and access to knowledge



Projected Mean Global Temp.

orange = 2000 CO2 level

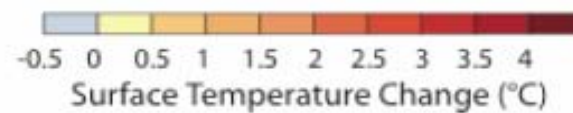
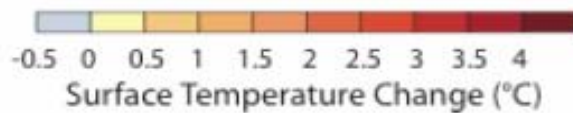
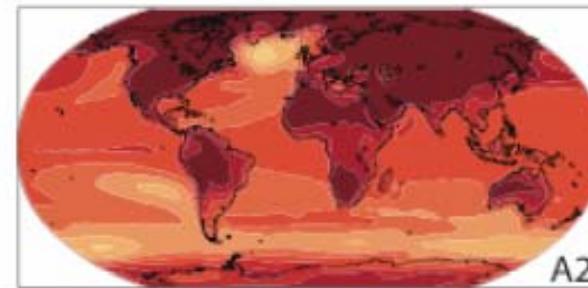
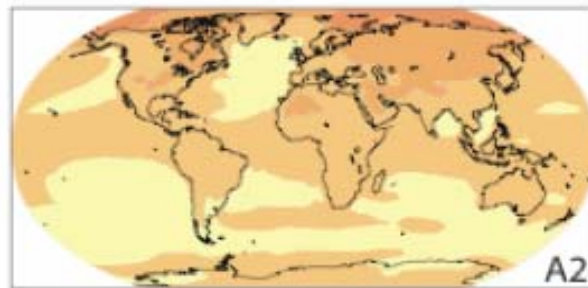
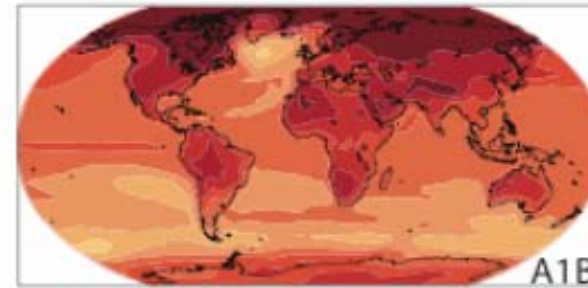
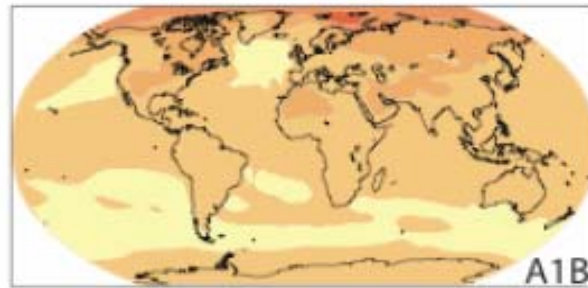
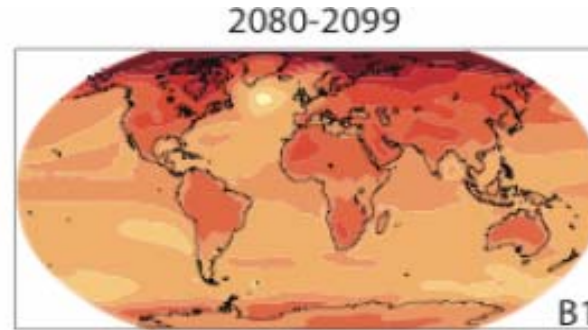
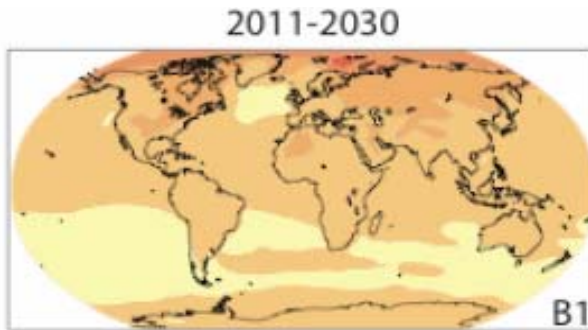
> 2 C temp. rise will occur whatever we do



Global Distribution of Mean Temp

Scenarios

**Polar
regions
worst
affected**



**B1 -
Best**

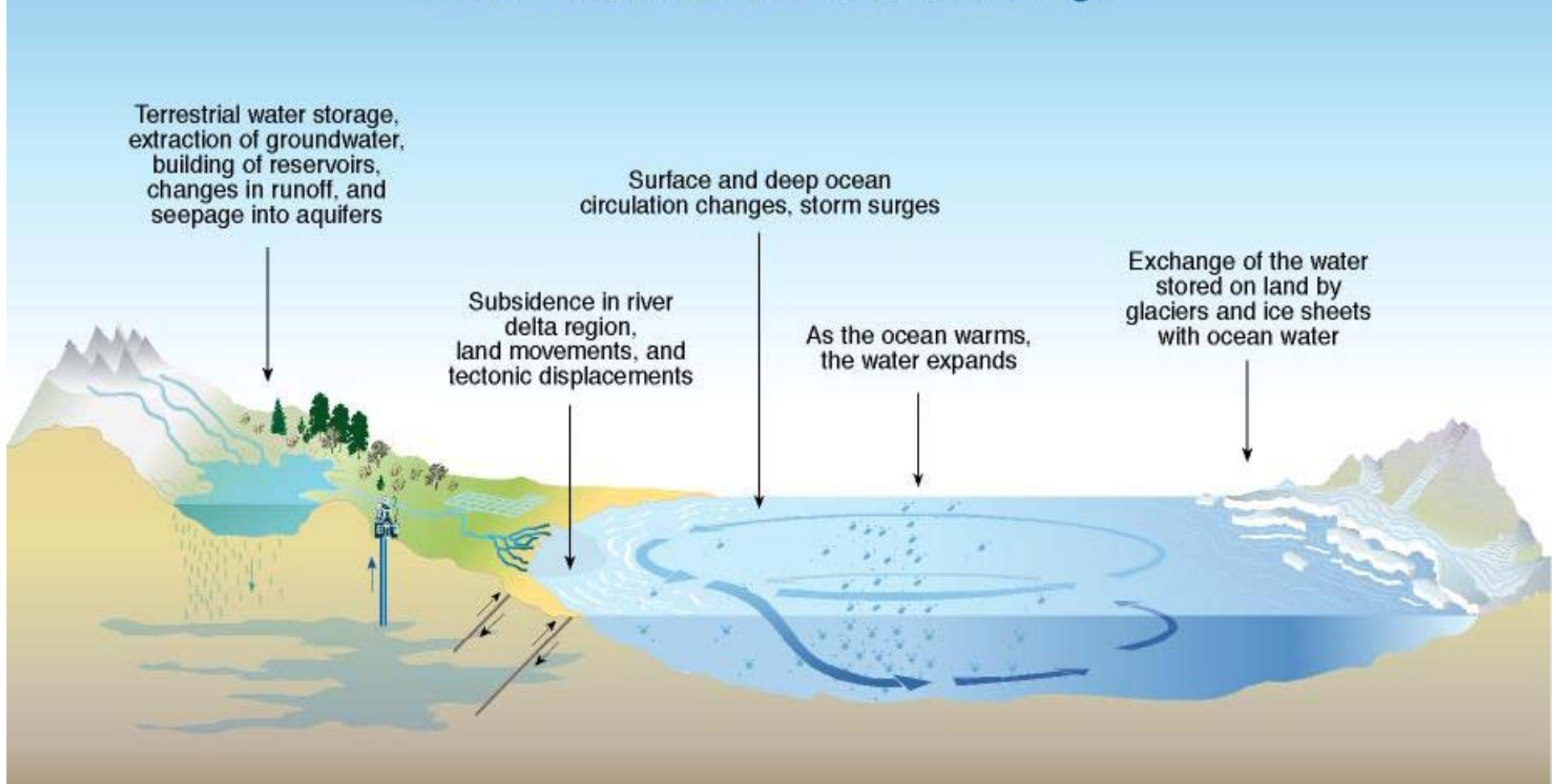
**A1B -
Medium**

**A2 -
Worst**



SEA LEVEL RISE will be caused by thermal expansion of the oceans and melting of land ice and ice sheets

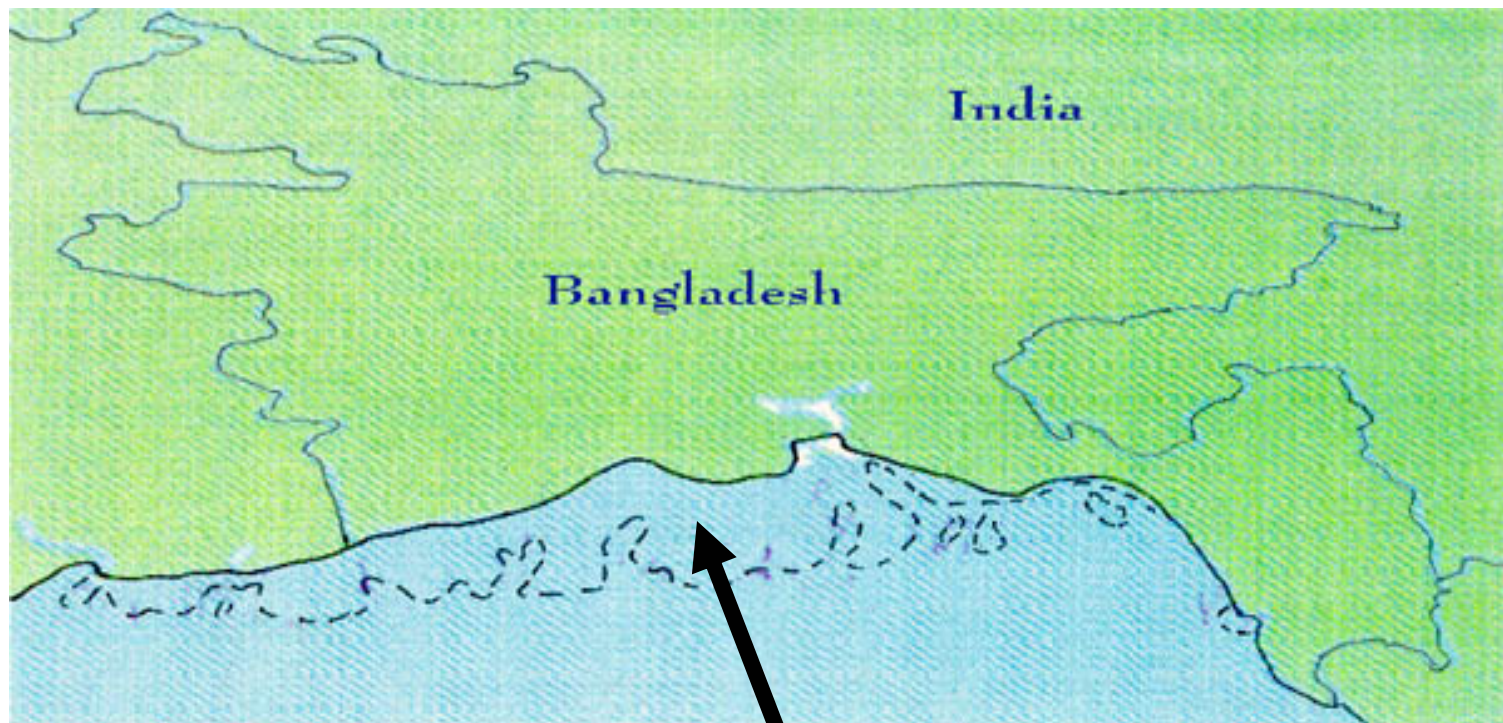
What causes the sea level to change ?



MEAN SEA LEVEL RISE of 0.4 m (range: 0.2 to 0.6) is projected by 2100
but with significant regional variations

Increased risk of floods, potentially displacing tens of millions of people, due to sea level rise and heavy rainfall events, especially in Small Island States and low-lying deltaic areas.

Bangladesh is projected to lose about 17% of its land area with a sea level rise of one meter - very difficult to adapt due to lack of adaptive capacity



Flooded area



Extreme Weather Events are Projected to Increase

Projected changes during 21st century

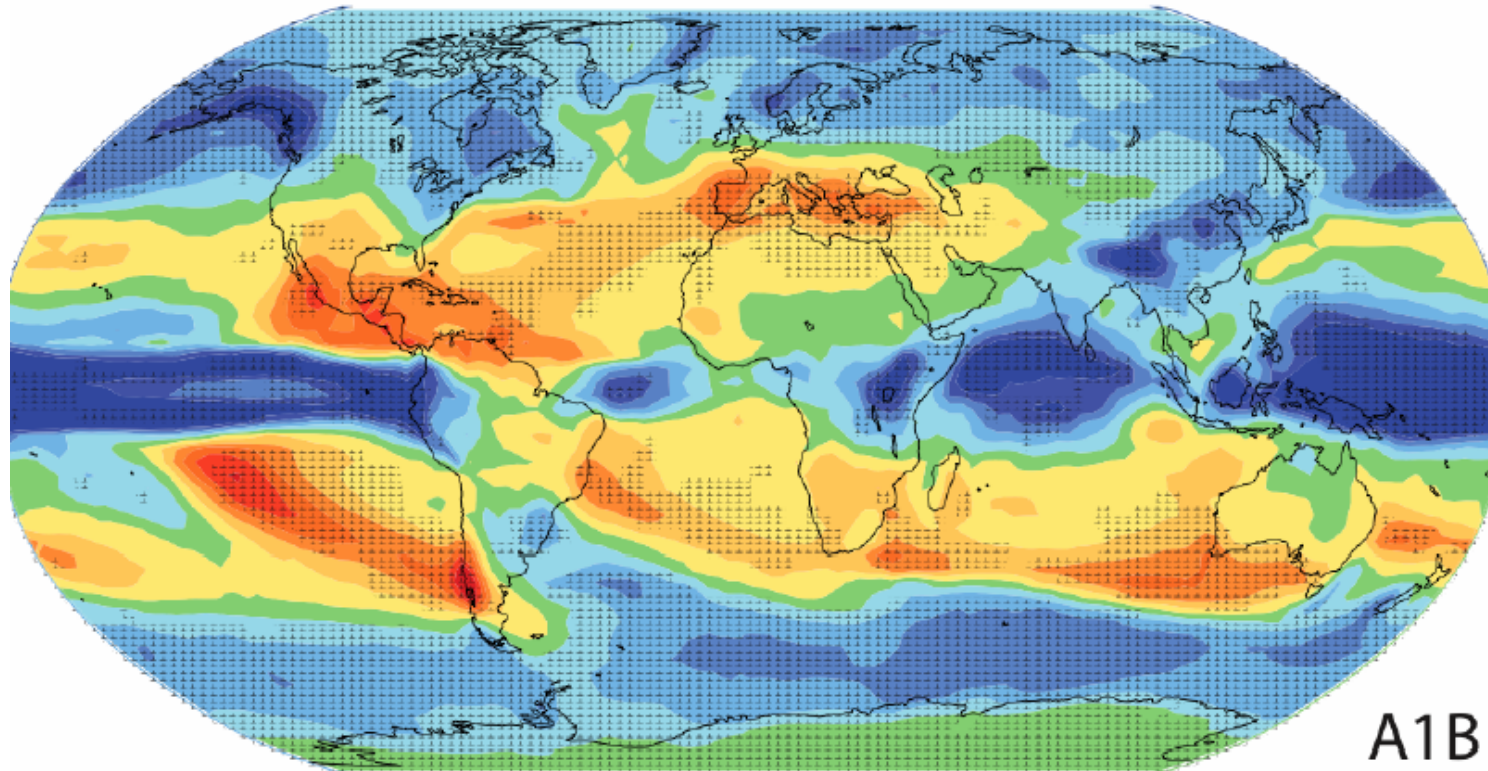
- Higher maximum temperatures; more hot days and heatwaves over nearly all land areas (*very likely*)
- Higher minimum temperatures; fewer cold days frost days and cold spells over nearly all land areas (*very likely*)
- more intense precipitation events over many areas (*very likely*)
- increased summer drying over most mid-latitude continental interiors and associated risk of drought (*likely*)
- increase in tropical cyclone peak wind intensity, mean and peak precipitation intensities (*likely*)

Examples of impacts

- Increased mortality in old people in urban areas
- Damage to crops
- Heat stress on livestock
- Extended range of pests and diseases
- Loss of some crop/fruit
- Land slides, mudslides, damage to property and increased insurance costs
- Reduced rangeland productivity, increased wildfires, decreased hydropower
- Damage to various ecological and socioeconomic systems

Dry areas get dryer & wet areas get wetter

2080-2099

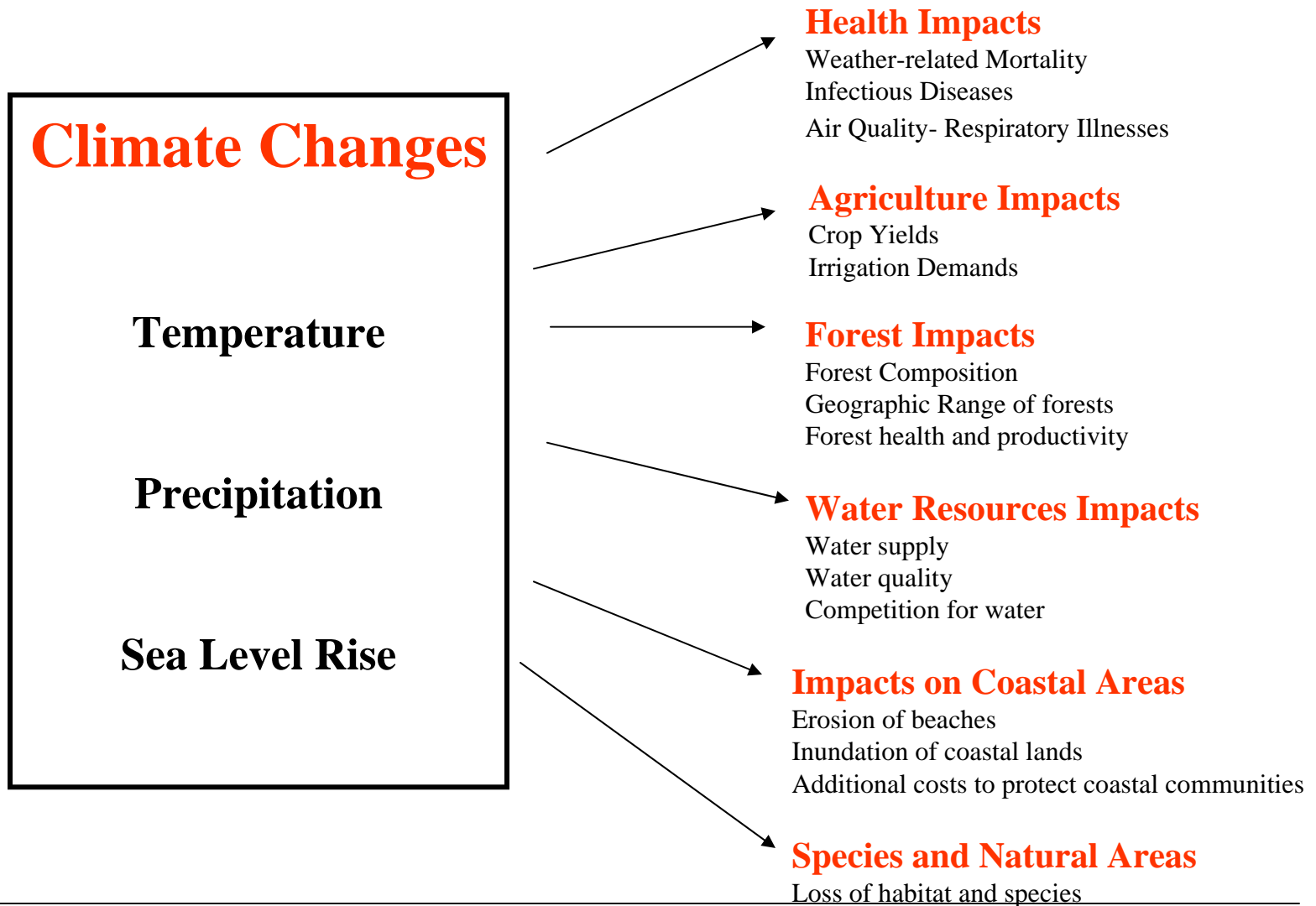


-0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5
Annual Mean Precipitation Change (mm/day)



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OVERALL: More adverse than beneficial impacts **on biological and socioeconomic systems**



Key IPCC Findings – A Few Beneficial Impacts

increased agricultural productivity in some mid-latitude regions (only for warming of up to a few degrees C)

increased water availability in some water-scarce regions

reduced winter mortality in mid- and high-latitudes

increase in timber supply (with well managed forests)



Potential Large Scale Impacts - Uncertain

Greenhouse gas emissions in the 21st century might set in motion large-scale, high-impact, non-linear, and potentially irreversible changes in physical and biological systems over the coming decades to millennia

- **Melting of ice sheets** (sustained warming of a few °C over millennia is projected to lead to an increase in sea level of several meters due to loss of Greenland and Antarctic Ice)
- **Thermohaline circulation**
- **Species extinction and biodiversity loss**
- **Catastrophic climate-development interactions**





- **The way we have met human needs in the past, has caused environmental degradation (including climate change), which in turn threatens the ability to meet present and future needs.**
- **Primary drivers underlying alternative development paths are similar to those for anthropogenic climate change, including economic growth, broad technological changes, life style patterns, demographic shifts (population size, age structure, and migration), and governance structures.**
- **Sustainable development is linked to and affects the environment. Thus, there are synergistic opportunities to meet human needs more sustainably, by adopting integrated SD-CC policies that enhance the effectiveness of response options.**



Global Responses to the Climate Change Challenge

- **Mitigation**
- **Adaptation**

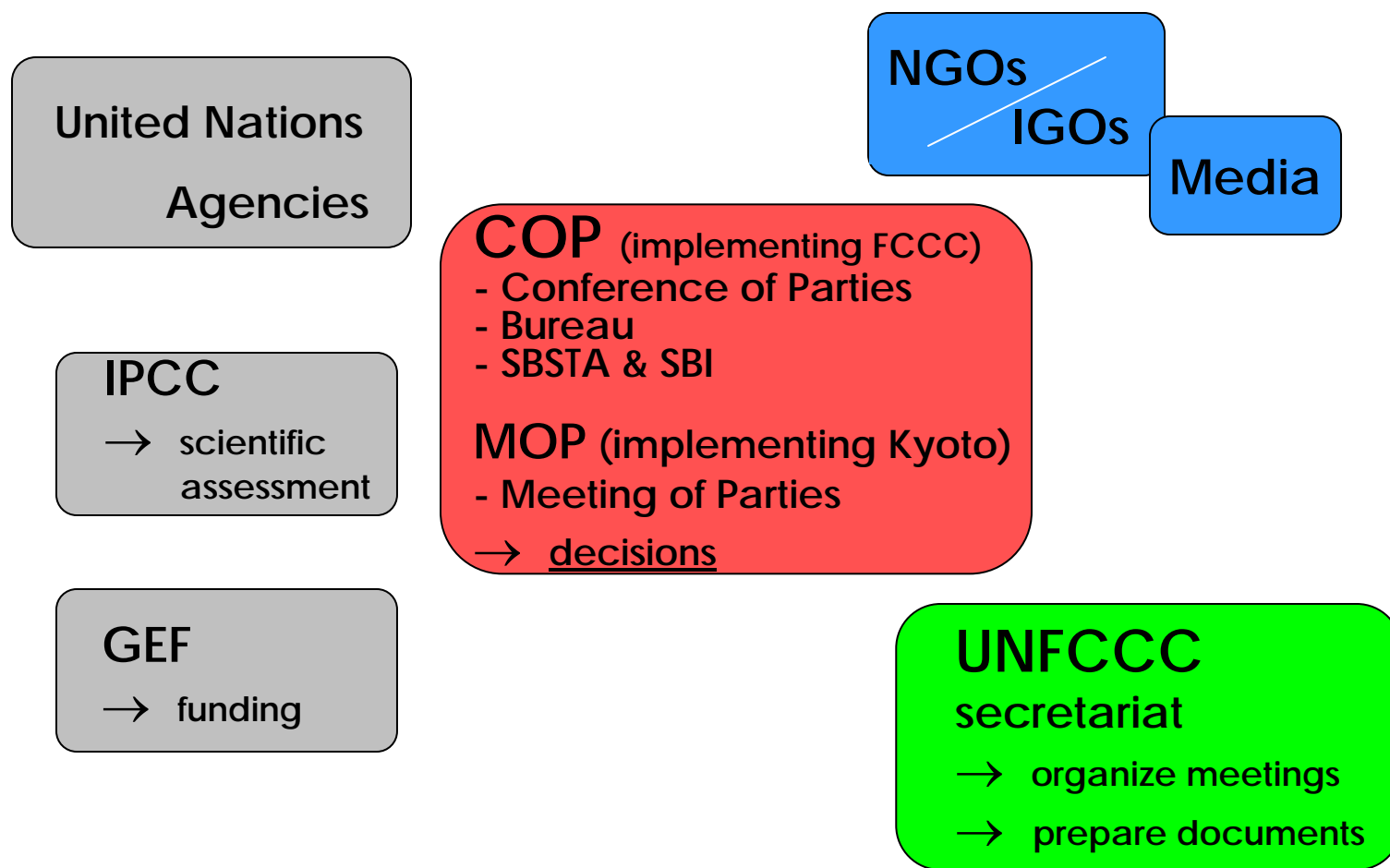


MOST DESIRABLE:

CC Policies that Combine Both Adaptation and Mitigation (Win-Win) and also Make Development More Sustainable (MDMS)



International institutional framework for Climate Change



Global Mitigation Response Options



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The Challenge of Mitigation

The **near-term** Challenge is to achieve the Kyoto targets.
Process continues with meeting of parties (MOP) –
separate from conference of parties (COP)

The **longer-term** challenge is to meet the objectives of Article 2 of the UNFCCC, i.e., stabilization of the atmospheric concentrations of GHG concentrations at a level that does not harm the climate system (food security, ecological systems and sustainable economic development).

Process starts with post-Kyoto (beyond 2012) - second round of commitments, discussions begin in 2008.

Mitigation: Kyoto Protocol (1997) in force in 2005 (without US)

1. Annex 1 Countries undertake mitigation -- GHG emission reductions (2008-2112) relative to 1990:

EU	- 8 %
USA	- 7 %
Japan	- 6 %
Australia	+ 8 %
Russian Federation	0 %

all developed countries - 5 %

2. No obligations for developing countries and economies in transition

3. Kyoto Mechanisms: CDM, JI, emissions trading



Near Term Trends in GHG Emissions 1970-2030

During 1970-2004

GHG emissions covered by the Kyoto Protocol have increased by about 70%.

CO₂ (77% of GHG), has grown by about 80%.

During 2000-2030

GHG emission will rise 45-110% with current policies.

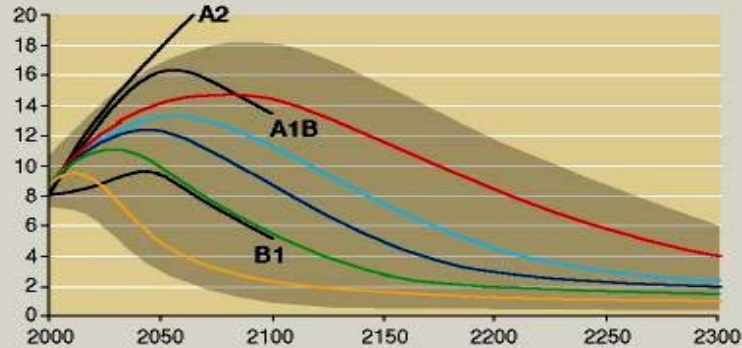
Two thirds of this growth will be in developing countries, but per capita emissions in developed countries will remain 3-4 times higher.



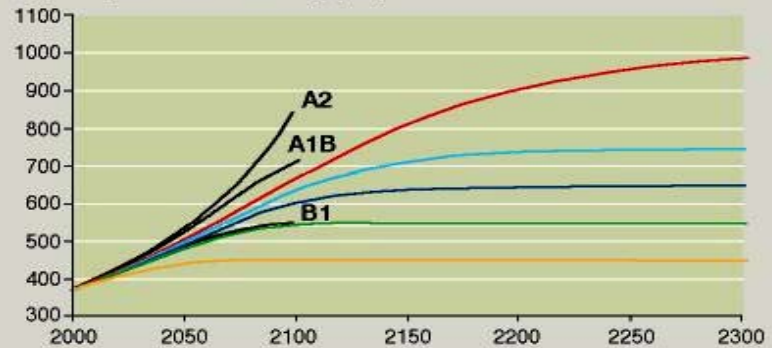
Stabilization of the atmospheric concentration of carbon dioxide will require significant emissions reductions

Emissions, concentrations, and temperature changes corresponding to different stabilization targets for CO₂ concentrations

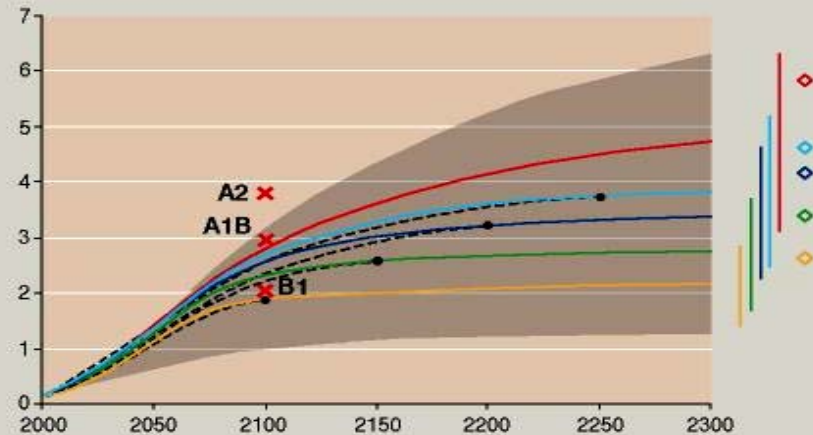
(a) CO₂ emissions (Gt C)



(b) CO₂ concentration (ppm)



(c) Global mean temperature change (°C)



Pre-industrial norm = 275 ppmv

WRE profiles

- WRE 1000
- WRE 750
- WRE 650
- WRE 550
- WRE 450

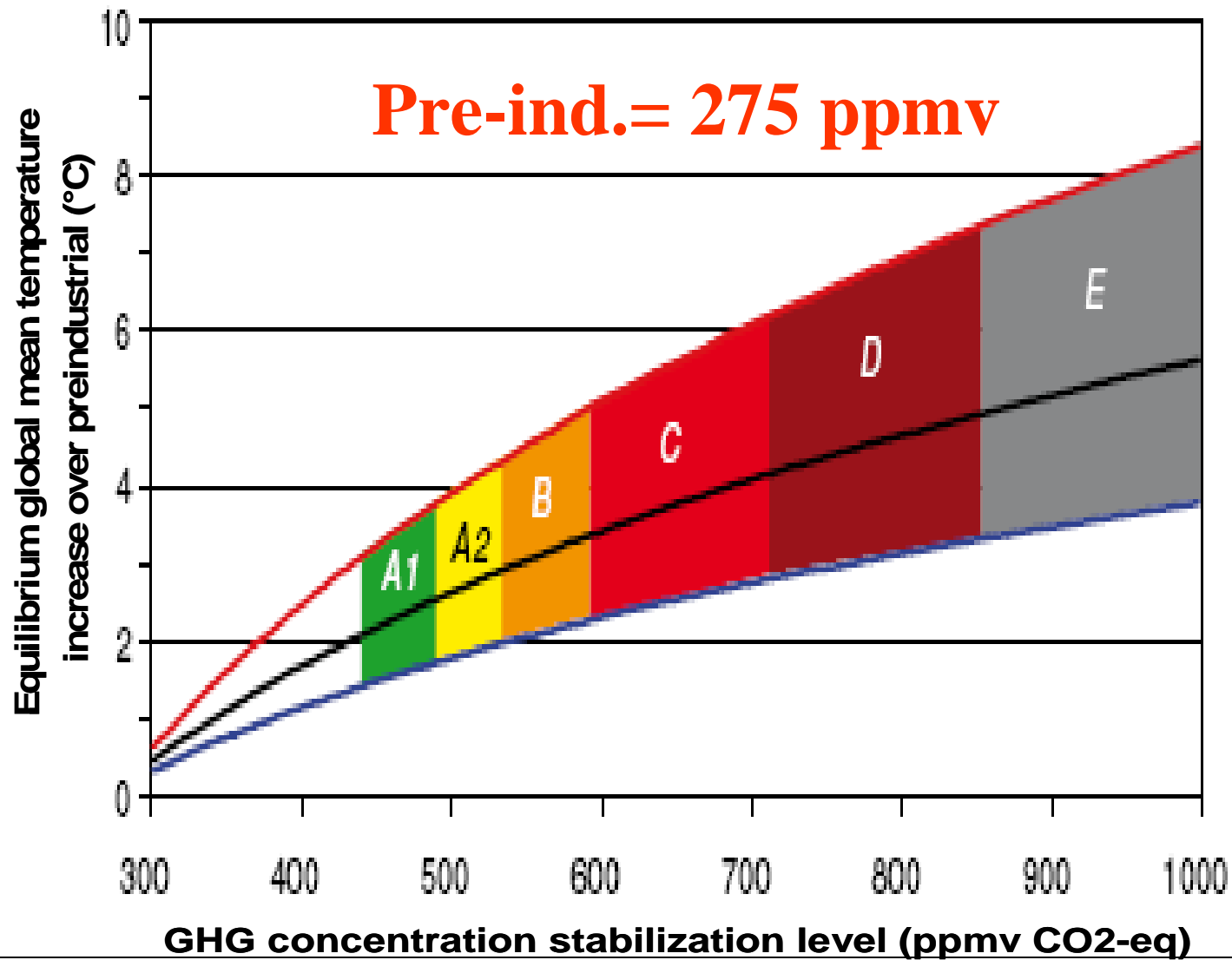
S profiles

SRES scenarios

—



Stabilisation levels and equilibrium global mean temperatures



Concentrations, mean temp. rise & peak year emissions

The lower the stabilization level, the more quickly emissions would need to peak and to decline thereafter.

Mitigation efforts over the next two to three decades will have a large impact on opportunities to achieve lower stabilization levels.

Stabilization level (ppm CO₂-eq)	Global Mean temp. incr. at equil. (°C)	Year CO₂ needs to peak	% GDP reduction in 2030	Reduction in 2050 relative to 2000
445 – 490	2.0 – 2.4	2000 - 2015	< 3	-85 to -50
490 – 535	2.4 – 2.8	2000 - 2020	< 2	-60 to -30
535 – 590	2.8 – 3.2	2010 - 2030	0.6	-30 to +5
590 – 710	3.2 – 4.0	2020 - 2060	0.2	+10 to +60
710 – 855	4.0 – 4.9	2050 - 2080		+25 to +85
855 – 1130	4.9 – 6.1	2060 - 2090		+90 to +140

GHG Mitigation Costs up to 2030: 0.5 to 2% GDP

Low cost mitigation possible – integrate CC into SD

Cost estimates for mitigation up to 2030: 0.5 to 2% of GDP

Global GDP loss will be about 0.2% for emissions trajectories stabilising around 650 ppmv CO₂-eq

Global GDP loss will be below 1% for emissions trajectories stabilising around 550 ppmv CO₂-eq (twice the pre-industrial norm)

Global GDP loss will be below 3% for emissions trajectories stabilising around 490 ppmv CO₂-eq (corresponds to about 2.5 C temp. rise)

Overall economic reduction potential by 2030

At costs <US\$ 20/tCO₂-eq reduction is 9-18 GtCO₂-eq.

At costs <US\$ 100/tCO₂-eq reduction is 16-31 GtCO₂eq – such emissions permit stabilization between 450 and 550 ppmv CO₂-eq.

Reductions are only achievable with adequate government policies.



There are also co-benefits of mitigation

- Near-term health benefits from reduced air pollution may offset a substantial fraction of mitigation costs
- Mitigation can also be positive for: energy security, balance of trade improvement, provision of modern energy services to rural areas and employment

BUT

- Mitigation in one country or group of countries could lead to higher emissions elsewhere (“carbon leakage”) or effects on the economy (“spill-over effects”).



Long-term stabilization (2100 and beyond) of GHGs concentrations is possible with SD

- Known technological options could achieve stabilization of carbon dioxide at levels of 450-550 ppm over the next 100 years
- Technology development and diffusion are important components of cost-effective stabilization
- The SD pathway to stabilization and the stabilization level itself are key determinants of mitigation costs



Sustainable development and climate change mitigation

- Making development more sustainable by changing development paths can make a major contribution to climate change mitigation
- Macroeconomic policy, agricultural policy, multilateral development bank lending, insurance practices, electricity market reform, energy security policy and forest conservation can significantly reduce emissions.
- Implementation may require resources to overcome multiple barriers.
- Possibilities to choose and implement mitigation options to realise synergies and avoid conflicts with other dimensions of sustainable development.



Policies are available to governments to realise mitigation of climate change

- Effectiveness of policies depends on national circumstances, their design, interaction, stringency and implementation
 - Integrating climate policies in broader development policies
 - Regulations and standards
 - Taxes and charges
 - Tradable permits
 - Financial incentives
 - Voluntary agreements
 - Information instruments
 - Research and development



The importance of “carbon price”

- Policies that provide a real or implicit price of carbon could create incentives for producers and consumers to significantly invest in low-GHG products, technologies and processes.
- Such policies could include economic instruments, government funding and regulation
- For stabilisation at around 550 ppm CO₂eq carbon prices should reach 20-80 US\$/tCO₂eq by 2030 (5-65 if “induced technological change” happens)
- At these carbon prices large shifts of investments into low carbon technologies can be expected
- Higher carbon prices could impose significant burdens on the poor, unless offsetting policies are implemented



The importance of technology policies

- Deployment of low-GHG emission technologies and RD&D would be required for achieving stabilization targets and cost reduction.
- The lower the stabilization levels, especially those of 550 ppm CO₂-eq or lower, the greater the need for more efficient RD&D efforts and investment in new technologies during the next few decades.
- Government support through financial contributions, tax credits, standard setting and market creation is important for effective technology development, innovation and deployment.
- Government funding for most energy research programmes has been flat or declining for nearly two decades (even after the UNFCCC came into force); now about half of 1980 level.



International agreements

- Notable achievements of the UNFCCC/Kyoto Protocol that may provide the foundation for future mitigation efforts:
 - global response to the climate problem,
 - stimulation of an array of national policies,
 - the creation of an international carbon market and
 - new institutional mechanisms
- Future agreements:
 - Greater cooperative efforts to reduce emissions will help to reduce global costs for achieving a given level of mitigation, or will improve environmental effectiveness
 - Improving, and expanding the scope of, market mechanisms (such as emission trading, Joint Implementation and CDM) could reduce overall mitigation costs

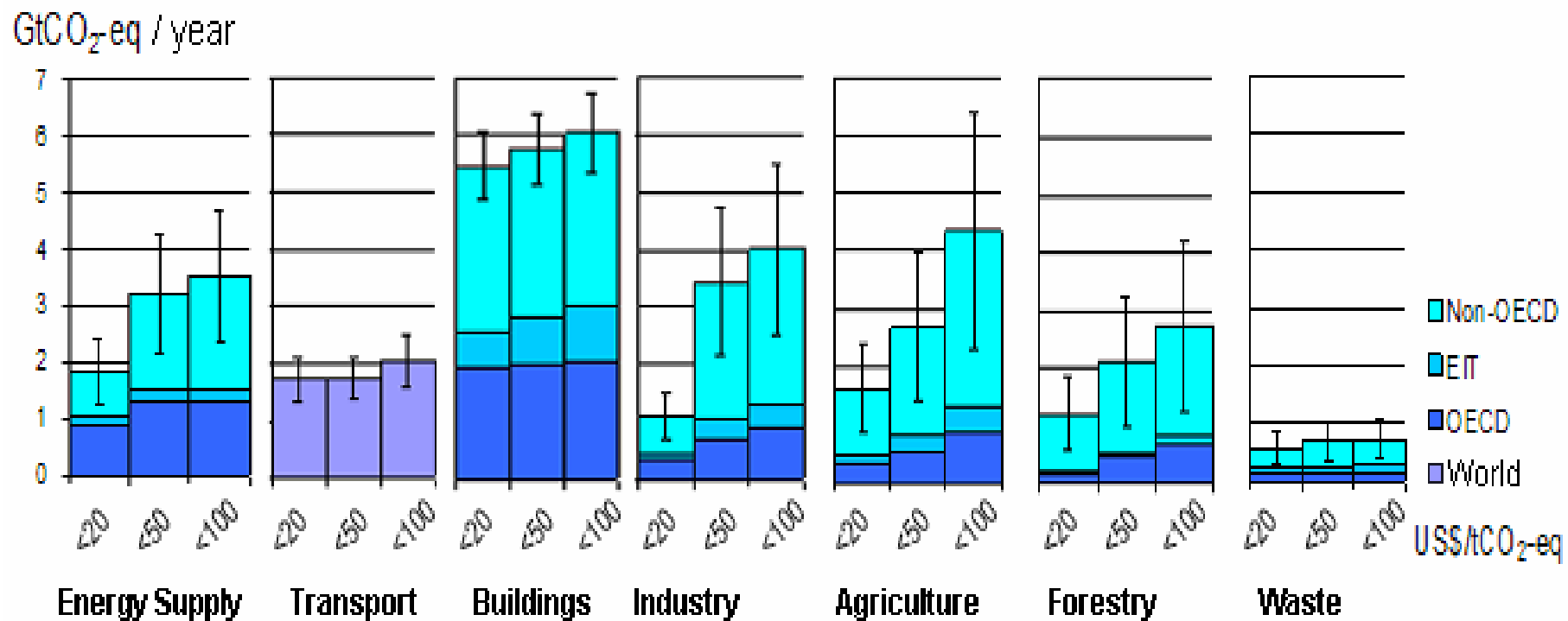


Technologies and policies exist to reduce near term (2010-2020) GHG emissions

- **Energy:** significant technical progress has been made in the last 5 years and at a faster rate than expected (wind turbines, elimination of industrial by-products, hybrid engine cars, fuel cell technology, underground carbon dioxide storage)
- **Land Use:** good potential for carbon sinks and reduced GHG emissions from both better management of existing land cover, and transformation of land use



All sectors and regions have the potential to contribute



Note: estimates do not include non-technical options, such as lifestyle changes.



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Changes in lifestyle and behaviour patterns can contribute to climate change mitigation

- Changes in occupant behaviour, cultural patterns and consumer choice in buildings.
- Reduction of car usage and efficient driving style, in relation to urban planning and availability of public transport
- Staff training, reward systems, regular feedback and documentation of existing practices in industrial organizations



Global Adaptation Response Options



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Most Vulnerable Systems and Sectors

- Some ecosystems:
 - Coral reefs; sea-ice regions
 - Tundra, boreal forests, mountain and Mediterranean regions
- Low-lying coasts, mangroves & salt marshes
- Water resources in mid-latitudes & dry Tropics
- Low-latitude agriculture
- Human health where adaptive capacity is low



Most Vulnerable Regions

- The Arctic
- Sub-Saharan Africa
- Small islands
- Asian megadeltas

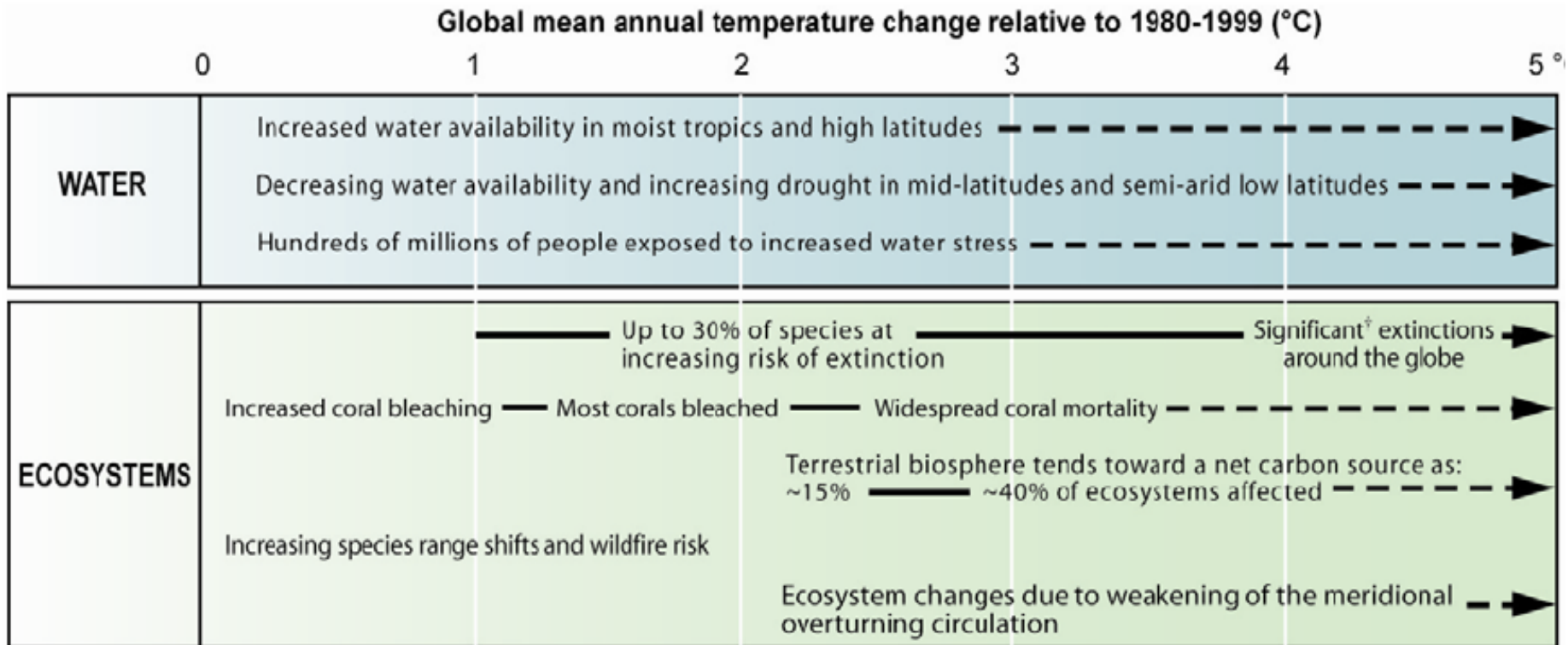


Most Vulnerable People

- **Poor**
- **Children**
- **Elderly**



Temperature rise and impacts overview - 1

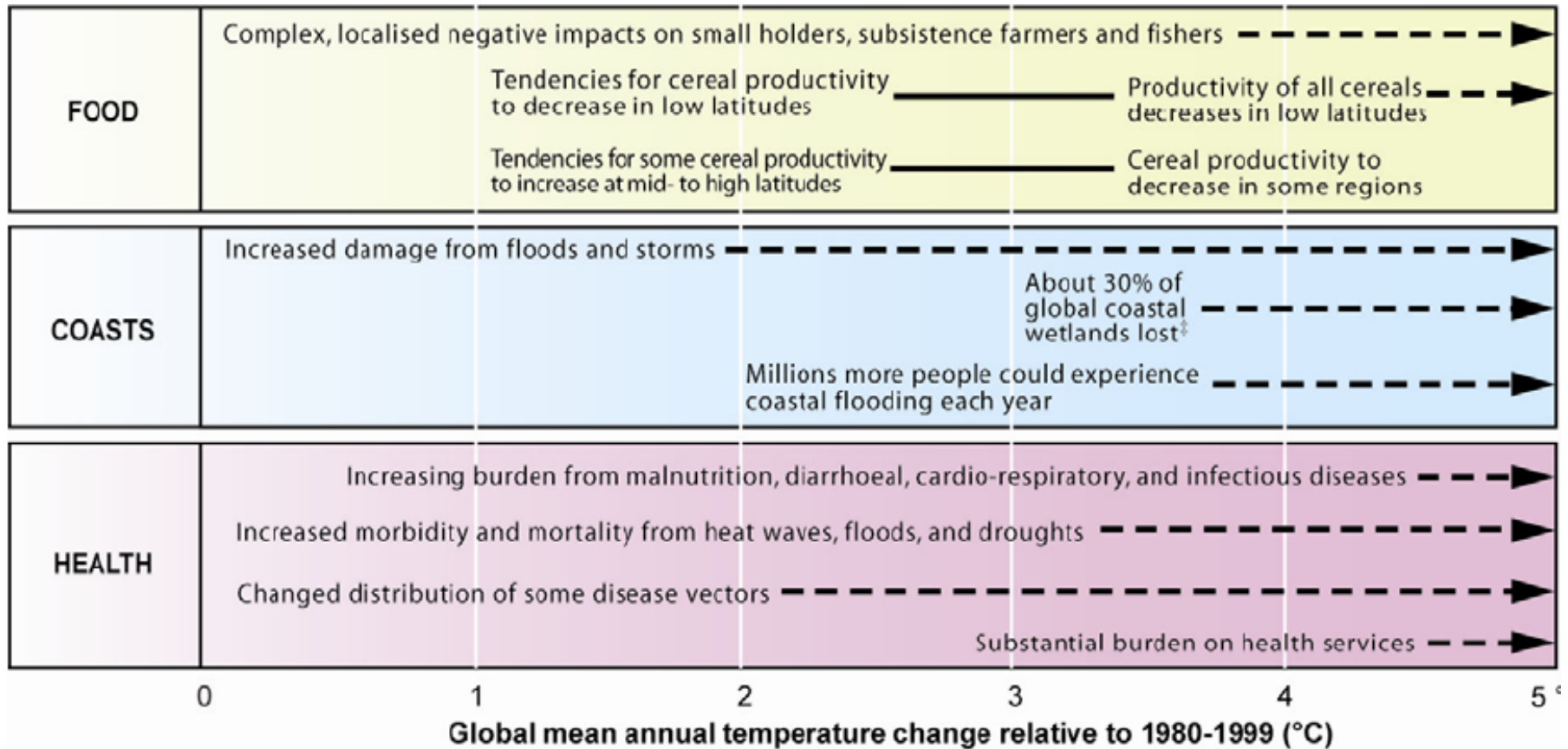


2



Temperature rise and impacts overview - 2

2



Main impacts on Sectors

- **Water**
 - increase in number of very wet and very dry areas
 - Saltwater intrusion in coastal areas, salinisation of groundwater
 - Increasing water stress
- **Ecosystems**
 - Some biodiversity loss
 - Forest expansion in northern areas
 - Increased wild fires
 - Loss of corals due to bleaching
 - Oceanic biotic move polewards
- **Food, Fibre and Forest Products**
 - Small beneficial impacts on crops in temperate regions
 - Poleward spread of diseases and pests
 - Warming will decrease livestock productivity
 - Increase in global forest product output
 - Changes in distribution and productivity of fish species

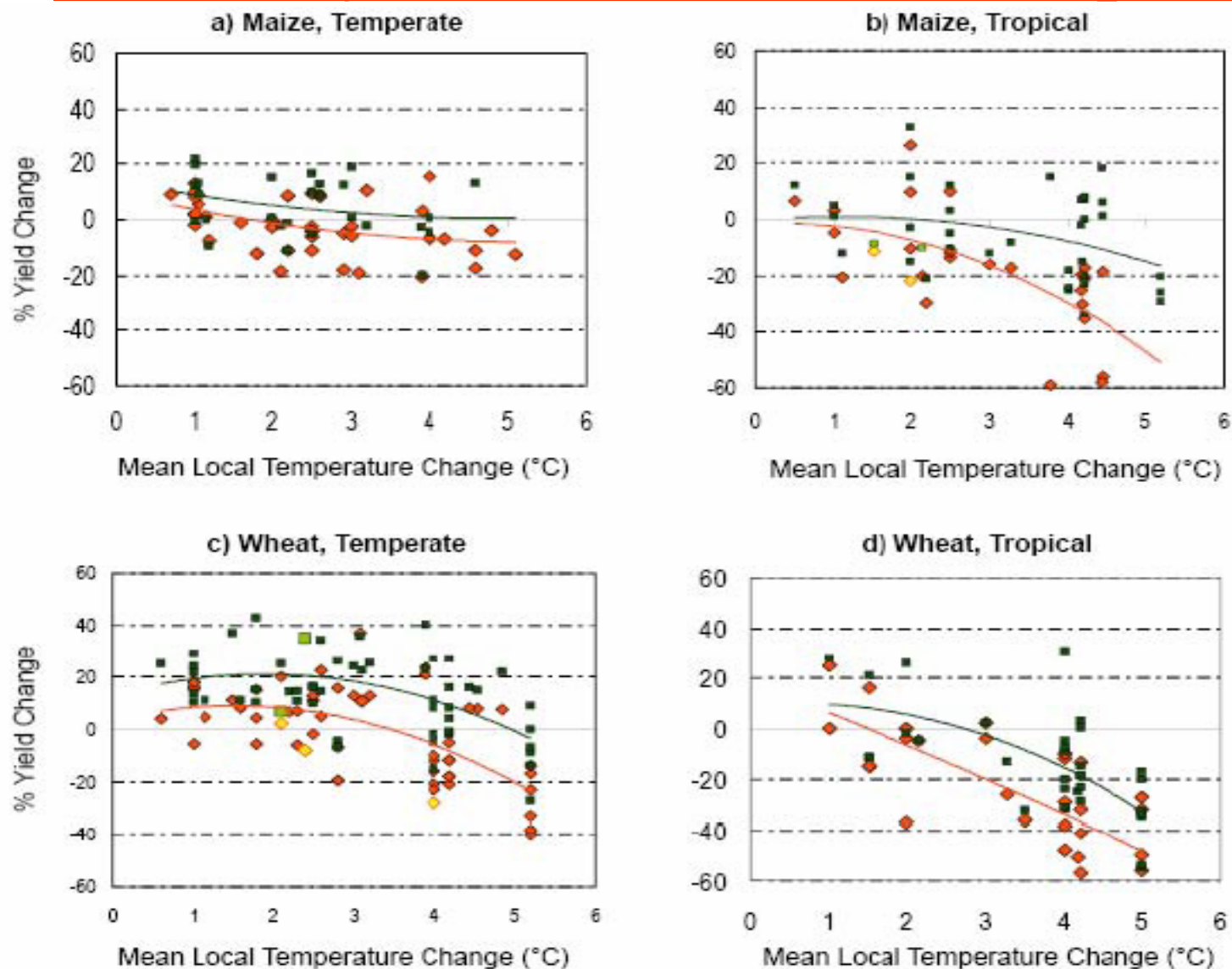


Main impacts on Sectors (Contd.)

- **Coastal Systems and Low-Lying Areas**
 - Greatest vulnerability expected along coastal strips of S. and S.E. Asia & urbanized coastal areas of Africa
 - Sea level rise impacts and costs are greater in developing countries
- **Industry, Settlements, and Society**
 - Vulnerability higher in those areas which rely on climate sensitive resources
 - Increase in cost of insurance cover
- **Health**
 - Increased mortality mainly from increased vector-borne and diarrheal diseases
 - Increases heat related health problems



Sensitivity of Cereal Yield to Temperature Rise



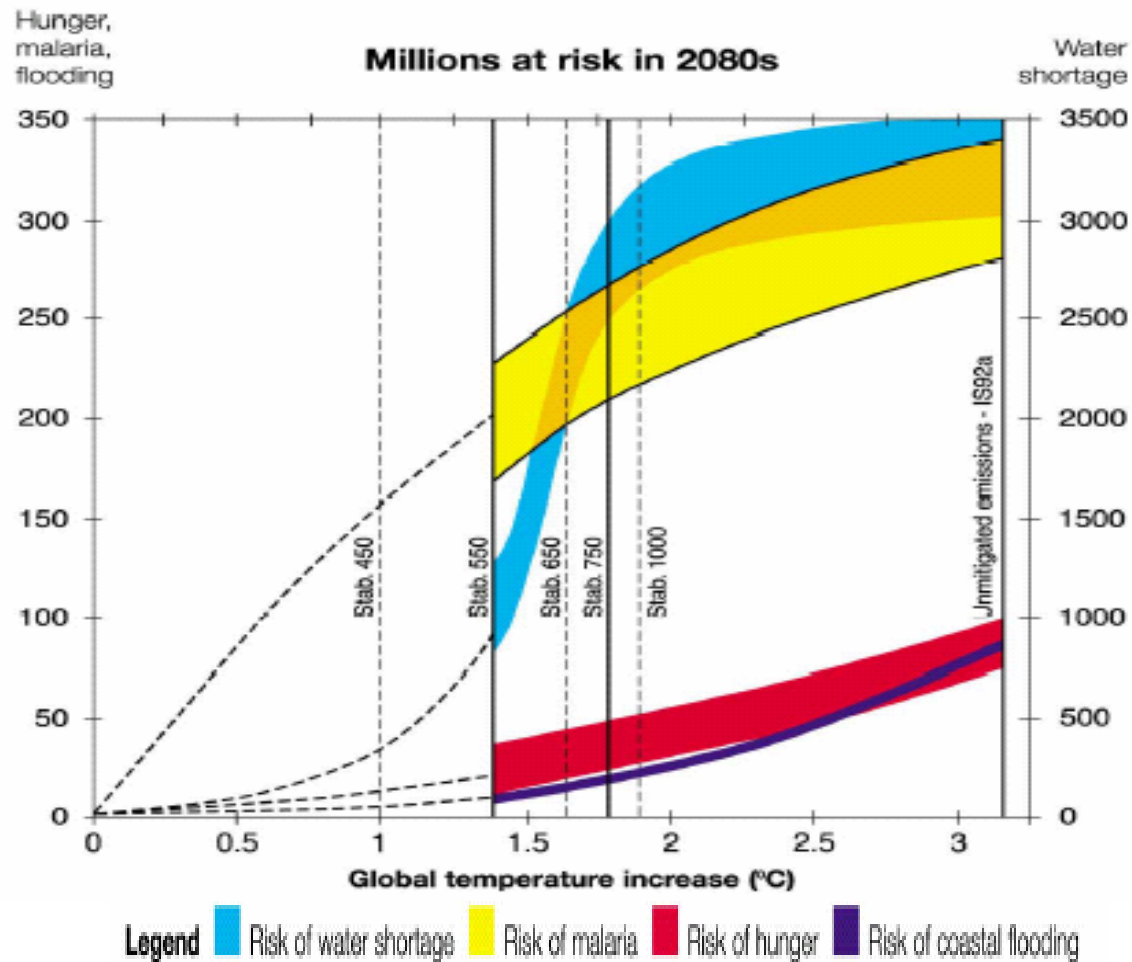
Orange = no adaptation

Black = with adaptation



Hundreds of Millions at Risk by 2080 - Malaria, Hunger, Water Shortage and Flooding

Note: EU Risk Threshold is 2 degrees C



Vector (insect)-borne Diseases

<i>Disease</i>	<i>Vector</i>	<i>Population at risk (millions)</i>	<i>Present distribution</i>	<i>Likelihood of altered distribution with warming</i>
Malaria	mosquito	2,100	(sub)tropics	✓✓
Schistosomiasis	water snail	600	(sub)tropics	✓✓
Filariasis	mosquito	900	(sub)tropics	✓
Onchocerciasis (river blindness)	black fly	90	Africa/Latin America	✓
African trypanosomiasis (sleeping sickness)	tsetse fly	50	tropical Africa	✓
Dengue	mosquito	unavailable	tropics	✓✓
Yellow fever	mosquito	unavailable	tropical South America & Africa	✓

Likely ✓
Very likely ✓✓

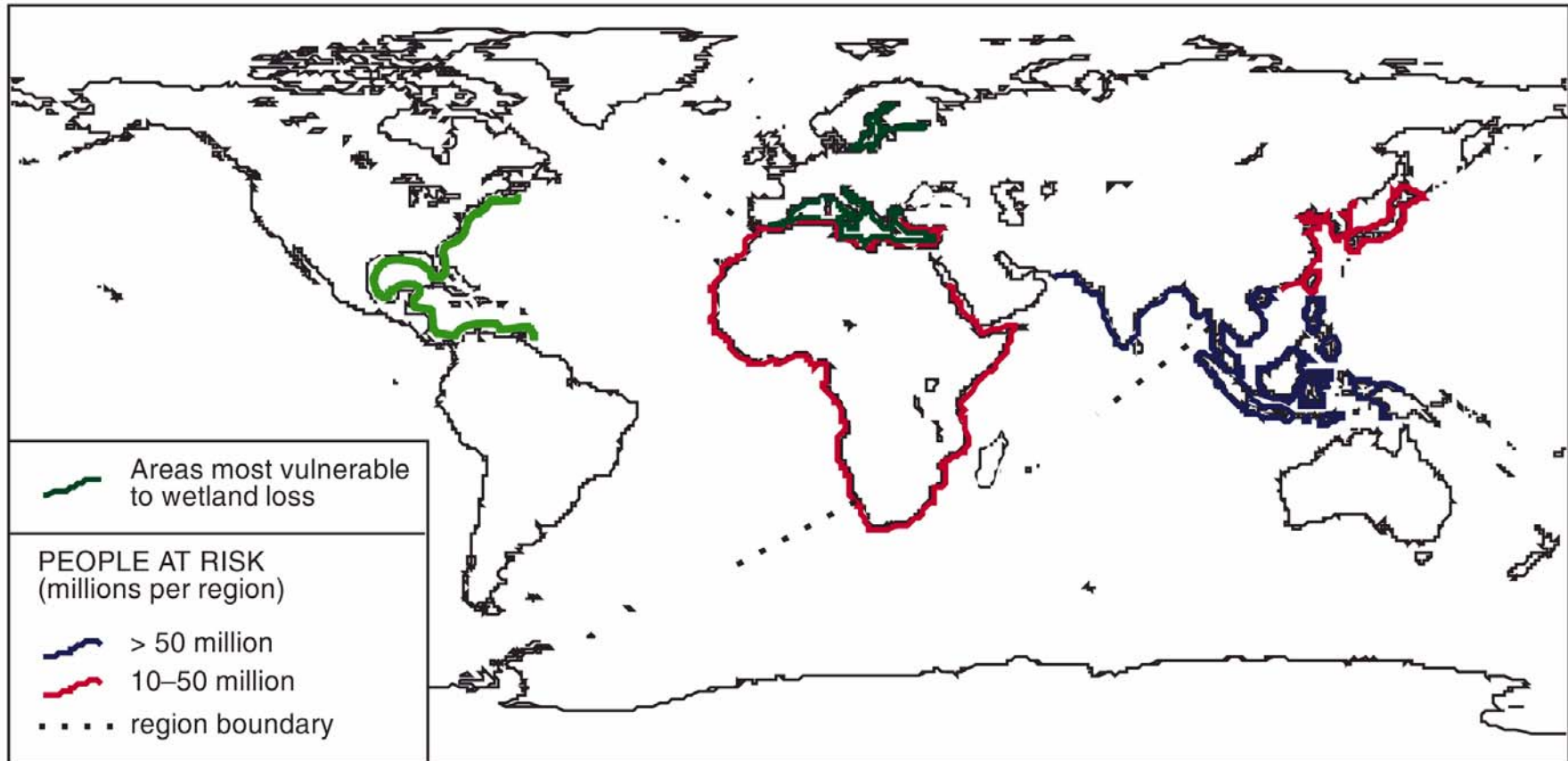
Source: Modified WHO, as cited in Stone (1995).



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People at Risk from a 44 cm Sea-level Rise by the 2080s

Assuming 1990s Level of Flood Protection



Source: R. Nicholls, Middlesex University in the U.K. Meteorological Office. 1997. *Climate Change and Its Impacts: A Global Perspective*.



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Ecosystems Vulnerability

A temperature increase of 1.5°C - 2.5°C over present, would put 20% - 30% of higher plants and animals at high risk of extinction



Extreme Events

- *Very likely* that **hot extremes, heat waves, and heavy precipitation** events will continue to become more frequent
 - *Likely* that future **tropical cyclones** will become more intense, with larger peak wind speeds and more heavy precipitation
 - **less confidence in decrease of total number**
 - Extra-tropical storm tracks projected to move poleward with consequent changes in wind, precipitation, and temperature patterns
-

Long term global aggregate damages **(present discounted net costs)**

Mean value = US\$ 12 per tonne CO₂ (US\$ 43 per tonne C)

Standard deviation = US\$ 23 per tonne CO₂

Range = US\$ 0 to 400 per tonne CO₂

Large variation is due to uncertainties and deliberate choices regarding climate sensitivity, response lags, discount rates, valuing non-market impacts (including ecosystem impacts), and the treatment of inter-regional equity and catastrophic losses.



Potential Adaptive Responses Available to Human Societies

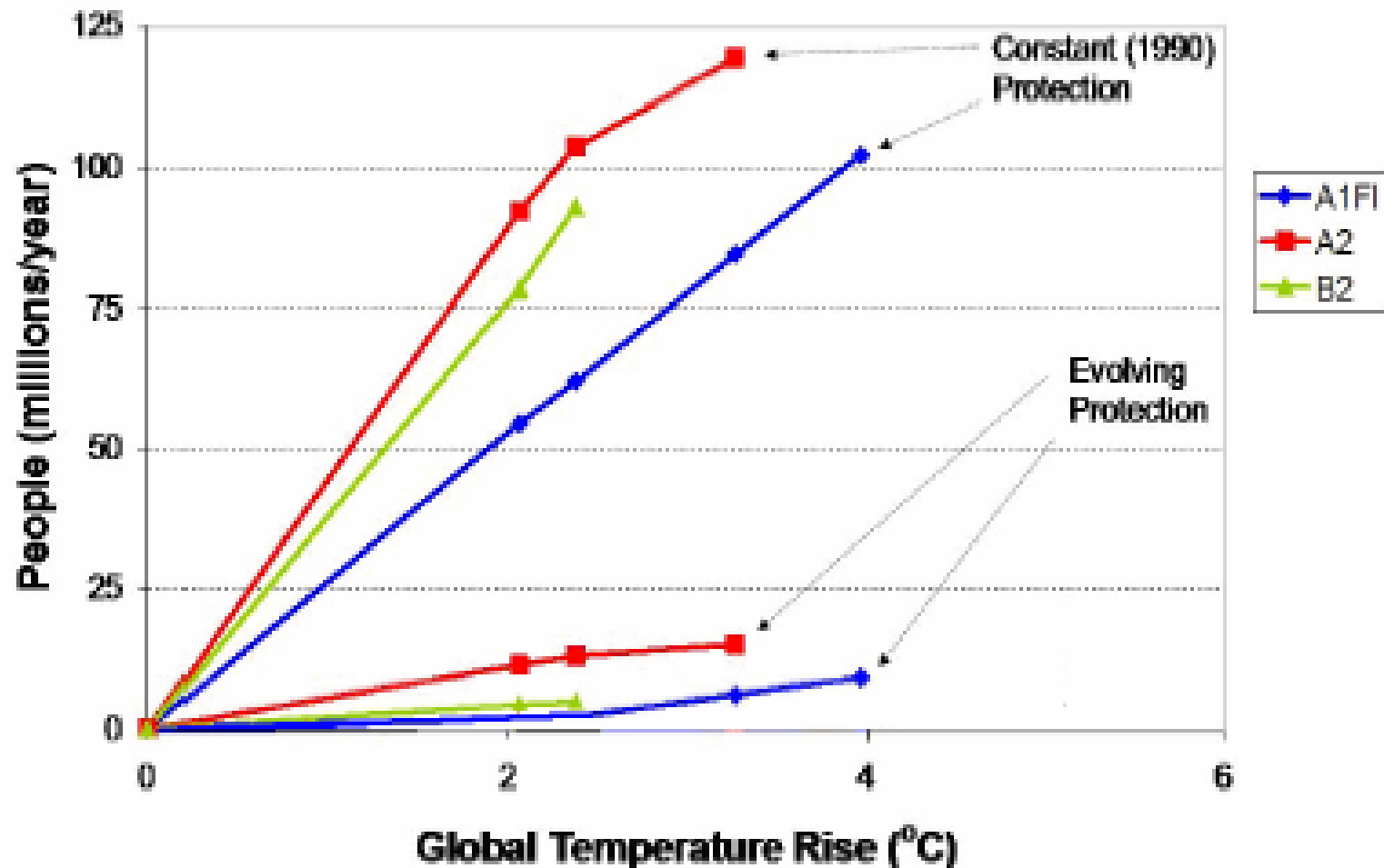
- Technological - (e.g. sea defenses, new crops)
- Behavioral – (e.g. new food and recreational choices)
- Managerial – (e.g. altered farm practices)
- Policy – (e.g. planning and regulations)



Adaptation Example: People flooded in coastal areas 2080

Evolving protection = spending increases at same rate as GDP.

Constant protection = spending maintained at 1990 levels.



Key IPCC Findings – Adaptation

- **Adaptation will be necessary to address impacts resulting from the warming which is already unavoidable due to past emissions**
- **Numerous adaptation options have been identified that can reduce adverse impacts of climate change and enhance beneficial ones , but will not prevent all damages**
- **Greater and more rapid climate change would increase adaptation costs and pose greater challenges**
- **Inertia is a widespread characteristic of the interacting climate, ecological and socio-economic systems which means that large scale impacts may not be observed for decades to centuries and mal-adaptations may occur**



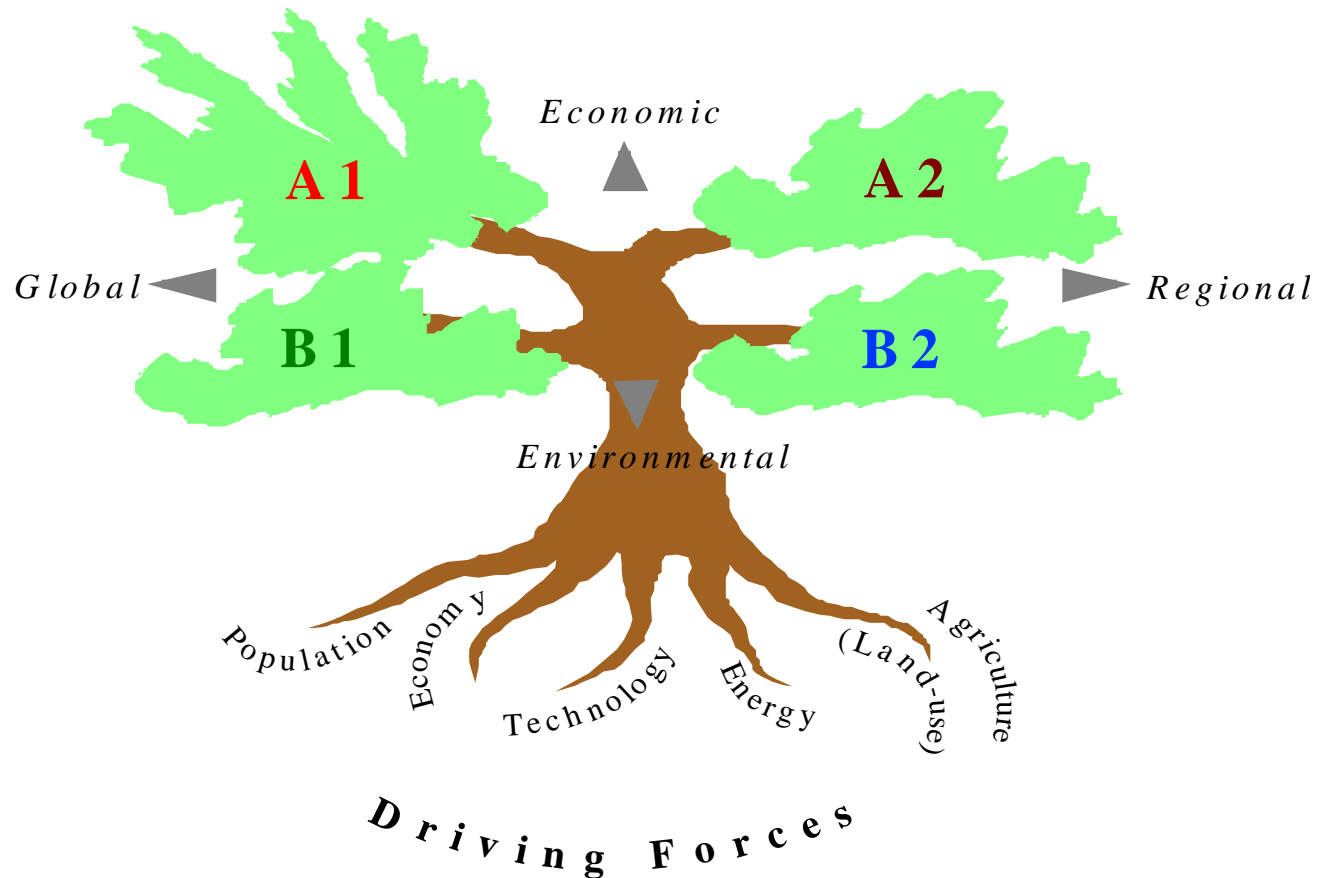
SD Strategies and effects on Mitigation and Adaptation



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SRES Scenarios are Driven by Development Paths

SRES Scenarios



SD → Vulnerability, Adaptation & Adaptive Capacity

SD strategies can contribute significantly to improving vulnerability to climate change and adaptive capacity, independent of climate change considerations. The adaptive capacity of a country can be enhanced when climate policies are integrated into national development policies – economic, social and environmental.



SD → Mitigation, Mitigative Capacity

SD strategies can contribute significantly to improving GHG emissions and sinks, independent of climate change considerations. The mitigative capacity of a country can be enhanced when climate policies are integrated into national development policies – economic, social and environmental.



WHY ? is climate important for future development
Climate Change undermines Sustainable
Development and unfairly penalizes the poor

HOW ? do we trace CC-SD links and make development
more sustainable (MDMS)
Study long term CC-SD circular interaction using
the Sustainomics framework



Tracing the Links Between Climate Change and Sustainable Development

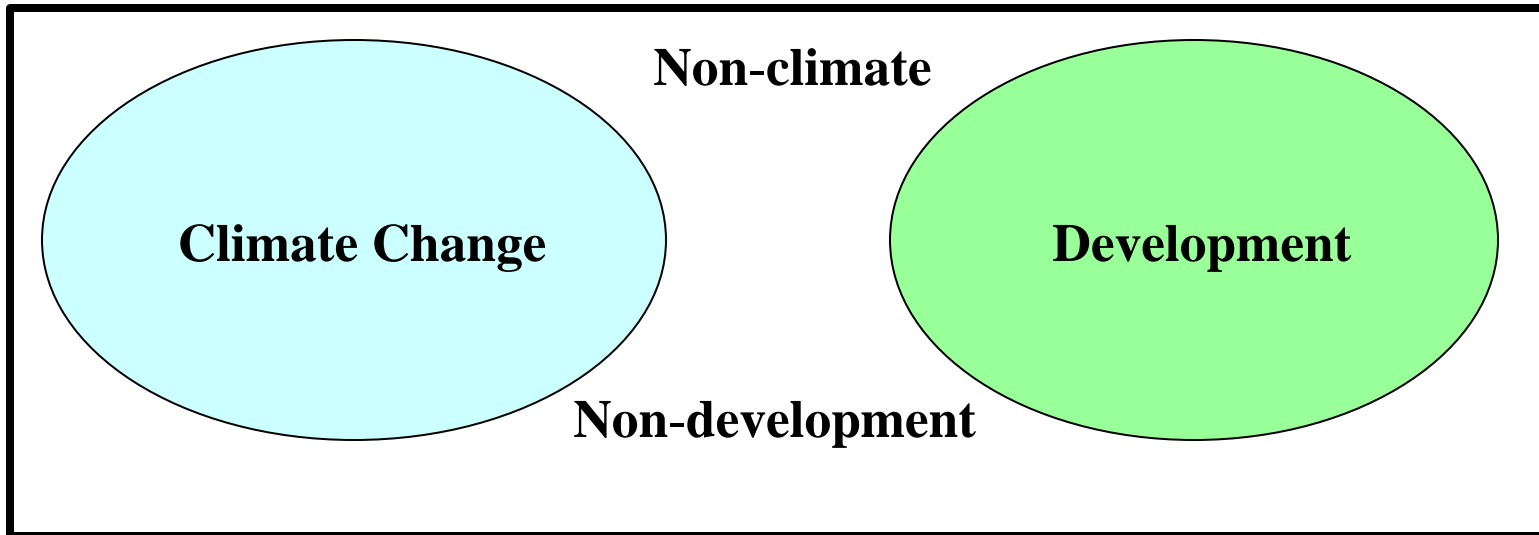


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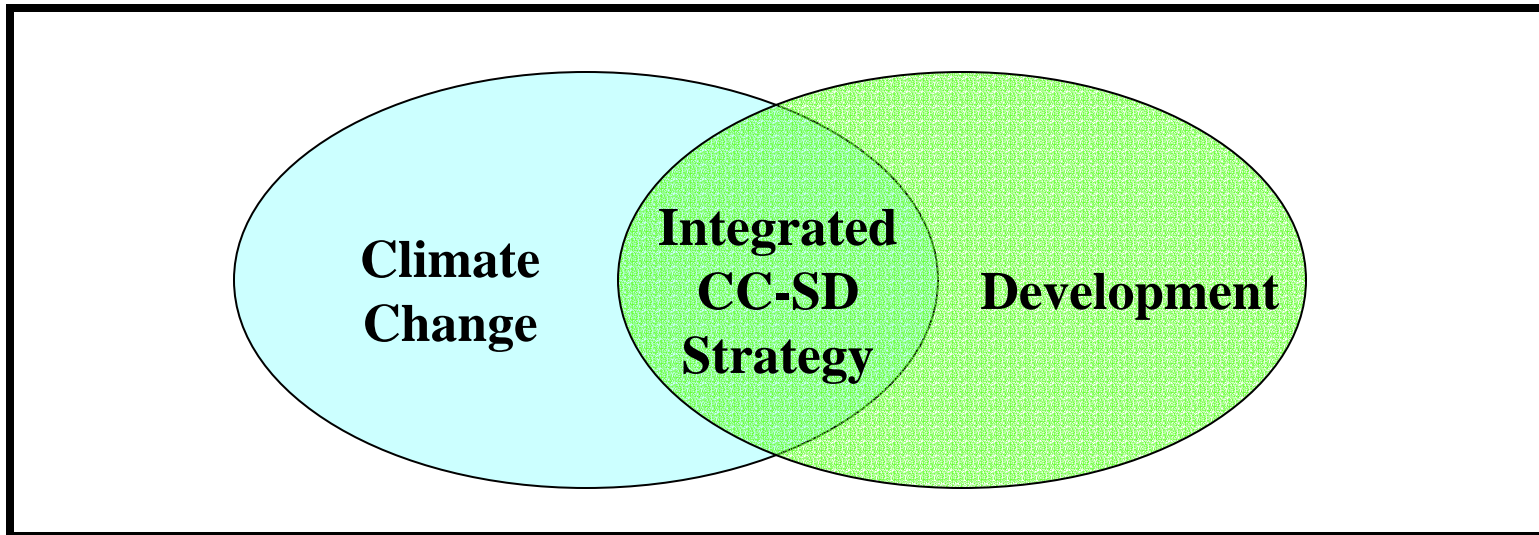
Linking Climate Change and Sustainable Development



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Former Viewpoint – AR1



Desirable Viewpoint (policy relevant) – AR4



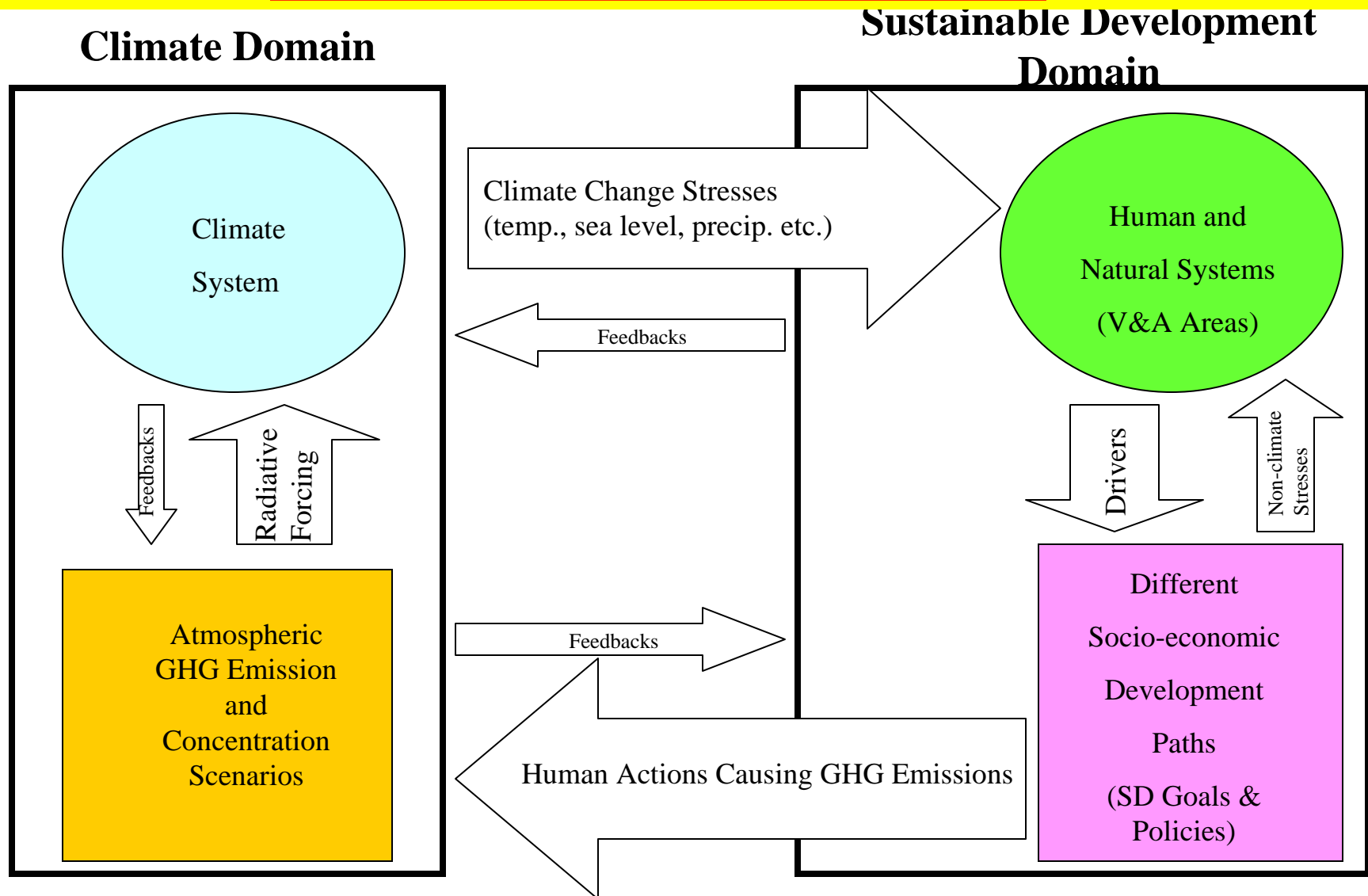
TWO-WAY LINKAGES BETWEEN CLIMATE CHANGE AND SUSTAINABLE DEVELOPMENT

CC → SD

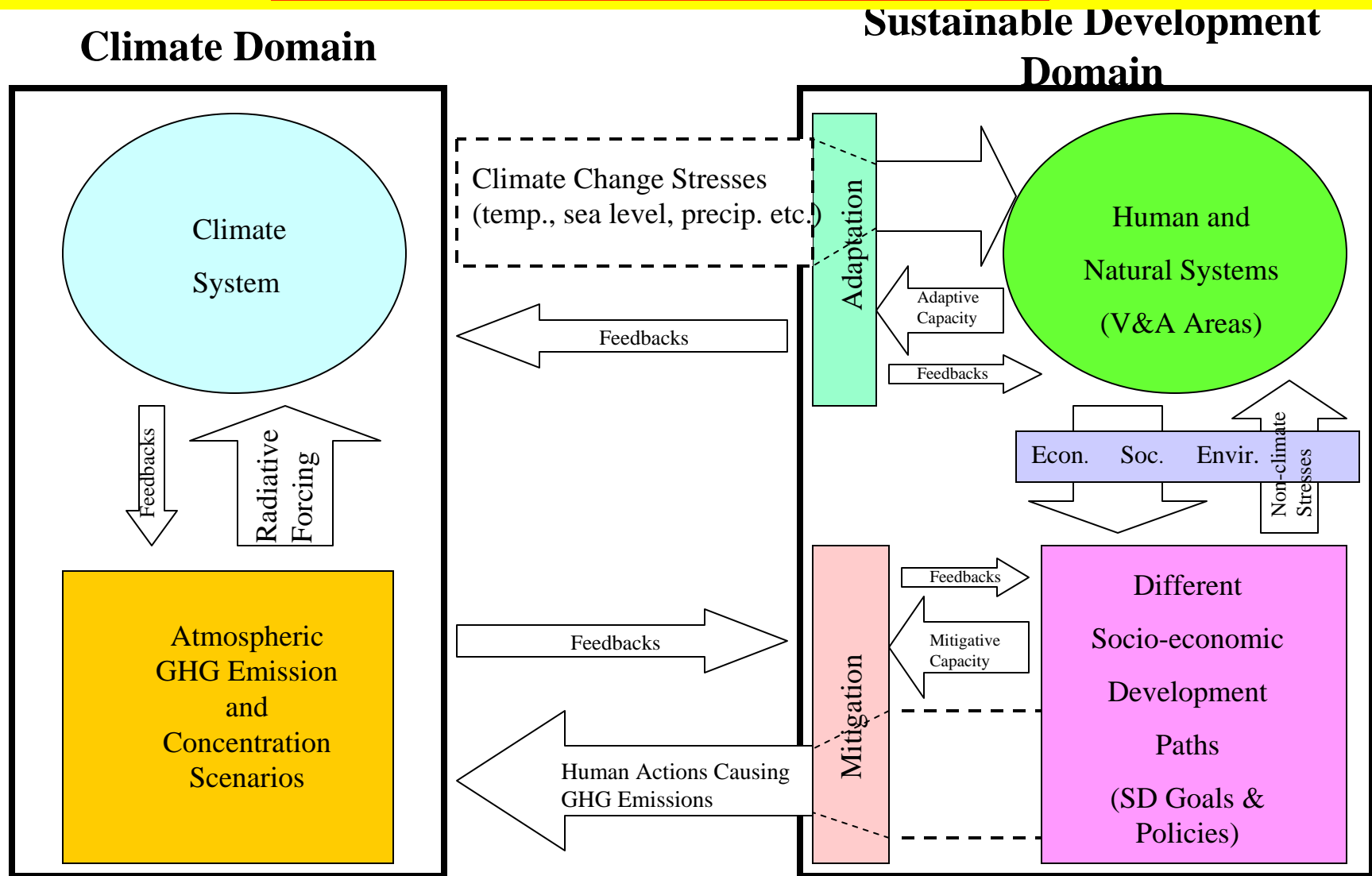
SD → CC



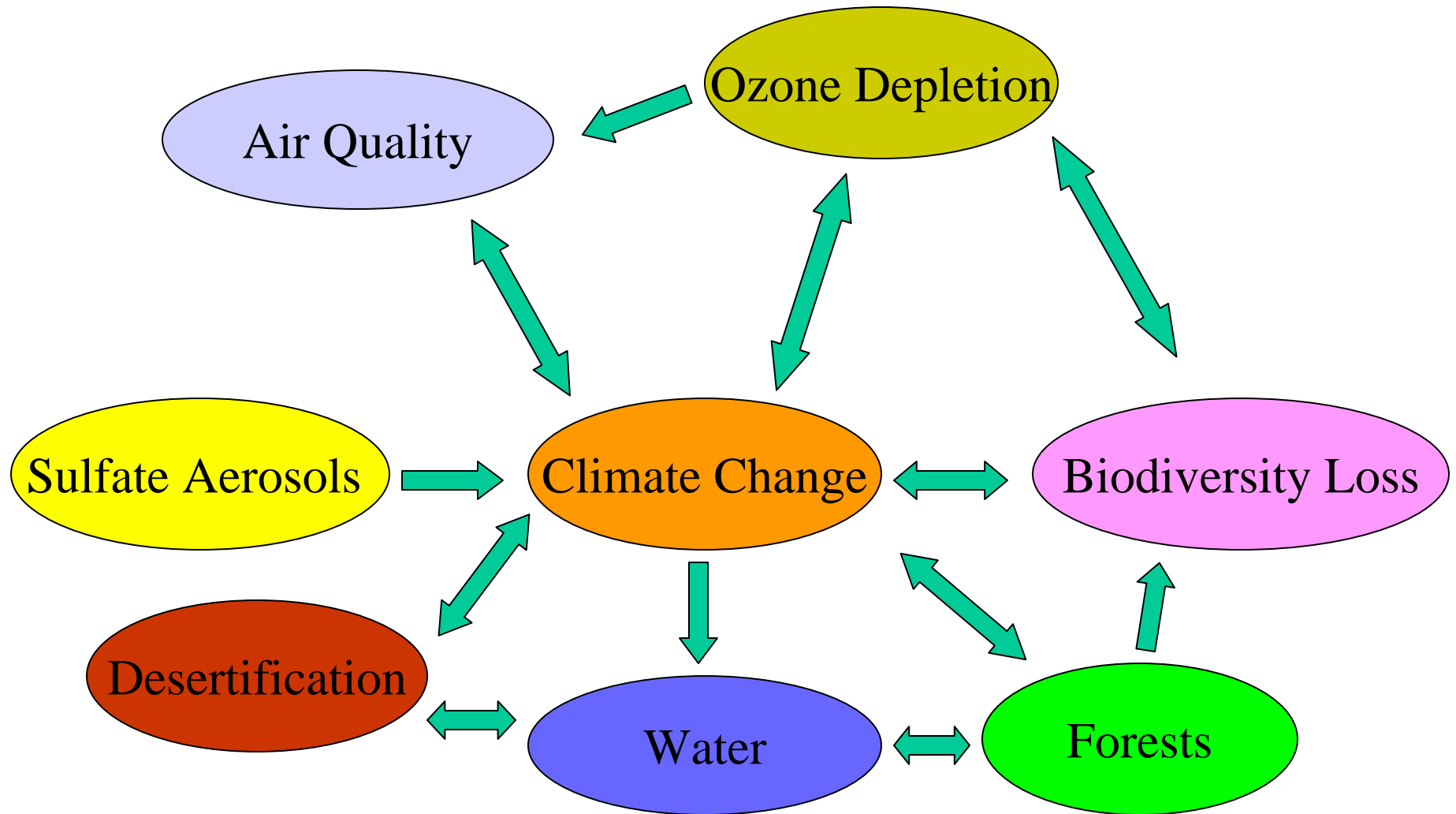
Global Level CC-SD Links 1



Global Level CC-SD Links 2



Further Complexity: Inter-Linkages with Other Environmental Issues



Conceptual Overview of CC-SD Links

- **Climate change and sustainable development interact in a complex, dynamic cycle, characterised by significant time delays and feedbacks**
- **The three major dimensions of sustainable development are economic, social and environmental. Key issues such as climate change, poverty, equity, and sustainability, can be related to all three dimensions**
- **Climate change impacts and responses are part of the larger question of how complex social, economic, and environmental sub-systems interact and shape prospects for sustainable development. There are multiple links**



Understanding Sustainable Development within the **SUSTAINOMICS Framework**



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SUSTAINOMICS

Core concepts and elements

- 1. Making development more sustainable (MDMS)**
- 2. Sustainable development triangle**
- 3. Transcending boundaries**
- 4. Full cycle application of integrative tools – from data gathering to practical policy implementation**



Understanding Sustainable Development: some (ideal) generic definitions

“development that meets the needs of the present without compromising the ability of future generations to meet their own needs”

Source: Bruntland et al. (1987)

“process for improving the range of opportunities that will enable individual human beings and communities to achieve their aspirations and full potential over a sustained period of time, while maintaining the resilience of economic, social and environmental systems”

Source: Munasinghe (1992, Rio Earth Summit)



Practical Target: Making Development More Sustainable (MDMS)

“An approach that will permit **sustained improvements in the quality of life** at a **lower intensity of resource use**, thereby preserving for future generations an undiminished or even **enhanced stock of productive assets** (manufactured, natural and social capital)”

Source: Munasinghe (1992), Rio Earth Summit



Application Framework:

SUSTAINOMICS

“framework for making development more sustainable (MDMS), which is trans-boundary, integrative, comprehensive, balanced, heuristic and practical.”

Source: Munasinghe (1992), Rio Earth Summit

Neologism balances S-N concerns, with equal attention on development and sustainability. Holistic, transboundary framework **avoids disciplinary bias** or ‘hegemony’, (integrating economic, social and environmental elements, with both optimal and durable approaches). Incremental MDMS approach **promotes practical implementation** and learning.



Rationale for approach based on **Making Development More Sustainable (MDMS)**

The precise definition of **sustainable development** remains an **elusive (perhaps unreachable) goal**.

Making development more sustainable (MDMS) is a less ambitious strategy based on **Sustainomics**, that offers greater promise.

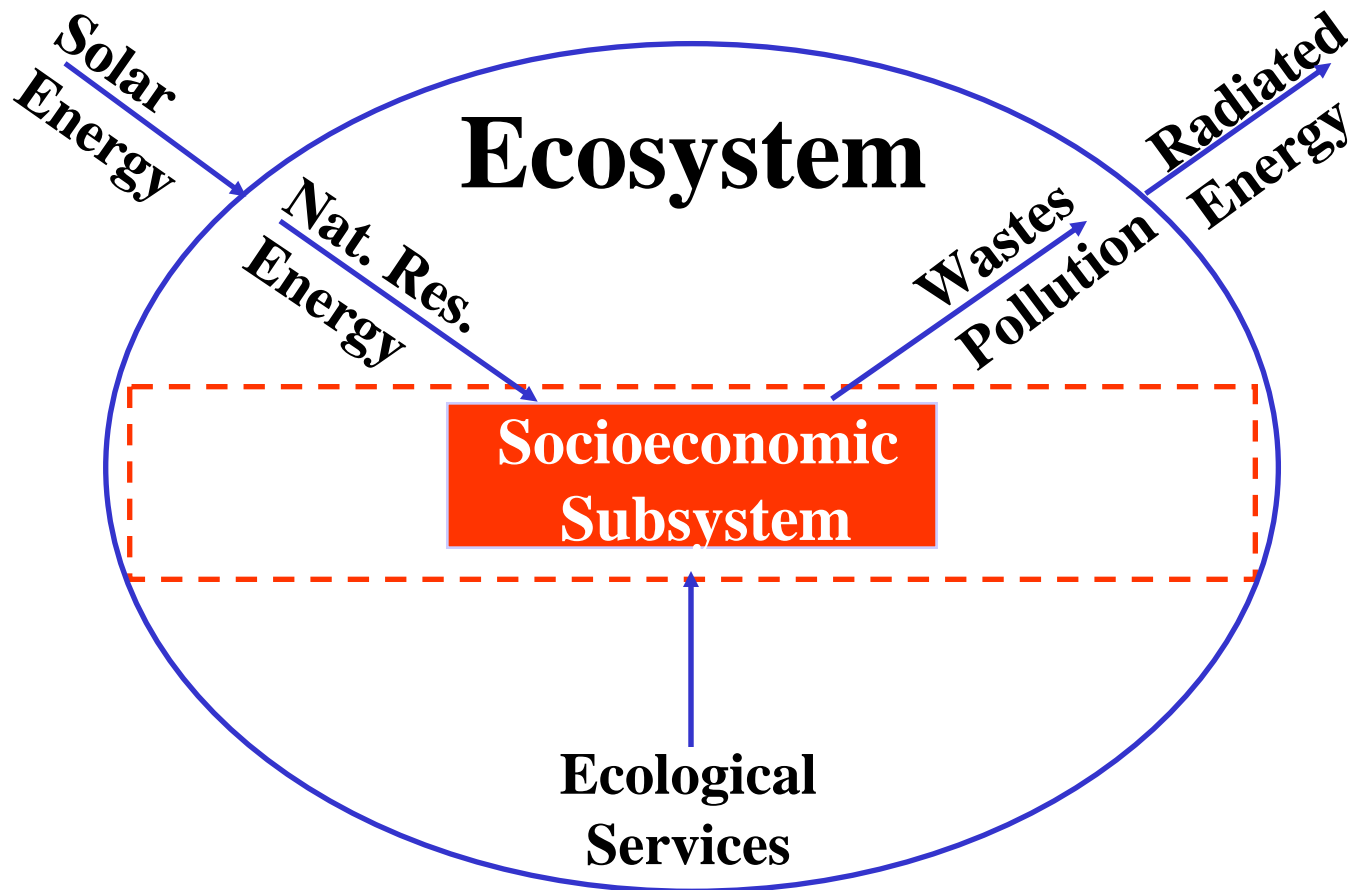
Such an incremental (or gradient-based) method is more practical, because **many unsustainable activities are easier to recognize and eliminate**.

Furthermore, **climate response strategies cannot be expected to address all the problems of sustainable development**.

Thus, climate change impacts and response strategies could be examined more meaningfully from the perspective of whether they make development more (or less) sustainable.



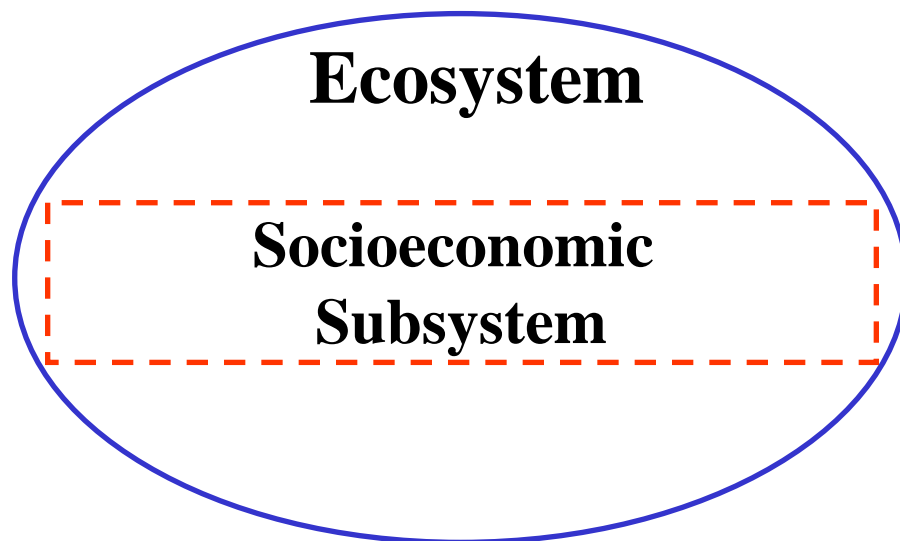
MDMS: Restructuring development and growth I



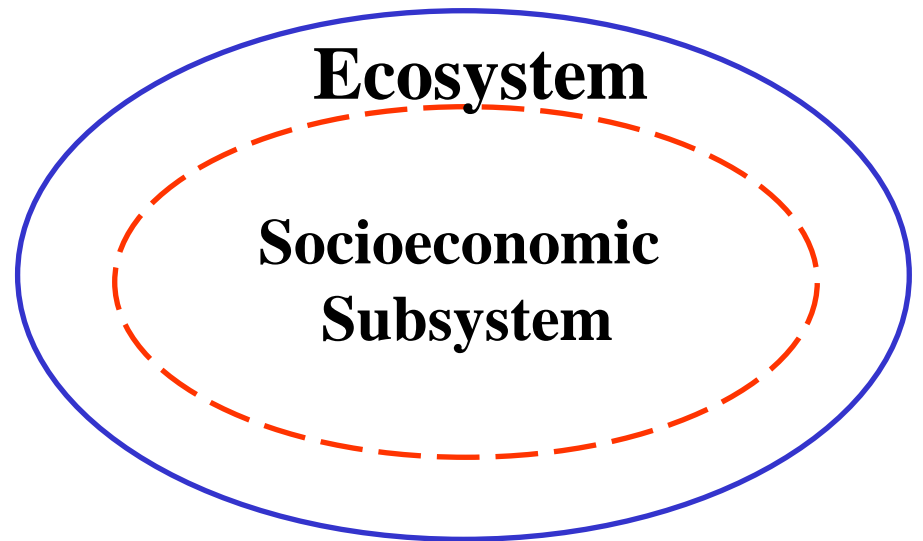
The capacity of the ecosystem may become overloaded by the growing socio-economic subsystem (broken lines).



MDMS: Restructuring development and growth II (rounding the rectangle)



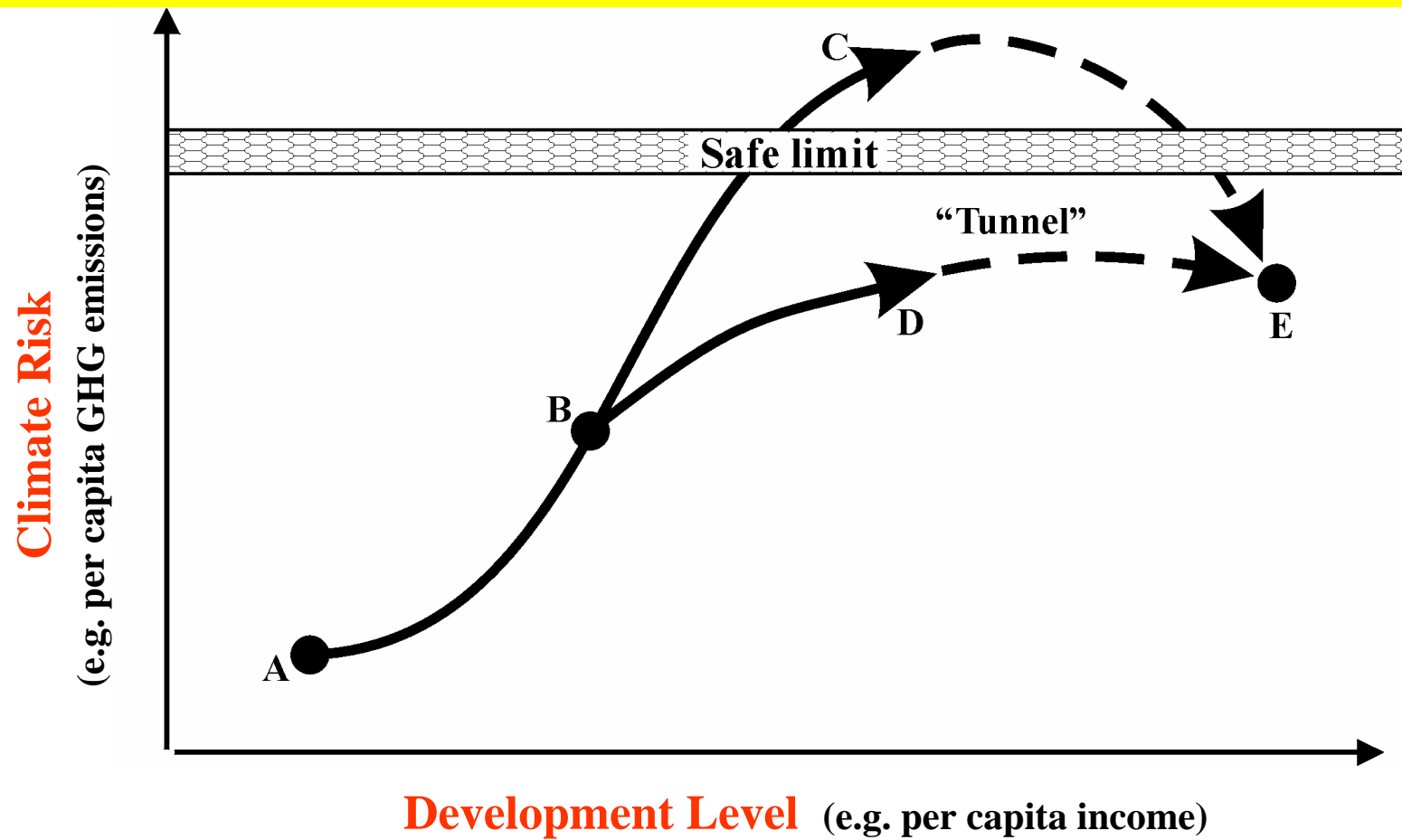
Unsustainable



Sustainable



MDMS via “Tunneling” : Climate Risk versus Development Level



Source: M. Munasinghe (1995) "Making Growth More Sustainable," *Ecological Economics*, 15:121-4.



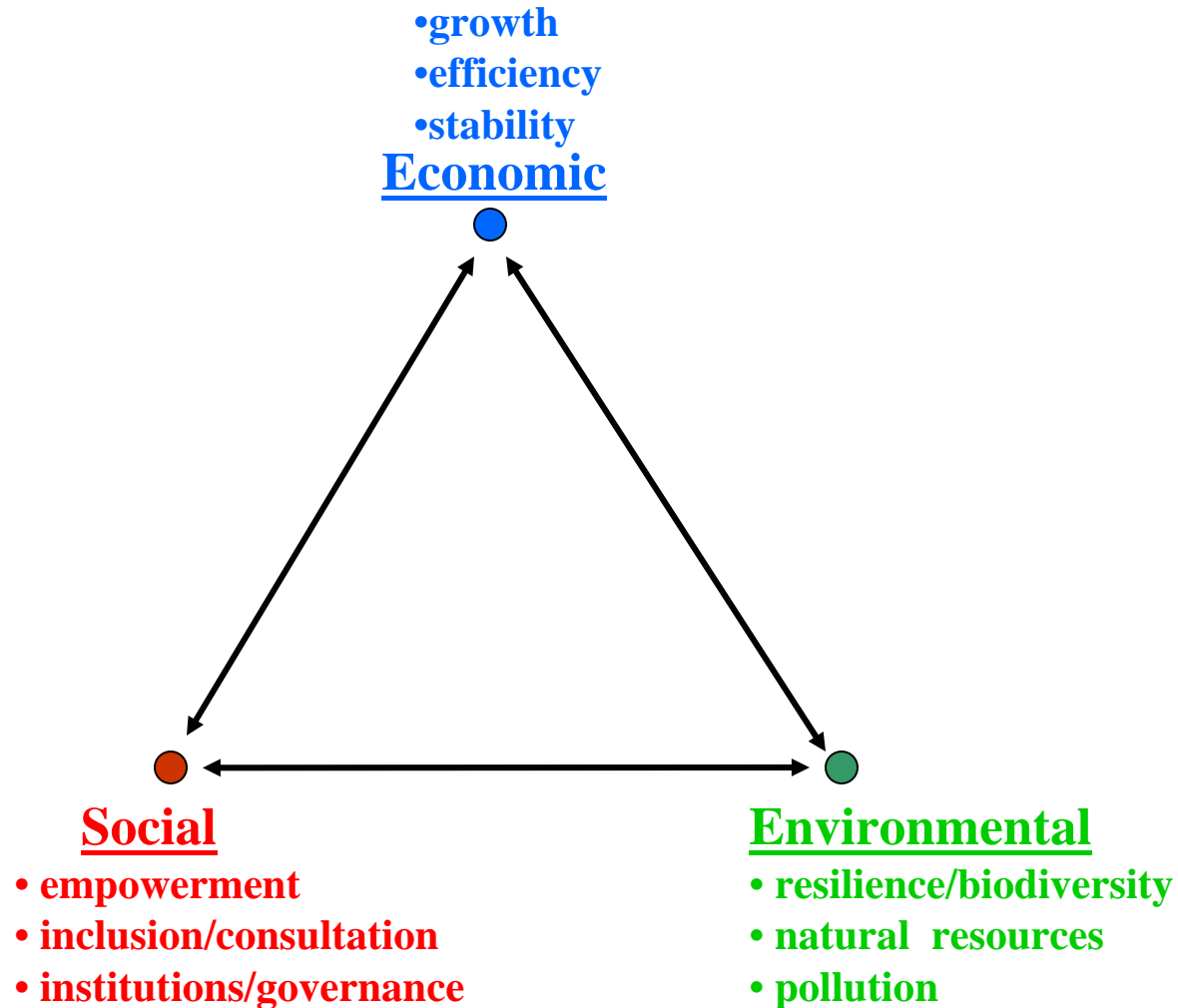
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SUSTAINOMICS

Core concepts and elements

1. Making development more sustainable (MDMS)
2. Sustainable development triangle
3. Transcending boundaries
4. Full cycle application of integrative tools – from data gathering to practical policy implementation



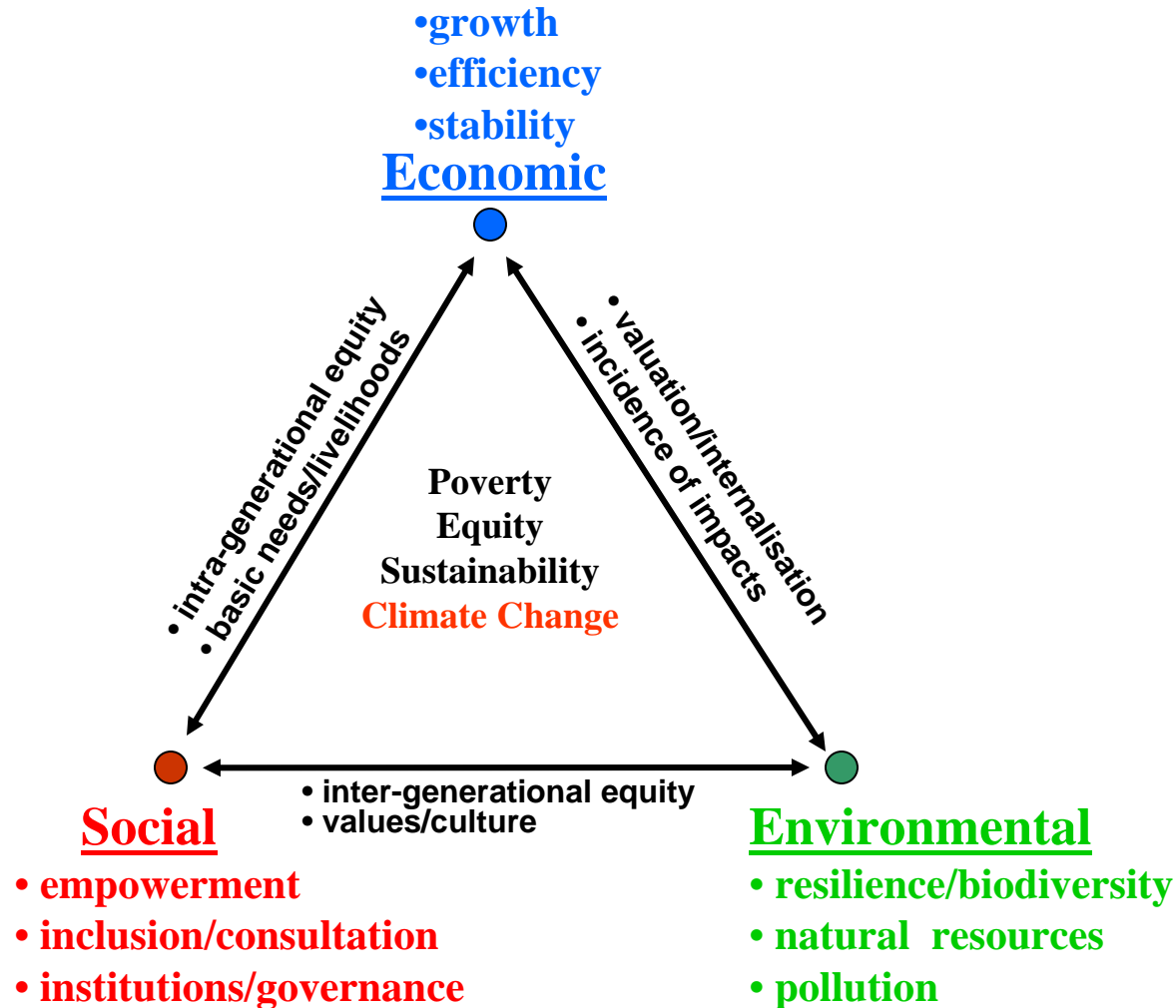


Sustainable Development Triangle - key elements and interconnections
(corners, sides and centre)

Source: Munasinghe [1992], Rio Earth Summit

MIND

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Sustainable Development Triangle - key elements and interconnections
(corners, sides and centre)

Source: Munasinghe [1992], Rio Earth Summit



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SUSTAINOMICS

Core concepts and elements

1. Making development more sustainable (MDMS)
2. Sustainable development triangle
3. **Transcending boundaries**
4. Full cycle application of integrative tools – from data gathering to practical policy implementation



Transcending Boundaries for Sustainable Development

- **Disciplinary**
- **Space**
- **Time**
- **Stakeholder**
- **Operational**



Transcending disciplines to address SD issues

SD Issues

- social justice, equity, values and culture
 - institutions and governance
 - markets and prices
 - technologies and management
- biological and physical resource base

Disciplines

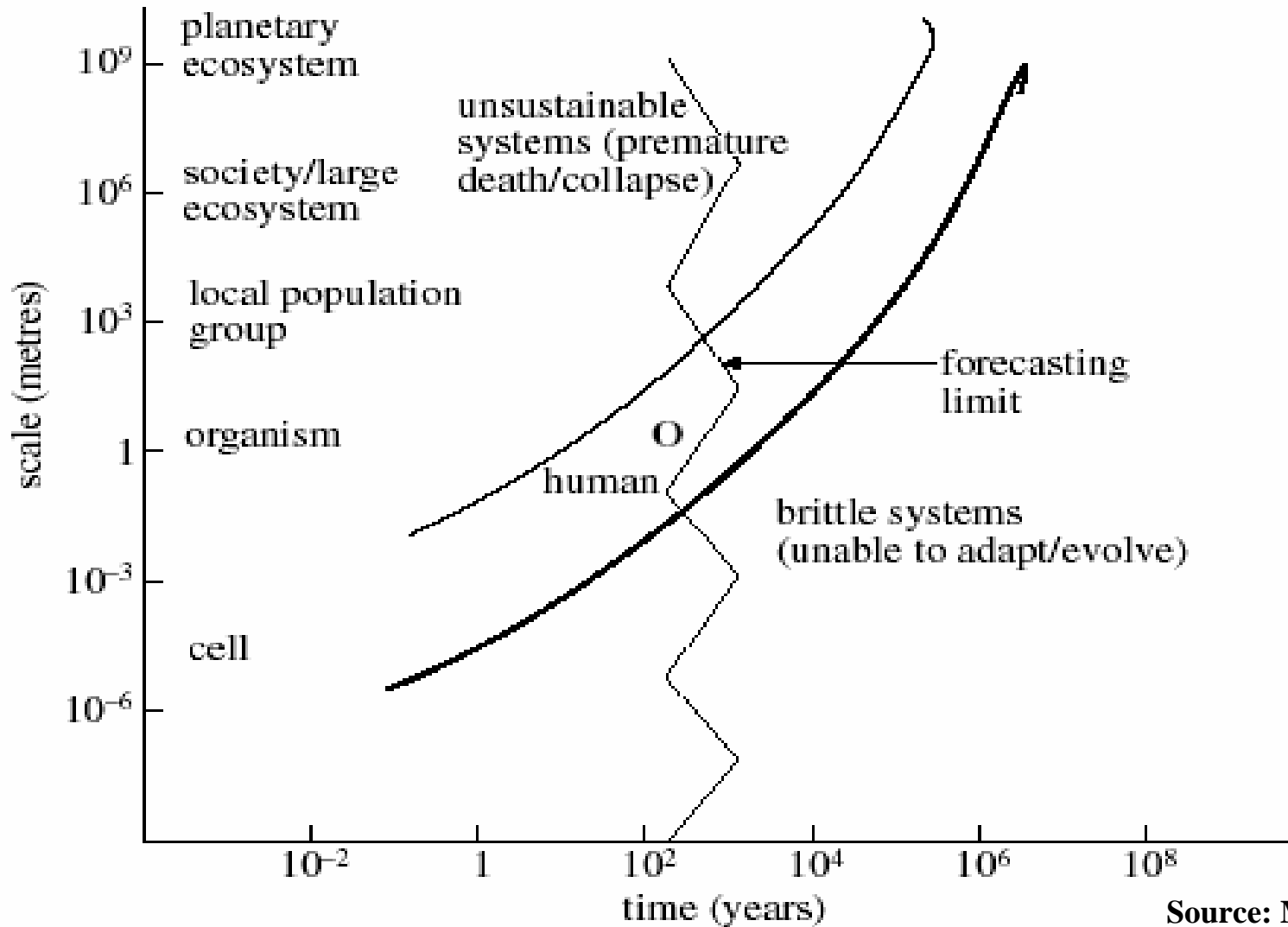
Philosophy
Sociology
Anthropology
Law
Politics
Economics
Finance
Management
Engineering
Ecology
Natural Sciences

Source: Munasinghe (2002), Int. J. of Sust. Dev.



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Transcending Boundaries of Space and Time – Norms for Sustainable Biological and Social Systems



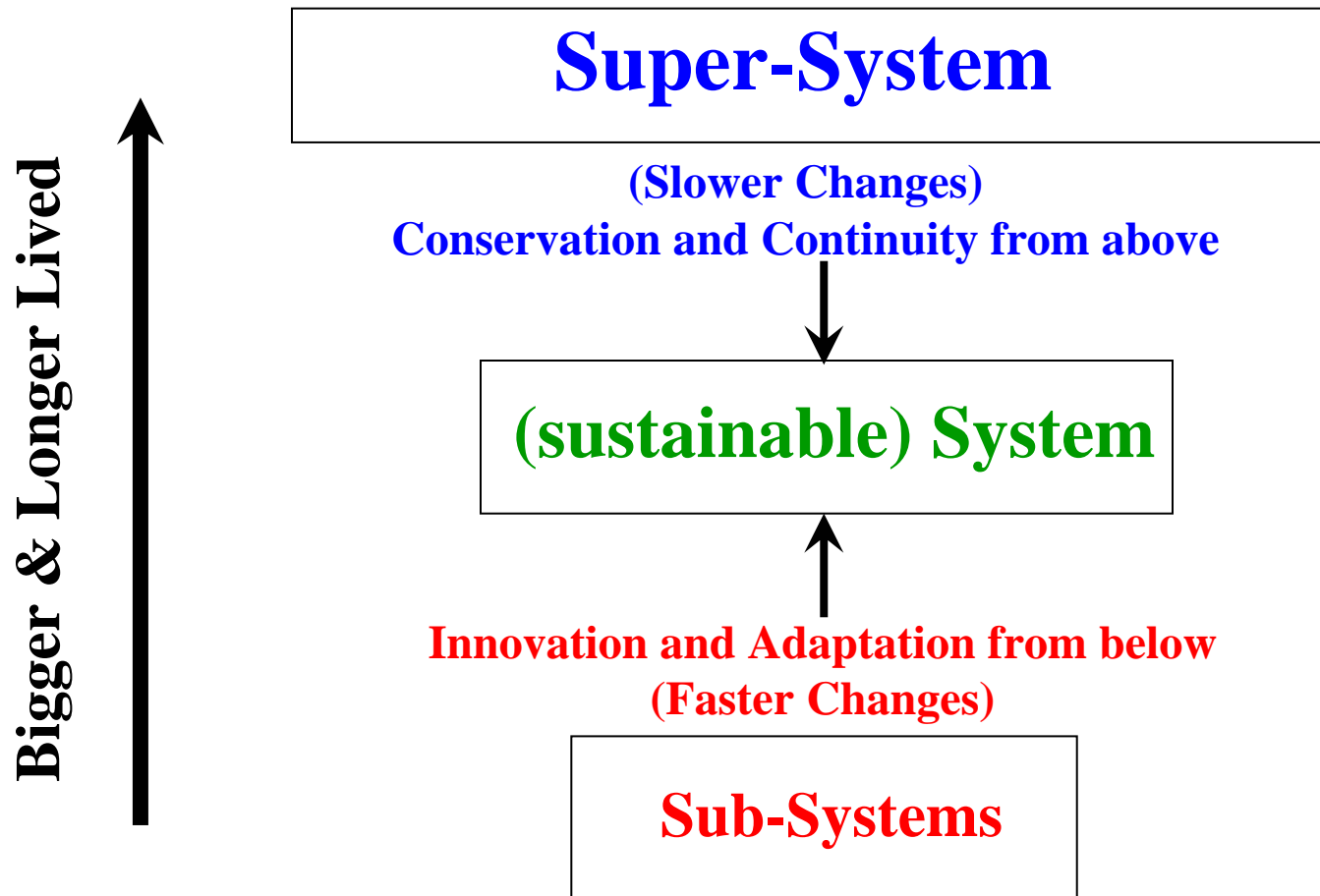
Source: Munasinghe (1994)



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Continuity across spatial and temporal scales

Panarchy of Systems Concept

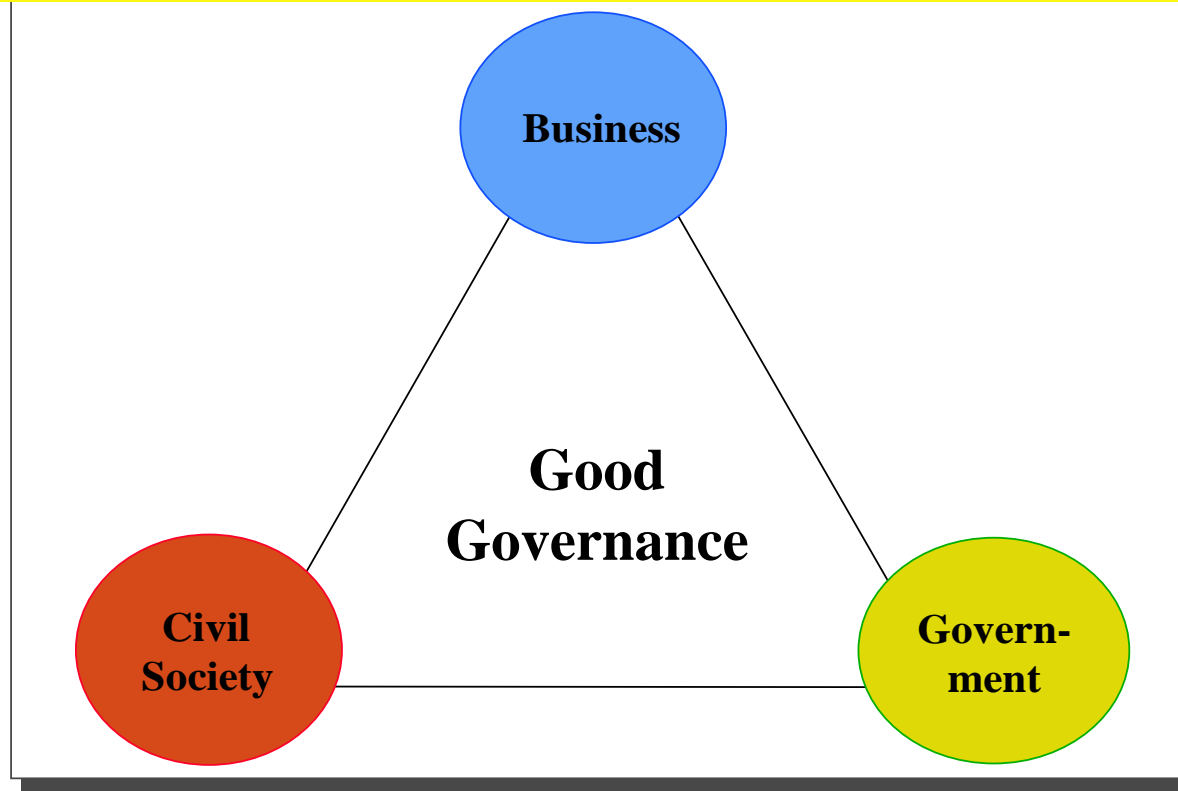


Source: Gunderson and Holling (2002)



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Transcending Stakeholder Boundaries to Ensure Cooperation for Sustainable Development



Not only **government**, but also **civil society** and **business** have a vital and balanced role to play in strengthening local, national and global citizenship

Source: Munasinghe (1992), Rio Earth Summit



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Transcending Operational Boundaries

ACTION

ACTOR

Observations and Data

Observers

Concepts and Ideas

Thinkers & Philosophers

Models & Analyses

Scientists & Analysts

Interpretation of Results

Translators & Communicators

Plans & Policies

Decision Makers

Practical Implementation

Implementing Agents



Each stage of activity has a tendency to become compartmentalised

Source: Munasinghe (2002), Int. J. of Sust. Dev.

MIND

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SUSTAINOMICS

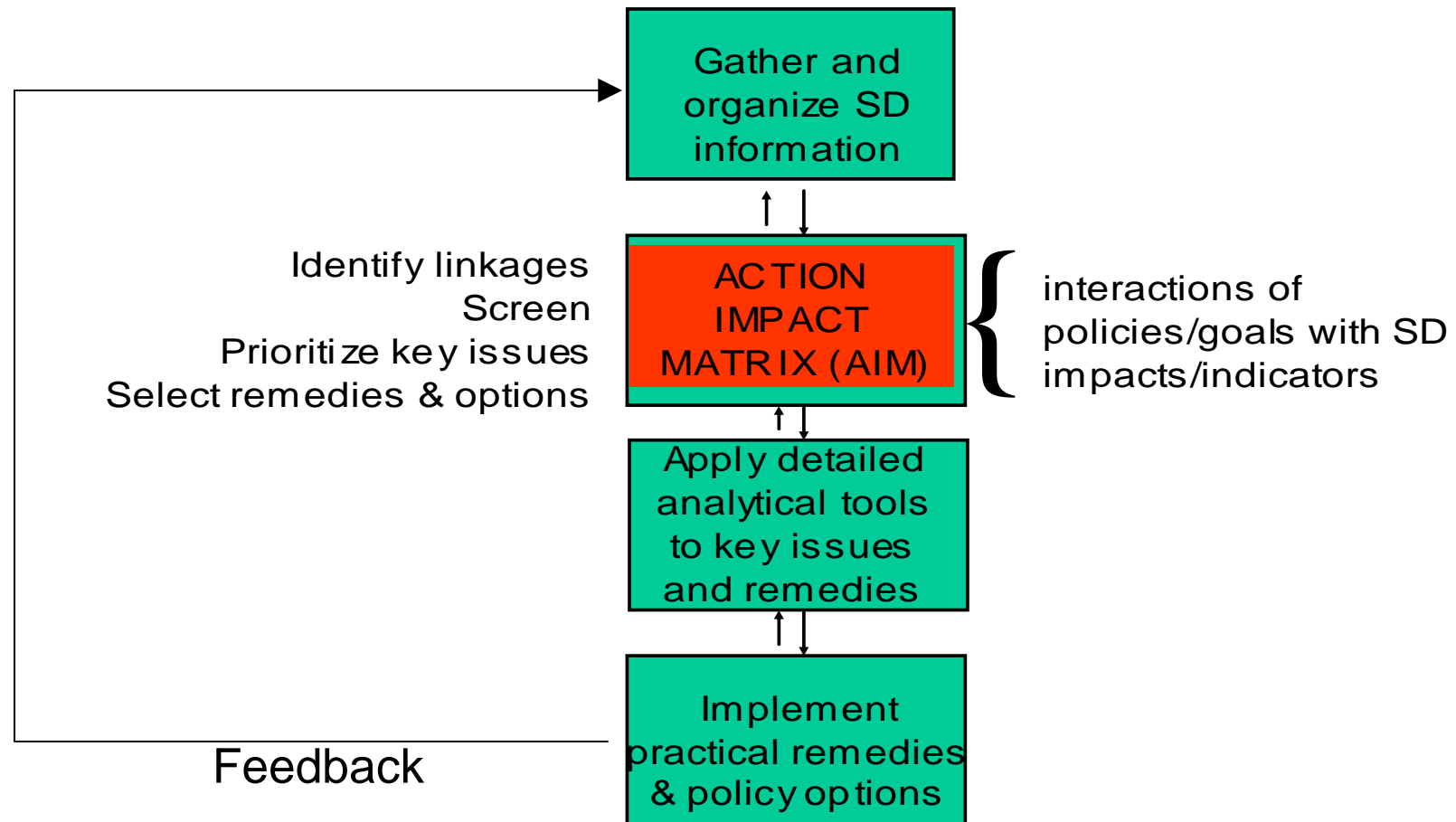
Core concepts and elements

1. Making development more sustainable (MDMS)
2. Sustainable development triangle
3. Transcending boundaries
4. Full cycle application of integrative tools – from data gathering to practical policy implementation



Full cycle application of integrative tools:

Action Impact Matrix (AIM) is key link from data gathering to practical policy application



Sustainomics – Overview

1. Core concepts and elements

- Making development more sustainable (MDMS)
- Sustainable development triangle
- Transcending boundaries
- Full cycle application of integrative tools – from data gathering to practical policy implementation

2. Integrative analytical tools and practical policy applications

- Restructuring development and growth
- Optimisation and durability
- SD analysis (macro level)
- Action impact matrix (AIM)
- Green accounting (SEEA-SNA)
- Integrated models (IAM, CGE, etc.)
- SD analysis (micro level)
- Multi-criteria analysis (MCA), cost-benefit analysis (CBA) and economic valuation
- SD indicators
- Empirical case studies at various levels -- global-transnational, national-macroeconomic, subnational-sectoral, and local-project.



Integrative analytical tools and practical applications **(linking across global, national and local levels)**

Integrative Analytical Tools

- 1. Restructuring Growth to Make Development More Sustainable (MDMS)**
- 2. Optimisation and Durability**
- 3. SD Analysis (Macro Level)**
- 4. Action Impact Matrix (AIM)**
- 5. Green Accounting (SEEA-SNA)**
- 6. Integrated Models (IAM, CGE, etc.)**
- 7. SD Analysis (Micro Level)**
- 8. Multi-Criteria Analysis (MCA), Cost-Benefit Analysis (CBA) and Economic Valuation**
- 9. SD Indicators**

Application Levels

A. Global-transnational

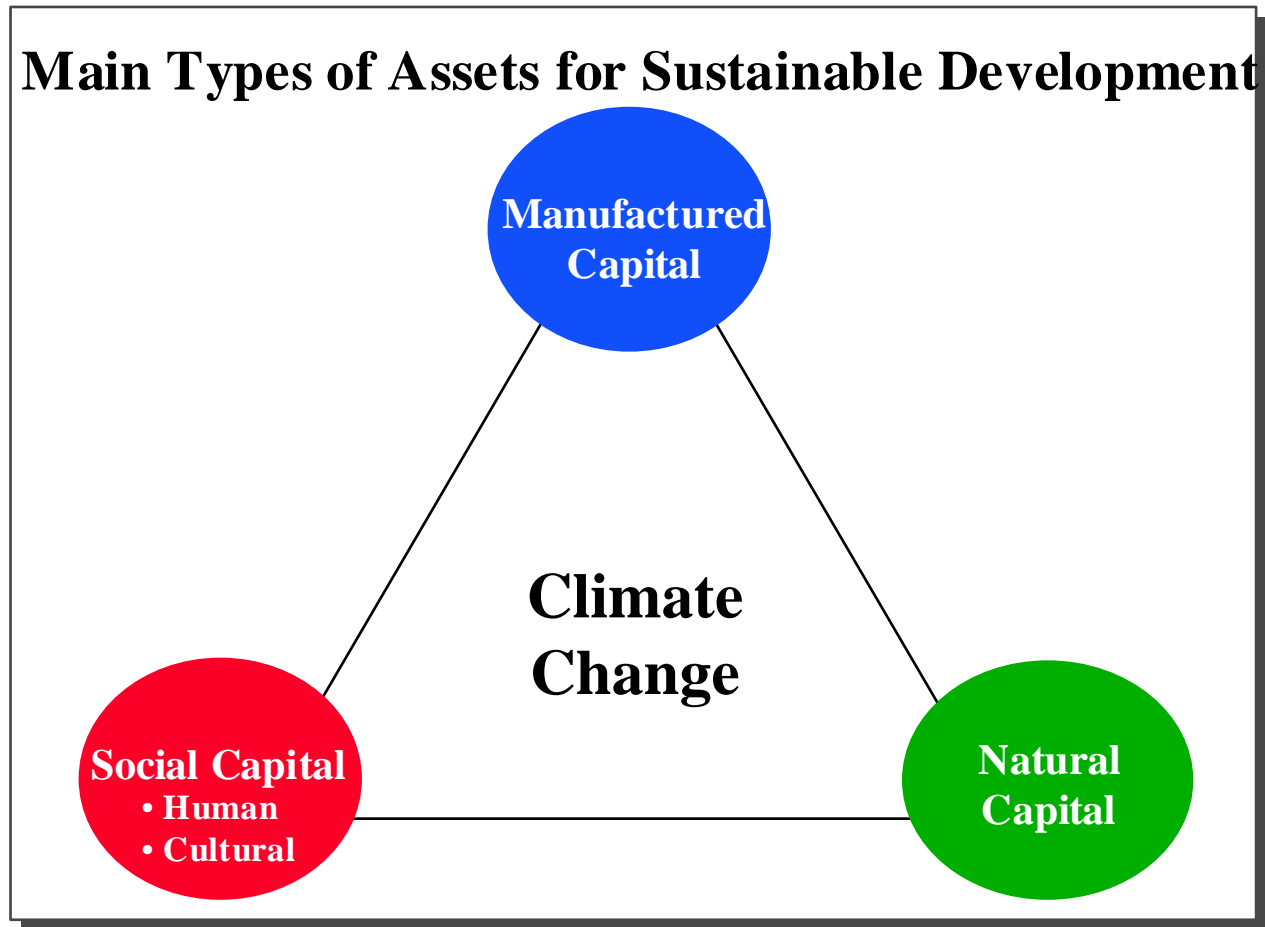
B. National-macroeconomic

C. Subnational-sectoral

D. Local-project

↑ Linkages Across Levels ↓

Integrating across the three dimensions of SD



Economic approach focuses on **optimality** - maximise growth
Environmental and social approaches rely on **durability** - system health

Diverse Definitions of Sustainability

Economic: Maximum flow of income that could be sustained indefinitely, without reducing stocks of productive assets. Economic efficiency ensures both efficient resource allocation in production and efficient consumption that maximises utility.

Ecological: Preserving the viability and normal functioning of natural systems, including system health ability to adapt to shocks across a range of spatial and temporal scales. Defined by a comprehensive, multiscale, hierarchical, dynamic measure describing system resilience, vigour and organization.

Social: Maintaining the resilience of social systems and limiting their vulnerability to sudden shocks. Involves building social capital to strengthen cohesion, protecting cultural diversity and values, and improving inclusion and participation - especially of disadvantaged groups.



Integration Via Optimal Development Paths

Maximize welfare (or utility), subject to non-decreasing stock of productive assets (or welfare itself). A simple example of maximization of the flow of aggregate welfare (W), cumulatively discounted over infinite time (t), is:

$$\text{Max} \int_0^{\infty} W(C, Z) \cdot e^{-r t} dt.$$

Here, W is a function of C (the consumption rate), and Z (a set of other relevant variables), while r is the discount rate.

C depends on the production rate of the economy, which in turn depends on stocks of various assets. Side constraints may be imposed to satisfy sustainability needs – e.g., non-decreasing consumption or stocks of productive assets (including natural resources).

Economic Optimisation - Integration via Economic Sustainability Rules

Maximum flow of income that could be sustained indefinitely, without reducing stocks of productive assets. Economic efficiency ensures both efficient resource allocation in production and efficient consumption that maximises utility.

Define A = Total assets

= Economic capital (E) + Natural capital (N) + Social capital (S)

Weak Sustainability Rule: $dA/dt > 0$

(different forms of assets are substitutable)

Strong Sustainability Rule: $dE/dt > 0$; $dN/dt > 0$; $dS/dt > 0$

(different forms of assets are complementary – not substitutable)



Durable Development Paths (Ecological)

Focus mainly on sustaining the quality of life – e.g., by satisfying environmental, social and economic sustainability requirements. They permit growth, but are not necessarily economically optimal. There is more willingness to trade off some economic optimality for the sake of greater safety, in order to stay within critical economic, environmental and social limits.

A simple durability index (D) for an organism or system is its expected lifespan (in a healthy state), as a fraction of the normal lifespan: $D = D(R, V, O, S)$; specifies durability (D) as a function of resilience (R), vigour (V), organization (O), and the state of the external environment (S) – especially in relation to damaging shocks.

Durable paths seek to increase diversity and adaptive capacity, while reducing risk.



SD Indicators

- Social
- Environmental
- Economic
- Institutional

many indicators are available; thus choice is critical for specific task at hand

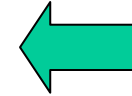


Long Term Vision of Sustainable Development

Human Interventions

Main Issues

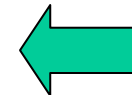
Poverty, Inequity,
Exclusion, Harm to
Environment (incl. CC)



Outcome of **unrestrained market forces** at work (“Washington consensus”, globalisation etc.)

Immediate Drivers

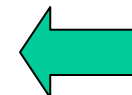
Consumption Patterns
Population
Technology
Governance



Make development more sustainable (MDMS) with systematic policy reform to manage market forces (Sustainomics)

Underlying Pressures

Basic Needs
Social Power Structure
Values, Choices
Knowledge Base



Catalyse a fundamental global sustainable dev. transition through grass roots citizens movements, driven by social justice and equity concerns (new SD paradigm)



WHY ? is climate important for future development
Climate Change undermines Sustainable
Development and unfairly penalizes the poor

HOW ? do we trace CC-SD links and make development
more sustainable (MDMS)
Study CC-SD circular interaction using the
Sustainomics framework

WHAT? are the practical analytical tools and policy
options to integrate CC responses into SD
strategy (from global to local levels)
Many case studies and examples of good
practice are available

Practical Applications of
Sustainomics to CC-SD
Linkages
Global, National and Project
Level Examples



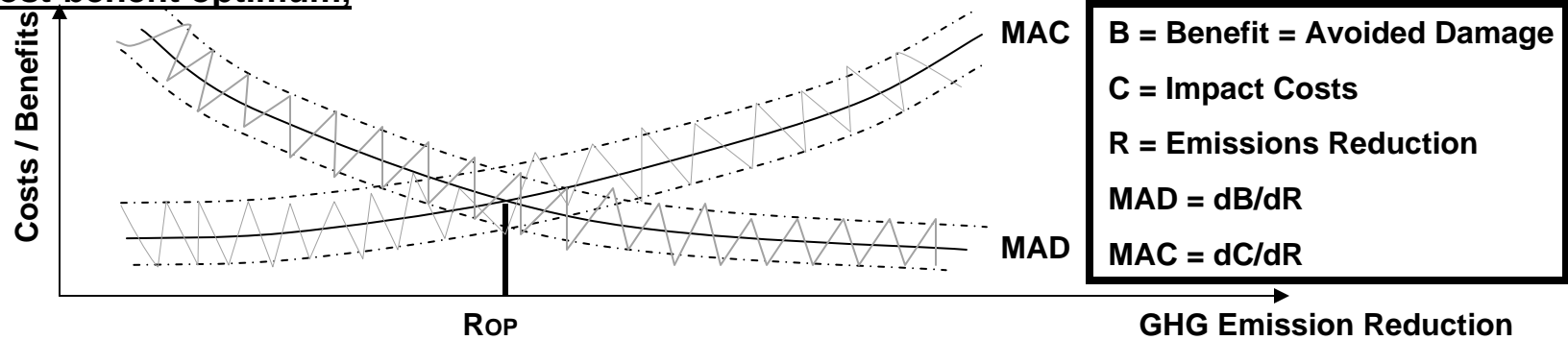
Global Level Application
Setting Mitigation Targets
based on Optimality and Durability



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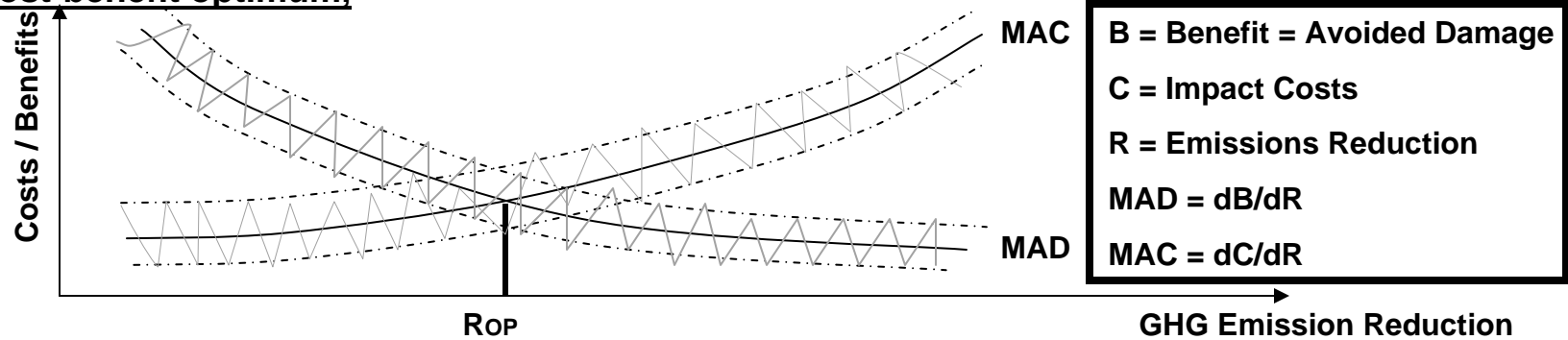
Interplay of optimality and durability in determining global mitigation targets - 1

(a) cost-benefit optimum,

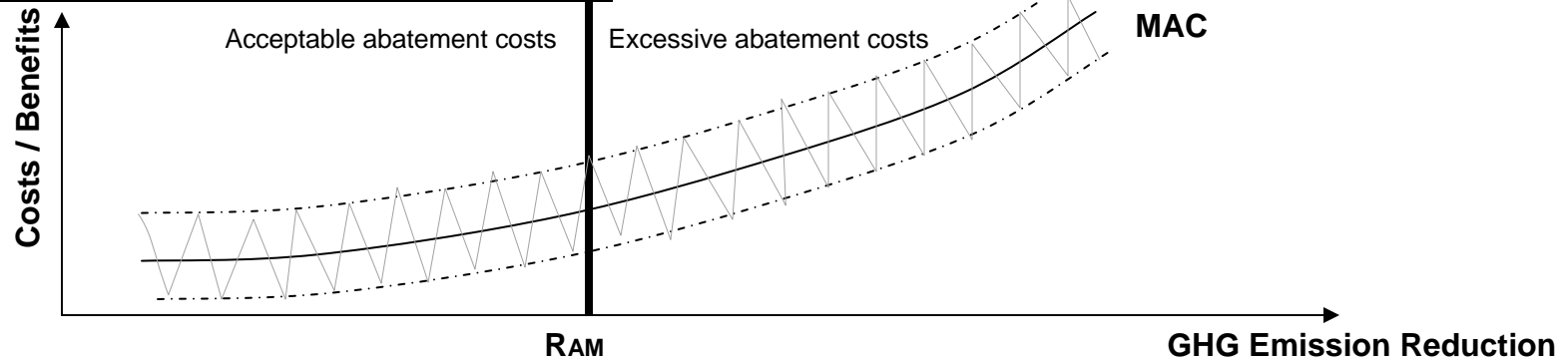


Interplay of optimality and durability in determining global mitigation targets - 2

(a) cost-benefit optimum,

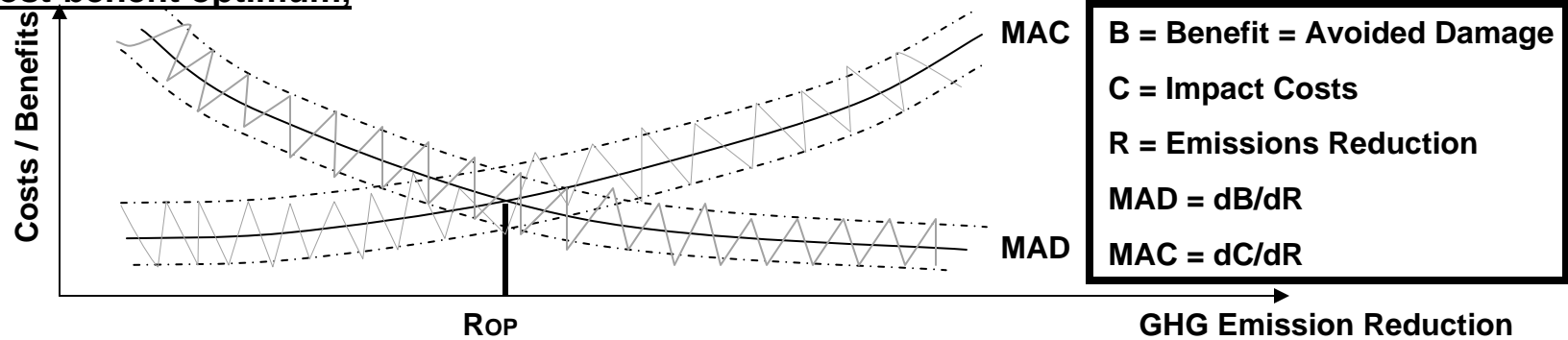


(b) affordable safe minimum standard,

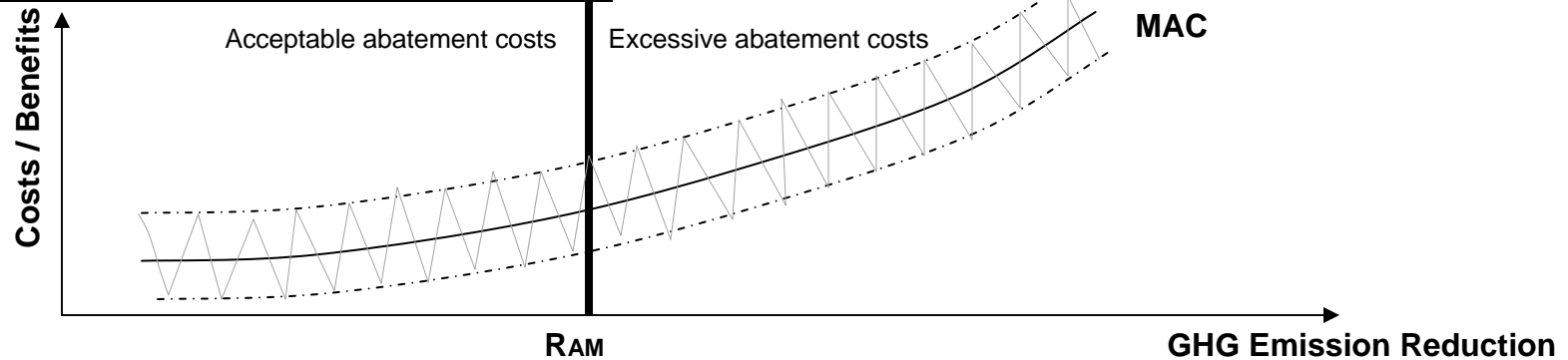


Interplay of optimality and durability in determining global mitigation targets - 3

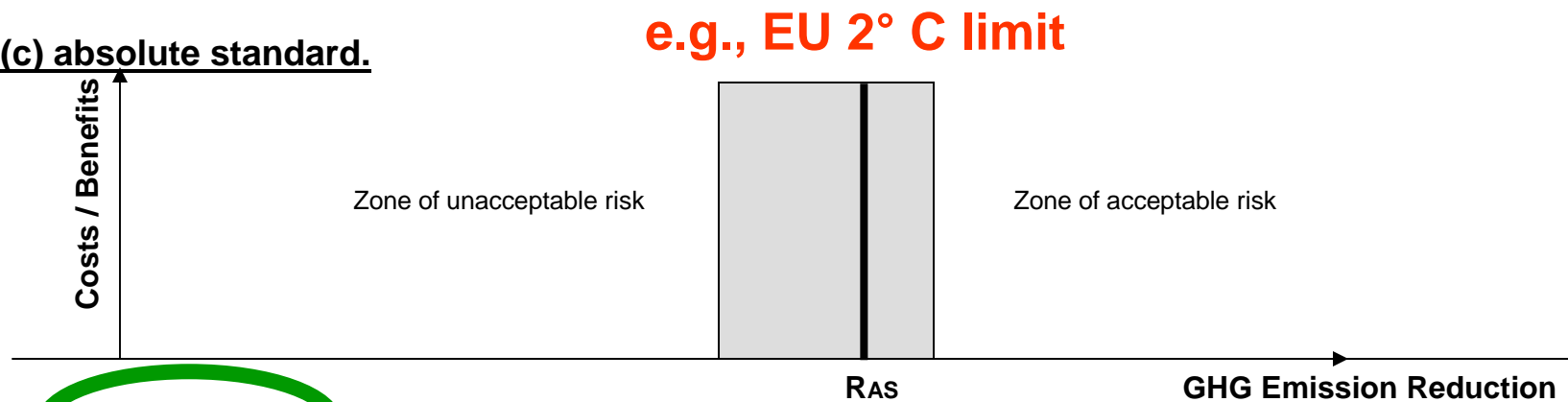
(a) cost-benefit optimum,



(b) affordable safe minimum standard,



(c) absolute standard.

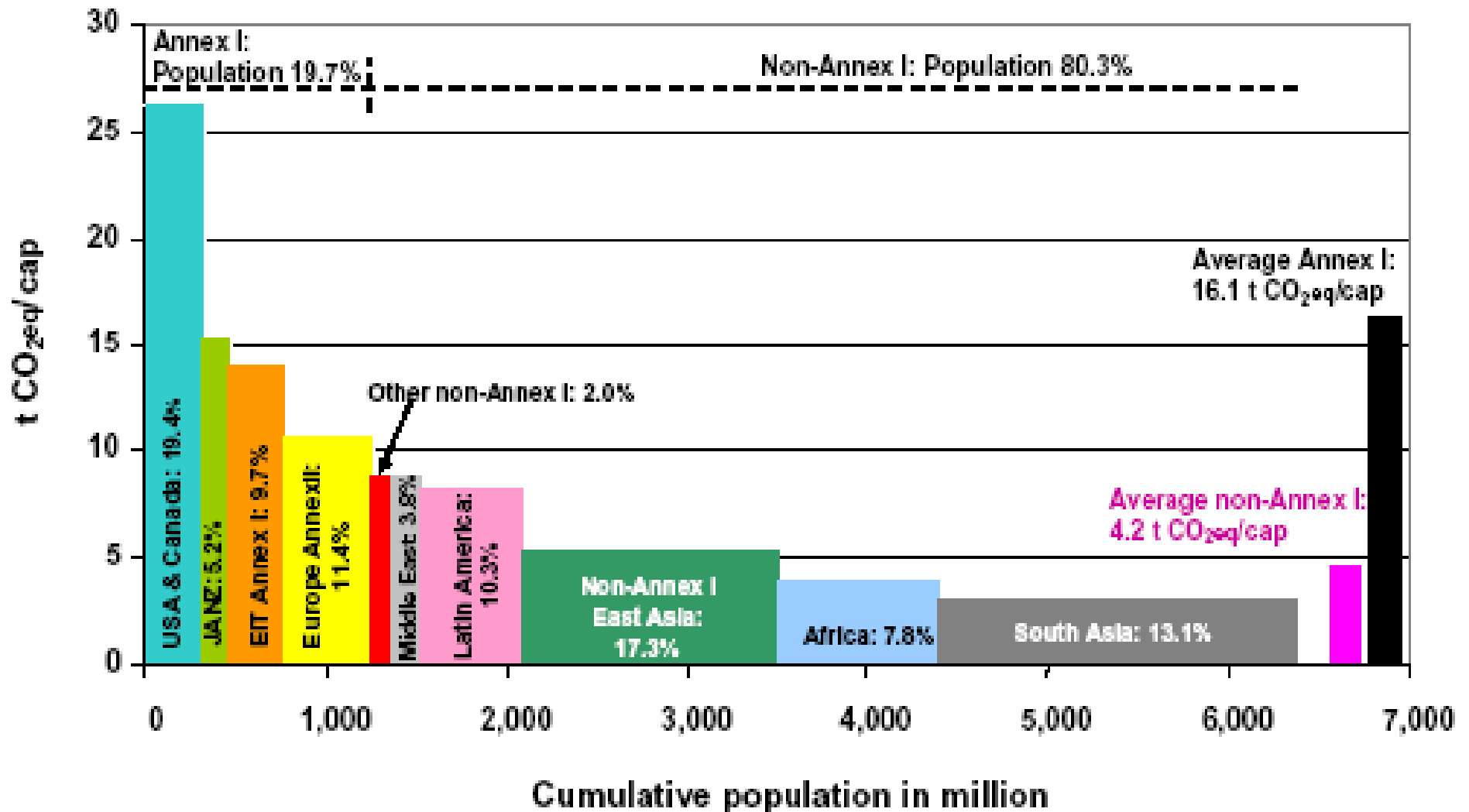


Global Interplay of Equity and Efficiency in Flexibility Mechanisms: Clean Development Mechanism (CDM) & Emissions Trading

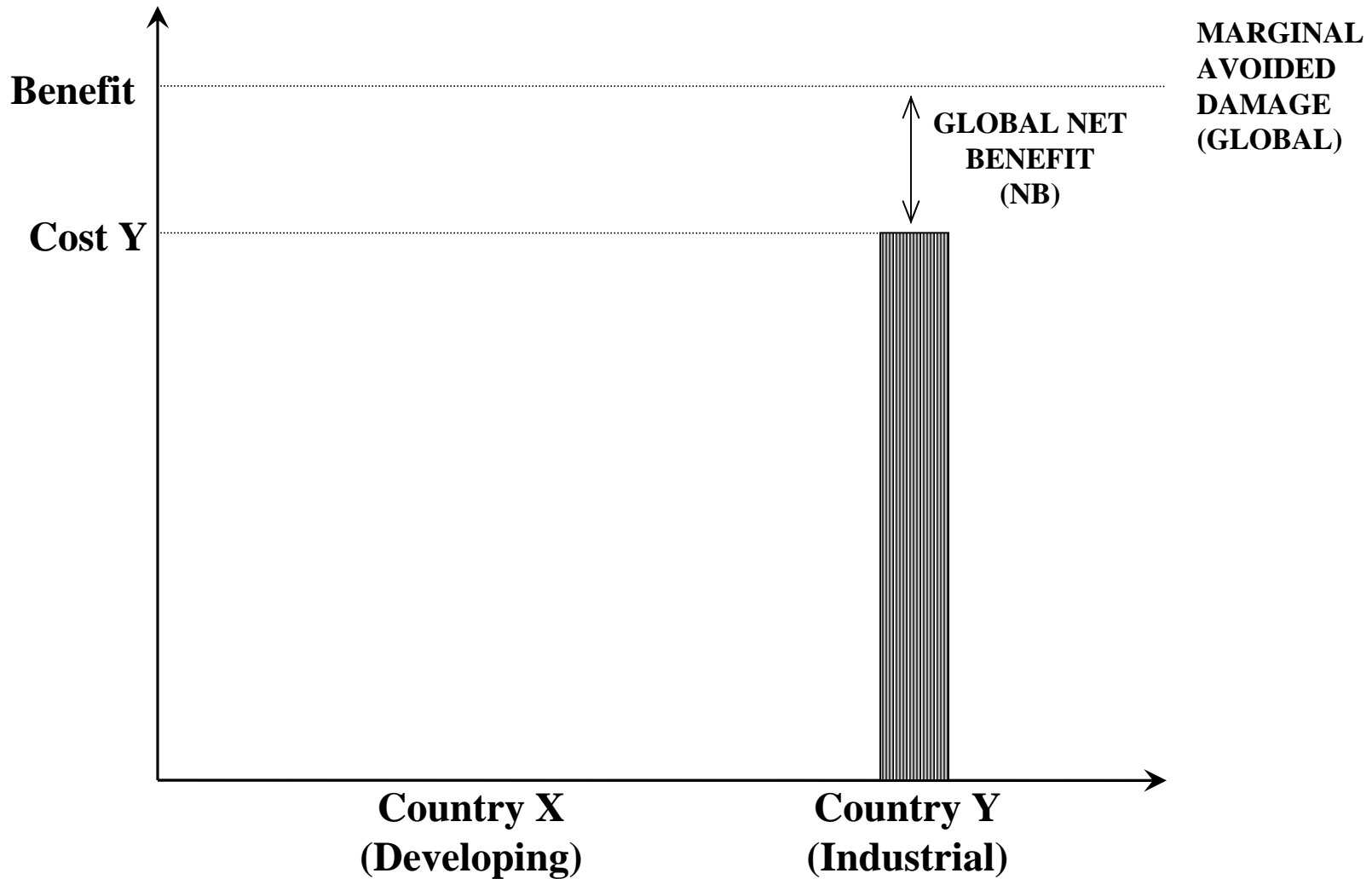


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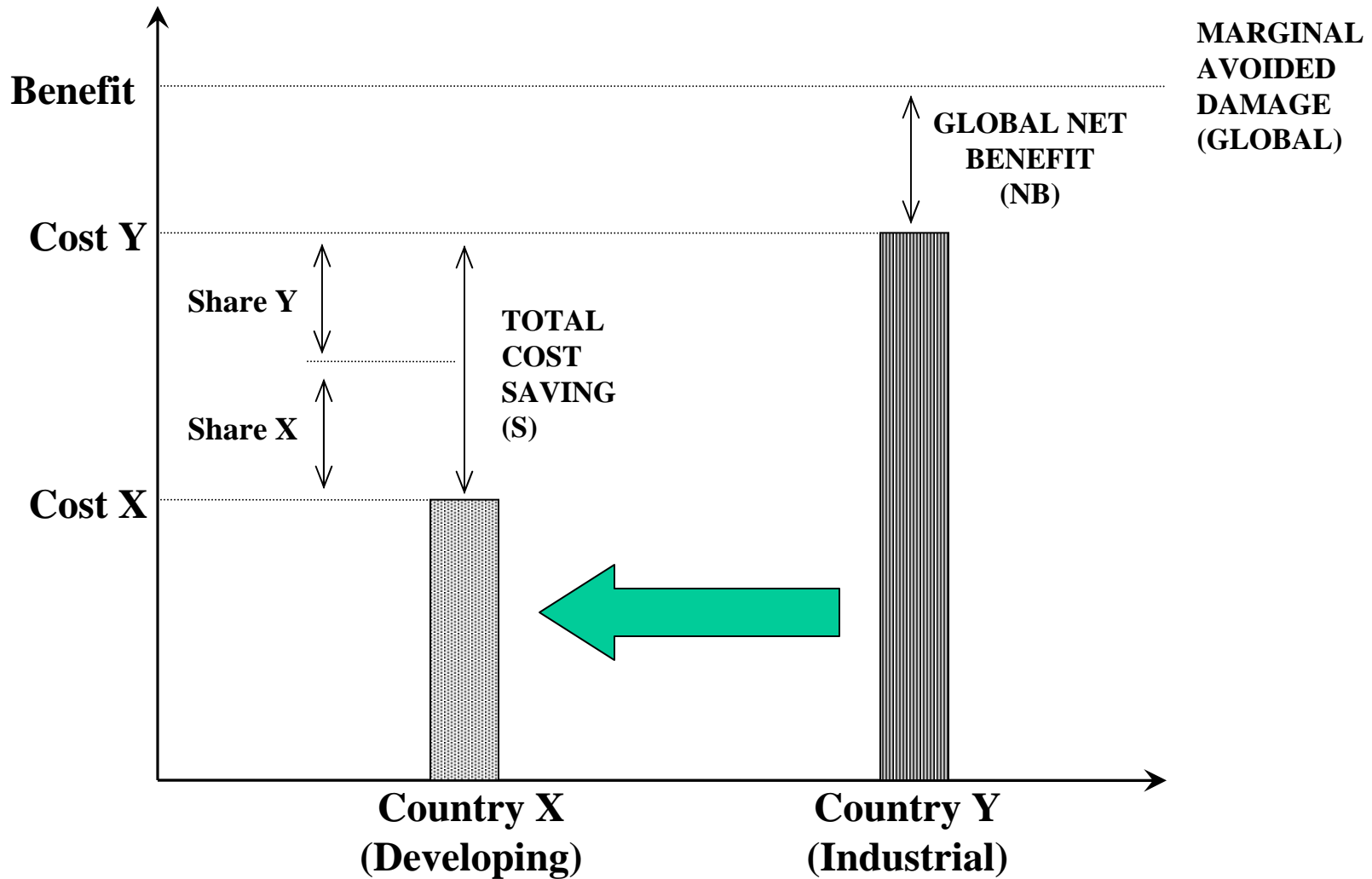
Per capita GHG emissions and population 2004



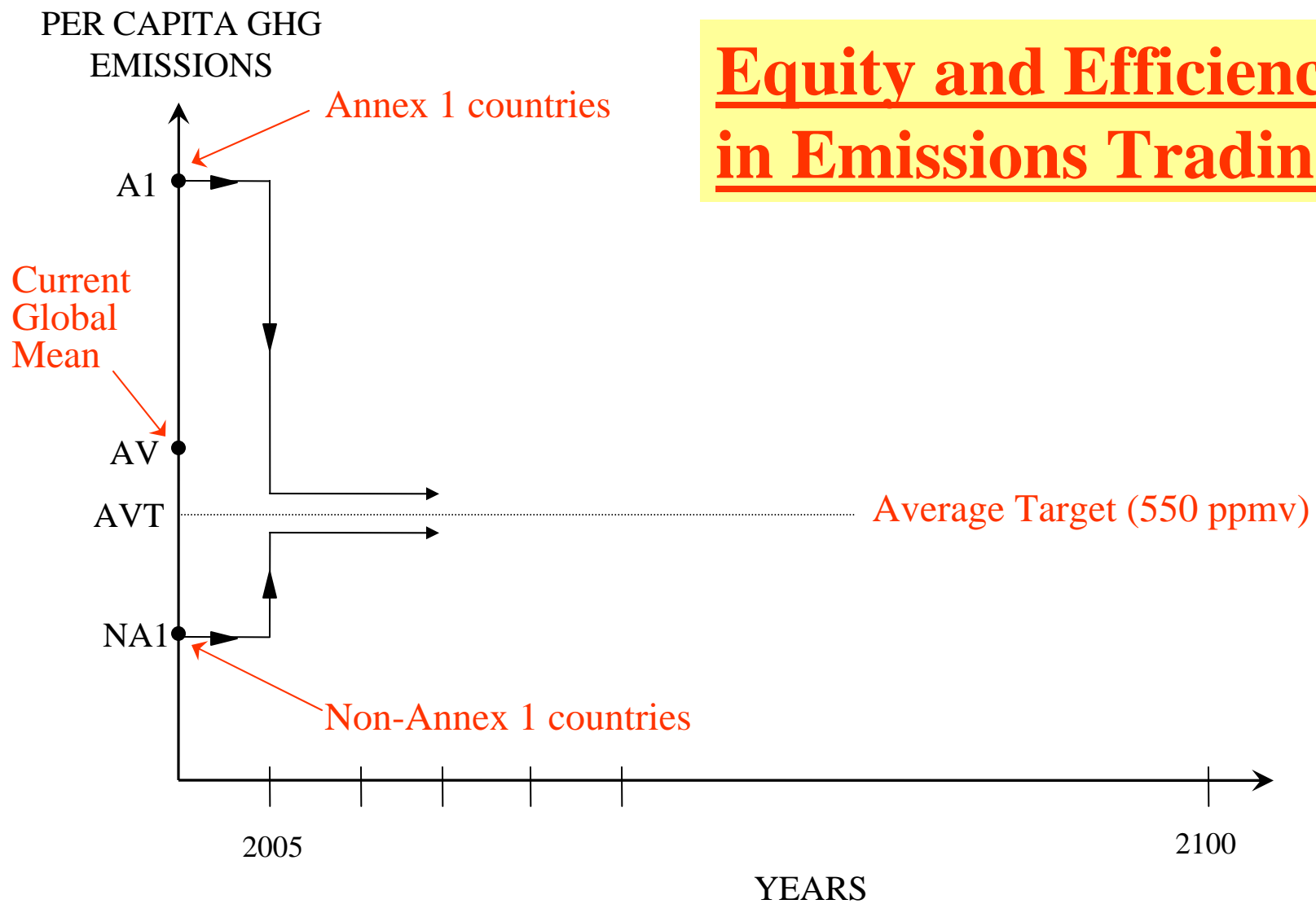
Global Interplay of Equity and Efficiency in Clean Development Mechanism (CDM) & JI: 1



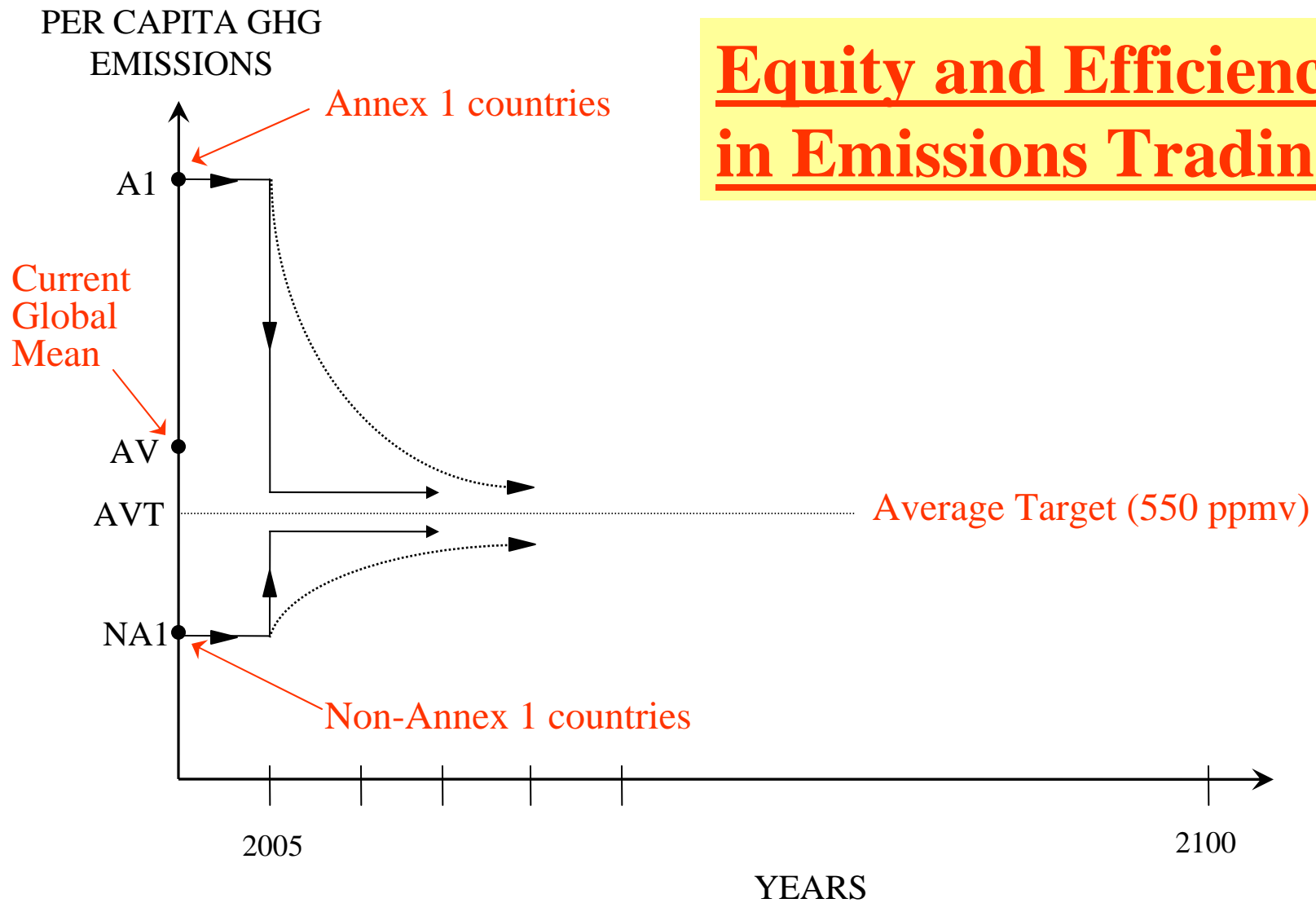
Global Interplay of Equity and Efficiency in Clean Development Mechanism (CDM) & JI: 2



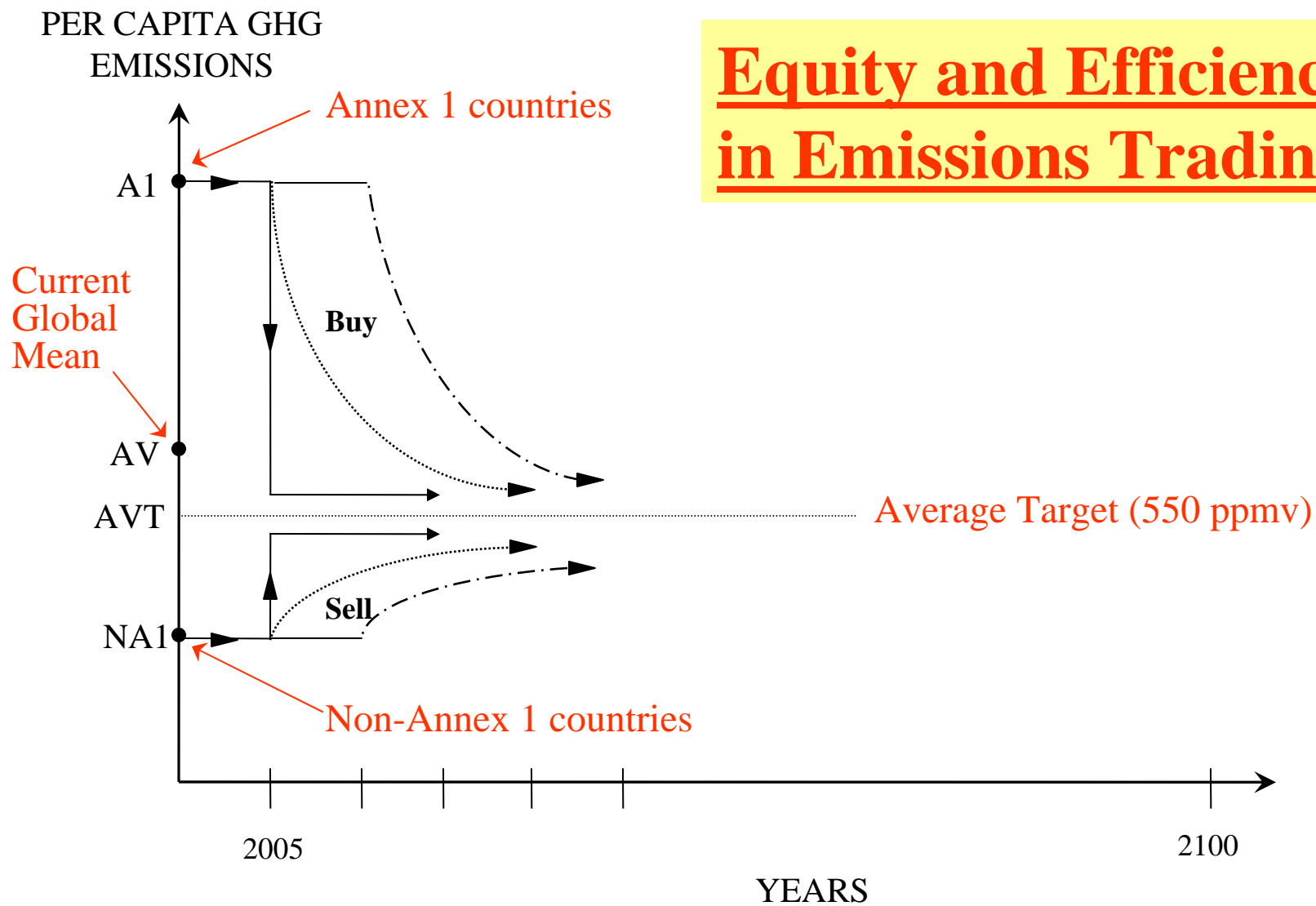
Equity and Efficiency in Emissions Trading 1



Equity and Efficiency in Emissions Trading 2



Equity and Efficiency in Emissions Trading 3



Country Level Actions

**Integrating Climate Change
Policies into National Sustainable
Development Strategy**



Developing Country Example:

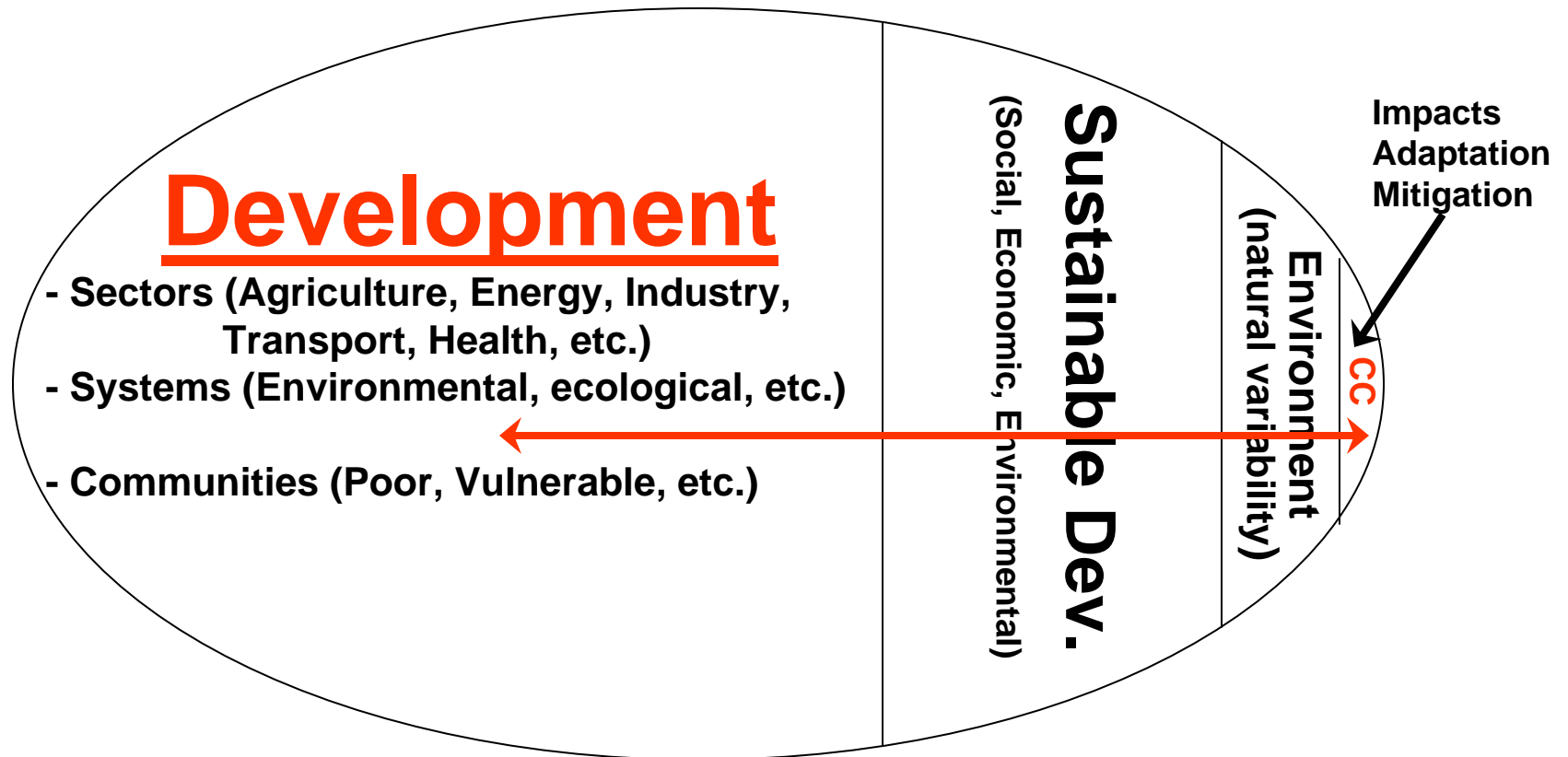
Typical Response Options for a National Climate Change Strategy

- 1. Grow Fast (reduce vulnerability to CC)**
- 2. Improve adaptive capacity (reduce impacts)**
- 3. Mitigate (FX incentives needed to offset costs)**
- 4. Integrate CC-SD strategy by combining 1,2 & 3**



National Level CC-SD Links

Decision makers see climate change as a minor element in the national sustainable development strategy

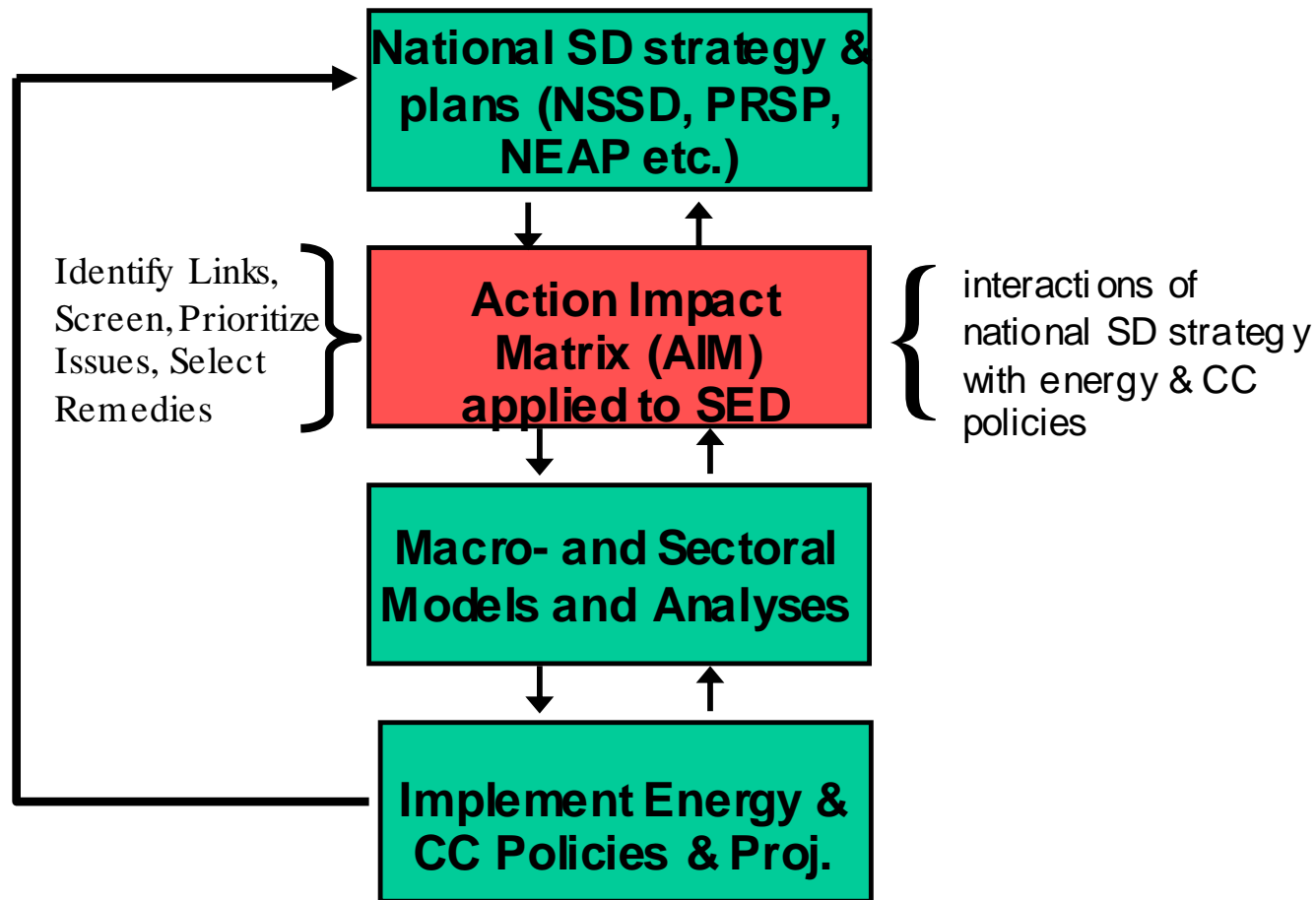


**Application of Action Impact
Matrix (AIM) Methodology to
Analyse SD-CC Links in Sri Lanka
Brief Introduction**



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Analysing SD-CC Links using the Action Impact Matrix (AIM)



Action Impact Matrix (AIM) Methodology

The AIM methodology may be used to better understand interactions among three key elements, at the country-specific level:

- (a) national development policies and goals;
- (b) key SD issues and indicators; and
- (c) climate change adaptation (and mitigation).

First, the two-way linkages between elements (a) and (b) are explored, in the context of natural climate variability. Then, we impose the additional impacts of element (c) on the interactions between elements (a) and (b).

The AIM approach analyses key economic-environmental-social interactions to identify potential barriers to making development more sustainable (MDMS) - including climate change. It also helps to determine the priority macro policies and strategies in economic, environmental and social spheres, that facilitate implementation of climate change adaptation and mitigation to overcome the effects of climate change.

Thus, the AIM helps to integrate CC within SD. It has been used since the early 1990s to link macroeconomic policies and environment.

AIM Process

The AIM methodology relies on a **fully participative stakeholder exercise** to generate the AIM itself. Up to 50 experts are drawn from government, academia, civil society and the private sector, who represent various disciplines and sectors relevant to both sustainable development and climate change. In the initial exercise, they usually interact intensively over a period of about two days, to build a preliminary AIM. This participative process is as important as the product (i.e., the AIM), since **important synergies and cooperative team-building activities emerge**. The collaboration helps participants to better understand opposing viewpoints, resolves conflicts, and ultimately facilitates implementation of agreed policy remedies. On subsequent occasions, the updating or fine-tuning of the initial AIM can be done within a few hours by the same group, since they are already conversant with the methodology.

AIM Principles

The AIM methodology is based on the **sustainomics framework** [1], which draws on the following principles:

1. **MDMS approach** – sustainable development is defined as a process (rather than an end point), while the step-by-step approach of “making development more sustainable” (MDMS) becomes the prime objective.
2. **Sustainable development triangle** - SD is viewed through three main domains or perspectives: social, economic and environmental.
3. **Trans-boundary approach** – analysis transcends conventional boundaries imposed by discipline, space, time, stakeholder viewpoints, and operability.
4. **Full cycle application of integrative tools** – Action Impact Matrix (AIM) is the key link from initial data gathering to practical policy application and feedback.

[1] Proposed at 1992 Rio Earth Summit - see Munasinghe (1992) and Munasinghe (2002).

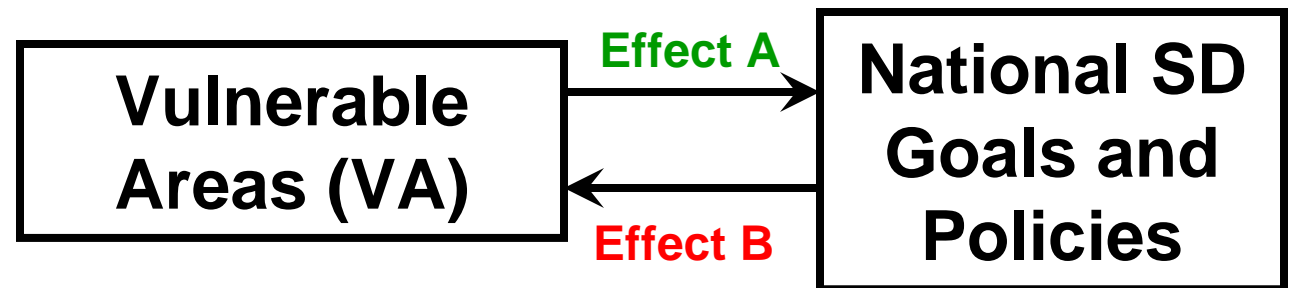


Integrating Adaptation into SD Strategy using the AIM



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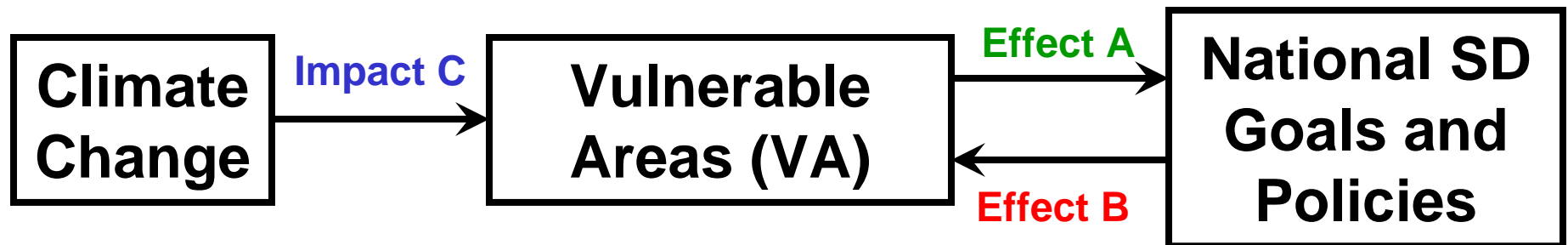
Action Impact Matrix (AIM) for Analyzing SD-CC Adaptation Links: 1



Step 1: DEV-AIM = Effect B
(Development Effects on VA)

Step 1: VED-AIM = Effect A
(VA Effects on Development)

Action Impact Matrix (AIM) for Analyzing SD-CC Adaptation Links: 2



Step 2: DEV-AIM = **Effect B** + **Impact C**
(Development Effects on VA)

Step 2: VED-AIM = **Effect A** + **Impact C**
(VA Effects on Development)

Building the AIM – Step 1: Identify Rows and Columns

Row Headings: key national macro-economic goals and policies.

Column Headings: key vulnerable areas (VA), and associated economic, environmental and social indicators.

		Vulnerable Areas (VA)			
		Economic		Environmental	Social
		(1) Agricultural output	(2) Industrial Activity	(3) Water Resources	(4) Health
<u>Dev. Goals/Policies</u>					
(A)	Growth				
(B)	Poverty alleviation				
(C)	Food Security				
(D)	Employment				



Adaptation Effects on Development (VED-AIM) in Sri Lanka – CC

Impacts and Effects of VA on Development Goals/Policies

Key Vulnerabilities, Impacts and Adaptation (VIA)

Notation

- + Beneficial
- Harmful
- 3 High
- 2 Moderate
- 1 Low

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
		Agric. Output	Hydro Power	Deforestation	Bio-div. (flora & fauna)	Wetlands & coastal ecosystems	Water resources	Poor communities	Human health	Infrastruct.	Industries & Tourism
(S0)	Status (Nat. Variability)	-1	0	-2	-1	-1	-2	-1	0	2	2
(S1)	Status (+CC Impacts =>)	-2	-1	-2	-2	-2	-3	-2	-1	-1	-1
Dev. Goals/Policies (+CC Impacts)											
(A)	Growth	-1	-1	-1	-1	-1	-2	-2	-1	-1	-1
(B)	Poverty alleviation	-2	0	-1	-1	-1	-2	-2	-2	-1	-1
(C)	Food Security	-3	0	-1	-1	-1	-3	-1	-1	0	0
(D)	Employment	-1	0	-1	0	-1	-2	-1	-2	-1	-2
(E)	Trade & Globalisation	-2	-1	0	0	0	-1	-1	0	-2	-1
(F)	Budget Deficit Reduction	-1	-1	0	0	0	0	0	-2	0	-1
(G)	Privatisation	0	1	1	0	0	1	0	0	-1	-1



VED-AIM Example: Priorities for Policy Analysis

The -3 values in cells C1 & C6: Agriculture, Water Resources → Food Security

Priority area for further detailed research and modeling. For example, a specific model may be used to study the effects of climate change induced rainfall variations (as well as temperature rise and possible carbon fertilisation) on the most important types of crops (for a study using Ricardian agricultural modelling, see Seo, Mendelsohn and Munasinghe, 2005). Specific policy options could be simulated – e.g., measures to protect against floods and droughts, more efficient use of water in agriculture, use of drought resistant crops, etc.

Detailed description of impacts of climate change on food security via agriculture and water resources

Background

Global warming will lead to temperature increases and alterations in the hydrological cycle through increases in surface temperature and rates of evaporation, and in some regions, increases in precipitation. Changes in the total amount of precipitation and its frequency and intensity directly affect the magnitude and timing of run-off and the intensity of floods and droughts. Such changes will have significant impacts on agriculture and water resources.

Rainfall

Dharmasena (2004), Bandara and Wickramagamage (2004)

Temperature

Zubair et al. (2004), Bandara & Wickramagamage, 2004.

Asian Brown Cloud (ABC)

Swain and Herath (2004), Herath et al, (2004), Pathirana and Herath (2004)



Building the AIM – Step 4: Filling DEV Matrix Cells

Determine effects of development goals and policies on key VA.

		Key Vulnerable Areas (VA)			
		Economic		Environ.	Social
		(1) Agricultural output	(2) Indust. Activity	(3) Water Resources	(4) Health
	+ = beneficial - = adverse				
	3 = HIGH 2 = MODERATE 1 = LOW				
	(S0) Status (only natural variability)	[-1] Agriculture is presently vulnerable			
	(S1) Status (with climate change)	[-2] Agricultural output is likely to decline further with changing rainfall & temp. rise			
<u>Development Goals/Policies</u>					
(A)	Growth				
(B)	Poverty alleviation				
(C)	Food Security				
(D)	Employment				



AIM Follow-up: Analyzing Macro- and Micro- Linkages

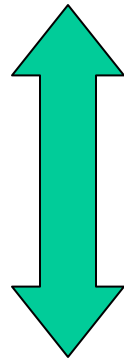
Examples:

- 1. CC-Macroeconomic analysis**
- 2. Adaptation assessment**



Assessing links between development plans and adaptation and mitigation – Macro and Sector Linkages

Macro Link



National Plans & Models (NSSD, PRSP & CGE etc.)

Action Impact Matrix (AIM)

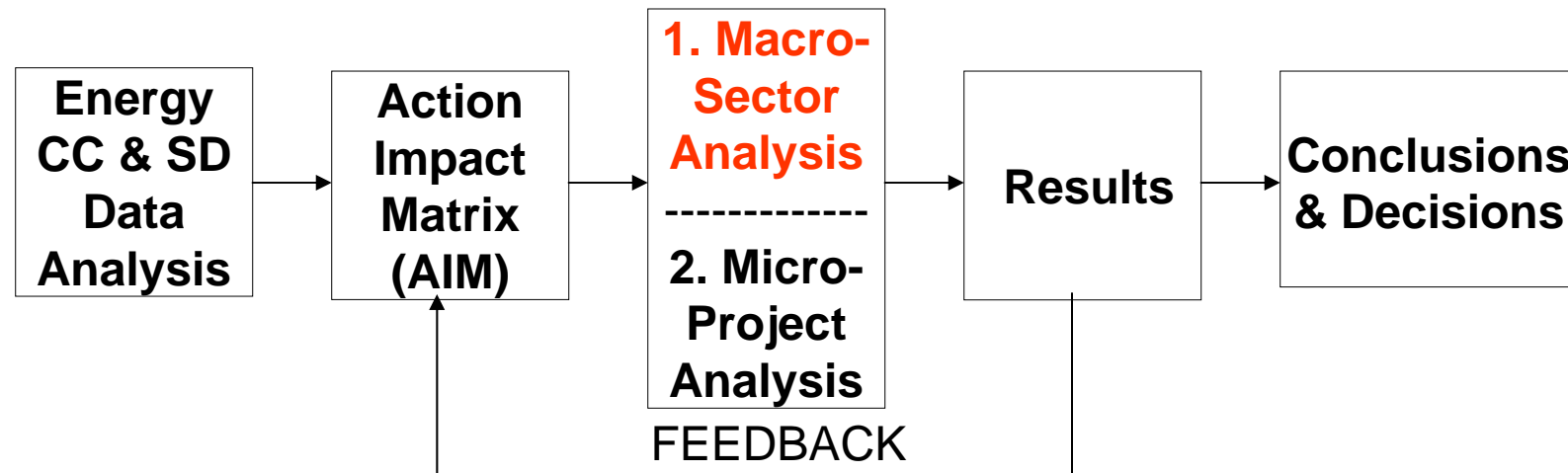
Climate Change Vulnerability, Adaptation & Mitigation

Adaptation & Mitigation Projects and Policies

{ interactions of national plans with climate change policies.



Summary of AIM-based Analytical Process: Macro Path

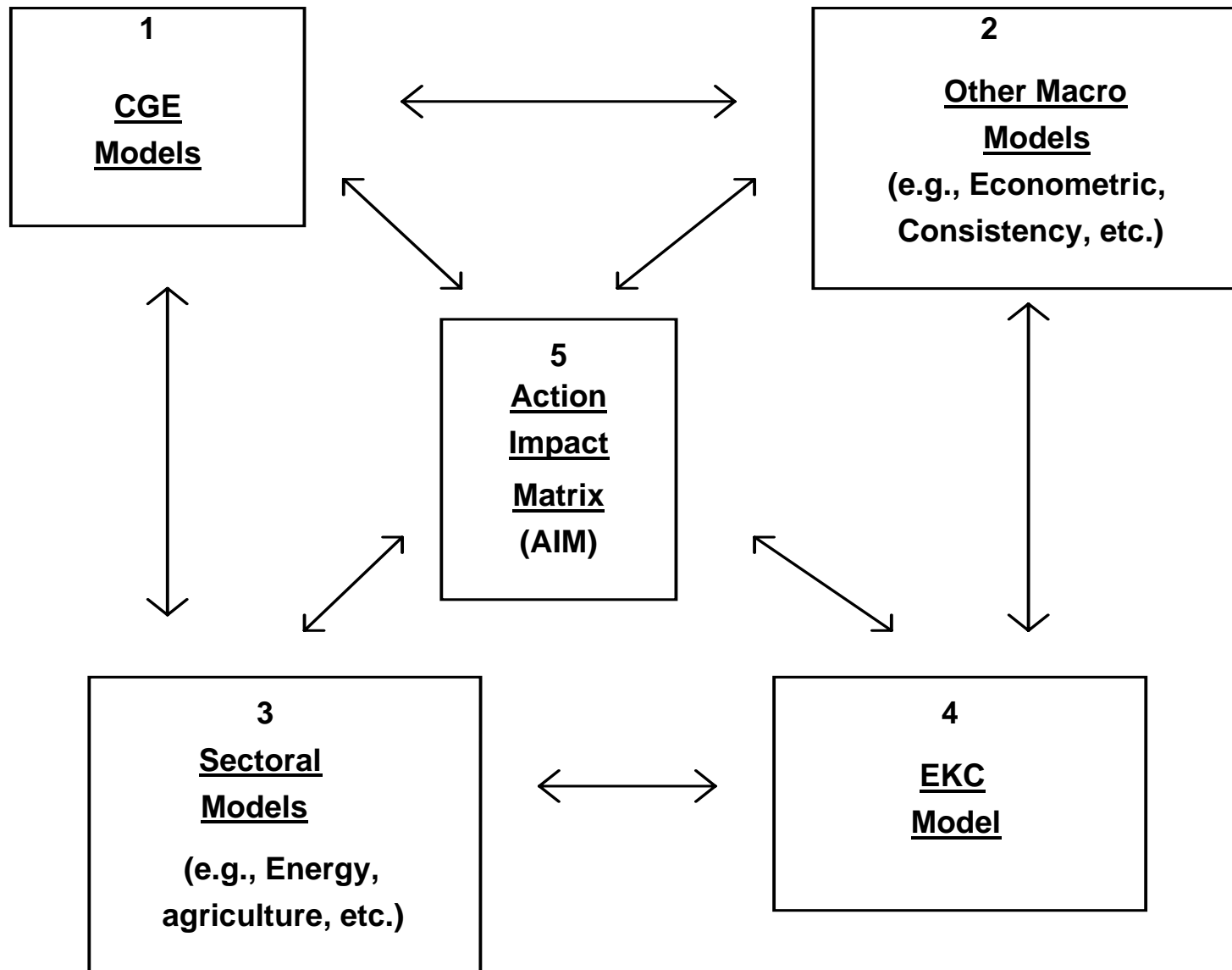


Integration via SD Analysis at the Macroeconomic/Sectoral Level (general equilibrium analysis)

1. Macroeconomic/Sectoral Modeling
2. Environmental and Macroeconomic Analysis
3. Poverty/Income Distributional Analysis

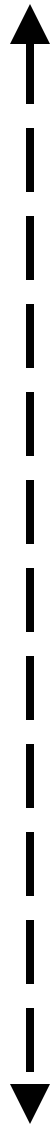


Generic Macro-modeling Approaches



Expanded National Income Accounts for SD

Social Accounting Matrix (SAM)



Economic Links
Basic
Input-Output
Table

**Environmental-
Economic Links**
Satellite
Environmental
Accounts

Economic-Social Links
Distribution of Income

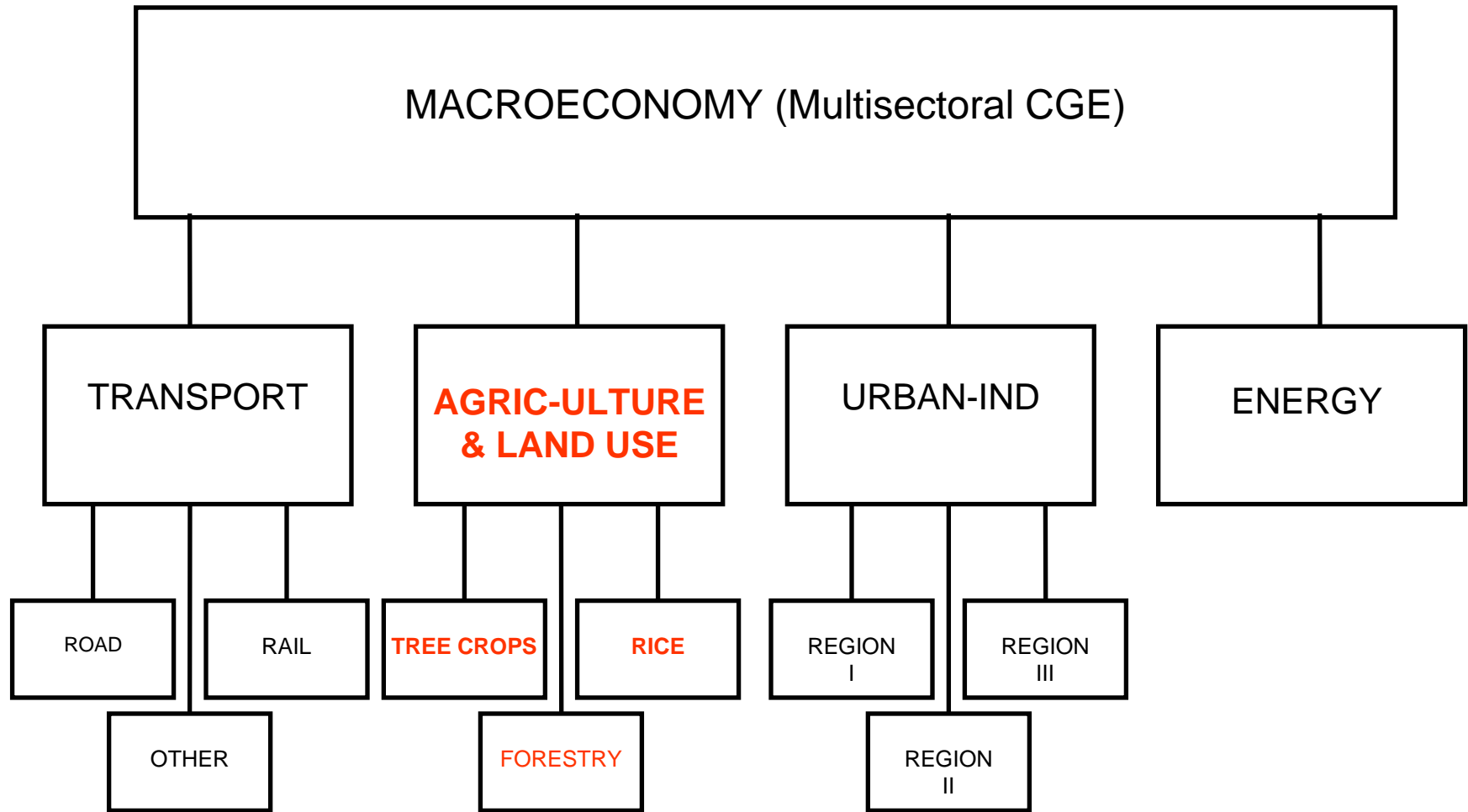
Envir.-Social Links
Distribution of
Environmental
Impacts



Source: Munasinghe (2001), Macroeconomics and Environment

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Sri Lanka Integrated SED Model Structure



AIM Detailed Follow-up Study: Sector Example

Analysing Climate Change Impacts on Agriculture in Sri Lanka Using a Ricardian Model

Source: M. Munasinghe and S. Perera (1996)



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Range of Climate Change Predictions for Sri Lanka in 2050 (Downscaled GCM)

Global Scenario	Period	Rainfall	Temperature
B1	NEM	Increase by 50 mm over the baseline	Max. temperature: increase by 0.8⁰ C Min. temperature : increase by 1.0⁰ C
B1	SWM	Increase by 350 mm over the baseline, especially over the Western slopes of the central hills	Max. temperature: increase by 0.8⁰ C Min. temperature : increase by 0.8⁰ C
A1F1	NEM	Increase by 70 mm over the baseline, especially over the Eastern slopes of the central hills	Max. temperature: increase by 1.1⁰ C Min. temperature : increase by 1.4⁰ C
A1F1	SWM	Increase by 520 mm over the baseline, especially over the Western slopes of the central hills	Max. temperature: increase by 1.1⁰ C Min. temperature : increase by 1.2⁰ C



**Sri Lanka - National level impact on Agric.
Revenue in 2050 – temp/rain & equity**
(A1F1 scenario based projection)

Crop	Temperature Effect	Rainfall Effect	Temp. Plus Rainfall Effect
Paddy (Rice) (dry zone – poorer)	-3.5%	-7.8%	-11.4%
Plantation Crops (wet zone – richer)	+1.5%	+2.0%	+3.5%



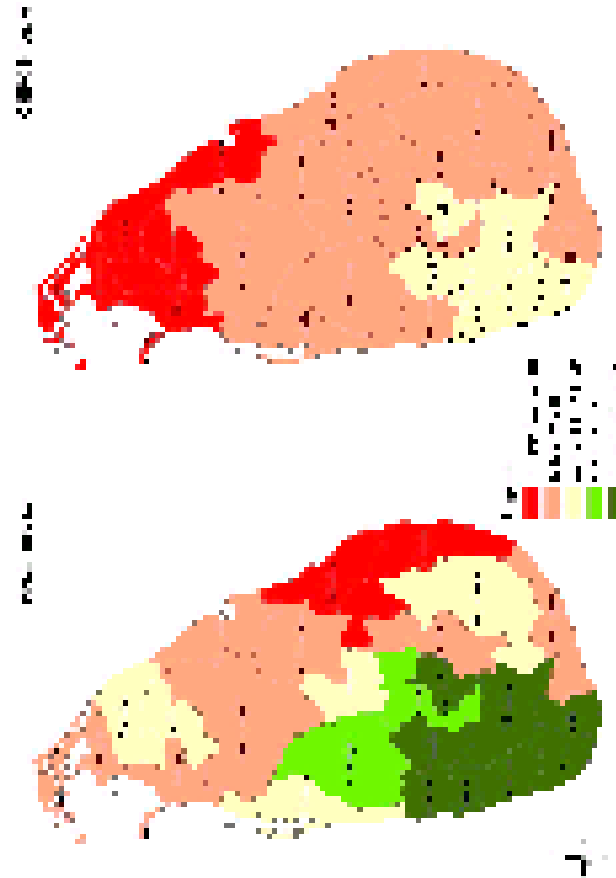
Impact on Sri Lanka national economy in 2050*
- GDP effect small BUT equity effect larger

Crop	Change of Total GDP in 2050 (%)	Change Agriculture GDP in 2050 (%)
Rice (dry zone – poorer)	-0.36	-2.46
Plantation Crops (wet zone – richer)	+0.10	+0.70
Rice + Plantation Crops	-0.26	- 1.76

***Note: Assuming the same economic structure in 2050**



Sri Lanka Impacts: HAD3 and CSIRO models



Change in net agriculture income: Results of various Ricardian models

Country	Temperature rise ($^{\circ}$ C) plus 7% rainfall increase	Change in net income (percent)	Source
Sri Lanka	2.0	-27	Basic model – Analysis 1 (this paper)
Sri Lanka	3.5	-46	Basic model – Analysis 1 (this paper)
Sri Lanka - Paddy	2.0	-10	Improved agricultural data - Analysis 2 (this paper)
Sri Lanka – Plantation crops	2.0	+39	Improved agricultural data - Analysis 2 (this paper)
Sri Lanka - Paddy	Temp.= +1.1 to 1.2 $^{\circ}$ C & Rainfall = +70 to 520 mm	- 11.4	Improved agricultural and climate data - Analysis 2 (this paper)
Sri Lanka - Plantation crops	Temp.= +1.1 to 1.2 $^{\circ}$ C & Rainfall = +70 to 520 mm	+ 3.5	Improved agricultural and climate data - Analysis 2 (this paper)
United States	2.0	-3 to +3	Mendelsohn, Nordhaus, and Shaw (1994)
India	2.0	-3 to -6	Sanghi, Mendelsohn, and Dinar (1998)
India	3.5	-3 to -8	Sanghi, Mendelsohn, and Dinar (1998)
India	2.0	-7 to -9	Kumar and Parikh (1998a)
India	3.5	-20 to -26	Kumar and Parikh (1998a)
Brazil	2.0	-5 to -11	Sanghi (1998)
Brazil	3.5	-7 to -14	Sanghi (1998)

Some Key Policy Implications

- 1. Overall impact on agricultural output and national economy is moderate, but some effects will emerge within next two decades**
- 2. Potential risk to food security (rice)**
- 3. Poverty impact on small farmers**
- 4. Equity impact (small rice farms versus large tree crop plantations)**
- 5. Demographic impact (potential migration from dry to wet zone)**



National Level Example

Macroeconomic Growth, Pollution and Energy Pricing Policy



Sri Lanka Integrated SED Model Structure

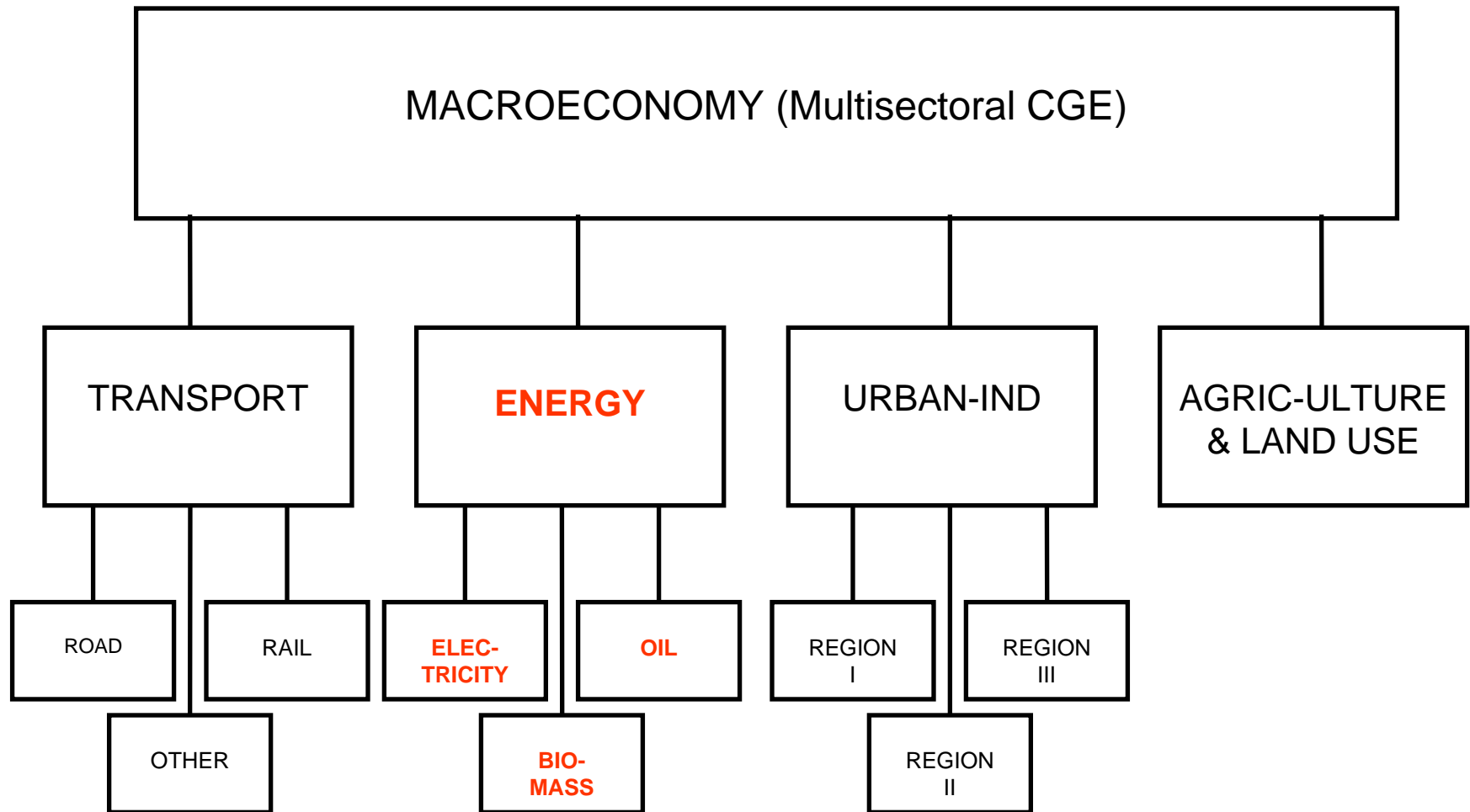
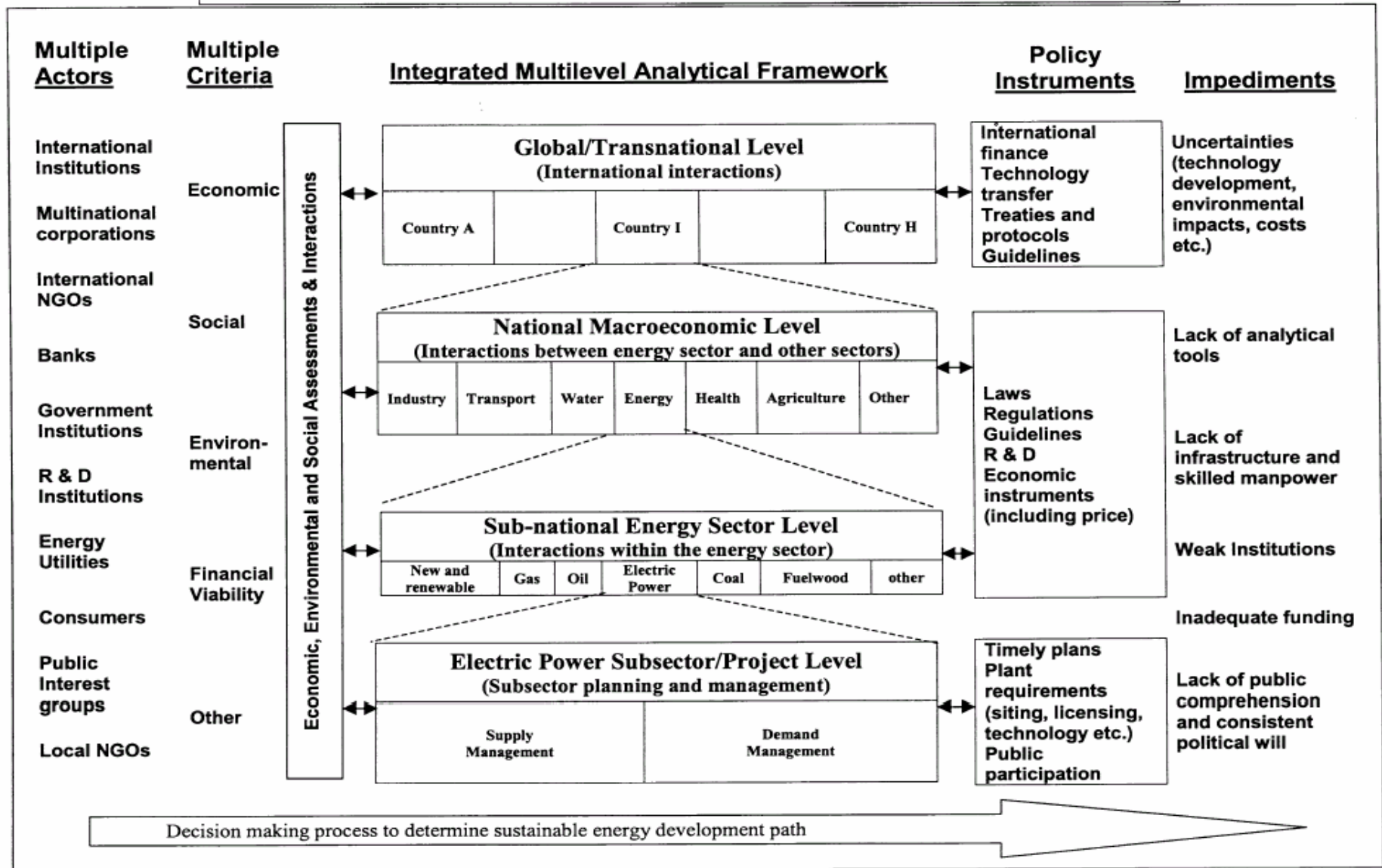


Figure 8. Framework for sustainable energy development Source: adapted from Munasinghe [1990].



SD and Macro/Sectoral Policies

- Macro/sectoral (economywide) policies are designed mainly to revive economies, boost growth, alleviate poverty, etc.
- They can have good social and environmental impacts -- e.g., economywide liberalization and market-based reforms will improve efficiency of natural resource use.
- However, growth often combines with economic imperfections to cause social and environmental damage.

Problem

- Unsustainable economic growth interacts unfavourably with pre-existing imperfections, to cause social and environmental harm.
 - Policy distortions
 - Market failures
 - Institutional constraints

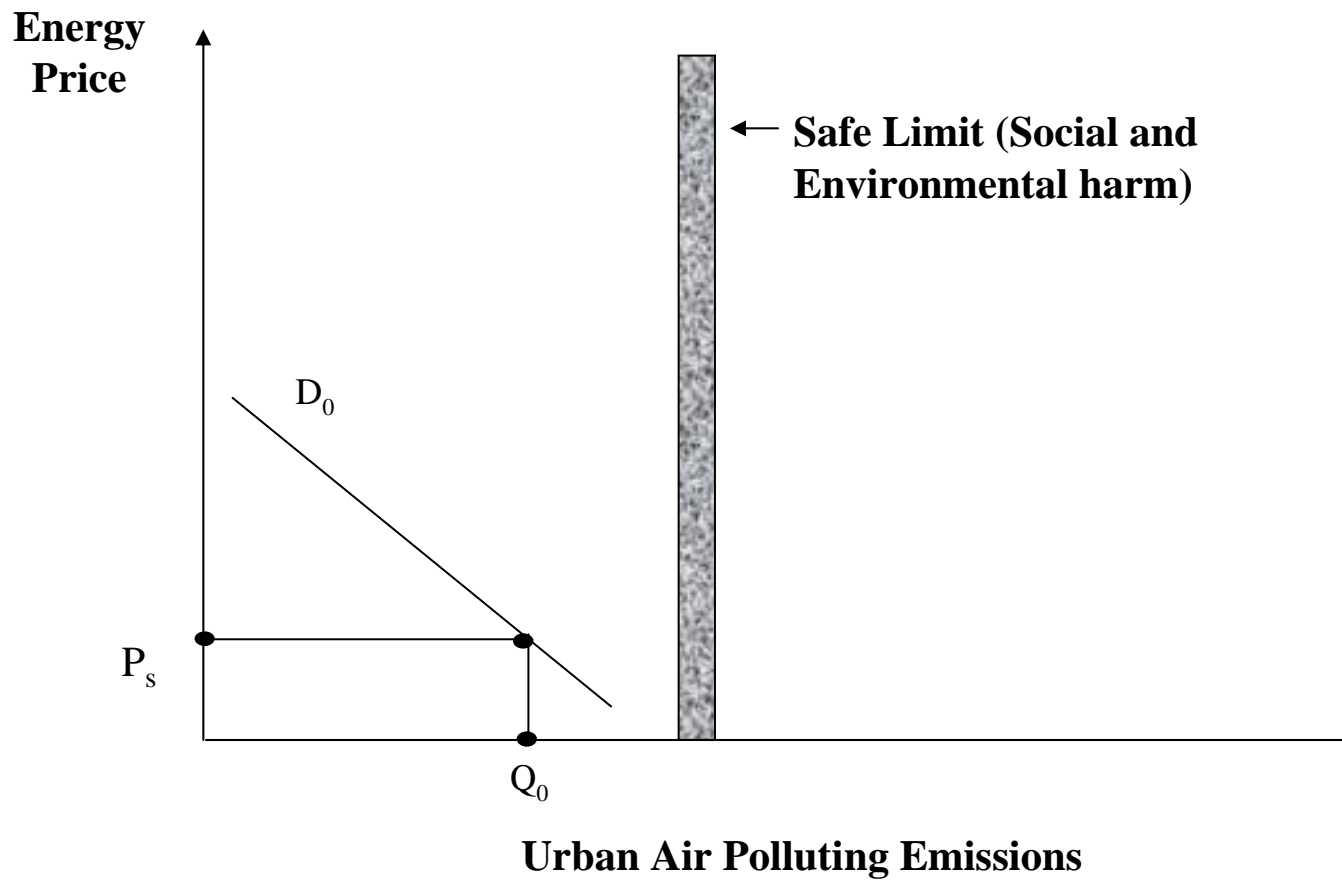
Remedy – Restructuring Development

- Introduce complementary measures to remove imperfections and reduce the vulnerability of society and the environment directly -- without reversing economywide reforms and affecting economic growth prospects.

Energy Pricing Incorporating Both Economic and Environmental Concerns

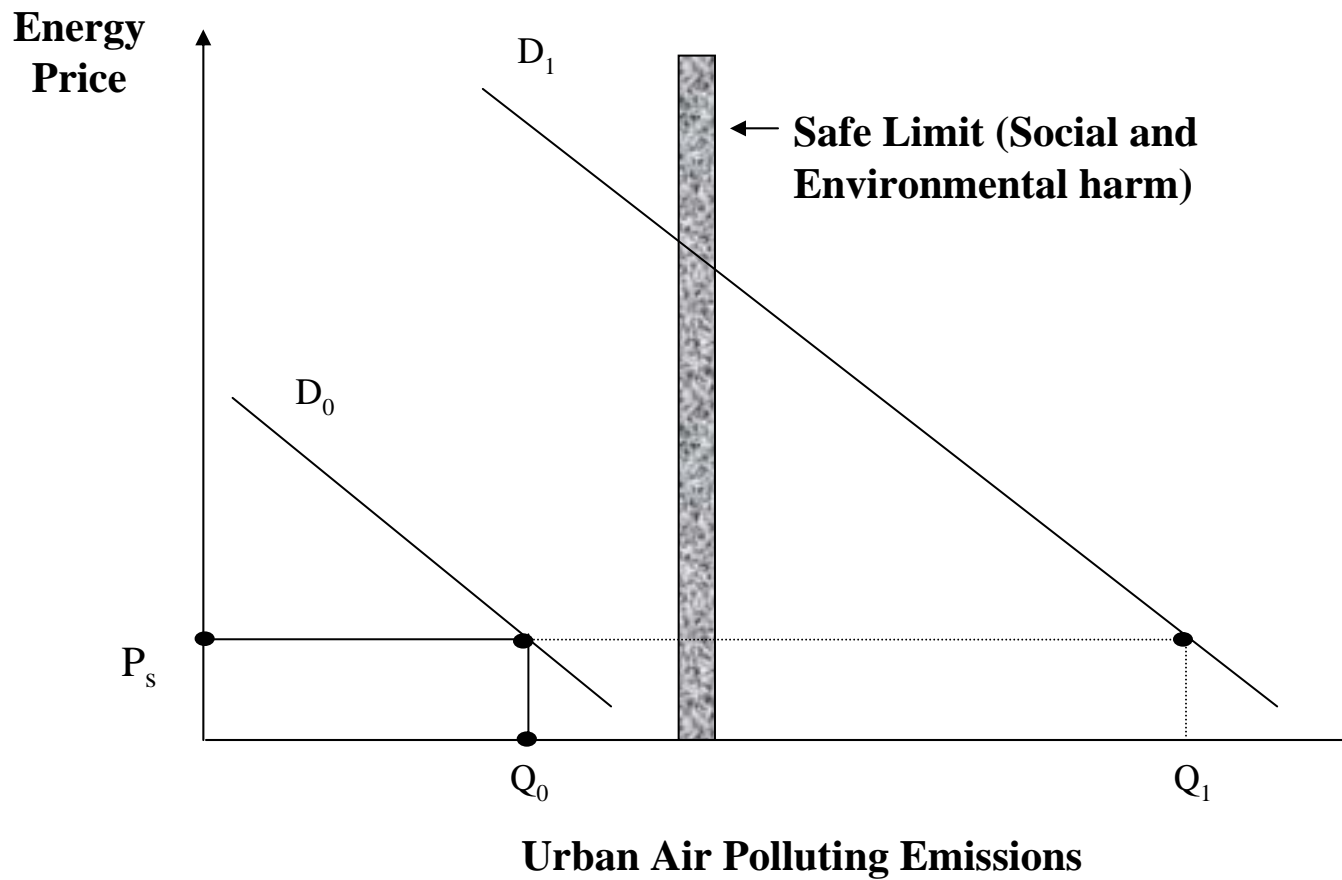


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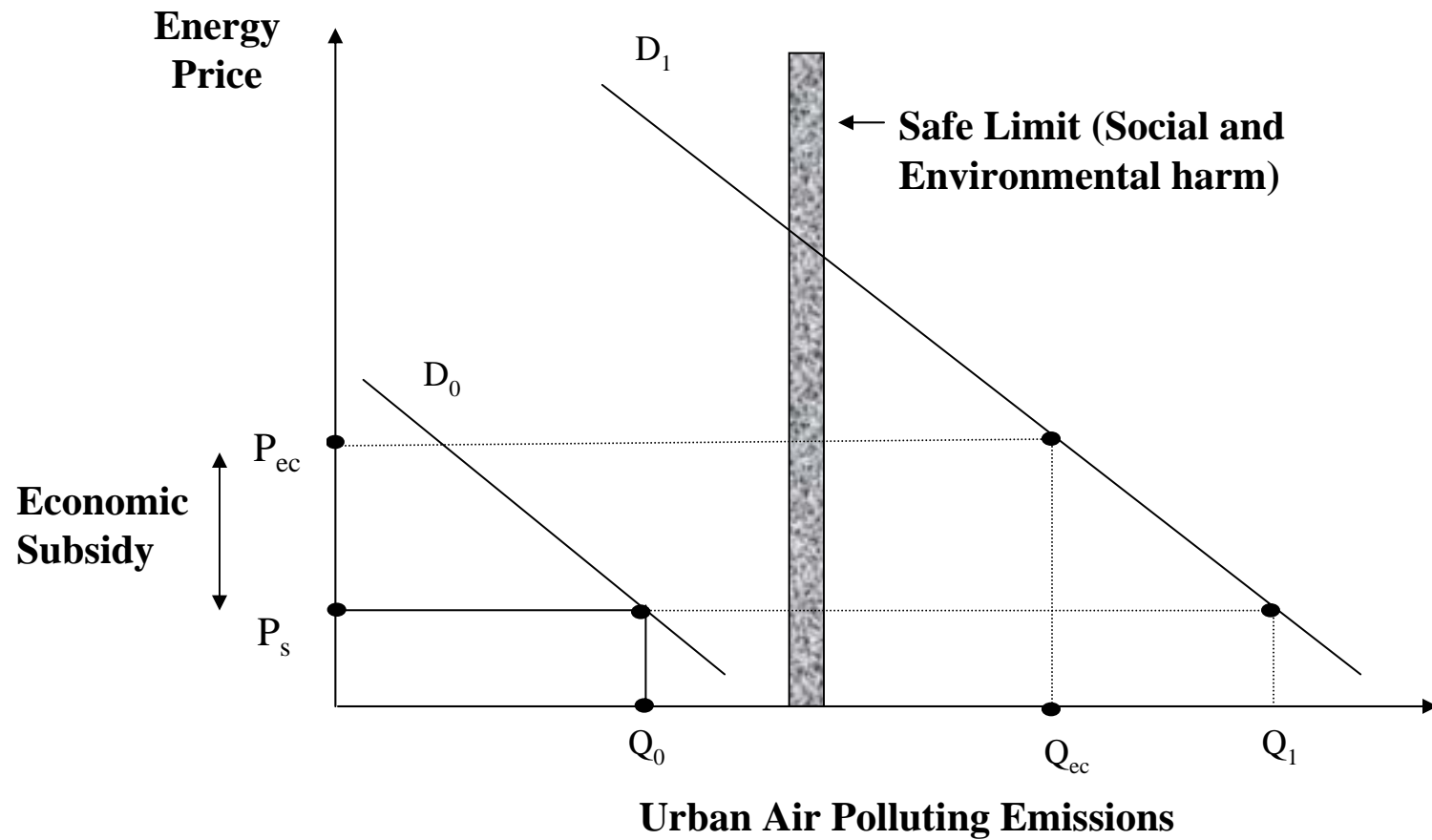
1. Low growth economy has demand D_0 . Air emissions Q_0 are below the safe limit even at subsidised price P_s .





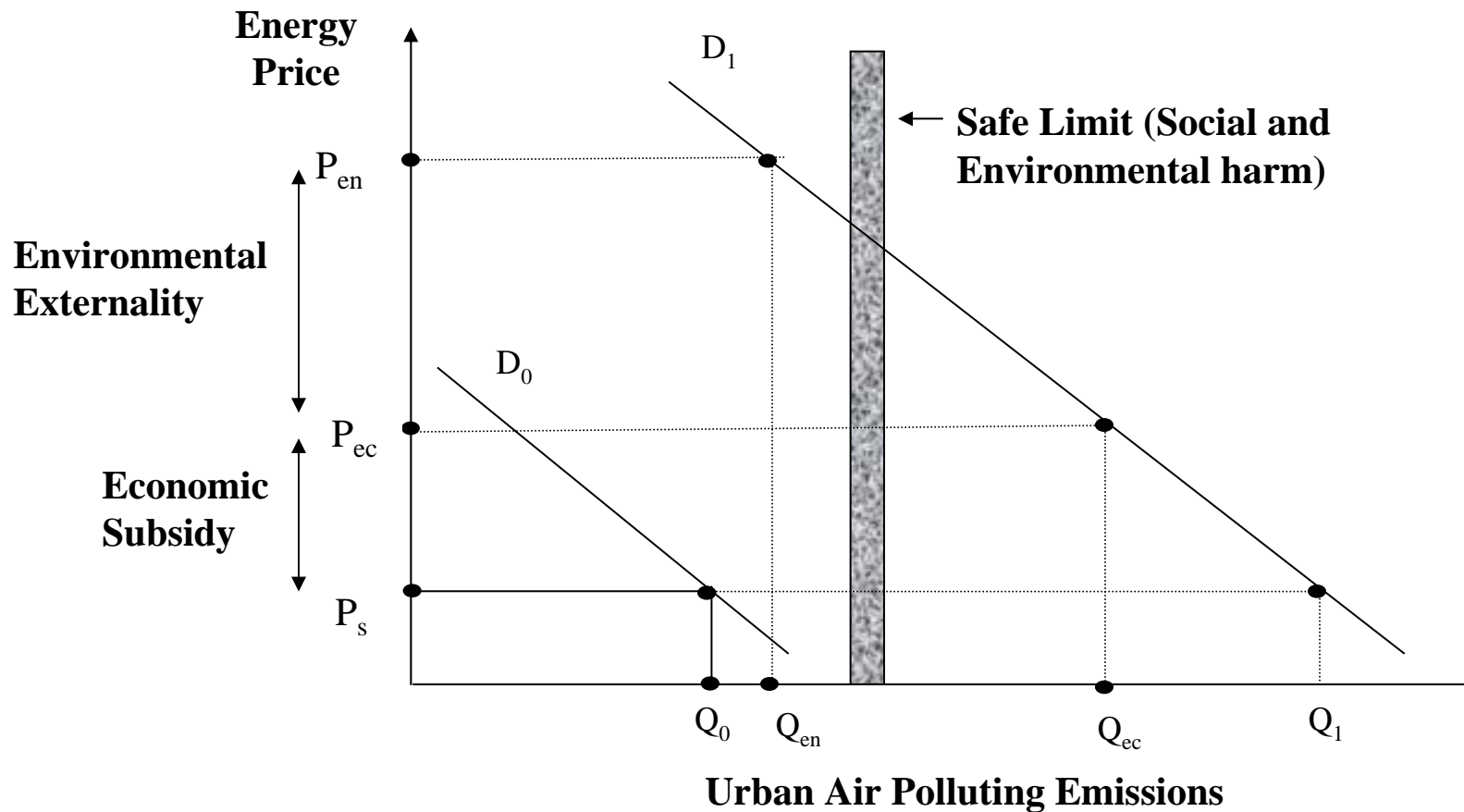
1. Low growth economy has demand D_0 . Air emissions Q_0 are below the safe limit even at subsidised price P_s .
2. Macroeconomic reforms stimulate growth of demand to D_1 and emissions Q_1 greatly exceed safe limit.





1. Low growth economy has demand D_0 . Air emissions Q_0 are below the safe limit even at subsidised price P_s .
2. Macroeconomic reforms stimulate growth of demand to D_1 and emissions Q_1 greatly exceed safe limit.
3. First increase in energy price (P_{ec}), eliminates economic subsidy and reduces emissions only to Q_{ec} .

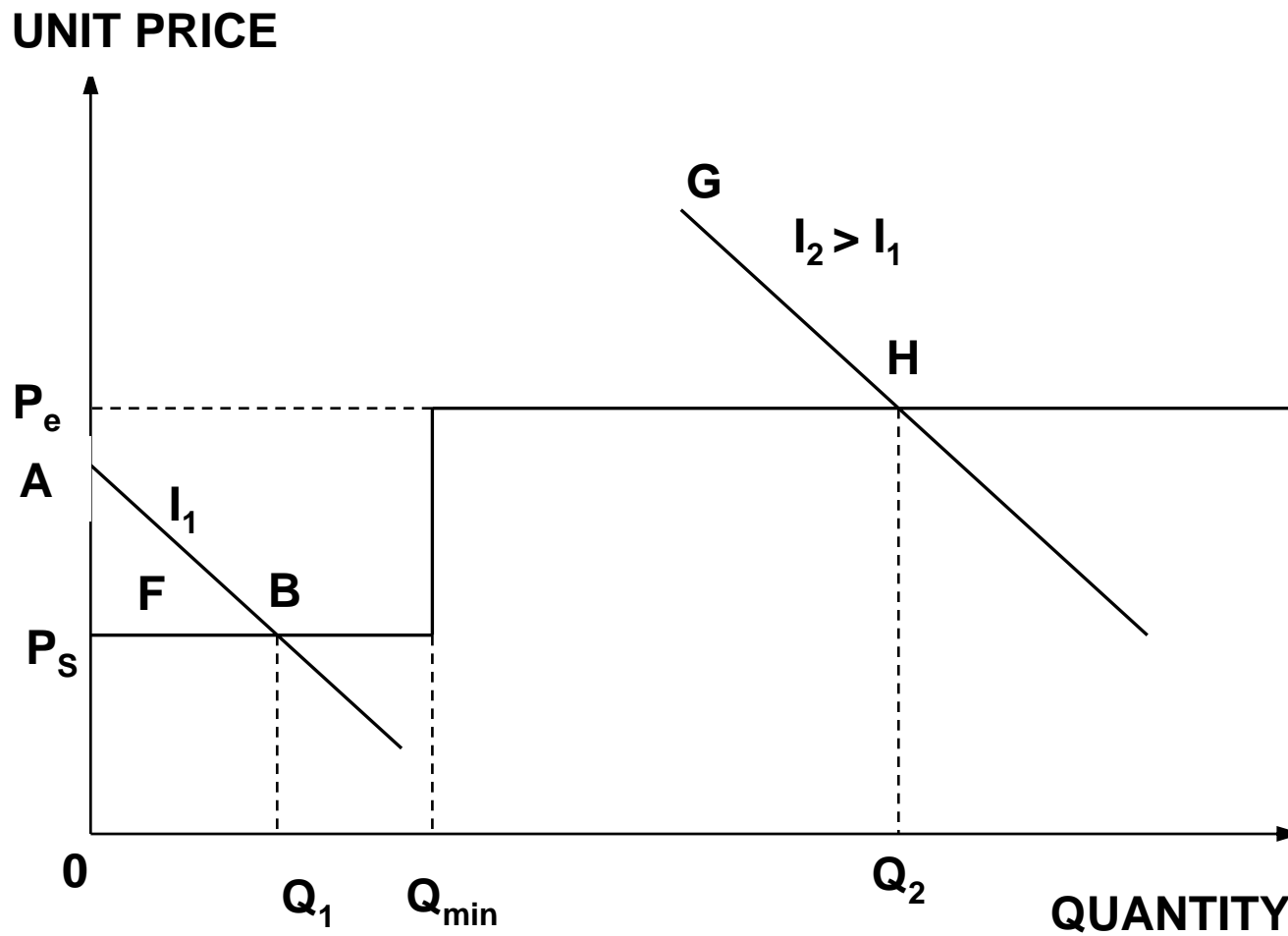




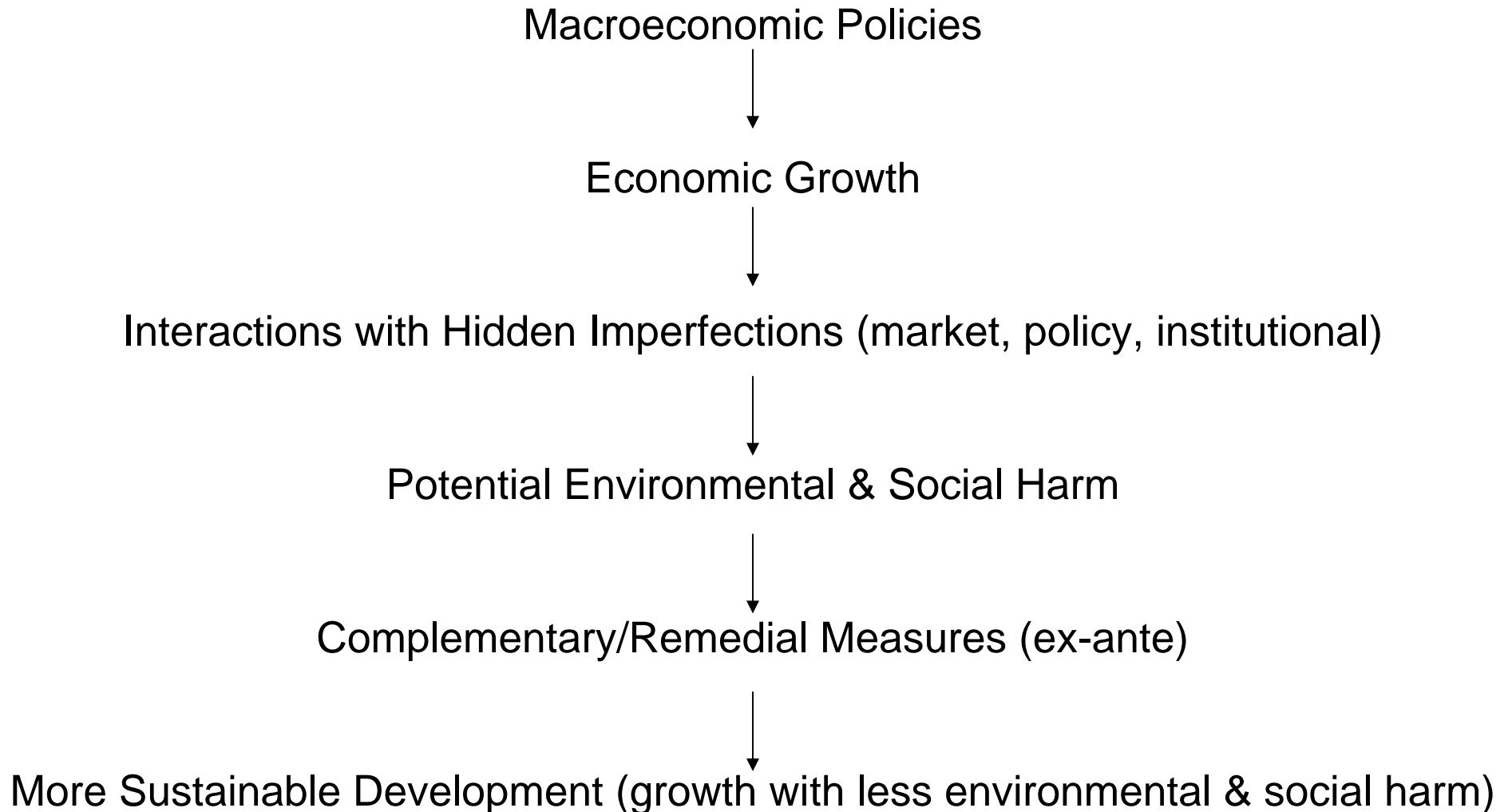
1. Low growth economy has demand D_0 . Air emissions Q_0 are below the safe limit even at subsidised price P_s .
2. Macroeconomic reforms stimulate growth of demand to D_1 and emissions Q_1 greatly exceed safe limit.
3. First increase in energy price (P_{ec}), eliminates economic subsidy and reduces emissions only to Q_{ec} .
4. Second energy price increase (P_{en}), adds environmental externality cost and reduces emissions to Q_{en} (within safe limit).



Introducing Social Concerns – Pricing Electricity to Meet Basic Needs



Summary Procedure: Economywide Analysis for MDMS



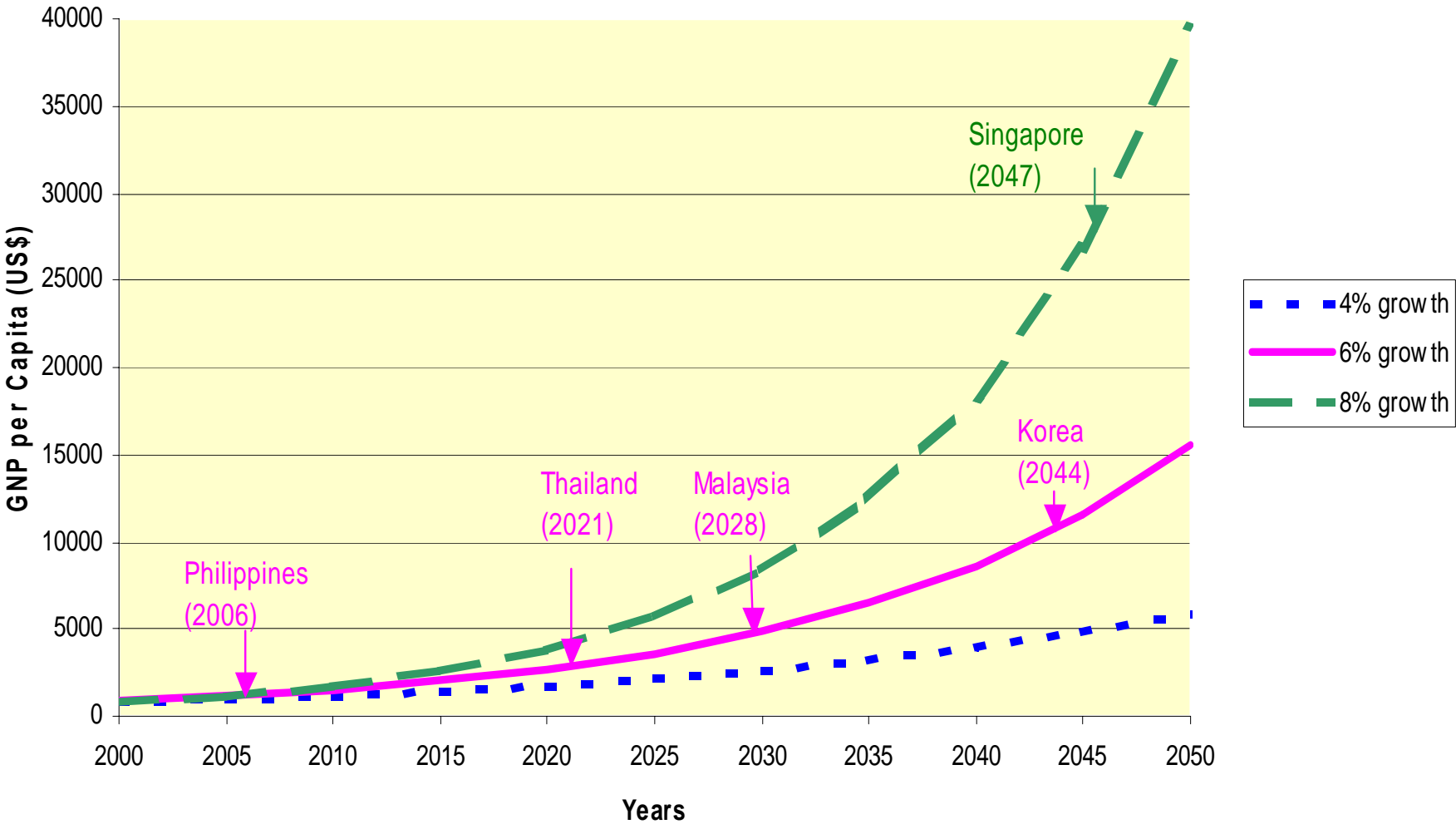
Energy Sector Level Example: Power System Planning in Sri Lanka (incorporating Climate Change Concerns)

Source: Meier and Munasinghe (1994)

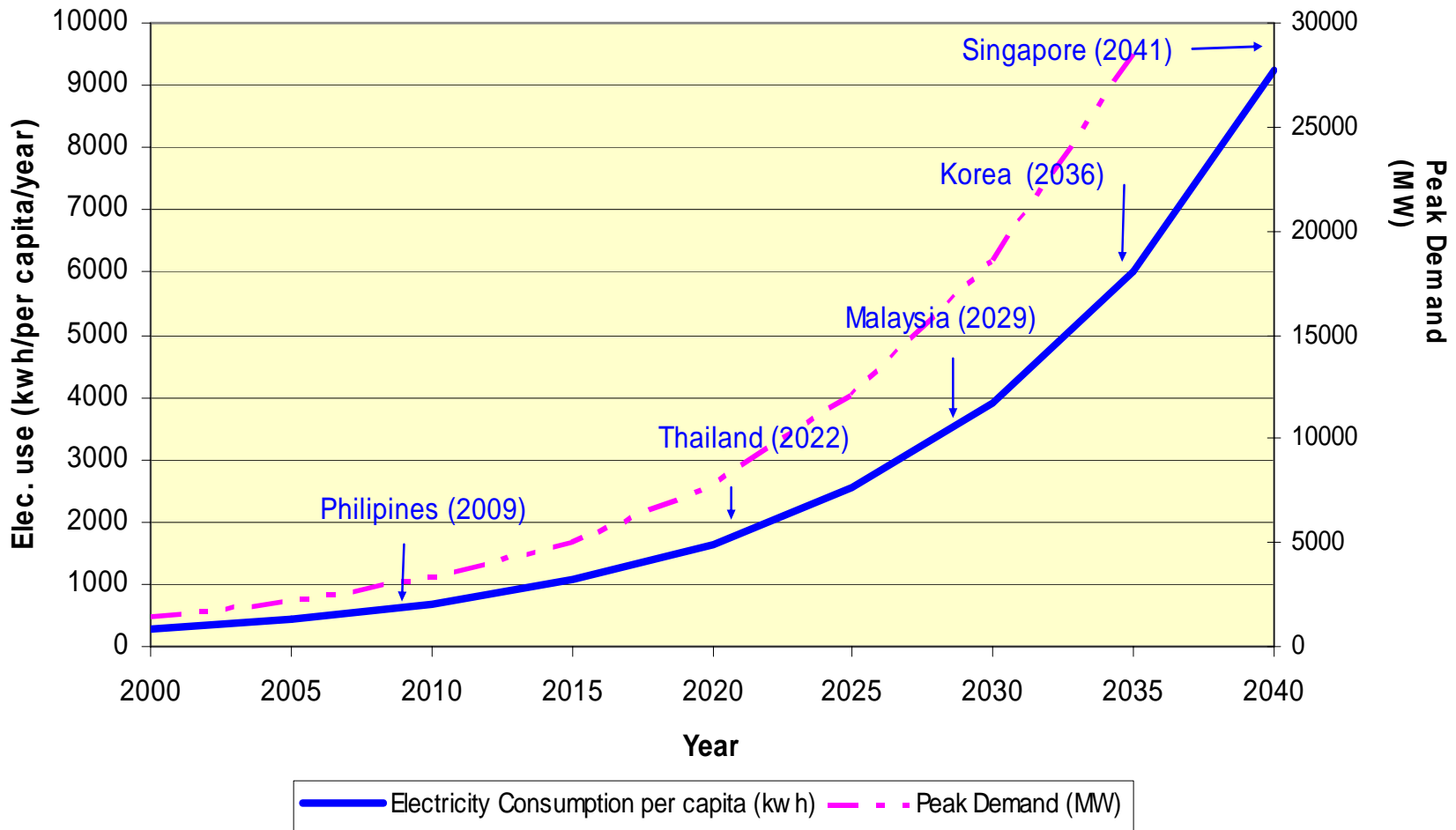


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Growth of GNP per Capita in Sri Lanka

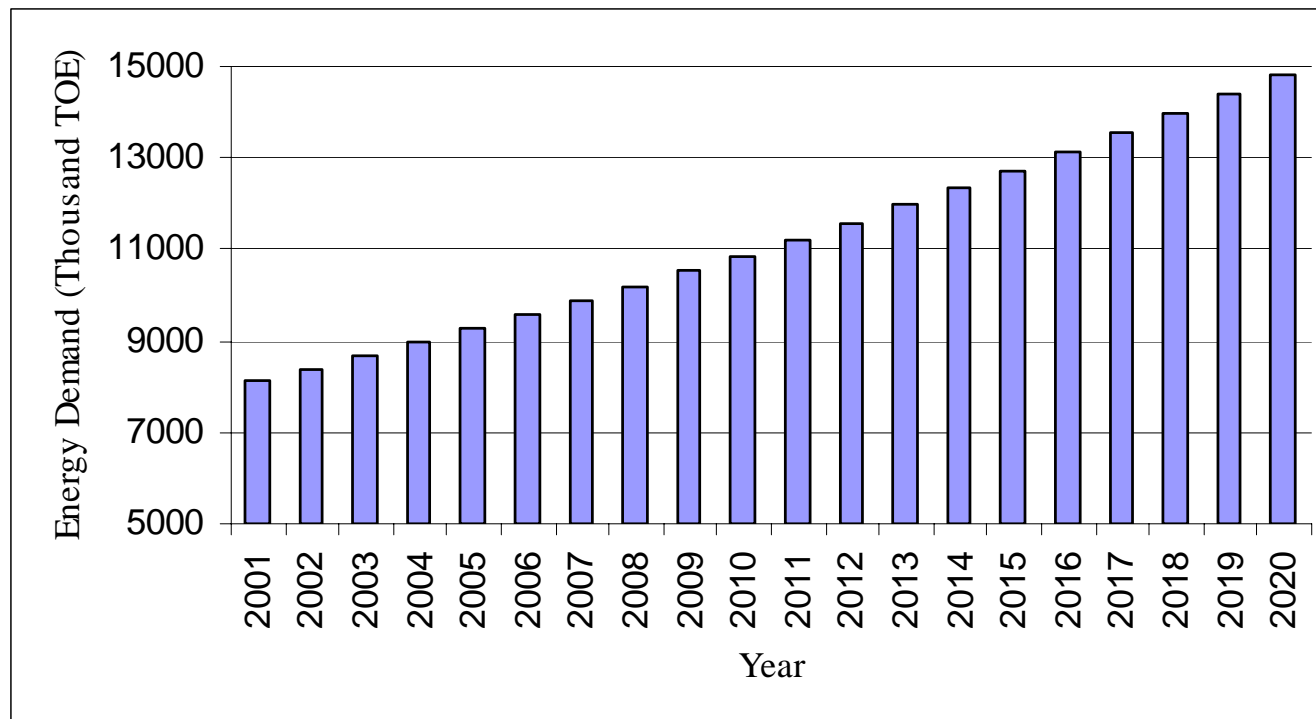


Annual electricity use per capita in Sri Lanka growing at 9% per annum (kwh)



Energy Demand Projection

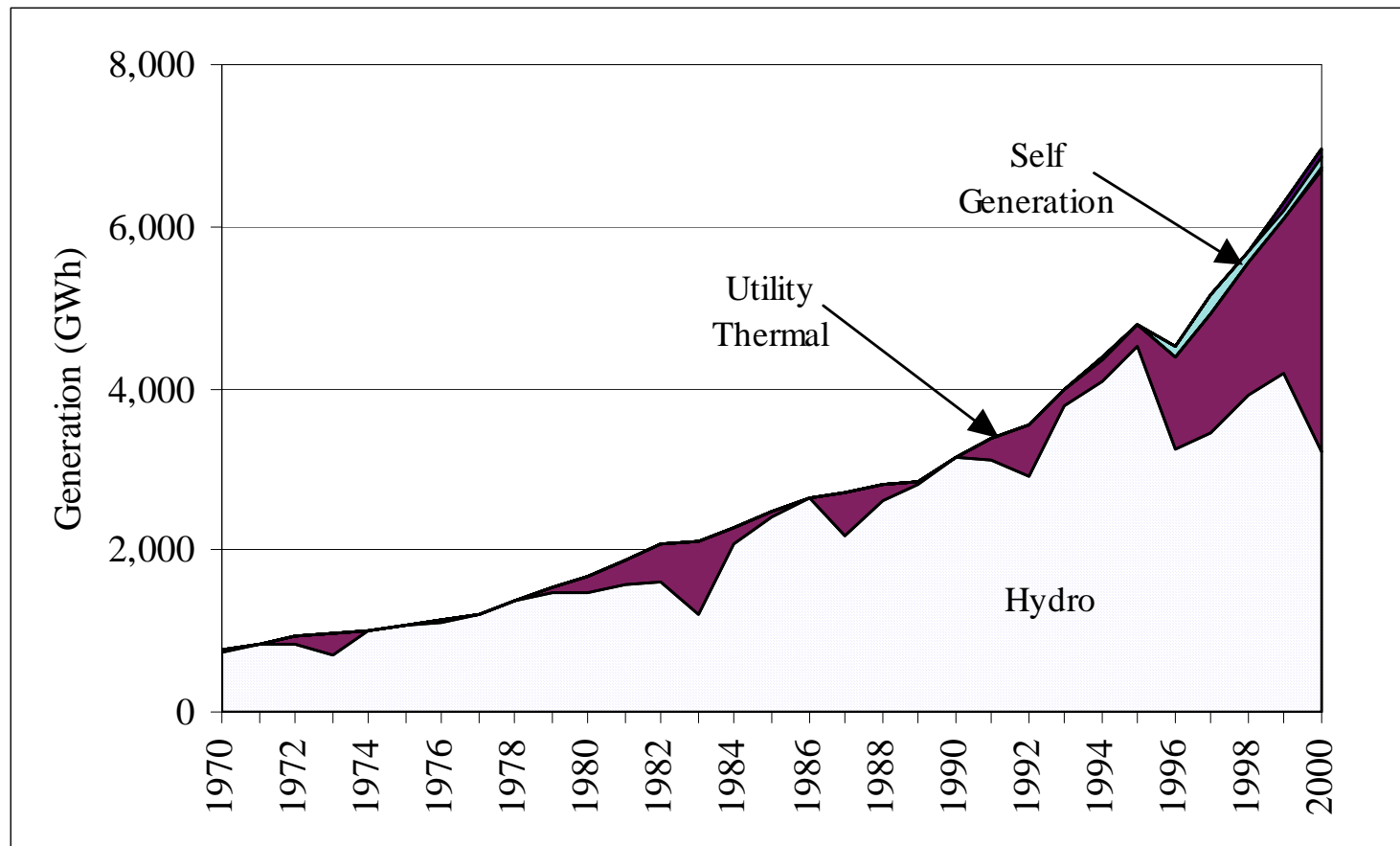
- Overall energy demand growth
 - 3-3.5% annual average growth rate



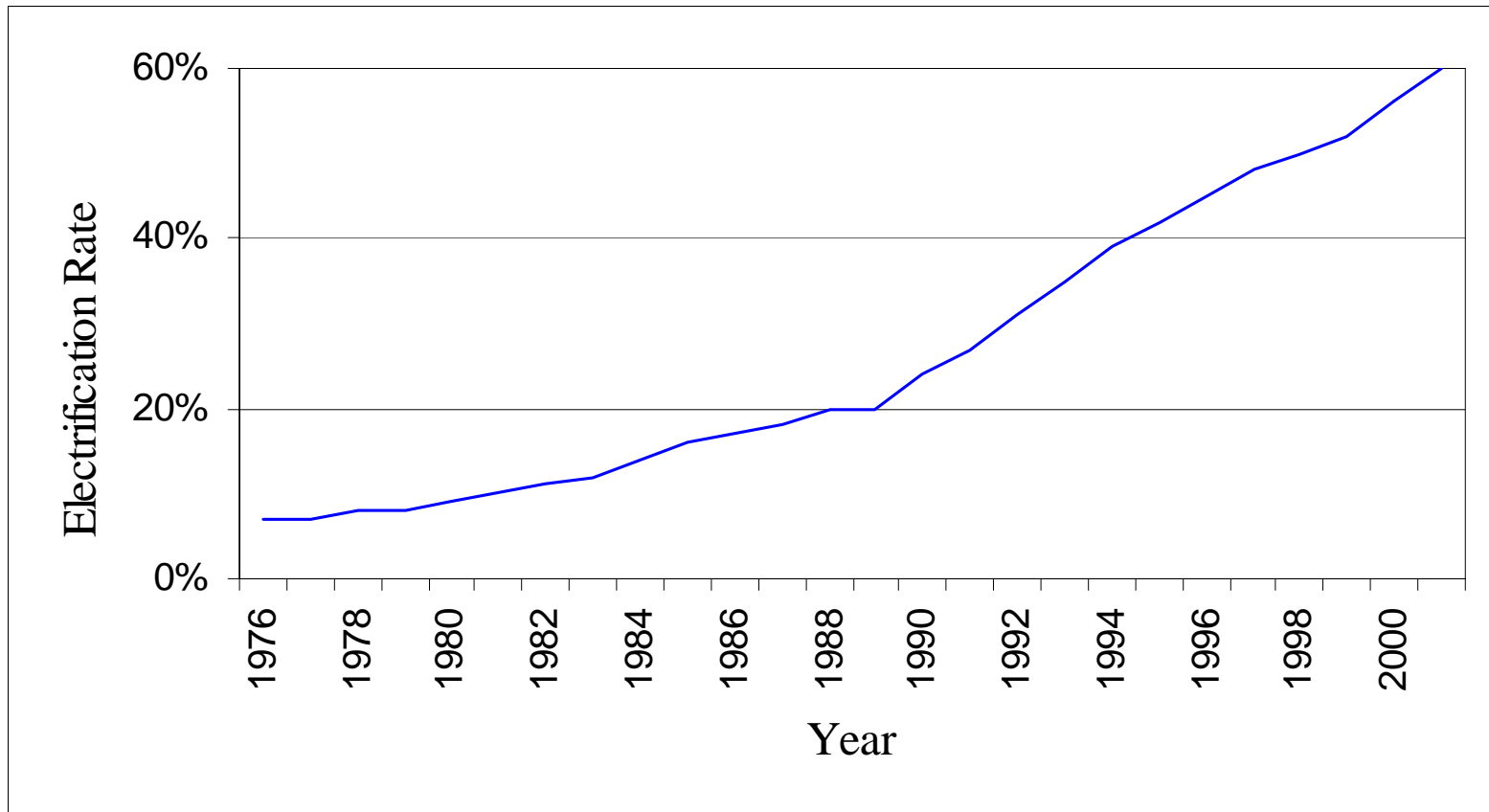
Source: CENS, Moratuwa Univ.



Electricity Demand Growth (8-10%) and Hydro-Thermal Energy Share



Sri Lanka Electrification Rate



Monthly average consumption per capita

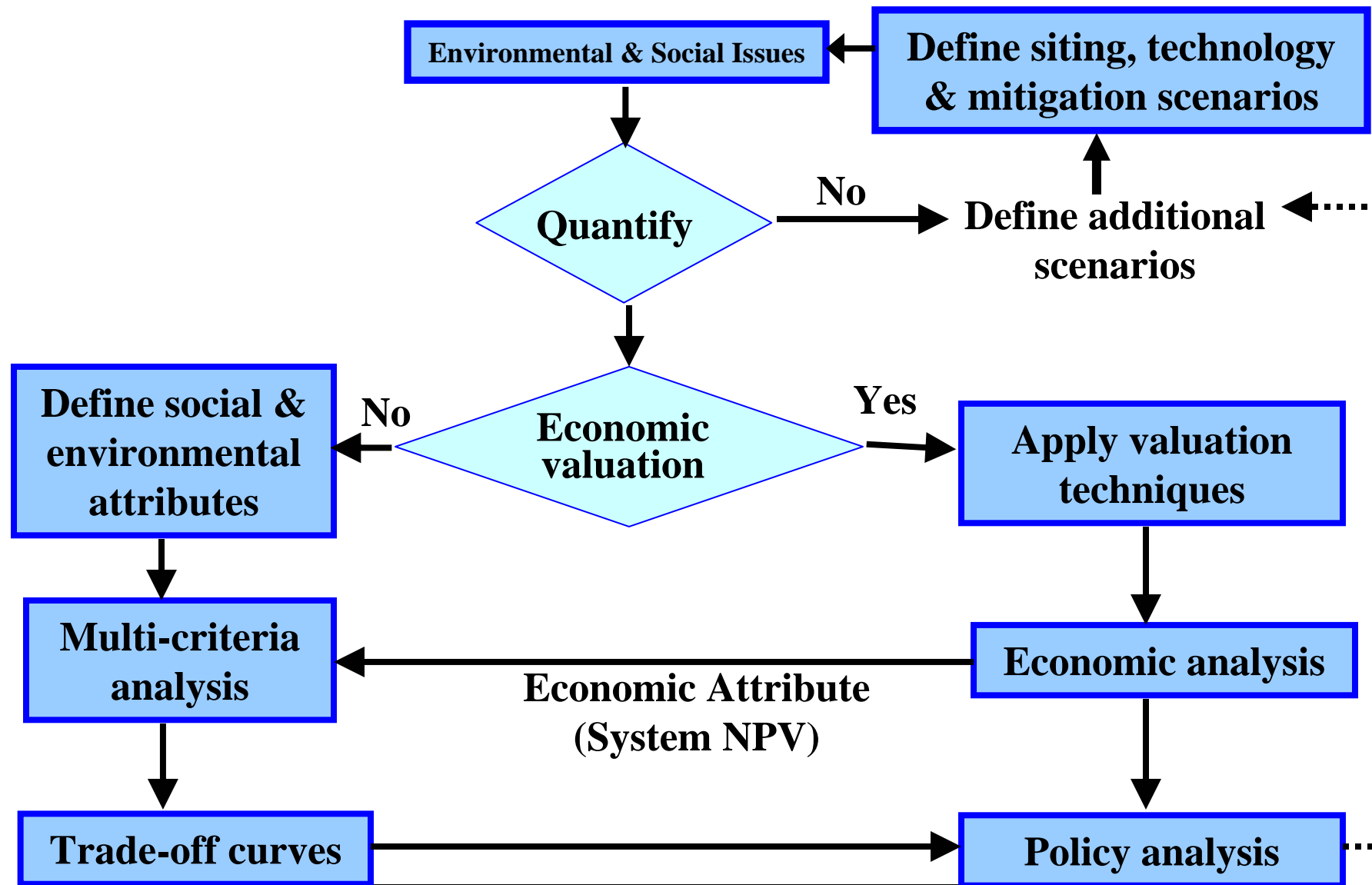
Income groups (% of total population)	Daily average consumption per capita (Rs.)
Poorest 20%	27
Second 20%	44
Third 20%	512
Fourth 20%	662
Richest 20%	1285

Source: World Bank based on 1992/2000 Sri Lanka Integrated Survey



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Sectoral Level Power Planning in Sri Lanka - Analytical Framework



MIND

Indicators used for assessment

Economic indicator: Least cost of supply (long run)

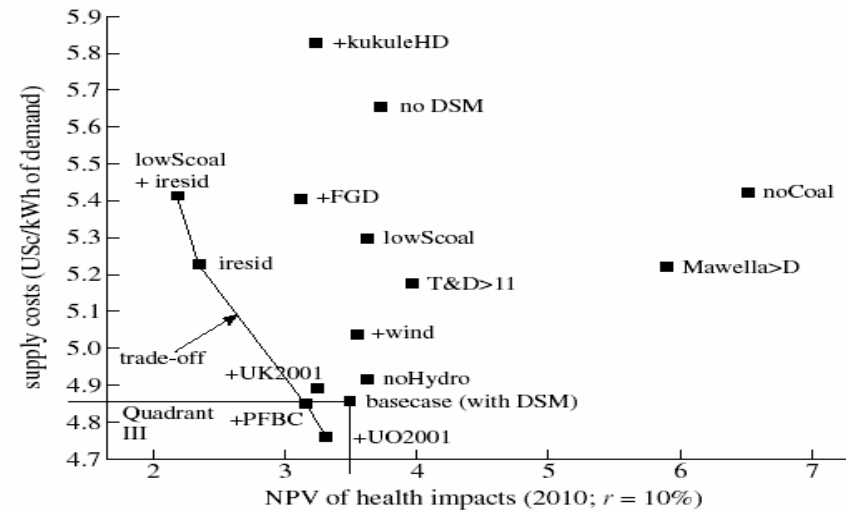
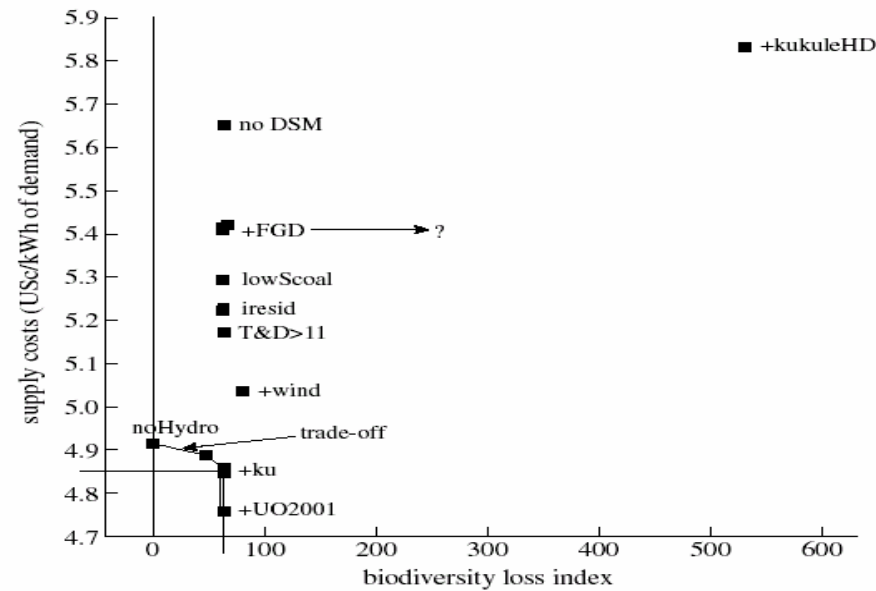
Env/Social Impact	Indicator
Global Warming	CO2 emissions
Health Effects	Population weighted incremental ambient concentrations of fine particulates and NOX
Air Pollution	SO2 and NOX emissions
Social Impact	Employment creation
Biodiversity Impact	Biodiversity Index



Sectoral Level: Power System Planning in Sri Lanka

MCA with trade-off curves between economic costs and (a) biodiversity impacts; and (b) health impacts

Source: Meier and Munasinghe (1994)



Conclusions of Study (1)

1. Easily valued impacts (e.g. lost production from inundated land, benefits of fisheries in reservoirs) are small relative to systems costs, and thus do not change results significantly.
2. Where explicit valuation is difficult (e.g. mortality and morbidity effects of air pollution), MCA and implicit valuation can provide important guidance for decision makers



Conclusions of Study (2)

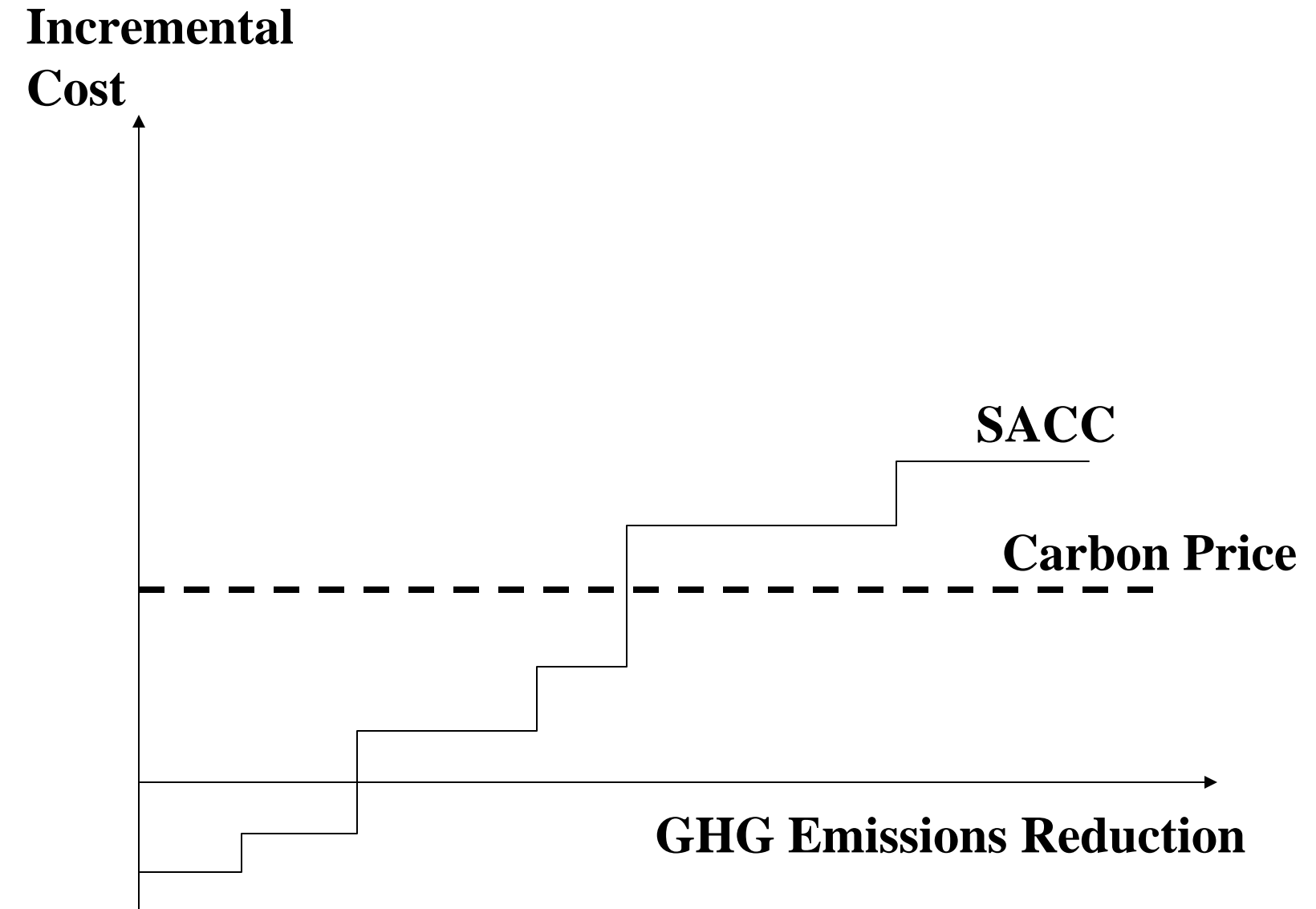
3. High dam version of Kukule can be excluded from consideration due to poor performance on all scales.
4. Implementation of certain DSM options yield positive gains in terms of environmental & economic criteria.
5. Possible to derive attribute scales that are useful proxies for impacts that are difficult to value (e.g. inclusion of health effects = installation of tighter pollution control in power plants near urban areas rather than installing FGD systems in remote sites.



Sri Lanka GHG Mitigation Options

- **Supply Side**
 - ⤴ Fuel switching (coal to oil to gas)
 - ⤴ Increased power plant efficiency
 - ⤴ Renewables (biomass, solar, wind, hydro, etc.)
 - ⤴ Carbon dioxide sequestration (long term?)
 - ⤴ Nuclear power (long term?)
- **Demand Side**
 - ⤴ Transportation
 - ⤴ Commercial and residential buildings
 - ⤴ Industry
- **Land-Use, Land-Use Change and Forestry**
 - ⤴ Afforestation, Reforestation and slowing Deforestation
 - ⤴ Improved Forest, Cropland and Rangeland Management
 - ⤴ Agroforestry
- **Waste Management and Reduced Halocarbon Emissions**

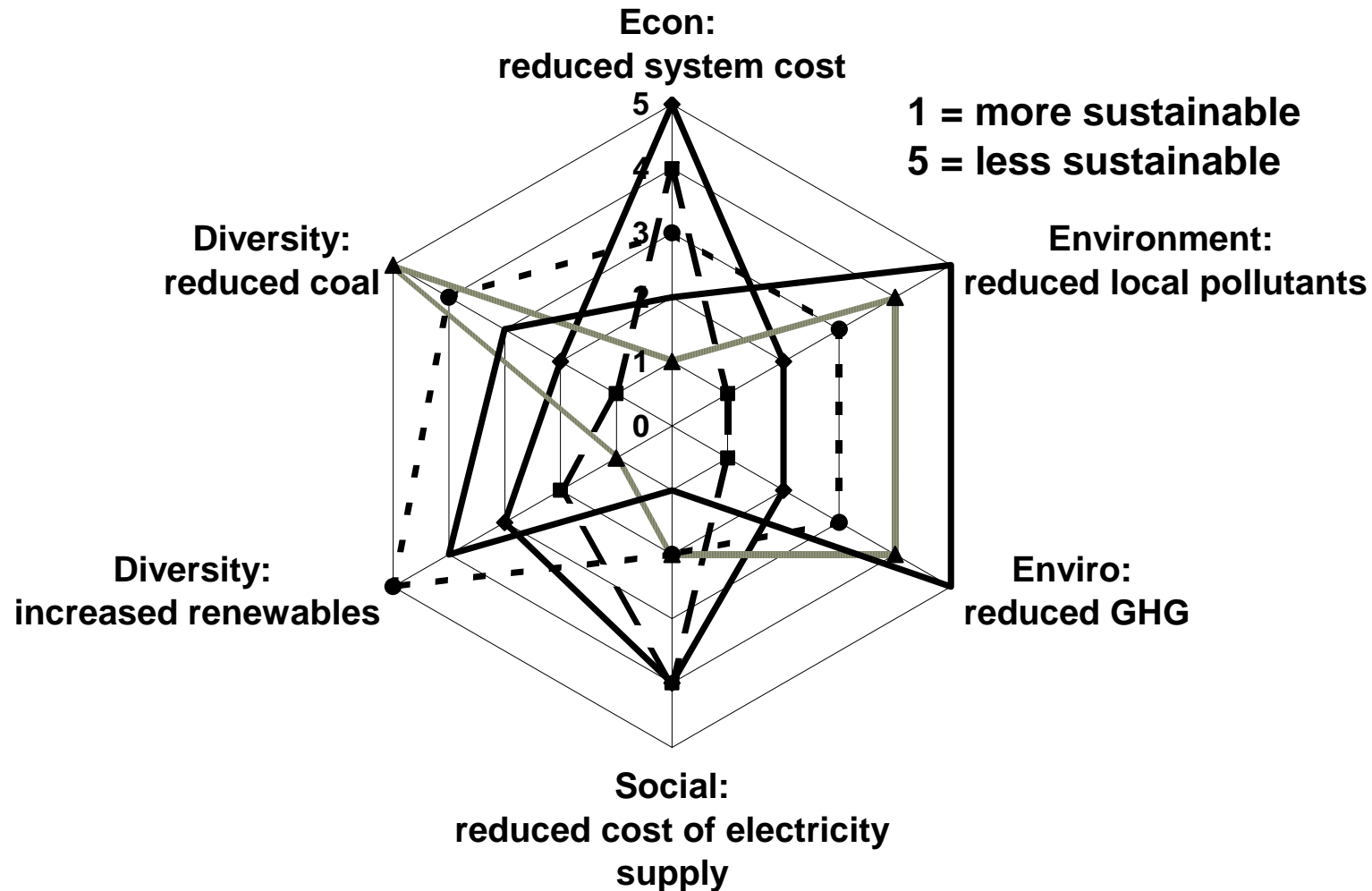
Determining a CDM-Mitigation Strategy



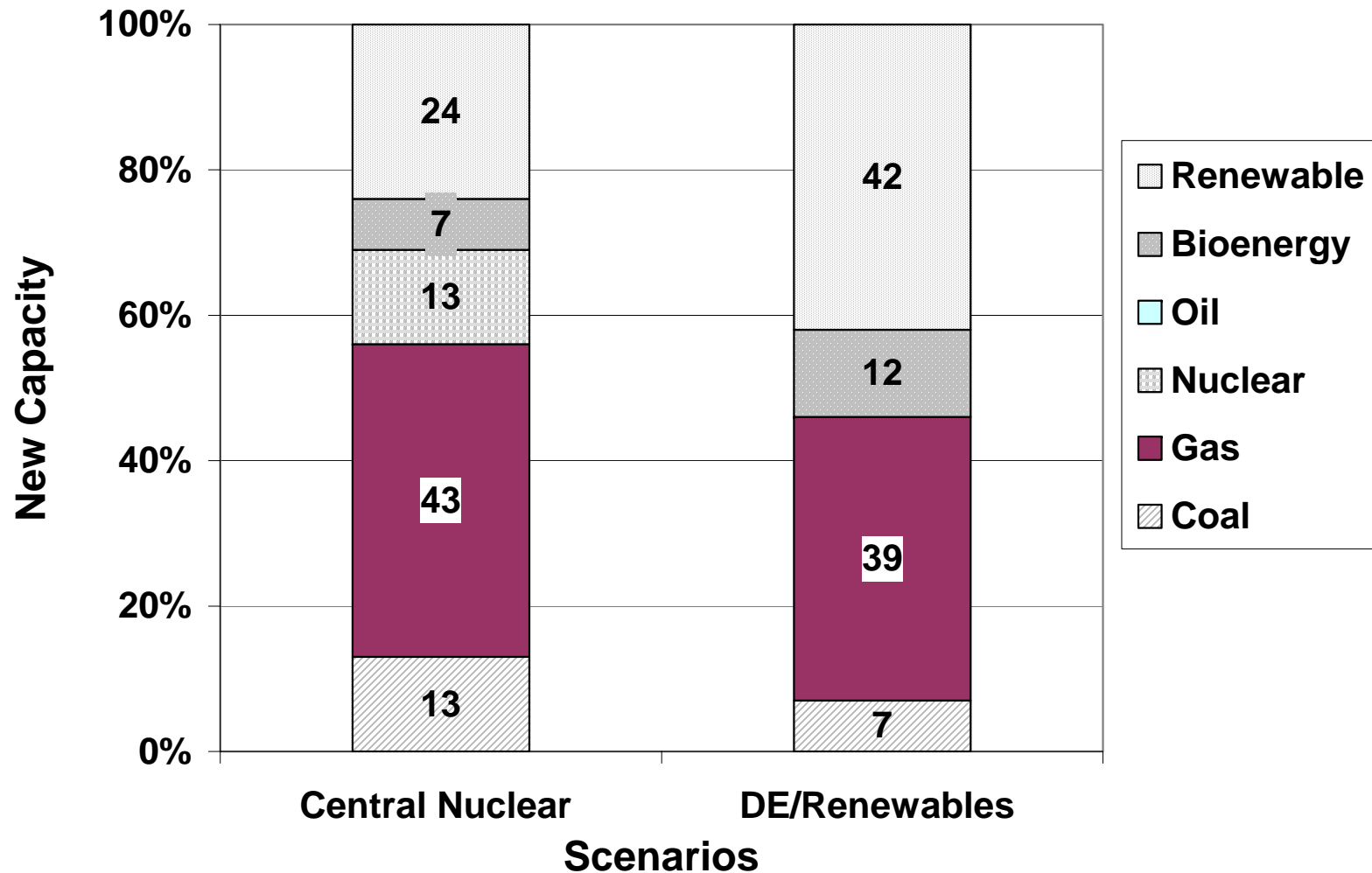
More National Level Examples:
Climate Change and
Sustainable Development in
South Africa and UK



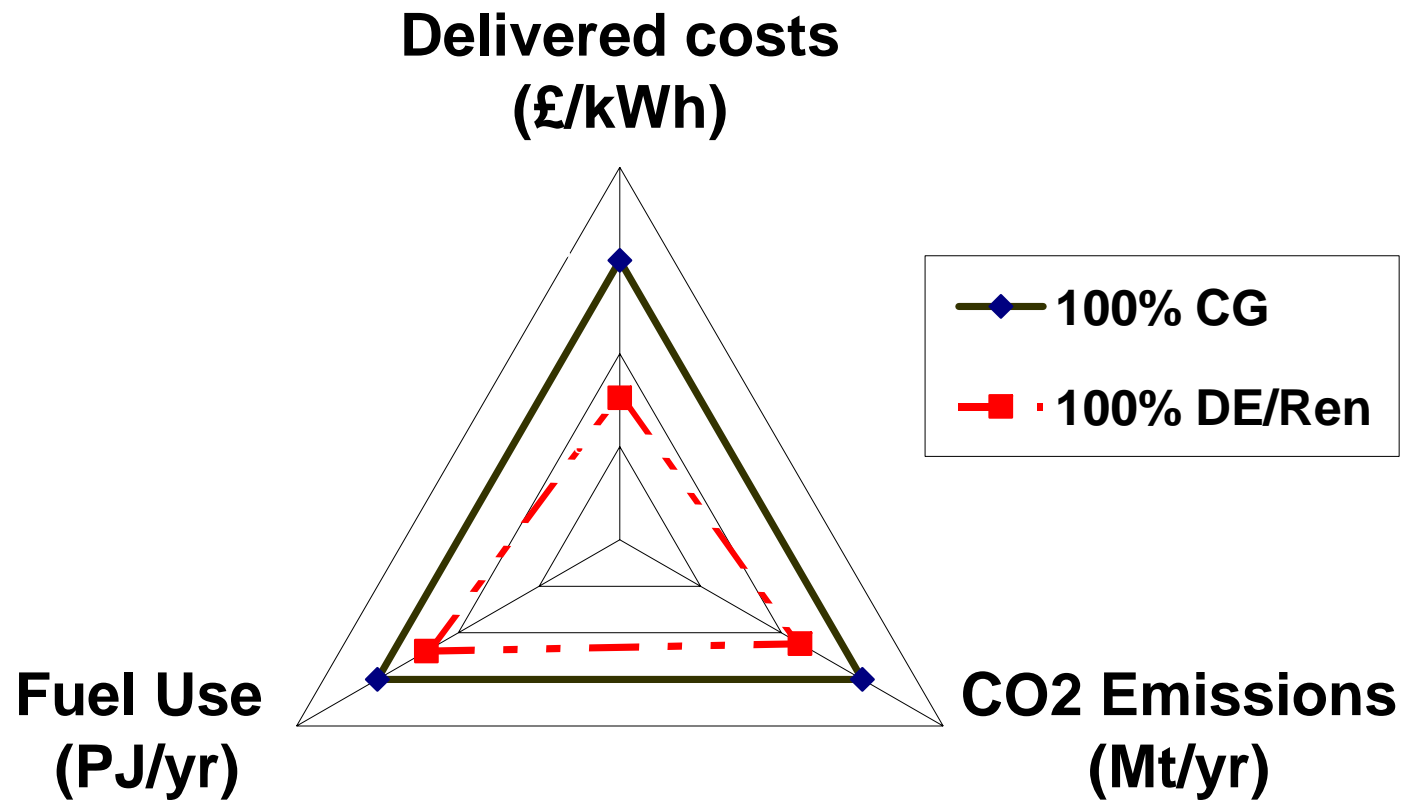
South Africa MCA: Energy Development Options



UK – WADE model power sector scenarios



UK: MCA of WADE model results

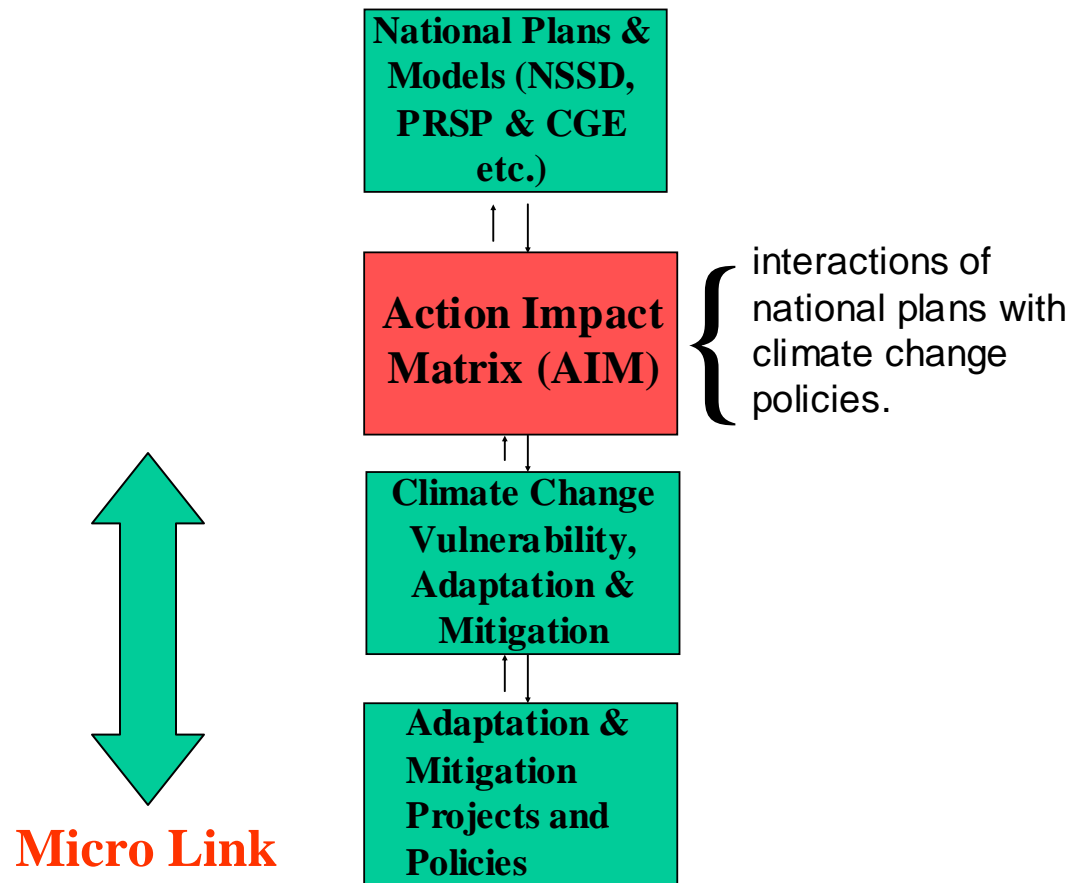


Project and Micro Level Analysis

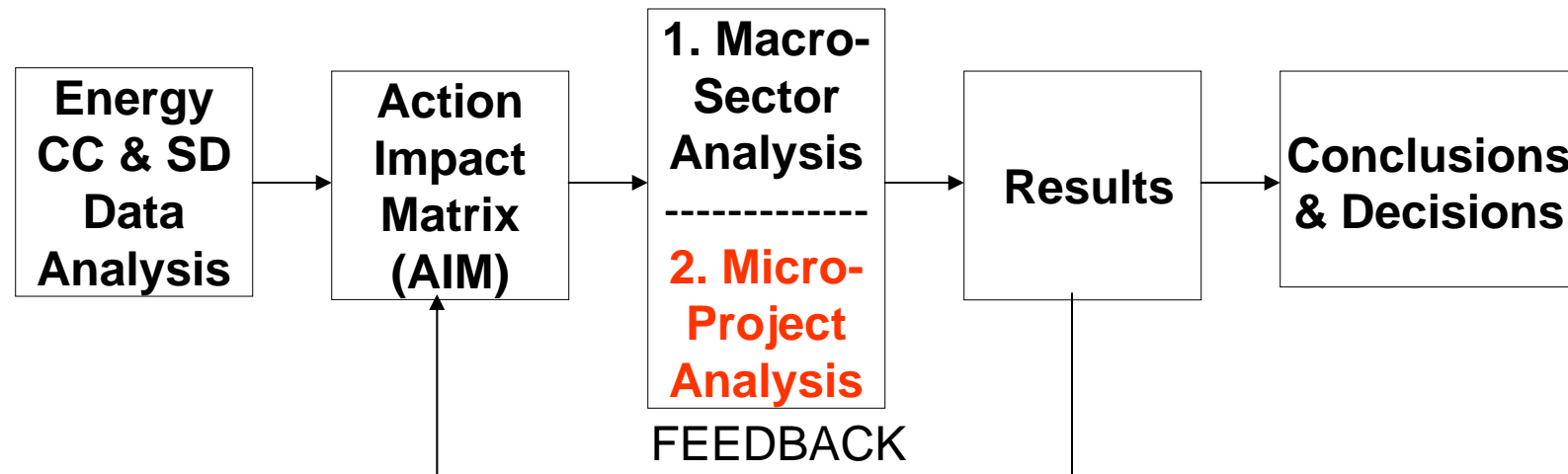


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Assessing links between development plans and adaptation and mitigation – Micro and Project Linkage



Summary of AIM-based Analytical Process: Project Path



Sustainable Development Assessment (SDA) **(partial equilibrium analysis at sector/project level)**

- 1. Economic/Financial Assessment (CBA)**
- 2. Environmental Assessment (EA)**
- 3. Social Assessment (SA)**
- 4. Poverty Assessment (PA)**
- 5. Technical Assessment (TA)**

Choice of appropriate SD indicators is vital for SD Assessment



Project Level Example

Assessing economic, social and ecological indicators for small hydro in Sri Lanka

Primary Source: Morimoto R., and Munasinghe M. (2005) “Small hydropower projects and sustainable energy development in Sri Lanka”, *Int. Journal of Global Environmental Issues*, Vol.4.

Summary: Munasinghe, M. (2002) “The sustainomics trans-disciplinary meta-framework for making development more sustainable: applications to energy issues”, *Int. J. of Sustainable Dev.*, Vol.4, No.2, pp.6-54.



Overview of study

- Energy affects all three dimensions of sustainable development.
- Reviews linkages between potential impacts of energy production and consumption on sustainable development,.
- Multi-criteria analysis used to assess the role of small hydroelectric power projects in sustainable energy development.
- 3 key variables:
 - Economic* - electricity supply costs,
 - Social* - numbers of people resettled,
 - Environmental* - biodiversity loss
- Analysis helps policy-makers compare and rank project alternatives more easily and effectively.
- The multi-criteria analysis, which includes environmental and social variables, supplements cost benefit analysis which is based on economic values alone.



Economic indicator used

Average generation costs per unit generated per year [C_i/Q_i]

where

C_i = total economic cost of project i

Q_i = quantity of electricity generated from project i

This measure is equivalent to using net benefits per unit of generation:

NB_i/Q_i

where

$NB_i = (B_i - C_i)$ = net benefit from project i ;

B_i = total benefit from project i ;

and we assume that the total benefit per unit generated is the same for all projects compared: B_i/Q_i

Another related measure would be the average generation costs per unit of GHG emissions reduced, assuming that each unit of hydro-electricity produced would reduce a unit of thermal generation and associated GHG emissions.



Environmental Indicator used

Average biodiversity index value per unit of energy produced per year:

$G_i = E_i / [\text{Hydroelectricity generated per year at site } i]$

where E_i is the biodiversity index

$$E_i = \sum_j w_j \cdot A_{ij}$$

where A_{ij} is the area (hectares) of ecosystem of type j at site i ,
 w_j is relative biodiversity value of ecosystem type j

Another useful indicator is average biodiversity index value per hectare of affected land

$F_i = E_i / [\sum_j A_{ij}] = E_i / [\text{Total land area affected at site } i]$



Social Indicator used

Resettlement = Number of people resettled per unit
of electricity generated per year

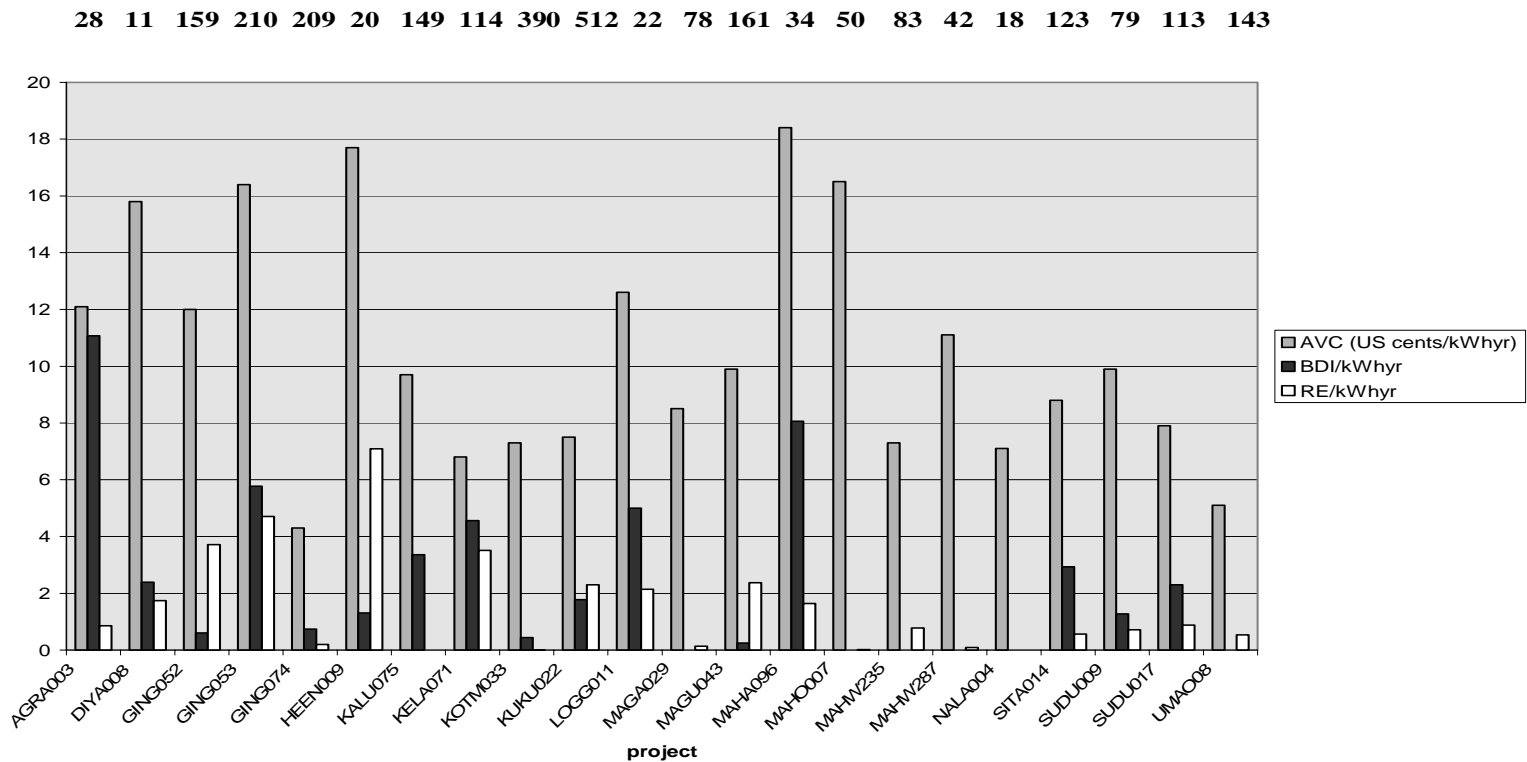
Minimising the number of people resettled due to dam construction is an important social objective.



Project Level:

Economic, social and ecological indicators for small hydro in Sri Lanka

Figure 4. Average generation costs (AVC), biodiversity index (BDI), and number of resettled people (RE) by hydroelectric project. All indices are per kWh per year. Numbers of people resettled and the biodiversity index are scaled for convenience (by the multipliers 10^{-5} and 10^{-9} respectively). The values at the top of the graph indicate the annual energy generation in gigawatt hours (GWh).



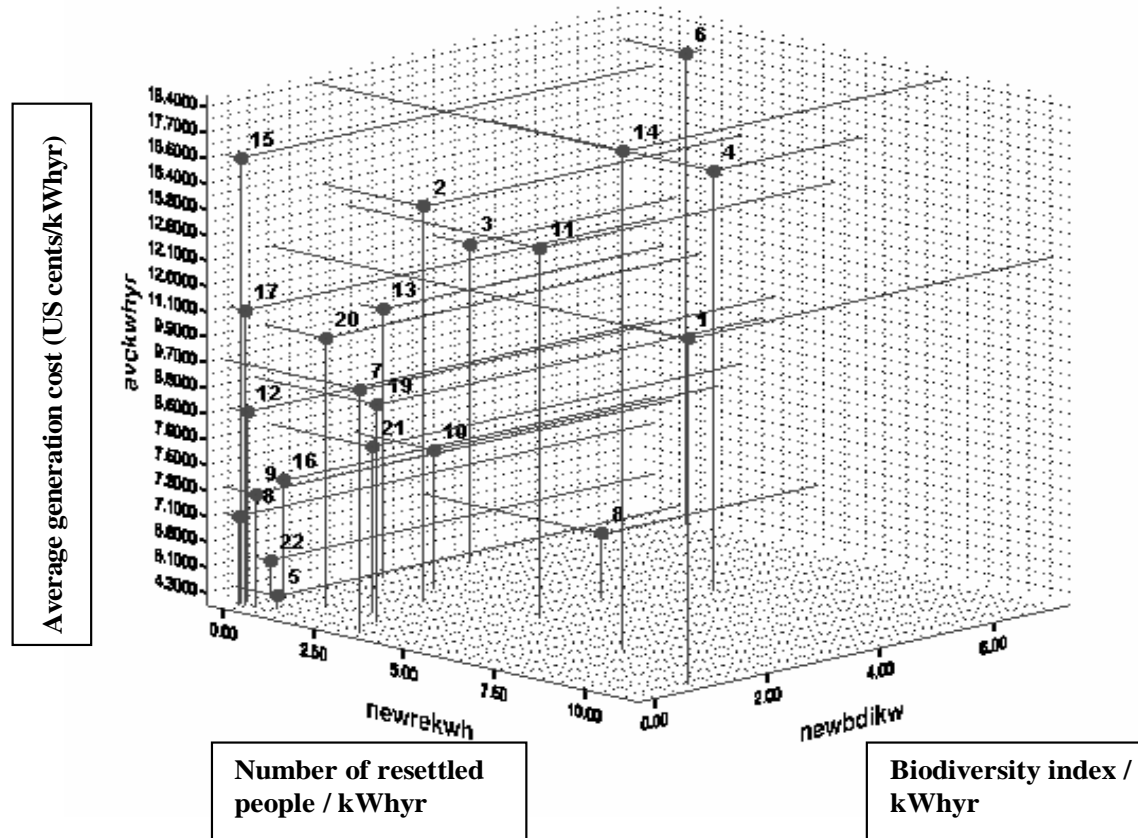
Source: CEB (1987); CEB (1988); Meier and Munasinghe (1994)



Three dimensional MCA of SD indicators of small hydro

Figure 5. Three dimensional MCA of sustainable development indicators for various hydropower options.

Source: Morimoto, Munasinghe and Meier [2000]



Conclusions of Study

- MCA helps policy-makers compare project alternatives more easily and effectively
- Looks at all aspects of project (social, environmental and economic) unlike CBA which emphasises economic aspects.



Summary and Conclusions About CC-SD Links

Development comes first – i.e., start from a sustainable development perspective, while recognising that poverty and equity will affect future development paths and vice versa, with many complex and dynamic feedback mechanisms. Ideally, climate change should become a core part of the overall sustainable development strategy.

Focus on ‘making development more sustainable’ – because improving the sustainability of existing development activities is an easier, more relevant and practical goal, rather than seeking the ideal of sustainable development.

Integrate and balance the social, economic and environmental dimensions of SD using trans-disciplinary approaches, but these perspectives may differ among countries and communities. Many useful analytical tools already exist.

Recognize durability and optimality as complementary, integrative approaches, and identifying where they might be appropriately applied.

Focus on the two-way interaction between sustainable development and climate change. Analyse links from national to local levels -- start with development documents (NSSDs, PRSPs and MDGs) and environmental documents (NEAPs) organized through the action impact matrix (AIM); then utilizes macro and sectoral approaches; and finally focuses on local SD effects.



Summary and Conclusions About CC-SD Links (contd)

Apply the action impact matrix (AIM) method to link and articulate development activities with climate change. The AIM process engages all key stakeholders and promotes consensus building. Matrix cells focus attention on the most important issues and suggest action priorities to solve problems (including both synergies and trade-offs).

Apply a range of sustainable development assessment (SDA) techniques to priority issues that were identified during the AIM process. Methods include economic analysis, environmental assessment, social assessment, and poverty assessment.

Use sectoral, regional and macro-models, to determine national sustainable development paths and policies that incorporate relevant concerns like poverty and equity.

Develop and implement strategies, policies and projects to simultaneously improve SD and CC (win-win). Analyse and address trade-offs with care. We have the human resources, tools to build a more sustainable planet.



Ancient Pali Blessing - MDMS

**“DEVO VASSATU KALENA
SASSA SAMPATTI HETU CA
PHITO BHAVATU LOKO CA
RAJA BHAVATU DHAMMIKO”**

**“May the rains come in time,
May the harvests be bountiful
May the people be happy and contented
May the king be righteous”**

Even in ancient times, a favourable environment, economic prosperity, social stability, and good governance, were well recognised as key factors for making development more sustainable.

Suggestions for Further Information

1. **Munasinghe, M. (2007) *Making Development More Sustainable: Sustainomics Framework and Practical Applications*, MIND Press, Munasinghe Institute for Development, Colombo.**
2. **Munasinghe, M., and Swart, R. (2005) *Primer on Climate Change and Sustainable Development*, Cambridge University Press, UK. –translated into Chinese**
3. **MIND (2005) *Action Impact Matrix (AIM) Application to Climate Change - Users Guide*, Munasinghe Institute for Development, Colombo.**
4. **Website URL: <www.mindlanka.org>**



**Making
Development More
Sustainable:
Sustainomics Framework
and Practical Applications**
Mohan Munasinghe

WEALTH



PEOPLE

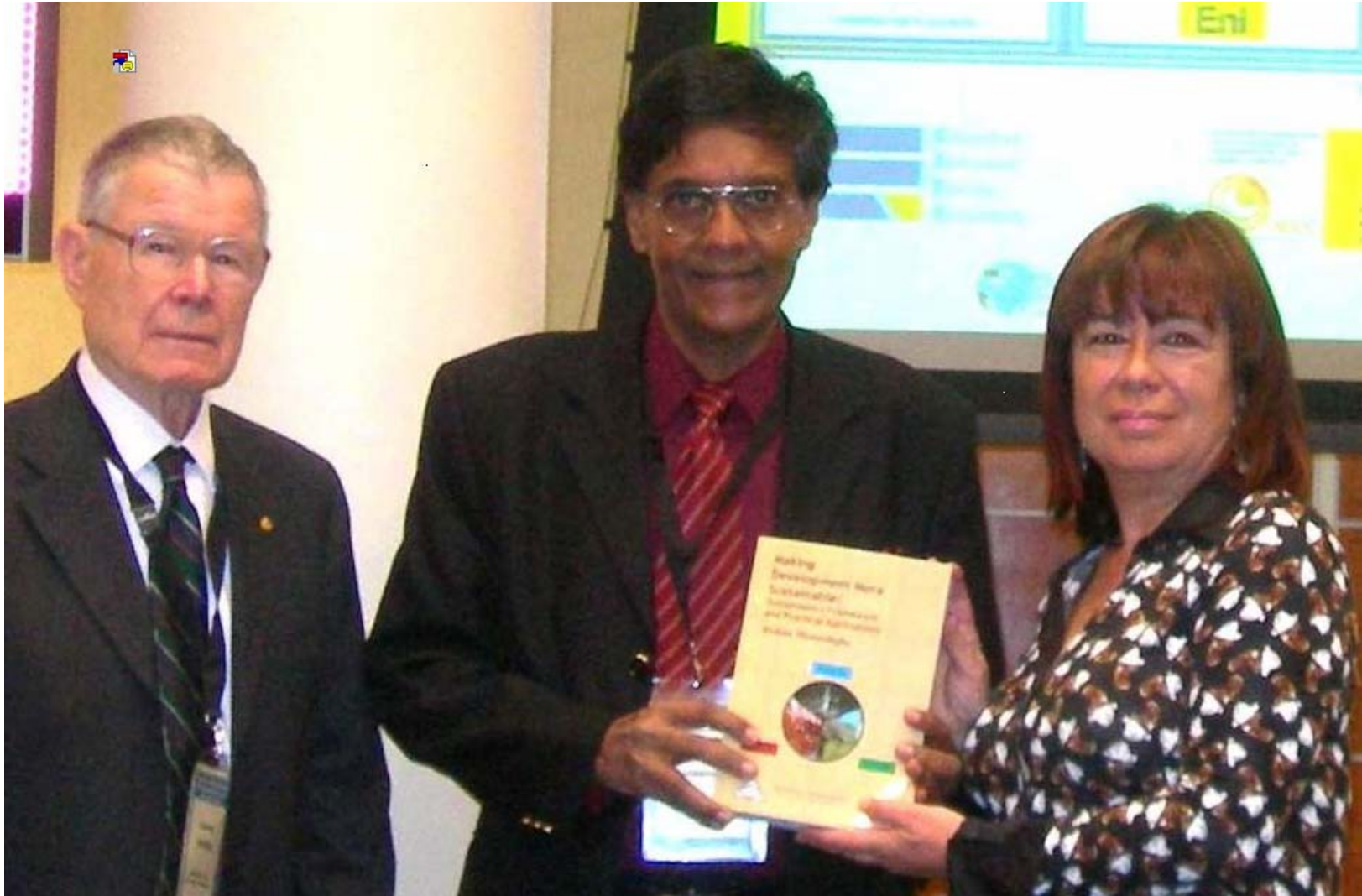
NATURE



MIND Press – Student Edition
For use in MIND approved courses



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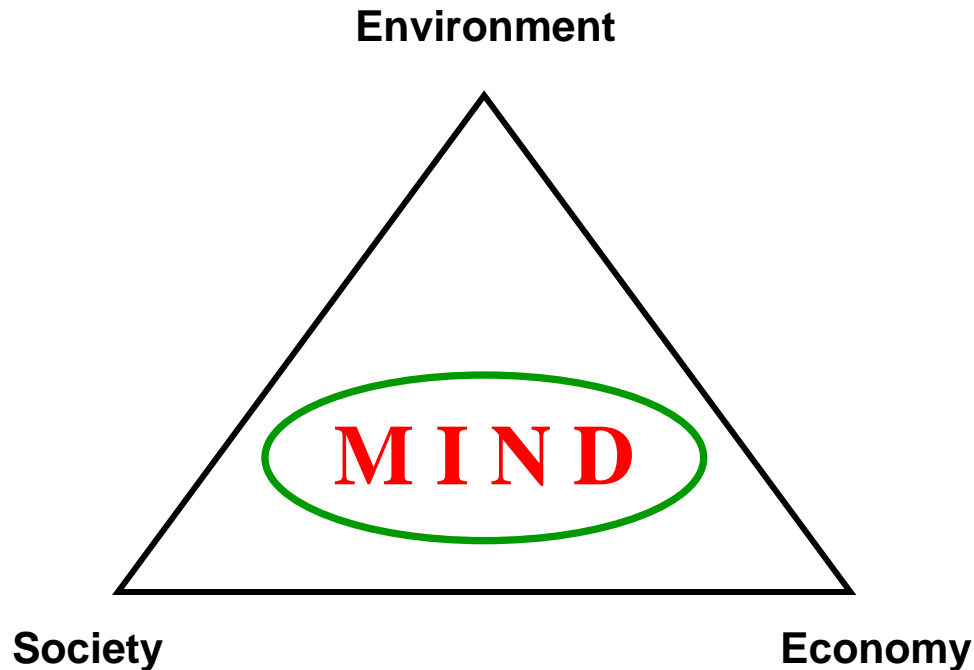


Prof. Mohan Munasinghe launched his new book 'Making Development More Sustainable: Sustainomics Framework and Practical Applications', with the felicitations of **Hon. Cristina Narbona** (right), Spanish Minister of Environment, and **Prof. Thomas Schelling** (left), 2005 Nobel Laureate in Economics, at the International Forum on Global Climate Change, organized by the European Union in April 2007, Madrid.



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An Introduction



Munasinghe Institute for Development

"making development more sustainable - MDMS"

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Munasinghe Institute for Development

MIND was established in the new millennium as a private, non-profit organization, to play a key role in nurturing communities of stakeholders and scholars to address major issues of **Sustainable Development (SD)** worldwide. MIND aims to explore viable means of achieving this goal in Sri Lanka and elsewhere without compromising social, economic, and environmental integrity.



PROGRAMMES

- **Awards**

Research fellowships, Scholarships, Sustainable Support Service (MS3), Book donations

- **Research & Training**

Training workshops/expert meetings

Applied research studies and evaluations

UN “Centre of Excellence” for Asia in the Climate Change Capacity Development (C3D) network of the United Nations Institute for Training and Research (UNITAR).





MIND CC-SD Training Course, CMA, Beijing, July-Aug, 2006
270 Senior Chinese Officials



Munasinghe Institute for Development



MIND SD Course, Delhi, Feb. 2007
25 Senior Indian Civil Service Officers



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**MIND-ERC CC-SD Training Course, University of Cape Town, October 2007,
for 30 Senior Decision Makers from Government, Business and Civil Society**



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SD Full Course, FES, Yale University, New Haven, 2004-5

24 Graduate Students



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**Thank You Very
Much**



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