Climate Change Implications for Future Energy Systems

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Drivers of the Climate Change Challenge

- Demographic (growth & composition)
- Economic (growth, structure, disparities)
- Social (values, lifestyles, policies)
- Technologic (rates & direction of change)
- Environmental (limits, adaptability)
- Valuation (discounting, non-market damages and benefits)

Drivers can be both source and remedy!

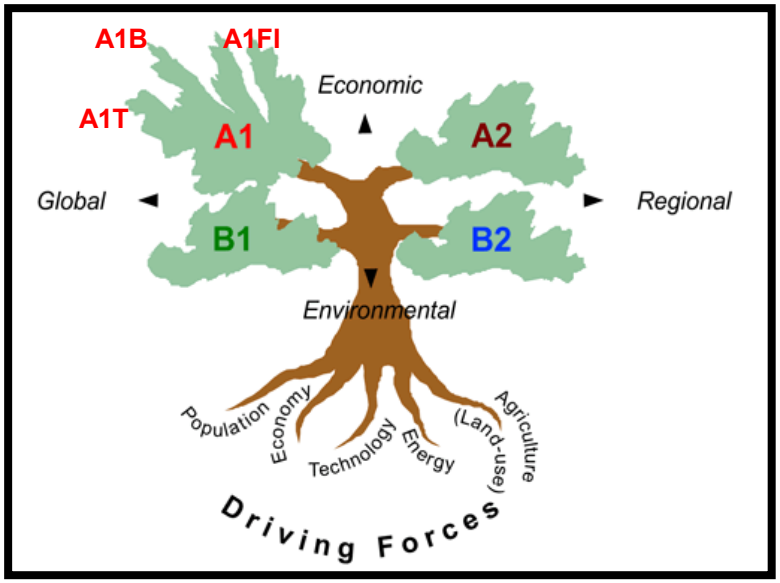
Forecasting impossible! → Scenario Approach

Global Carbon & Warming Budgets

GtC				°C warming	*uncertainty*
530	Emissions 1700-2007				
245	Atmospheric increase			0.8	*0.3 - 1.2*
1000	Reserves of coal, oil, gas				
>20,000	Total carbon fuel endowment				
	Emissions 2000-2100, no climate policy				
>2000	High	A2, A1FI		>4.0	*2.5 - 7.5*
1300-1500	Medium	B2		~3.0	*2.0 - 5.0*
1000	Low	B1, A1T		~2.7	*1.5 - 4.5*
	Emissions 2000-2100, for stabilization at:				
		ppm CO_2	ppm CO_2-e		
850		500	680	2.5	*1.4 - 4.0*
650		450	600	2.1	*1.2 - 3.5*
<400		380	500	<2.0	*1.0 - 3.0*

Scope for climate stabilization efforts depend on:
(1) Baseline and (2) Climate Target

A Taxonomy of Scenarios (ex. IPCC SRES)



<u>Different</u> combination of driving forces can lead to <u>similar</u> emissions and climate change outcomes

EMISSIONS:

High: POP: High
GDP: Medium
Efficiency: Low
TECH: Dirty

A1FI
A2
A1B

Medium:

B2
A1T

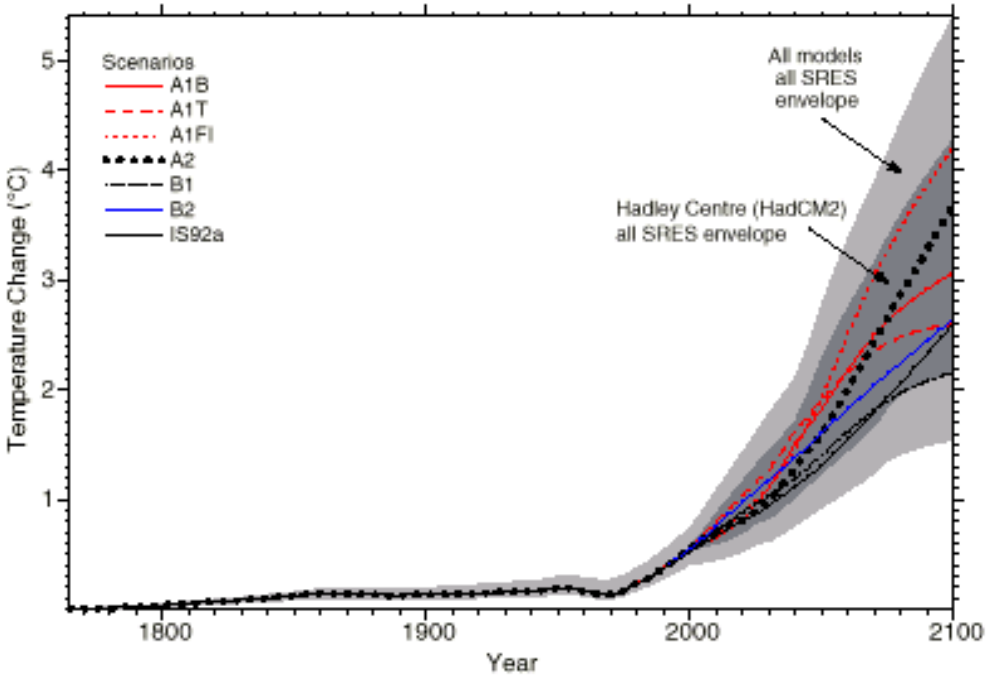
Low: POP: Low
GDP: High
Efficiency: High
TECH: Clean

B1

Largest TECH leverage of climate policies: high GDP (capital turnover) and high efficiency!

Climate Change:

Projected Global Mean Temperature Change and Sources of Uncertainty (IPCC-TAR, 2001)



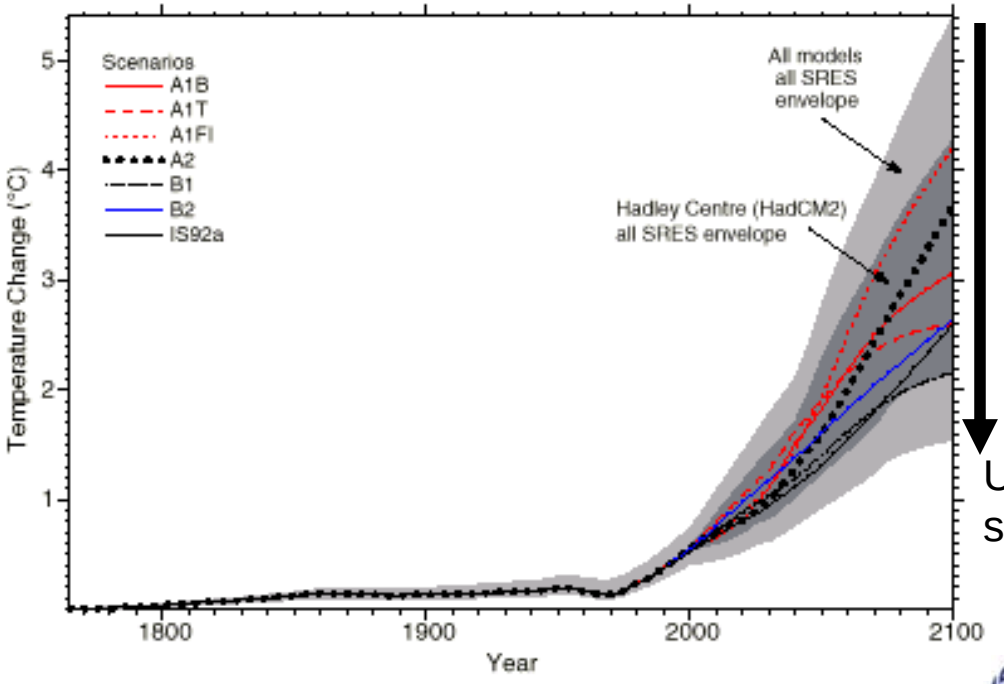
INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

WMO UNEP

IPCC WG1 TAR: "By 2100, the range in the surface temperature response across the group of climate models run with a given scenario is comparable to the range obtained from a single model run with the different SRES scenarios"

Climate Change:

Projected Global Mean Temperature Change and Sources of Uncertainty (IPCC-TAR, 2001)



Baseline Uncertainty:
50 % climate (sensitivity) modeling
25% emissions (POP+GDP influence)
25% emissions (TECH influence)

Uncertainty on extent and success of climate policies

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC)

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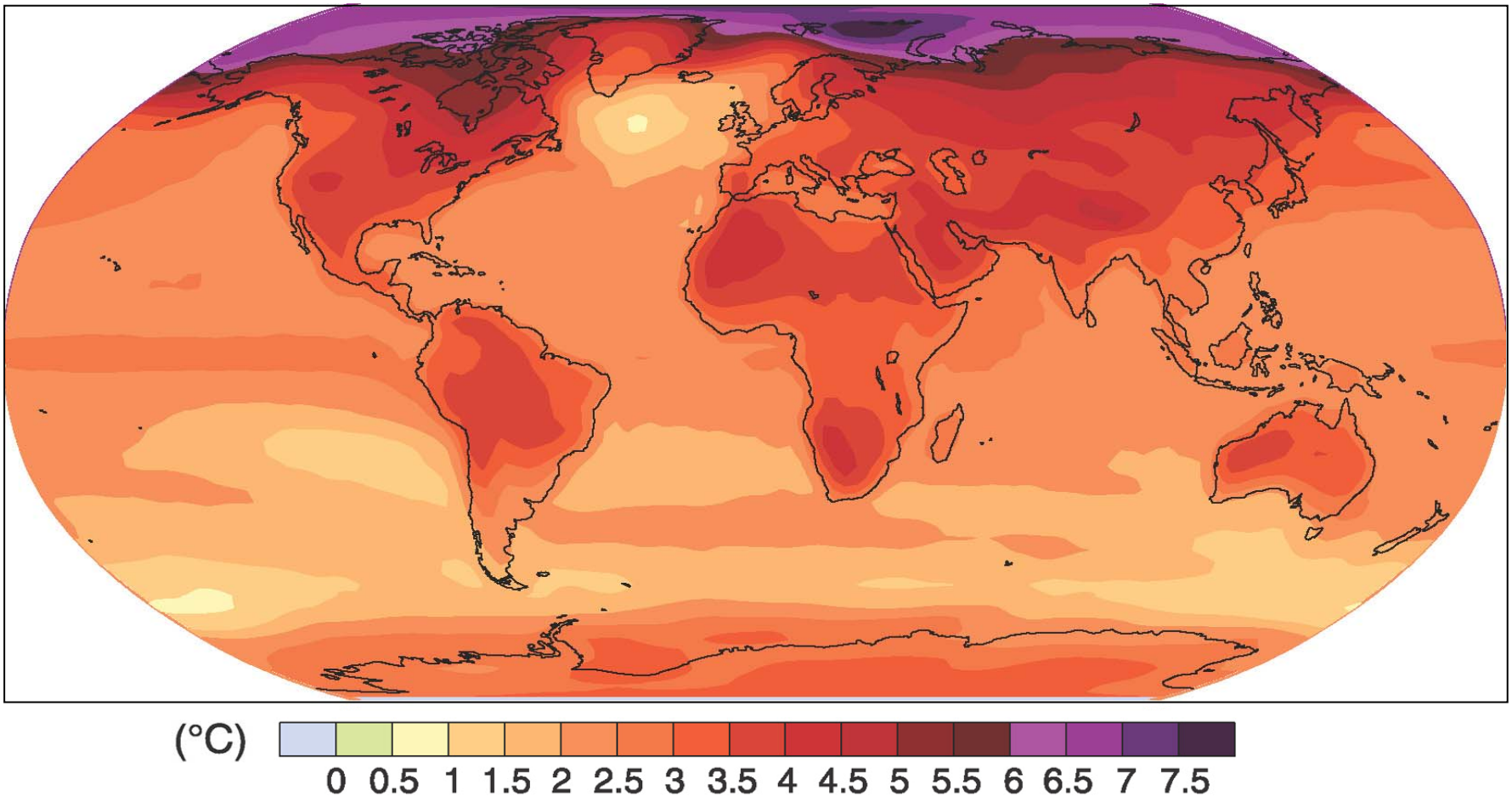
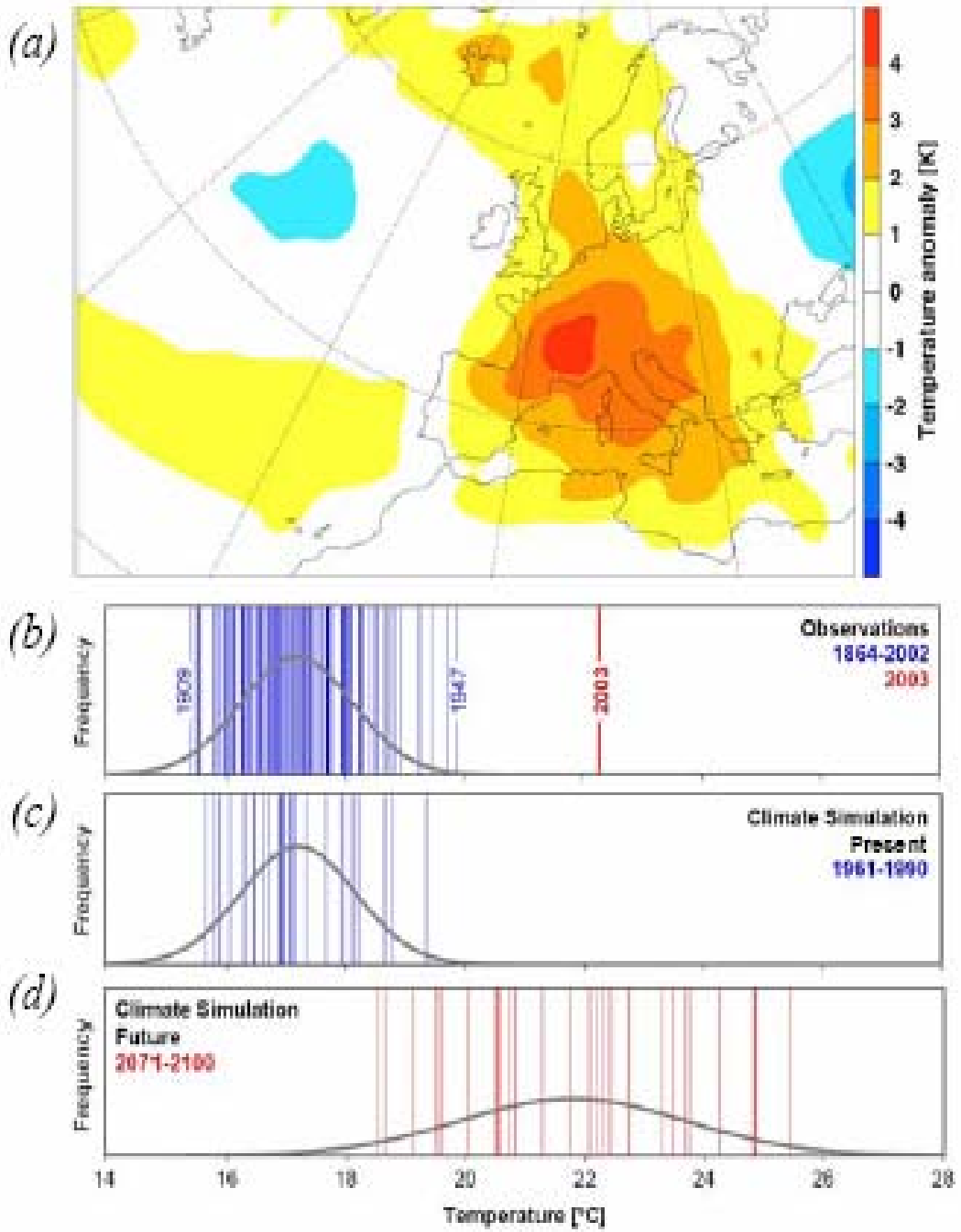
Note minimum committed warming of >1.5 °C

Projected Surface Temperature Change

A1B, 2090-2099 relative to 1980-1999



Source: IPCC-AR4 WG1, 2007



EU Regional Climate Variability: Observations (b) modeled for present (c) and future (d) conditions.

Note 2003 heat wave being far outside both observational and model range.

IPCC uncertainty terminology (adopted from Schneider and Moss) : <1% probability *="exceptionally unlikely"* (but 2003 happened!)

Air Conditioning

	% of Households with AC	% commercial buildings with AC
US	81%	80%
Japan	85%	~100%
EU	5%	27%
China (urban HH)	7%	n.a.

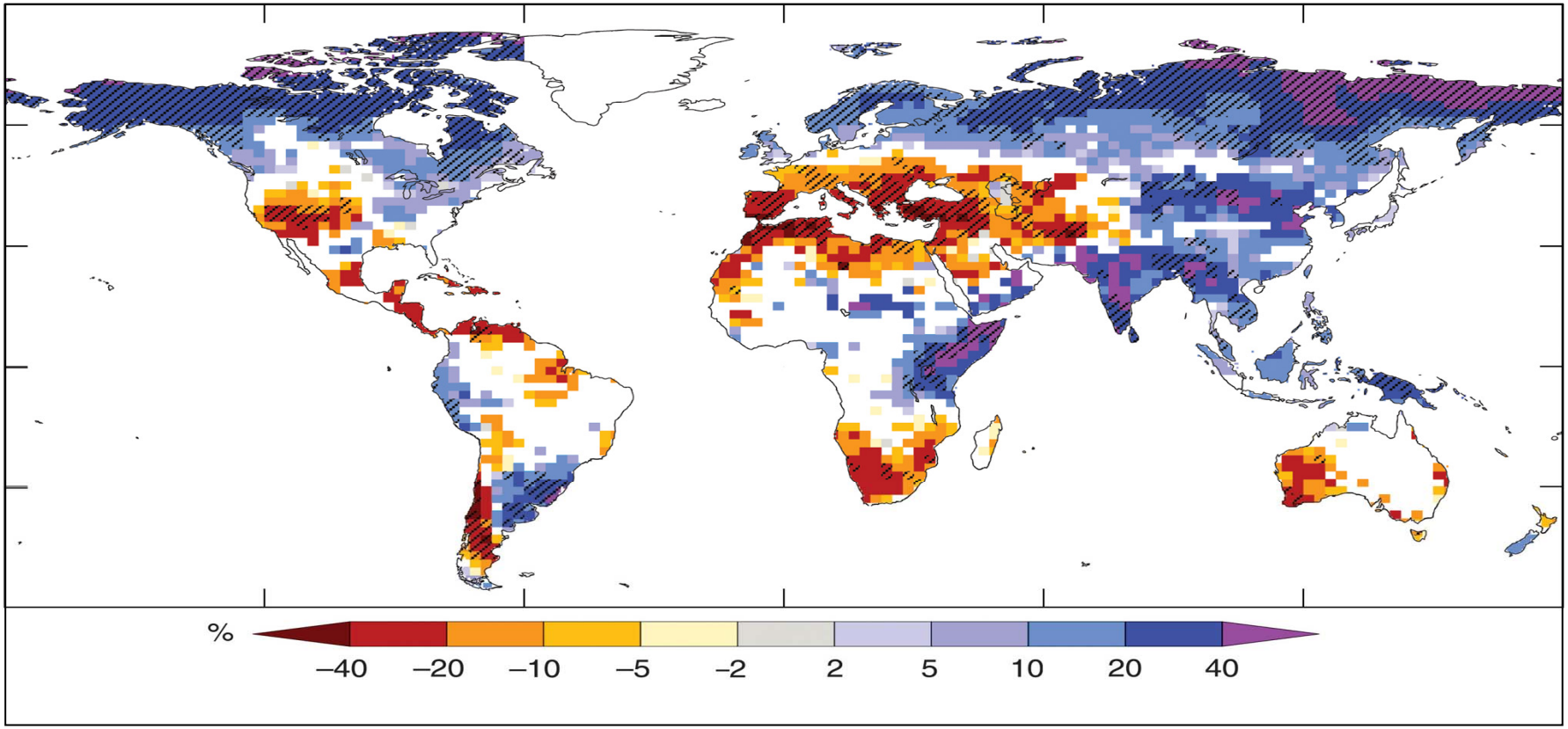
Conservative Projection: 4-fold increase in EU to 2020 worldwide to 2030

World AC electricity use: 2000: 800 TWh
2030: >2700 TWh
(=75% of total US electricity)

Source: P. Waide, IEA

Projected Water Availability (Runoff)

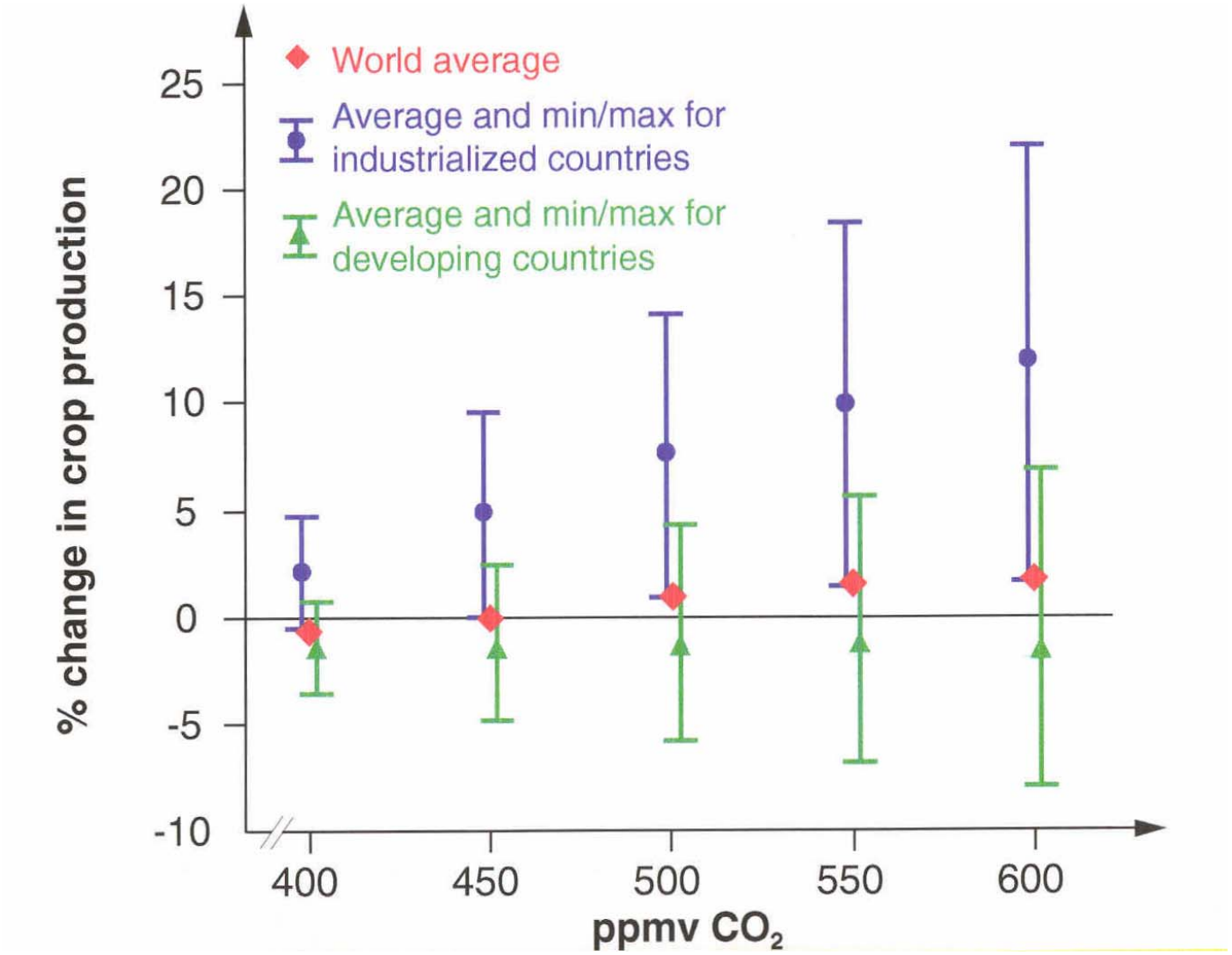
A1B, 2090-2099 relative to 1980-1999



Source: IPCC-AR4 WG1, 2007

Note: Hatched areas indicate good model agreement, white areas indicate model disagreement

Agricultural Impacts of Climate Change Scenarios.

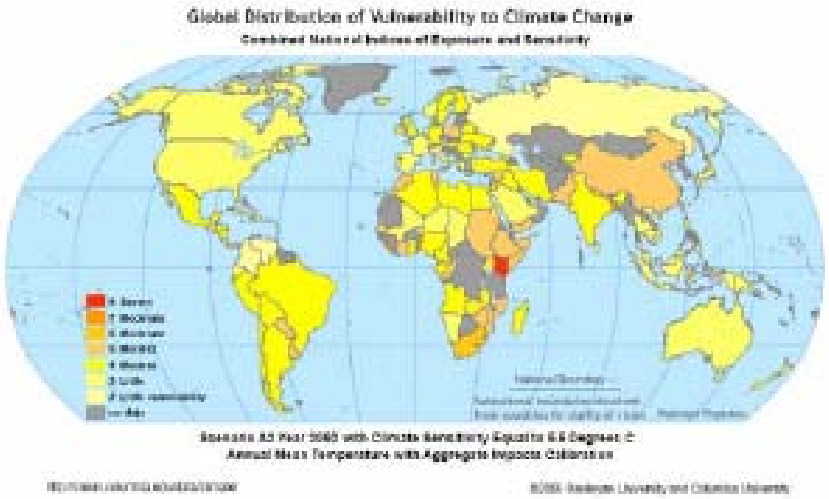


Source: IIASA LUCC, 2000.

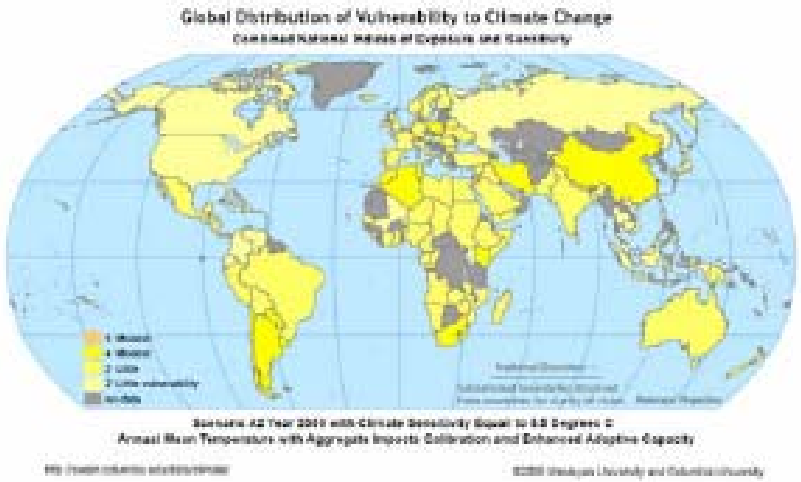
Reducing CC Vulnerabilities

- Economic & Social Development
  un-targeted and asymmetrical
  poverty vulnerability: -
  affluence vulnerability: +
- Adaptation
  targeted to CC
- Emissions reduction (mitigation)
  lowering CC but not eliminating it
  (min committed warming >1.5 °C)

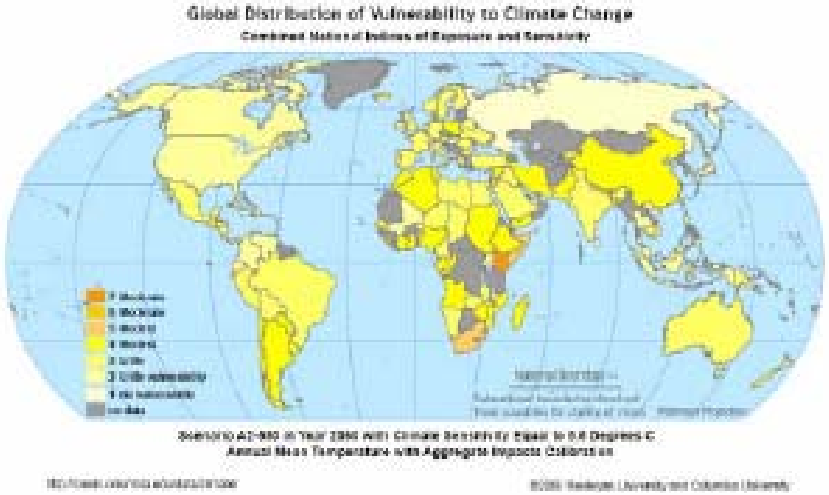
Vulnerability to CC by 2050 (IPCC-AR4 WG2, 2007)



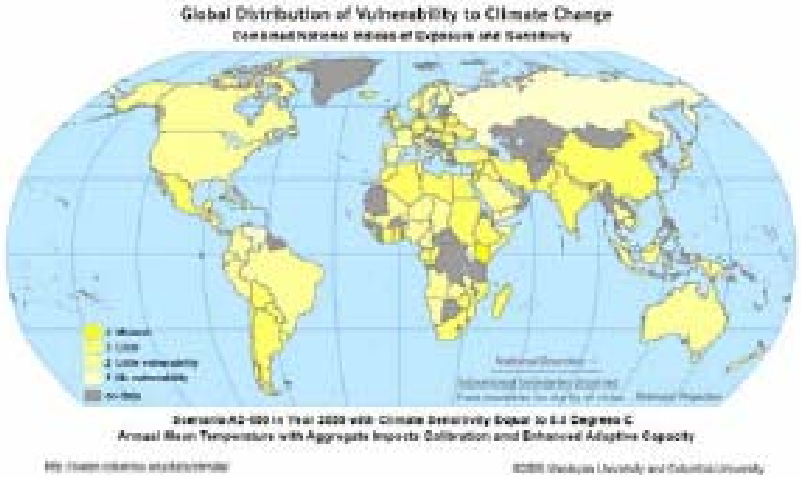
Panel A **A2 current adaptive capacity**



Panel B **Improved adaptive capacity**



Panel C **Mitigation only (550 stab)**



Panel D **Mitigation + improved adaptation**

Climate Change: The Bottom Line

- **Vast uncertainties**
  (targets & mitigation feasibility/costs):
  -- impacts (warming plus variability)
  -- technology (which ones when, where, how)
- **Magnitude of challenge depends on:**
  -- future development in “South”
  -- technologies available
  (efficiency AND clean supply)
- **Policy Approach:** Rather than: “wait and do nothing”/ “optimum” path,
  get prepared, hedge risks, adapt
  (develop incentives, institutions, and technology mitigation/adaptation response portfolios)

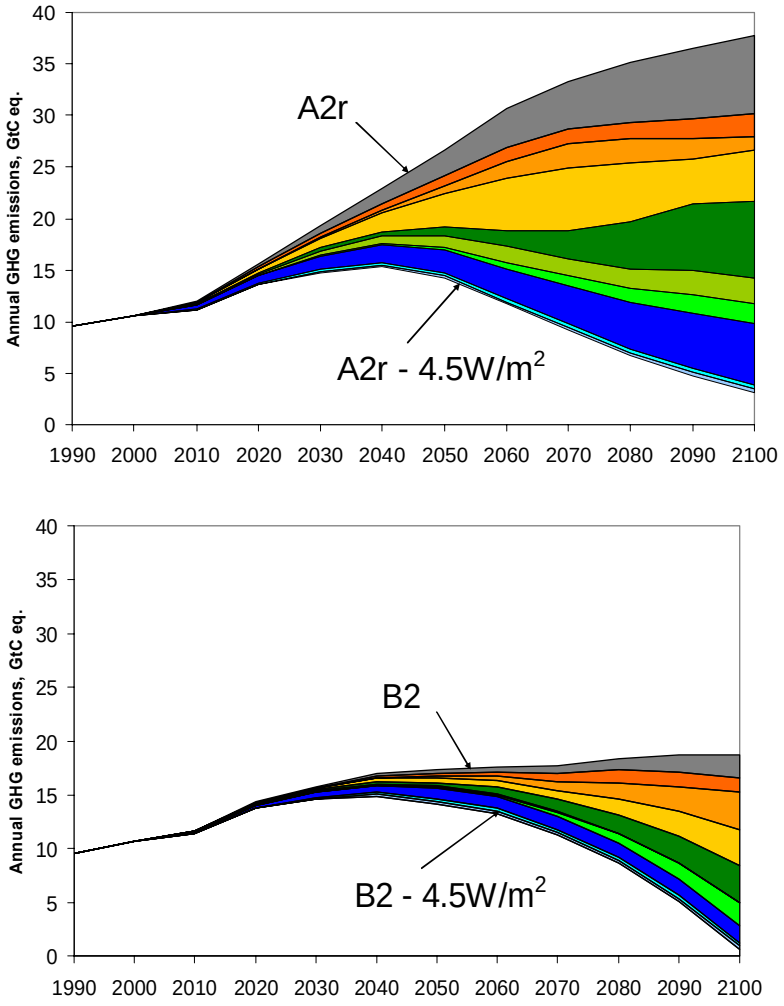
Mitigation Technology Portfolio Analysis

- Paramount importance of Baseline
- Costs matter
- Diffusion time constants matter
- Differences in where technology is developed and where it is deployed
- Technological interdependence and systemic aspects important in “transition” analysis
- Non-energy, non-CO2 can help (lower costs), but cannot solve problem (reduce energy-CO2)
- Multiple drivers, but all channeled via investments

Σ: Popular “wedge” analysis fails on all above accounts!

Mitigation Scenario Analysis

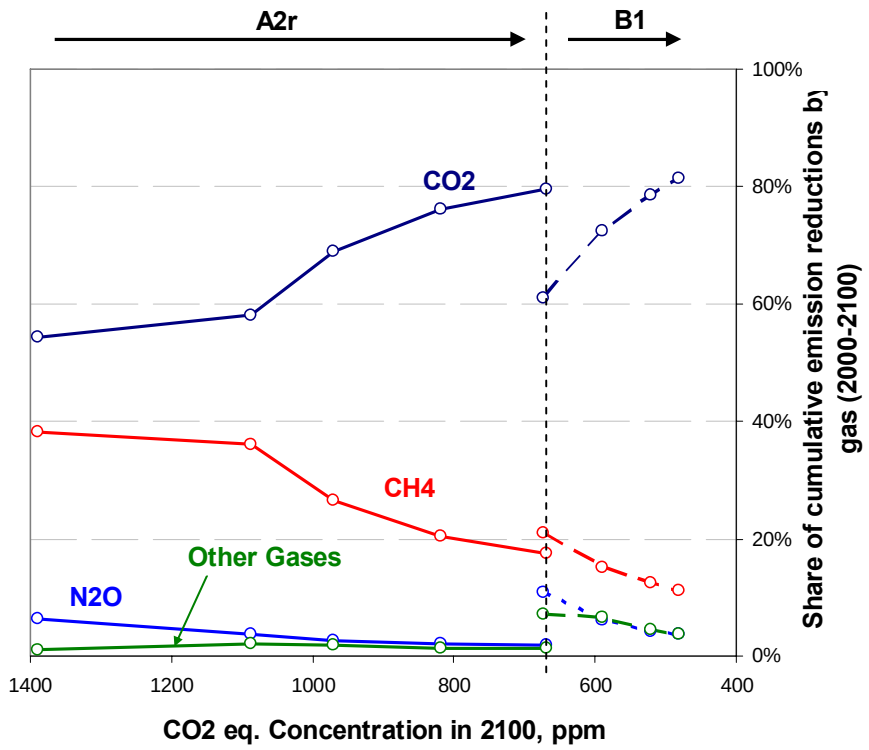
Source: Riahi et al., TFSC 74(2007)

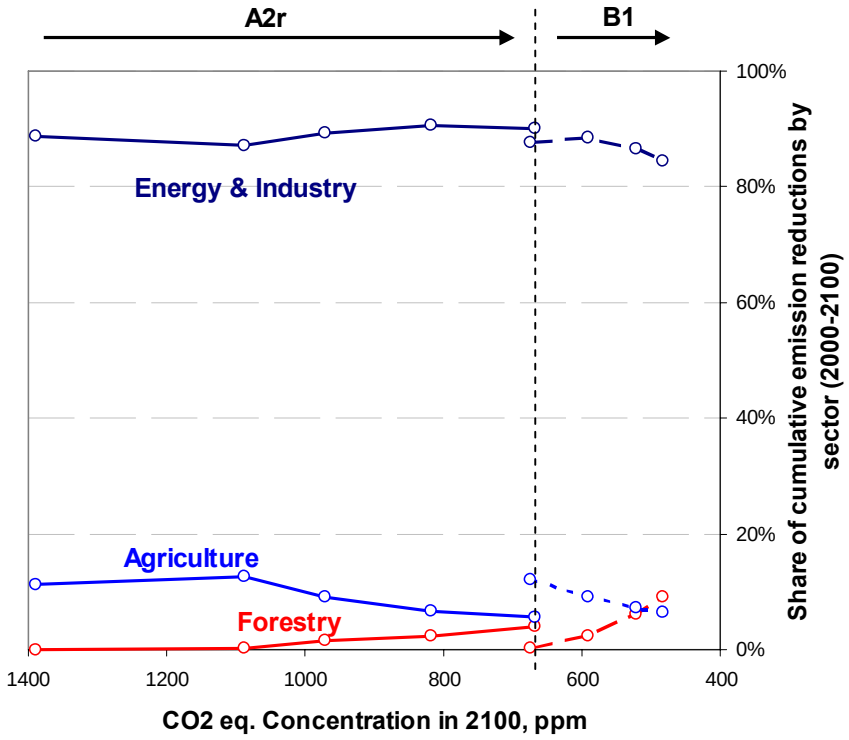


Σ: Mitigation "wedges" are baseline and target dependent

Emissions & Reduction Measures

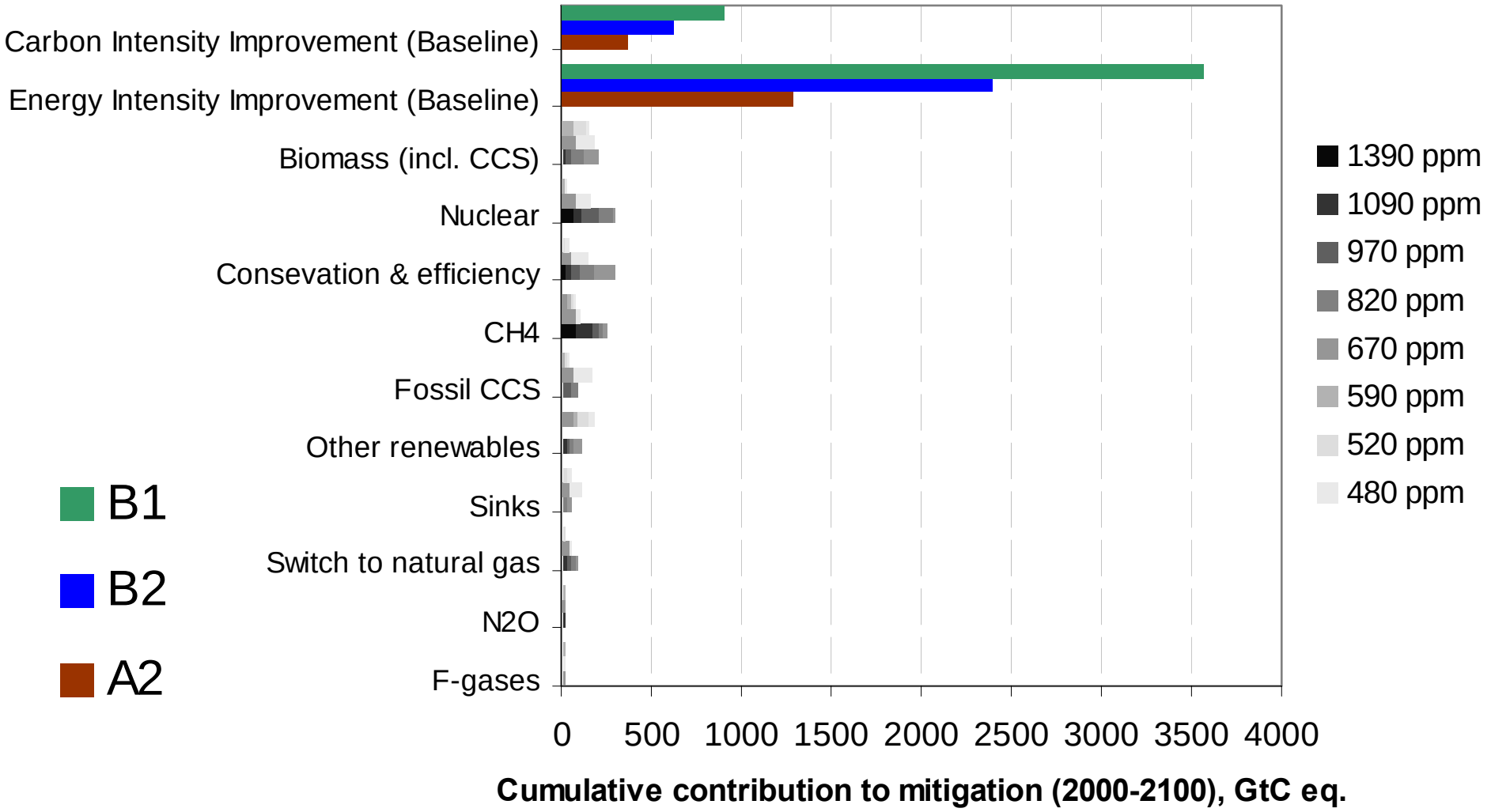
Multiple sectors and stabilization levels





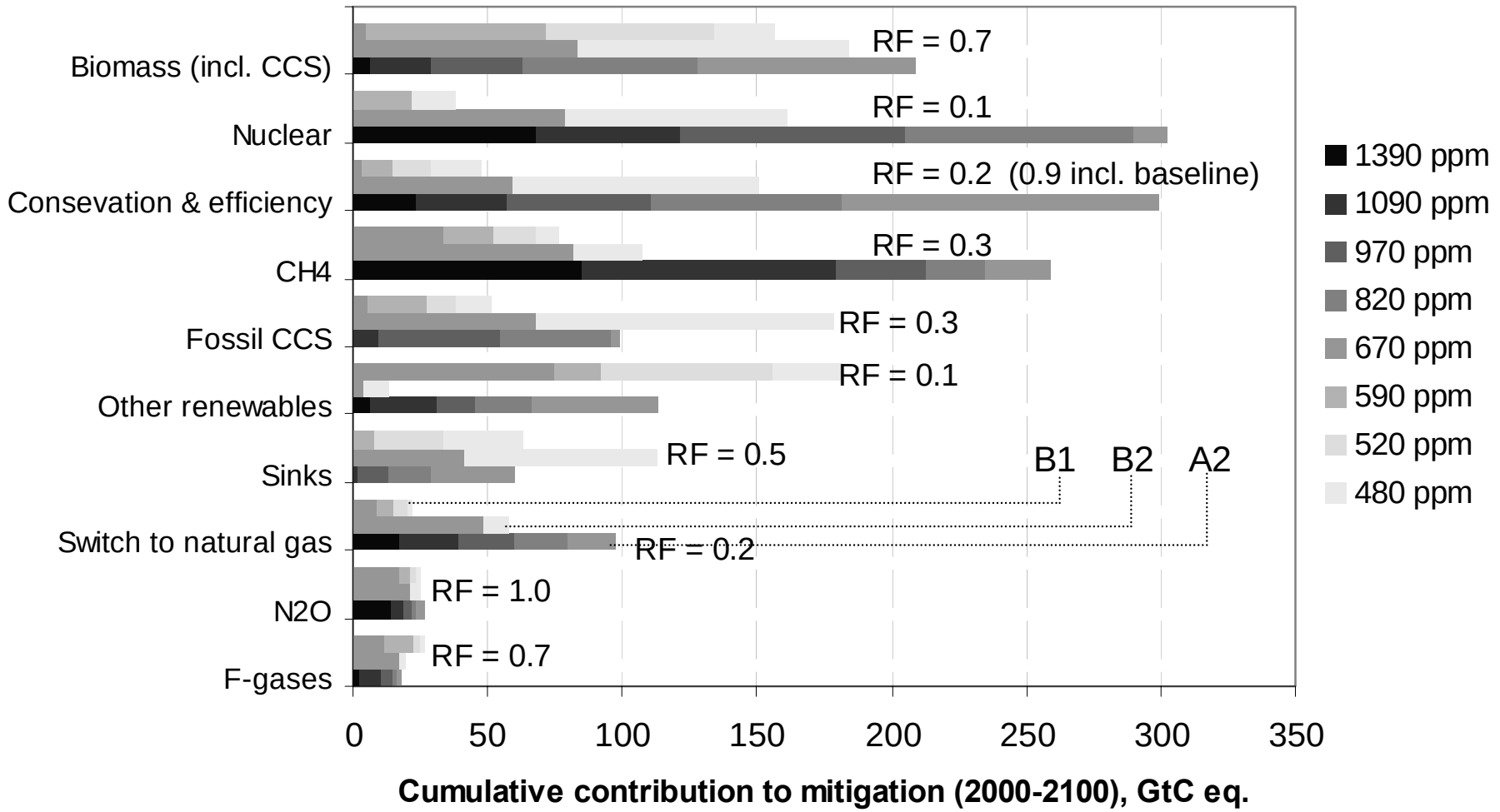
Σ: Energy CO_2 remains main problem and target for mitigation

Emission Reduction Measures



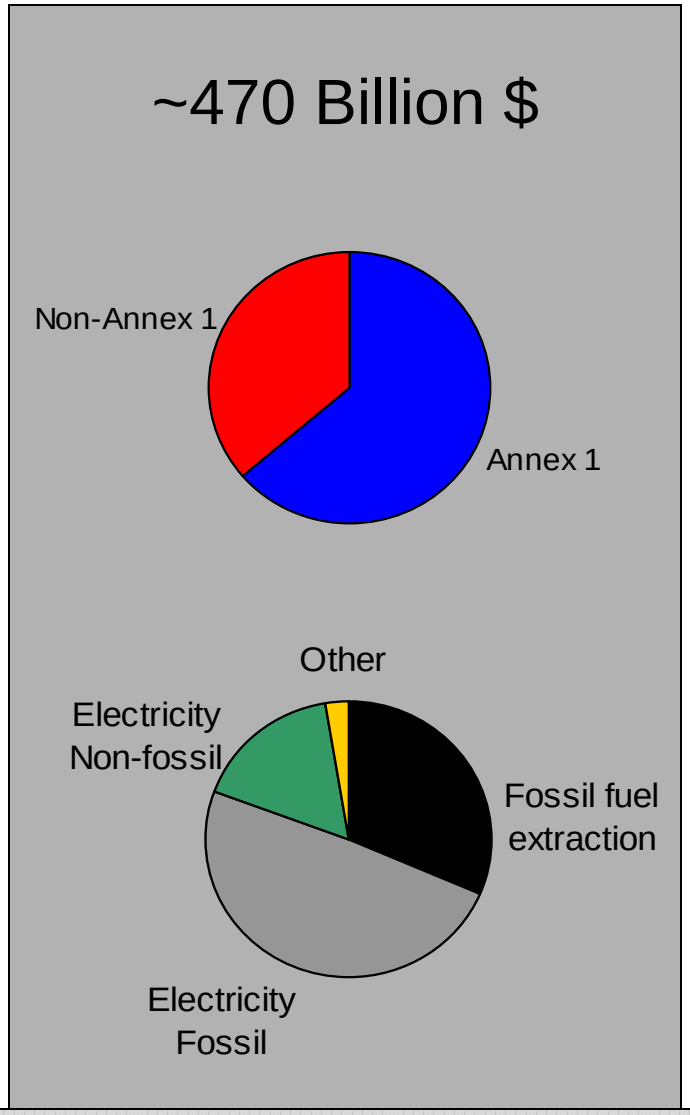
Σ: Technological change in Baseline best hedging against target uncertainty

Emission Reduction Measures



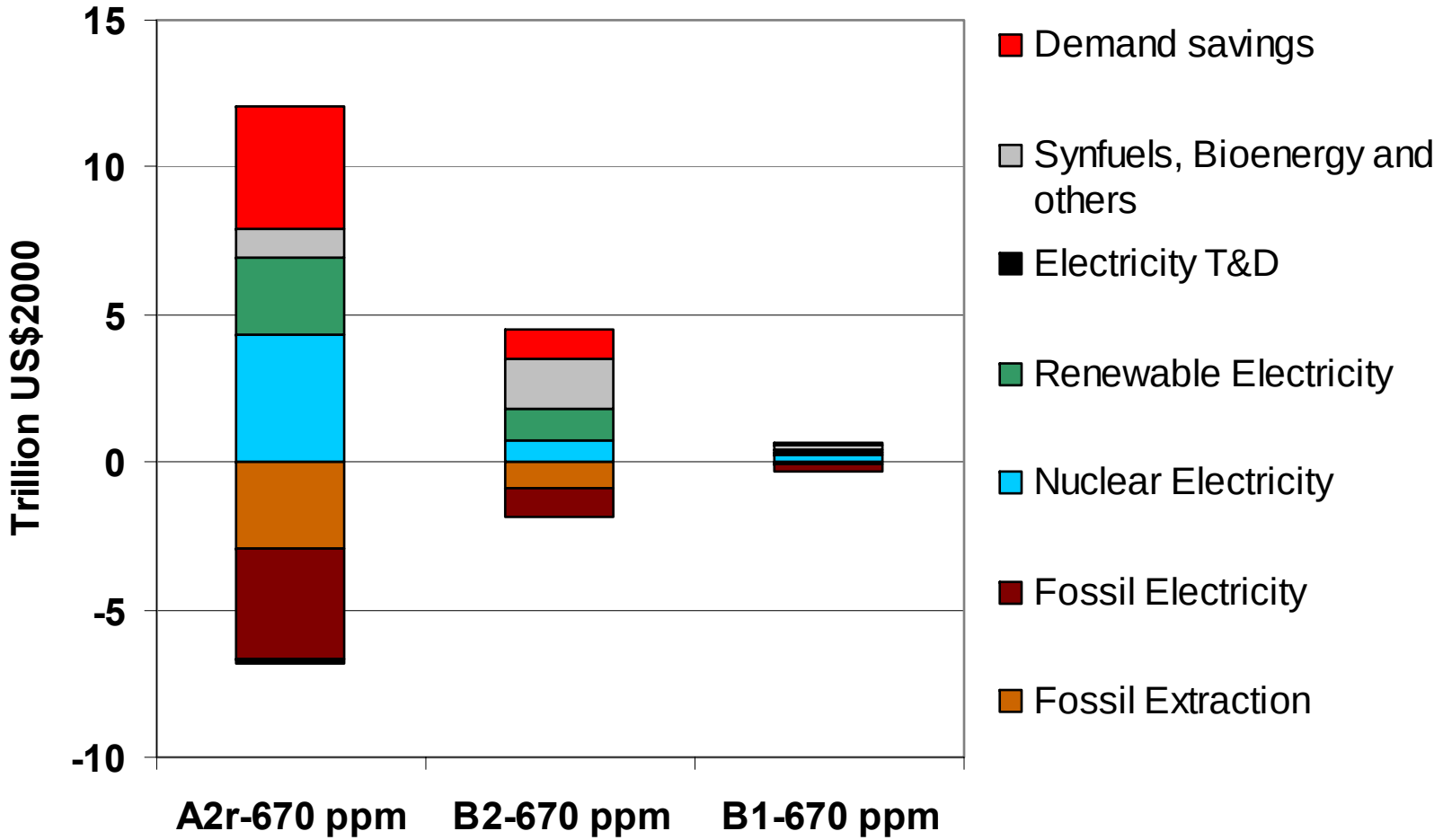
RF = Robustness factor of options across scenario uncertainty is highest for:
F-gases and N2O reduction, energy conservation & efficiency,
and biomass+CCS "wildcard" (if feasible)

Energy Sector Investments Today



Note Annex-I and fossil fuel bias!

Changes of Investments (2000-2050) due to Climate Constraints



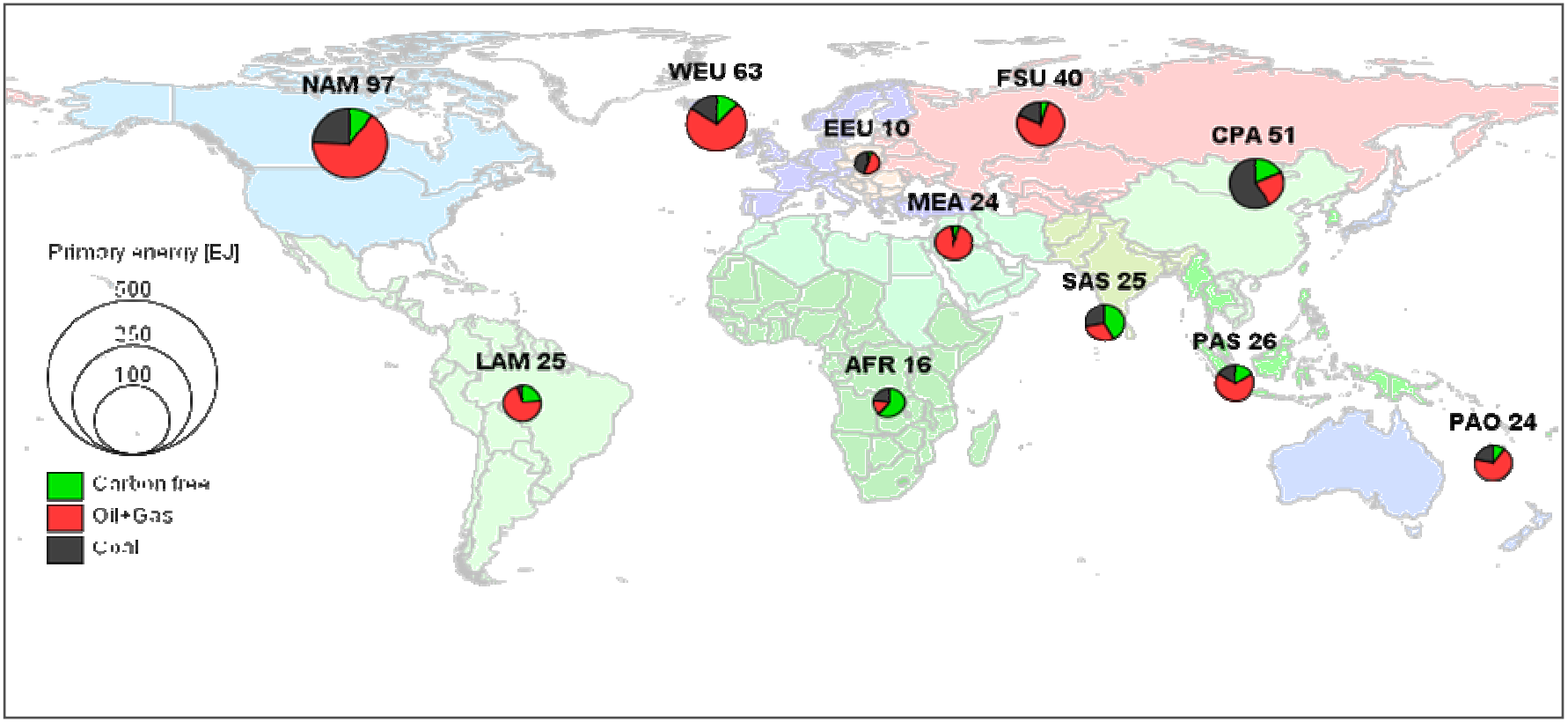
Climate policies will lead to both winners and losers in the battle for investments. The institutional dimensions and the differences between established large and nascent growing sectors must not be ignored

Energy Systems Implications

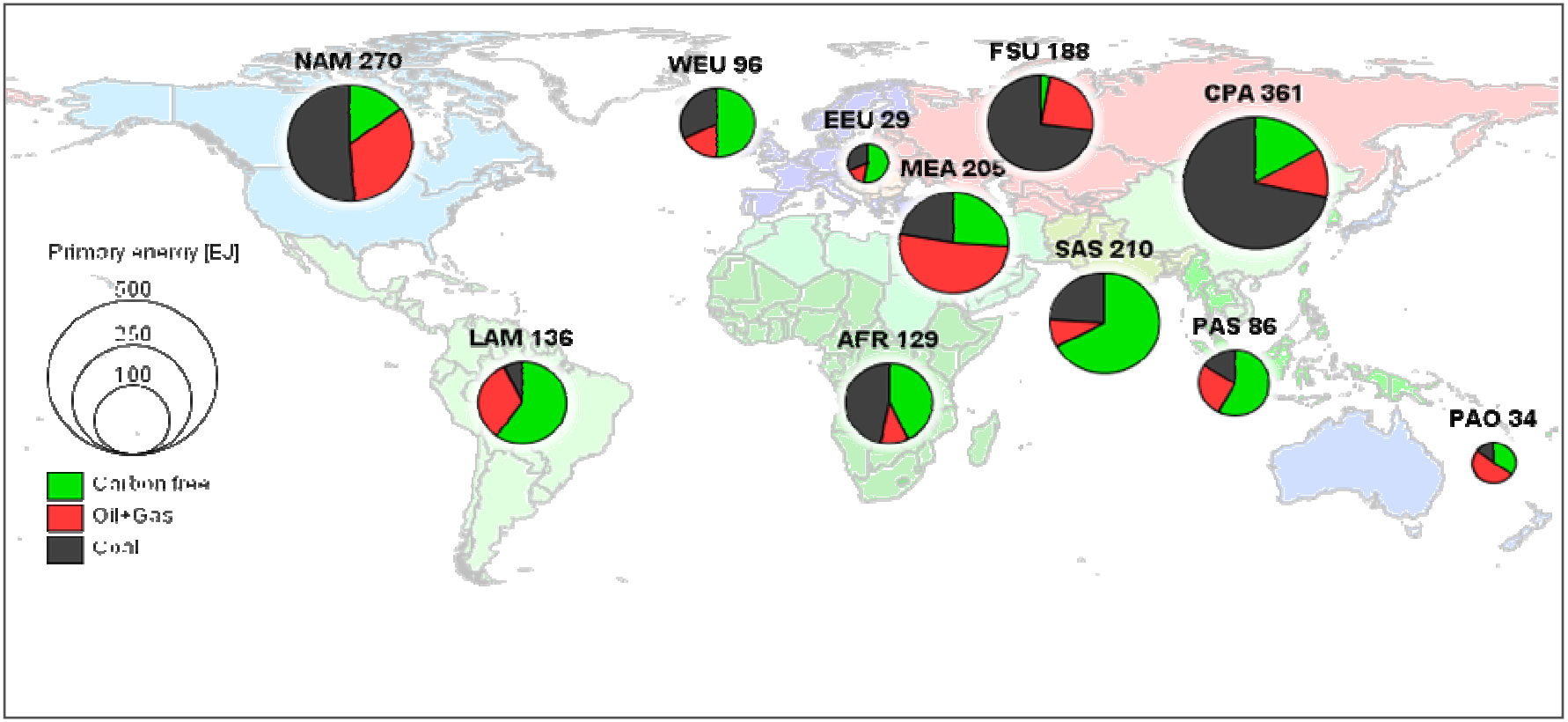
- Highest vulnerability in energy sector (prime climate policy target under increasing demand, incl. from CC)
- Long-term target: Zero emissions
- Large point sources (power plants): Early targets and risk of stranded investments (prepare for CCS or nuclear or “die”)
- Transformation constraint: End-use (lifestyles) and infrastructures (esp. in transportation)

“Conventional wisdom” scenarios are poor strategic guide for transition planning

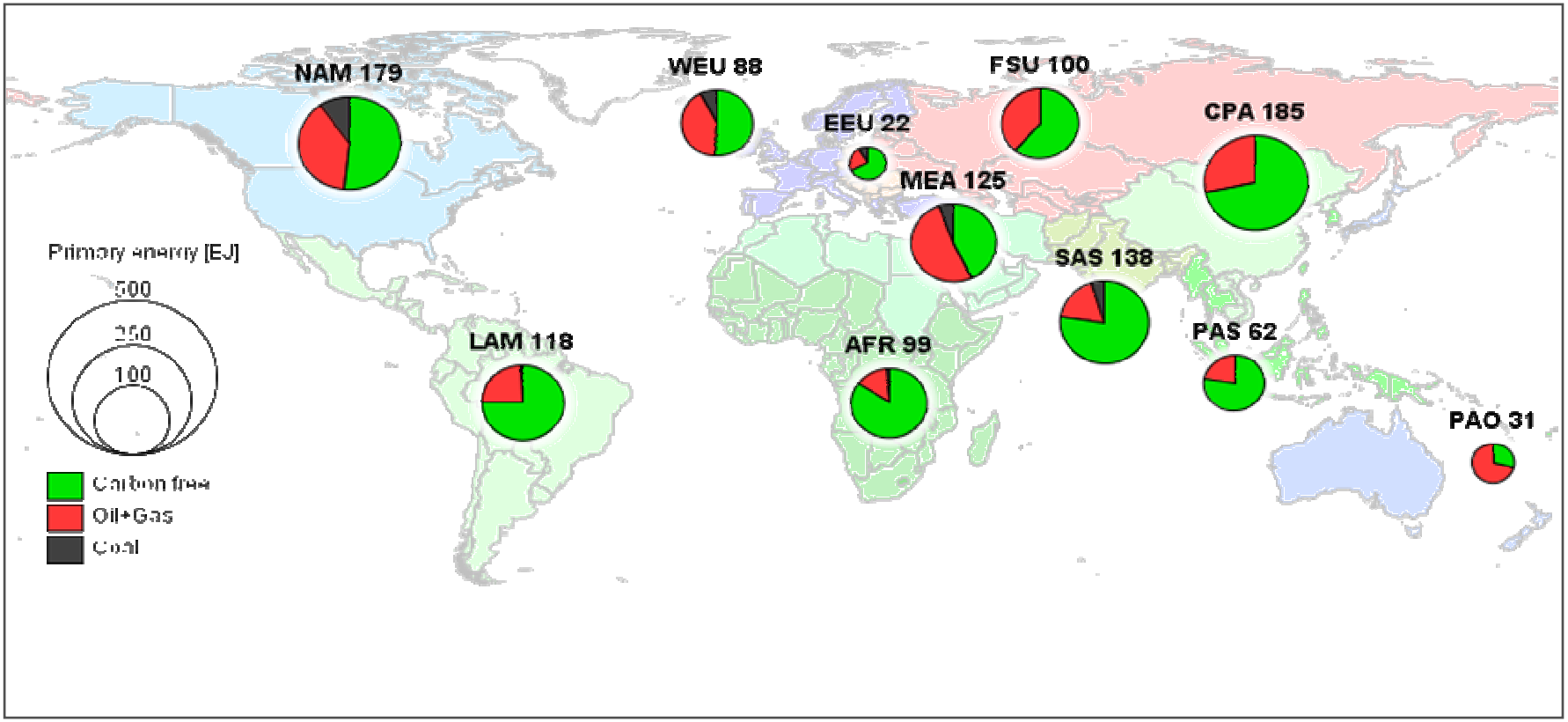
A2r - 2000


NAM 97
WEU 63
FSU 40
EEU 10
CPA 51
MEA 24
SAS 25
PAS 26
LAM 25
AFR 16
PAO 24
Primary energy [EJ]
500
250
100
Carbon free
Oil+Gas
Coal

A2r - 2100


NAM 270
WEU 96
FSU 188
CPA 361
EEU 29
MEA 205
SAS 210
LAM 136
AFR 129
PAS 86
PAO 34
Primary energy [EJ]
500
250
100
Carbon free
Oil+Gas
Coal

A2r - 2100 – 670 ppm stabilization



North -- South

- Responsibility: Mostly in Annex-I
- Vulnerability: Mostly in “South”

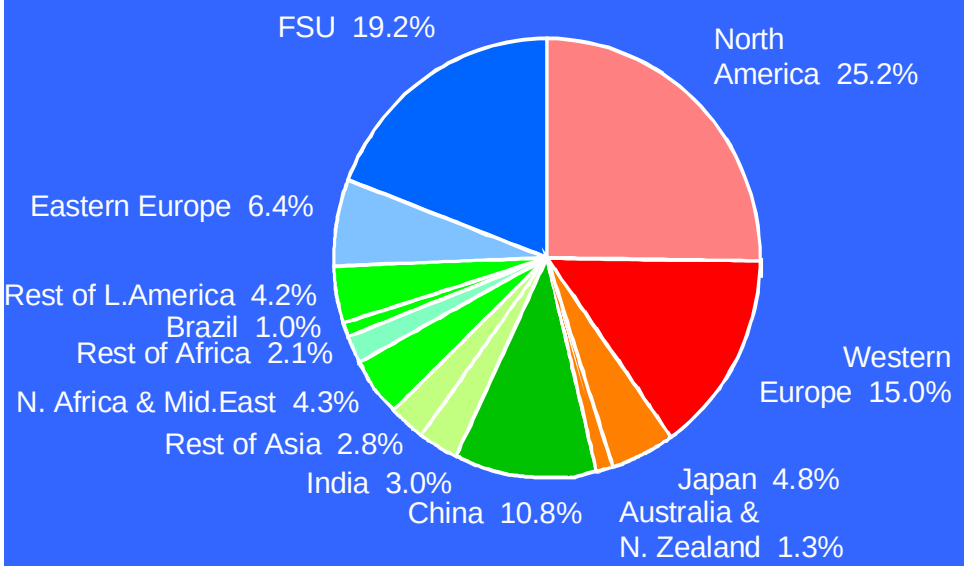
- Adaptation capacity: Mostly in Annex-I
- Future emission growth: Mostly in “South”

- Near-term mitigation potential: highest in Annex-I
- Near-term mitigation costs: lowest in “South”

Contribution to CO_2 Concentration Increase

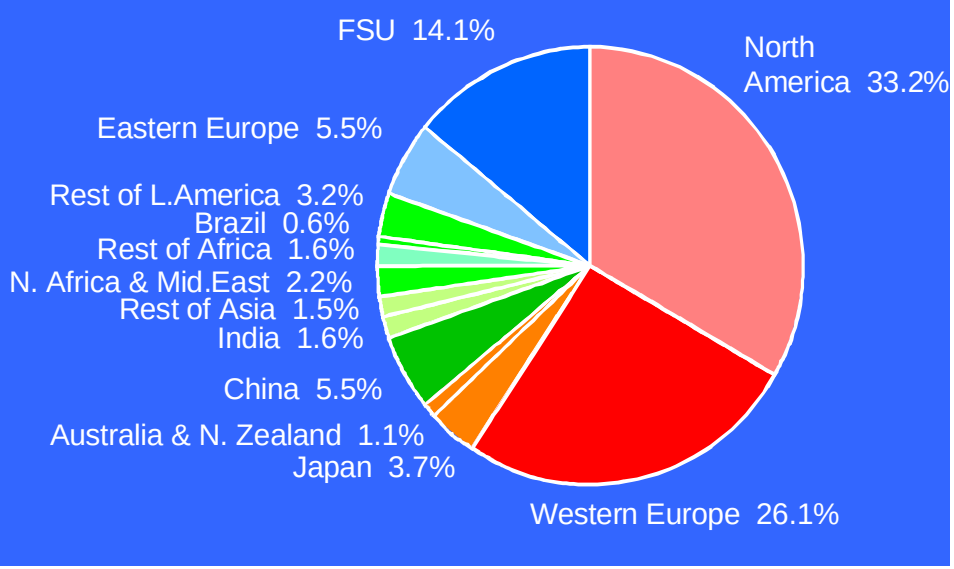
~1990

FCCC Annex I countries: 71.9%
Developing countries: 28.1%

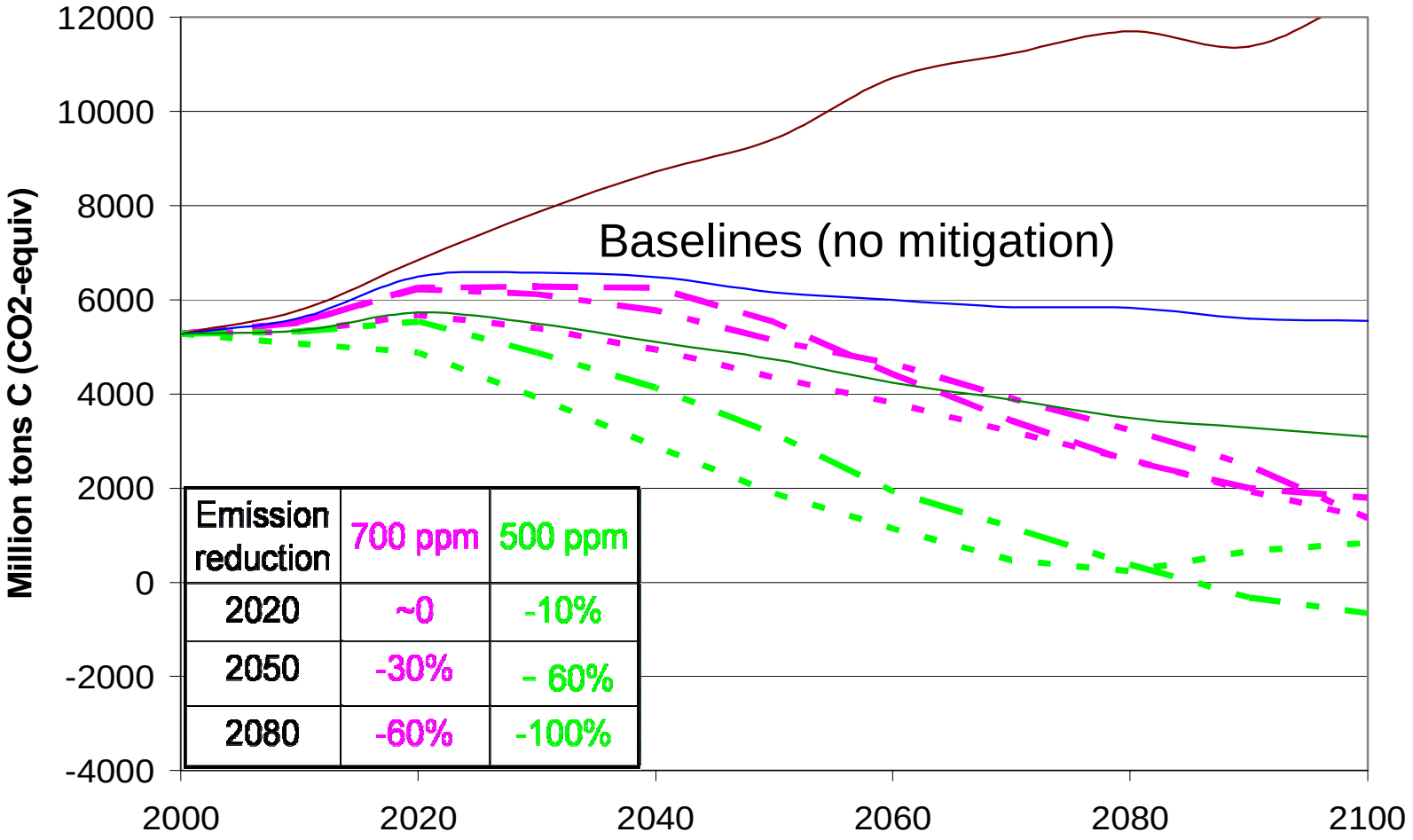


1800-1990

FCCC Annex I countries: 83.7%
Developing countries: 16.3%

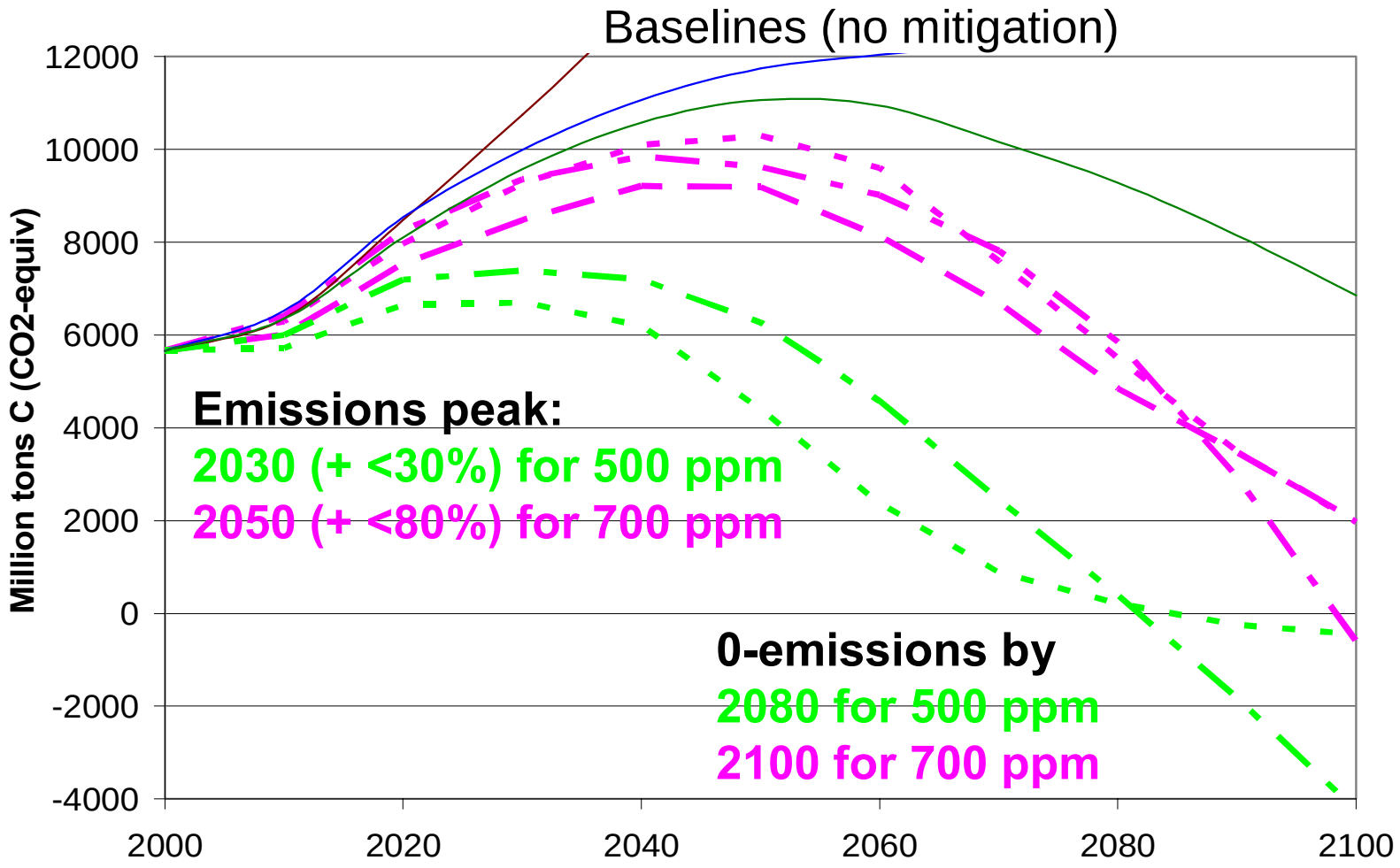


UNFCC Annex-I Emissions (all GHGs CO_2-equiv)



Climate stabilization: **700 ppm by 2100 (2.5°C)**
500 ppm by 2100 (<2°C)

Developing Countries (all GHGs CO_2-equiv)



Climate stabilization: 700 ppm by 2100 (2.5°C)
500 ppm by 2100 (<2°C)

Strategies for Addressing Climate Change

- Given pervasive uncertainty, adopt portfolio approach (mitigation+adaptation)
- Largest "silver bullet": Demand management
- Biggest challenge: Not in engineering but in political economy (consistency of long-term incentives/signals)
- Largest "shifts" required: less technological, but in OECD innovation environment (reverse declining R&D, investments, short-term market myopia) and integration of developing countries

Σ: Modeling can help in identifying optimal technology hedging portfolios but cannot help in solving the incentive/innovation environment problem