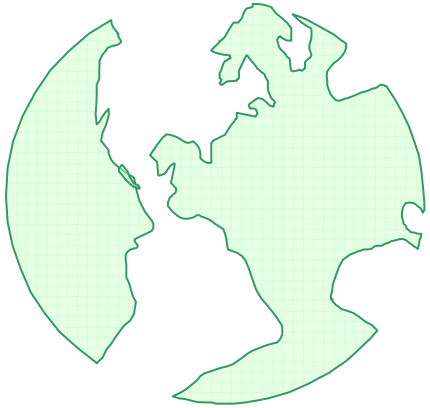
The Climate Change Risk Assessment Framework: Integrating Impacts into Modeling



Presented

By

Jane Leggett, US EPA

Overview of Presentation

- Purposes in building CCRAF, what makes it different
- Overview of modules
- Illustrative results
- Priorities for Improvements

CCRAF's Principal Objectives

- Integrated Assessment
  - IPCC TAR: "*Policymakers require a coherent synthesis of all aspects of climate change*"
  - Interactions and feedbacks among processes are important to results
- Probabilistic Treatment of Uncertainty
  - Includes uncertainty in decision paradigm
- Transparency and accessibility

a1

Warnings!

- The Climate Change Risk Assessment Framework (CCRAF) will serve some specific analytic functions – but NOT ALL!
- CCRAF is global and generalized – results will be more reliable at high scales of aggregation
- CCRAF is incomplete and includes many but not all uncertainties.
- Like all models, CCRAF is illustrative and an aid to thinking about a complex problem – *it does not provide "answers"*

Slide 4

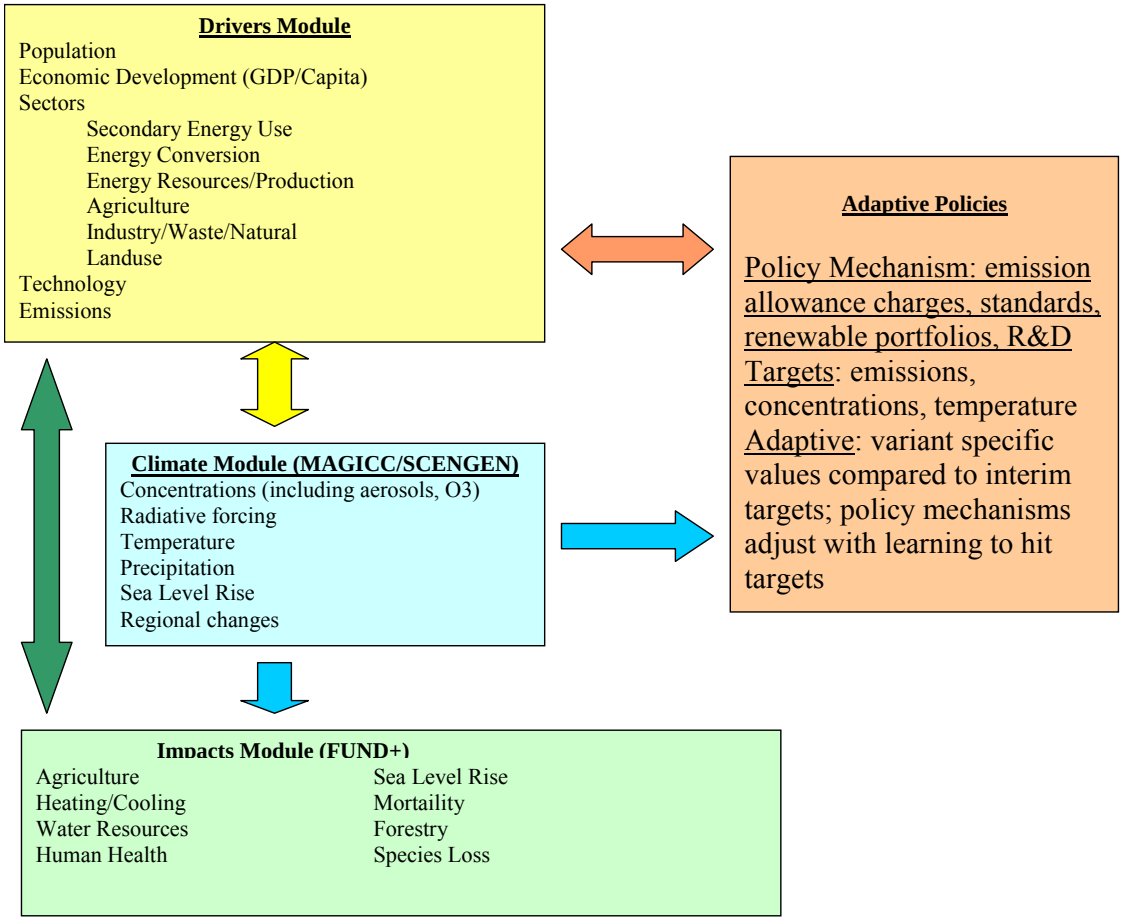
a1 Also stress that CCRAF is still being tested and we are still finding errors -- mostly minor. However, these results must be taken as preliminary -- not to be quoted or cited.

admin, 2/24/2004

CCRAF: General Features

- Autoregressive, dynamic
- 15 regions: USA, Canada, Europe, FSU-Europe (Russia, Ukraine, Belorus, Moldavia), Central Asia and Caucasus (includes Pakistan, Afganistan, and Mongolia), Middle East, China, Japan, India, South-East Asia, Australia and New Zealand, Africa, Brazil, **Mexico**, Rest of Latin America
- Annual time steps, 1990 to 2100+
- Fully Integrated
- Stochastic

CCRAF Integrates Major Processes



Socio-Economic Drivers of Emissions

Drivers Module

Population
Economic Development as GDP/capita

Energy
Agriculture
Industry
Land-Use
Waste

Emissions

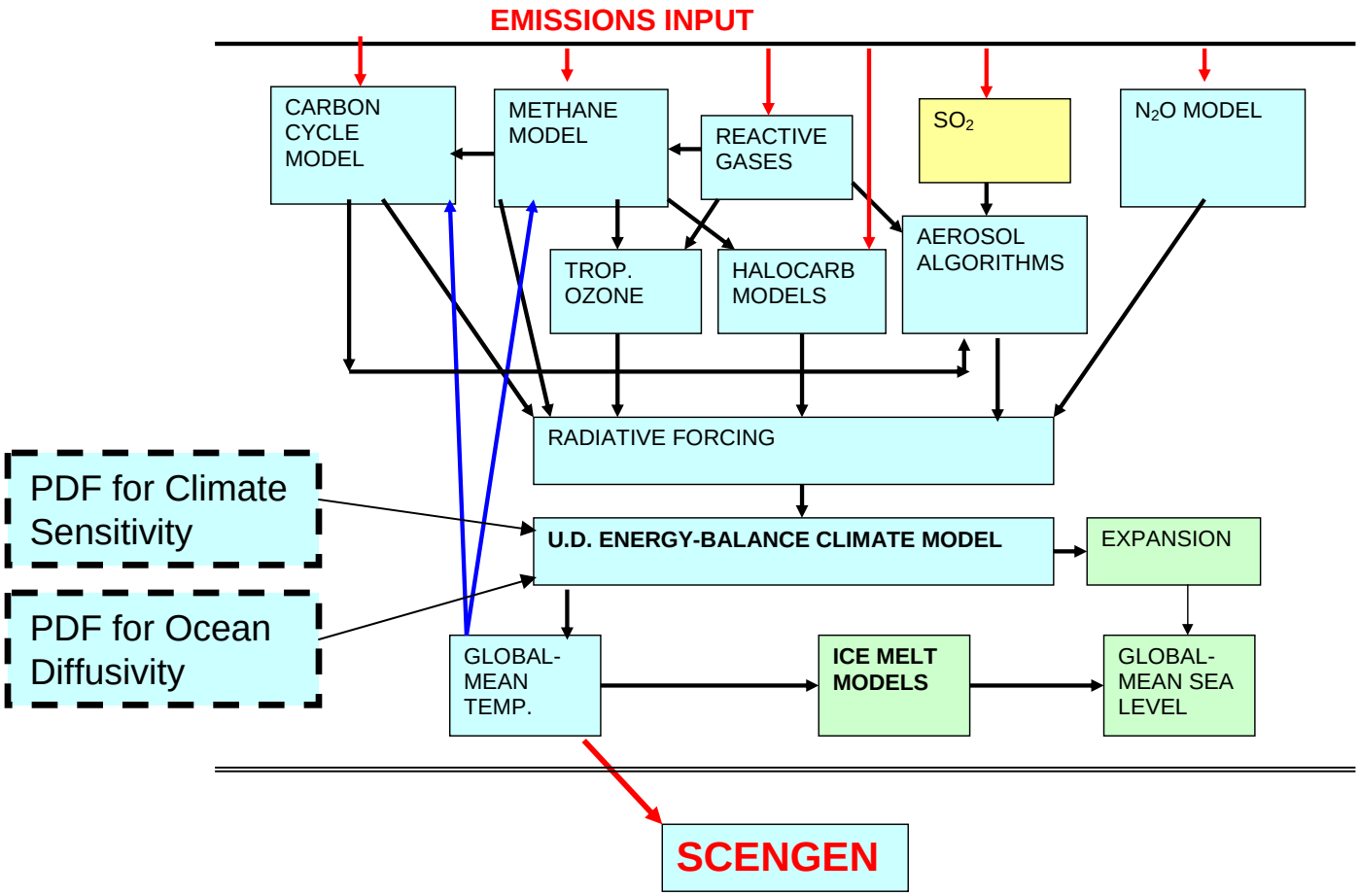
Emissions Estimation

- Emissions
  - CO_2, CH_4, N_2O
  - CO, NO_x, SO_2, NMVOC
  - C_2F_6, CF_4, PFC/PFPE, SF_6
  - HFC-125, HFC-134a, HFC-143a, HFC-152a, HFC-227ea, HFC-23, HFC-236fa, HFC-245ca, HFC-32, HFC-4310mee
  - In coming months: BC and OC
- Emission Sources
  - Adipic Acid, Atmospheric Deposition, Burning of Agricultural Waste, Cement Production, Coal Production, Waste Water, Enteric Fermentation Cattle, Enteric Fermentation Dairy, Enteric Fermentation Other, Enteric Fermentation Swine, Fertilizer, Gas Production, Industrial Waste Water, Iron & Steel, Landfills, Land use Change, Manure Management, Nitric Acid, Oil Production, Post Burning Effects, Residential Biomass, Rice Cult, Savanna Burning, Vegetation Fires, Waste Incineration

Climate Module

- Begins with Wigley and Raper's MAGICC
  - used in IPCC TAR
  - couples gas cycle, climate, and ice-melt and Sea Level Rise (SLR)
- calculates changes in:
  - GHG, aerosol and tropospheric O_3 concentrations;
  - radiative forcing (gas by gas);
  - global mean temperature;
  - sea level rise
- SCENGEN allocates dGMT to 5° X 5° patterns of temperature and precipitation change
- Includes two additional random variables
  - Vertical diffusion
  - Climate sensitivity

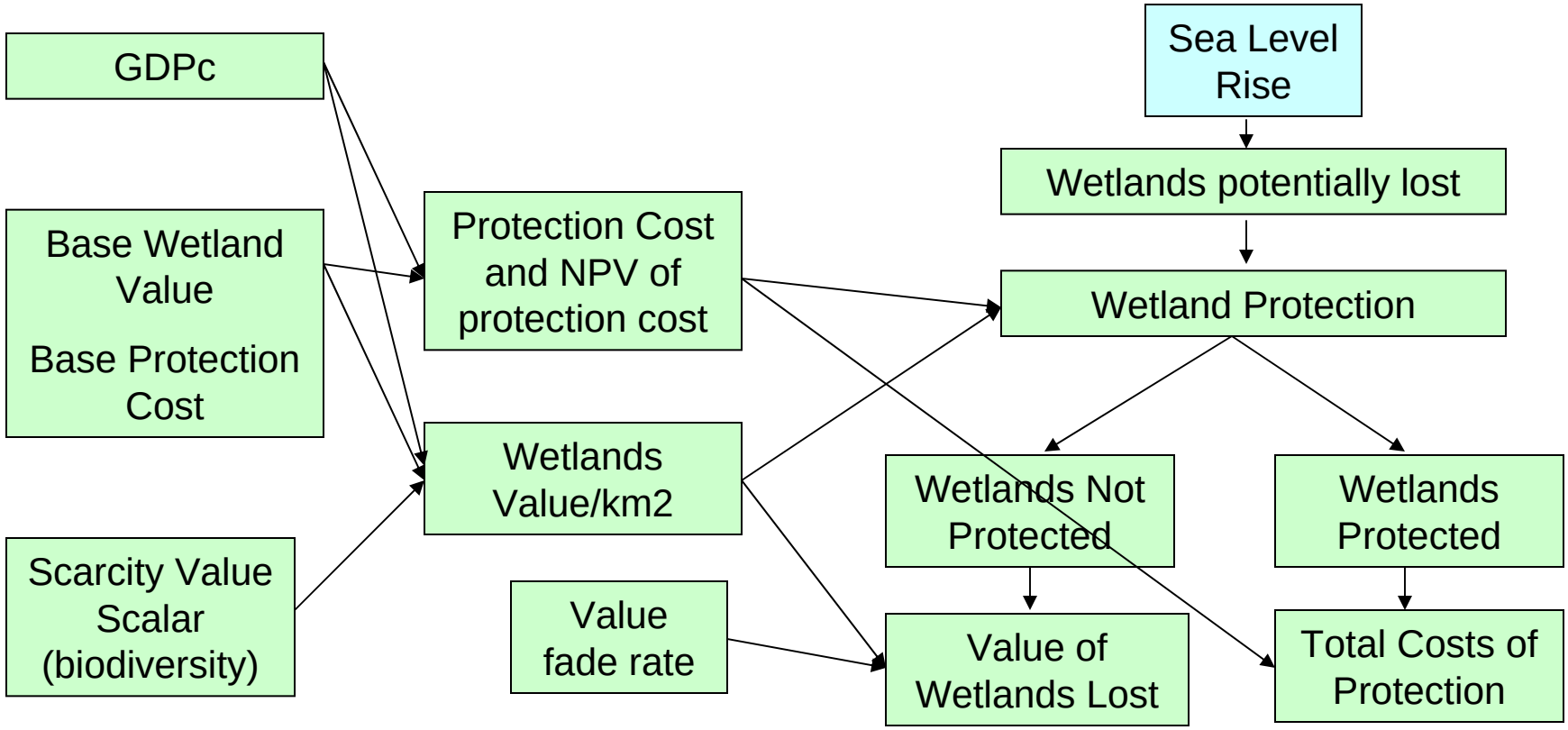
Climate Module: From MAGICC



Impacts Module

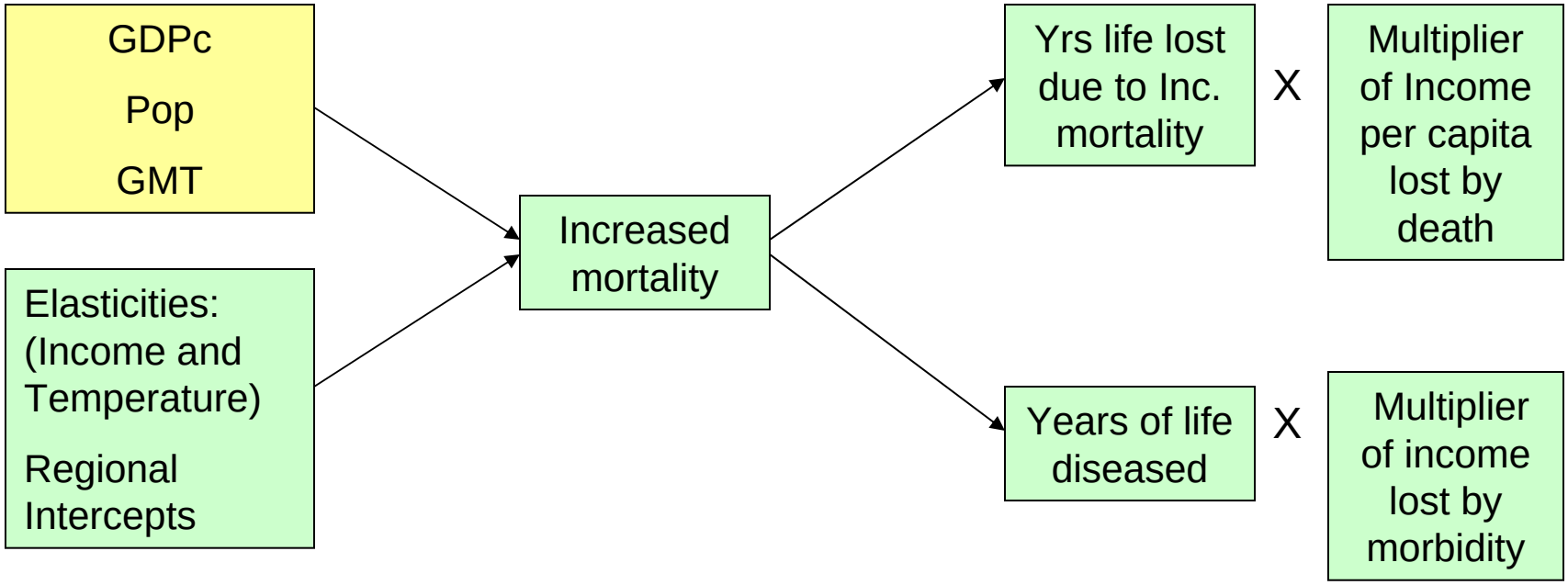
- Economic costs from
  - Water systems
  - Forestry
  - Heating and cooling
  - Agriculture
  - Loss of dry lands
  - Migration costs (immigration)
  - Coastal protection
- Other losses including
  - Cost of mortality
  - Morbidity costs
  - Loss of wetlands
  - Migration costs (leaving)

Impacts Module: Loss of Wetlands and Protection Costs due to SLR



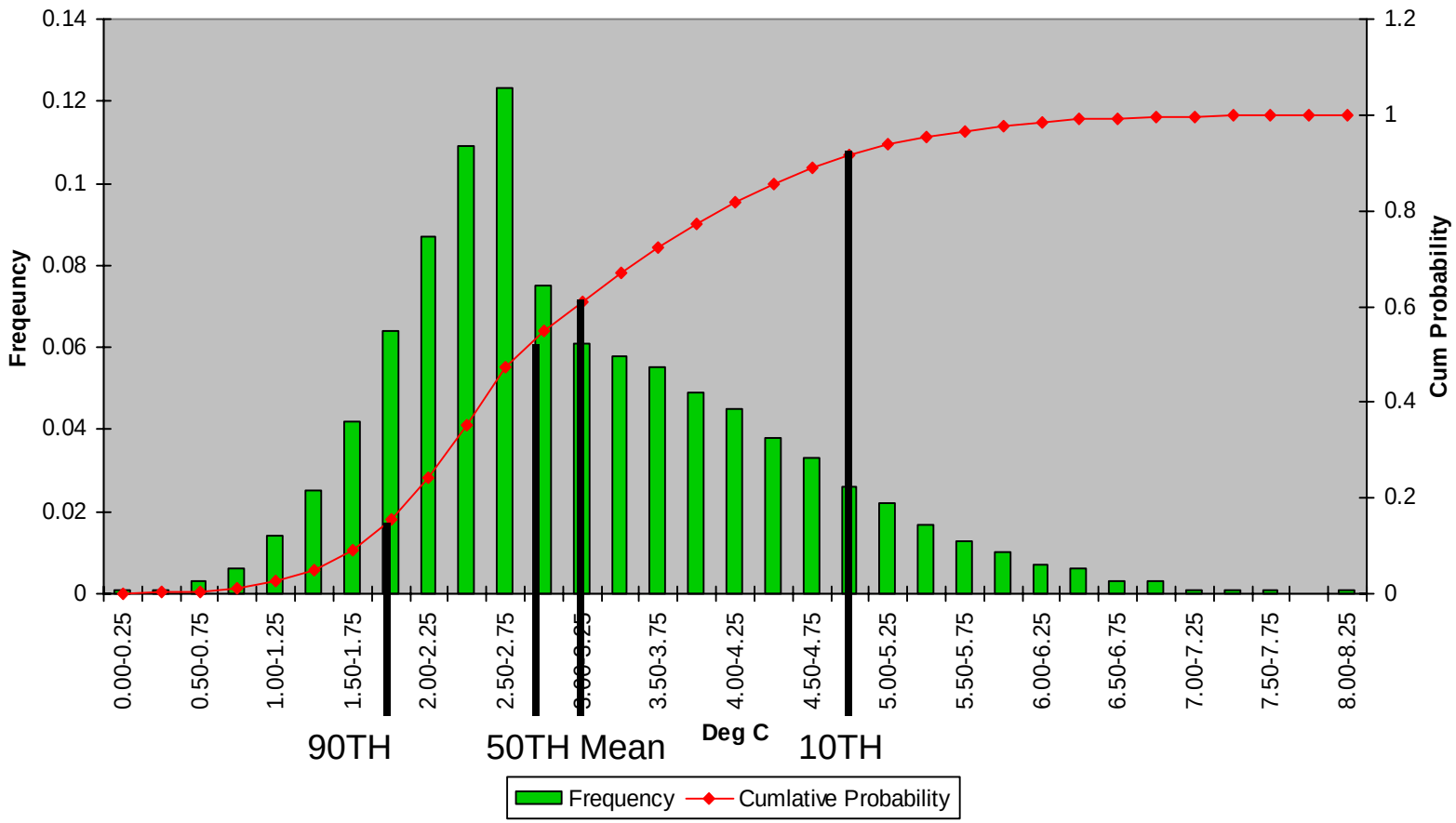
From Tol's FUND v2.2, data sources: Hoozemans et al. (1993), Bijlsma et al. (1995), Nicholls and Leatherman (1995a,b), Bijlsma et al. (1996). The OECD average of wetland value was set at 5 million $/km2, following Fankhauser (1994c).

Impacts Module: Costs Due to Malaria (and Other Diseases)

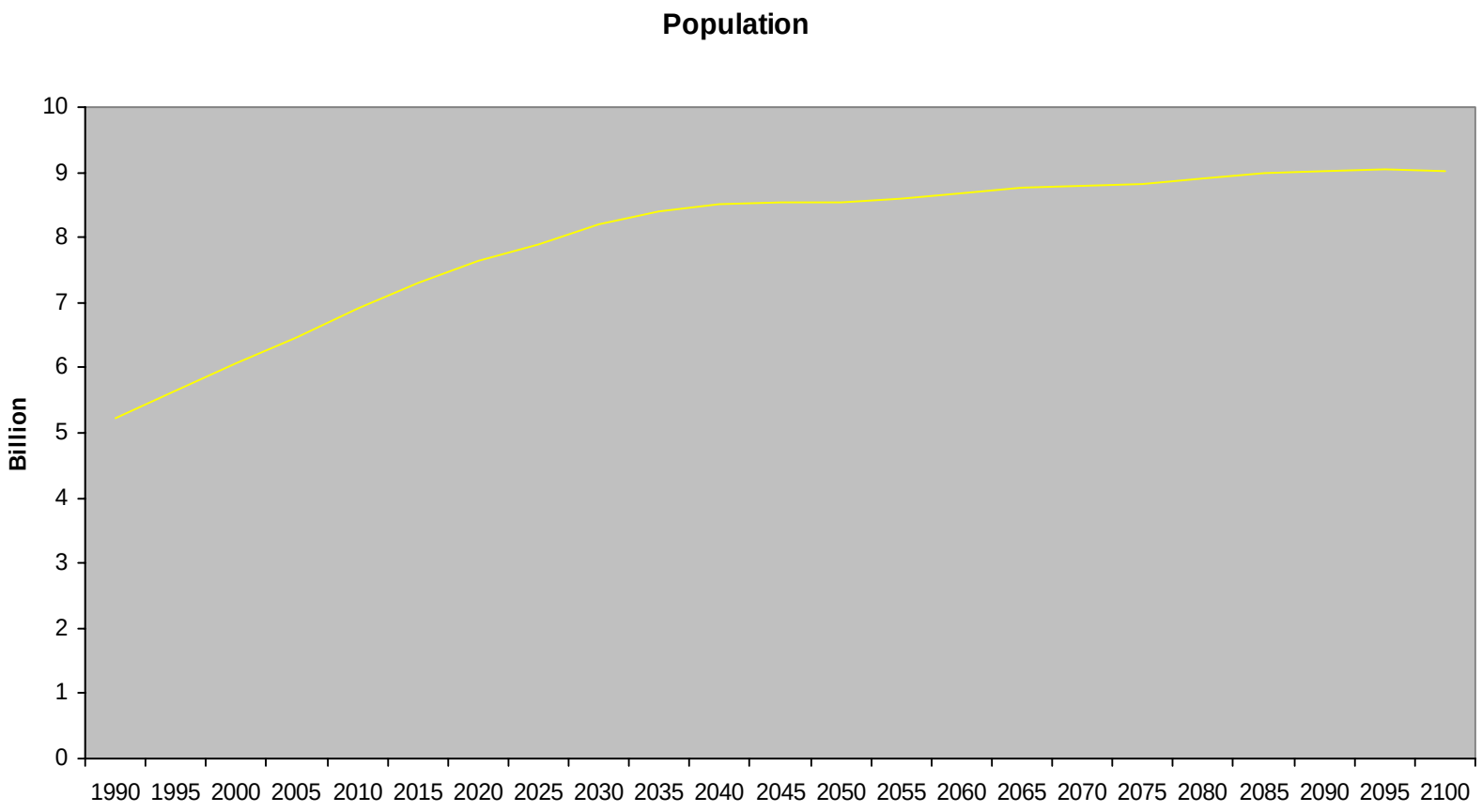


Formulation from Tol's FUND v2.2, based on Martin and Lefebvre (1995); Martens et al. (1995, 1997; cf. Martens, 1997); Morita et al. (1995); and Murray and Lopez (1996)

PDF for Climate Sensitivity



Monte Carlo Method Generates Systematic Assessment of Uncertainty



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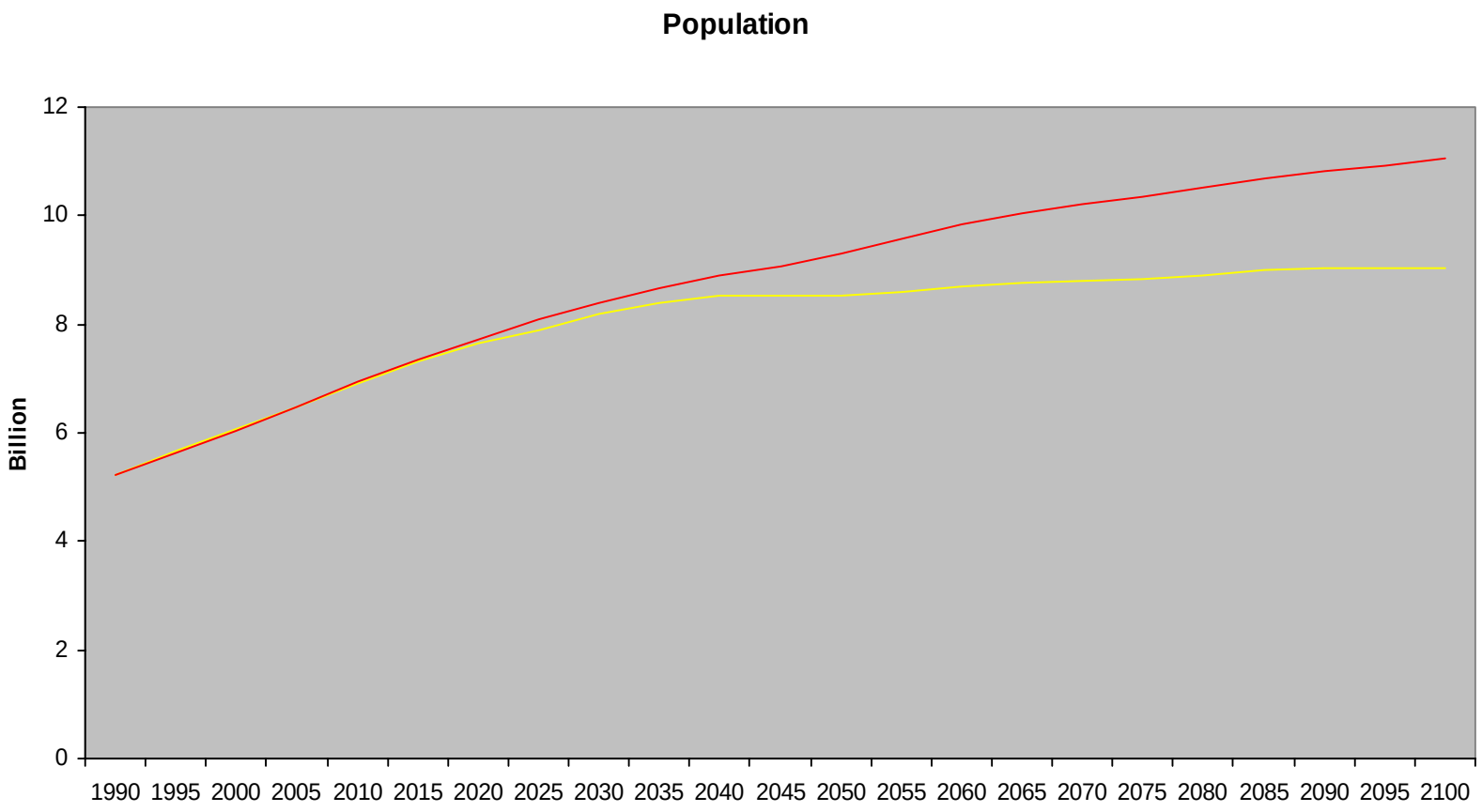

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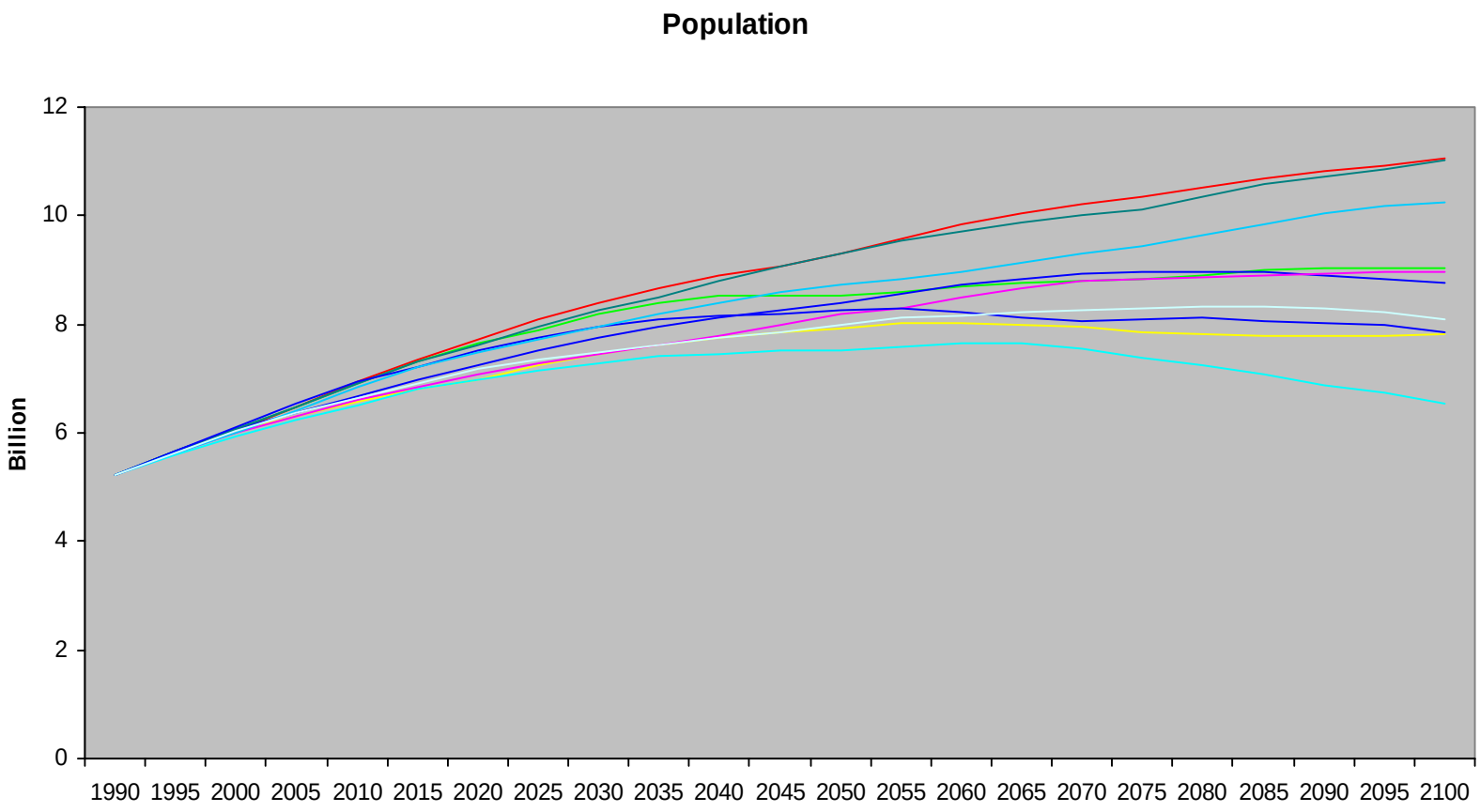

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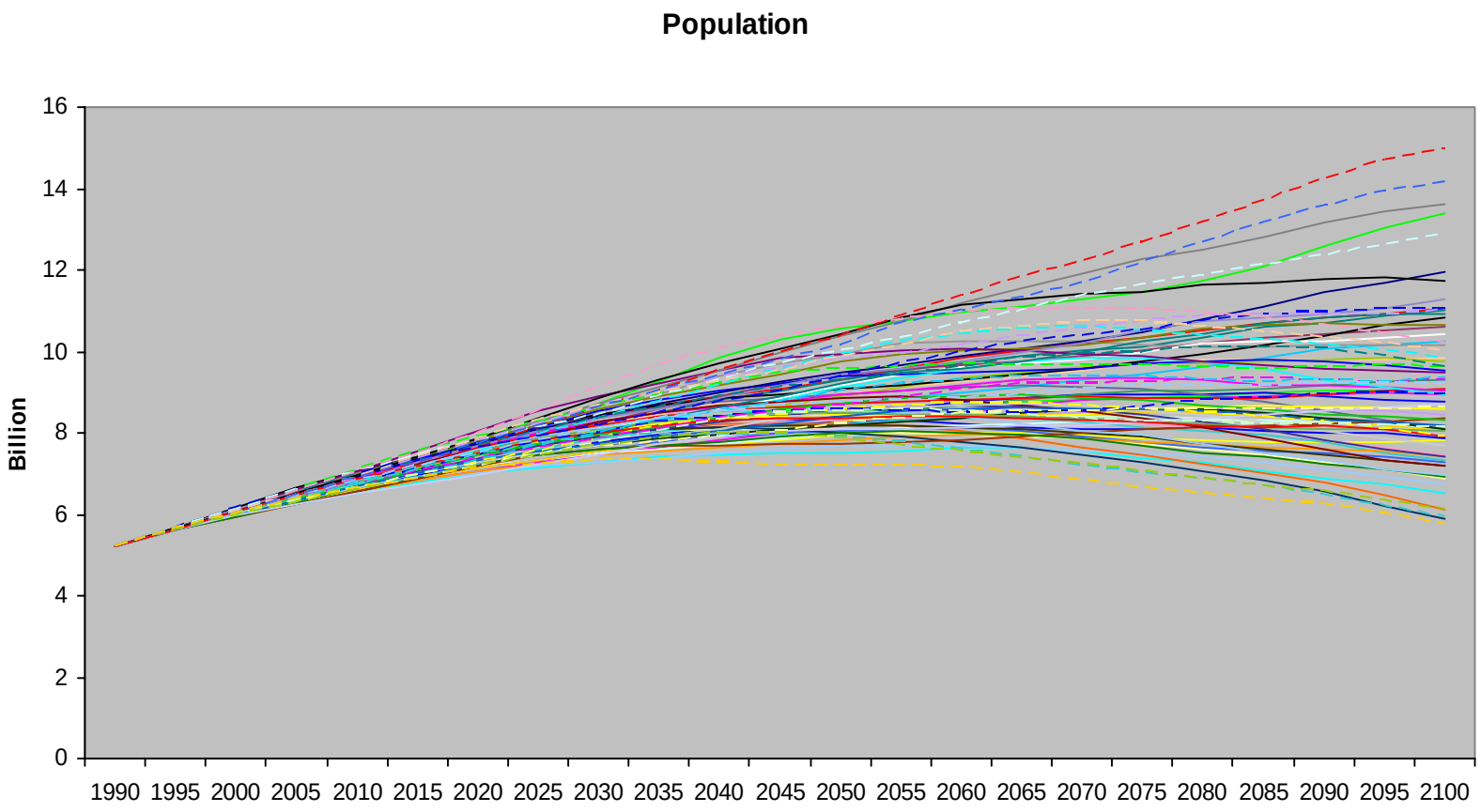

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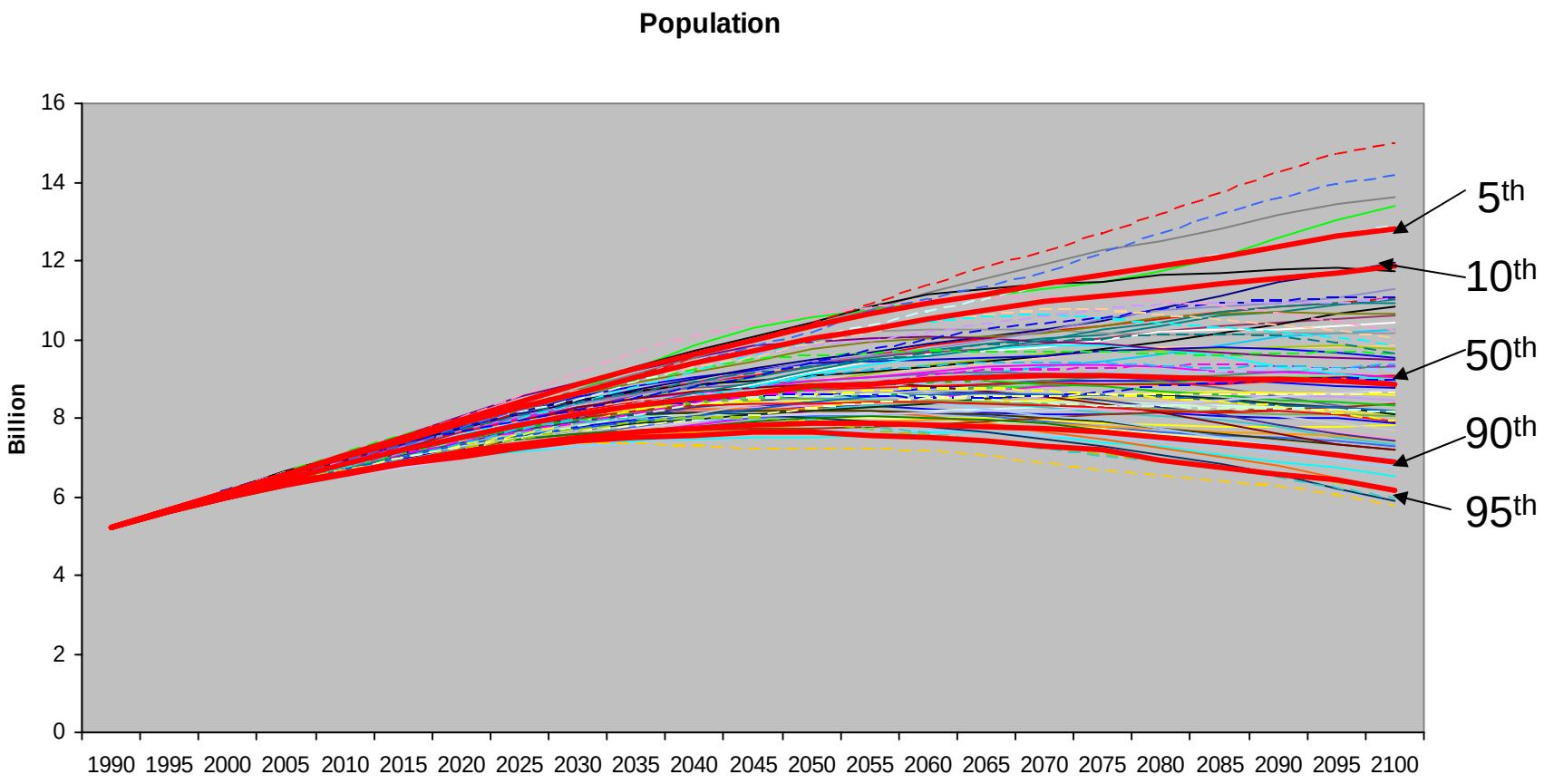
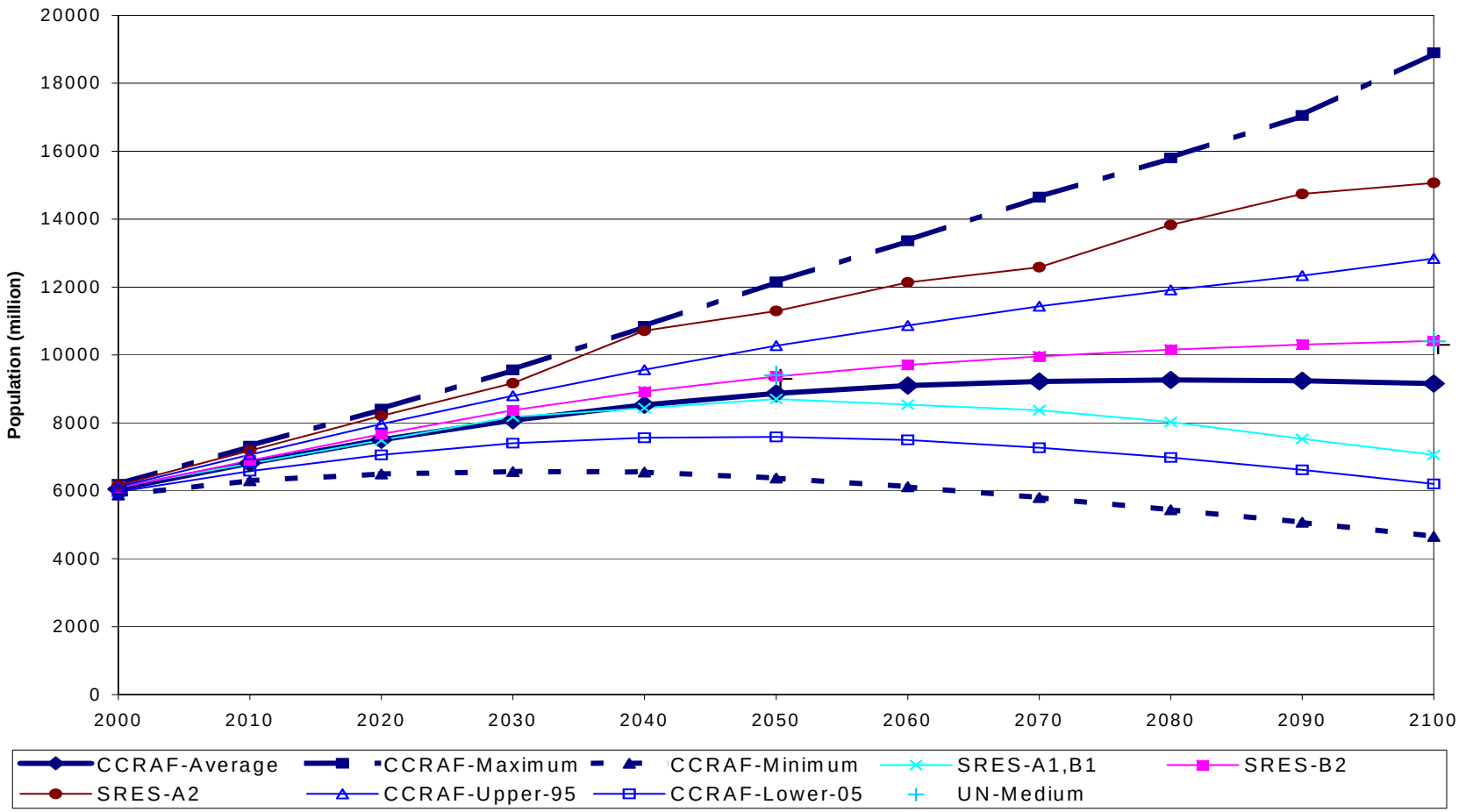


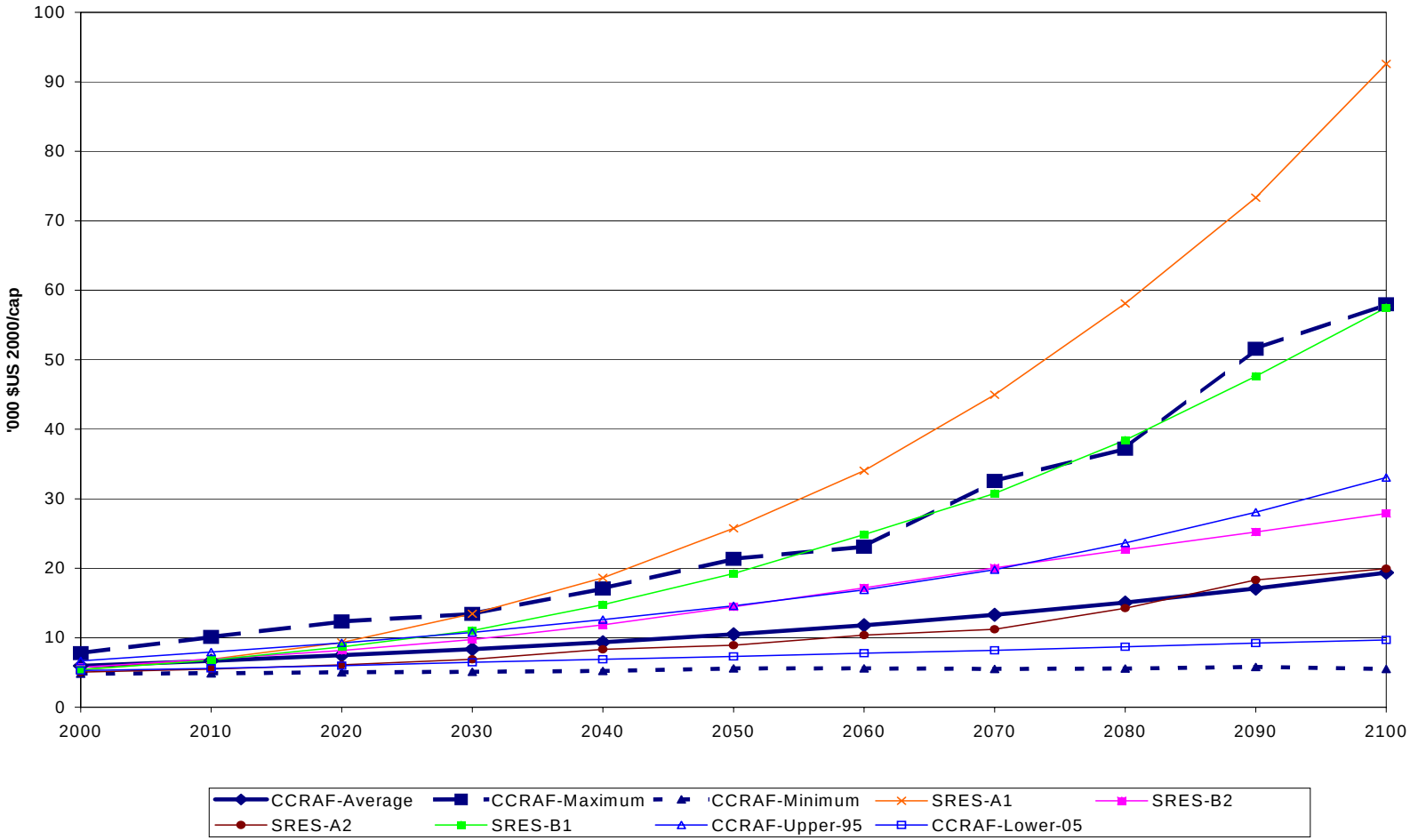
Policy Mechanisms

- "Adaptive" policies
  - Targets can be for GHG emissions, concentrations, GMT (to be added), perceived climate sensitivity, and possibly incurred impacts
  - In a simulation, policies may be revised in each "decision period" based on evolving information
- Types of Policies
  - Emissions allowance charges
  - Increased R&D (to be added)
  - Efficiency Standards (to be added)
  - Renewable portfolio requirements (to be added)
- Other Factors
  - International emissions trading possible (by country groups)
  - Afforestation, reforestation, biofuels (to be added as response options)
  - Different targets for different regions possible (for emissions only)
  - Targets can be proportional to economic or population growth

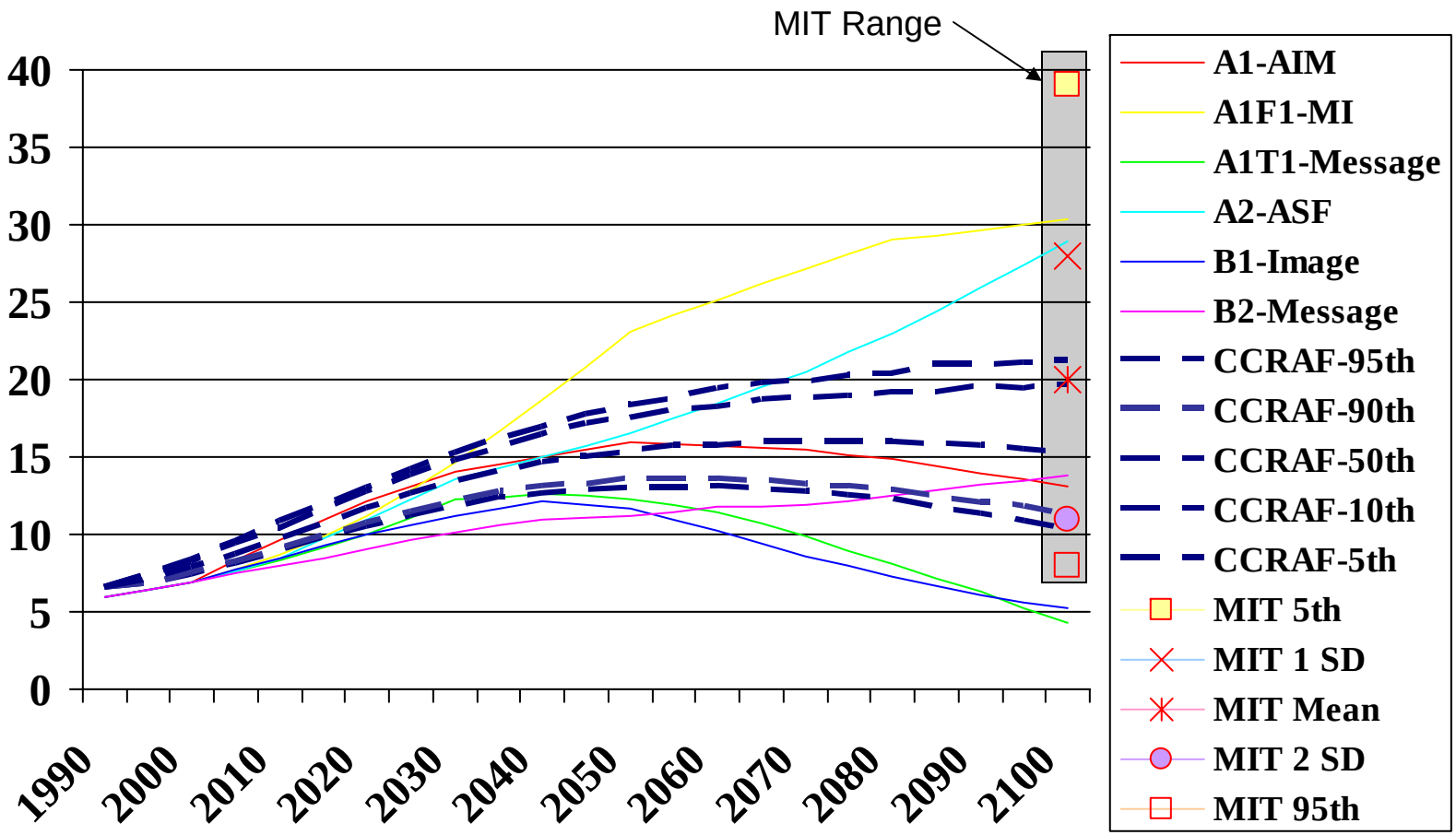
Population: CCRAF compared to SRES



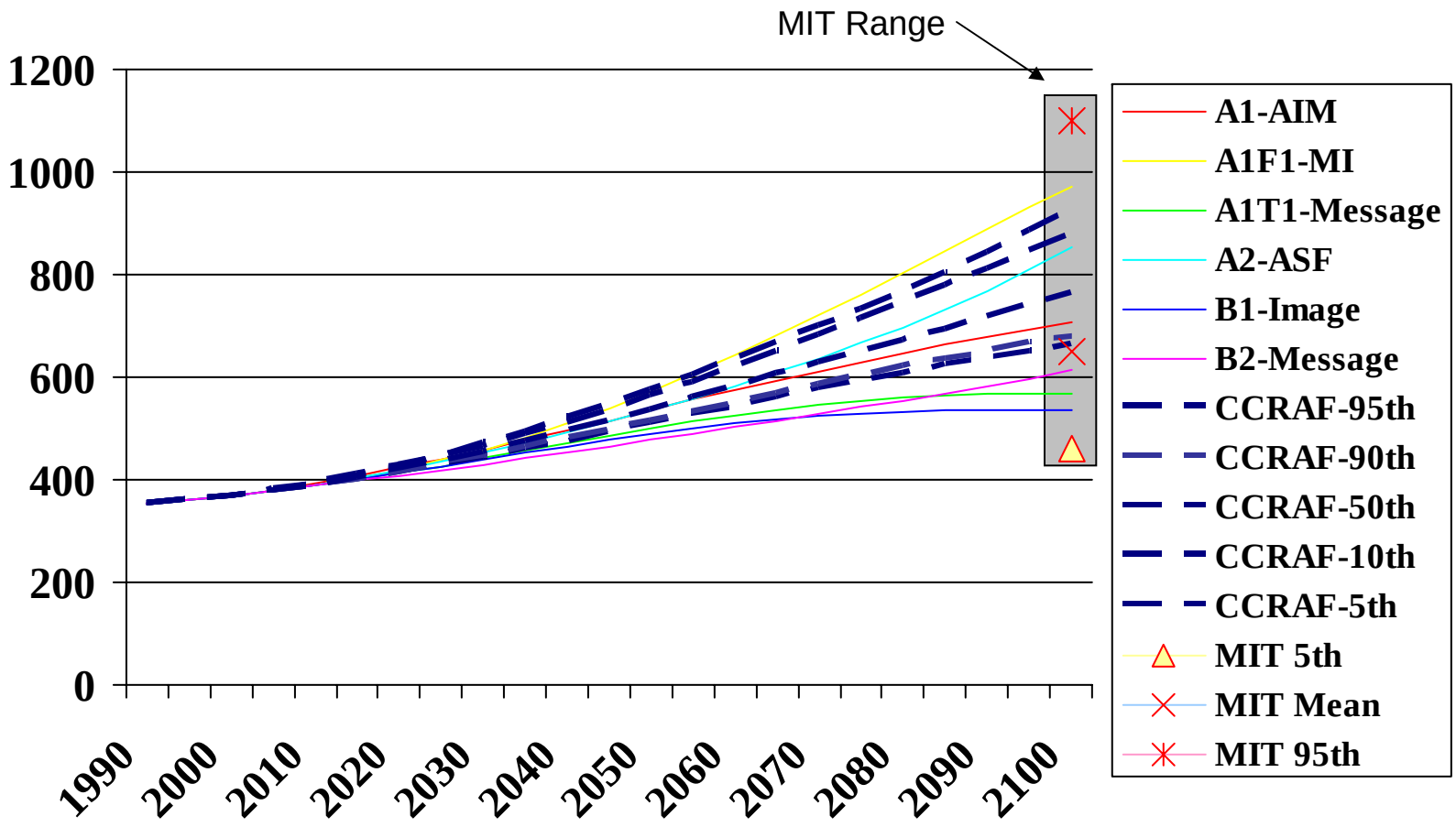
GDP per Capita: CCRAF compared to SRES



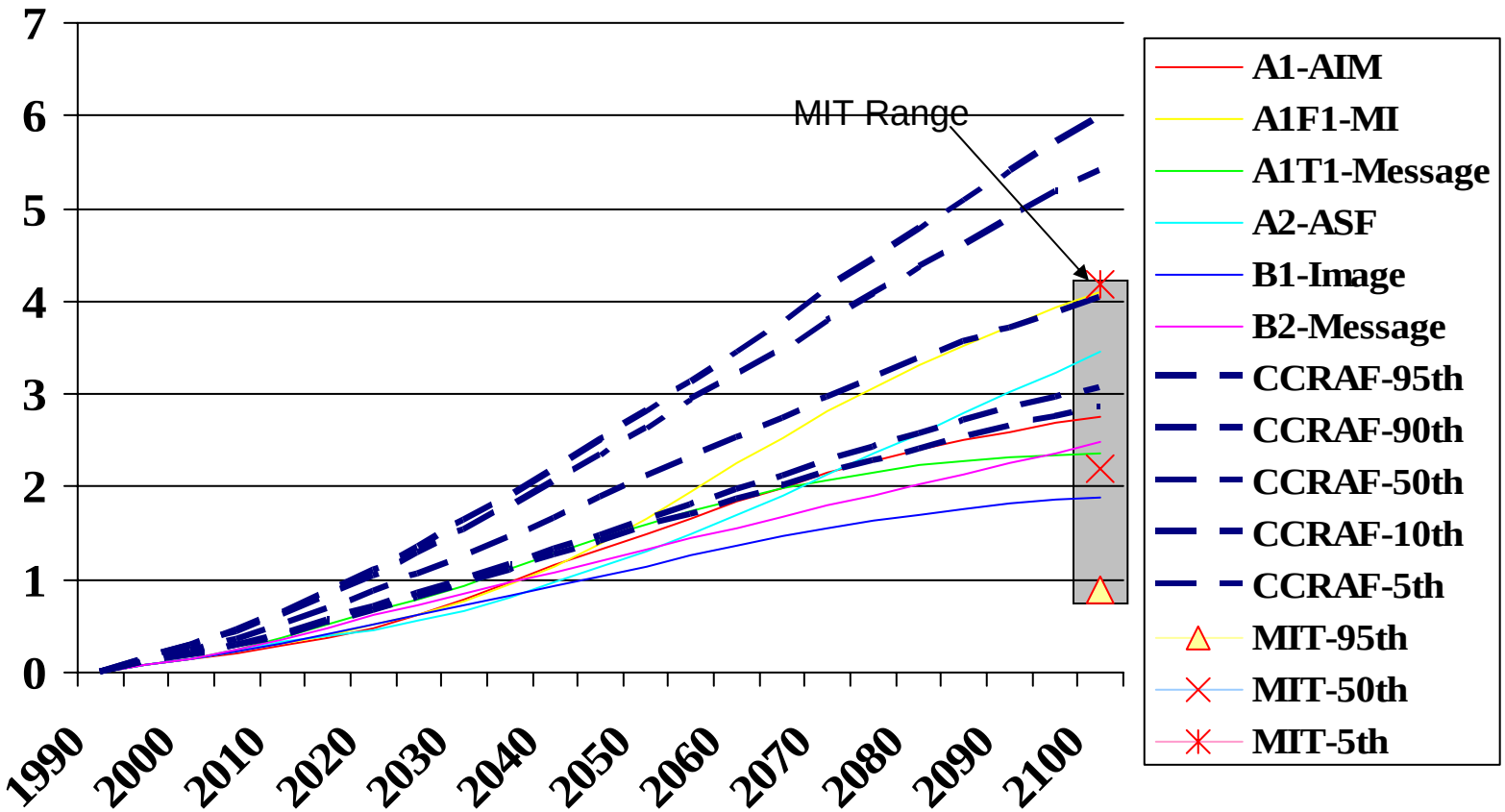
How do the CCRAF CO_2 emissions compare to SRES and MIT emission scenarios?



How do the CCRAF CO_2 concentrations compare to TAR and MIT concentrations?

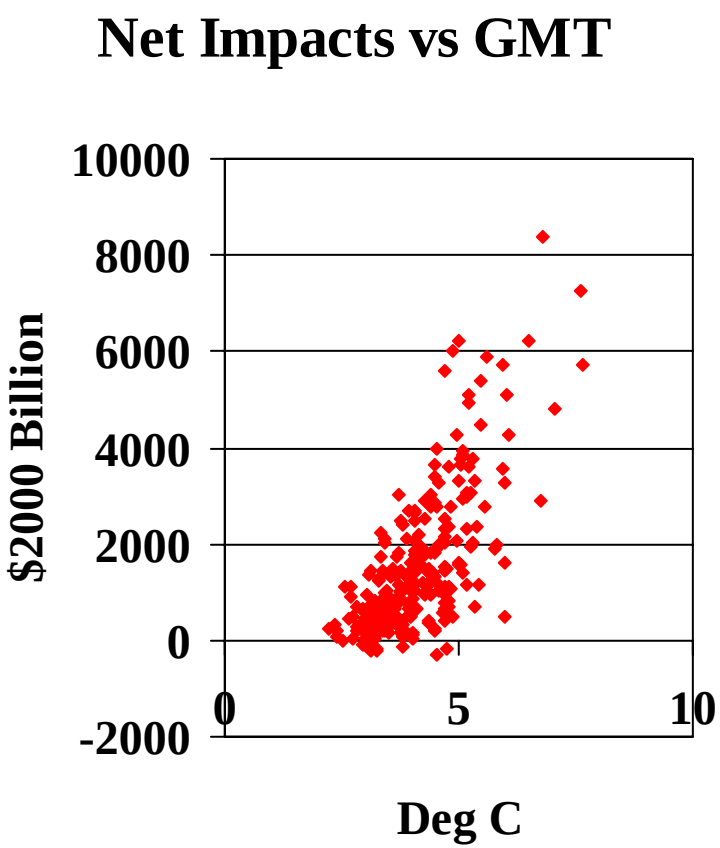


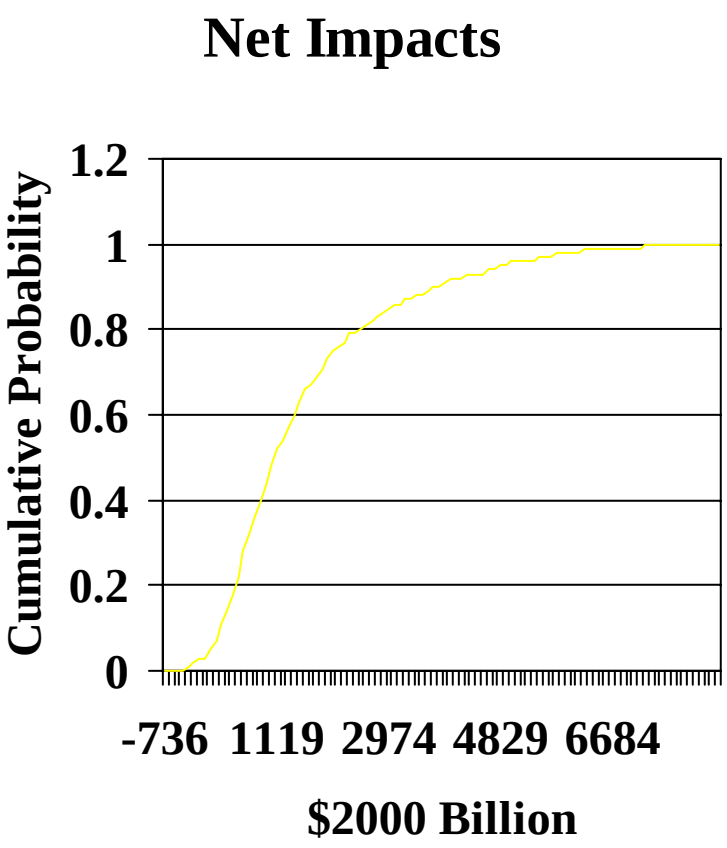
How do the CCRAF GMT compare to TAR* and MIT GMT?



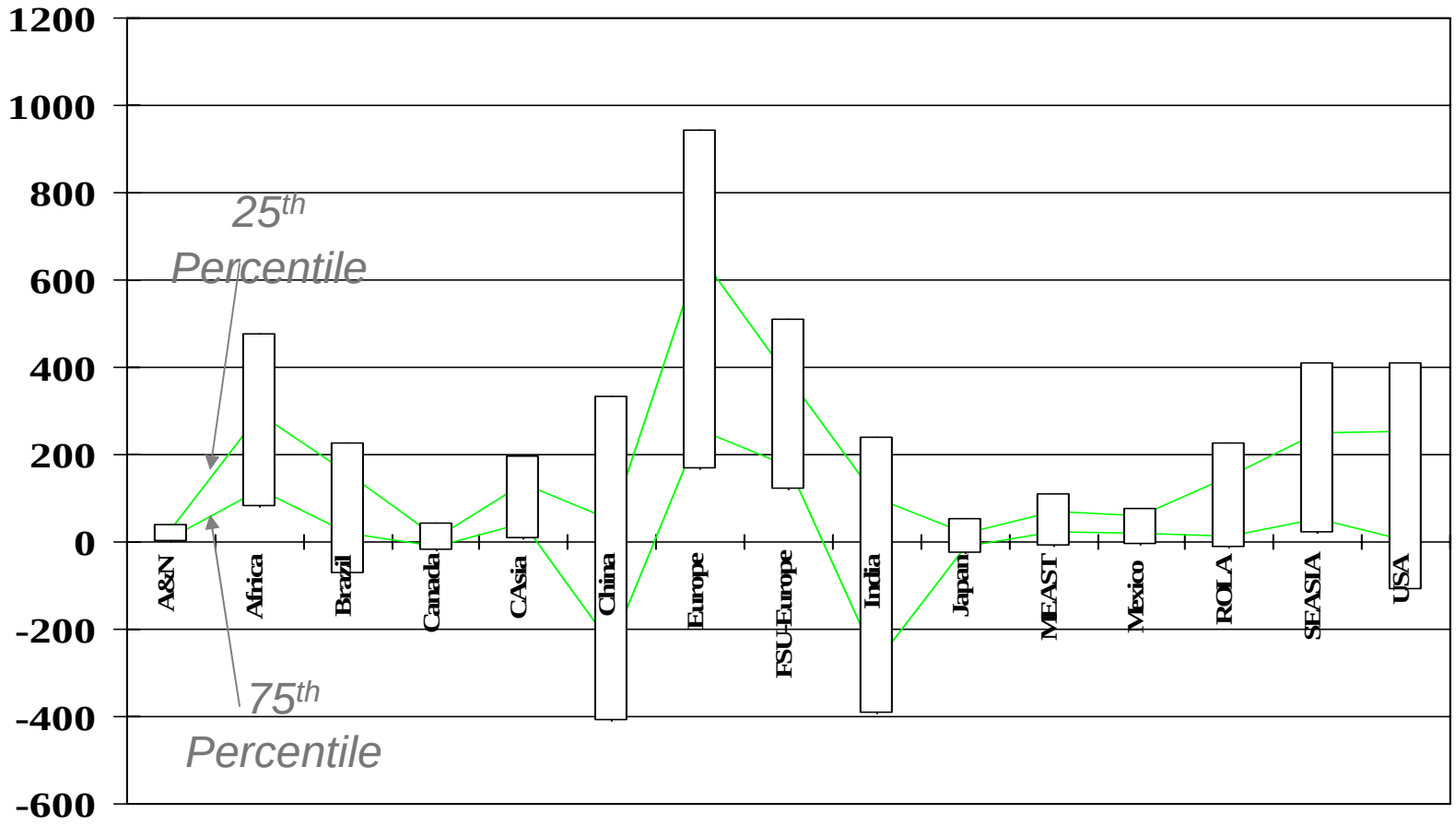
*TAR Estimates based on a single value of 2.6 deg C climate sensitivity only, while CCRAF results reflect probability density function of climate sensitivity

Illustrative Results:
How are impacts related to GMT?





Illustrative Results:
How similarly are regions impacted?



Illustrative Results for Mexico:

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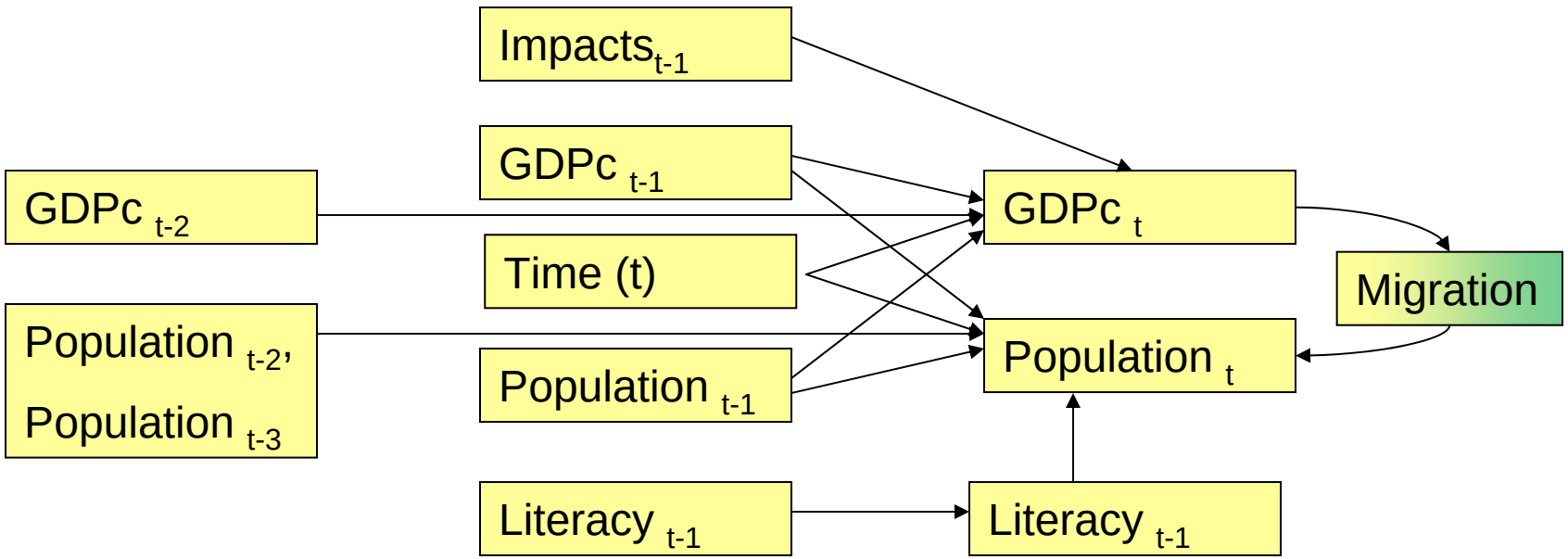
Priorities for Further Improvement

- Address some areas of concern
  - Continue to refine agricultural impacts
  - Re-evaluate water resource impacts and consider interactions with agriculture
  - Include more non-market impacts, e.g. coral reefs
- Finalize draft documentation
- Peer review

Extra Slides Follow

- For reference only: not for translation or presentation

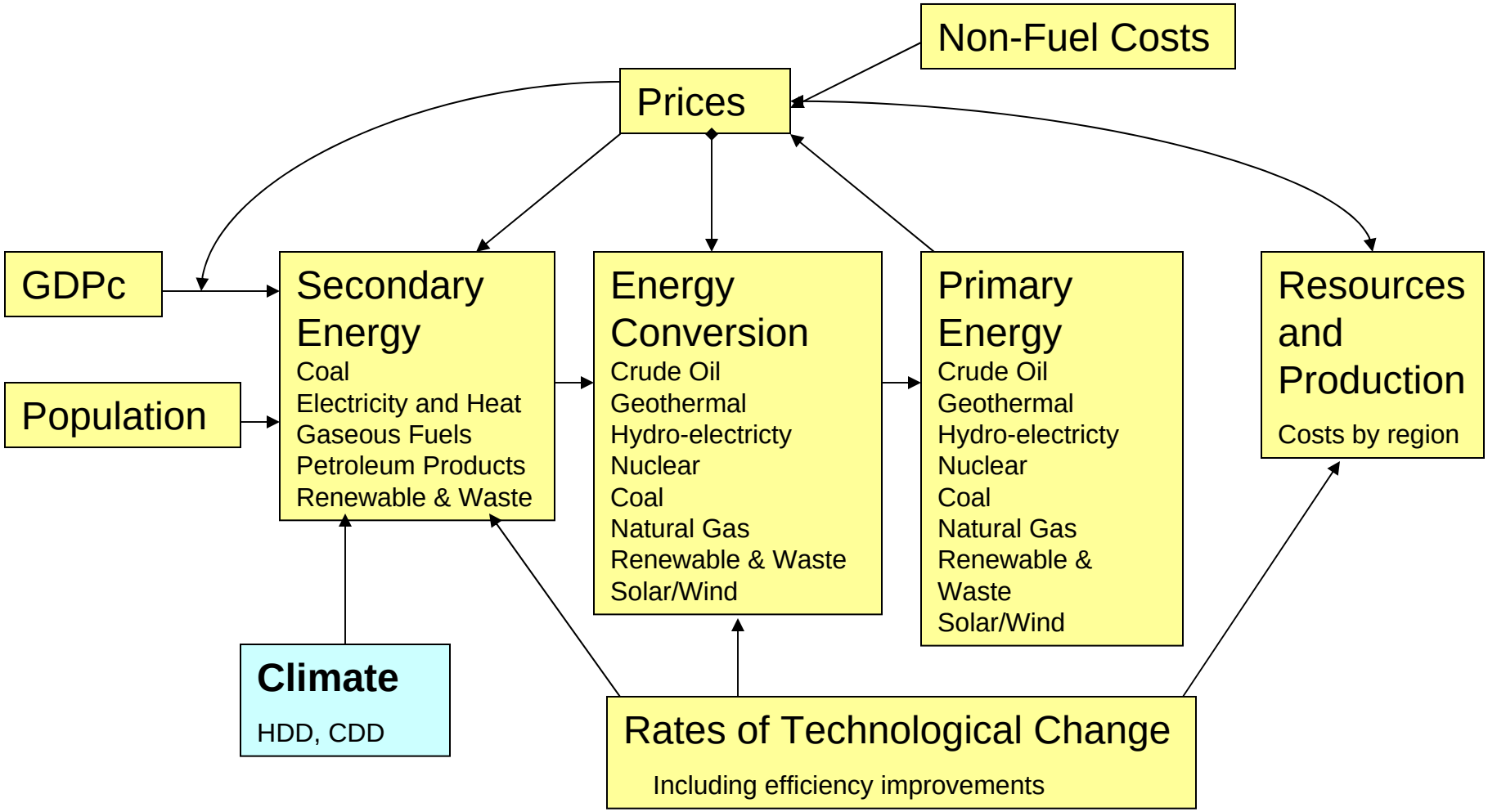
Population and GDPc Formulation: Endogenized



Population and GDPc Formulation: Formulas

- $dP(t) = e^{a1} * dP(t-1)^{b1} * dP(t-2)^{c1} * Lit(t)^{d1} * GDPc(t-1)^{e1} * e^{(f1 * (1/(t-T))}$
- $GDPc(t) = e^{a2} * GDPc(t-1)^{b2} * dGDPc(t-1)^{c2} * dP(t)^{d2} * e^{((f2 * 1/(t – T))}$

Energy Sector – A Partial Equilibrium Formulation



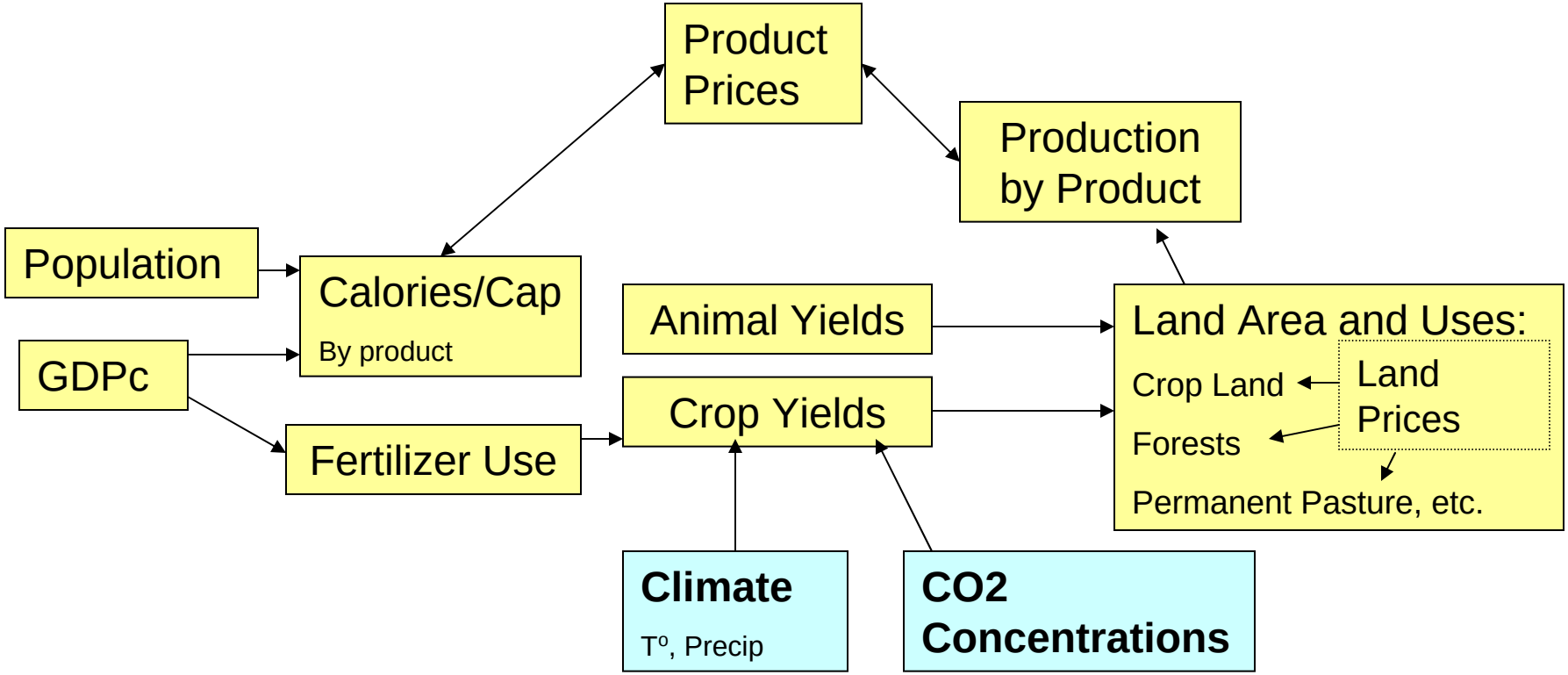
Energy Sector – Key Points

- Partial Equilibrium
- Secondary energy use
  - Autoregressive based on regression analysis
  - Includes elasticities for price and income
  - Includes efficiency trends
  - Fuel prices include emission allowance costs
  - Data source OECD/IEA
- Energy conversion
  - Vintaging model
  - New Capacity comes in at maximum efficiency (random variable)
  - Prices used to allocate new capacity
- Energy use for energy processing and in production
  - Set as ratio of energy produced in region
- Non-renewable
  - Resources and extraction prices are uncertain
  - Model keeps track of reserves and cumulative production
  - Production in year based on reserves and P/R ratio
- Renewable
  - Production capacity and extraction prices are uncertain

Energy Sector – Formulas

- Total Secondary Energy Use
  - $SEc_{t,r} = e^{a} * SEc_{t-1,r}^{\ b} * Min(GDP_{ct,r}, TRS)^{c} * (GDPc_{t,r}/Min(GDPc_{t,r}, TRS))^{d} * e^{(g*(1/(t-1945)))} * (PrcA_{t,r})^{PEavg} * (HDD_{t,r}-HDD_{1990,r})^{HC} * (CDD_{t,r}-CDD_{1990,r})^{CC} * e^{ARC(SEc)}$
- Secondary Energy Use by Energy Type
  - $SES_{t,r,k} = e^{a(k)} * SES_{t-1,r,k}^{\ b(k)} * Min(GDPc_{t,r},TRS)^{c(k)} * (GDPc_{t,r}/Min(GDPc_{t,r},TRS))^{d(k)} * (PrcA_{t,r})^{PEavg(k)} * (PrcO_{t,r,k})^{PEown(k)} * e^{ARC(SESk)}$
- Where
  - $SEc_{t,r}$ is the secondary energy use per capita
  - $SES_{t,r,k}$ is the share of secondary energy use by fuel type
  - $GDP_{ct,r}$ is the GDP per capita
  - TRS is the Income threshold ($7500/capita)
  - $PRCA_{t,r}$ is the average price of energy for secondary use
  - $PrcO_{t,r,k}$ is the adjusted price of fuel
  - a, b, c, d, g, PEavg, PEown, HC, and CC are elasticities
  - $HDD_{t,r}$ and $CDD_{t,r}$ are heating and cooling degree days

Agriculture Sector: A Partial Equilibrium Formulation



Agriculture Sector – Key Points

- Sectors based on FAO data categories
  - Wheat, Beef &Veal, Fruits & Vegetables, Fish & Other Aquatic Animals, Poultry, Rice, Maize, Other C4, Other C3, Milk, Other, Pig, Oil Crops, Non-food, and category for Sheep, Goat, Other, and Animal Fat
- Estimated using production and mass balance data from FAO for the period 1961 to 2000
- Demand Model
  - Autoregressive
  - Includes price and income elasticities by region and 15 products
  - Overall long-term price elasticity of -0.48
- Production Model
  - Crop yields are a function of fertilizer use and changes in NPP
  - Includes decaying time component
  - Fertilizer use a function of income and time
- Prices used to equilibrate supply and demand
- Outputs feed into the land use module

Agriculture Sector – Formulas

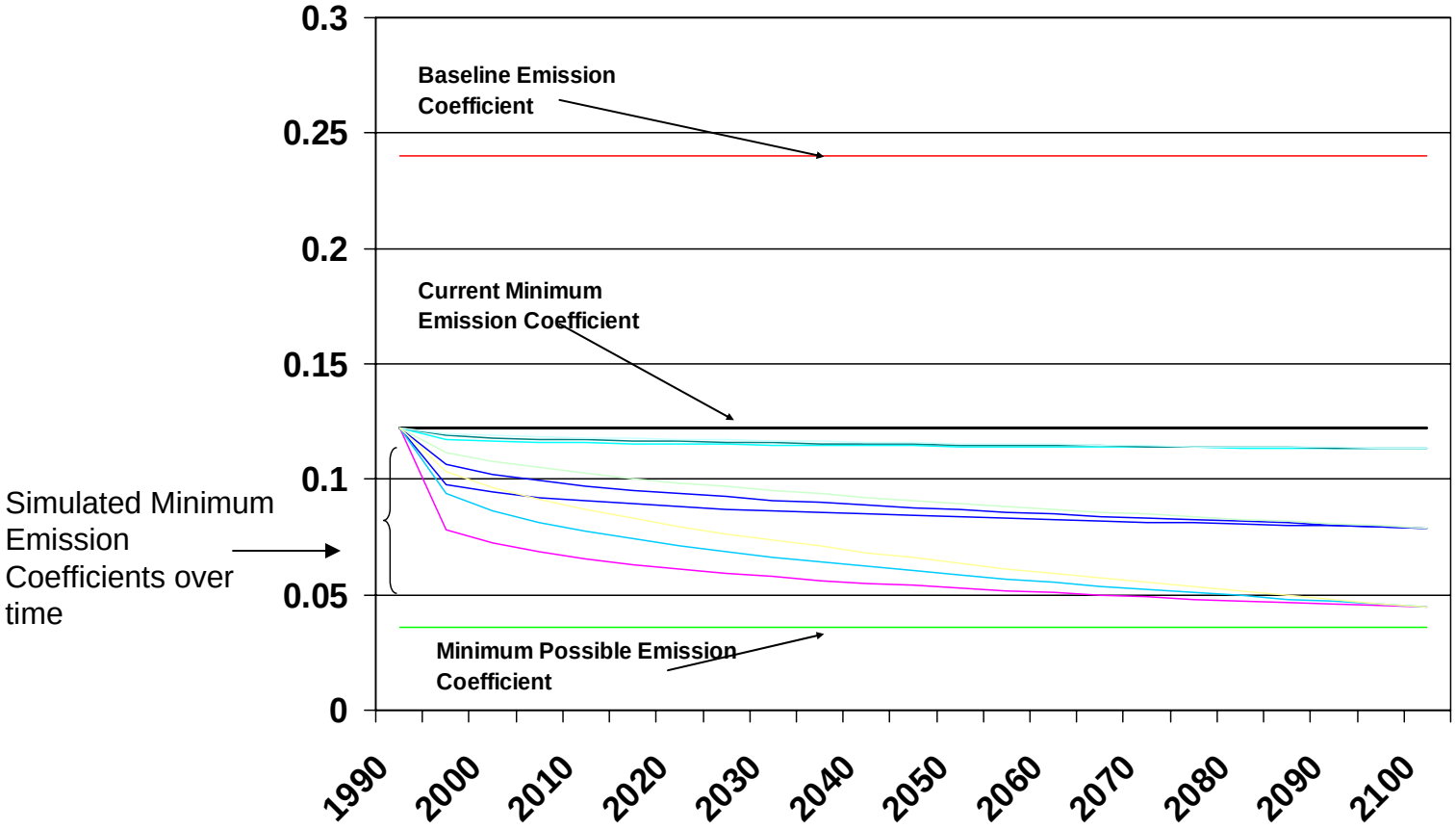
- Demand ($CD_{t,r,k}$)
  - $CD_{t,r,k} = (a * CD_{t-1,r,k} + \lambda_{r,k} + b*ln(Min(GDPc_{t,r}, TRS)) + c* ln(GDPc_{t,r}/Min(GDPc_{t,r}, TRS)) + x_{t,r,k} * StErr_k) * (P_{t,r,k}/P_{t-1,k,r})^f$
- Fertilizer Use
  - $F_{t,,r} = F_{t-1,r}^{\ a} * Min(GDPc_{t,r}, TRS)^b * (GDPc_{t,r}/Min(GDPc_{t,r}, TRS))^c * e^{\lambda(r)} * e^{\alpha*SE}$
- Where
  - a,b,c are elasticities
  - $x_{t,r,k}$ and α are N(0,1) pseudo random value
  - $P_{t,r,k}$ is the price of the agricultural product
  - Ft,,r is the fertilizer use per hectare
  - λ(r) is a regional intercept
  - $StErr_k$ and SE are the standard error from the regressions

Agriculture Sector – Formulas

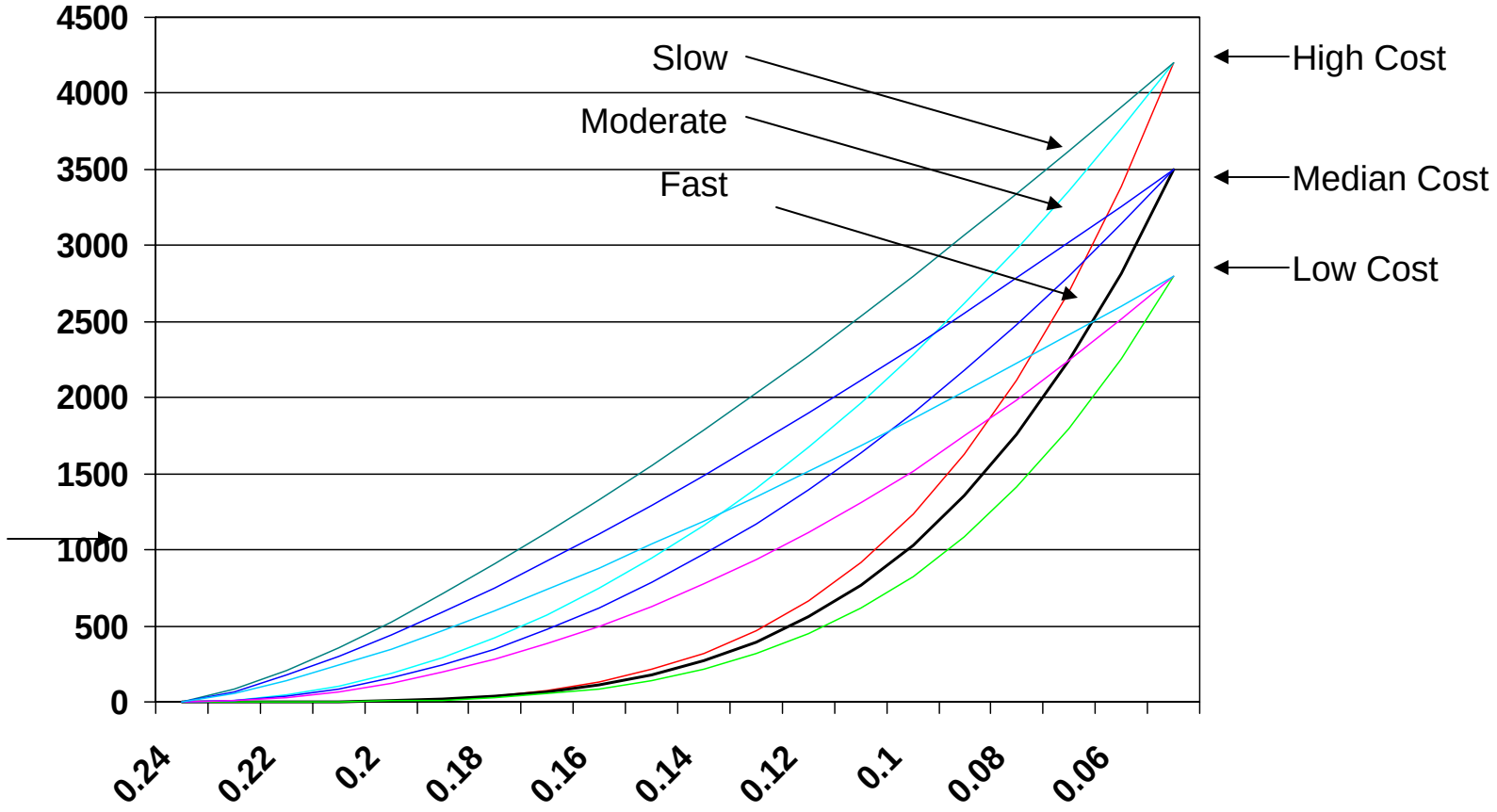
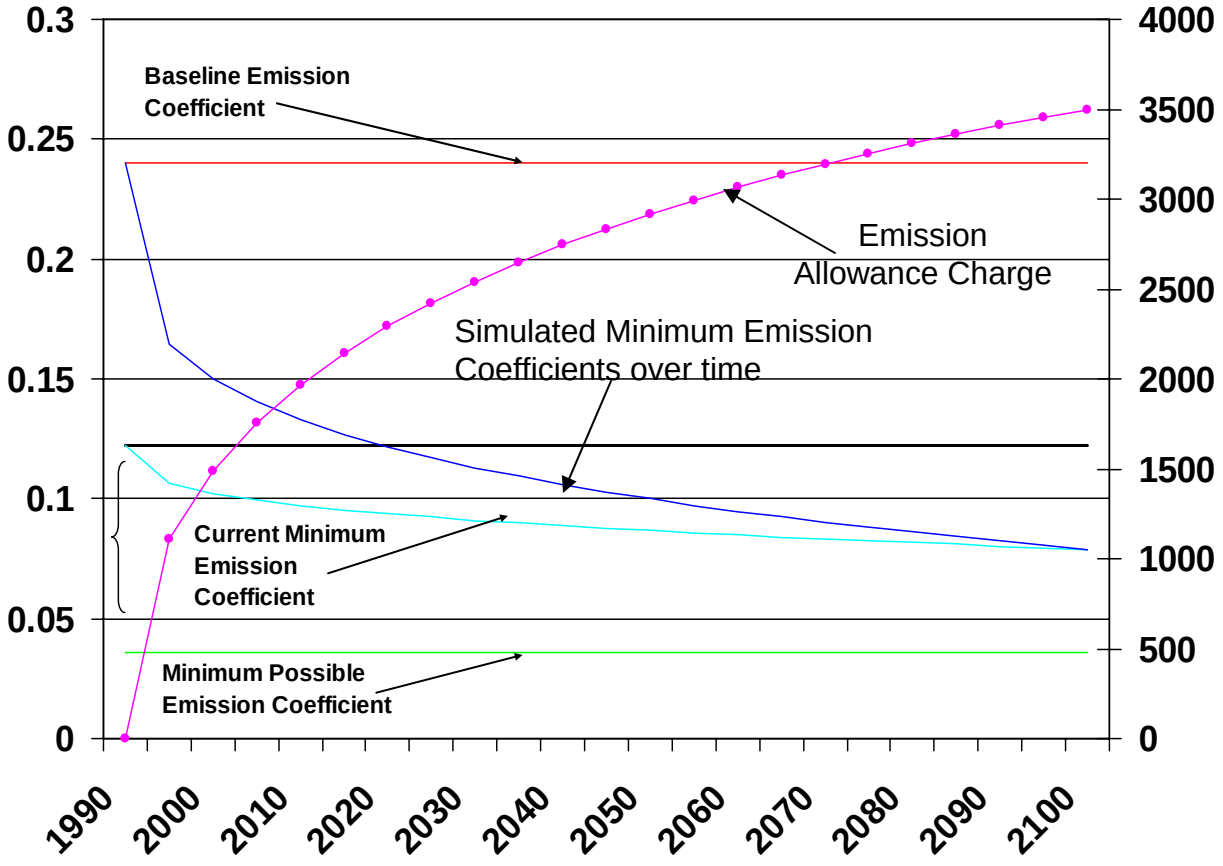
- *Crops Yield ($Y_{t,r,k}$)*
  - $Y_{t,r,k} = Y_{t-1,r,k}^{a} * F_{t,r,k}^{b} * e^{(c + \beta * YSE(k)) * (1/(t-1900))} * e^{\lambda(r,k)} * e^{\alpha * SE(k)}$
- *Animals Yield ($Y_{t,r,k}$)*
  - $Y_{t,r,k} = Y_{t-1,r,k}^{a} * AD_{t,r,k}^{b} * e^{(c + \beta * YSE(k)) * (1/(t-1900))} * e^{\lambda(r,k)} * e^{\alpha * SE(k)}$
- Land Use
  - $AH_{t,r,k}/AH_{t-1,r,k} = P_{t,r,k}/P_{t-1,r,k} / (Y_{t,r,k}/Y_{t-1,r,k})$
- Where
  - a, b, c, β are elasticities
  - λ(r,k) are regional intercepts
  - YSE(k) and SE(k) are standard errors from the regressions
  - $AH_{t,r,k}$ is the area harvested

Emissions Estimation:

Probabilistic rates of advance, plus controls



Emission Abatement Curves:
Emission Coefficient and Emission Allowance Charges



Emission Abatement Curves:
Realization of Emission Abatement Curve