TISS-DSF Emissions Model

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Framework for the Model

- Nature imposes a global carbon budget
  - Mitigation efforts must begin with recognition of physical constraints on emissions
- The atmosphere is to be regarded as a global commons
  - Validates equity as the basic rule for the partitioning of global carbon budget
- Dual Character of CO2 emissions
  - Both ‘pollution’ and ‘necessity’

Rule I - Equity Based Rules For Partitioning Remaining Carbon Space

- Countries cut ``consumption emissions'' if current share > fair share of carbon space.
- Countries are allowed ``development'' emissions if current share < fair share of carbon space.
- Reduction in emissions even for those developing countries that can reach fair share at end of time period

- **Objective – Minimize (negative) deviation from fair share**

Historical Responsibility

- Current Total Stock of Carbon in the Atmosphere (from base year to 2009)
- Total contribution of each country/region to atmospheric stock

- Possible base year
  - 1850 – Start of emissions (post industrial revolution)
  - 1970 – CO2 emissions monitoring recognized by 1972 in the UN Stockholm conference on the Human Environment

Historical Emissions

- Of the total non-LUCF emissions:
  - 68% emitted after 1970

	*Non- LUCF Only		Fair Share
	1850 Basis	1970 Basis	2009 Population Basis
USA	28.8%	24.4%	4.6%
EU	26.1%	19.9%	7.2%
Other Annex-I	18.9%	21.5%	6.9%
India	2.6%	3.3%	17.4%
China	10.0%	13.5%	19.6%
Brazil	0.9%	1.1%	2.8%
Other Emerging Economies	8.5%	11.0%	12.2%
Rest of the World	4.2%	5.4%	29.3%

Shift of Base Year

- Over-occupation not a result of early industrialisation
- Improvement in efficiency not equal to emissions reductions. Independent efforts required by Annex-I
- Loss of ground for China and 'Other Emerging Economies' (but close to fair share attained nonetheless)

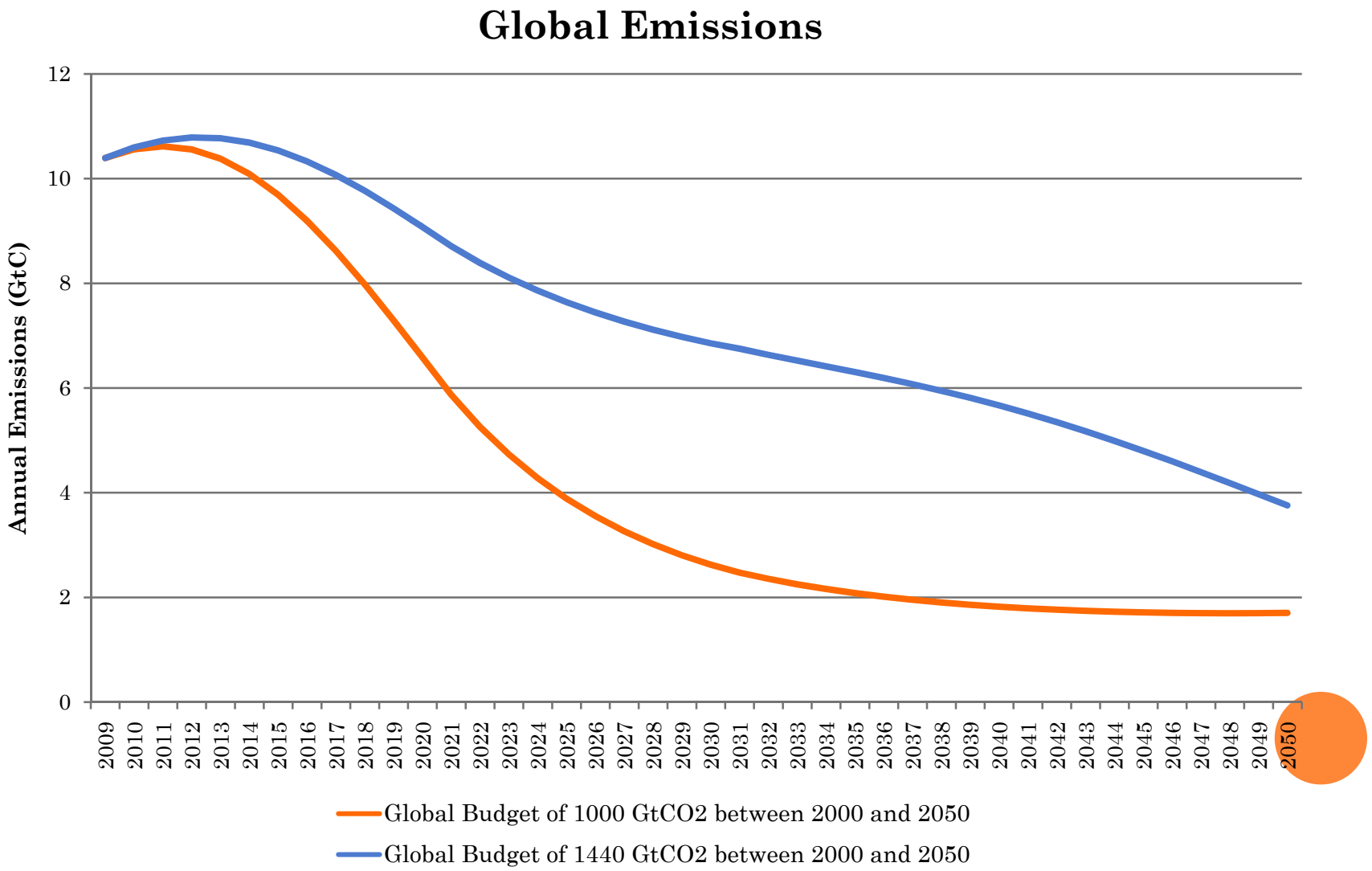
Rule II – Fixing The Global Carbon Budget

- Dependent on degree of risk
- 2ºC over pre-industrial levels generally accepted
- Range of probabilities for given carbon budget

- Between 2000 and 2050
  - 1000 GtCO2 → Probability between 10% and 42% of exceeding a 2 deg C rise
  - 1440 GtCO2 → Probability between 29% and 70% of exceeding a 2 deg C rise

  (Meinshausen et al.)

Difference Between The Two Budgets – Representative Trajectories



Rule III – Per Capita Annual Flows

- Countries with per capita emissions above specified thresholds must do more

Objective – Minimize (negative) deviation from specified threshold of per capita emissions

Rule I, Rule II, Rule III – weighted 10:10:3

(More weight to violating equity in stock and the global carbon budget)

Emissions and Growth Rates

- Current Emissions (2009)
  - Non-LUCF (Land Use Change and Forestry) + LUCF
- Current Rate of Growth of Emissions
  - Average rate of growth of total emissions (LUCF + non-LUCF) for the last 5 years
- Population
  - Constant Population → 2009
  - Moving Population →Projections from the UN WPP till 2050

The Emissions Model

- Dynamically implement rules I-III as “soft constraints”
- For each milestone year maximum rate of reduction and maximum rate of growth specified **in common for all countries**
- 16 Region GAMS based non-linear model produces region/country wise carbon allocations based on Rules I, II and III

Allocation of future emissions – Focus on Physical Carbon Space

- Dynamical Method
  - Continuous re-allocation of the physical carbon space
  - Determined by a small set of parameters
  - Parameters that can be applied equally to all countries
  - More suitable where there is coordinated action by all countries
- Static Method
  - Share of each country is determined a priori
  - Requires several parameters to be individually adjusted
  - More suitable where there is unilateral mitigation action

Dynamical Model – Key Input Parameters

- Maximum Rate of Reduction
  - E.g. Of 1990 levels, 48% by 2020, 97% by 2050 (slightly higher than IPCC AR4 high end cuts)
  - Of 1990 levels, 63% by 2020, 99% by 2050 (inspired by GDR but not identical)
- Maximum growth rate allowed – specified as a multiple of current growth rate

	Option-A	Option-B
2020	1.8 times	1.8 times
2030	1.5 times	2 times
2050	0.5 times	3 times
2100	-6	-6

Four Basic Scenarios

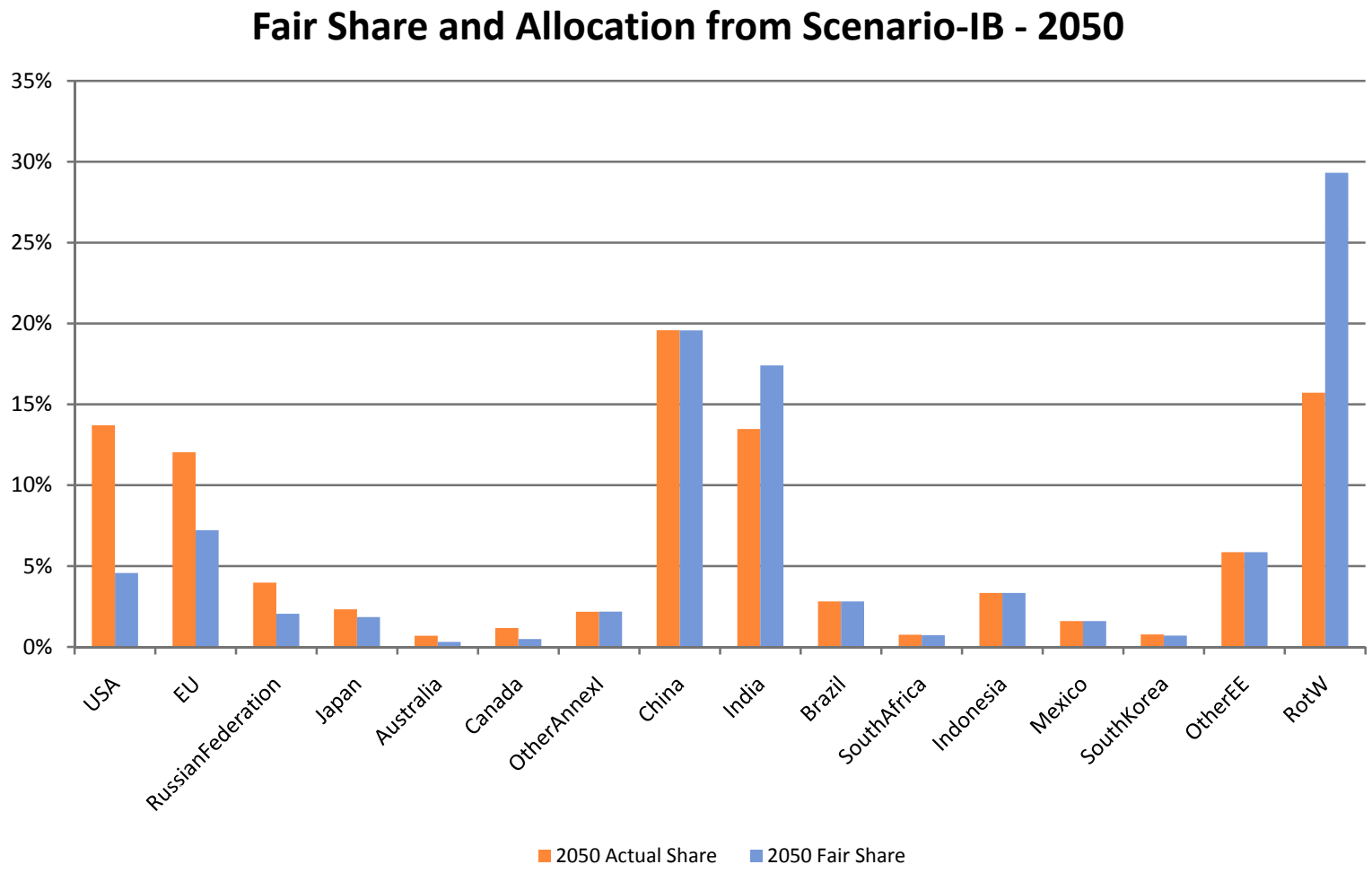
Scenarios	Description
Scenario –I (A,B)	Only Rule I – Equity in Stock
Scenario-II (A,B)	Rule I and III – Equity in Stock with penalties on per capita emissions above specified thresholds
Scenario-III (A,B)	Rule I and II – Equity in Stock within a global carbon budget
Scenario-IV (A,B)	Rule I, II and III – Equity in Stock and penalties on high per capita emissions within a global carbon budget

Budgets Between 2010 and 2050 (1850-Basis)

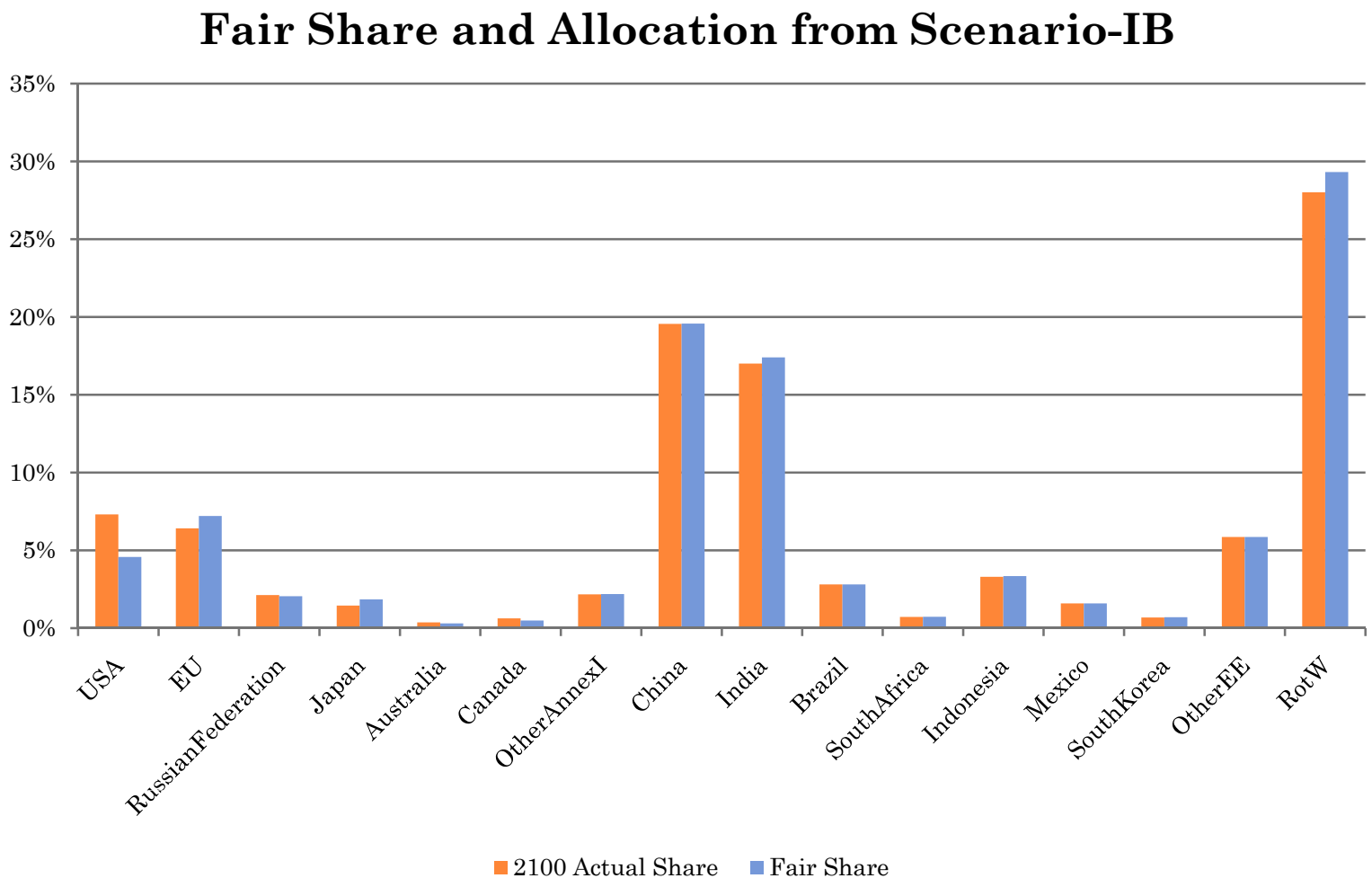
GtC	Option-A	Option-B
Scenario -I	1702	1848
Scenario -II	1688	1828
Scenario -III	1444	1444
Scenario -IV	1434	1434

Comparisons of Scenarios III & IV and prone to error for small budgets (3%)

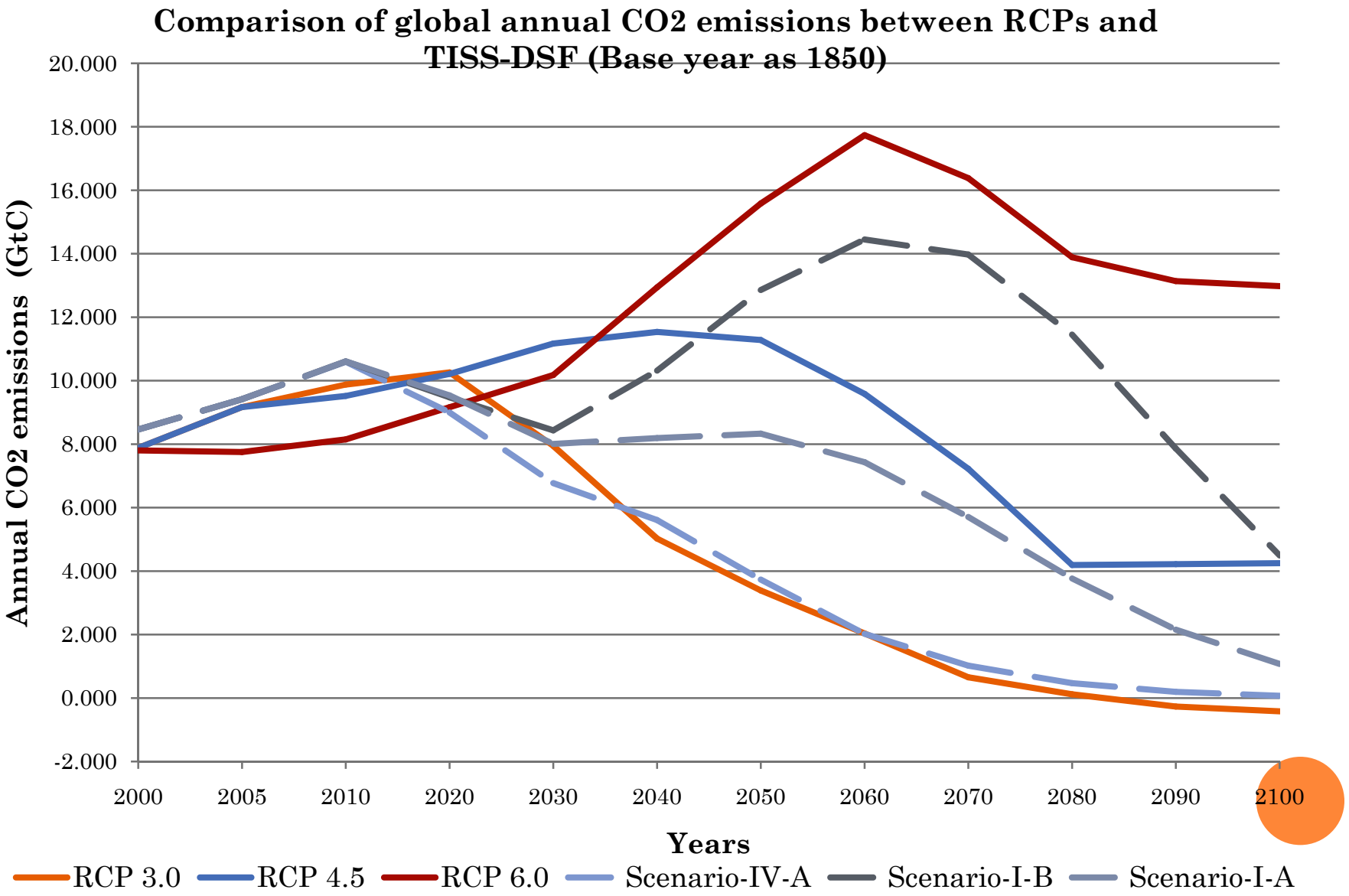
Scenario IB - 2050



Scenario-IB - 2100



Equity Not a Runaway Scenario (but not acceptable)



Concentration and Temperature

	CO2 Concentration in 2100 (ppm)	Temperature rise in 2100 relative to 1765	Probability for exceeding 2 deg.C (Range)	(Illustrative)
RCP 3.0	403.2	1.65		
RCP 4.5	524.6	2.37		
RCP 6.0	673.4	2.98		
Scenario-IA	468.6	2.06	44% - 83%	67%
Scenario-IB	570.2	2.59	57% - 91%	79%
Scenario-IVA	406.2	1.66	30% - 71%	52%

Equity not a runaway scenario

Thank you

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Generation of Actual Emission Trajectories

- 2010 to 2100 → divided into 4 time periods
  - 2009 to 2020
  - 2020 to 2030
  - 2030 to 2050
  - 2050 to 2100
- For each milestone year maximum rate of reduction and maximum rate of growth specified
- Optimiser picks a value between the limits based on constraints

The model – Constrained Optimisation

- Global Budget
  - A pre-decided carbon budget to restrict temperature increase
  - A = Global Budget – Σ(Cumulative emissions of each country and region)
- Contribution to Stock
  - Difference between *fair share* of total atmospheric stock and *actual contribution*
  - B = (Fair Share of Total Stock – Actual Share of Total Stock)$_{\text{for each country}}$
- Per Capita Emissions
  - Difference between an *acceptable threshold for per capita emissions* and *actual per capita emissions*
  - C = (Acceptable per capita emissions – Actual per capita emissions)$_{\text{for each country}}$

Objective Function

- Minimize
  - Negative deviations from global budget,
  - Negative deviations from fair share of stock
  - Negative deviations from acceptable level of per capita emissions
  - Objective Function = Minimize (Negative A + Negative B + Negative C)

- Within the constraints of a global carbon budget
  - Countries above fair share have to reduce emissions
  - Countries below fair share are allowed to increase emission
  - Degree of reduction or increase depends on how far countries are from fair share of stock and per capita emissions thresholds

16 Regions

Annex-I	Non-Annex-I
USA	China
EU	India
Russian Federation	Brazil
Japan	South Africa
Australia	Indonesia
Canada	South Korea
Other Annex-I	Mexico
	Other Emerging Economies
	Rest of the World

Other Emerging Economies

- Argentina, Chile, Egypt, Iran, Israel, Malaysia, Saudi Arabia, Singapore, Taiwan, Thailand, Uzbekistan and Venezuela.