HEALTH BENEFITS OF LOW CARBON POLICIES

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Low Carbon Policies Have Strong Health Benefits

- Reductions in air pollution ($PM_{2.5}$, ozone)
- Adoption of renewable energy to replace traditional fuels in poor households
- High ambition GHG reduction targets reduce climate impacts with negative health consequences (extreme events, heatwaves..)
- Benefits are greater in countries where local air pollution has not been subject to strong direct controls (mostly developng countries)
- Benefits will also depend on how the target reductions in GHG emissions are shared across the world.

The Paris Climate Agreement

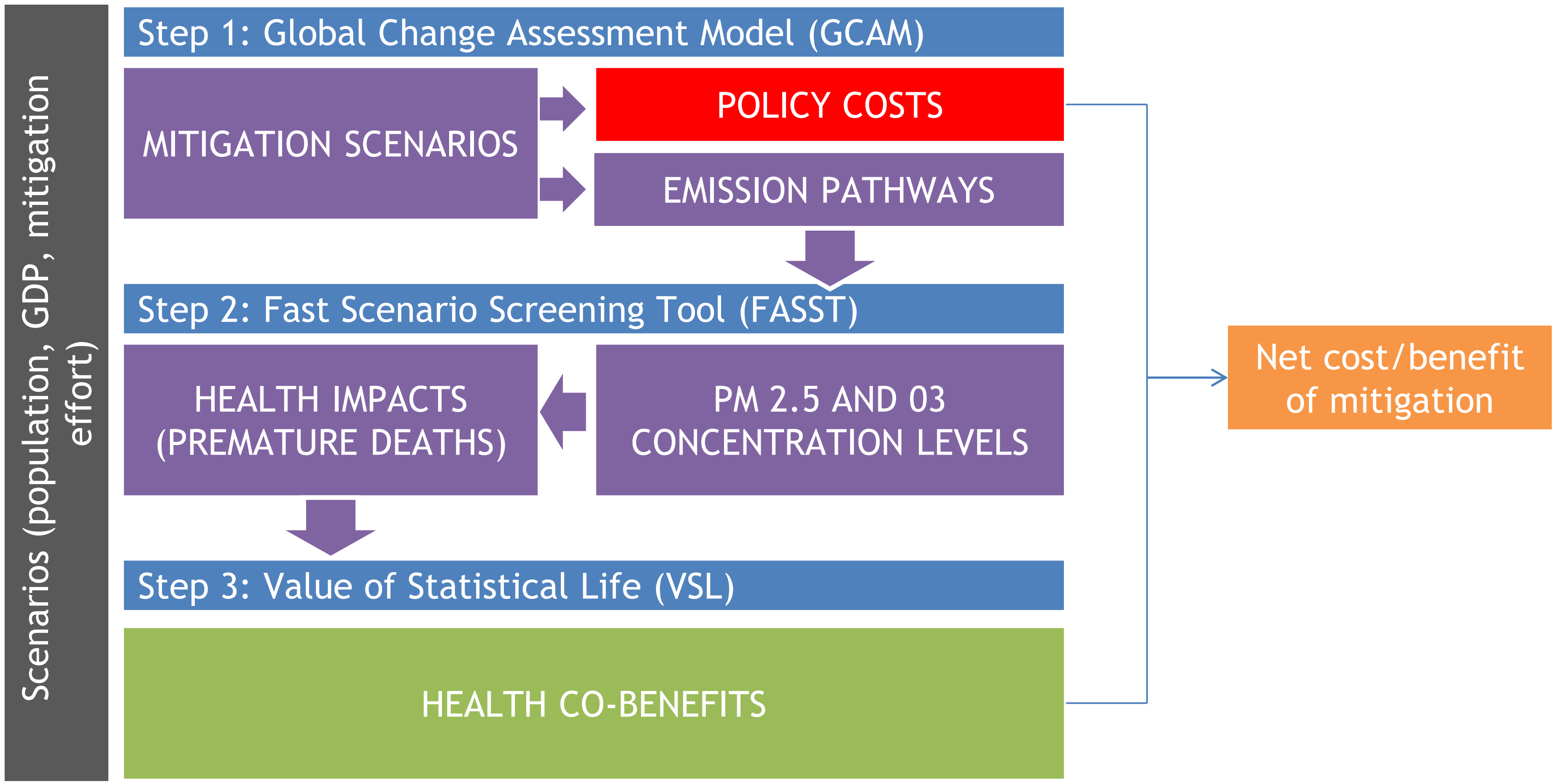
- The agreement sets a long-term stabilisation target of a 2°C increase and signatories have agreed to pursue efforts to limit the increase to 1·5°C
- Concrete measures to achieve these targets have not yet been agreed. A key concern when evaluating different climate policies is their net cost, with a component of overall policy cost being the associated co-benefits.
- Overall policy cost = mitigation cost – health and other co-benefits.
- Co-benefits are additional benefits related to the reduction of greenhouse gas emissions but not directly related to climate change, such as air quality improvement, technological innovation, or employment creation.
- The current commitments by countries under the Paris agreement (NDCs) will not achieve the 2°C targets. Likely increase under commitments is 2·9–3·4°C by the end of the century

Health Co-benefits of Paris Agreement

- We look at co-benefits by region under different emissions reductions targets for the regions.
- Previous work on co-benefits has not looked at the topic in these terms – it has assumed a global reduction in emissions achieved through a global carbon tax.
- The work to be presented has been published:
  - Markandya A., Sampedro J., Smith SJ., Van Dingenen R., Pizarro-Irizar C., Arto I., González-Eguino M. Health co-benefits from air pollution and mitigation costs of the Paris Agreement: a modelling study, *The Lancet Planetary Health*. 10.1016/S2542-5196(18)30029-9.
- We look at the overall policy costs by region for different burden sharing rules to achieve both the 2°C and the 1.5°C global targets.
- We can then discuss some of the implications of the results for policy.

Methods

- Step 1: Define scenarios to 2050 that result in different climate outcomes: a baseline, case of only NDC mitigation, 2°C and 1.5°C.
- For each scenario obtain the GHG emissions trajectories and local air pollution emissions by region to 2050 using an Integrated Assessment Model called GCAM
- For each emission and local air pollution trajectory calculate the concentrations by region using the TM5-Fast Scenario Screening Tool air quality source-receptor model, which translates emission levels into pollutant concentrations, exposure, and premature deaths
- Value the costs of the emissions reductions in economic terms and the health impacts in monetary terms using a value of premature death and a morbidty cost per case



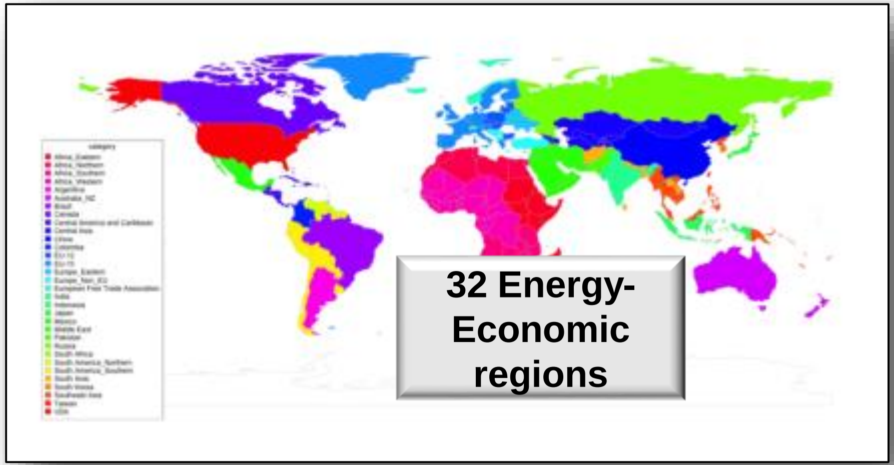
Scenarios (population, GDP, mitigation effort)
Step 1: Global Change Assessment Model (GCAM)
MITIGATION SCENARIOS
POLICY COSTS
EMISSION PATHWAYS
Step 2: Fast Scenario Screening Tool (FASST)
HEALTH IMPACTS (PREMATURE DEATHS)
PM 2.5 AND 03 CONCENTRATION LEVELS
Step 3: Value of Statistical Life (VSL)
HEALTH CO-BENEFITS
Net cost/benefit of mitigation

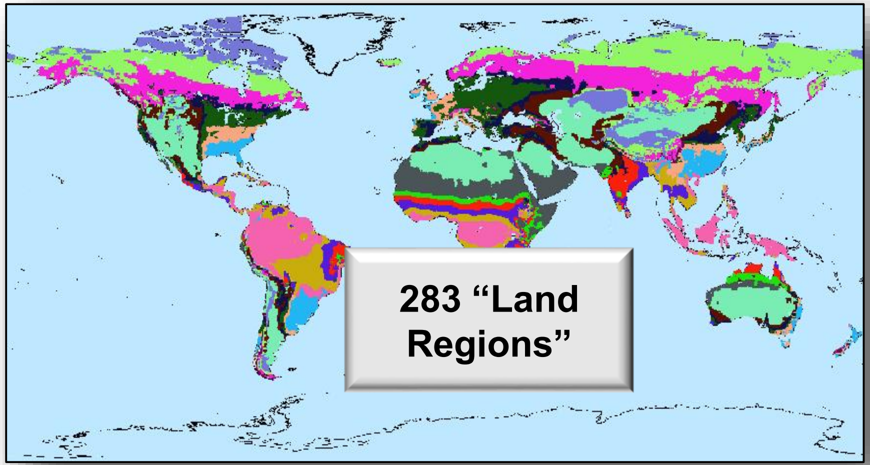
THE GCAM MODEL

- GCAM is an integrated assessment model that has been used in most major climate and energy assessments over the past 20 years, including the last International Panel on Climate Change (IPCC) Report.
- The model is disaggregated into 32 geopolitical regions and operates in 5 year time steps from 2005 to 2100
- GCAM provides the mitigation cost of different energy and climate policies for each specific region. It also reports the emissions of the main air pollutants including organic carbon, black carbon, nitrogen oxides, non-methane volatile organic compounds, carbon monoxide and sulphur dioxide, which are the main precursors of PM2.5 and ozone.
- Emissions depend on emissions factors that are technology-specific and on emissions controls that are country-specific. Both these are set in the model in which technology choices are endogenous.

GCAM MODEL

- GCAM is a **global integrated assessment model**
- GCAM links **Economic, Energy, Land-use,** and **Climate** systems
- Runs in **5-year time-steps. (until 2100)**
- Meant to analyze consequences of policy actions and interdependencies
- The GCAM core is global, written in C++, and data driven.
- It was developed by the PNNL (Pacific Northwest National Laboratory).



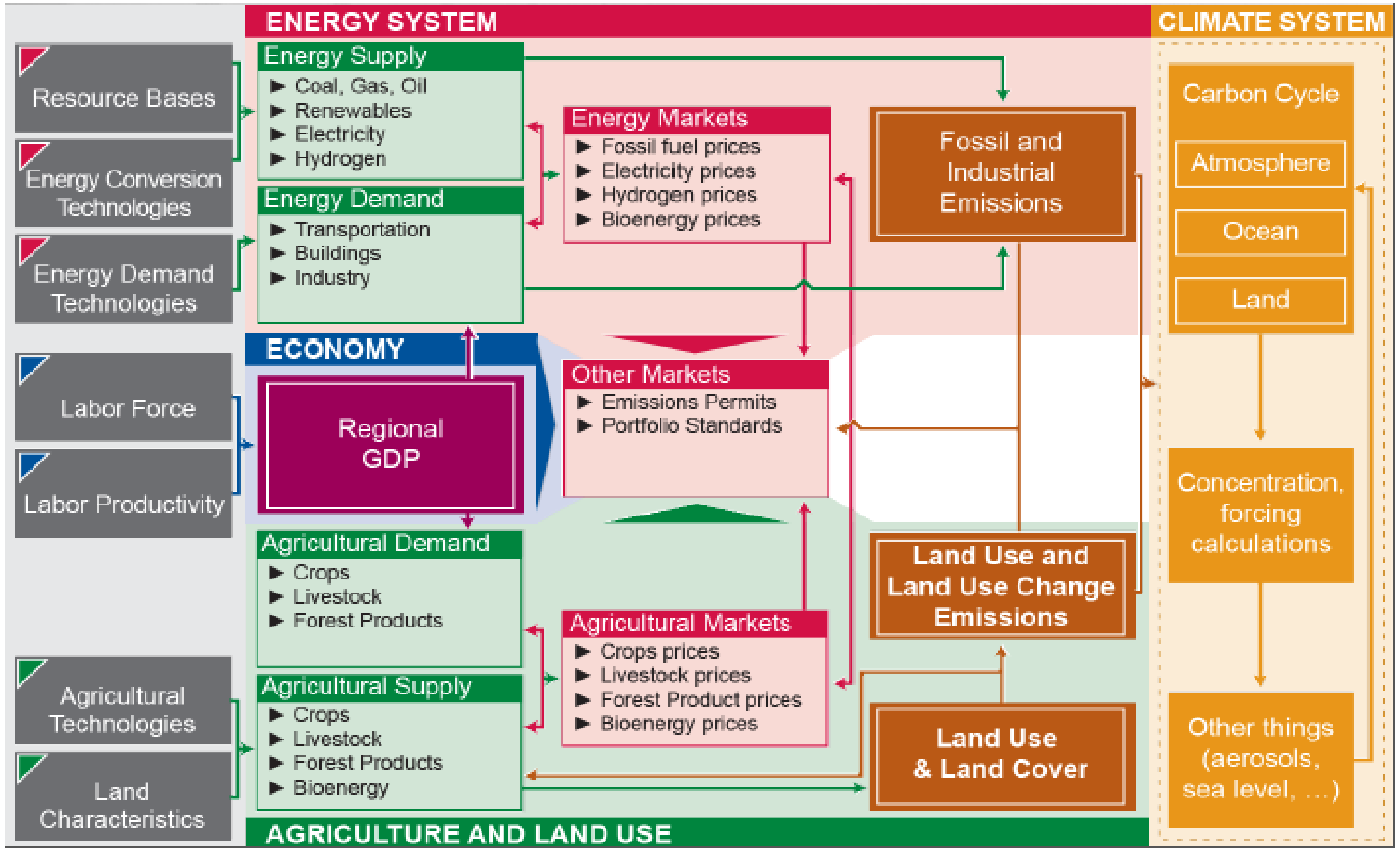


Source Kyle et al 2015

GCAM MODEL

- GCAM was one of four models chosen to create the representative concentration pathways for the IPCC's AR5.
- GCAM has participated in virtually every major climate/energy/economics assessment over the last 20 years:
  - Every EMF study on climate
  - Every IPCC assessment
- GCAM is a open-source model that BC3 has used in different projects:
  - FP7: CECILIA, FLAGSHIP, COMPLEX
  - H2020: TRANSRISK

GCAM MAIN STRUCTURE



GCAM MAIN STRUCTURE- SOCIOECONOMIC FACTORS

Population:

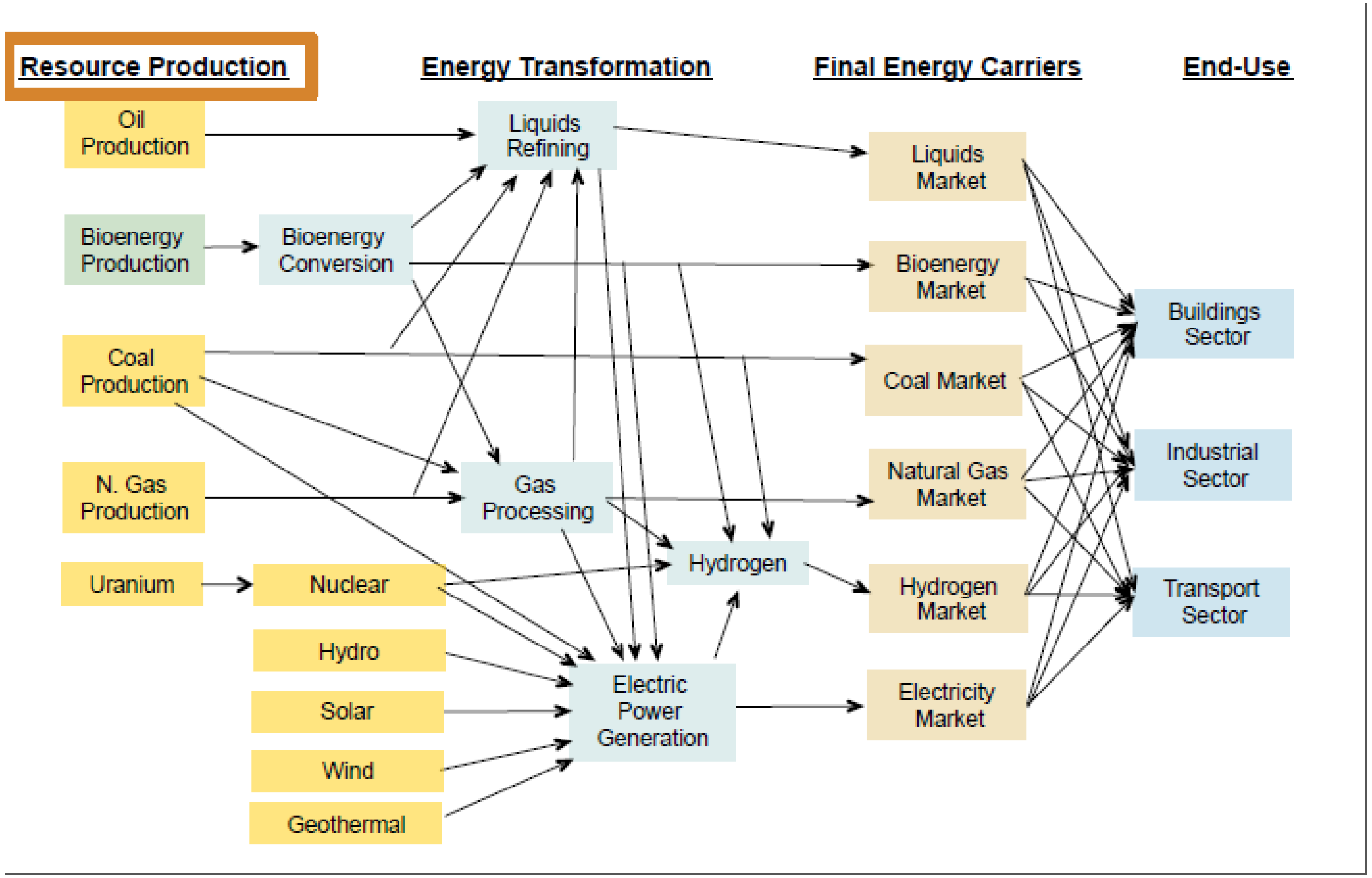
- Exogenously specified
- Does not change in response to policy, technology, etc.

GDP:

- Exogenously specified assumptions about labor productivity growth
- Does not change in response to policy, technology, etc.

SSP2

GCAM MAIN STRUCTURE- THE ENERGY SYSTEM



Source Kyle et al 2015

GCAM MAIN STRUCTURE- TECHNOLOGY COMPETITION

$$s_i = \frac{\alpha_i c_i^{\sigma}}{\sum_j \alpha_j c_j^{\sigma}}$$

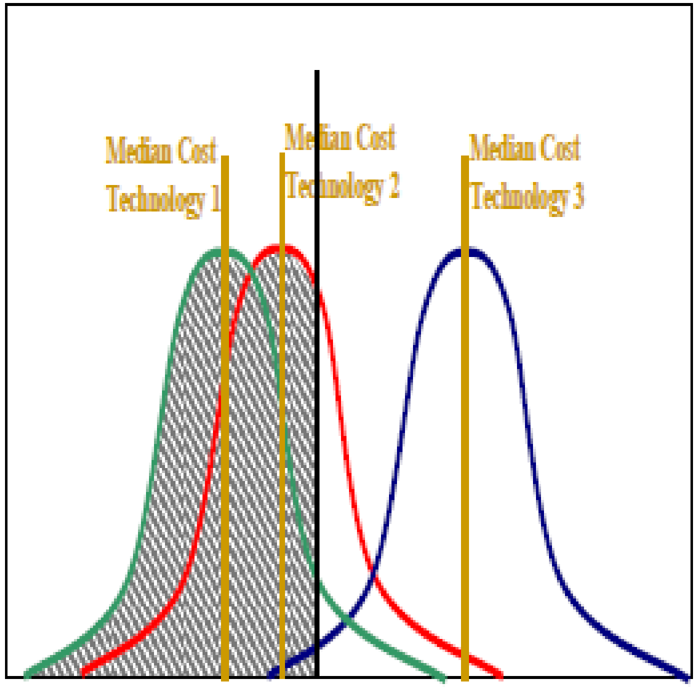
How does the model choose between different technology-alternatives?

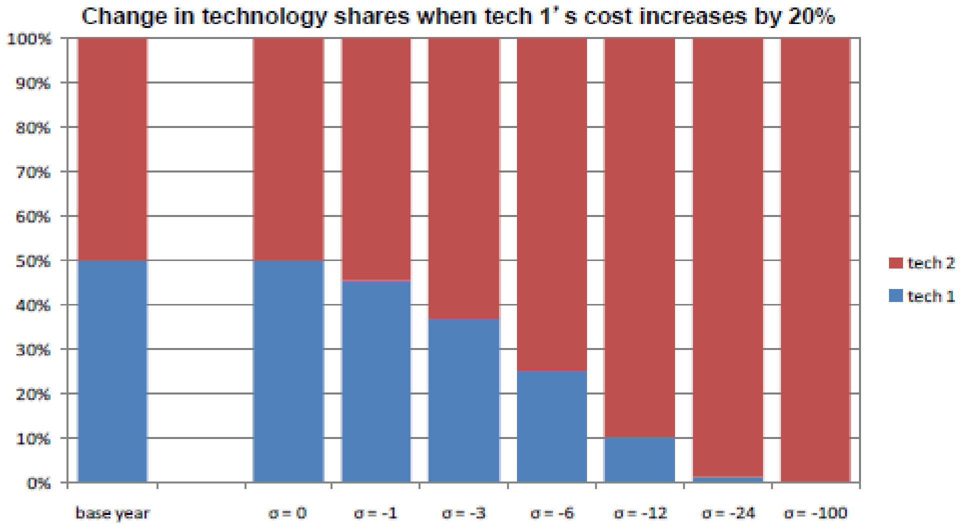
LOGIT SYSTEM:

s: share of technology i

a: weight of technology i

c: costs of technology i





Source: Clarke and Edmonds (1993), McFadden (1974)

GCAM MAIN STRUCTURE- EMISSIONS

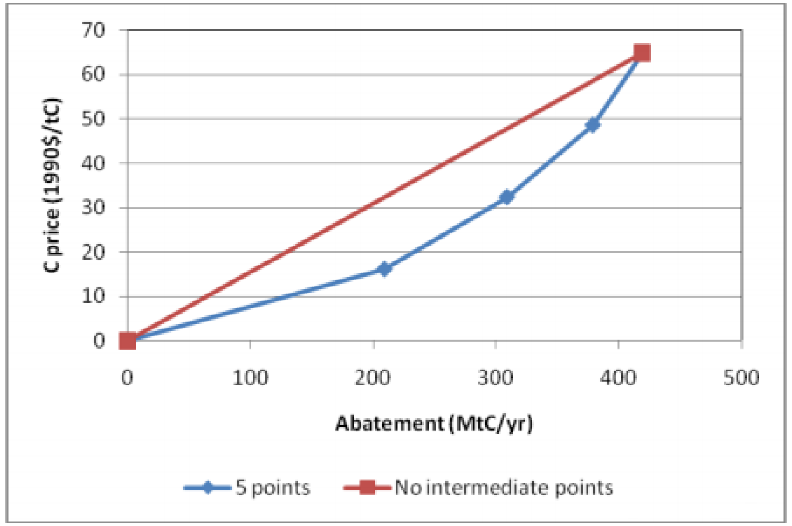
- GCAM tracks emissions for several gases and species
  - CO_2, CH_4, N_2O, CF_4, C_2F_6, SF_6, HFC125, HFC134a, HFC245fa, SO_2, BC, OC, CO, VOCs, NO_x, NH_3
  - We calculate CO_2 from fossil fuel & industrial uses, as well as from land-use change

- Each gas is associated with a specific activity and changes throughout the coming century as:
  - The activity level changes
    - Increasing the activity increases emissions
  - Pollution controls increase
    - As incomes rise, we assume that regions will reduce pollutant emissions
  - A carbon price is applied
    - We use MAC curves to reduce the emissions of GHGs as the carbon price rises

- Emissions are produced at a region level (32 regions for energy, 283 regions for agriculture & land-use).

GCAM MAIN STRUCTURE – POLICY COST

- Emissions abatement costs are calculated as the integral under the marginal abatement cost schedule.
- By default, this is calculated as the area underneath the marginal abatement curve with five points. This setting can be changed.
- Marginal abatement cost curves (MACCS) usually present an exponential shape. Technology availability and cost influence this shape.

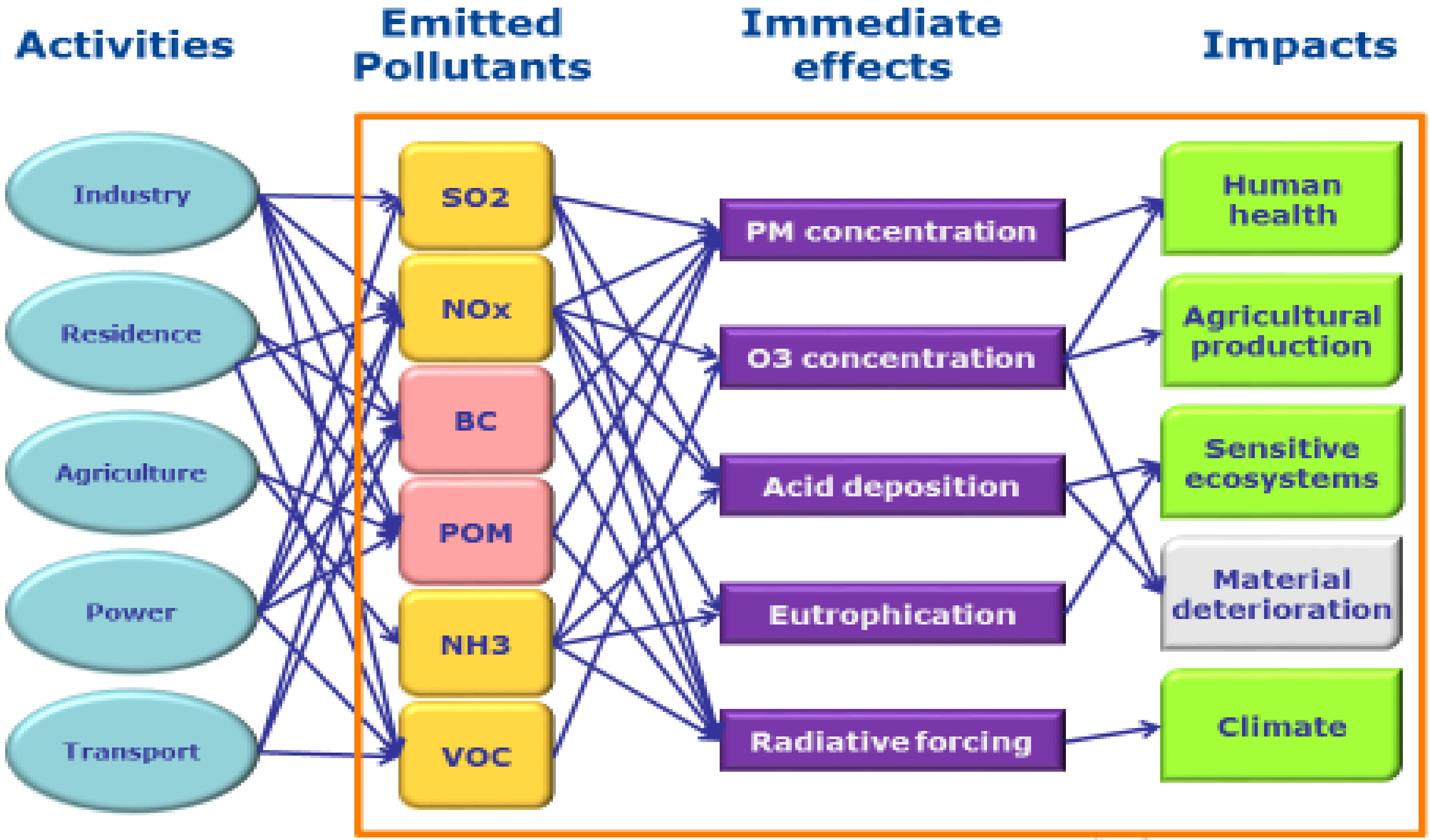


The TM5 FASST MODEL

- TM5-FASST is a reduced-form global air quality source-receptor model developed by the European Commission's Joint Research Centre.
- The model analyses how the emissions of a source region affect receptor points (grid cells) in terms of concentrations, and subsequently, premature deaths.
- Given the concentration levels for each region, the model calculates the premature deaths derived from exposure to ozone and PM2·5, disaggregating by different causes of death
- For ozone the cause is respiratory disease and for PM2.5 it is for ischaemic heart disease, chronic obstructive pulmonary disease, stroke, lung cancer, and acute lower respiratory airway infections.
- The calculations use the GBD 2015 Risk Factors Collaborators. These calculations require baseline mortality rates, which are taken from WHO data.

FASST

- The TM5-FASST tool, developed at JRC Ispra (Italy), allows us to evaluate how air pollutant emissions affect large scale pollutant concentrations and their impact on human health (mortality, years of life lost) and crop yields
- It links emissions of pollutants in a given source region with downwind impacts, using knowledge of meteorology and atmospheric chemistry
- The model analyses effects of both primary and secondary pollutants
- The tool is specifically designed to compare a defined scenario with a counterfactual case (baseline), that can also be defined by the user



TM5-FASST model framework

European Commission

THE VALUATION MODULE

- To monetise the estimated health impacts, the VSL was used. VSL is the monetary value of a relative change in mortality risk reduction (usually taken to be in the range from 3/10 000 to 2/10 000).
- Given the absence of empirical studies that estimate VSL for all countries, procedures have been developed to transfer the results of existing studies to other regions, aiming to overcome this limitation.
- The VSL value for OECD countries is taken to be in the range US$1.8 to 4.5 million. For other countries the value is calculated as:

$$VSL_{c,t} = VSL_{OECD,2005} \times \left(\frac{Y_{c,2005}}{Y_{OECD,2005}}\right)^{b} \times (1+\%\Delta Y)^{b}$$

- In addition, morbidity costs are added as 10% of mortality costs.

THE SCENARIOS

- The scenarios have three main components:
    1. A general socioeconomic storyline represented by the Shared Socioeconomic Pathways of the IPCC framework (SSP)
    2. A model quantification of that storyline
    3. A set of mitigation strategies where current national mitigation targets are extended based on different equity criteria to allocate the carbon budgets for different temperature stabilization objectives
- For 1. we chose SSP2, which is a “middle of the road” option and assumes:
    - Current trends continue with some progress towards the Sustainable Development Goals, with lower energy and material intensity consumption and lower fossil fuel dependency
    - Unequal development rate between low income countries and a persistence of global and in-country inequalities.
    - Low level of investment in education prevents low population growth.
    - Global governance achieves an intermediate level of environmental protection

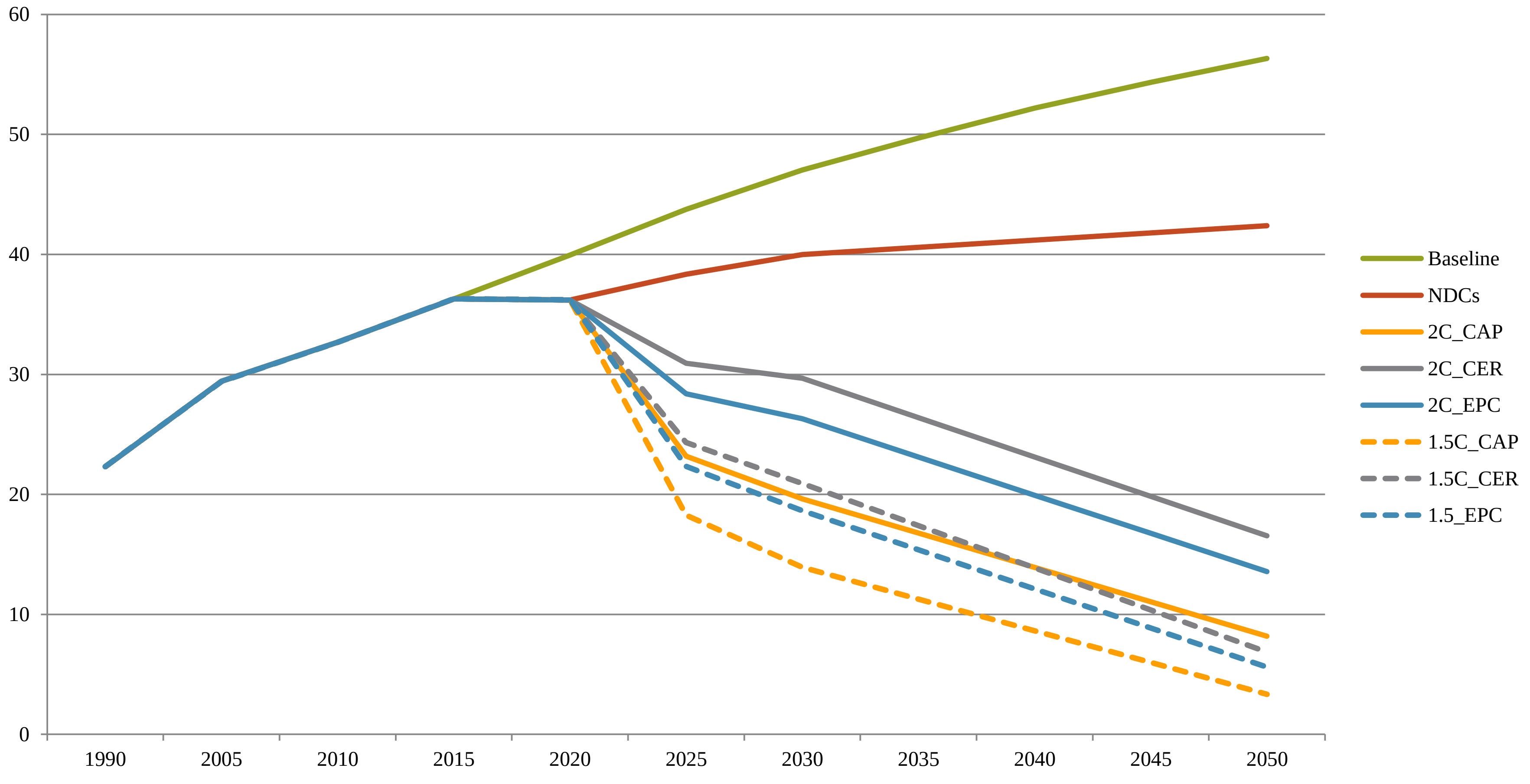
THE SCENARIOS

- The mitigation strategies are divided following two criteria:
  - The global temperature target
  - The regional distribution of the mitigation effort associated with each target.
- Regarding the temperature target, in addition to a baseline scenario where no climate policy is set, three scenarios have been chosen:
  - The Nationally Determined Contributions (hereinafter NDCs),
  - 2ºC stabilization target
  - 1.5ºC stabilization target (both objectives for the year 2100).
- The regional distribution of the effort is based on 3 criteria: constant emissions ratio, a capability criteria and an equality criteria. There are more but these seem to us the most likely to be used to determine actual distributions.

WHAT THE ALLOCATIONS MEAN: % REDUCTIONS RELATIVE TO THE NDC SCENARIO (2020-2050)

	2C_CAP	2C_CER	2C_EPC	1.5C_CAP	1.5C_CER	1·5_EPC
China	-69%	-35%	-52%	-75%	-54%	-65%
USA	-40%	57%	-16%	-52%	8%	-37%
EU-27	-43%	35%	-4%	-55%	-7%	-31%
India	-60%	-71%	-36%	-72%	-79%	-58%
ROW	-50%	-47%	-46%	-64%	-63%	-62%
Total	-55%	-35%	-42%	-67%	-55%	-59%

CO_2 EMISSIONS BY YEAR AND SCENARIO



DISTRIBUTION OF MITIGATION EFFORT

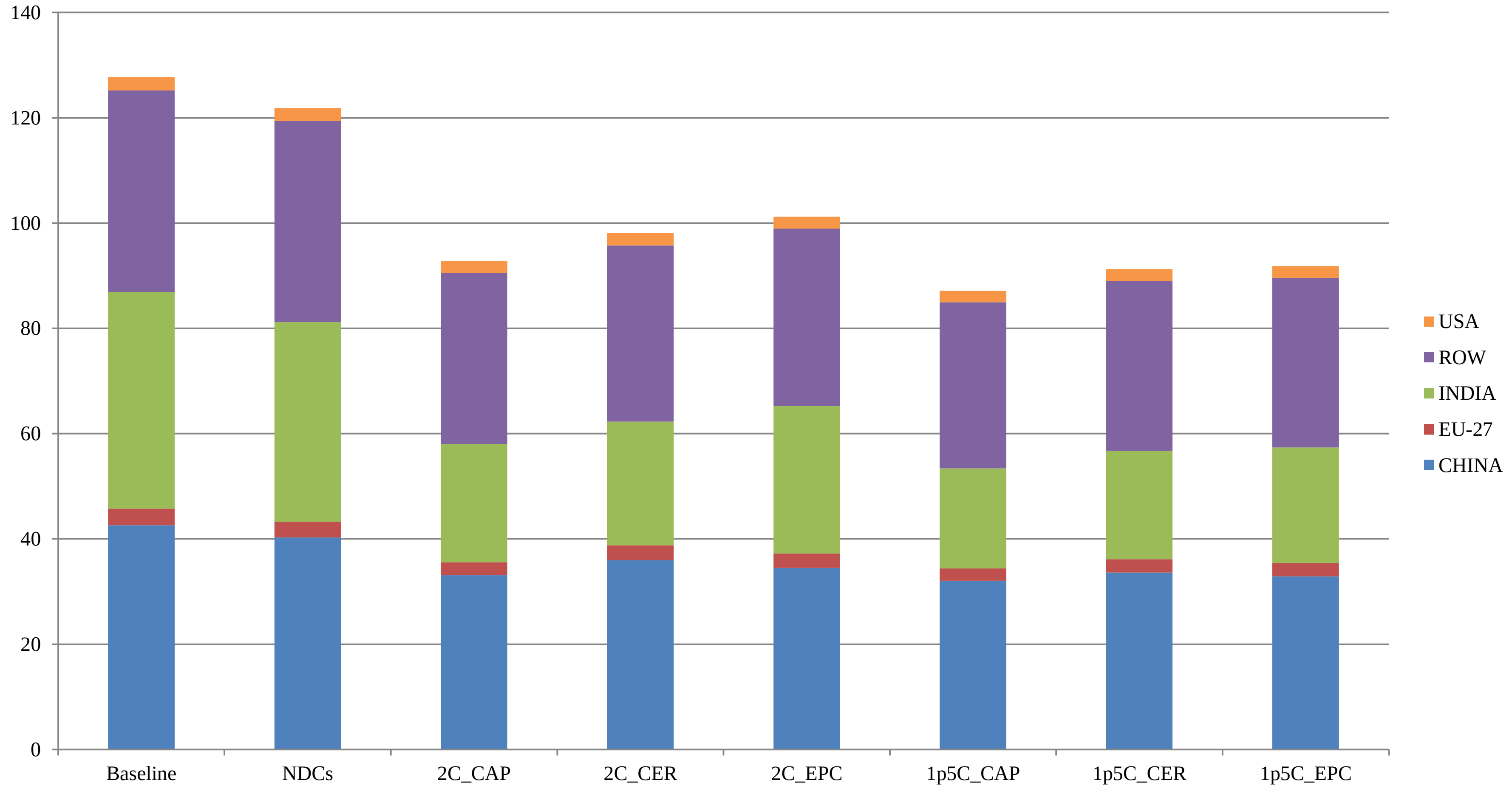
Allocation name	Code	IPCC Category	Allocation characteristics
Constant emission ratios	CER	Staged approach	Maintains current emission ratios, preserves status quo. This approach also referred to as grandfathering, is not considered as an equitable option in climate justice and is not supported as such by any Party.
Capability	CAP	Capability	Countries with high GDP per capita have low emissions allocations
Equal per capita	EPC	Equality	Convergence towards equal annual emissions per person by 2040

Robiou du Pont Y, Jeffery ML, Gütschow J, Rogelj J, Christoff P, Meinshausen M. Equitable mitigation to achieve the Paris Agreement goals. Nat Clim Change. 2016 Dec 19;7(1):38–43

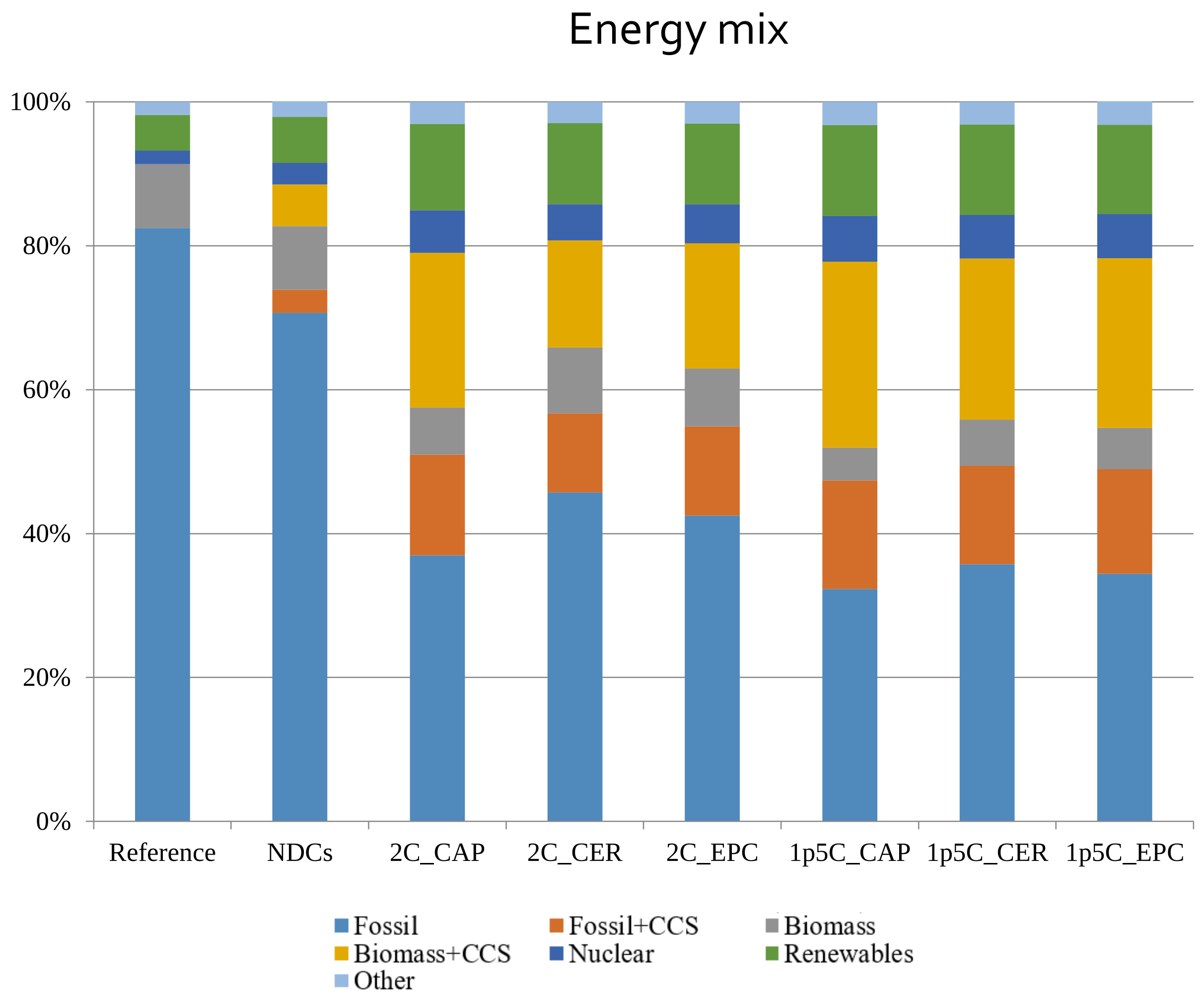
RESULTS: DEATHS AVOIDED

- In the NDC scenario the number of deaths decreases around 5% relative to the reference
- The reductions for the mitigation scenarios are 21-27% for the 2ºC scenarios and 28-32% for the 1·5ºC scenarios.
- The highest number of premature deaths are in China (33-37% of the global deaths) and India (24-32%)
- The 2°C and 1.5° C targets benefit India most, then China but not so much the EU and USA

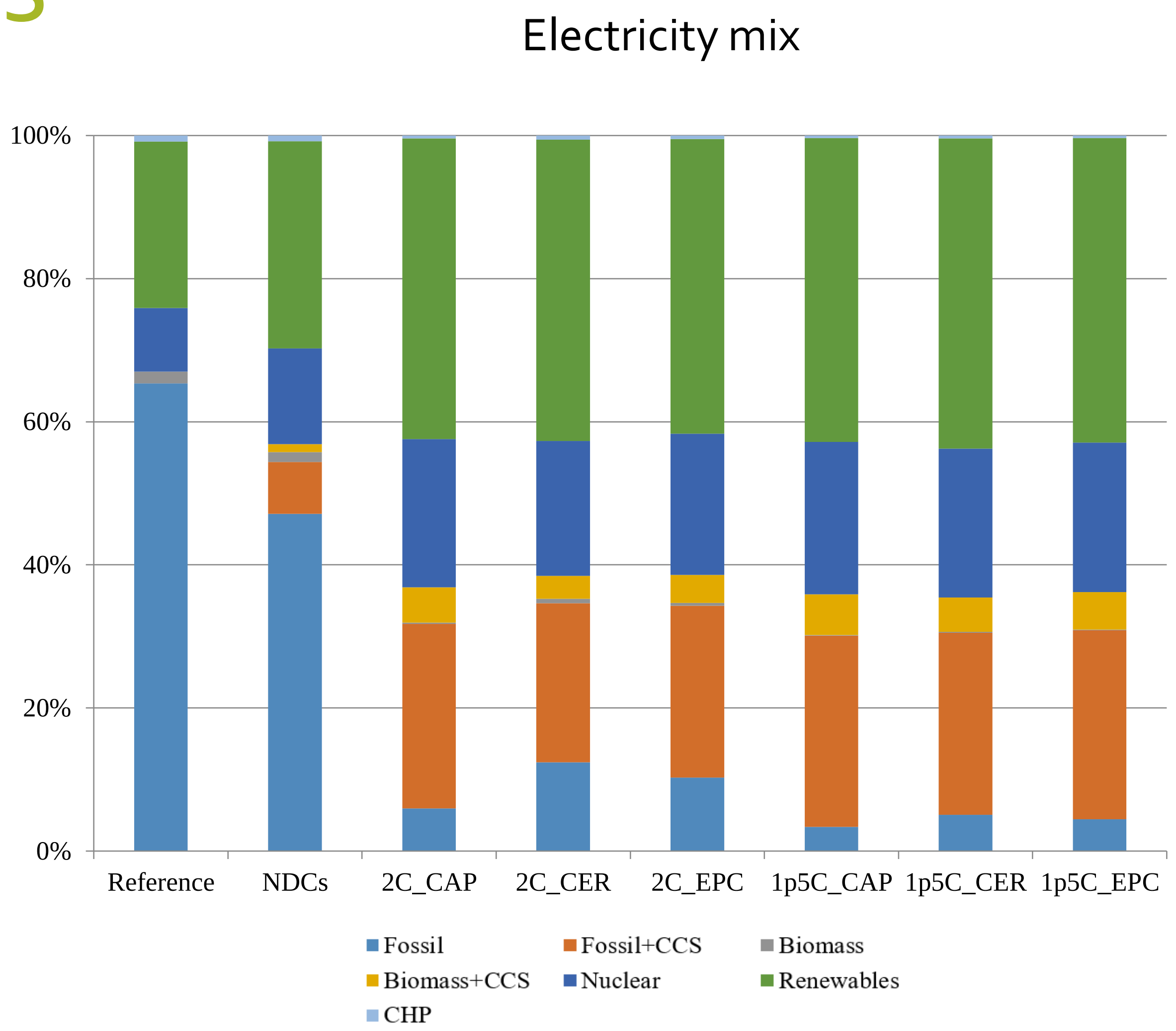
Cumulative (2020-2050) premature deaths per region and scenario (million people)



Results



Energy mix
100%
80%
60%
40%
20%
0%
Reference
NDCs
2C_CAP
2C_CER
2C_EPC
1p5C_CAP
1p5C_CER
1p5C_EPC
Fossil
Fossil+CCS
Biomass
Biomass+CCS
Nuclear
Renewables
Other



Electricity mix
100%
80%
60%
40%
20%
0%
Reference
NDCs
2C_CAP
2C_CER
2C_EPC
1p5C_CAP
1p5C_CER
1p5C_EPC
Fossil
Fossil+CCS
Biomass
Biomass+CCS
Nuclear
Renewables
CHP

RESULTS: MITIGATION COSTS

- Cost shares for the scenarios vary a great deal depending on which mitigation sharing option is chosen.
- From a global macroeconomic perspective, these costs are low. For the 2°C target the global costs range from 0·5% to 1% of global GDP, while for the 1·5°C target the range is 1%-1·3%.
- Between the scenarios the lowest costs emerge under the CER or EPC scenario and the highest ones under the CAP scenario.
- Costs are cumulative for 2020-2050 added using a 3% discount rate. Sensitivity analysis shows that relative costs do not change much with 0% or 6% rates.

MITIGATION COSTS BY REGION AND SCENARIO (2020-2050)

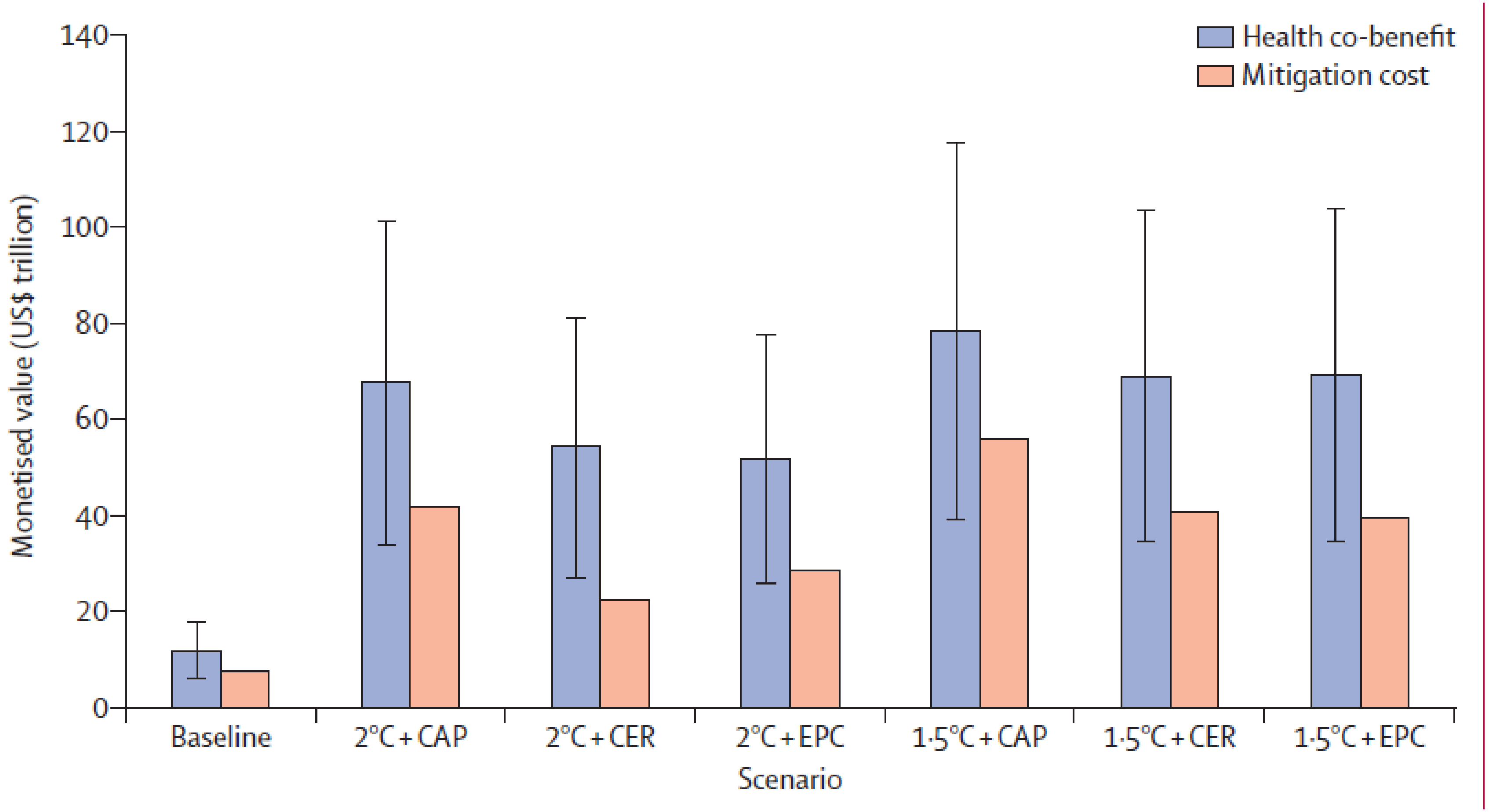
	NDCs	2°C + CAP	2°C + CER	2°C + EPC	1·5°C + CAP	1·5°C + CER	1·5°C + EPC
USA	66·3% ($4·9 trillion)	20·2% ($8·4 trillion)	9·4% ($2·1 trillion)	22·5% ($6·4 trillion)	17·7% ($9·9 trillion)	12·4% ($5·0 trillion)	19·3% ($7·7 trillion)
EU-27	28·9% ($2·2 trillion)	11·5% ($4·8 trillion)	4·5% ($1·0 trillion)	9·0% ($2·5 trillion)	10·4% ($5·8 trillion)	6·9% ($2·8 trillion)	9·4% ($3·7 trillion)
China	3·2% ($0·2 trillion)	31·1% ($13·0 trillion)	18·6% ($4·1 trillion)	28·1% ($8·0 trillion)	27·9% ($15·6 trillion)	21·8% ($8·8 trillion)	26·1% ($10·4 trillion)
India	1·0% ($0·1 trillion)	9·4% ($3·9 trillion)	23·0% ($5·1 trillion)	6·2% ($1·8 trillion)	10·2% ($5·7 trillion)	16·0% ($6·5 trillion)	7·8% ($3·1 trillion)
ROW	0·6% ($0·0 trillion)	27·8% ($11·6 trillion)	44·5% ($9·8 trillion)	34·2% ($9·7 trillion)	33·9% ($19·0 trillion)	43·0% ($17·4 trillion)	37·4% ($14·9 trillion)
Total	100% ($7·5 trillion)	100% ($41·6 trillion)	100% ($22·1 trillion)	100% ($28·3 trillion)	100% ($56·1 trillion)	100% ($40·6 trillion)	100% ($39·7 trillion)

Regions are ordered according to their income per capita. Percentages are the proportion of global mitigation cost borne by each region and values in parentheses are absolute mitigation costs in US$. The discount rate used for the calculation is 3%. NDCs=nationally determined contributions. CAP=capability scenario. CER=constant emission ratios scenario. EPC=equal per capita scenario. EU-27=the 27 countries of the European Union in 2007–13. ROW=the rest of the world.

HEALTH CO-BENEFITS RELATIVE TO MITIGATION COSTS

- Next figure shows the health co-benefits and mitigation cost for each scenario.
- Health co-benefits are the difference between the monetized health damage of each policy scenario with respect the baseline.
- The figure includes an uncertainty range based on a sensitivity analysis for VSL -- the variable most influential in determining the health benefits – with the lower and the upper VSL values drawn from the literature.
- The most notable result is that at the global level the central value of the health co-benefit is greater than the cost of achieving the mitigation target for all the scenarios.
- The health co-benefit to mitigation cost ratio ranges from 1·4 (1.5C_CAP) to 2·45 (2C_CER) for the central value.
- The sensitivity analysis shows that even when taking the lower bound (of VSL), the health co-benefits are very close to the mitigation cost, covering between 70-91% of that cost.

HEALTH CO-BENEFITS VS. MITIGATION COSTS (GLOBAL FIGURES)



NET MARGINAL BENEFITS BY REGION AND SCENARIO

- More important are the net benefits of different policies by region.
- The next table shows these net benefits in steps. The first row gives the net benefits (health benefits - mitigation costs) for the NDC versus the baseline. The next block gives the net benefits of various scenarios for 2°C relative t the baseline. The last block give the additional benefits of going from a 2°C to a 1.5°C target.
- For the NDCS not all regions have positive net benefits (EU, ROW and USA have a cost). But the cost is small (about 1-5% of GDP). India and China have a net gain.
- For the 2°C target the same regions have a cost, which depends on the allocation rule. The cost is in the range 0.5-5.9% for EU and 1.5-8.6% for USA. India and China remain beneficiaries.
- The marginal benefits of going to 1.5°C from a 2°C are positive for India and China. There are small net costs for the other regions – in the range of 0.4-1.3% for the EU and 1.1-3.0% for the USA.

Scenario	China	EU-27	India	ROW	USA	TOTAL
NDCs	6.36(3.06 ; 9.66)	-2.01(-2.08 ; -1.93)	5.12(2.52 ; 7.72)	-0.72(-0.38 ; -1.06)	-4.42(-4.68 ; -4.16)	4.33(-1.57 ; 10.24)
2°C						
CAP	14.49(0.77 ; 28.21)	-2.70(-3.74 ; -1.67)	26.25(11.18 ; 41.33)	-5.01(-8.29 ; -1.73)	-7.12(-7.76 ; -6.48)	25.91(-7.84 ; 59.67)
CER	14.89(5.39 ; 24.39)	-0.22(-0.60 ; 0.17)	23.40(9.16 ; 37.64)	-4.81(-7.32 ; -2.29)	-1.23(-1.65 ; -0.81)	32.03(4.97 ; 59.10)
EPC	15.22(3.62 ; 26.82)	-1.22(-1.88 ; -0.56)	19.21(8.73 ; 29.70)	-4.42(-7.05 ; -1.79)	-5.33(-5.85 ; -4.81)	23.46(-2.44 ; 49.35)
1·5°C						
CAP	0.27(-1.21 ; 1.75)	-0.27(-0.65 ; 0.12)	3.76(0.98 ; 6.55)	-6.21(-6.83 ; -5.59)	-1.21(-1.37 ; -1.06)	-3.66(-9.08 ; 1.77)
CER	2.08(-1.32 ; 5.47)	-0.60(-1.20 ; -0.01)	3.28(0.93 ; 5.63)	-5.92(-6.76 ; -5.08)	-2.47(-2.70 ; -2.24)	-3.63(-11.05 ; 3.78)
EPC	2.31(-0.05 ; 4.67)	-0.19(-0.68 ; 0.31)	8.40(3.53 ; 13.28)	-3.46(-4.32 ; -2.60)	-0.93(-1.11 ; -0.76)	6.14(-2.63 ; 14.90)
GDP	73	46	35	131	48	333

Figures are cumulative 2020-2050 in US$ trillion discounted at 3%. Scenario is SSP2.

CONCLUSIONS

- Globally the co-benefits are enough to outweigh the mitigation costs for the Paris Targets under all 3 allocation rules.
- The net benefits are quite large for India and China, especially India.
- The other regions have a net cost. It depends on the allocation rule and is relatively small.
- In all calculations we have not taken into account the **benefits of the targets** in terms of less impacts from climate change!
- Various studies show these to be comparable with the costs imposed on the regions that face a cost.

POINTS FOR DISCUSSION

- If this is true, why is it difficult to get agreement to commit to the mitigation efforts needed for the 2°C target?
  - When the burden has to be shared for anything there is always disagreement.
  - The costs that matter are not the aggregate costs to 2050 but the short term costs (maybe the next 5 years?)
  - The mitigation costs are concentrated in a few sectors and they are politically powerful in the countries concerned. The health benefits are diffuse and harder to organize for politically.
  - Evidence from psychology/ economics shows that losses have a higher cost than gains.
- What additional actions do we need to take to realise the Paris targets?