Shared Socioeconomic Pathways and Integrated Assessment Models in Climate Science

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History

1990s:

- SRES – Special Report on Emissions Scenarios (IPCC TAR 2001, IPCC AR4 2007)
  - four different possible future trajectories of population, economic growth and GHG emissions.

Later:

- RCPs – Represented Contraction Pathways (IPCC AR5 2014)
  - different levels of GHG and other radiative forcing that might occur in the future
  - four pathways, spanning a broad range of forcing in 2100 (2.6, 4.5, 6.0, and 8.5 W/m2),
  - no socioeconomic “narratives”.
  - set pathways for GHG concentrations and, effectively, the amount of warming

- SSPs – Shared Socioeconomic Pathways (IPCC AR6 2021)
  - five different ways in which the world might evolve in the absence of climate policy
  - how socioeconomic factors (population, economic growth, education, urbanisation and the rate of technological development) may change over the next century.
  - how different levels of climate change mitigation could be achieved when the mitigation targets of RCPs are included.

The development of the SSPs

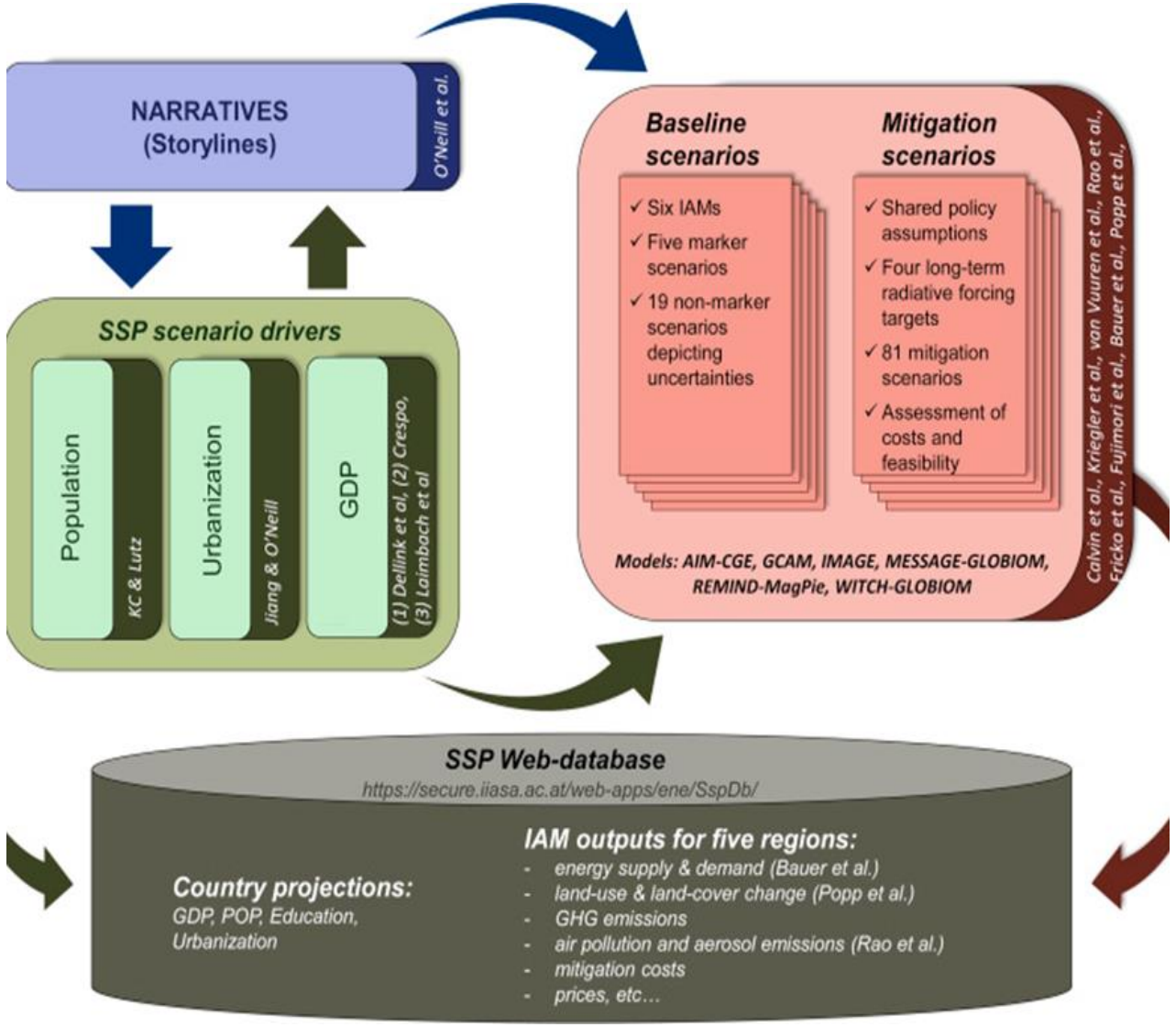
STEP 1 Design of the **narratives**, providing the fundamental underlying logic for each SSP, focusing also on those elements of socioeconomic change that often cannot be covered by formal models.

STEP 2 Extensions of the narratives in terms of model **"input tables", describing in qualitative terms the main SSP characteristics** and scenario assumptions.

STEP 3 Elaboration of the basic elements of the SSPs in terms of **demographic and economic drivers** using quantitative models.

STEP 4 Elaboration of developments in the energy system, land use and greenhouse gas and air pollutant emissions of the **SSP baseline scenarios** using a set of Integrated Assessment Models (IAMs)

STEP 5 Elaboration of these elements by IAMs for the **SSP mitigation scenarios**.



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SSP Narratives

SSP1: Sustainability (Taking the Green Road)

SSP2: Middle of the Road

SSP3: Regional Rivalry (A Rocky Road)

SSP4: Inequality (A Road divided)

SSP5: Fossil-fueled Development (Taking the Highway)

Summary of SSP narratives

SSP1 **Sustainability – Taking the Green Road** (Low challenges to mitigation and adaptation)
The world shifts gradually, but pervasively, toward a **more sustainable path**, emphasizing more inclusive development that **respects perceived environmental boundaries**. Management of the global commons slowly improves, educational and health investments accelerate the demographic transition, and the emphasis on economic growth shifts toward a broader **emphasis on human well-being**. Driven by an increasing commitment to achieving development goals, **inequality is reduced** both across and within countries. Consumption is oriented toward **low material growth** and **lower resource and energy intensity**.

SSP2 **Middle of the Road** (Medium challenges to mitigation and adaptation)
The world follows a path in which social, economic, and technological **trends do not shift markedly from historical patterns**. **Development and income growth proceeds unevenly**, with some countries making relatively good progress while others fall short of expectations. Global and national institutions work toward but make **slow progress in achieving sustainable development goals**. **Environmental systems experience degradation**, although there are some improvements and overall the intensity of resource and energy use declines. **Global population growth is moderate** and levels off in the second half of the century. Income inequality persists or improves only slowly and **challenges to reducing vulnerability to societal and environmental changes remain**.

SSP3 **Regional Rivalry – A Rocky Road** (High challenges to mitigation and adaptation)

A resurgent nationalism, concerns about competitiveness and security, and regional conflicts **push countries to increasingly focus on domestic or, at most, regional issues**. Policies shift over time to become increasingly oriented toward national and regional security issues. Countries focus on achieving **energy and food security goals within their own regions at the expense of broader-based development**. **Investments in education and technological development decline. Economic development is slow, consumption is material-intensive**, and **inequalities persist or worsen over time**. **Population growth** is low in industrialized and high in developing countries. A low international priority for addressing environmental concerns leads to **strong environmental degradation in some regions**.

SSP4 **Inequality – A Road Divided** (Low challenges to mitigation, high challenges to adaptation)

Highly unequal investments in human capital, combined with **increasing disparities in economic opportunity and political power**, lead to increasing inequalities and stratification both across and within countries. Over time, **a gap widens** between an internationally-connected society that contributes to knowledge- and capital-intensive sectors of the global economy, and a fragmented collection of lower-income, poorly educated societies that work in a labor intensive, low-tech economy. **Social cohesion degrades and conflict and unrest** become increasingly common. **Technology development is high in the high-tech economy and sectors**. The globally connected energy sector diversifies, with **investments in both carbon-intensive fuels like coal and unconventional oil, but also low-carbon energy sources**. **Environmental policies focus on local issues around middle and high income areas.**

SSP5 **Fossil-fueled Development – Taking the Highway** (High challenges to mitigation, low challenges to adaptation)

This world places increasing faith in **competitive markets, innovation and participatory societies** to produce rapid **technological progress and development of human capital** as the path to sustainable development. Global markets are increasingly integrated. There are also **strong investments in health, education, and institutions to enhance human and social capital**. At the same time, the push for economic and social development is coupled with the **exploitation of abundant fossil fuel resources** and the adoption of **resource and energy intensive lifestyles** around the world. All these factors lead to **rapid growth of the global economy**, while global population peaks and declines in the 21st century. **Local environmental problems like air pollution are successfully managed**. There is faith in the ability to effectively manage social and ecological systems, including by geo-engineering if necessary.

Mitigation and adaptation challenges

SSP1: Sustainability (Taking the Green Road)

SSP2: Middle of the Road

SSP3: Regional Rivalry (A Rocky Road)

SSP4: Inequality (A Road divided)

SSP5: Fossil-fueled Development (Taking the Highway)

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1: Qualitative assumptions for energy demand

SSP Element	SSP 1			SSP 2			SSP 3			SSP 4			SSP 5		
	Country Income Groupings														
	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High	Low	Med	High
Non-climate Policies															
Traditional Fuel Use	fast phase-out, driven by policies and economic development			intermediate phase-out, regionally diverse speed			continued realiance on traditional fuels			continued traditional fuel use	some traditional fuel use among low income housholds		fast phase-out, driven by development priority		
Energy Demand Side															
Lifestyles	modest service demands (less material intensive)			medium service demands (generally material intensive)			medium service demands (material intensive)			low service demands	modest service demands		high service demands (very material intensive)		
Environmental Awareness	high			medium			low			low	high		medium (low for global level/high for local level)		
Energy Intensity of Services															
Industry	low			medium			high			high	low		medium		
Buildings	low			medium			high			medium	low/medium		medium		
Transportation	low			medium			medium		high	low/medium	low		high		
General Comments				some regional diversity retained											

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2: Qualitative assumptions for fossil energy supply

	SSP1	SSP2	SSP3		SSP4			SSP5
	Sustainability	Middle of the Road	Regional Rivalry		Inequality			Fossil fueled development
			Country grouping		Country grouping by income			
			Exporter	Importer	Low	Medium	High	
Coal								
Macro-economy	cost driver	neutral	cost reducing		cost driver	cost driver	neutral	cost reducing
Technological progress	slow	medium	slow	fast		medium		very fast
National & environmental policy	very restrictive	supportive	very suportive		supportive	supportive	restrictive	very supportive
Conv. hydrocarbons								
Macro-economy	neutral	neutral	neutral		cost driver	neutral	cost reducing	cost reducing
Technological progress	medium	medium	medium			fast		very fast
National & environmental policy	restrictive	supportive	not supportive	supportive	supportive	supportive	restrictive	very supportive
Unconv. hydrocarbons								
Macro-economy	neutral	neutral	neutral		cost driver	neutral	cost reducing	cost reducing
Technological progress	slow	medium	slow	medium		medium		very fast
National & environmental policy	very restrictive	supportive	not supportive	very supportive	supportive	supportive	restrictive	very supportive
General								
Trade barriers	free trade	some barriers	high barriers			barriers		free

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3: Qualitative assumptions for energy conversion technologies

	SSP 1			SSP 2			SSP 3			SSP 4			SSP 5		
	Country Income Groupings														
SSP Element	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**	**Low**	**Med**	**High**
Conventional and Unconventional Fossil Fuel Conversion (synfuel and syngas in parenthesis if different)															
Technology Development		Med			Med			Low		Low	Med	Med		Med (High)	
Social Acceptance		Low			Med			High		High	Low	Low		High	
Commercial Biomass Conversion															
Technology Development		High			Med			Low		High	High	High		Med	
Social Acceptance		Low			Med			High		High	High	High		Med	
Non-bio Renewables Conversion															
Technology Development		High			Med			Low		High	High	High		Med	
Social Acceptance		High			Med			Med		High	High	High		Low	
Nuclear Power															
Technology Development		Med			Med		Low	Low	Med	High	High	High		Med	
Social Acceptance		Low			Med		High	High	High	High	Med	Med		Med	
CCS (under climate policy only)															
Technology Development		Med			Med			Med		High	High	High		High	
Social Acceptance		Low			Med			Med		High	Med	Med		Med	

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4: Qualitative assumptions for Land-use change dynamics

SSP1	SSP2	SSP3	SSP4	SSP5
Land use is strongly regulated, e.g. tropical deforestation rates are strongly reduced. Crop yields are rapidly increasing in low- and medium-income regions, leading to a faster catching-up with high income countries. Healthy diets with low animal-calorie shares and low waste prevail. In an open, globalized economy, food is traded internationally.	Land use change is incompletely regulated, i.e. tropical deforestation continues, although at slowly declining rates over time. Rates of crop yield increase decline slowly over time, but low-income regions catch up to a certain extent. Caloric consumption and animal calorie shares converge towards medium levels. International trade remains to large extent regionalised.	Land use change is hardly regulated, i.e. tropical deforestation continues at current rates. Rates of crop yield increase decline strongly over time, due to little investment. While rich countries are characterized by unhealthy diets with high animal shares wasteful treatment of food, risk of hunger remains high in many poor countries. A regionalized world leads to reduced trade flows.	Land use change is strongly regulated in high income countries, but tropical deforestation still occurs in poor countries. High income countries achieve high crop yield increases, while low income countries remain relatively unproductive in agriculture. Caloric consumption and animal calorie shares converge towards medium levels. Food trade is globalized, but access to markets is limited in poor countries, increasing vulnerability for non-connected population groups.	Land use change is incompletely regulated, i.e. tropical deforestation continues, although at slowly declining rates over time. Crop yields are rapidly increasing. Unhealthy diets with high animal shares and high waste prevail. Barriers to international trade are strongly reduced, and strong globalization leads to high levels of international trade.

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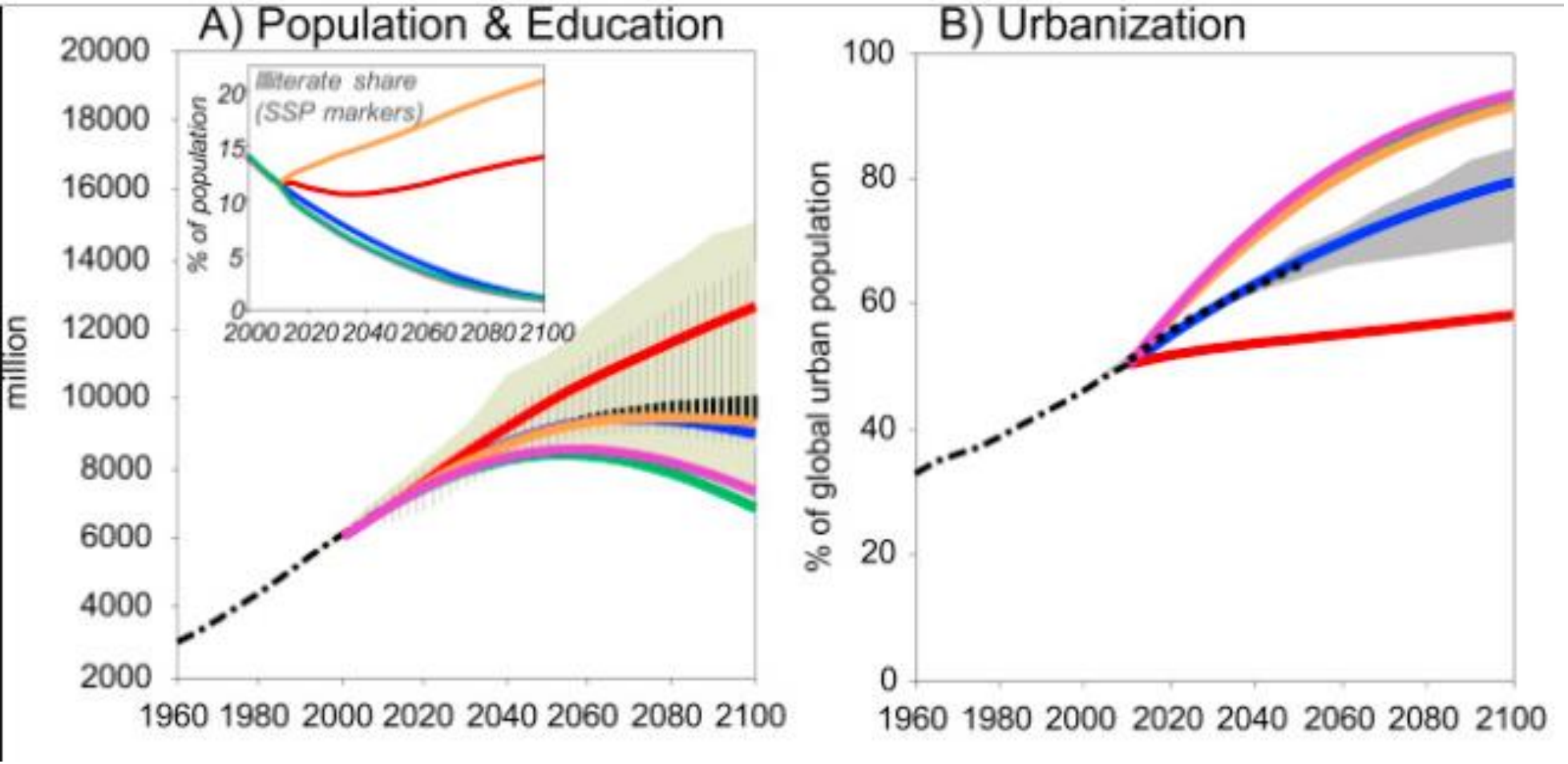
Demographic drivers



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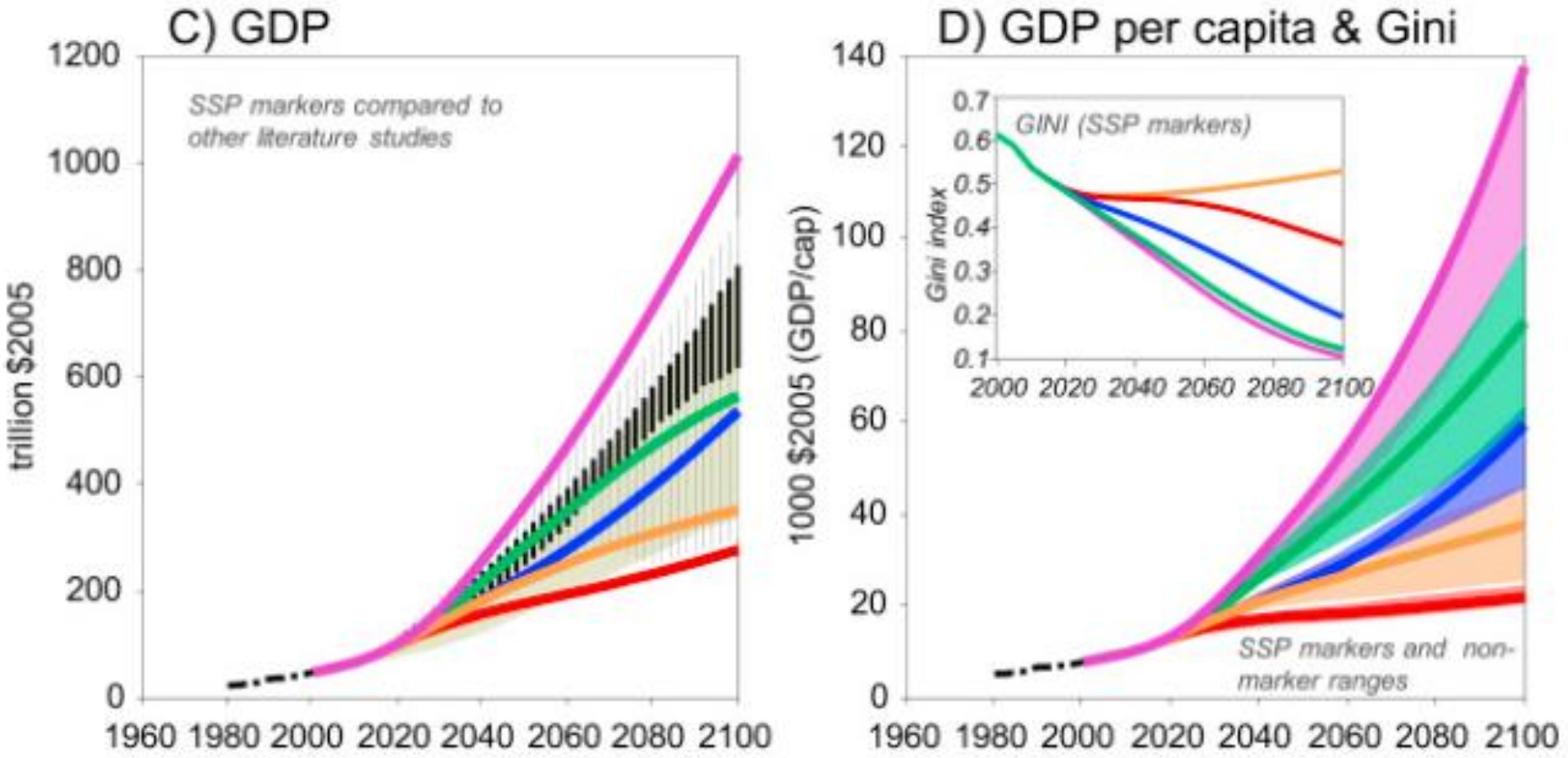
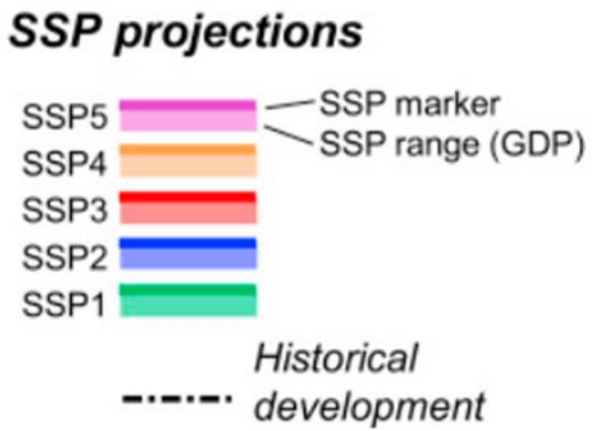
Economic drivers





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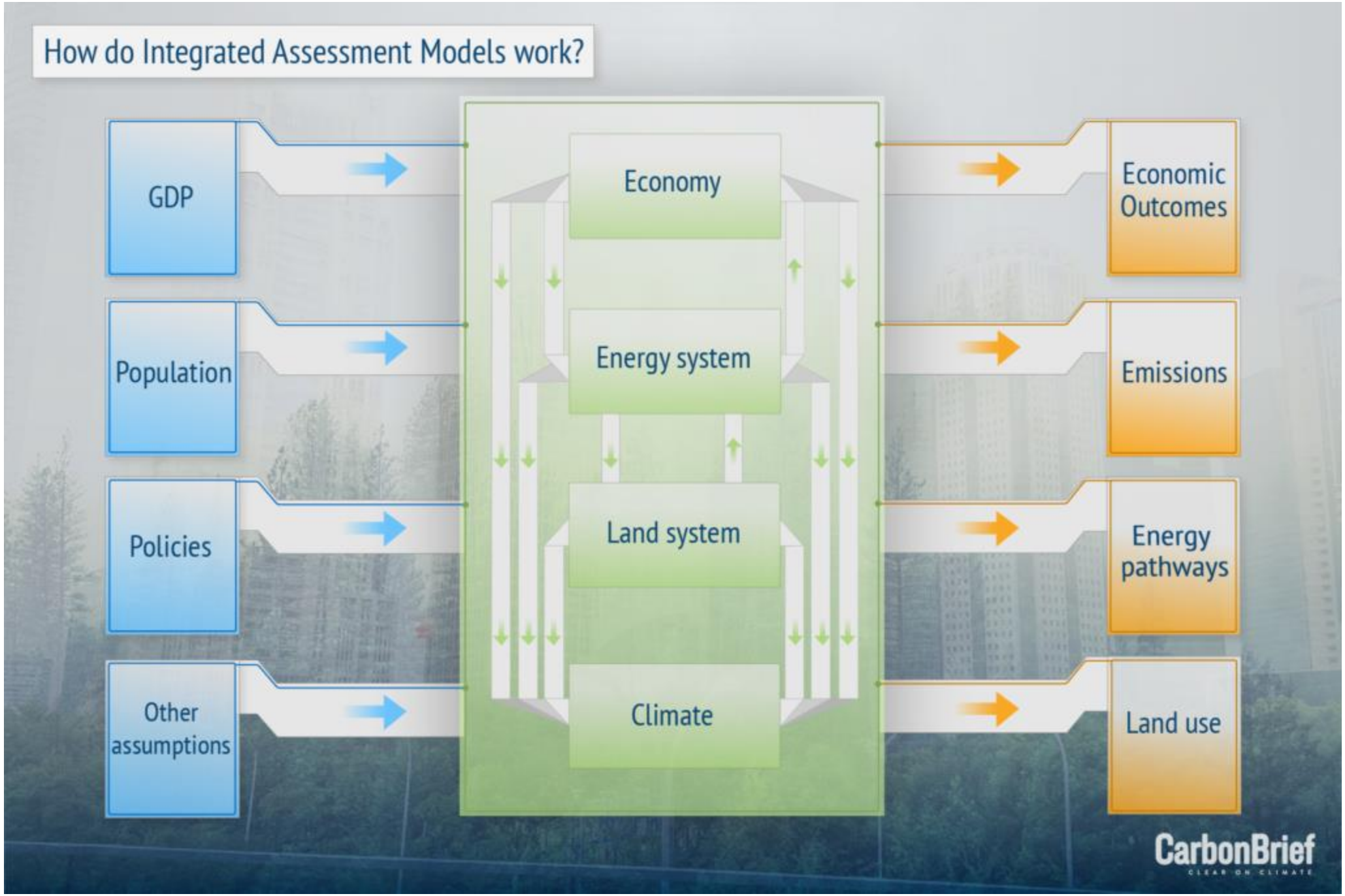
How do Integrated Assessment Models work?
GDP
Population
Policies
Other assumptions
Economy
Energy system
Land system
Climate
Economic Outcomes
Emissions
Energy pathways
Land use
CarbonBrief
CLEAR ON CLIMATE

IAM models as used for the development of the SSP scenarios

Model name (hosting institution)	SSP Marker	SSP coverage (# of scenarios)	Model category	Solution Algorithm
AIM/CGE (NIES)	SSP3 (Fujimori et al.,2016)	SSP1, SSP2, SSP3, SSP4, SSP5 (22 scenarios)	General equilibrium (GE)	Recursive dynamic
GCAM (PNNL)	SSP4 (Calvin et al., 2016)	SSP1, SSP2, SSP3, SSP4, SSP5 (20 scenarios)	Partial equilibrium (PE)	Recursive dynamic
IMAGE (PBL)	SSP1 (van Vuuren et al.,2016)	SSP1, SSP2, SSP3, (13 scenarios)	Hybrid (systems dynamic model and GE for agriculture)	Recursive dynamic
MESSAGE-GLOBIOM (IIASA)	SSP2 (Fricko et al.,2016)	SSP1, SSP2, SSP3, (13 scenarios)	Hybrid (systems engineering partial equilibrium models linked to aggregated GE)	Intertemporal optimization
REMIND-MAgPIE (PIK)	SSP5 (Kriegler et al.,2016)	SSP1, SSP2, SSP5, (14 scenarios)	General equilibrium (GE)	Intertemporal optimization
WITCH-GLOBIOM (FEEM)	–	SSP1, SSP2, SSP3, SSP4, SSP5 (23 scenarios)	General equilibrium (GE)	Intertemporal optimization

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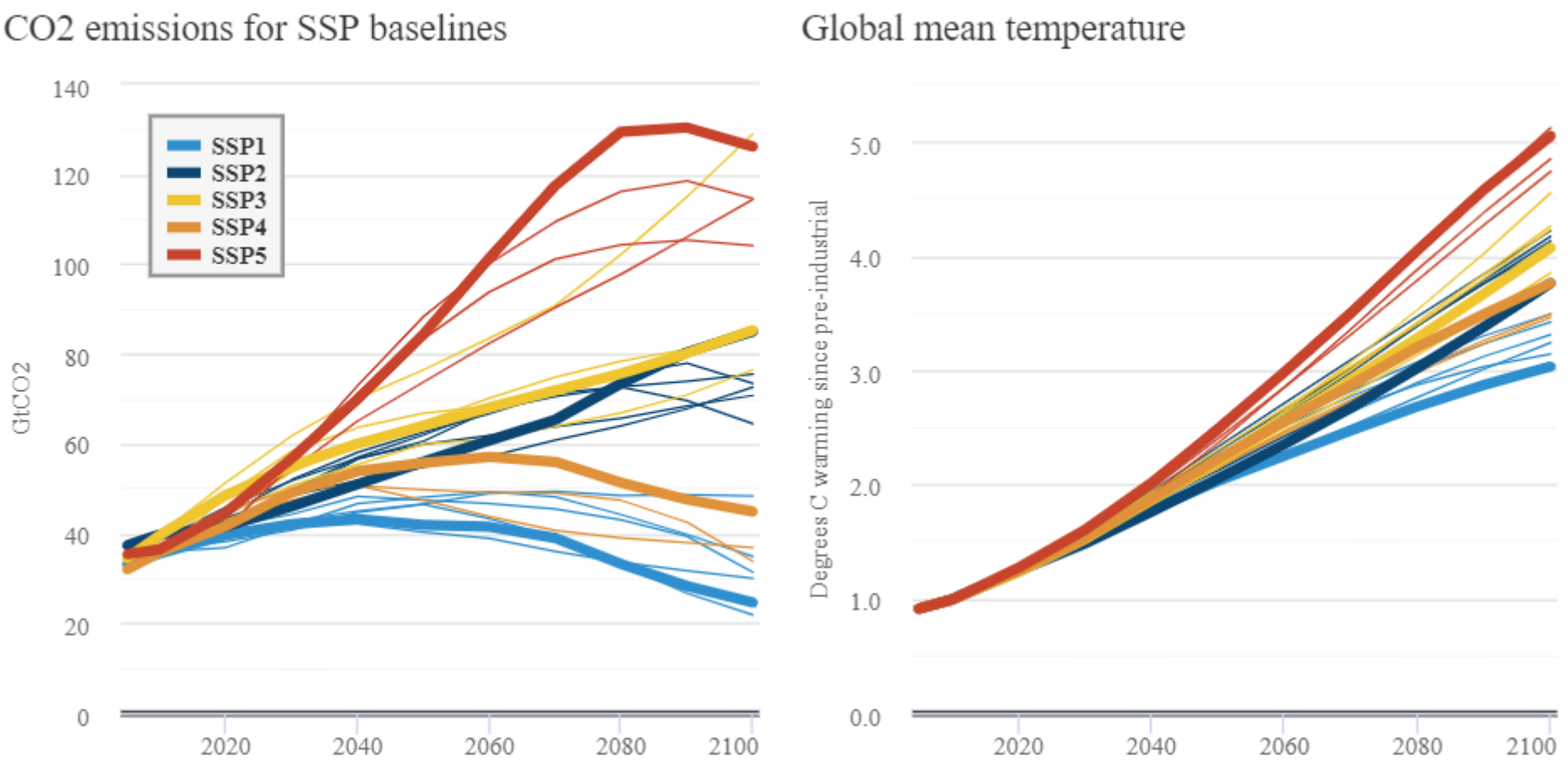
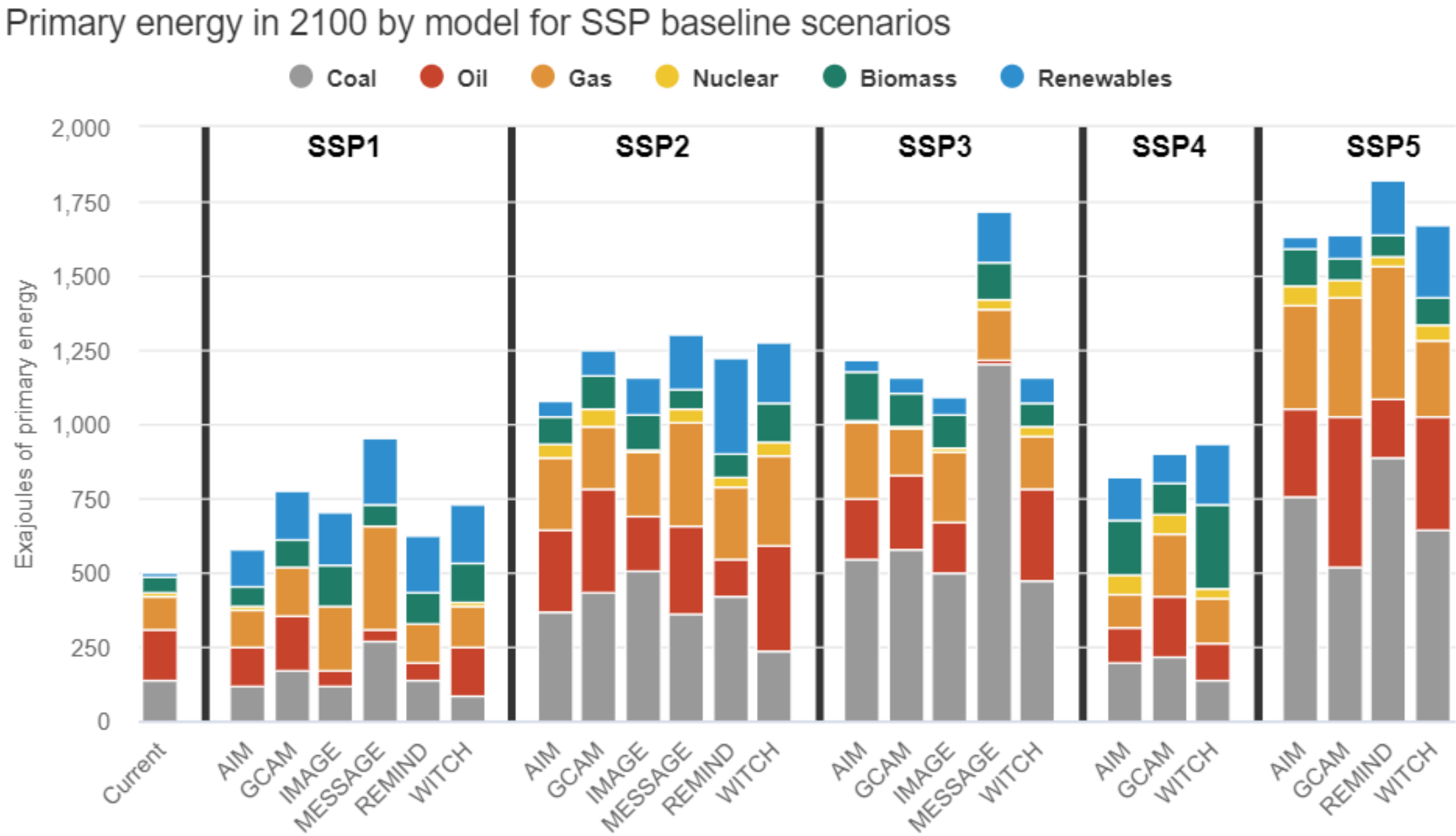


Chart by Carbon Brief

"Model for the Assessment of Greenhouse Gas Induced Climate Change" (MAGICC), a simple climate model which translates emissions into atmospheric concentrations, radiative forcing and global average temperature change



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Shared Policy Assumptions (SPA)

Policy stringency in the near term and the timing of regional participation	**Coverage of land use emissions**
SSP1, SSP4 Early accession with global collaboration as of 2020	*SSP1, SSP5* Effective coverage (at the level of emissions control in the energy and industrial sectors)
SSP2, SSP5 Some delays in establishing global action with regions transitioning to global cooperation between 2020–2040	*SSP2, SSP4* Intermediately effective coverage (limited REDD, but effective coverage of agricultural emissions)
SSP3 Late accession – higher income regions join global regime between 2020–2040, while lower income regions follow between 2030 and 2050	*SSP3* Very limited coverage (implementation failures and high transaction costs)

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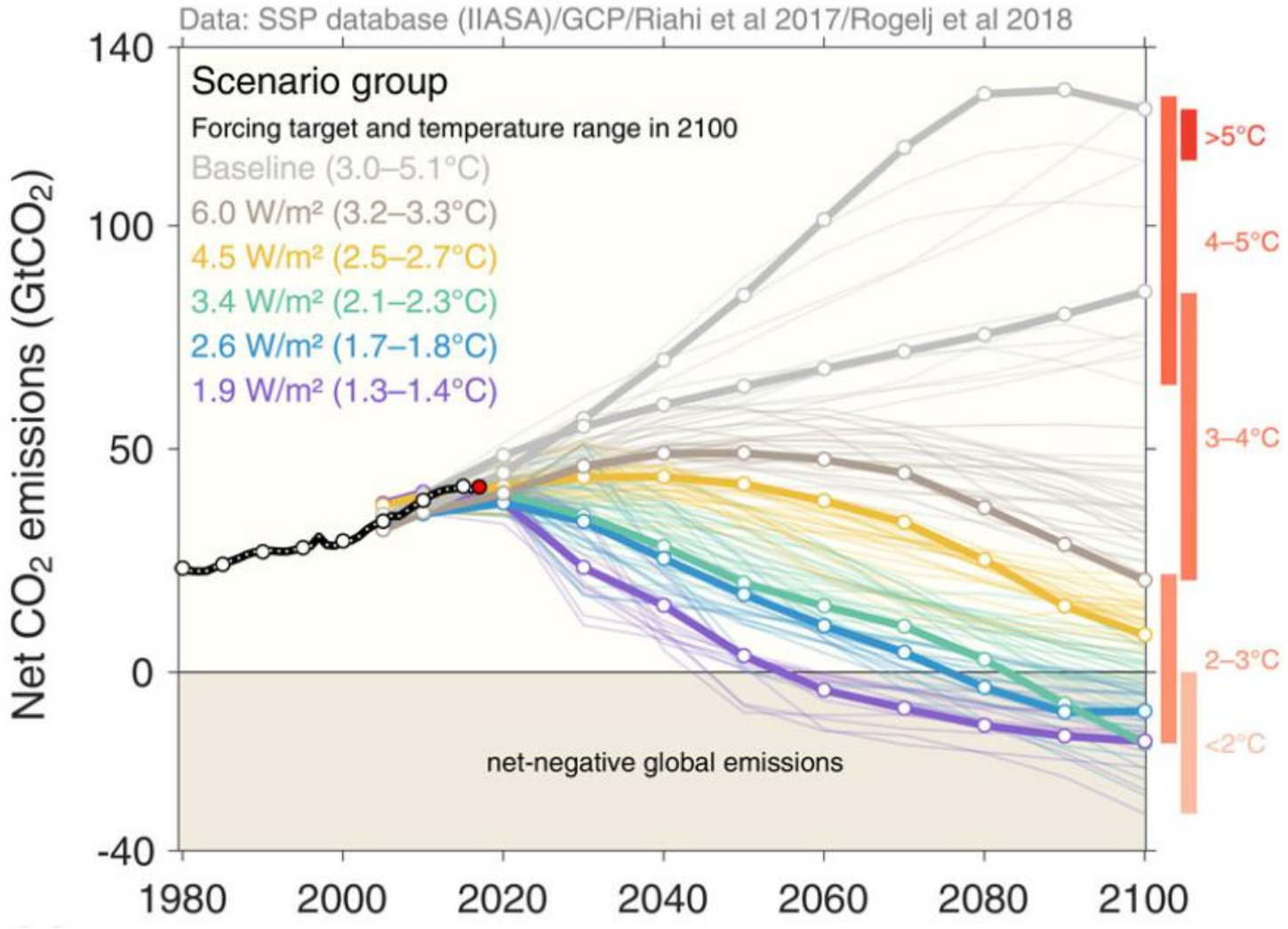
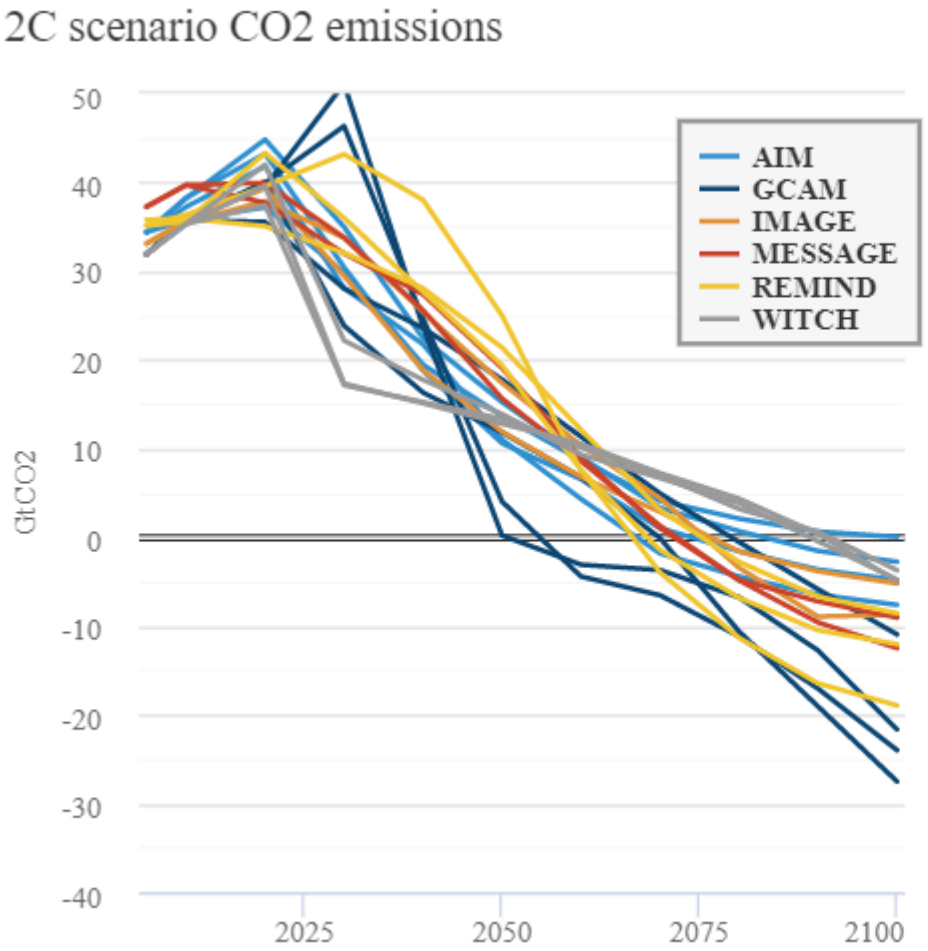
Mitigation Targets

Defined by radiative forcing levels analogous to the RCPs (2.6, 4.5, 6.0 W/m2) + 1.9 W/m2 + 3.4 W/m2



RCP2.6



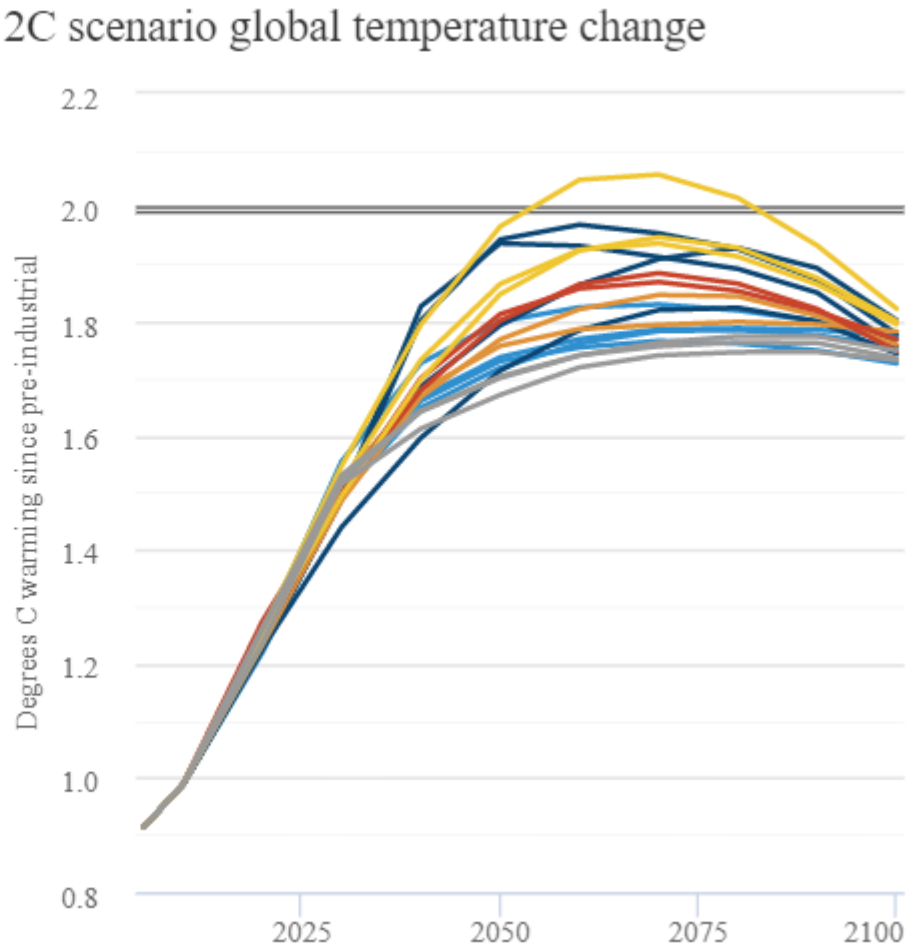
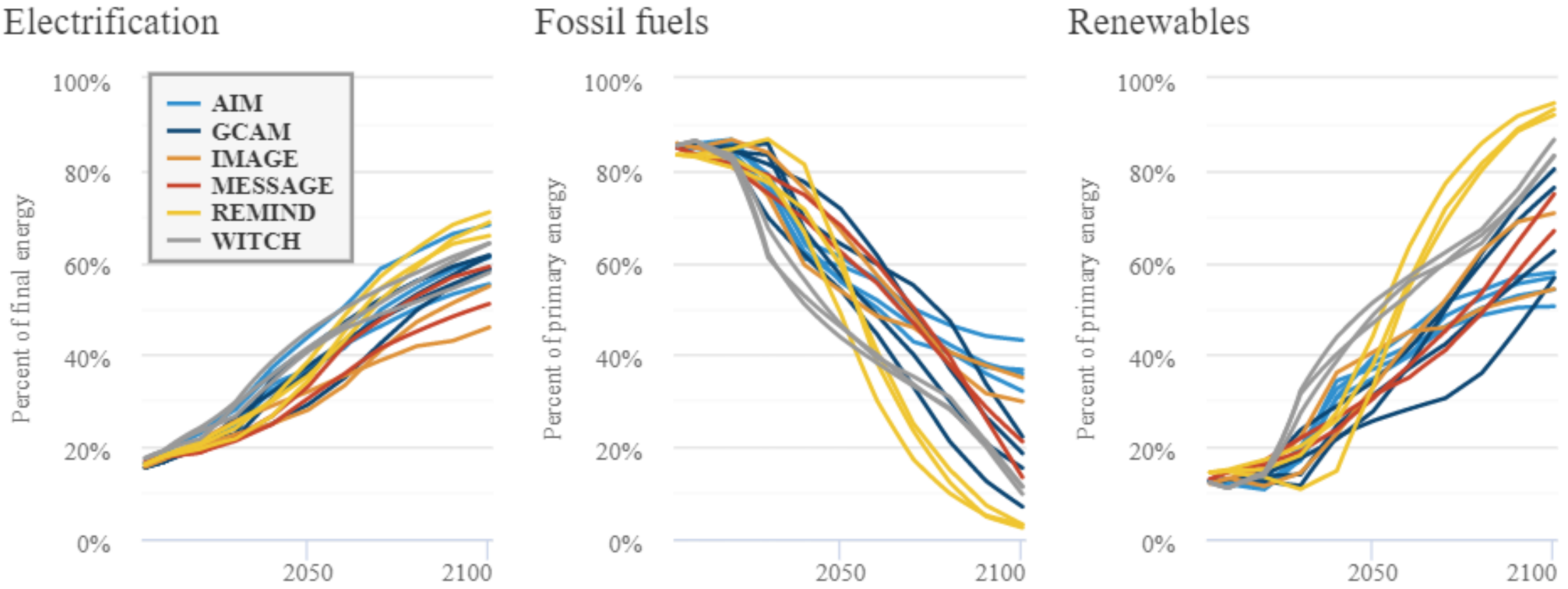


Chart by Carbon Brief

RCP2.6



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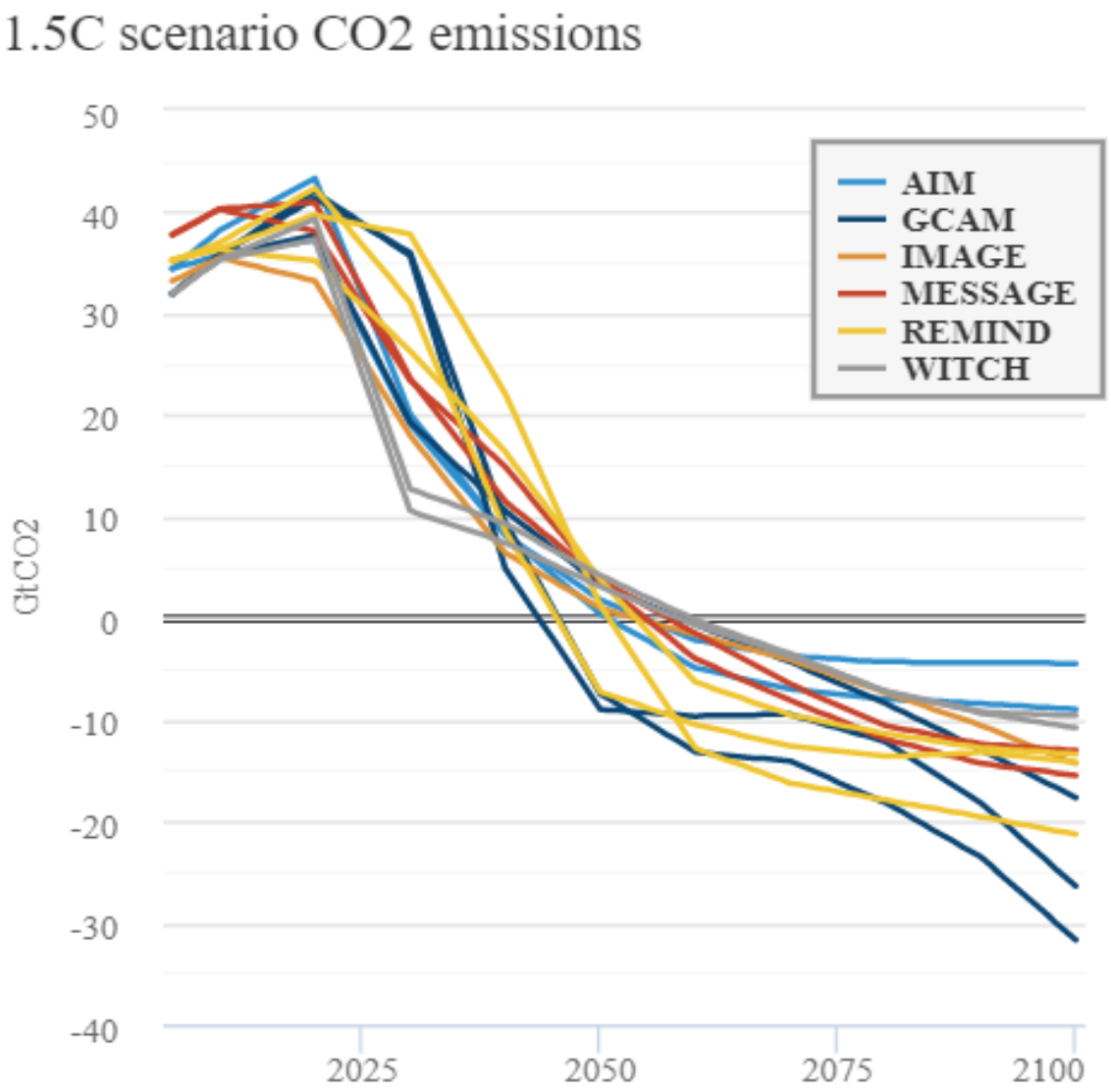
RCP1.9



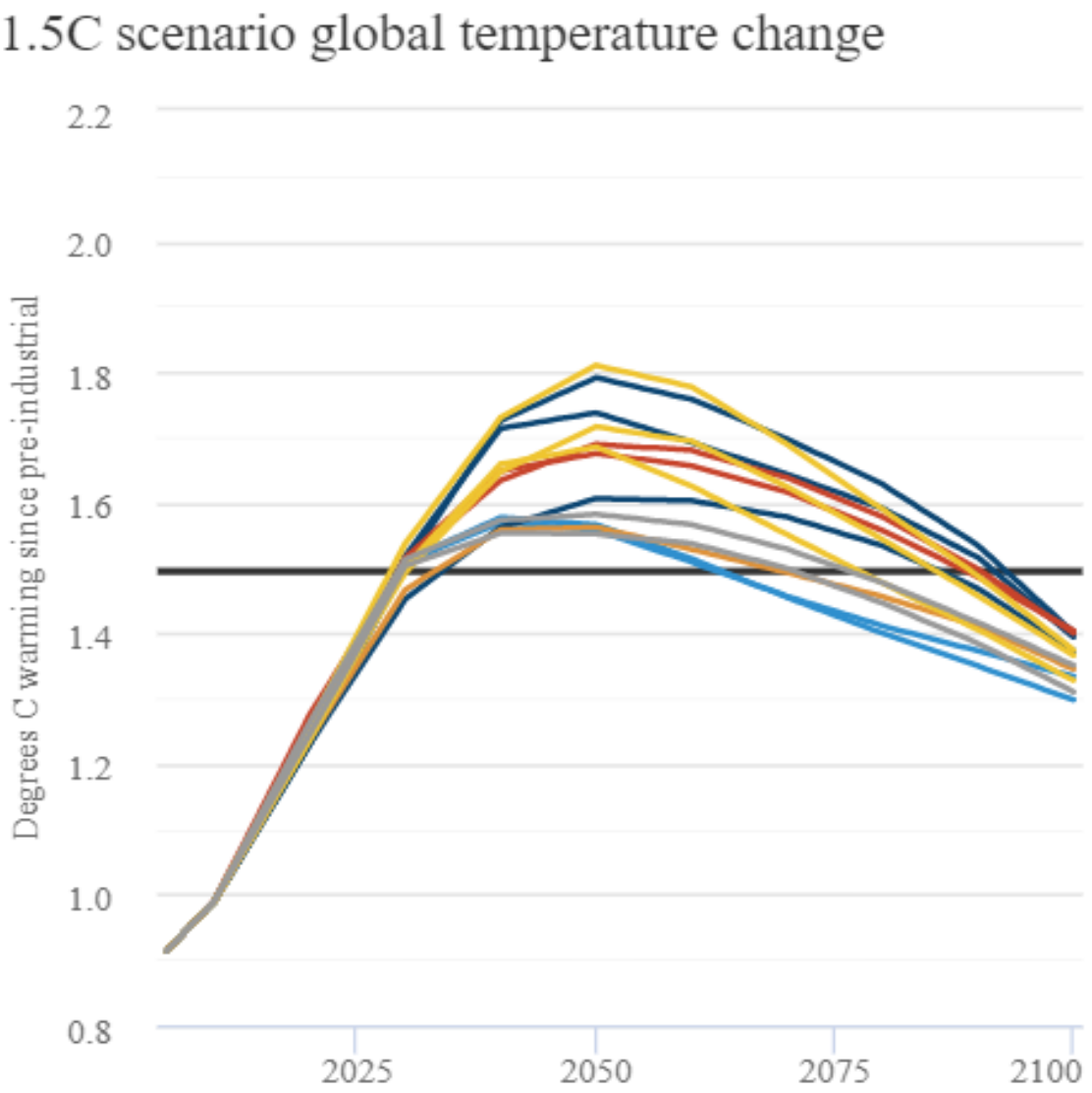
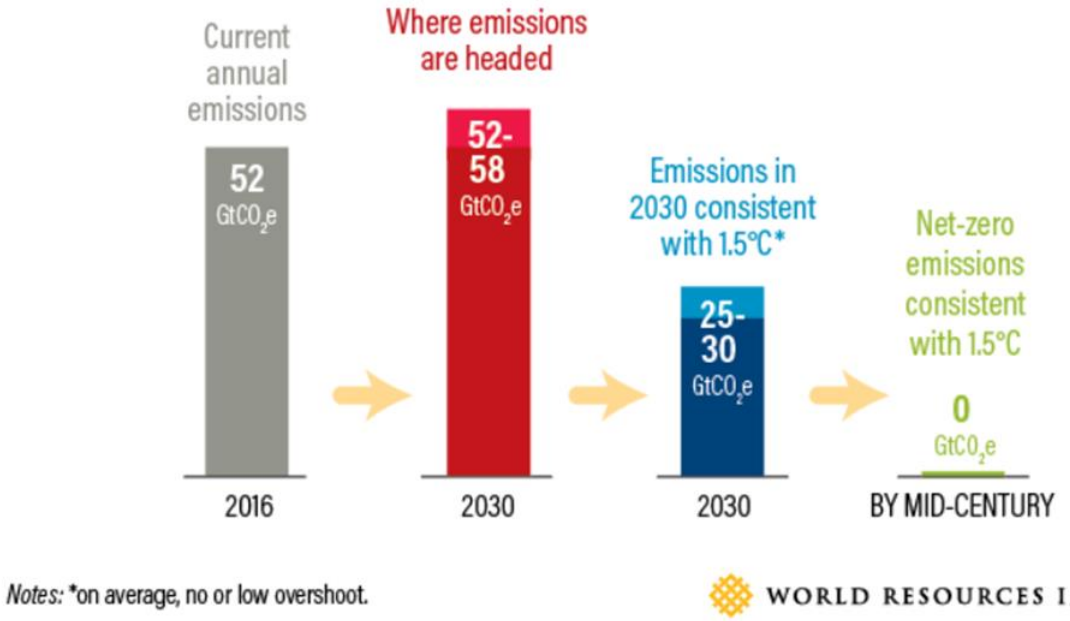


Chart by Carbon Brief

Common features of 1.5°C pathways

- By 2030, halving the emissions, and by mid-century, CO2 emissions falling to net-zero



- Renewables supplying 70 percent to 85 percent of electricity and unabated coal use being largely phased out
- Use of carbon dioxide removal (CDR) in the order of 100 –1000 GtCO2 over the 21st century

CDR deployed at such a scale is unproven, and is a major risk to our ability to limit warming to 1.5˚C !!!

The sector coupling and carbon-neutral energy storage technologies which are hot topics in the energy planning and modeling science could shed a different light, couldn’t they?