IAM History and Role in Climate Negotiations

Prof. Roberto Schaeffer

Centre for Energy and Environmental Economics (Cenergia), COPPE/UFRJ

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How this presentation is organized

1. A Brief History of IAMs
2. How IAMs have been key for IPCC Reports
3. How IAMs are being used for policymaking
4. Final considerations and open discussions

1. Integrated Assessment Models (IAMs): A Brief

IAMs emerged in the 1970s as a response to the need for comprehensive analysis of complex systems. They evolved to incorporate more sectors, technological advancements, and became essential tools for policymakers and researchers to assess the long-term impacts of policy decisions.

Evolution of IAMs

1

Early Focus

Early IAMs focused primarily on energy-economic modeling and understanding the interactions between energy systems and the economy. The first IAMs were relatively simple, with a focus on energy production and consumption dynamics.

2

Environmental Considerations

The introduction of climate change as a global concern led to the incorporation of environmental aspects into IAMs. IAMs evolved to incorporate agriculture, land use, and transportation.

3

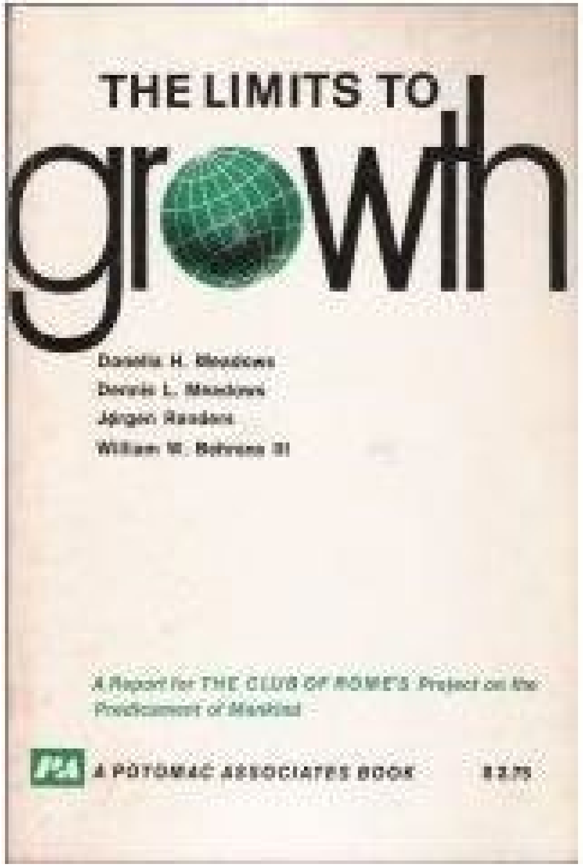
Sophisticated Modeling

Technological advancements and increased computational power allowed for more sophisticated modeling techniques and improved representations of complex systems.

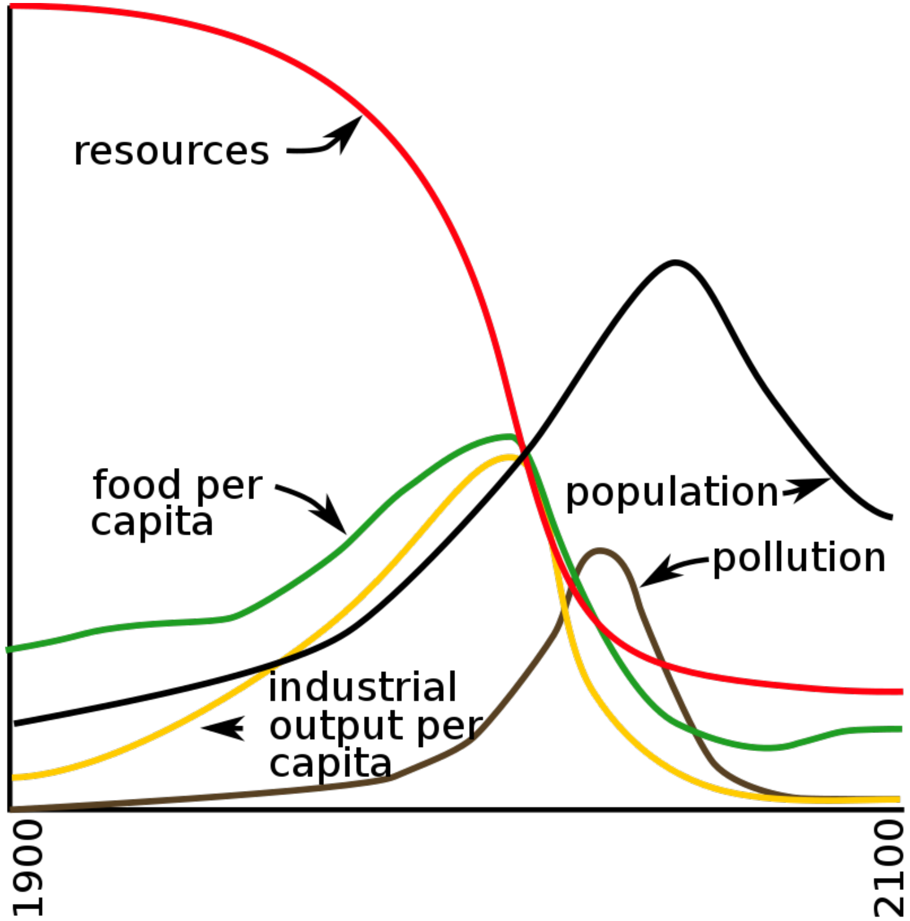
The First Landmark: *The Limits to Growth* World3 Model

Were we on track to sustainable development or steadily depleting the Earth's resources? The pioneering work of the World3 model.

The "Club of Rome Project on Predicament of Mankind at MIT," directed by Dennis Meadows from 1970 to 1972, resulted in the publication of what was known as the first report to the Club of Rome (*The Limits to Growth*, 1972)



The Limits to Growth was based on the World3 model, a computer simulation model of interactions between population, industrial growth, food production and limits in the ecosystems of the Earth



What is *The Limits to Growth*?

The Classic Text

A widely acclaimed book from 1972 that served as a call for action on environmental concerns.

Groundbreaking Computer Model

The World3 model, based on over 200 years of data, simulates the complex relationships between the global economy and environment.

A Vision of the Future

Predicted several global issues whose impacts are still being felt today: resource depletion, climate change, and overpopulation.

The World3 Model: A Comprehensive Simulation

Population Growth

Modeling population trends, including fertility, mortality, and migration patterns, to explore the impact on the planet.

Industrial Growth

Examining the relationship between the production of raw materials and the amount of pollution they generate.

Food Supply

Some thought exponential food production meant no shortage. The model shows it is unsustainable due to resource depletion and environmental damage.

Ecosystems and Resources

The world's ecosystems and resources are finite. Hitting these limits leads to irreversible environmental damage and dwindling availability of resources.

Population Growth

Urbanisation

Urbanisation has driven widespread land-use change and increased demand for natural resources.

Family Planning

Policies that promote small families can help reduce population growth and its impact on the environment.

Migration

Displaced peoples have strained ecosystems and resources in many parts of the world.

Industrial Growth and Environmental Damage

1 Fossil Fuels

The energy resources that power much of industrial growth pollute the environment, contributing to climate change and jeopardizing human health.

2 Deforestation

Forests absorb carbon dioxide, support biodiversity and stabilize local rainfall, but they are being lost rapidly due to expanding agricultural and industrial activities.

3 Water Scarcity

Industrial processes consume large quantities of water and pollute rivers and other water sources.

Ecological Limits and Resource Depletion

Renewable Energy

We need to shift from fossil fuels to renewable energy sources such as solar, wind, and hydropower.

Reduce Resource Consumption

Reduce our consumption by reducing our use of non-essential goods and improving resource efficiency.

Green Innovation

Investment in green innovation and sustainable technologies will help produce a balance between economic growth and ecological sustainability.

Limits of *The Limits to Growth*

Controversy

There have been criticisms of the methodological limitation of the model and its predictions. Some argue they were slightly exaggerative.

The Reality

Even with limitations, the book provides valuable insights, resonating with concerns that still challenge us today.

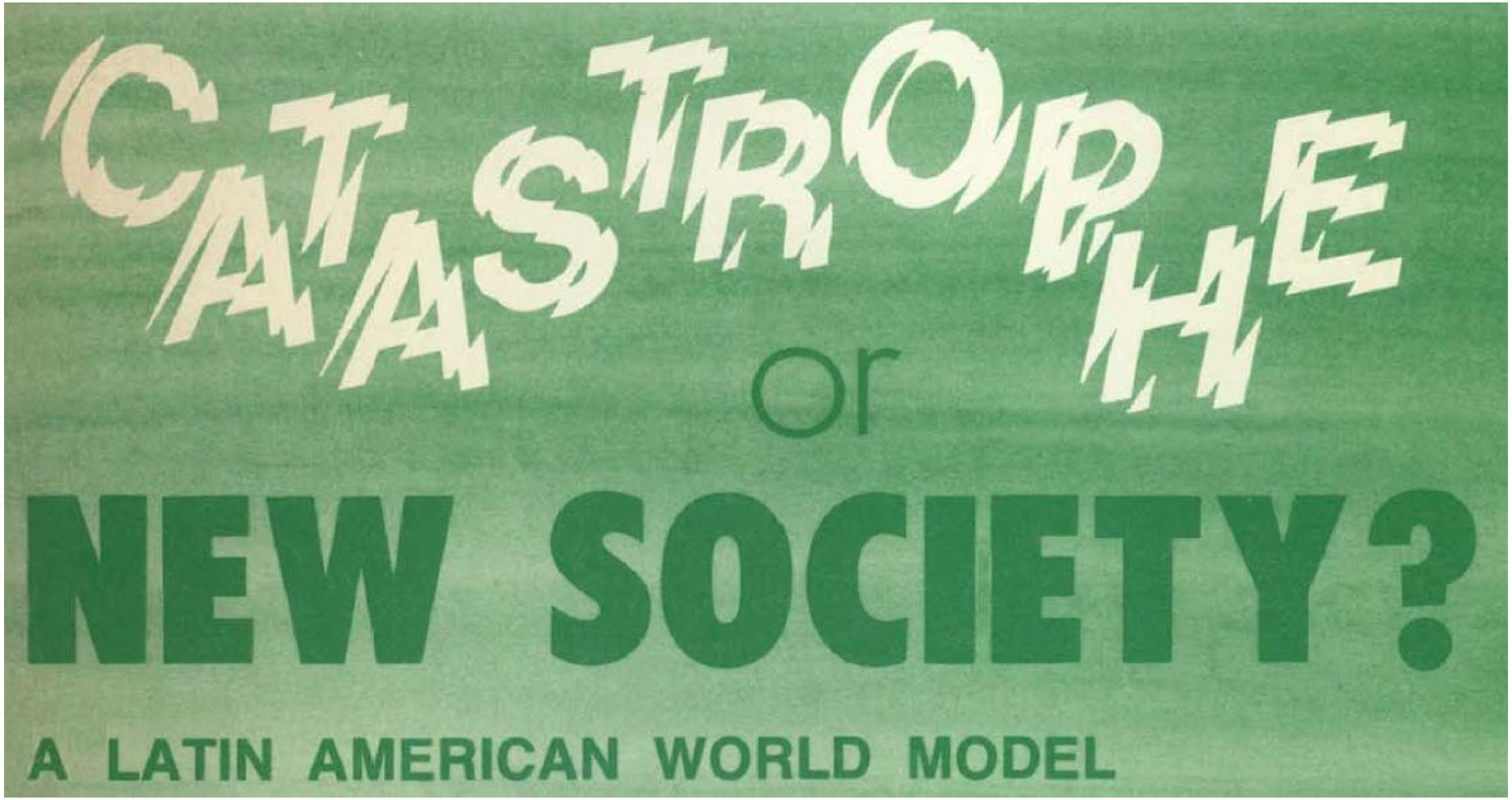
Inspiring Change

The book triggered international debate, inspiring change in attitudes and policies regarding environmental issues and sustainable development.

The Second Landmark: The Bariloche Model and its Revolutionary Approach

The Fundacion Bariloche Model from Argentina, first presented in 1974, is an innovative approach to societal development and transformation.

Known as the "Bariloche Model," that model was first presented in 1974 (A. O. Herrera et al. *Catastrophe or New Society? A Latin American World Model*. Canada: IDRC, 1976)



Introduction to the Bariloche Model

1. **Contextual Framework**

   The Bariloche Model seeks to solve societal problems by analyzing them through a multidisciplinary lens.

2. **Interdisciplinarity**

   The model combines tools from various disciplines such as economics, politics, and environmental science.

3. **Collaboration**

   The collaboration between experts and the community ensures a holistic approach to societal development.

4. **Key Concepts**

   Concepts like sustainability, equity, and community participation are central to the Bariloche Model.

History and Context of the 1974 Presentation

Political Climate

The presentation was made during a time of political and social upheaval in Latin America.

A Climate of Change

The Bariloche Model emerged as a response to a changing world, full of opportunities to rethink societal transformation.

Inspiration and Collaboration

The model was inspired by the work of the Club of Rome and was developed collaboratively by experts from different fields.

Key Features and Components of the Model

Systems Thinking	The model emphasizes the need for systems thinking while understanding the complexity of societal problems.
Participatory Approach	The involvement of the community in problem-solving processes guarantees solutions that cater to their needs.
Interdisciplinary Collaboration	Different fields come together to contribute expertise, resulting in a comprehensive and holistic approach.
Sustainability and Equity	The model prioritizes sustainability and equity, ensuring long-term solutions that benefit everyone.

Implications and Impact of the Bariloche Model

Impact on Society

The model has the potential to transform society, making it more equitable, sustainable, and participatory.

1

2

3

International Recognition

The Bariloche Model has received international recognition as a successful approach to societal transformation.

Implementation Challenges

Implementing the Bariloche Model can be challenging, requiring political will, financial resources, and expert collaboration

Critiques and Limitations

1 Overly Idealistic

The model's holistic approach can be difficult to implement in practice, often appearing too idealistic.

2 Limited Financial Resources

The model requires significant financial resources, secure funding streams, and support to achieve long-term goals.

3 Political Support

The model is highly political, requiring support at the highest levels of government and institutions for successful implementation.

4 Not a One-Size-Fits-All Solution

The Bariloche Model may not be suitable for all societal problems and is not a one-size-fits-all solution.

After that Start the Usefulness of IAMs only Increased

Long-Term Assessment

IAMs are essential tools for policymakers and researchers to assess the long-term impacts of policy decisions on energy, climate, and the economy.

Scenario Analysis

IAMs are used to explore various scenarios and policy options to address climate change and sustainable development challenges.

Improved Decision-Making

IAMs help policymakers make informed decisions by providing insights into the economic, social, and environmental trade-offs of policy options.

The Evolution of IAMs

Simple Beginnings

The earliest IAMs used punch card input and focused on energy production and consumption dynamics.

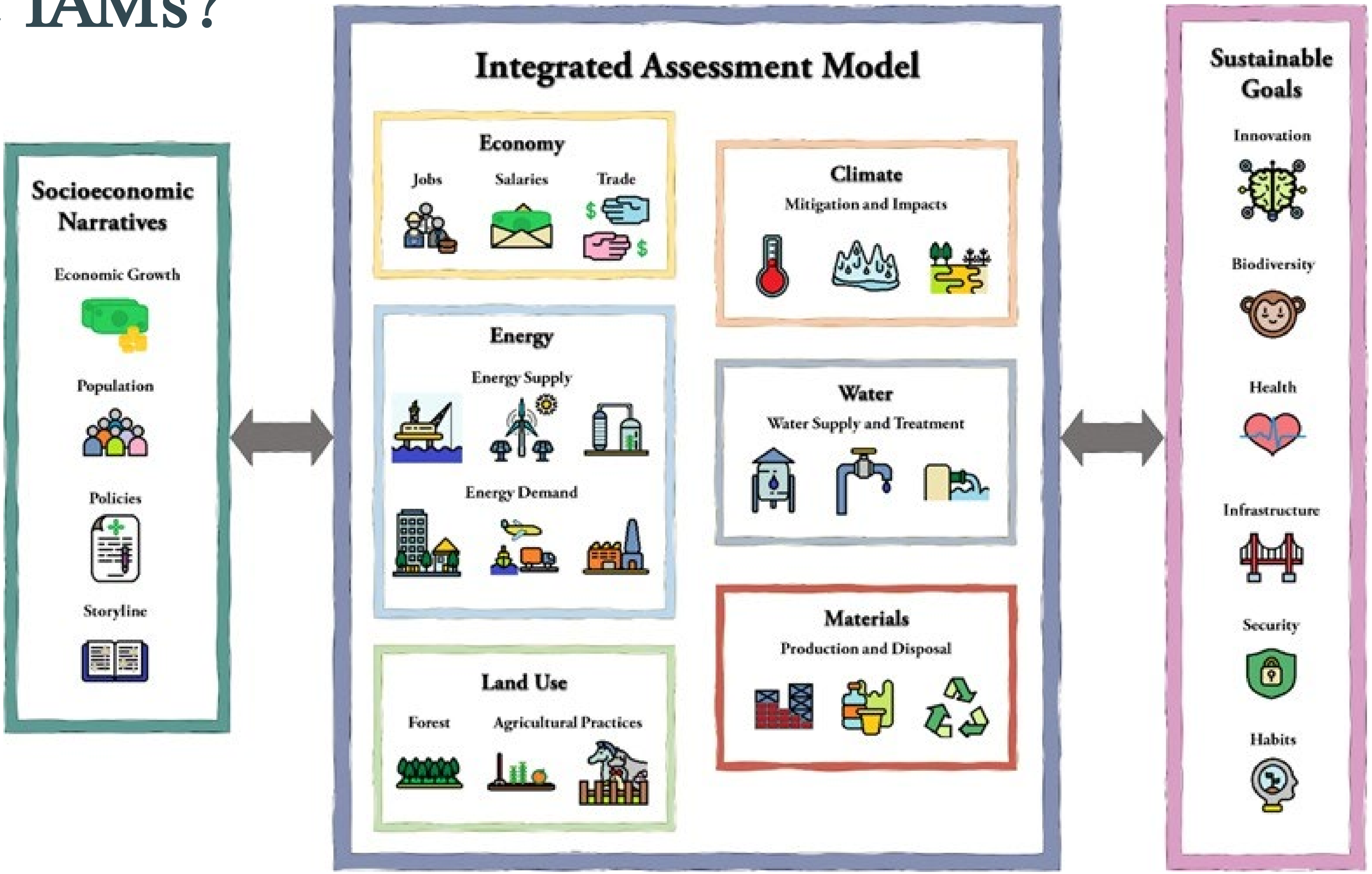
Technological Advancements

With better computational power, IAMs evolved to incorporate agriculture, land use, and transportation.

The Future of IAMs

Looking ahead, IAMs use sophisticated modeling techniques to provide insights into the long-term impacts of climate and energy policy.

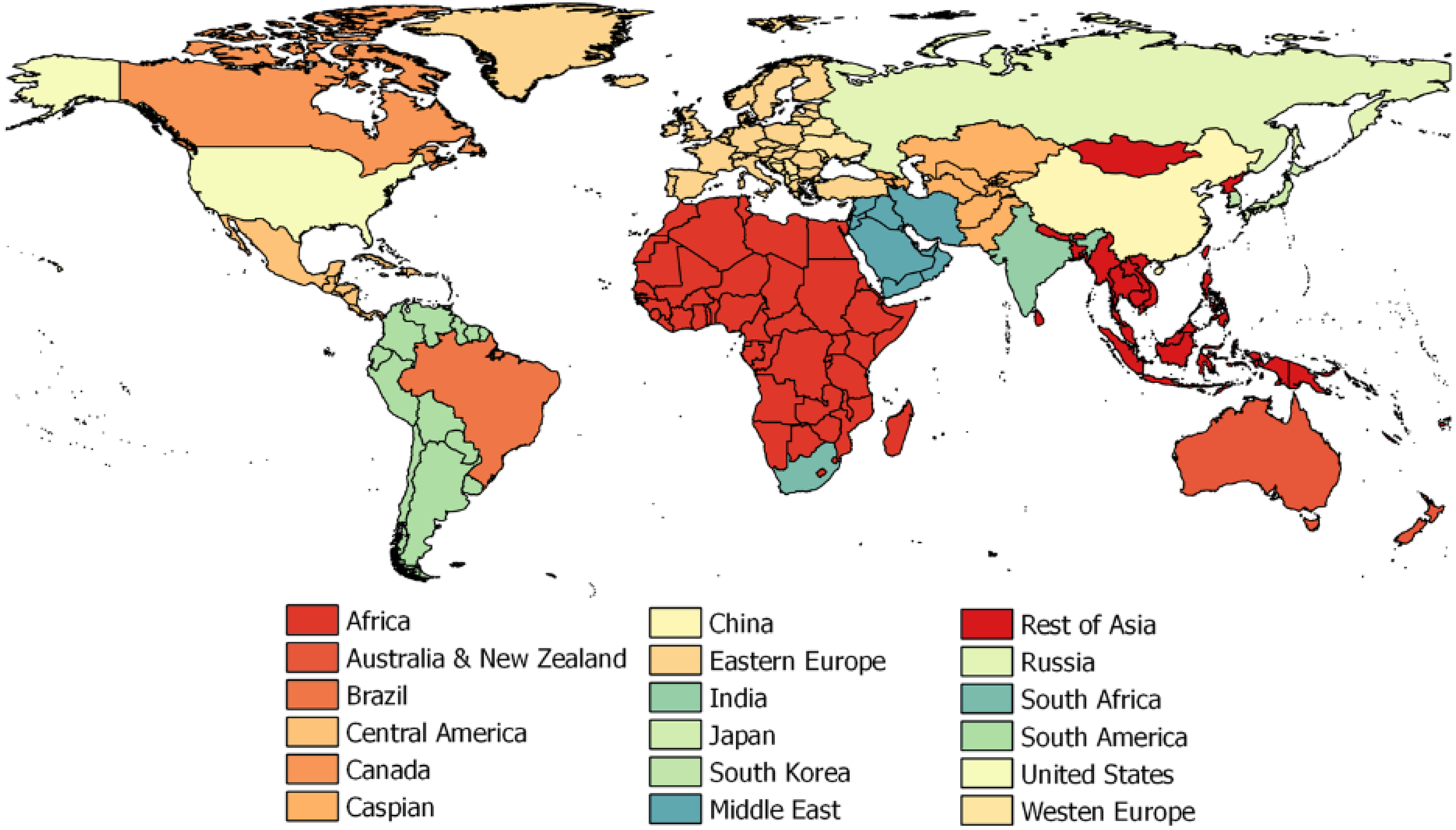
But IAMs?


Socioeconomic Narratives
Economic Growth
Population
Policies
Storyline
Integrated Assessment Model
Economy
Jobs
Salaries
Trade
Energy
Energy Supply
Energy Demand
Land Use
Forest
Agricultural Practices
Climate
Mitigation and Impacts
Water
Water Supply and Treatment
Materials
Production and Disposal
Sustainable Goals
Innovation
Biodiversity
Health
Infrastructure
Security
Habits

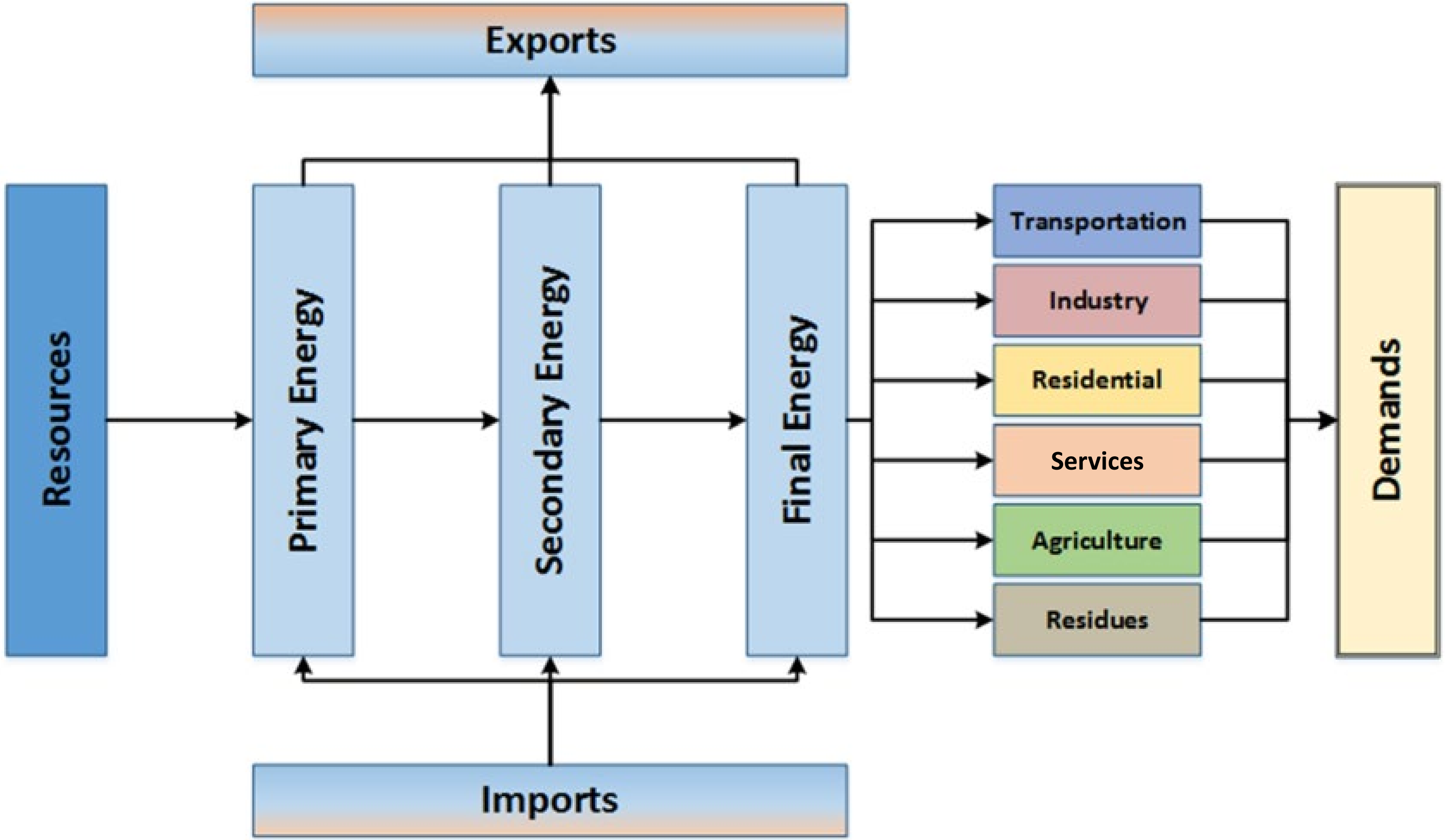
COmputable **F**ramework **F**or **E**nergy and the **E**nvironment (COFFEE) Model

- Global model with 18 regions
- Time horizon: 2010 to 2100
- Includes Energy System and Land System
  - Completely integrated (hard-link)
  - Assessment of potential synergies/trade-offs in energy, environmental and climate policies
- Rochedo, P. "Development of a global integrated energy model to evaluate the Brazilian role in climate change mitigation scenarios".
  - DSc thesis, Programa de Planejamento Energético, COPPE/UFRJ, RJ (2016).

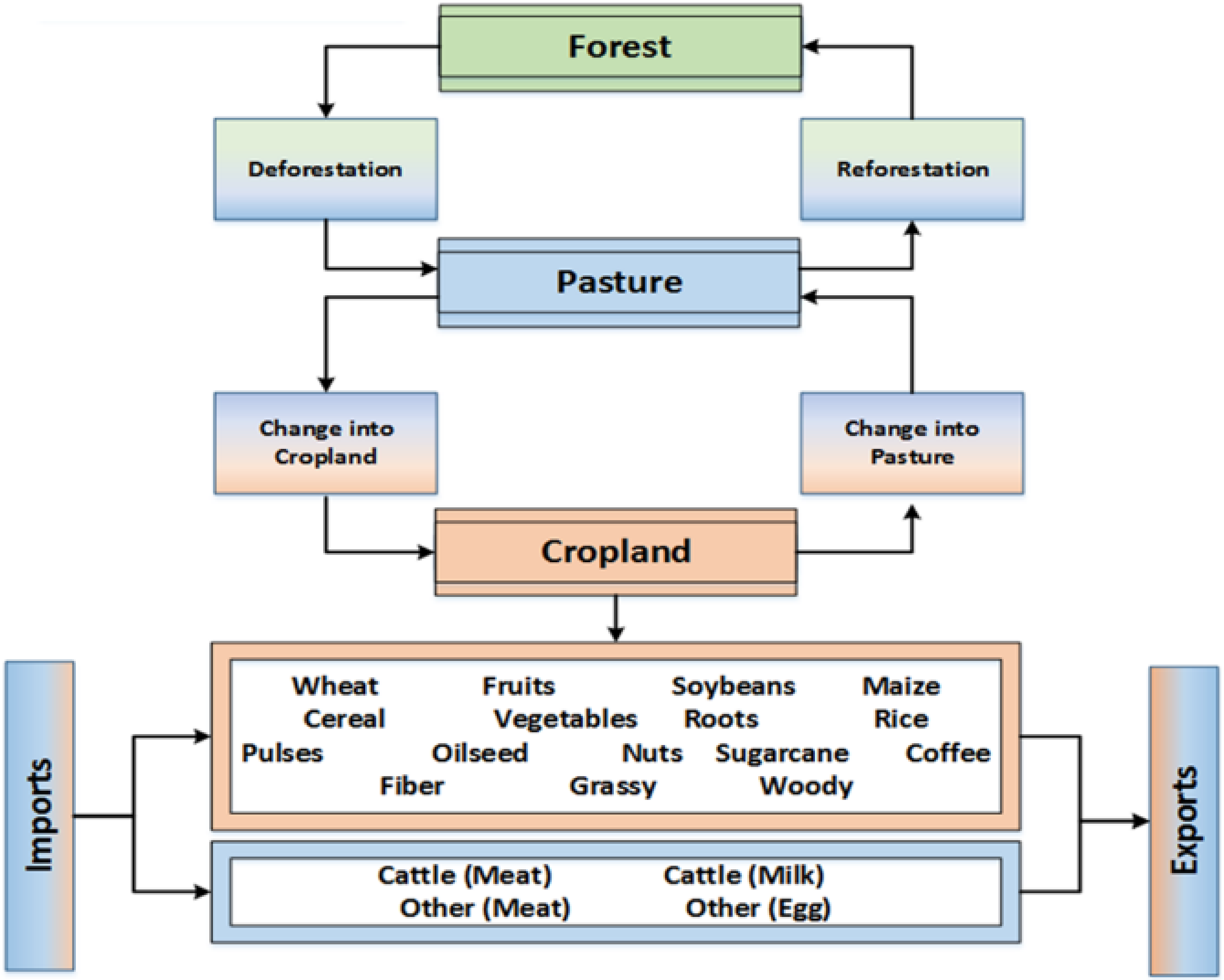
The COFFEE Model: overview



The COFFEE Model: energy system



The COFFEE Model: land system (simplified)



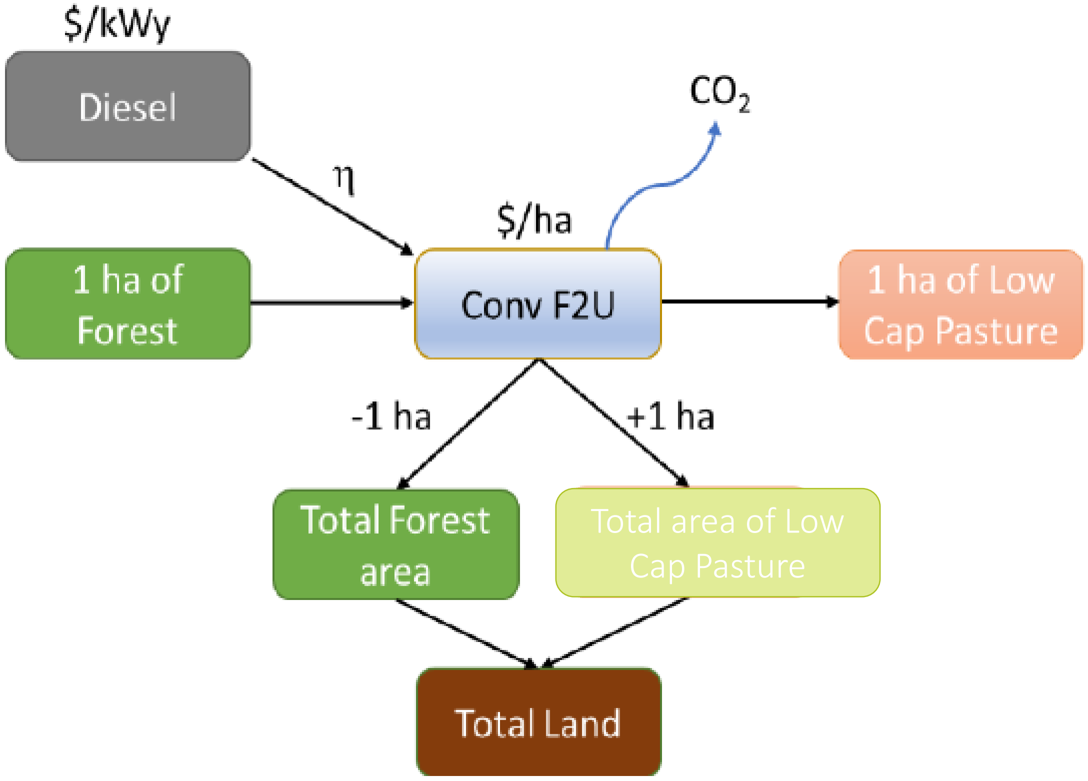
Land use structure

Land use transition matrix

Data required:

- Land cover types and surface
- Productivity by land cover type
- Agricultural production cost
- Water consumption
- Fuel specific consumption and costs
- GHG emissions
- Conversion Efficiency

Land use conversion process



Brazilian Land Use and Energy System (BLUES) Model

- National model with 6 regions
- Time horizon: 2010 to 2060
- Perfect foresight
- Bottom-up model
- Demand-side is more technologically detailed (than COFFEE)
  - Specific technologies for Brazil
- Integration of the energy chain
- Hard-link integration between land use, energy and materials
- Environmental benefits (pollution and water)

Spatial-temporal resolution

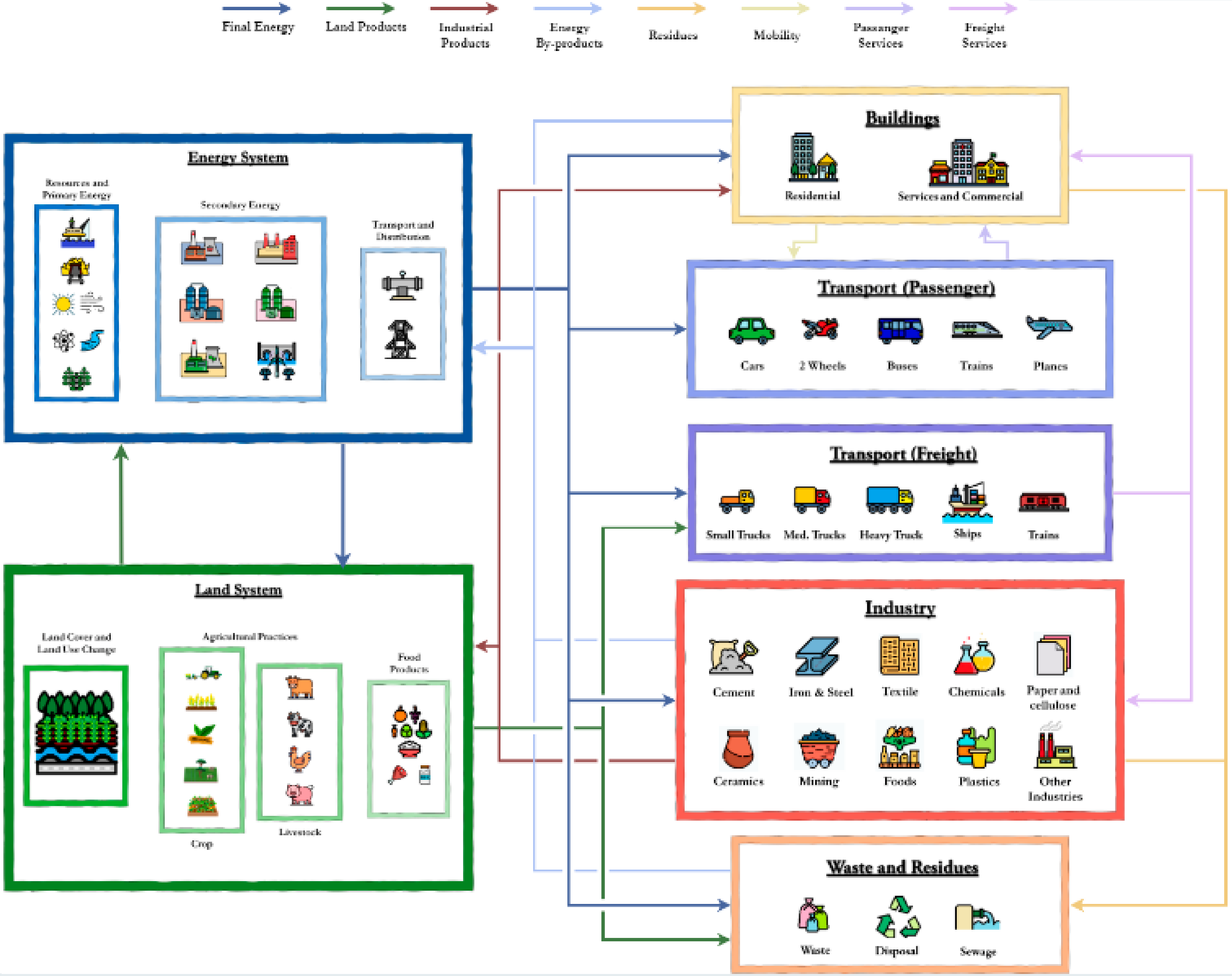
Base year → 2010

Horizon: 2010 – 2060
each 5 year

Seasonality: 12 months

Load curve: 24 hours

BLUES sectors



Energy System

- Energy Supply: very detailed representation of energy production and conversion technologies
- Including fossil and renewables, conventional and modern options

Oil&Gas

- Post and pre-salt representation
- CCS options
- Detailed refineries
  - With biomass co-processing
- Detailed oil products
- T&D of natural gas

Biofuels

- Various options of biomass options for energy conversion
  - Liquids
  - Solids
  - Gaseous
  - Electricity
- Several BECCS options

Power sector

- Representation of several source and technology
  - Fossil and renewable sources
- Resources seasonality and variability:
  - Hydro, wind, solar, etc
- Several CCS options
- T&D lines and storage

Imports and exports:
crude oil, natural gas, oil products and electricity

Energy System

- Energy Demand: detailed representation of the most relevant economic sectors
  - Energy service demand for most sectors and several energy efficiency measures.

Transport

- **Passenger transport**: cars, bikes, buses, light commercial, subway and non-motorized, airplanes and ships.
- **Freight transport**: 5 types of trucks, light commercial, ships, airplanes and trains.
- Energy service: passenger-kilometer (pkm) for passenger and ton-kilometer (tkm) for freights
- Energy efficiency options
- New technologies and fuels options
- Modal choice; Various electrification options

Industrial Sector

- **11 subsectors**: cement, metals, ceramics, chemicals, food and beverage, mining, paper and pulp, textile and other industries.
- Energy and non-energy consumption
- Material demands (e.g. cement, steel, white and red ceramics, pulp and paper, chemicals, etc)
- Processes-based modelling and energy efficiency options
  - Detailing of industrial processes emissions
  - Abatement measures, including CCS

Buildings

- **Residential** and **Services**
- Energy Service: lightning, cooling, water heating, cooking, refrigeration and appliances
- Specific consideration for each region, with energy efficiency options
- Includes **distributed generation** through photovoltaic solar energy

Residues

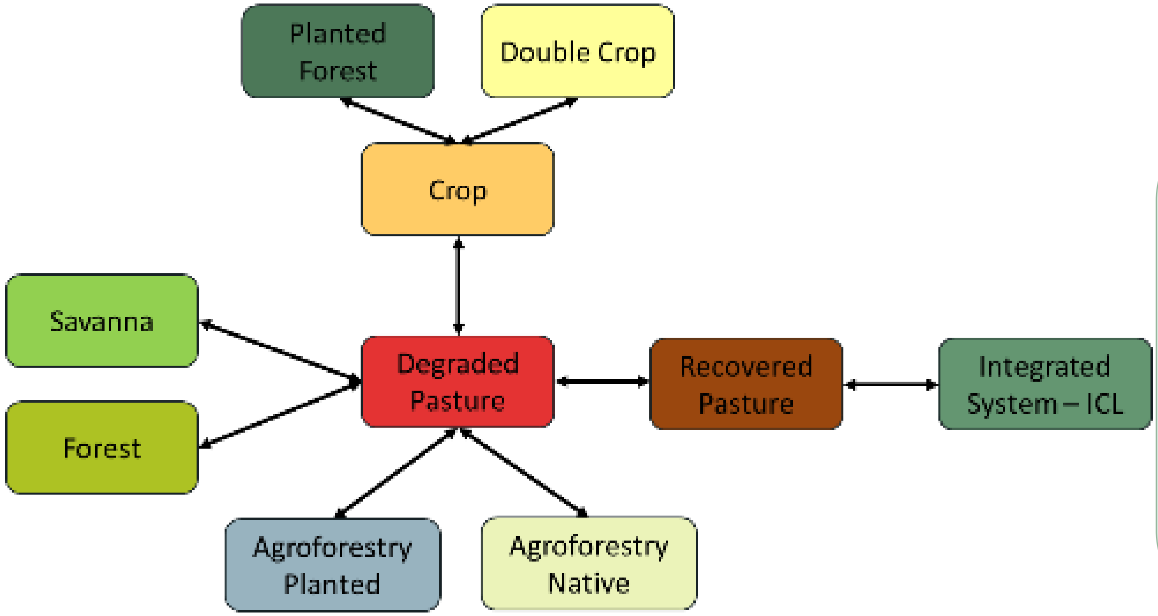
- **Urban solid waste generation** and **Water treatment**
- **Waste disposal**: sanitary landfill, controlled landfill, composting, recycling, biodigestion, incineration
- Waste-to-energy options available
- Several mitigation options for non-CO_2 gases

Land system

- Land Cover: Wide range of land cover and their transitions represented and detailed at the regional level for each of the five regions of the model

Land Cover

- 12 land covers
  - 2 protected native vegetation
  - 2 native vegetation
  - 2 pasture
  - 2 crop production
  - 1 forestry
  - 3 integrated systems
- Regionalized below and above ground carbon stocks for each land cover



Land Cover Change

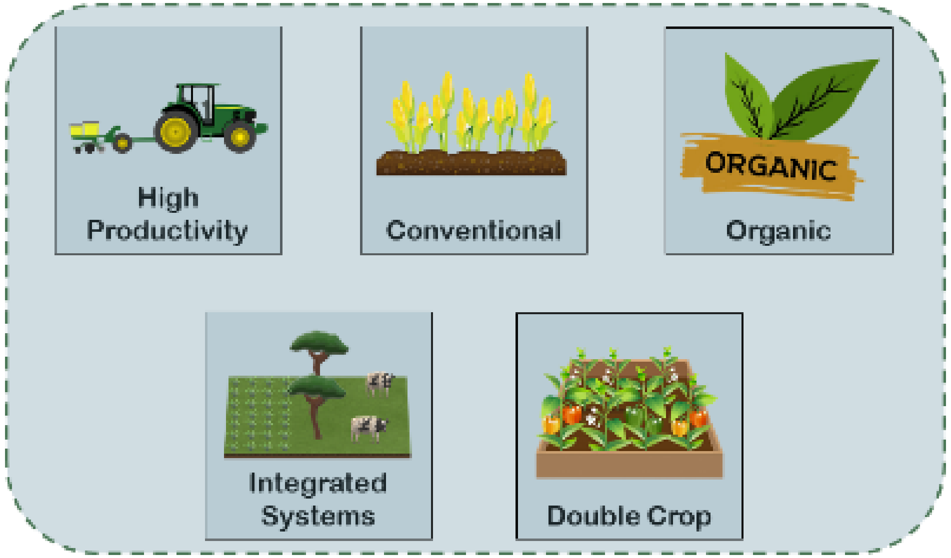
- 18 land cover changes
- Considering:
  - Variation of carbon stock below and above ground between transitions (emissions)
  - Costs
  - Annual potential for land cover change

Land system

- Land Use: Large number of detailed agricultural practices at regional level for each of the five regions of the model
  - Including the main inputs, outputs, emissions, costs and potentials of each production technology

Agricultural Productions

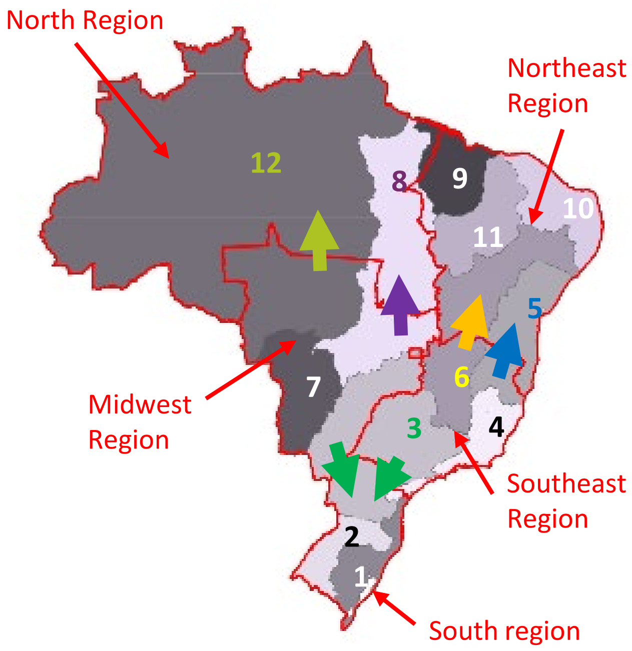
- 21 agricultural productions
  - 16 agricultural crops (cereals, coffee, fiber, fruits, grassy, maize, nuts, oilseeds, pulses, rice, roots, soybean, sugarcane, vegetables, wheat and woody)
  - 5 animal management (cattle meat, cattle milk, chicken meat, eggs and pork meat)



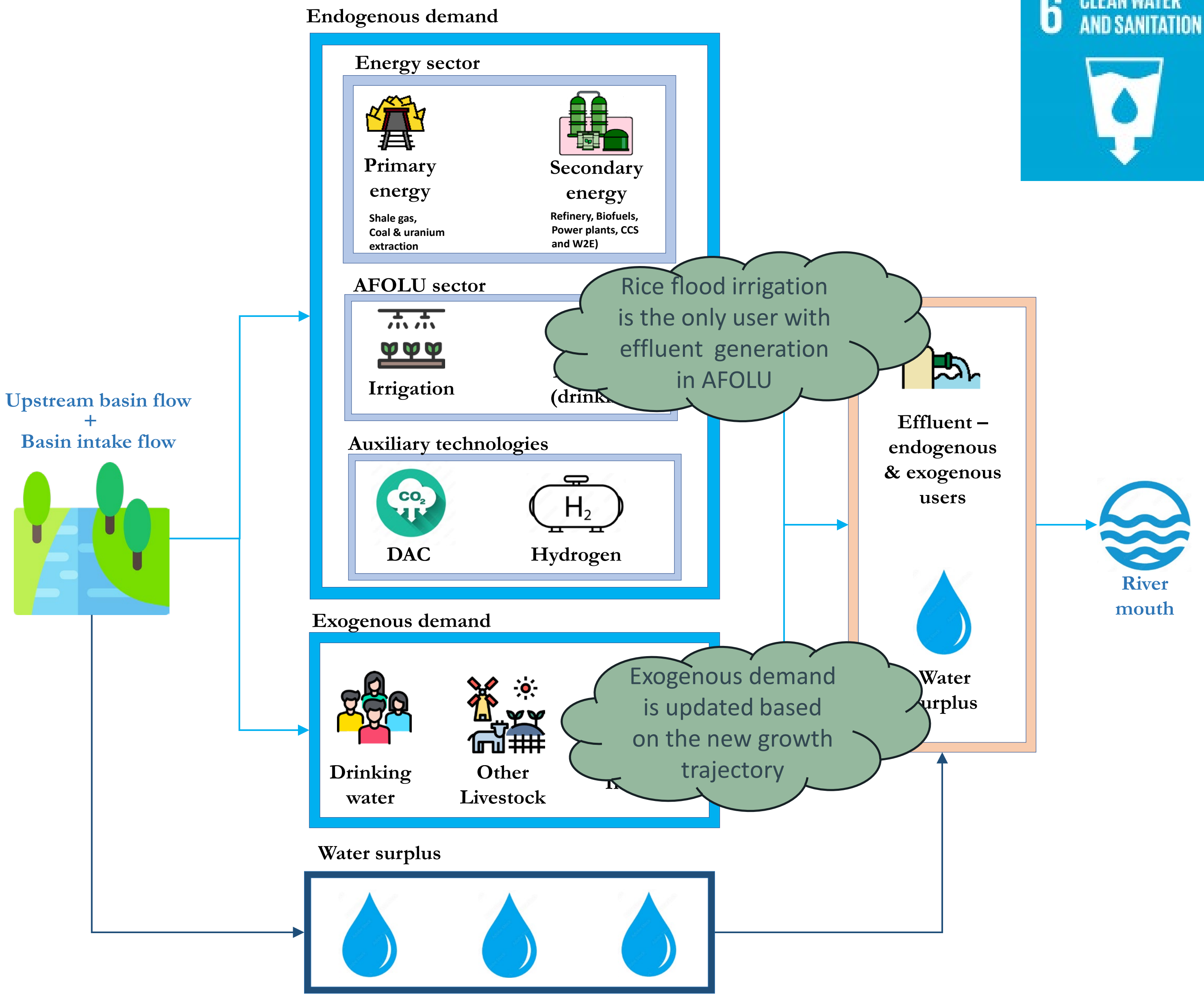
Agricultural Practices

- 5 agricultural practices
  - Conventional
  - High Productivity
  - Organic
  - Double Crop
  - Integrated Systems/Agroforestry
- 21 agricultural productions
  - 16 agricultural crops
  - 5 animal management
- Inputs
  - Fertilizers (chemical and organic)
  - Pesticides (chemical and organic)
  - Water

Water availability



18 basins
Q95 flow (ANA, 2020)



Allows you to analyse:

- Water management
- Infrastructure investment
- Costs/taxes for water use
- Different availabilities (e.g. climate change constraints)

Air Pollutants

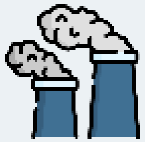
Air pollutants: $PM_{2.5}$, NO_x, SO_2, VOC, CO for all sectors

- Emission factors and control measures:
  - National information as far as possible: CETESB, PROCONVE, ANP, CONAMA, among others.
  - International databases: IIASA, EMEP/EEA, US EPA and scientific literature.
- Control measures options for $PM_{2.5}$, NO_x, SO_2 with efficiencies and costs

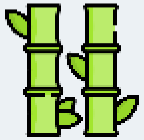
Mobile sources (transport sector):

- Sulphur limits for diesel and gasoline
- PROCONVE (~EURO) limits
- Exogenous vintage curves
- Tires and break emissions

Stationary sources:



- Industry and energy sectors
- Combustion and process emissions



- Agriculture emissions
- Residues burned emissions (sugarcane)

Applications of IAMs

1. **Energy Sector**

   IAMs play a critical role in analyzing energy demand and supply, as well as the impacts of climate and energy policy.

2. **Climate Change Mitigation**

   IAMs help identify policies and strategies that reduce greenhouse gas emissions and mitigate climate change.

3. **Sustainable Development**

   IAMs assist policymakers in developing sustainable development strategies by analyzing the economic, social and environmental impacts of policy decisions.

Limitations of IAMs

1 Assumptions and Uncertainties

IAMs are reliant on numerous assumptions and uncertain data, limiting their accuracy and predictive power.

2 Over-Simplification

IAMs are complex models that often make oversimplifications of reality and the relationships between various systems.

3 Ethical Concerns

IAMs raise ethical questions about how to balance short-term economic interests with long-term social and environmental sustainability.

IAMs and Climate Change

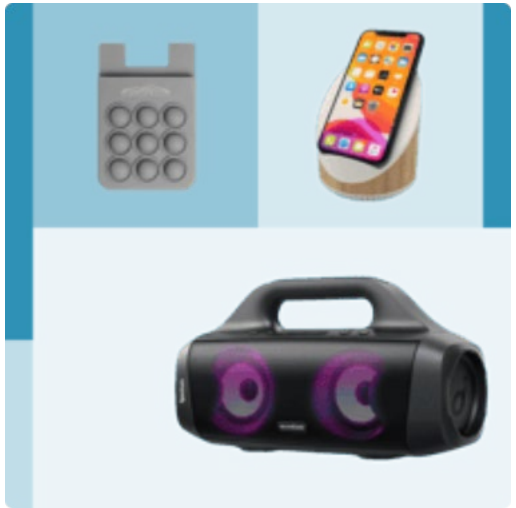
Mitigation vs. Adaptation

IAMs analyze the economic and environmental trade-offs between mitigation, reducing greenhouse gas emissions, and adaptation, adjusting to climate change impacts.

Equity and Distributive Impacts

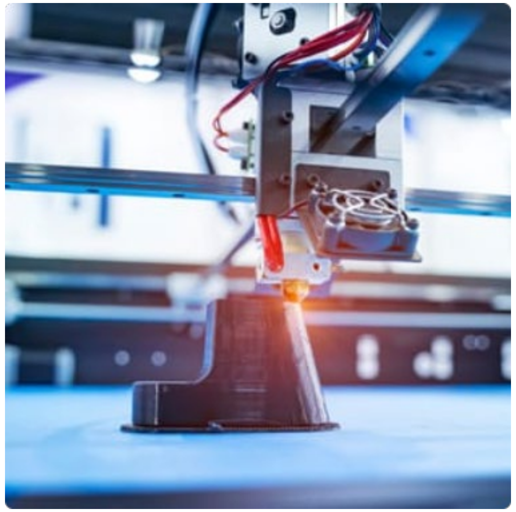
IAMs analyze how different policy scenarios impact vulnerable populations, especially in developing countries.

Technological Change in IAMs



Emerging Technologies

IAMs incorporate emerging technologies like renewable energy and electric vehicles to project future energy systems.



Advanced Modeling Techniques

Advanced modeling techniques like agent-based models improve IAMs' performance and accuracy.

Data Visualization

IAMs can use data visualization technologies to make their output more accessible and engaging to policy makers and the public.

The Importance of IAMs

A Tool for Sustainable Development

IAMs play an important role in developing policies and strategies that balance environmental, social and economic concerns for a sustainable future.

Facilitate Better Decision Making

With their ability to analyze interdependent systems, IAMs help policymakers make informed decisions and assess the impacts of different policies.

Support Climate Action

IAMs help identify effective policies and strategies to mitigate greenhouse gas emissions and limit the impacts of climate change.

The Future of IAMs

Addressing New Challenges

IAMs will need to incorporate emerging issues like biodiversity loss, ocean acidification, and the circular economy to remain relevant.

1

2

3

Increasing Importance

As the world continues to grapple with complex global challenges, IAMs will become increasingly important tools for policymakers and researchers.

Continuing Technological Innovations

Advances in data collection, processing, and storage, as well as simulation and visualization technologies, will enable even more sophisticated IAMs in the future.

Conclusion

Looking Ahead

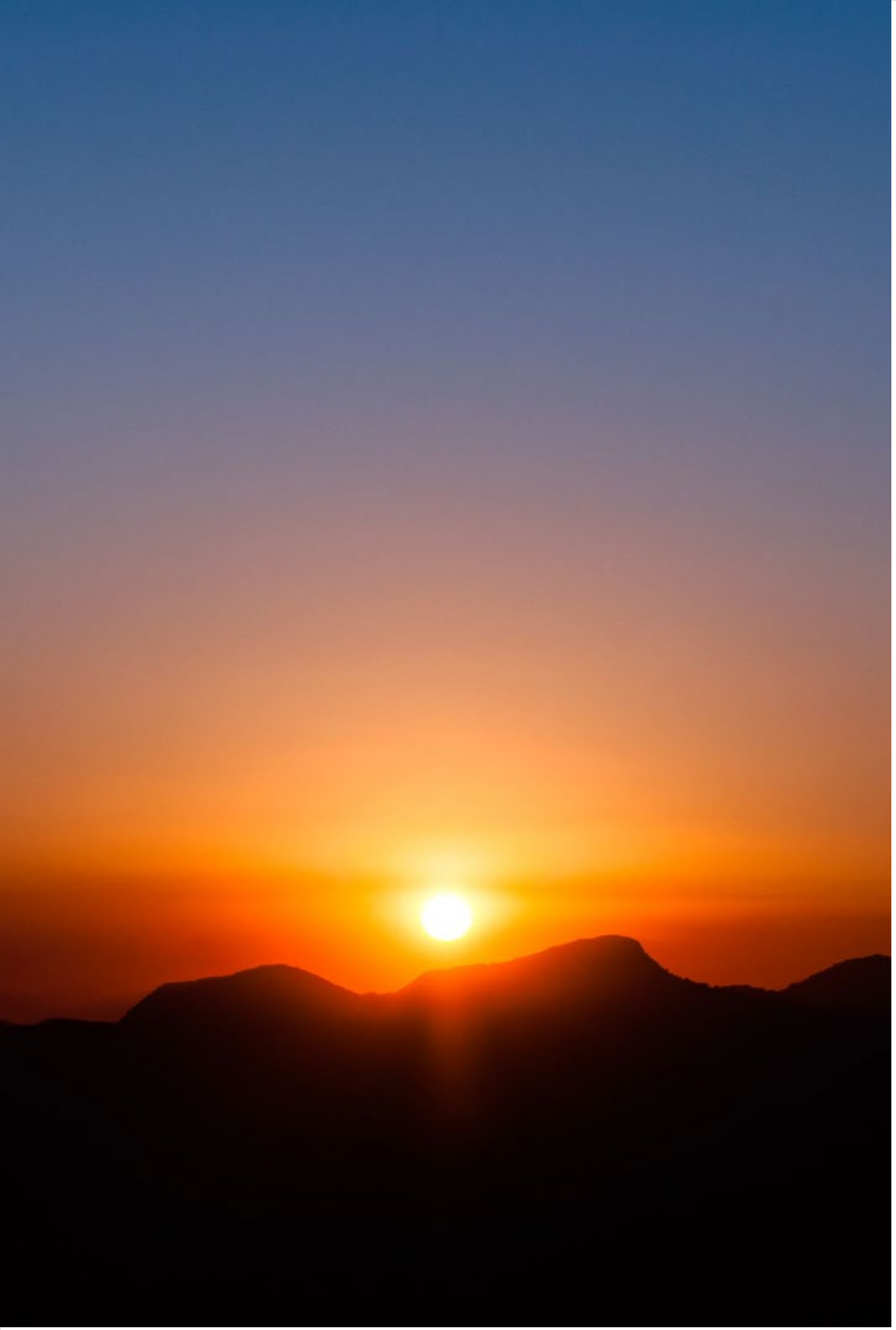
With their ability to analyze complex interdependent systems, IAMs are essential tools for addressing global sustainability challenges.

The Need for Collaboration

The success of IAMs depends on interdisciplinary collaboration across academia, industry, and government.

Urgency for Action

As the impacts of climate change become increasingly severe, the use of IAMs will be even more critical to identify effective policy solutions for a sustainable future.



2. How IAMs Have Been Key for IPCC Reports

The Intergovernmental Panel on Climate Change (IPCC) has been using IAMs to project future greenhouse gas emissions and assess the effectiveness of mitigation strategies. Let us briefly explore now the history and evolution of IAMs in IPCC reports.

IPCC 1990 SA90 Scenarios

Introduction to IPCC and its reports

The IPCC was established in 1988 by the World Meteorological Organization and the United Nations Environment Programme to provide scientific assessment on climate change. Its first report, the First Assessment Report (FAR), was published in 1990.

Overview of IPCC 1990 SA90 scenarios

The IPCC 1990 SA90 scenarios were part of the FAR. They included six scenarios of future greenhouse gas emissions, each corresponding to a specific economic development path.

Energy sector assumptions

The scenarios considered various energy sources and technologies, including renewables, nuclear, fossil fuels and energy efficiency improvements, and their impact on greenhouse gas emissions.

Land use assumptions

The scenarios also studied the impact of land-use changes, such as deforestation and afforestation, on greenhouse gas emissions and atmospheric CO2 concentrations.

IPCC 1990 SA90 Scenarios (Cont.)

1 **Emissions projections**

The scenarios projected that greenhouse gas emissions would increase significantly over the following century, with corresponding increases in atmospheric CO2 concentrations and global warming.

2 **Key findings and conclusions**

The scenarios highlighted the urgent need for mitigation strategies to limit greenhouse gas emissions and avoid the most severe impacts of climate change on ecosystems, economies, and human well-being. They paved the way for the development of more sophisticated and comprehensive IAMs in subsequent IPCC reports.

Using IAMs in IPCC Reports

1

Introduction to IAMs

2

History and Evolution of IAMs in IPCC Reports

IAMs have been used in all IPCC reports since the Second Assessment Report (SAR) in 1995. Their complexity and scope have increased with each subsequent report, reflecting advances in scientific knowledge and computing power.

3

IAMs Used in ARs and Special Reports

4

Advantages and Limitations of Using IAMs

IAMs provide valuable insights into the complex relationship between human activities and climate change, but they also face challenges such as uncertainty, data limitations, and simplification of real-world complexities.

1992: The Six IPCC IS92 Scenarios

In 1992, the Intergovernmental Panel on Climate Change (IPCC) published six emissions scenarios, known as the IS92 scenarios, which projected future emissions based on different socio-economic factors.

Adapted from the Fourth National Climate Assessment (2018)

1995: The Evaluation Scenarios

In 1995, the IPCC introduced evaluation scenarios to assess the impact of carbon dioxide in the atmosphere. These scenarios helped frame climate change discussions for years to come.

1996: Panel Decision New Scenarios

In 1996, the IPCC made the decision to develop new scenarios, recognizing the limitations of the previous models. This led to the emergence of new modeling approaches.

2000: The SRES

The SRES (Special Report on Emissions Scenarios) was introduced in 2000, introducing a new framework for scenario development. This report helped to establish a standardized set of emissions scenarios.

2001: Mitigation Scenarios

In 2001, the IPCC introduced mitigation scenarios to explore ways in which humanity could address the issue of climate change. These scenarios helped to frame policy discussions and decision-making processes.

2007: AR4 Assessment of Stabilization Scenarios

The AR4 (Fourth Assessment Report) introduced stabilization scenarios, which explored ways in which greenhouse gas concentrations could be stabilized. These scenarios helped guide discussions on climate change policy.

2011: SRREN

The SRREN (Special Report on Renewable Energy Sources and Climate Change Mitigation) explored the potential of renewable energy sources to mitigate climate change. This report helped to frame discussions on sustainable energy policy.

WGIII AR5 Mitigation Scenarios

Business as usual scenario

This scenario assumes that the world will continue to emit greenhouse gases at current rates without any additional policies or interventions.

Renewable energy scenario

This scenario assumes that renewables like solar, wind, geothermal, and hydropower would meet the majority of global energy demand.

Fossil fuel with carbon capture and storage (CCS)

This scenario assumes that fossil fuels will still be a part of the energy mix, but with CCS to capture CO_2 emissions from power plants and industrial processes.

WGIII IPCC SR1.5 Scenarios

1 Energy system transformation

This scenario involves a rapid transition to a low-carbon economy, with a focus on renewable energy and energy efficiency measures.

2 Carbon dioxide removal (CDR)

This scenario combines a range of CDR technologies to remove CO2 from the atmosphere, including afforestation, reforestation, soil carbon sequestration, and bioenergy with carbon capture and storage (BECCS).

3 Behavior and lifestyle change

This scenario assumes a significant shift in consumer behavior towards a more sustainable lifestyle, with a focus on reducing consumption, reducing waste, and eating less meat.

AR6 WGIII Chapter 3 Scenarios: Some key points

1

Net-zero emissions by 2050

Some scenarios assume global carbon neutrality by mid-century, with the complete phase-out of fossil fuels and the rapid adoption of clean energy technologies.

2

Increased carbon uptake

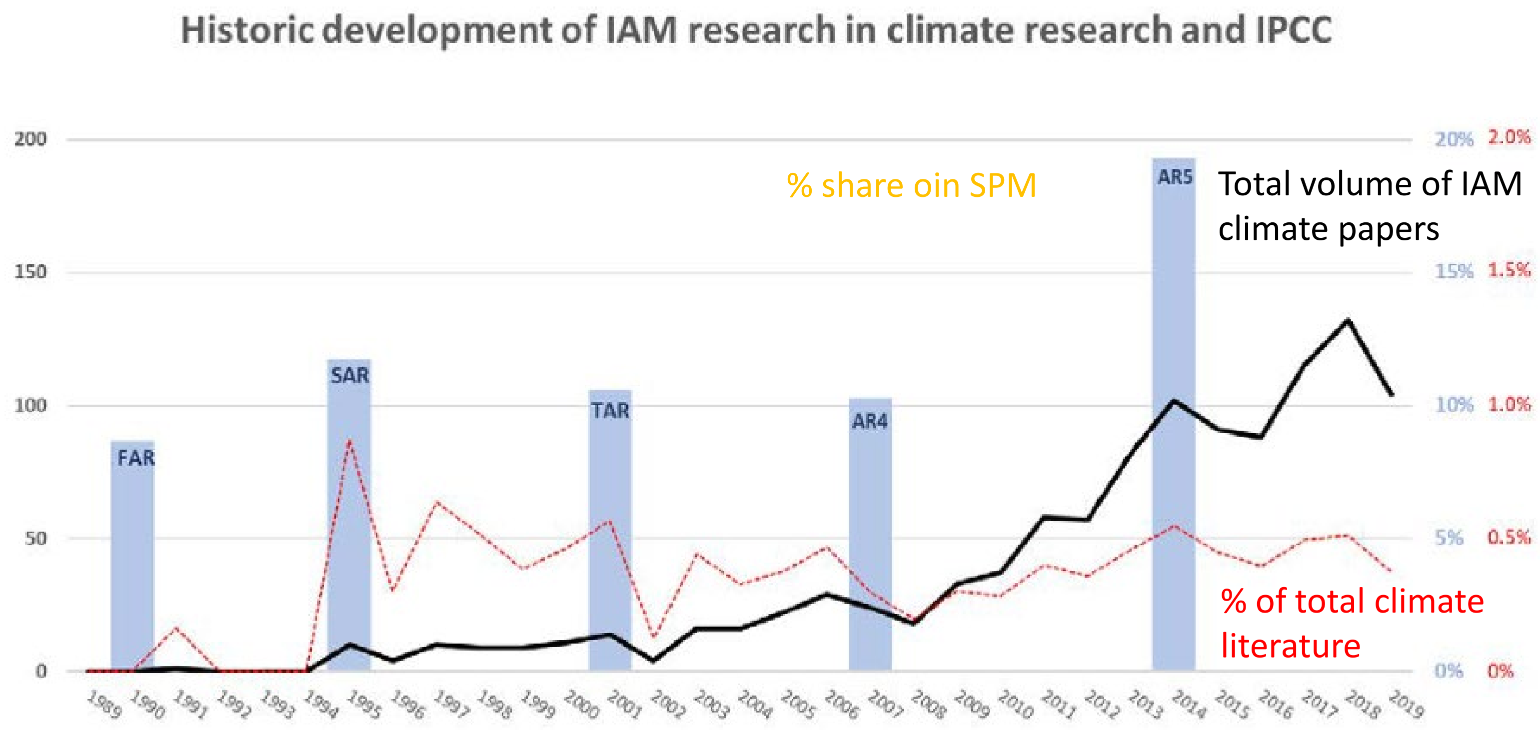
Some scenarios focus on carbon sequestration and land-use management through techniques such as reforestation, afforestation, and changes in agricultural practices to achieve net-negative carbon emissions.

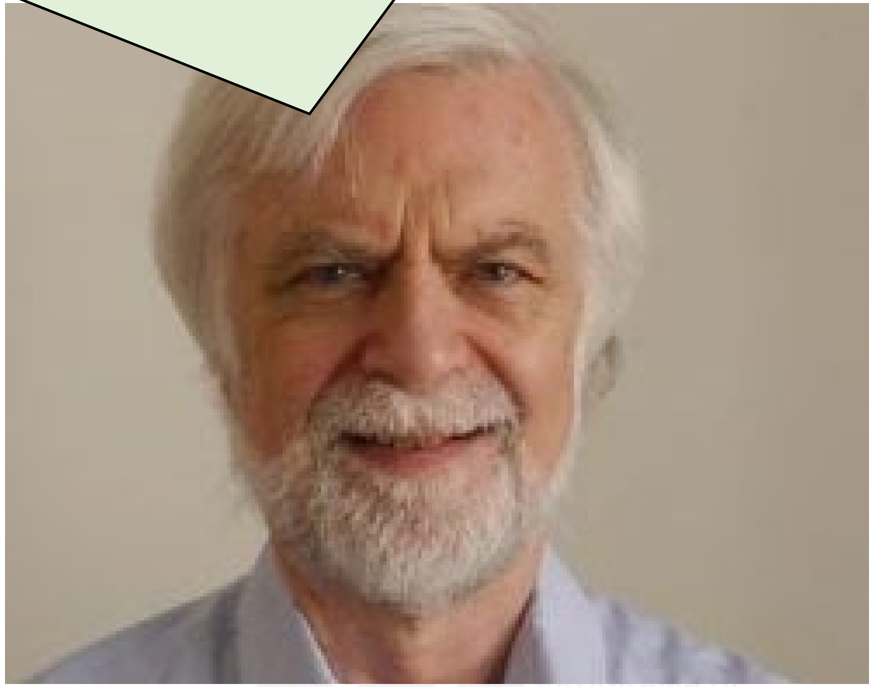
3

Reduced energy demand

Some scenarios assume lower energy demand through energy-efficient buildings, transportation, and appliances, as well as behavioral changes such as reduced travel and consumption.

IAMs constitute up to 6% of the [IPCC] report contents, approximately 25% of the summary for policymakers [SPM] and the best part of the press coverage.





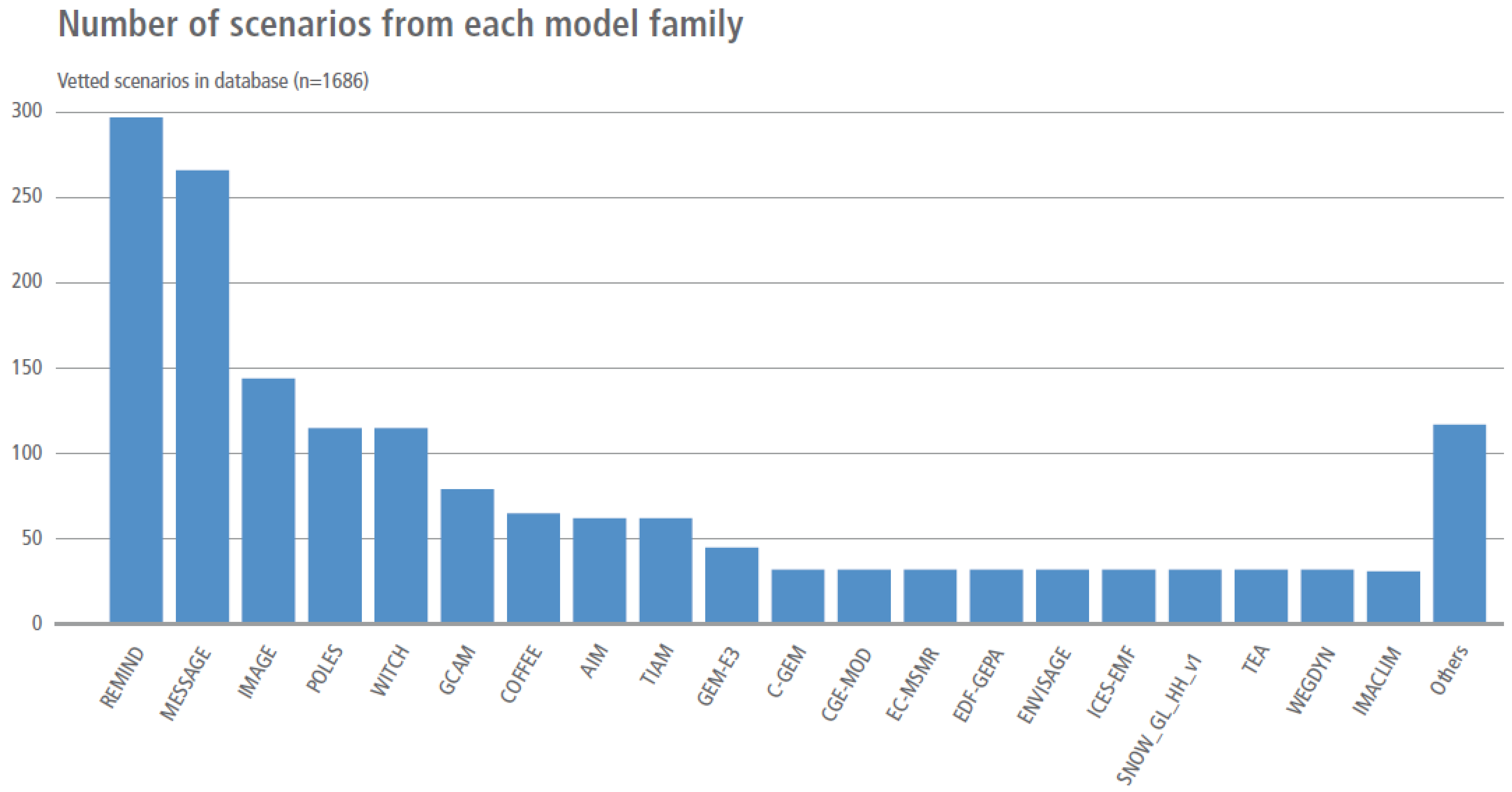


Figure 3.1 | Scenario counts from each model family defined as all versions under the same model's name.

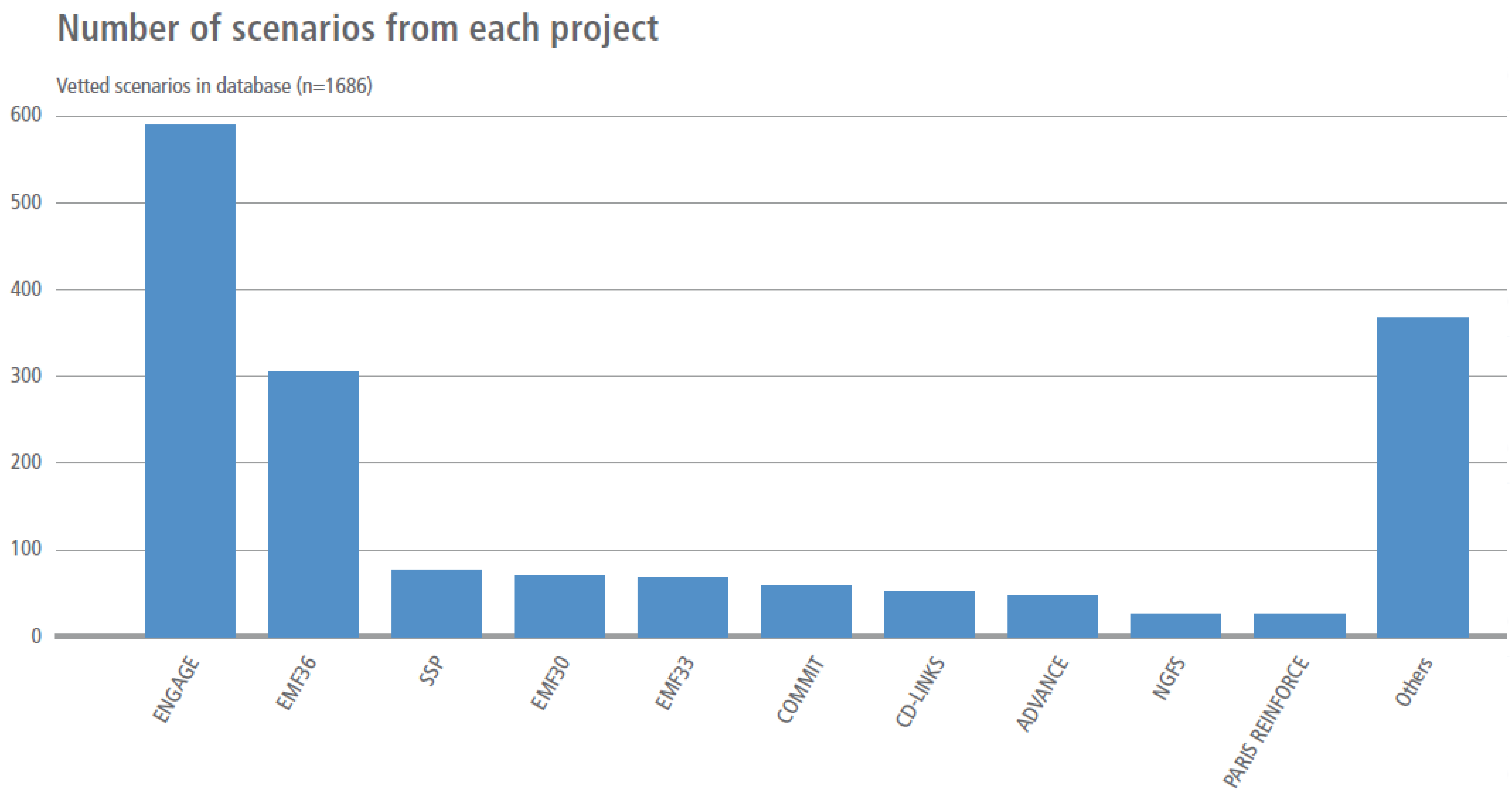


Figure 3.2 | Scenario counts from each named project.

Table 3.1 | Classification of emissions scenarios into warming levels using MAGICC

Category	Description	WGI SSP	WGIII IP/IMP	Scenarios
C1: Limit warming to 1.5°C (>50%) with no or limited overshoot	Reach or exceed 1.5°C during the 21st century with a likelihood of ≤67%, and limit warming to 1.5°C in 2100 with a likelihood >50%. Limited overshoot refers to exceeding 1.5°C by up to about 0.1°C and for up to several decades.	SSP1-1.9	IMP-SP, IMP-LD, IMP-Ren	**97**
C2: Return warming to 1.5°C (>50%) after a high overshoot	Exceed warming of 1.5°C during the 21st century with a likelihood of >67%, and limit warming to 1.5°C in 2100 with a likelihood of >50%. High overshoot refers to temporarily exceeding 1.5°C global warming by 0.1°C–0.3°C for up to several decades.		IMP-Neg[a]	**133**
C3: *Limit warming to 2°C (>67%)*	Limit peak warming to 2°C throughout the 21st century with a likelihood of >67%.	SSP1-2.6	IMP-GS	**311**
C4: Limit warming to 2°C (>50%)	Limit peak warming to 2°C throughout the 21st century with a likelihood of >50%.			**159**
C5: Limit warming to 2.5°C (>50%)	Limit peak warming to 2.5°C throughout the 21st century with a likelihood of >50%.			**212**
C6: Limit warming to 3°C (>50%)	Limit peak warming to 3°C throughout the 21st century with a likelihood of >50%.	SSP2-4.5	ModAct	**97**
C7: Limit warming to 4°C (>50%)	Limit peak warming to 4°C throughout the 21st century with a likelihood of >50%.	SSP3-7.0	CurPol	**164**
C8: Exceed warming of 4°C (≥50%)	Exceed warming of 4°C during the 21st century with a likelihood of ≥50%.	SSP5-8.5		**29**
C1, C2, C3: limit warming to 2°C (>67%) or lower	All scenarios in Categories C1, C2 and C3			**541**

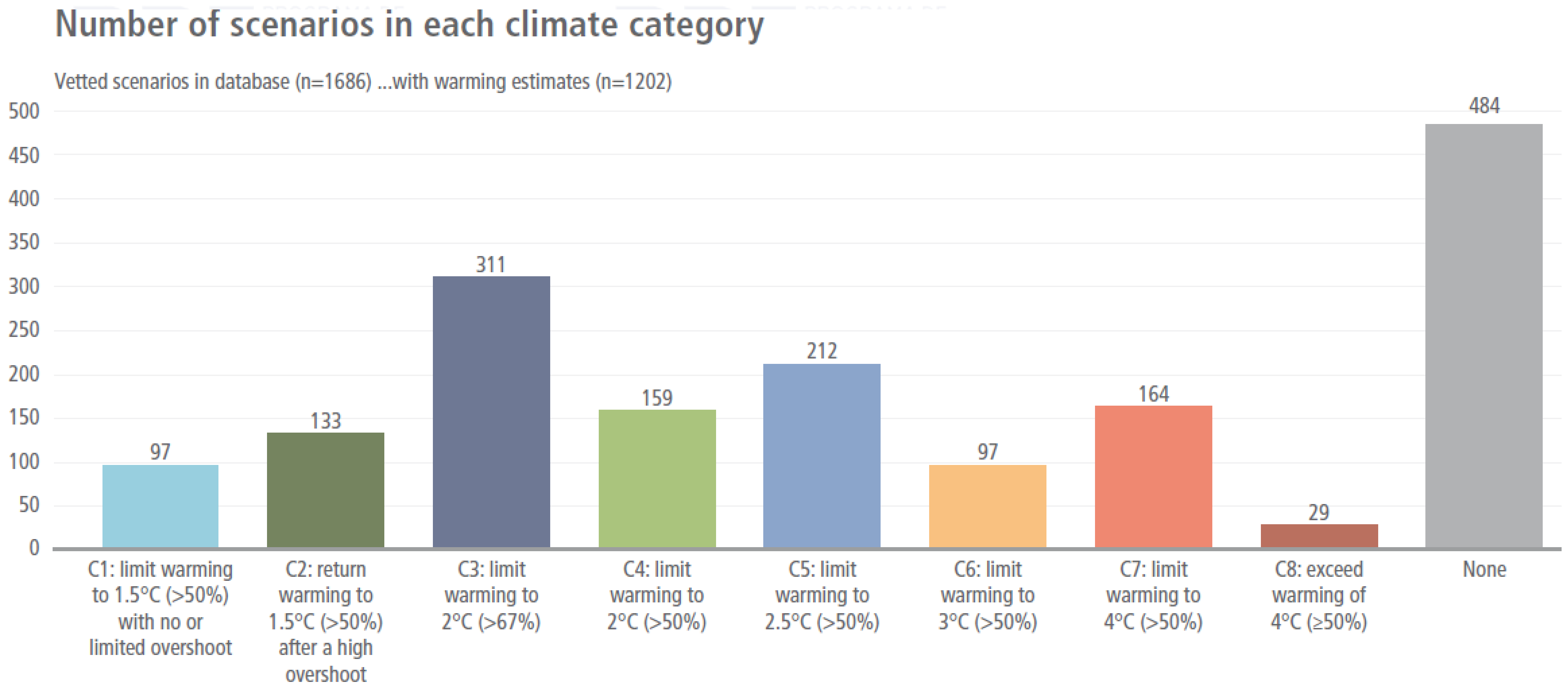


Figure 3.3 | Of the 1686 scenarios that passed vetting, 1202 had sufficient data available to be classified according to temperature, with an uneven distribution across warming levels.

WGIII scenario collection, vetting and assessment:

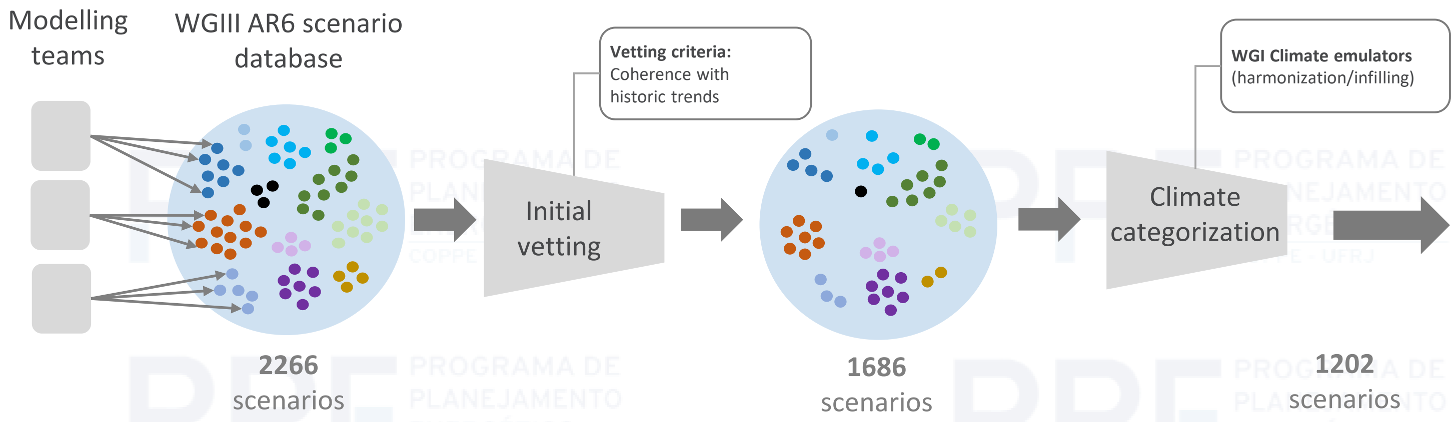
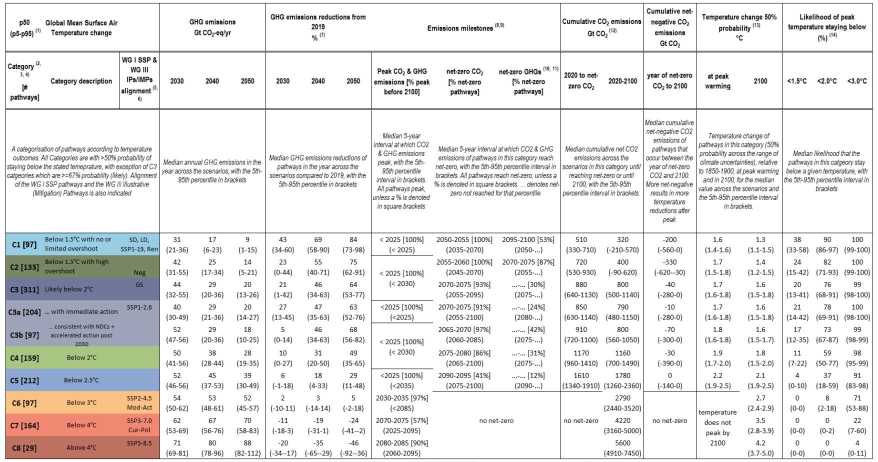


Table SPM1



Category (2, 3, 4) [# pathways]	Category description	WG I SSP & WG III IPs/IMPs alignment (5, 6)	GHG emissions $Gt\ CO_2$-eq/yr: 2030	2040	2050	GHG emissions reductions from 2019 % (7): 2030	2040	2050	Emissions milestones (8,9): Peak CO_2 & GHG emissions [% peak before 2100]	net-zero CO_2 [% net-zero pathways]	net-zero GHGs (10, 11) [% net-zero pathways]	Cumulative CO_2 emissions $Gt\ CO_2$ (12): 2020 to net-zero CO_2	2020-2100	Cumulative net-negative CO_2 emissions $Gt\ CO_2$: year of net-zero CO_2 to 2100	Temperature change 50% probability (13) °C: at peak warming	2100	Likelihood of peak temperature staying below (%) (14): <1.5°C	<2.0°C	<3.0°C
p50 (p5-p95) (1)	Global Mean Surface Air Temperature change																		
A categorisation of pathways according to temperature outcomes. All Categories are with >50% probability of staying below the stated temeprature, with exception of C3 catgeories which are >=67% probability (likely). Alignment of the WG I SSP pathways and the WG III Illustrative (Mitigation) Pathways is also indicated			Median annual GHG emissions in the year across the scenarios, with the 5th-95th percentile in brackets			Median GHG emissions reductions of pathways in the year across the scenarios compared to 2019, with the 5th-95th percentile in brackets			Median 5-year interval at which CO2 & GHG emissions peak, with the 5th-95th percentile interval in brackets. All pathways peak, unless a % is denoted in square brackets	Median 5-year interval at which CO2 & GHG emissions of pathways in this category reach net-zero, with the 5th-95th percentile interval in brackets. All pathways reach net-zero, unless a % is denoted in square brackets. … denotes net-zero not reached for that percentile.		Median cumulative net CO2 emissions across the scenarios in this category until reaching net-zero or until 2100, with the 5th-95th percentile interval in brackets.		Median cumulative net-negative CO2 emissions of pathways that occur between the year of net-zero CO2 and 2100. More net-negative results in more temperature reductions after peak	Temperature change of pathways in this category (50% probability across the range of climate uncertainties), relative to 1850-1900, at peak warming and in 2100, for the median value across the scenarios and the 5th-95th percentile interval in brackets.		Median likelihood that the pathways in this catgeory stay below a given temperature, with the 5th-95th percentile interval in brackets		
C1 [97]	Below 1.5°C with no or limited overshoot	SD, LD, SSP1-19, Ren	31 (21-36)	17 (6-23)	9 (1-15)	43 (34-60)	69 (58-90)	84 (73-98)	< 2025 [100%] (< 2025)	2050-2055 [100%] (2035-2070)	2095-2100 [53%] (2050-…)	510 (330-710)	320 (-210-570)	-200 (-560-0)	1.6 (1.4-1.6)	1.3 (1.1-1.5)	38 (33-58)	90 (86-97)	100 (99-100)
C2 [133]	Below 1.5°C with high overshoot	Neg	42 (31-55)	25 (17-34)	14 (5-21)	23 (0-44)	55 (40-71)	75 (62-91)	< 2025 [100%] (< 2030)	2055-2060 [100%] (2045-2070)	2070-2075 [87%] (2055-…)	720 (530-930)	400 (-90-620)	-330 (-620--30)	1.7 (1.5-1.8)	1.4 (1.2-1.5)	24 (15-42)	82 (71-93)	100 (99-100)
C3 [311]	Likely below 2°C	GS	44 (32-55)	29 (20-36)	20 (13-26)	21 (1-42)	46 (34-63)	64 (53-77)		2070-2075 [93%] (2055-2095)	…-… [30%] (2075-…)	880 (640-1130)	800 (500-1140)	-40 (-280-0)	1.7 (1.6-1.8)	1.6 (1.5-1.8)	20 (13-41)	76 (68-91)	99 (98-100)
C3a [204]	… with immediate action	SSP1-2.6	40 (30-49)	29 (21-36)	20 (14-27)	27 (13-45)	47 (35-63)	63 (52-76)	<2025 [100%] (<2025)	2070-2075 [91%] (2055-2100)	…-… [24%] (2080-…)	850 (630-1140)	790 (480-1150)	-10 (-280-0)	1.7 (1.6-1.8)	1.6 (1.5-1.8)	21 (14-42)	78 (69-91)	100 (98-100)
C3b [97]	… consistent with NDCs + accelerated action post 2030		52 (47-56)	29 (20-36)	18 (10-25)	5 (0-14)	46 (34-63)	68 (56-82)	< 2025 [100%] (< 2030)	2065-2070 [97%] (2060-2085)	…-… [42%] (2075-…)	910 (720-1100)	800 (560-1050)	-70 (-300-0)	1.8 (1.6-1.8)	1.6 (1.5-1.7)	17 (12-35)	73 (67-87)	99 (98-99)
C4 [159]	Below 2°C		50 (41-56)	38 (28-44)	28 (19-35)	10 (0-27)	31 (20-50)	49 (35-65)		2075-2080 [86%] (2065-2100)	…-… [31%] (2075-…)	1170 (960-1410)	1160 (700-1490)	-30 (-390-0)	1.9 (1.7-2.0)	1.8 (1.5-2.0)	11 (7-22)	59 (50-77)	98 (95-99)
C5 [212]	Below 2.5°C		52 (46-56)	45 (37-53)	39 (30-49)	6 (-1-18)	18 (4-33)	29 (11-48)	<2025 [100%] (<2035)	2090-2095 [41%] (2075-2100)	…-… [12%] (2090-…)	1610 (1340-1910)	1780 (1260-2360)	0 (-140-0)	2.2 (1.9-2.5)	2.1 (1.9-2.5)	4 (0-10)	37 (18-59)	91 (83-98)
C6 [97]	Below 3°C	SSP2-4.5 Mod-Act	54 (50-62)	53 (48-61)	52 (45-57)	2 (-10-11)	3 (-14-14)	5 (-2-18)	2030-2035 [97%] (<2085)				2790 (2440-3520)			2.7 (2.4-2.9)	0 (0-0)	8 (2-18)	71 (53-88)
C7 [164]	Below 4°C	SSP3-7.0 Cur-Pol	62 (53-69)	67 (56-76)	70 (58-83)	-11 (-18-3)	-19 (-31-1)	-24 (-41--2)	2070-2075 [57%] (2025-2095)	no net-zero		no net-zero	4220 (3160-5000)	no net-zero	temperature does not peak by 2100	3.5 (2.8-3.9)	0 (0-0)	0 (0-2)	22 (7-60)
C8 [29]	Above 4°C	SSP5-8.5	71 (69-81)	80 (78-96)	88 (82-112)	-20 (-34--17)	-35 (-65--29)	-46 (-92--36)	2080-2085 [90%] (2060-2095)				5600 (4910-7450)			4.2 (3.7-5.0)	0 (0-0)	0 (0-0)	4 (0-11)

190 Models (91+ modeling families):

- ✓ 98 globally comprehensive,
- ✓ 71 national or multi-regional,
- ✓ 20 sectoral models

Scenarios :

- ✓ 3131 submitted scenarios (global, sectoral, national)
- ✓ 2266 with sufficient information for climate assessment
- ✓ 1686 scenarios passed the baseline vetting
- ✓ 1202 in final Ch 3 climate assessment

WGIII scenario collection, vetting and assessment:

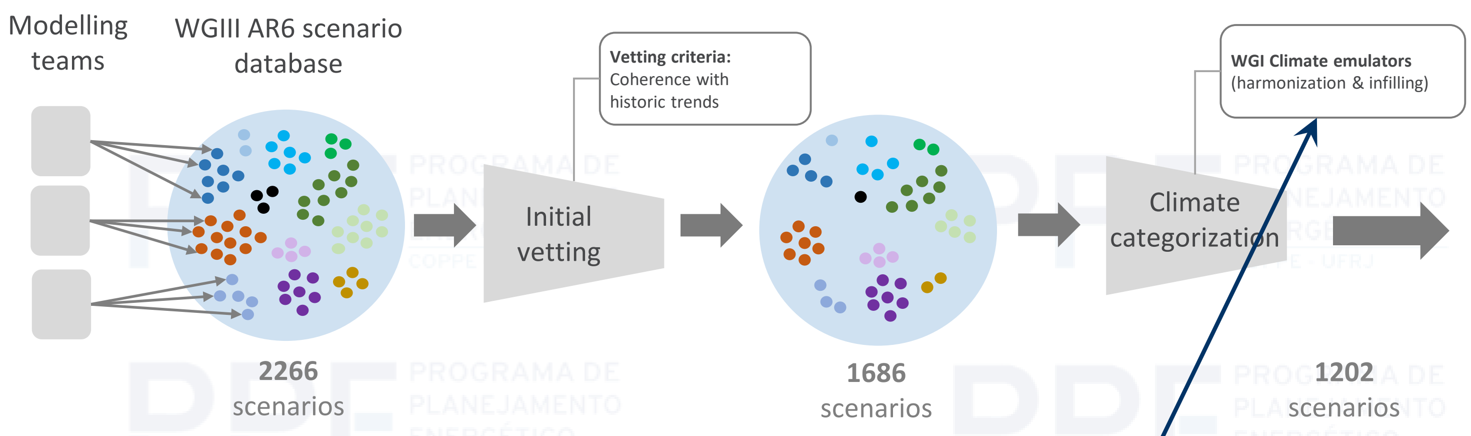


Table SPM1

p50 (p5-p95) [1] Global Mean Surface Air Temperature change			GHG emissions Gt CO_2-eq/yr			GHG emissions reductions from 2019 % [7]			Emissions milestones [8,9]			Cumulative CO_2 emissions Gt CO_2 [12]		Cumulative net-negative CO_2 emissions Gt CO_2	Temperature change 50% probability [13] °C		Likelihood of peak temperature staying below (%) [14]		
Category [2,3,4] [# pathways]	Category description	WG I SSP & WG III IPs/IMPs alignment [5,6]	2030	2040	2050	2030	2040	2050	Peak CO_2 & GHG emissions [% peak before 2100]	net-zero CO_2 [% net-zero pathways]	net-zero GHGs [10,11] [% net-zero pathways]	2020 to net-zero CO_2	2020-2100	year of net-zero CO_2 to 2100	at peak warming	2100	<1.5°C	<2.0°C	<3.0°C
A categorisation of pathways according to temperature outcomes. All Categories are with >50% probability of staying below the stated temeprature, with exception of C3 catgeories which are >=67% probability (likely). Alignment of the WG I SSP pathways and the WG III Illustrative (Mitigation) Pathways is also indicated			Median annual GHG emissions in the year across the scenarios, with the 5th-95th percentile in brackets			Median GHG emissions reductions of pathways in the year across the scenarios compared to 2019, with the 5th-95th percentile in brackets			Median 5-year interval at which CO2 & GHG emissions peak, with the 5th-95th percentile interval in brackets. All pathways peak, unless a % is denoted in square brackets	Median 5-year interval at which CO2 & GHG emissions of pathways in this category reach net-zero, with the 5th-95th percentile interval in brackets. All pathways reach net-zero, unless a % is denoted in square brackets. ... denotes net-zero not reached for that percentile.		Median cumulative net CO2 emissions across the scenarios in this category until reaching net-zero or until 2100, with the 5th-95th percentile interval in brackets.		Median cumulative net-negative CO2 emissions of pathways that occur between the year of net-zero CO2 and 2100. More net-negative results in more temperature reductions after peak	Temperature change of pathways in this category (50% probability across the range of climate uncertainties), relative to 1850-1900, at peak warming and in 2100, for the median value across the scenarios and the 5th-95th percentile interval in brackets.		Median likelihood that the pathways in this catgeory stay below a given temperature, with the 5th-95th percentile interval in brackets		
C1 [97]	Below 1.5°C with no or limited overshoot	SD, LD, SSP1-19, Ren	31 (21-36)	17 (6-23)	9 (1-15)	43 (34-60)	69 (58-90)	84 (73-98)	< 2025 [100%] (< 2025)	2050-2055 [100%] (2035-2070)	2095-2100 [53%] (2050-...)	510 (330-710)	320 (-210-570)	-200 (-560-0)	1.6 (1.4-1.6)	1.3 (1.1-1.5)	38 (33-58)	90 (86-97)	100 (99-100)
C2 [133]	Below 1.5°C with high overshoot	Neg	42 (31-55)	25 (17-34)	14 (5-21)	23 (0-44)	55 (40-71)	75 (62-91)	< 2025 [100%] (< 2030)	2055-2060 [100%] (2045-2070)	2070-2075 [87%] (2055-...)	720 (530-930)	400 (-90-620)	-330 (-620--30)	1.7 (1.5-1.8)	1.4 (1.2-1.5)	24 (15-42)	82 (71-93)	100 (99-100)
C3 [311]	Likely below 2°C	GS	44 (32-55)	29 (20-36)	20 (13-26)	21 (1-42)	46 (34-63)	64 (53-77)		2070-2075 [93%] (2055-2095)	...-... [30%] (2075-...)	880 (640-1130)	800 (500-1140)	-40 (-280-0)	1.7 (1.6-1.8)	1.6 (1.5-1.8)	20 (13-41)	76 (68-91)	99 (98-100)
C3a [204]	... with immediate action	SSP1-2.6	40 (30-49)	29 (21-36)	20 (14-27)	27 (13-45)	47 (35-63)	63 (52-76)	<2025 [100%] (<2025)	2070-2075 [91%] (2055-2100)	...-... [24%] (2080-...)	850 (630-1140)	790 (480-1150)	-10 (-280-0)	1.7 (1.6-1.8)	1.6 (1.5-1.8)	21 (14-42)	78 (69-91)	100 (98-100)
C3b [97]	... consistent with NDCs + accelerated action post 2030		52 (47-56)	29 (20-36)	18 (10-25)	5 (0-14)	46 (34-63)	68 (56-82)	< 2025 [100%] (< 2030)	2065-2070 [97%] (2060-2085)	...-... [42%] (2075-...)	910 (720-1100)	800 (560-1050)	-70 (-300-0)	1.8 (1.6-1.8)	1.6 (1.5-1.7)	17 (12-35)	73 (67-87)	99 (98-99)
C4 [159]	Below 2°C		50 (41-56)	38 (28-44)	28 (19-35)	10 (0-27)	31 (20-50)	49 (35-65)		2075-2080 [86%] (2065-2100)	...-... [31%] (2075-...)	1170 (960-1410)	1160 (700-1490)	-30 (-390-0)	1.9 (1.7-2.0)	1.8 (1.5-2.0)	11 (7-22)	59 (50-77)	98 (95-99)
C5 [212]	Below 2.5°C		52 (46-56)	45 (37-53)	39 (30-49)	6 (-1-18)	18 (4-33)	29 (11-48)	<2025 [100%] (<2035)	2090-2095 [41%] (2075-2100)	...-... [12%] (2090-...)	1610 (1340-1910)	1780 (1260-2360)	0 (-140-0)	2.2 (1.9-2.5)	2.1 (1.9-2.5)	4 (0-10)	37 (18-59)	91 (83-98)
C6 [97]	Below 3°C	SSP2-4.5 Mod-Act	54 (50-62)	53 (48-61)	52 (45-57)	2 (-10-11)	3 (-14-14)	5 (-2-18)	2030-2035 [97%] (<2085)	no net-zero		no net-zero	2790 (2440-3520)	no net-zero	temperature does not peak by 2100	2.7 (2.4-2.9)	0 (0-0)	8 (2-18)	71 (53-88)
C7 [164]	Below 4°C	SSP3-7.0 Cur-Pol	62 (53-69)	67 (56-76)	70 (58-83)	-11 (-18-3)	-19 (-31-1)	-24 (-41--2)	2070-2075 [57%] (2025-2095)				4220 (3160-5000)			3.5 (2.8-3.9)	0 (0-0)	0 (0-2)	22 (7-60)
C8 [29]	Above 4°C	SSP5-8.5	71 (69-81)	80 (78-96)	88 (82-112)	-20 (-34--17)	-35 (-65--29)	-46 (-92--36)	2080-2085 [90%] (2060-2095)				5600 (4910-7450)			4.2 (3.7-5.0)	0 (0-0)	0 (0-0)	4 (0-11)

- ✓ Improved infilling and harmonization methodologies compared to SR15
- ✓ Harmonized to historical emissions in 2015 (consistent with WG1) compared to 2010 for SR15.
- ✓ Two climate emulators: MAGICC7 and FAIR v1.6, calibrated to closely match the global warming response to emissions as assessed in (WGI Cross-chapter box 7.1). (CICERO_ESM used for additional sensitivity in the chapter 3)

Category [2, 3, 4] [# pathways]	Category description	WG I SSP & WG III IPs/IMPs alignment [5, 6]	p50 (p5-p95) [1] Global Mean Surface Air Temperature change
C1 [97]	Below 1.5°C with no or limited overshoot	SD, LD, SSP1-19, Ren	
C2 [133]	Below 1.5°C with high overshoot	Neg	
C3 [311]	Likely below 2°C	GS	
C3a [204]	… with immediate action	SSP1-2.6	
C3b [97]	… consistent with NDCs + accelerated action post 2030		
C4 [159]	Below 2°C		
C5 [212]	Below 2.5°C		
C6 [97]	Below 3°C	SSP2-4.5 Mod-Act	
C7 [164]	Below 4°C	SSP3-7.0 Cur-Pol	
C8 [29]	Above 4°C	SSP5-8.5	

Definition of the categories follows (largely) SR1.5

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Categories of scenarios are distinct; they do not subsume categories of scenarios consistent with lower levels of warming, e.g., the category of scenarios likely to limit warming to 2°C does not include scenarios limiting warming to 1.5°C. Where relevant, scenarios belonging to the group of categories C1-C3 are referred to in this SPM as scenarios likely to limit warming to below 2°C or lower. **{Scenario Box}**

<4°C peak warming with >50% chance

>4°C peak warming with >50% chance

Table SPM 1

Scenarios are used in WGIII together with bottom-up sectoral information to…

- ✓ Describe the solution space and key characteristics of (alternative) pathways
- ✓ Illustrate the pace of change for limiting warming to specific levels
  - ✓ Emissions reduction needs
  - ✓ Overshoot
  - ✓ Systems characteristics (upscaling of mitigation options, demand-side changes, CDR needs)
  - ✓ Sectoral contributions
- ✓ Net zero CO2 and net zero GHG systems (including timing and balance of sources and sinks)
- ✓ Economics and costs of mitigation (and costs of inaction)
- ✓ Associated feasibility challenges and risks
- ✓ Policy gaps (investments, emissions)

Scenario categories · **GHG emissions** · **Emissions milestones** · **Cumulative emissions** · **Temperature outcomes**

p50 (p5-p95)[1] Global Mean Surface Air Temperature change			GHG emissions Gt CO_2-eq/yr			GHG emissions reductions from 2019 %[7]			Emissions milestones[8,9]			Cumulative CO_2 emissions Gt CO_2[12]		Cumulative net-negative CO_2 emissions Gt CO_2	Temperature change 50% probability[13] °C		Likelihood of peak temperature staying below (%)[14]		
Category[2, 3, 4] [# pathways]	Category description	WG I SSP & WG III IPs/IMPs alignment[5, 6]	2030	2040	2050	2030	2040	2050	Peak CO_2 & GHG emissions [% peak before 2100]	net-zero CO_2 [% net-zero pathways]	net-zero GHGs[10, 11] [% net-zero pathways]	2020 to net-zero CO_2	2020-2100	year of net-zero CO_2 to 2100	at peak warming	2100	<1.5°C	<2.0°C	<3.0°C
A categorisation of pathways according to temperature outcomes. All Categories are with >50% probability of staying below the stated temeprature, with exception of C3 catgeories which are >=67% probability (likely). Alignment of the WG I SSP pathways and the WG III Illustrative (Mitigation) Pathways is also indicated			*Median annual GHG emissions in the year across the scenarios, with the 5th-95th percentile in brackets*			*Median GHG emissions reductions of pathways in the year across the scenarios compared to 2019, with the 5th-95th percentile in brackets*			*Median 5-year interval at which CO2 & GHG emissions peak, with the 5th-95th percentile interval in brackets. All pathways peak, unless a % is denoted in square brackets*	*Median 5-year interval at which CO2 & GHG emissions of pathways in this category reach net-zero, with the 5th-95th percentile interval in brackets. All pathways reach net-zero, unless a % is denoted in square brackets. … denotes net-zero not reached for that percentile.*		*Median cumulative net CO2 emissions across the scenarios in this category until reaching net-zero or until 2100, with the 5th-95th percentile interval in brackets.*		*Median cumulative net-negative CO2 emissions of pathways that occur between the year of net-zero CO2 and 2100. More net-negative results in more temperature reductions after peak*	*Temperature change of pathways in this category (50% probability across the range of climate uncertainties), relative to 1850-1900, at peak warming and in 2100, for the median value across the scenarios and the 5th-95th percentile interval in brackets.*		*Median likelihood that the pathways in this catgeory stay below a given temperature, with the 5th-95th percentile interval in brackets*		
C1 [97]	Below 1.5°C with no or limited overshoot	SD, LD, SSP1-19, Ren	31 (21-36)	17 (6-23)	9 (1-15)	43 (34-60)	69 (58-90)	84 (73-98)	< 2025 [100%] (< 2025)	2050-2055 [100%] (2035-2070)	2095-2100 [53%] (2050-...)	510 (330-710)	320 (-210-570)	-200 (-560-0)	1.6 (1.4-1.6)	1.3 (1.1-1.5)	38 (33-58)	90 (86-97)	100 (99-100)
C2 [133]	Below 1.5°C with high overshoot	Neg	42 (31-55)	25 (17-34)	14 (5-21)	23 (0-44)	55 (40-71)	75 (62-91)	< 2025 [100%] (< 2030)	2055-2060 [100%] (2045-2070)	2070-2075 [87%] (2055-...)	720 (530-930)	400 (-90-620)	-330 (-620--30)	1.7 (1.5-1.8)	1.4 (1.2-1.5)	24 (15-42)	82 (71-93)	100 (99-100)
C3 [311]	Likely below 2°C	GS	44 (32-55)	29 (20-36)	20 (13-26)	21 (1-42)	46 (34-63)	64 (53-77)	< 2025 [100%] (< 2030)	2070-2075 [93%] (2055-2095)	...-... [30%] (2075-...)	880 (640-1130)	800 (500-1140)	-40 (-280-0)	1.7 (1.6-1.8)	1.6 (1.5-1.8)	20 (13-41)	76 (68-91)	99 (98-100)
C3a [204]	... with immediate action	SSP1-2.6	40 (30-49)	29 (21-36)	20 (14-27)	27 (13-45)	47 (35-63)	63 (52-76)	<2025 [100%] (<2025)	2070-2075 [91%] (2055-2100)	...-... [24%] (2080-...)	850 (630-1140)	790 (480-1150)	-10 (-280-0)	1.7 (1.6-1.8)	1.6 (1.5-1.8)	21 (14-42)	78 (69-91)	100 (98-100)
C3b [97]	... consistent with NDCs + accelerated action post 2030		52 (47-56)	29 (20-36)	18 (10-25)	5 (0-14)	46 (34-63)	68 (56-82)	< 2025 [100%] (< 2030)	2065-2070 [97%] (2060-2085)	...-... [42%] (2075-...)	910 (720-1100)	800 (560-1050)	-70 (-300-0)	1.8 (1.6-1.8)	1.6 (1.5-1.7)	17 (12-35)	73 (67-87)	99 (98-99)
C4 [159]	Below 2°C		50 (41-56)	38 (28-44)	28 (19-35)	10 (0-27)	31 (20-50)	49 (35-65)	< 2025 [100%] (< 2030)	2075-2080 [86%] (2065-2100)	...-... [31%] (2075-...)	1170 (960-1410)	1160 (700-1490)	-30 (-390-0)	1.9 (1.7-2.0)	1.8 (1.5-2.0)	11 (7-22)	59 (50-77)	98 (95-99)
C5 [212]	Below 2.5°C		52 (46-56)	45 (37-53)	39 (30-49)	6 (-1-18)	18 (4-33)	29 (11-48)	<2025 [100%] (<2035)	2090-2095 [41%] (2075-2100)	...-... [12%] (2090-...)	1610 (1340-1910)	1780 (1260-2360)	0 (-140-0)	2.2 (1.9-2.5)	2.1 (1.9-2.5)	4 (0-10)	37 (18-59)	91 (83-98)
C6 [97]	Below 3°C	SSP2-4.5 Mod-Act	54 (50-62)	53 (48-61)	52 (45-57)	2 (-10-11)	3 (-14-14)	5 (-2-18)	2030-2035 [97%] (<2085)	no net-zero	no net-zero	no net-zero	2790 (2440-3520)	no net-zero	temperature does not peak by 2100	2.7 (2.4-2.9)	0 (0-0)	8 (2-18)	71 (53-88)
C7 [164]	Below 4°C	SSP3-7.0 Cur-Pol	62 (53-69)	67 (56-76)	70 (58-83)	-11 (-18-3)	-19 (-31-1)	-24 (-41--2)	2070-2075 [57%] (2025-2095)	no net-zero	no net-zero	no net-zero	4220 (3160-5000)	no net-zero	temperature does not peak by 2100	3.5 (2.8-3.9)	0 (0-0)	0 (0-2)	22 (7-60)
C8 [29]	Above 4°C	SSP5-8.5	71 (69-81)	80 (78-96)	88 (82-112)	-20 (-34--17)	-35 (-65--29)	-46 (-92--36)	2080-2085 [90%] (2060-2095)	no net-zero	no net-zero	no net-zero	5600 (4910-7450)	no net-zero	temperature does not peak by 2100	4.2 (3.7-5.0)	0 (0-0)	0 (0-0)	4 (0-11)

Table SPM 1

Some improvements since AR5

- ✓ Complementary use of full database, IMPs and SSPs
- ✓ Extension to regional, national and sectoral scenarios
- ✓ Huge increase in participation from community – majority of teams 1st time
- ✓ National pathways informing NDC assessment (chapter 3&4 collaboration)
- ✓ Scenarios database used in more than half of the chapters (10 out of 17) and half of the SPM figures use scenario data
- ✓ Improved comparison of IAM and sectoral models
- ✓ Improved consistency, transparency and reproducibility across the report (AR6 Scenario Explorer: https://data.ece.iiasa.ac.at/ar6/)

A 3 year collaborative journey…

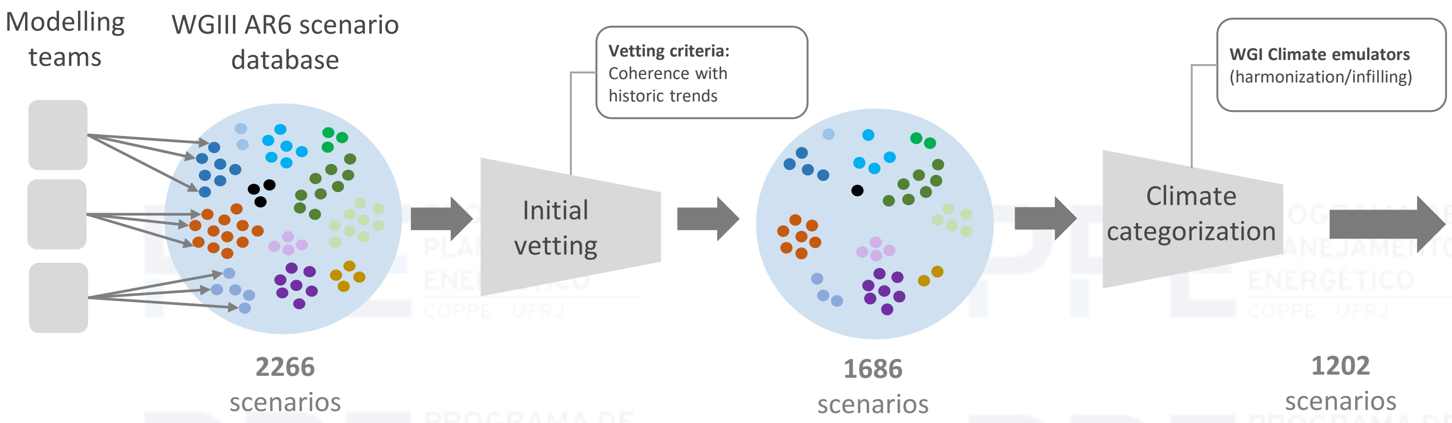
D. Huppmann et al. (2018).
doi: [10.1038/s41558-018-0317-4](https://doi.org/10.1038/s41558-018-0317-4)

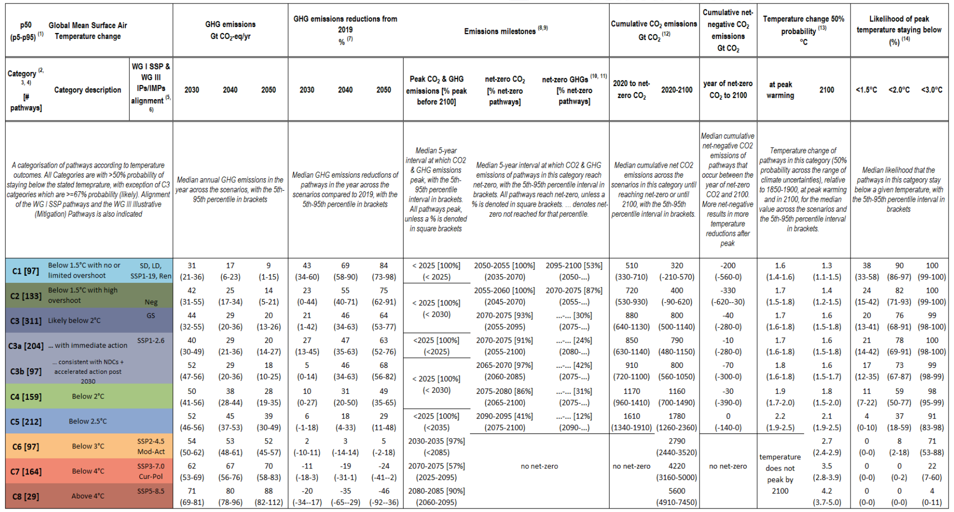
3131 scenarios
1799 variables
220 million datapoints

188 models from 50+ model teams

An IPCC scenario database that integrates disciplines, scales and communities

WGIII scenario collection, vetting and assessment





Category (2, 3, 4) [# pathways]	Category description	WG I SSP & WG III IPs/IMPs alignment (5, 6)	GHG emissions Gt CO_2-eq/yr: 2030	GHG emissions: 2040	GHG emissions: 2050	GHG emissions reductions from 2019 % (7): 2030	GHG reductions: 2040	GHG reductions: 2050	Emissions milestones (8,9): Peak CO_2 & GHG emissions [% peak before 2100]	Emissions milestones: net-zero CO_2 [% net-zero pathways]	Emissions milestones: net-zero GHGs (10, 11) [% net-zero pathways]	Cumulative CO_2 emissions Gt CO_2 (12): 2020 to net-zero CO_2	Cumulative CO_2 emissions: 2020-2100	Cumulative net-negative CO_2 emissions Gt CO_2: year of net-zero CO_2 to 2100	Temperature change 50% probability (13) °C: at peak warming	Temperature change: 2100	Likelihood of peak temperature staying below (%) (14): <1.5°C	Likelihood: <2.0°C	Likelihood: <3.0°C
A categorisation of pathways according to temperature outcomes. All Categories are with >50% probability of staying below the stated temeprature, with exception of C3 catgeories which are >=67% probability (likely). Alignment of the WG I SSP pathways and the WG III Illustrative (Mitigation) Pathways is also indicated			Median annual GHG emissions in the year across the scenarios, with the 5th-95th percentile in brackets			Median GHG emissions reductions of pathways in the year across the scenarios compared to 2019, with the 5th-95th percentile in brackets			Median 5-year interval at which CO2 & GHG emissions peak, with the 5th-95th percentile interval in brackets. All pathways peak, unless a % is denoted in square brackets	Median 5-year interval at which CO2 & GHG emissions of pathways in this category reach net-zero, with the 5th-95th percentile interval in brackets. All pathways reach net-zero, unless a % is denoted in square brackets. … denotes net-zero not reached for that percentile.		Median cumulative net CO2 emissions across the scenarios in this category until reaching net-zero or until 2100, with the 5th-95th percentile interval in brackets.		Median cumulative net-negative CO2 emissions of pathways that occur between the year of net-zero CO2 and 2100. More net-negative results in more temperature reductions after peak	Temperature change of pathways in this category (50% probability across the range of climate uncertainties), relative to 1850-1900, at peak warming and in 2100, for the median value across the scenarios and the 5th-95th percentile interval in brackets.		Median likelihood that the pathways in this catgeory stay below a given temperature, with the 5th-95th percentile interval in brackets		
C1 [97]	Below 1.5°C with no or limited overshoot	SD, LD, SSP1-19, Ren	31 (21-36)	17 (6-23)	9 (1-15)	43 (34-60)	69 (58-90)	84 (73-98)	< 2025 [100%] (< 2025)	2050-2055 [100%] (2035-2070)	2095-2100 [53%] (2050-...)	510 (330-710)	320 (-210-570)	-200 (-560-0)	1.6 (1.4-1.6)	1.3 (1.1-1.5)	38 (33-58)	90 (86-97)	100 (99-100)
C2 [133]	Below 1.5°C with high overshoot	Neg	42 (31-55)	25 (17-34)	14 (5-21)	23 (0-44)	55 (40-71)	75 (62-91)	< 2025 [100%] (< 2030)	2055-2060 [100%] (2045-2070)	2070-2075 [87%] (2055-...)	720 (530-930)	400 (-90-620)	-330 (-620--30)	1.7 (1.5-1.8)	1.4 (1.2-1.5)	24 (15-42)	82 (71-93)	100 (99-100)
C3 [311]	Likely below 2°C	GS	44 (32-55)	29 (20-36)	20 (13-26)	21 (1-42)	46 (34-63)	64 (53-77)		2070-2075 [93%] (2055-2095)	...-... [30%] (2075-...)	880 (640-1130)	800 (500-1140)	-40 (-280-0)	1.7 (1.6-1.8)	1.6 (1.5-1.8)	20 (13-41)	76 (68-91)	99 (98-100)
C3a [204]	... with immediate action	SSP1-2.6	40 (30-49)	29 (21-36)	20 (14-27)	27 (13-45)	47 (35-63)	63 (52-76)	<2025 [100%] (<2025)	2070-2075 [91%] (2055-2100)	...-... [24%] (2080-...)	850 (630-1140)	790 (480-1150)	-10 (-280-0)	1.7 (1.6-1.8)	1.6 (1.5-1.8)	21 (14-42)	78 (69-91)	100 (98-100)
C3b [97]	... consistent with NDCs + accelerated action post 2030		52 (47-56)	29 (20-36)	18 (10-25)	5 (0-14)	46 (34-63)	68 (56-82)	< 2025 [100%] (< 2030)	2065-2070 [97%] (2060-2085)	...-... [42%] (2075-...)	910 (720-1100)	800 (560-1050)	-70 (-300-0)	1.8 (1.6-1.8)	1.6 (1.5-1.7)	17 (12-35)	73 (67-87)	99 (98-99)
C4 [159]	Below 2°C		50 (41-56)	38 (28-44)	28 (19-35)	10 (0-27)	31 (20-50)	49 (35-65)		2075-2080 [86%] (2065-2100)	...-... [31%] (2075-...)	1170 (960-1410)	1160 (700-1490)	-30 (-390-0)	1.9 (1.7-2.0)	1.8 (1.5-2.0)	11 (7-22)	59 (50-77)	98 (95-99)
C5 [212]	Below 2.5°C		52 (46-56)	45 (37-53)	39 (30-49)	6 (-1-18)	18 (4-33)	29 (11-48)	<2025 [100%] (<2035)	2090-2095 [41%] (2075-2100)	...-... [12%] (2090-...)	1610 (1340-1910)	1780 (1260-2360)	0 (-140-0)	2.2 (1.9-2.5)	2.1 (1.9-2.5)	4 (0-10)	37 (18-59)	91 (83-98)
C6 [97]	Below 3°C	SSP2-4.5 Mod-Act	54 (50-62)	53 (48-61)	52 (45-57)	2 (-10-11)	3 (-14-14)	5 (-2-18)	2030-2035 [97%] (<2085)				2790 (2440-3520)			2.7 (2.4-2.9)	0 (0-0)	8 (2-18)	71 (53-88)
C7 [164]	Below 4°C	SSP3-7.0 Cur-Pol	62 (53-69)	67 (56-76)	70 (58-83)	-11 (-18-3)	-19 (-31-1)	-24 (-41--2)	2070-2075 [57%] (2025-2095)	no net-zero		no net-zero	4220 (3160-5000)	no net-zero	temperature does not peak by 2100	3.5 (2.8-3.9)	0 (0-0)	0 (0-2)	22 (7-60)
C8 [29]	Above 4°C	SSP5-8.5	71 (69-81)	80 (78-96)	88 (82-112)	-20 (-34--17)	-35 (-65--29)	-46 (-92--36)	2080-2085 [90%] (2060-2095)				5600 (4910-7450)			4.2 (3.7-5.0)	0 (0-0)	0 (0-0)	4 (0-11)

Table SPM1

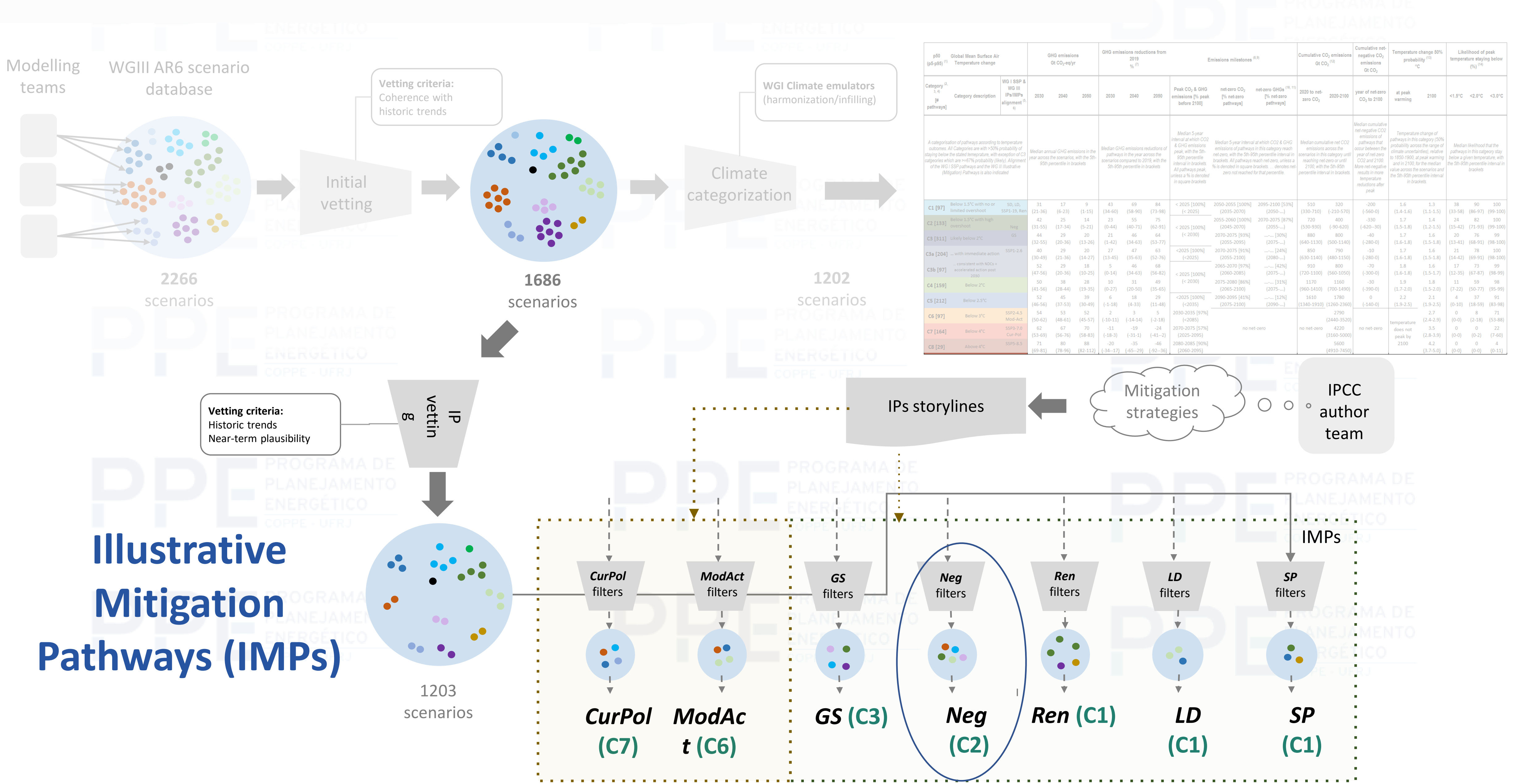
Scenarios :

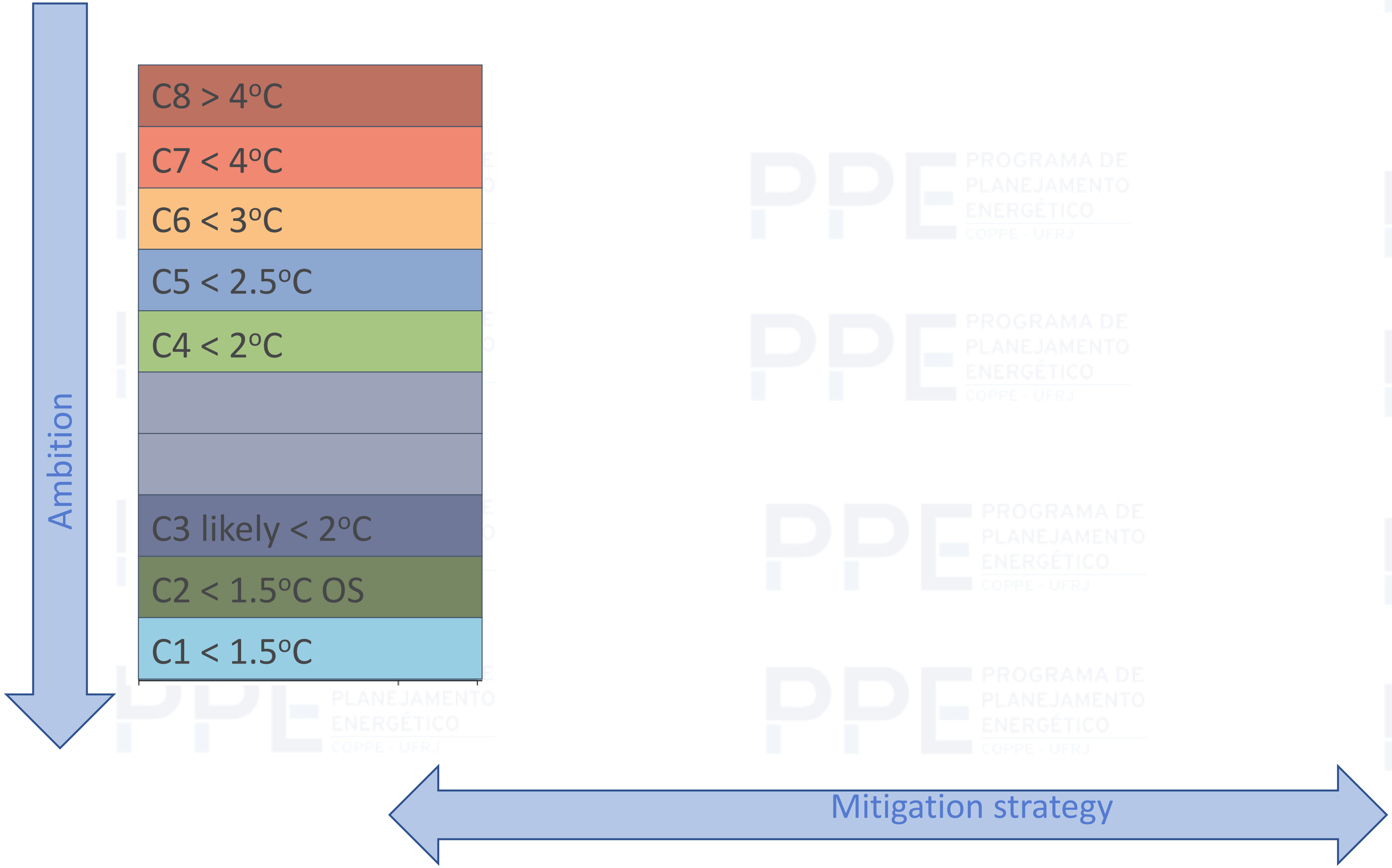
- ✓ 3131 submitted scenarios (global, sectoral, national)
- ✓ 2266 with sufficient information for climate assessment
- ✓ 1686 scenarios passed the baseline vetting
- ✓ 1202 in final Ch 3 climate assessment

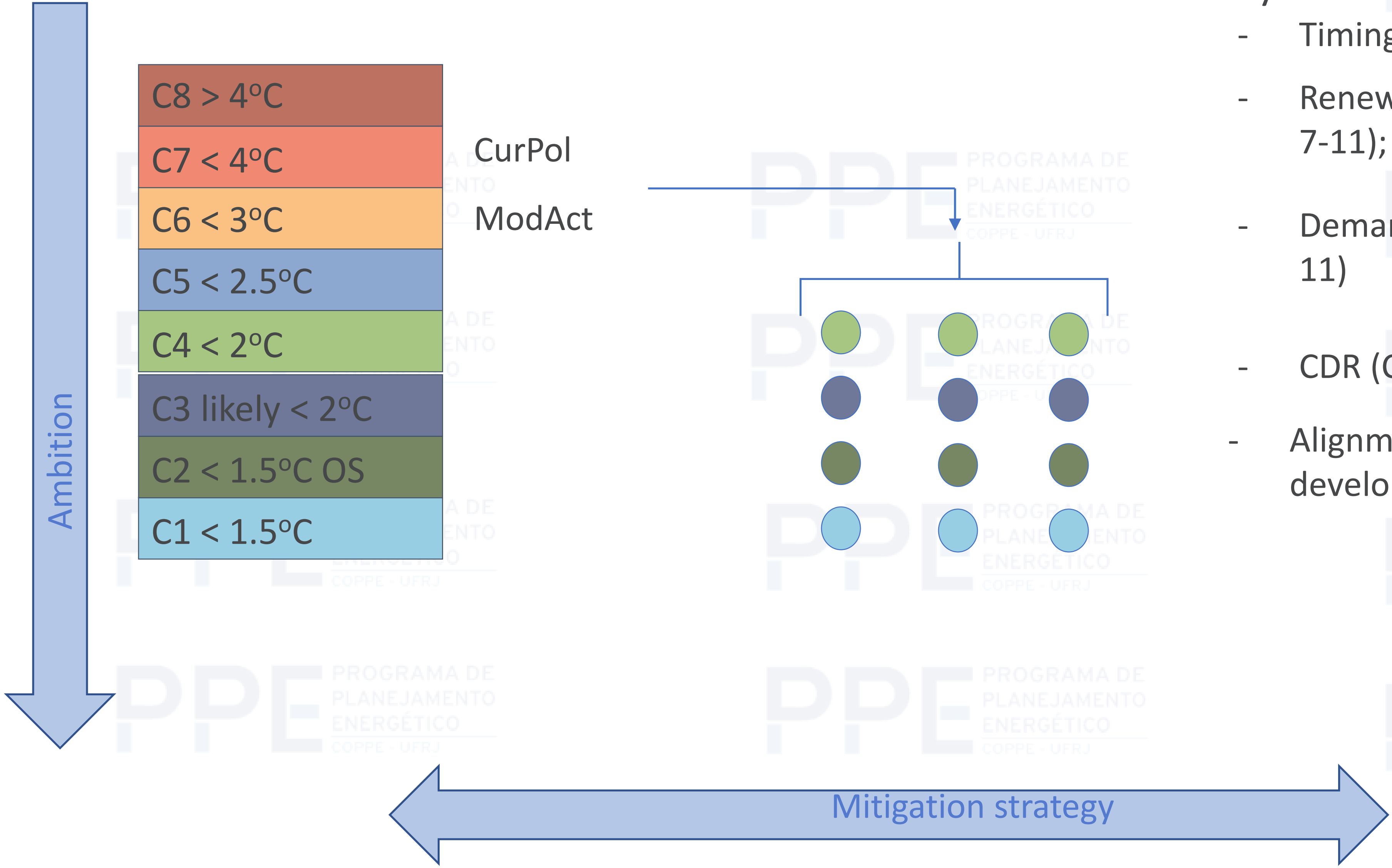
188 Models (91+ modeling families):

- ✓ 98 globally comprehensive,
- ✓ 71 national or multi-regional,
- ✓ 20 sectoral models
- ✓ Input and output data

WGIII Illustrative Mitigation Pathways

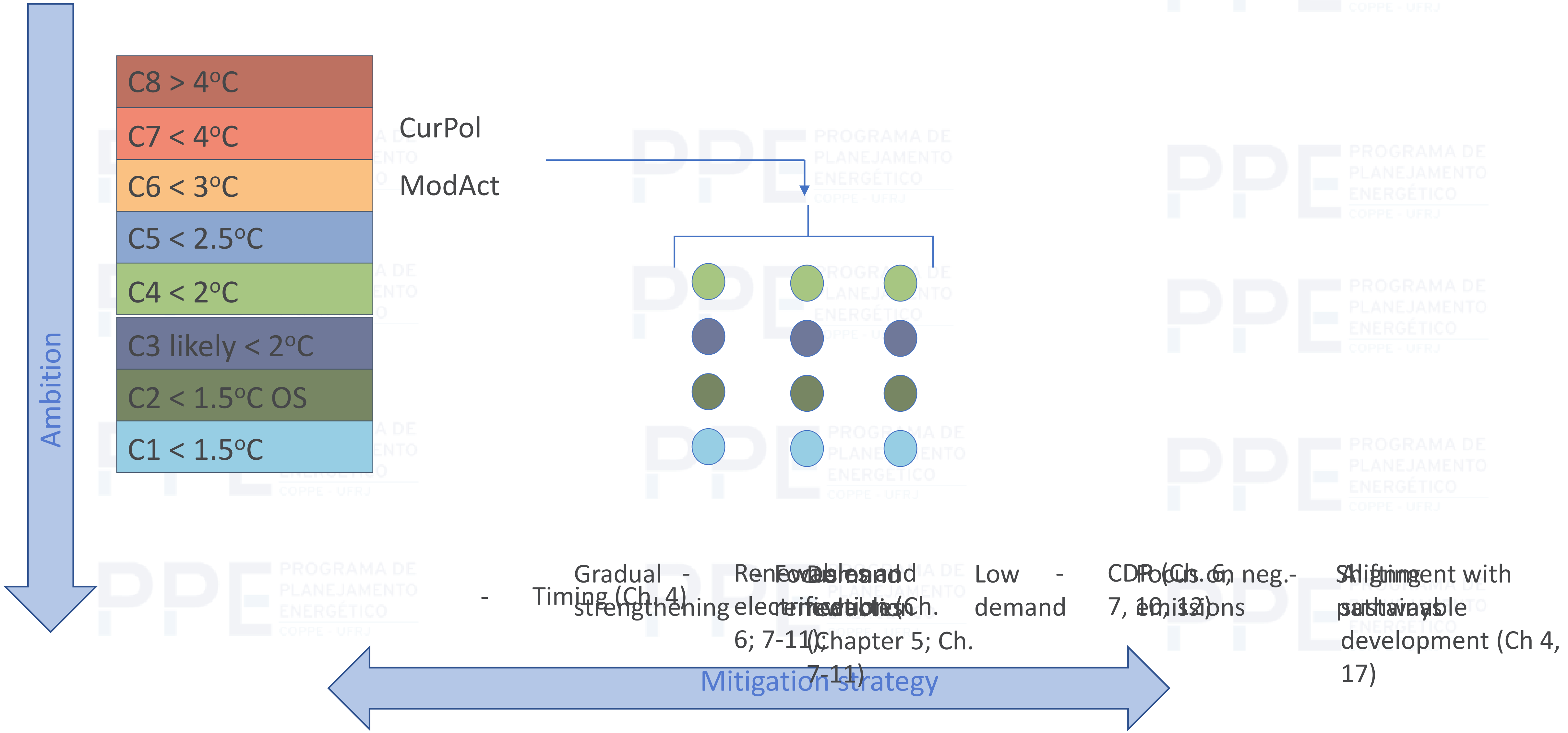



Ambition
C8 > 4ºC
C7 < 4ºC
C6 < 3ºC
C5 < 2.5ºC
C4 < 2ºC
C3 likely < 2ºC
C2 < 1.5ºC OS
C1 < 1.5ºC
Mitigation strategy

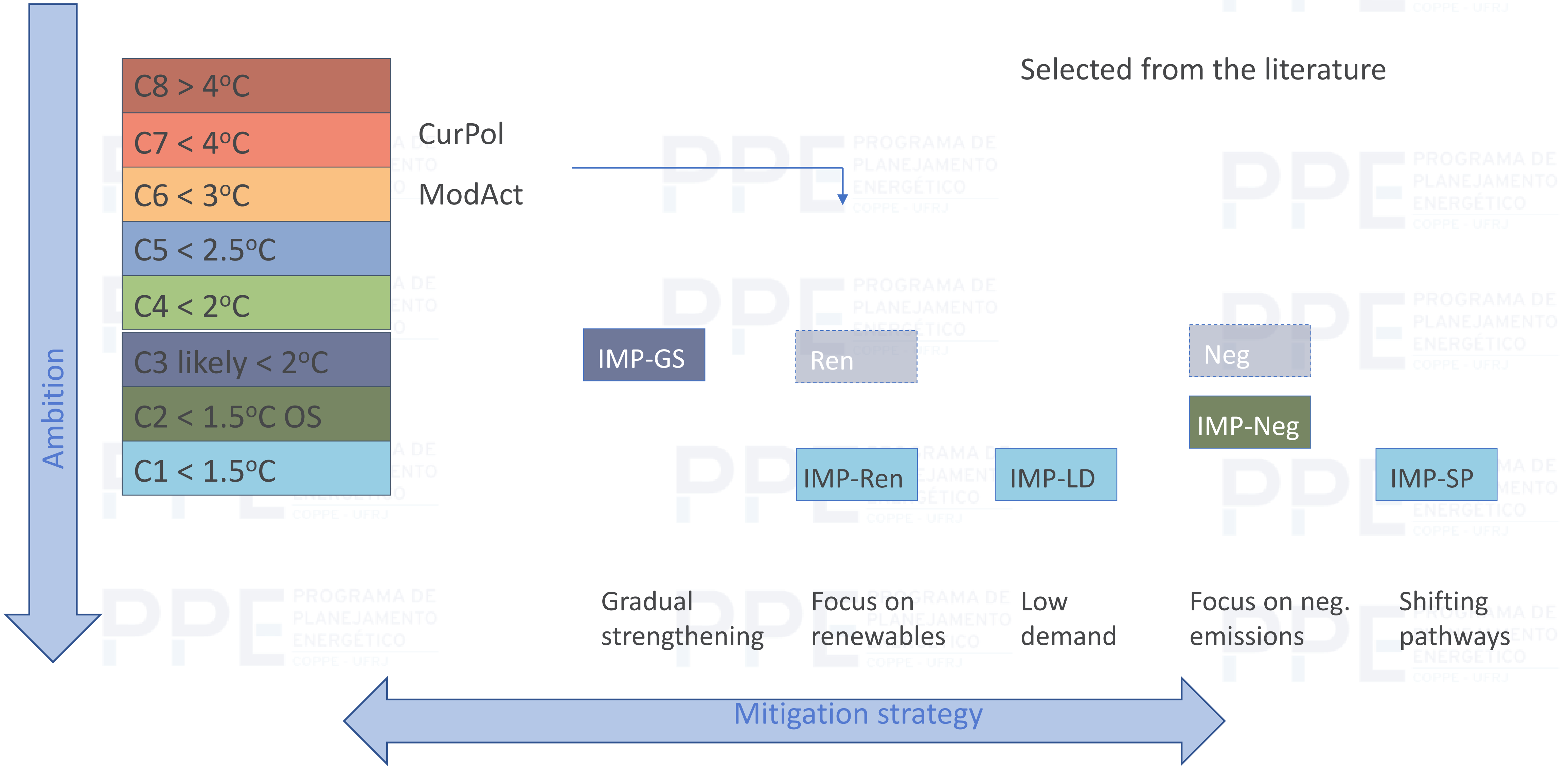


Key themes:

- Timing (Ch. 4)
- Renewables and electrification (Ch. 6; 7-11);
- Demand reduction (Chapter 5; Ch. 7-11)
- CDR (Ch. 6, 7, 10, 12)
- Alignment with sustainable development (Ch 4, 17)



Ambition
C8 > 4°C
C7 < 4°C
C6 < 3°C
C5 < 2.5°C
C4 < 2°C
C3 likely < 2°C
C2 < 1.5°C OS
C1 < 1.5°C
CurPol
ModAct
Timing (Ch. 4)
Gradual strengthening
Low demand
Mitigation strategy



Selected from the literature
C8 > 4°C
C7 < 4°C
C6 < 3°C
C5 < 2.5°C
C4 < 2°C
C3 likely < 2°C
C2 < 1.5°C OS
C1 < 1.5°C
CurPol
ModAct
Ambition
IMP-GS
Ren
Neg
IMP-Neg
IMP-Ren
IMP-LD
IMP-SP
Gradual strengthening
Focus on renewables
Low demand
Focus on neg. emissions
Shifting pathways
Mitigation strategy

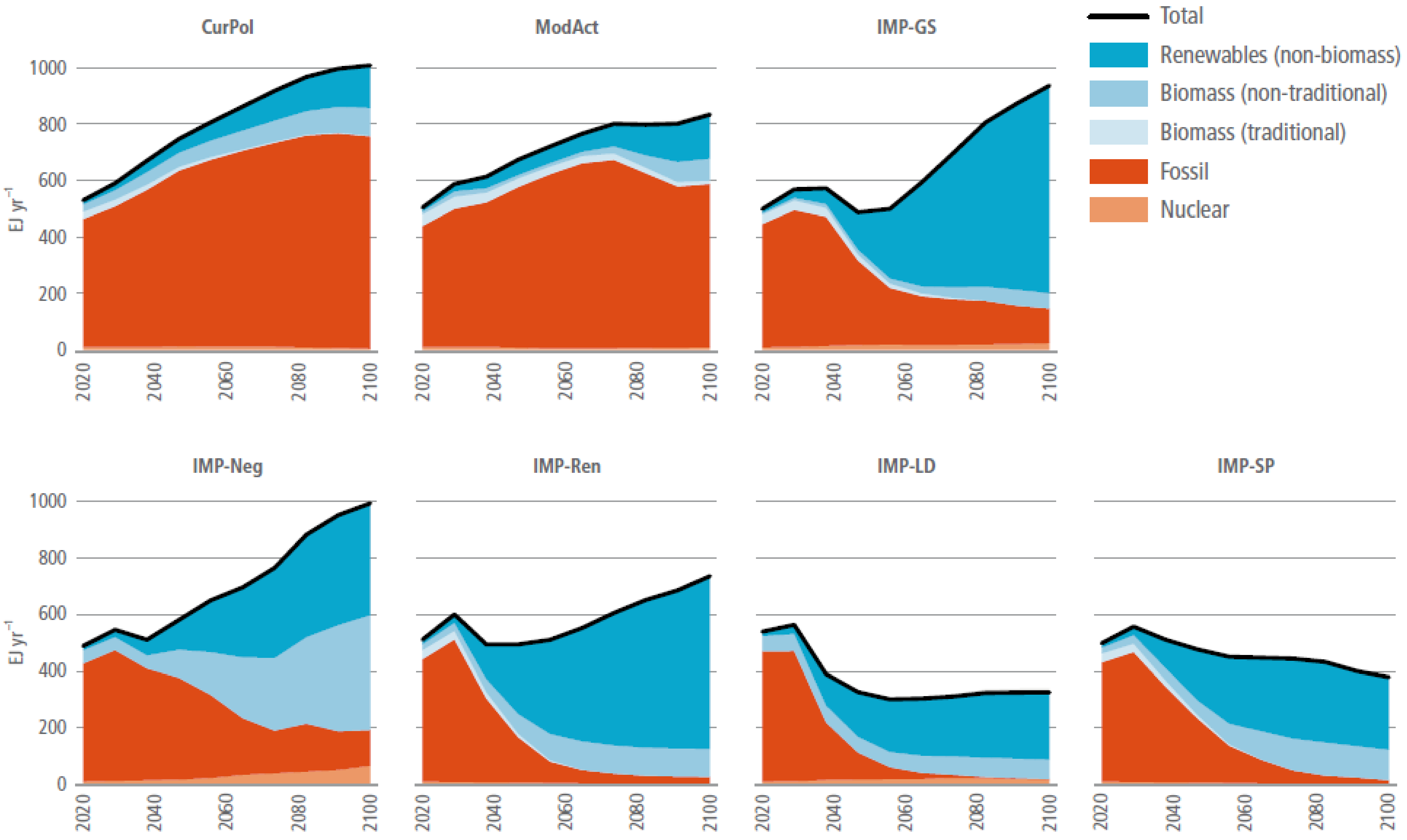


Figure 3.8 | The energy system in each of the illustrative pathways (IPs).

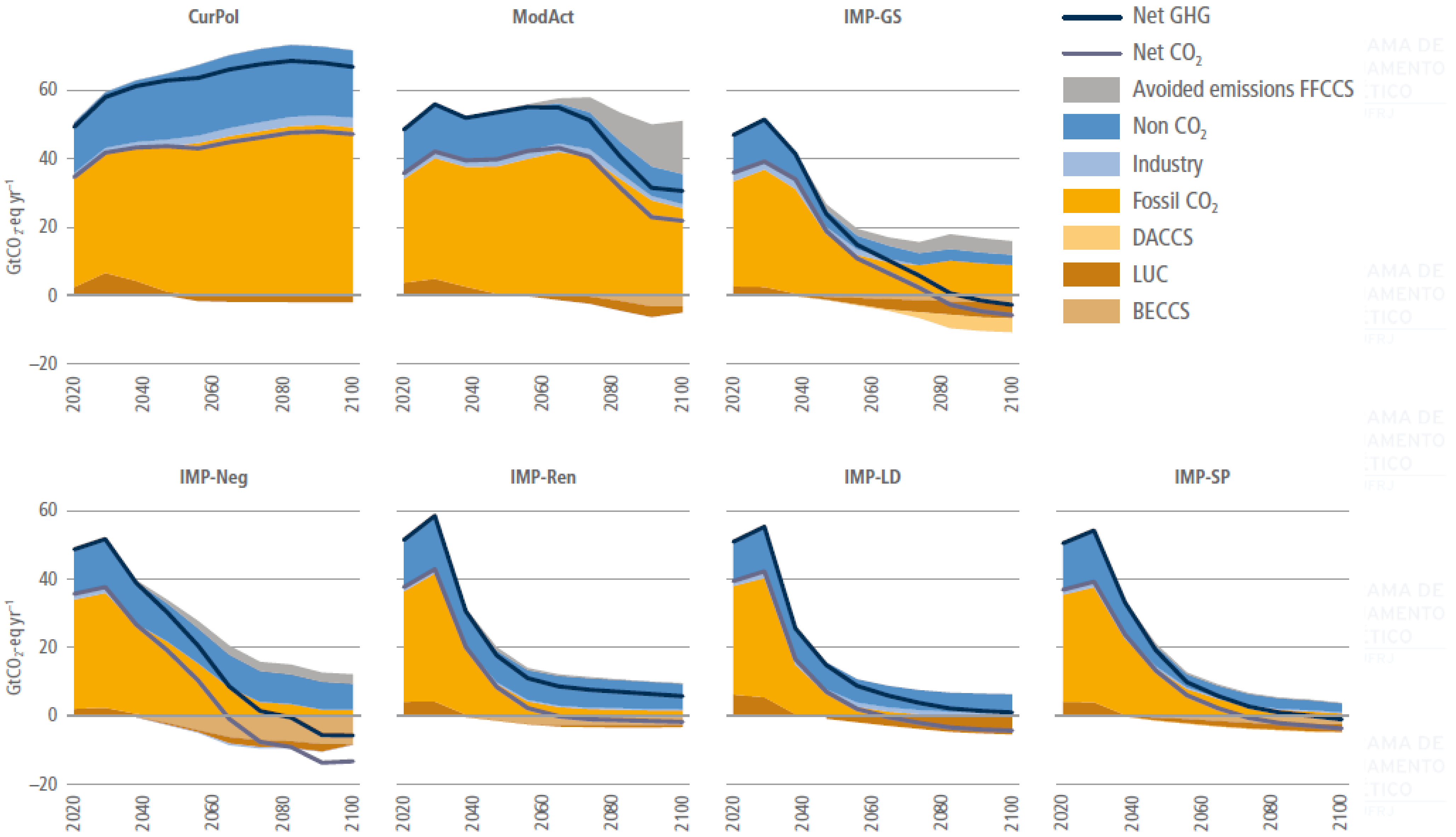


Figure 3.7 | The residual fossil fuel and industry emissions, carbon dioxide removal (CDR) {LUC, DACCS, BECCS}, and non-CO_2 emissions (using AR6 GWP-100) for each of the seven illustrative pathways (IPs). Fossil CCS is also shown, though this does not lead to emissions to the atmosphere (Section 3.2.5).

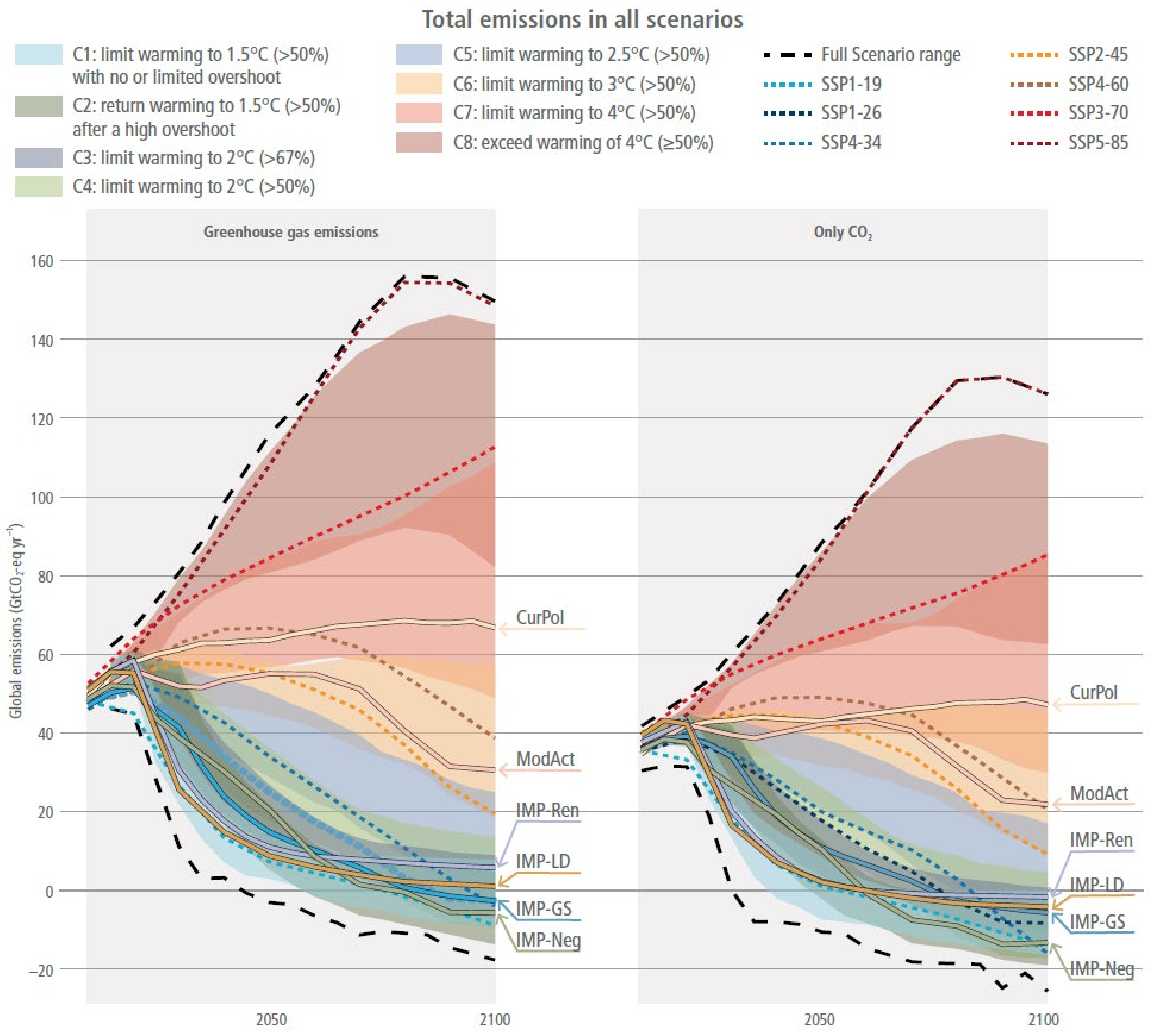


Figure 3.10 | Total emissions profiles in the scenarios based on climate category for GHGs (AR6 GWP-100) and CO_2. The Illustrative mitigation pathways (IMPs) are also indicated.

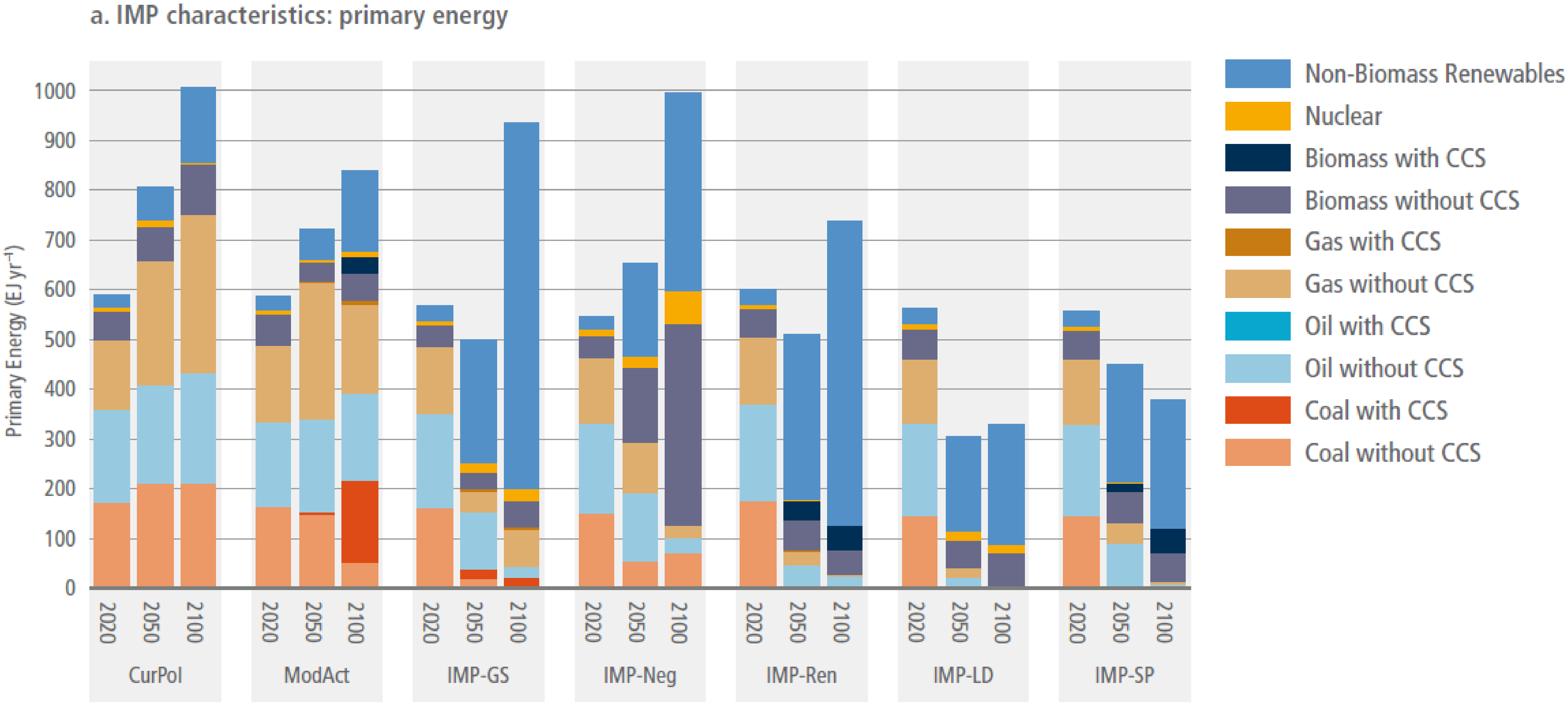


Figure 3.16 | Primary energy use and net emissions at net zero year for the different IMPS

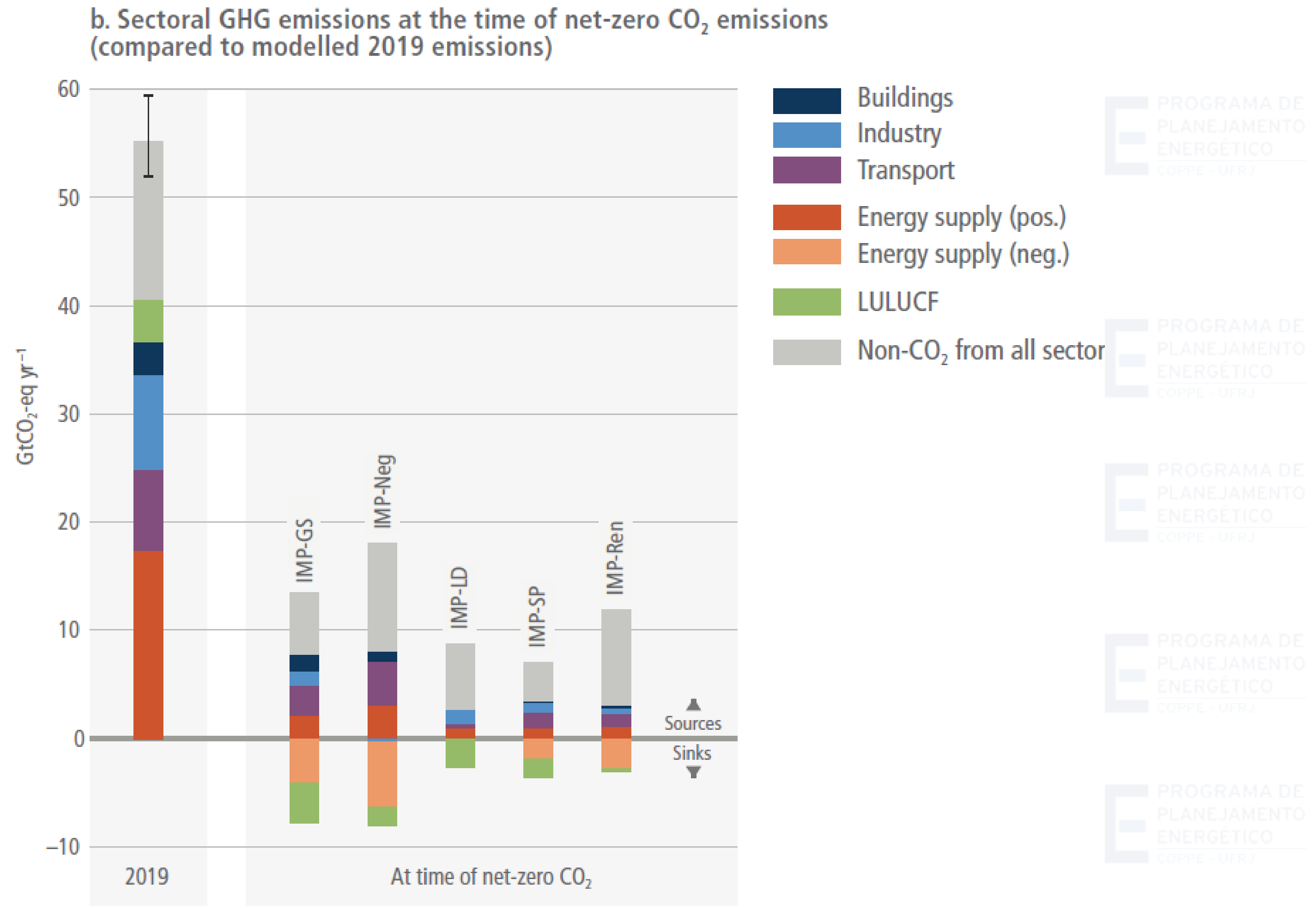


Figure 3.16 | Primary energy use and net emissions at net zero year for the different IMPS

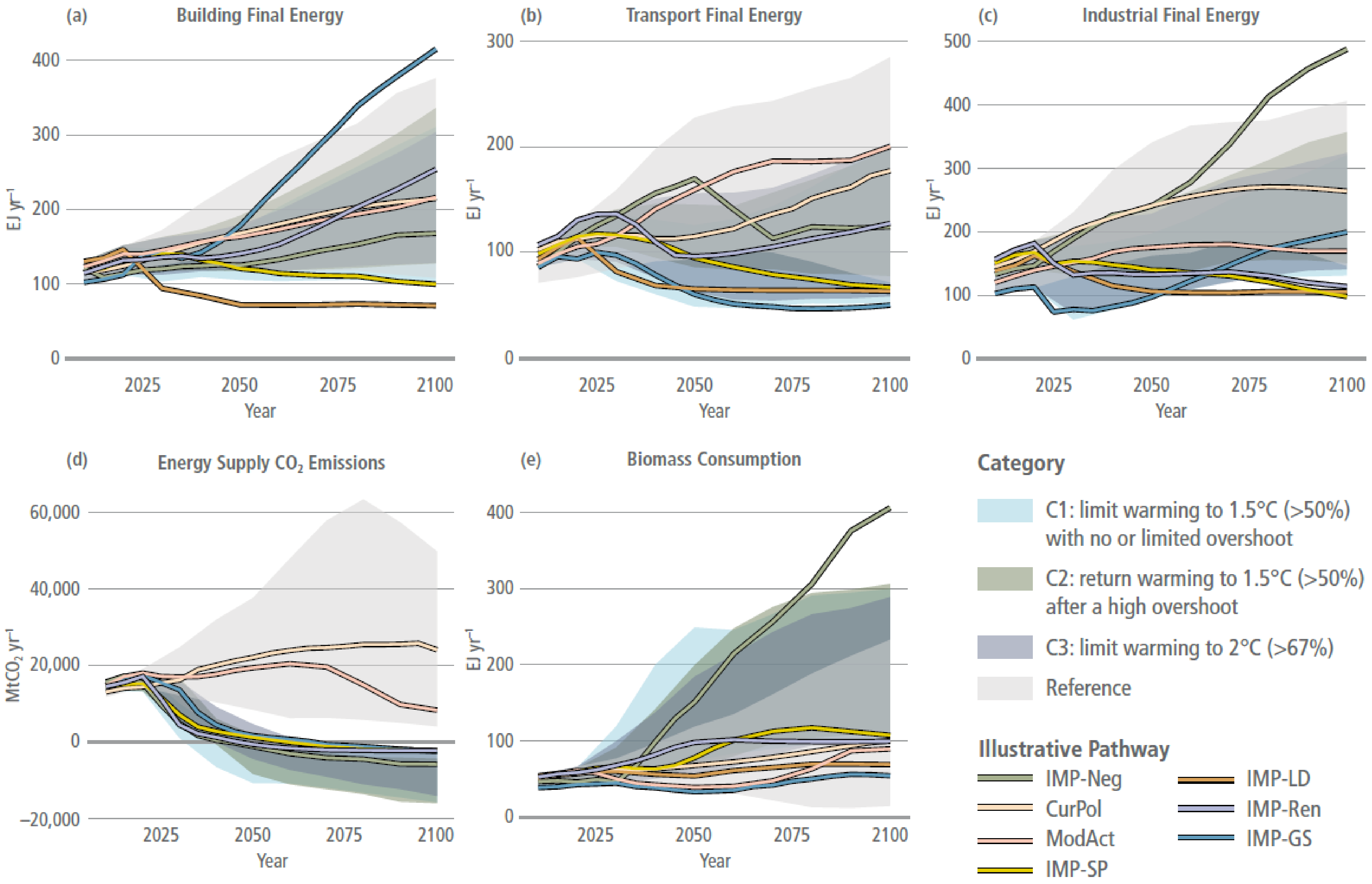


Figure 3.18 | Indicators of demand and supply-side mitigation in the Illustrative Pathways (lines) and the 5–95% range of Reference, 1.5°C and 2°C scenarios (shaded areas).

Mitigation Scenarios: What Do They Mean?

Reduced greenhouse gas emissions

All the scenarios aim at preventing further damage caused by greenhouse gas emissions by reducing their rate.

Less pollution, healthier environment

Mitigating climate change will lead to cleaner air and water, reduced acid rain, and lower risks of environmental disasters like wildfires and floods.

New economic opportunities

The transition to a low-carbon economy will create new opportunities, such as renewable energy industries, electric vehicles, and sustainable agriculture.

Equity and social justice

Mitigation scenarios can promote social and economic equity by creating green jobs, protecting vulnerable populations and reducing poverty.

The Future of Climate Scenarios

1 New Data Sources

Advances in technology and new data sources will provide more accurate data for climate models, resulting in more accurate scenarios.

2 Innovative Approaches

Developments in modeling techniques will allow for more innovative and comprehensive approaches to scenario development.

3 Interdisciplinary Collaboration

Interdisciplinary collaboration will lead to more comprehensive and nuanced climate scenarios that take into account a wide range of factors.

Summary

The IPCC has been using IAMs to assess the impact of human activities on climate change since its very beginning.

The 1990 SA90 scenarios highlighted the urgent need for mitigation strategies to limit greenhouse gas emissions and avoid the most severe impacts of climate change.

IAMs simulate the interactions between the economic, energy, and land-use sectors, and their impact on greenhouse gas emissions and climate change.

IAMs have been used in all IPCC reports since the Second Assessment Report (SAR) in 1995 and have provided valuable insights into the effectiveness of various mitigation strategies.

IAMs face challenges such as uncertainty, data limitations, and simplification of real-world complexities.

Despite these challenges, IAMs remain an essential tool for understanding the relationship between human activities and climate change and informing climate policy decisions.

3. How IAMs are being used for policymaking

The use of IAMs in climate policy has become increasingly valuable in countries' NDC preparation, LTS development, and target negotiation during COPs. In this presentation, we explore the various ways IAMs are shaping global climate policy.

Using IAMs for NDC Preparation

1

Emissions Projections

IAMs provide projections of future greenhouse gas emissions under different policy scenarios. This may inform the development of ambitious yet realistic NDCs.

2

Cost-Benefit Analysis

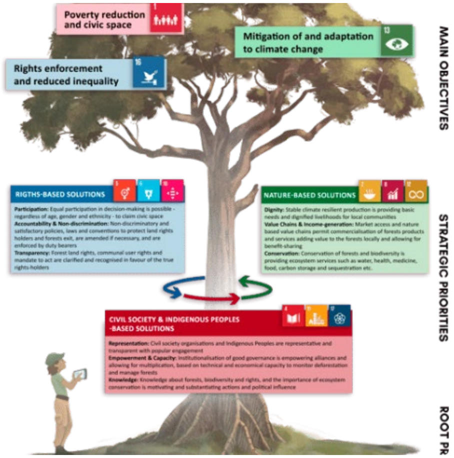
IAMs may offer a way to assess the costs and benefits of different mitigation options. This helps countries identify the most cost-effective and impactful measures within their socio-economic context.

3

Adaptation Planning

IAMs can also help countries identify the most vulnerable sectors, ecosystems, and populations and prioritize adaptation measures to reduce the associated risks.

IAMs and Long-Term Strategies



Renewables Integration

IAMs can help countries assess the potential of different renewable energy options and the best way to integrate them into the energy system while ensuring reliability, affordability and reducing emissions.

Urban Planning

IAMs can also inform urban planning decisions by evaluating the costs and benefits of different modes of transportation, building designs, and land-use policies.

Nature-Based Solutions

IAMs can guide the development of policies and incentives to preserve and restore natural ecosystems, which are crucial for carbon sequestration and biodiversity conservation.

Energy Efficiency

IAMs help countries evaluate the potential of implementing energy efficiency measures in various sectors and their associated costs and benefits.

Using IAMs for Climate Negotiations during COPs

1

Equity Assessment

IAMs can help assess the equitable distribution of efforts and benefits across different countries or groups of countries.

2

Innovative Finance

IAMs can inform innovative financing mechanisms such as carbon markets or green bonds which can help mobilize private sector investments in low-carbon sectors.

3

Technology Transfer

IAMs can help assess the cost and potential benefits of technology transfer between countries to support climate action and capacity building.

Benefits and Limitations of IAMs

Benefits:

- Basis for evidence-based climate policy decisions
- Allows for systematic comparison of different policy options
- Provides an integrated view of the climate challenge

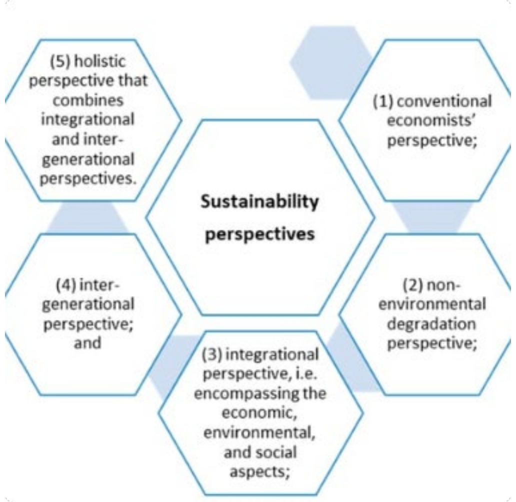
Limitations:

- Assumptions and uncertainty in data can lead to biases in results
- Models can be complex and require expertise to interpret
- May not adequately capture the multiple dimensions of equity

Benefits of Using IAMs for Policymaking

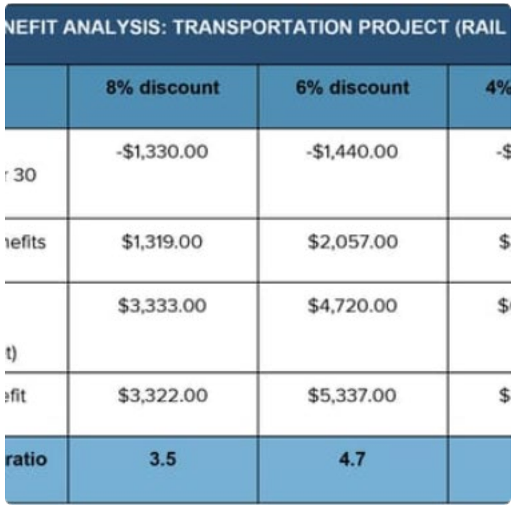
Effective Mitigation Strategies

IAMs can help policymakers identify the most effective climate mitigation strategies for different sectors of the economy, providing a roadmap for achieving sustainable development.



Sustainable Development

IAMs can also be used to explore the interactions between climate policies and other development objectives, helping to maximize benefits and minimize unintended consequences.



NEFIT ANALYSIS: TRANSPORTATION PROJECT (RAIL

	8% discount	6% discount	4%
30	-$1,330.00	-$1,440.00	-$
nefits	$1,319.00	$2,057.00	$
t)	$3,333.00	$4,720.00	$
efit	$3,322.00	$5,337.00	$
ratio	3.5	4.7	

Cost Benefit Analysis

IAMs can enable policymakers to carry out detailed cost-benefit analyses of different climate policies and targets, providing critical information for decision-making.

Real-World Applications of IAMs

1 Paris Agreement

IAMs were used extensively in the negotiation of the Paris Agreement, providing valuable information to help countries agree on ambitious climate targets.

2 Energy Planning

IAMs can be used by many countries to develop long-term energy plans and assess the impact of different policy scenarios on energy systems.

3 Global economic impacts

IAMs can also provide insights into the potential economic impacts of climate change and climate policies.

Using IAMs to Inform Policy Decisions

Use in Decision-Making

IAMs can provide policymakers with reliable and detailed assessments of the potential impacts of different climate policies and targets, offering crucial information to support policy decision-making.

Credibility

IAMs are highly regarded by experts in the field, providing policymakers with a credible and robust basis for making climate policy decisions.

Public Engagement

IAMs can also help to engage with the public, by enabling policymakers to communicate the costs and benefits of different climate policies in tangible and accessible ways.

Conclusion

Key Takeaways

IAMs can inform policy decisions at different levels, from NDC preparation to climate negotiations. IAMs are valuable tools for evaluating the costs, benefits, and trade-offs of different climate policy options.

Some of the IAMC's Commitments

We are committed to advancing the use of IAMs in climate policy by supporting research, capacity building, and knowledge sharing among policymakers, practitioners, and researchers.

Future Challenges for IAMs

1 Data Availability

IAMs rely on high-quality data from a range of sources, which can be challenging to obtain, particularly in developing countries.

2 Limitations in Scope

IAMs are limited in their ability to capture some of the more complex aspects of the climate system, including feedback loops and tipping points.

3 Model Validation

Ensuring that IAMs accurately reflect real-world conditions and outcomes is a key challenge, requiring continued development and refinement of the models.

In Summary

1

Powerful Tools

IAMs are powerful tools for informing climate policy decisions and negotiations, providing policymakers with valuable insights into the costs and benefits of different policies and targets.

2

Challenges Remain

Despite their many advantages, IAMs face certain challenges, such as data availability and limitations in scope, which require ongoing development and refinement.

3

A Roadmap to a Sustainable Future

By continuing to improve and expand the use of IAMs, policymakers will be better equipped to achieve the sustainable, low-carbon future that the world urgently needs.

4. Final considerations and open discussions: Now it is up to you, folks!

cenergia

COPPE
UFRJ

Thank you very much

roberto@ppe.ufrj.br

https://www.cenergialab.coppe.ufrj.br/

@CenergiaLab