International Institute for Applied Systems Analysis
IIASA www.iiasa.ac.at

science for global insight

# IPCC Scenarios, Representative Concentration Pathways (RCPs) and Shared Socioeconomic Scenarios (SSPs)

Volker Krey

Material courtesy of Keywan Riahi

# A Brief History of (IPCC) Scenarios

# IPCC: Climate Change Scenarios

## Projections

What can happen?

- Socioeconomic projections
- Emissions, concentration, climate forcing projections
- Climate change projections
- Climate impact projections
- Integrated projections

EXPLORATORY

## Pathways

What should happen?
How to reach certain goals?

- Socioeconomic pathways
- Mitigation pathways
- Adaptation pathways
- Climate-resilient development pathways
- Integrated (transformation) pathways
- Sustainable development pathways

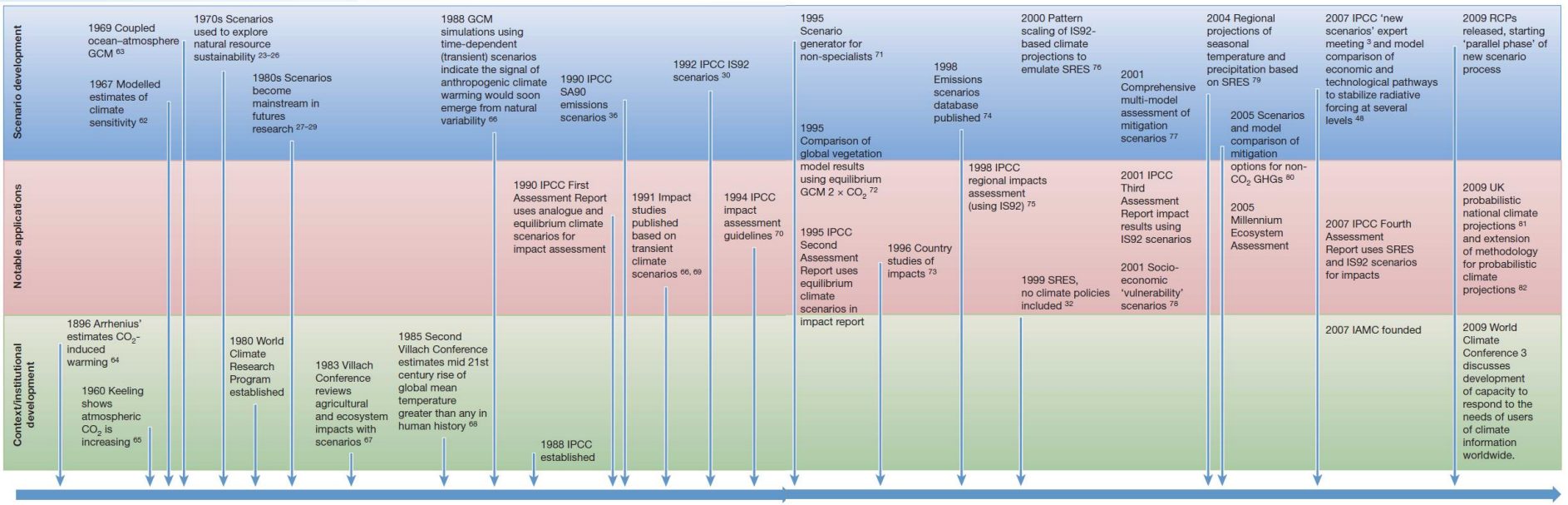
NORMATIVE

**Used as a set**

- Baseline and policy scenario pairs
- Multiple pathways to a single goal
- Set of pathways to different goals
- Range of projections spanning possible futures

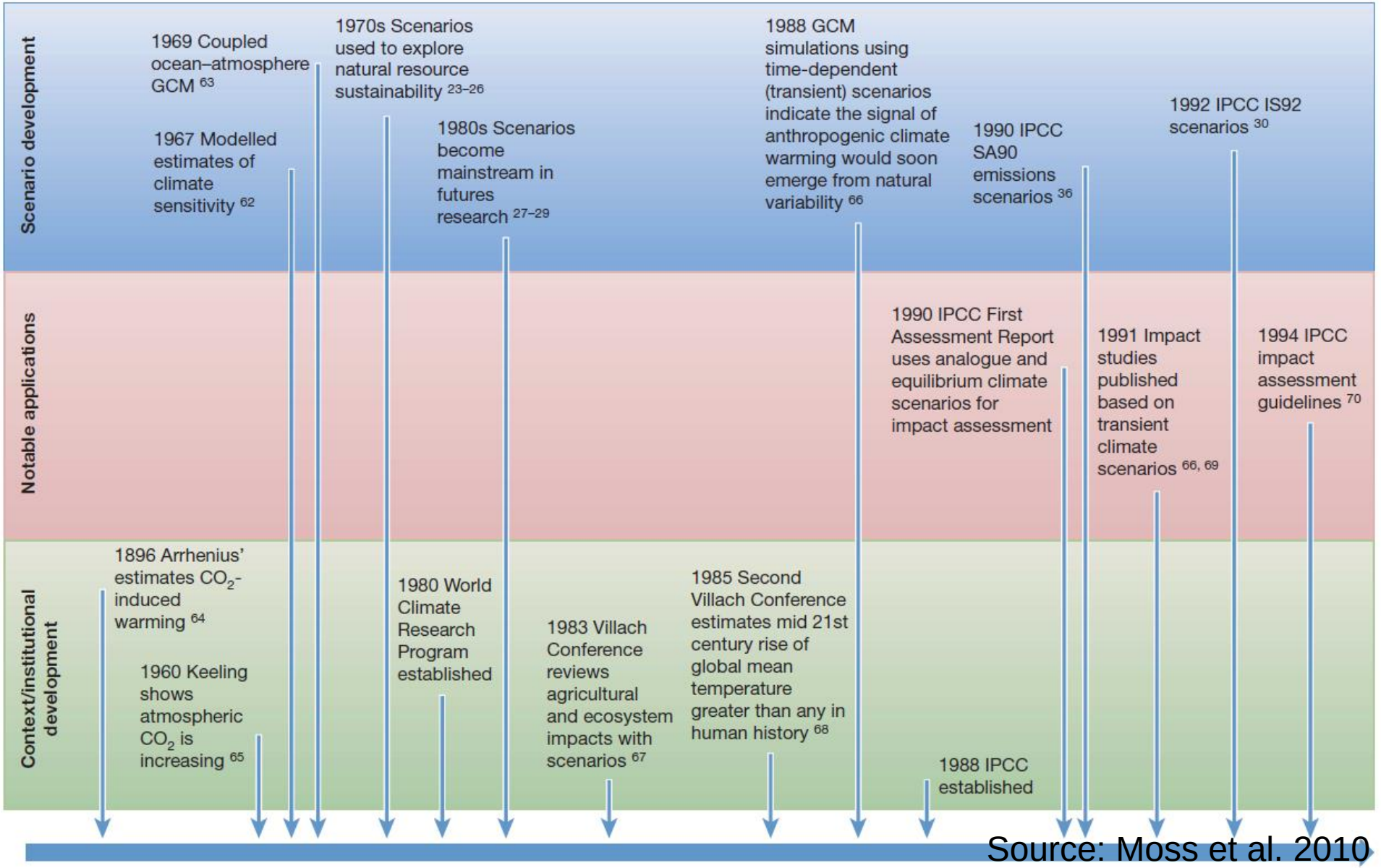
Source: Elmar Kriegler, SENSES project

# History of (IPCC) scenarios (1896-2009)



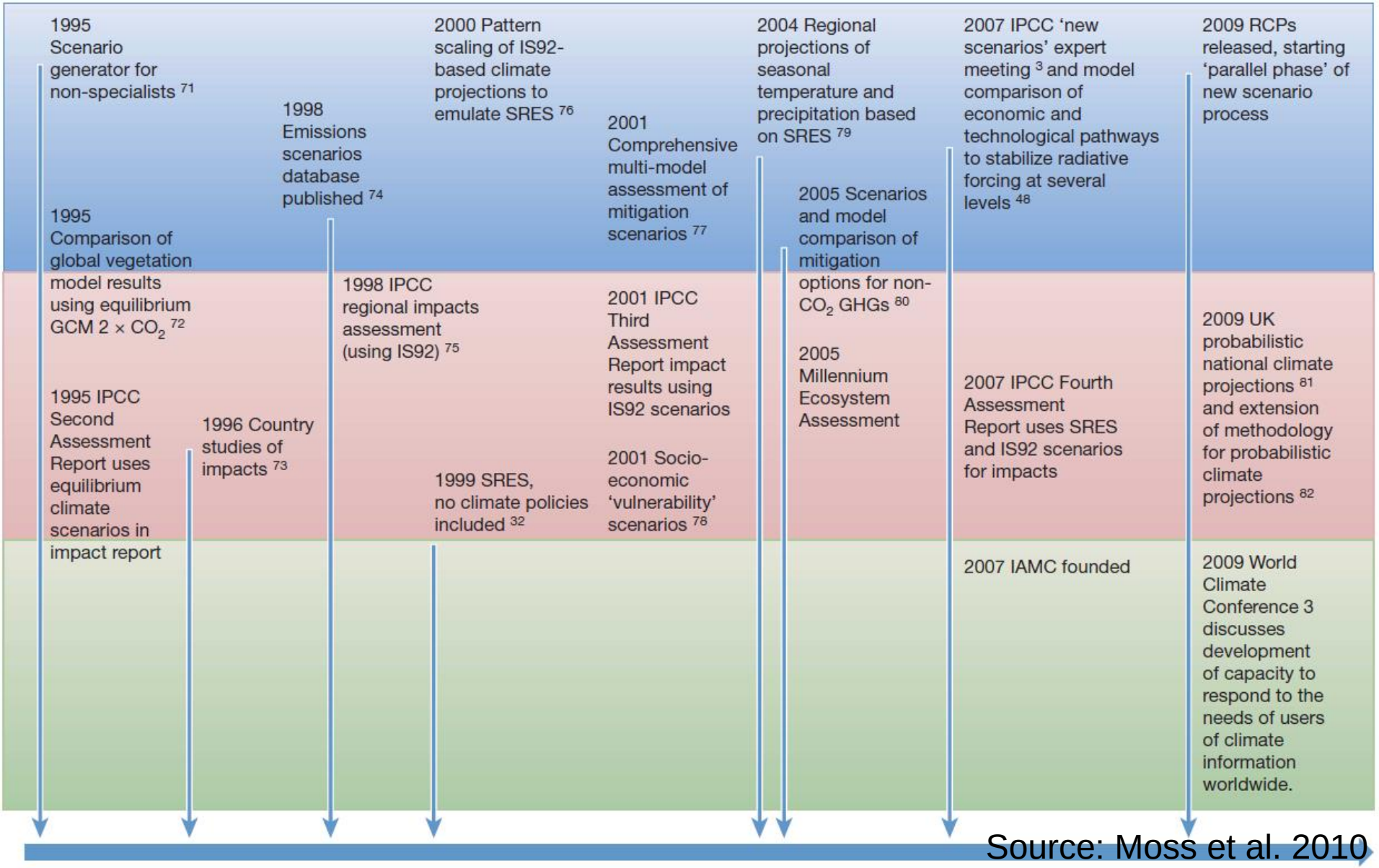

Source: Moss et al. 2010

# History of (IPCC) scenarios (1896-1994)




Source: Moss et al. 2010

# History of (IPCC) scenarios (1995-2009)




Source: Moss et al. 2010

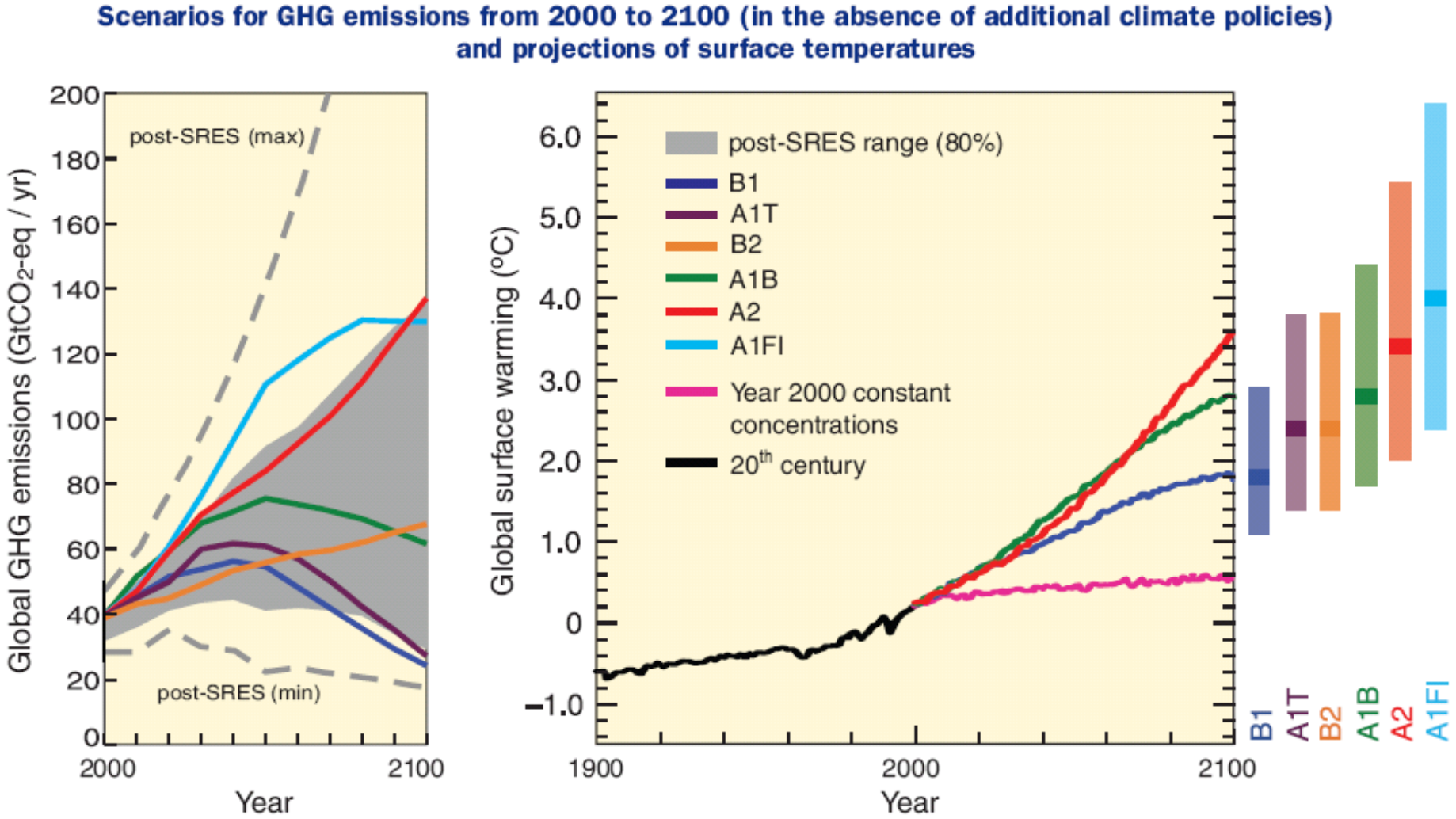
# Scenarios in IPCC

**A clarification**

- last official “IPCC scenarios” were published in 2000 as part of the Special Report on Emissions Scenarios (SRES)
- since then, IPCC has only assessed scenarios that were published in the (peer-reviewed) literature

# The “New Scenarios Process”

# Introduction: Reasons for new scenarios



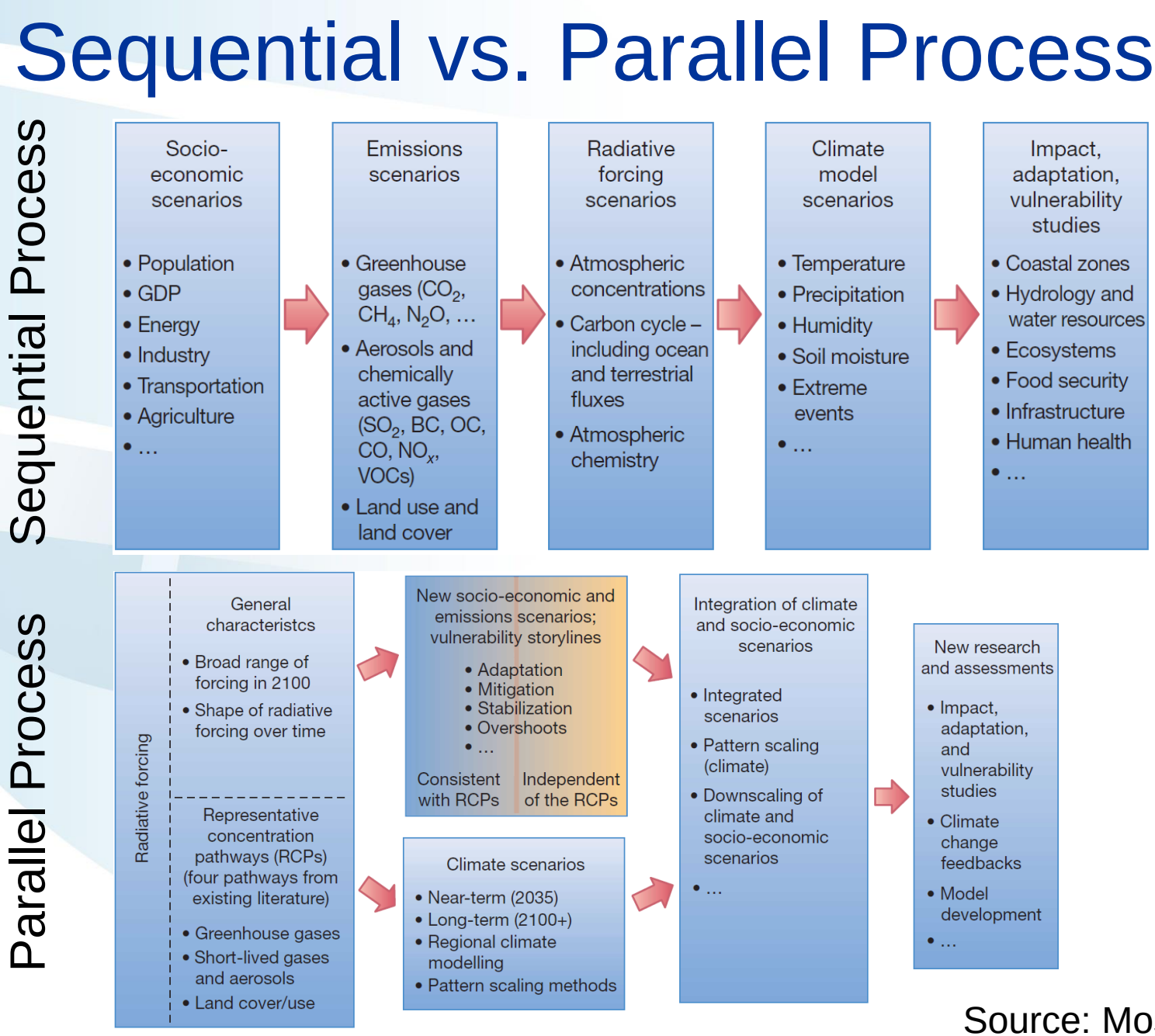

Source: IPCC AR4 (2007)

# Reasons for new scenarios

- Four important reasons to develop new community scenarios for climate assessment:
  - 1. Need to cover a wider range of GHG concentrations (SRES only included baseline scenarios)
  - 2. Need for a wider set of parameters (Climate models have become more complex; higher information need).
  - 3. Need for scenarios that cover mitigation & adaptation issues (need for more collaboration between "WGs")
  - 4. Use more recent insight into trends in scenario drivers (update)

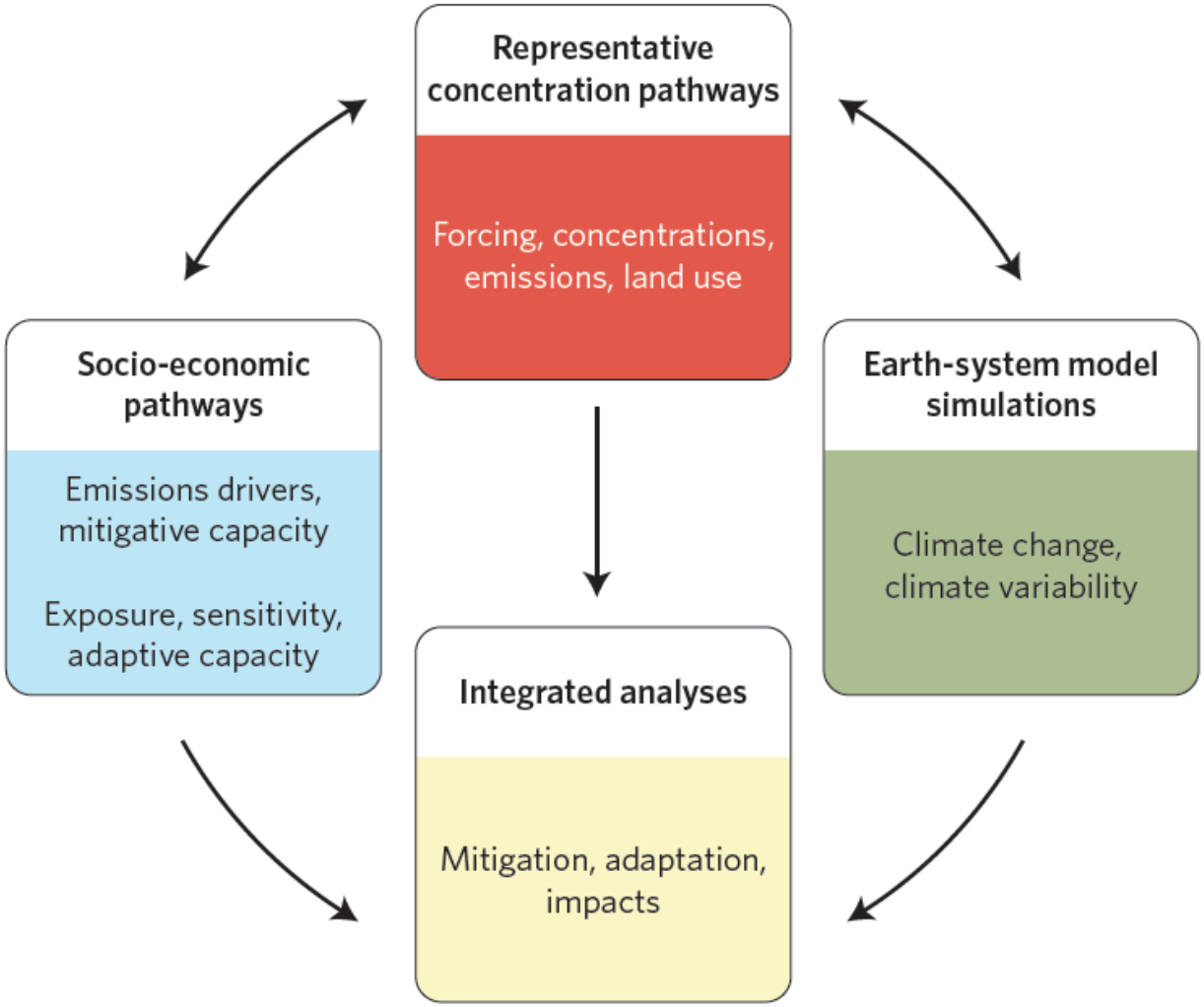
Moss et al. (2010) The next generation of scenarios for climate change research and assessment. Nature 463:747-756.

# Sequential vs. Parallel Process




Source: Moss et al. 2010

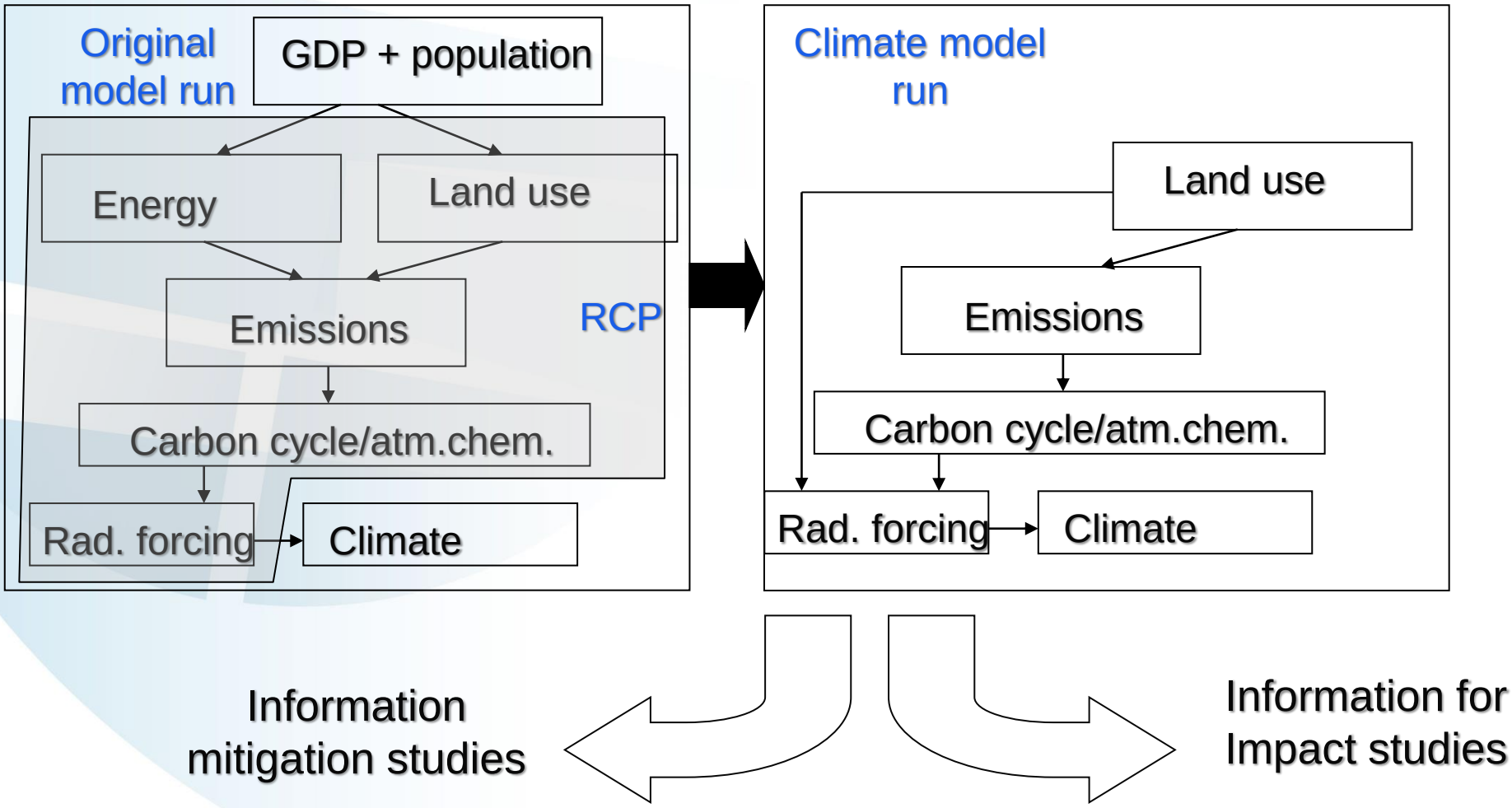
# The Parallel Process



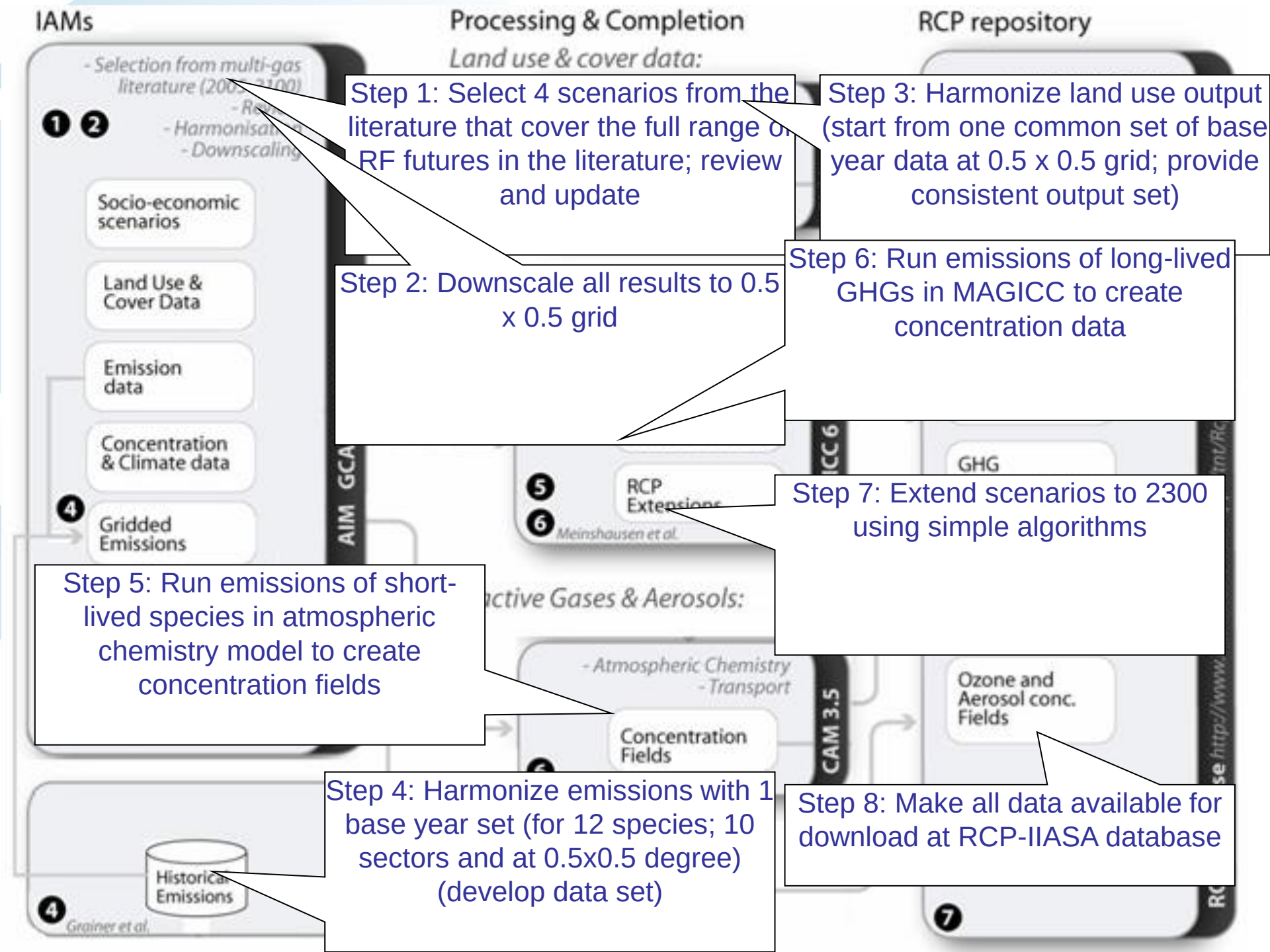

Source: O'Neill & Schweizer, 2011

# Representative Concentration Pathways (RCPs)

# Overall RCP framework of experiments

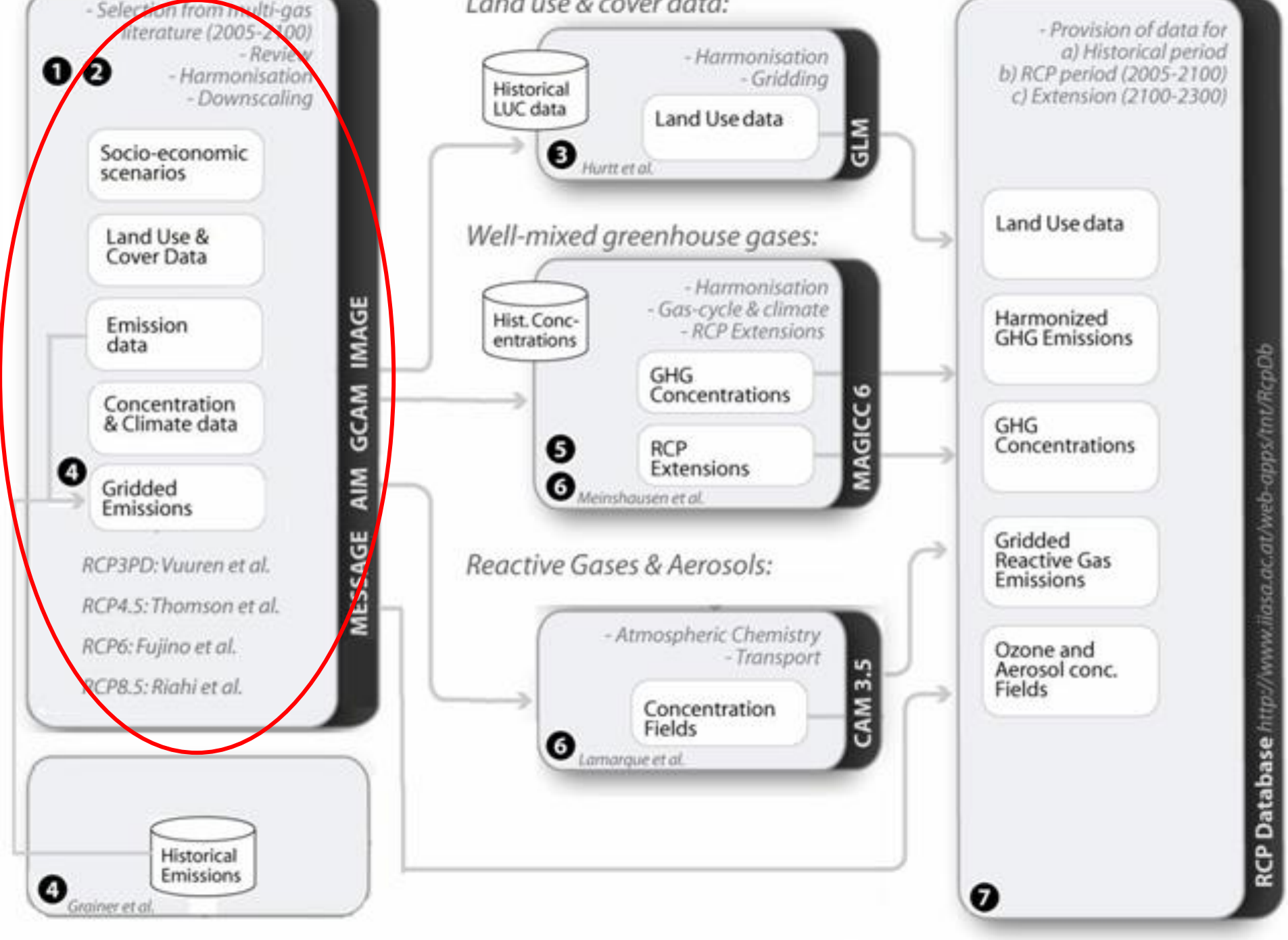



Van Vuuren, D.P. et al 2011. Representative Concentration Pathways: An overview. Climatic Change.

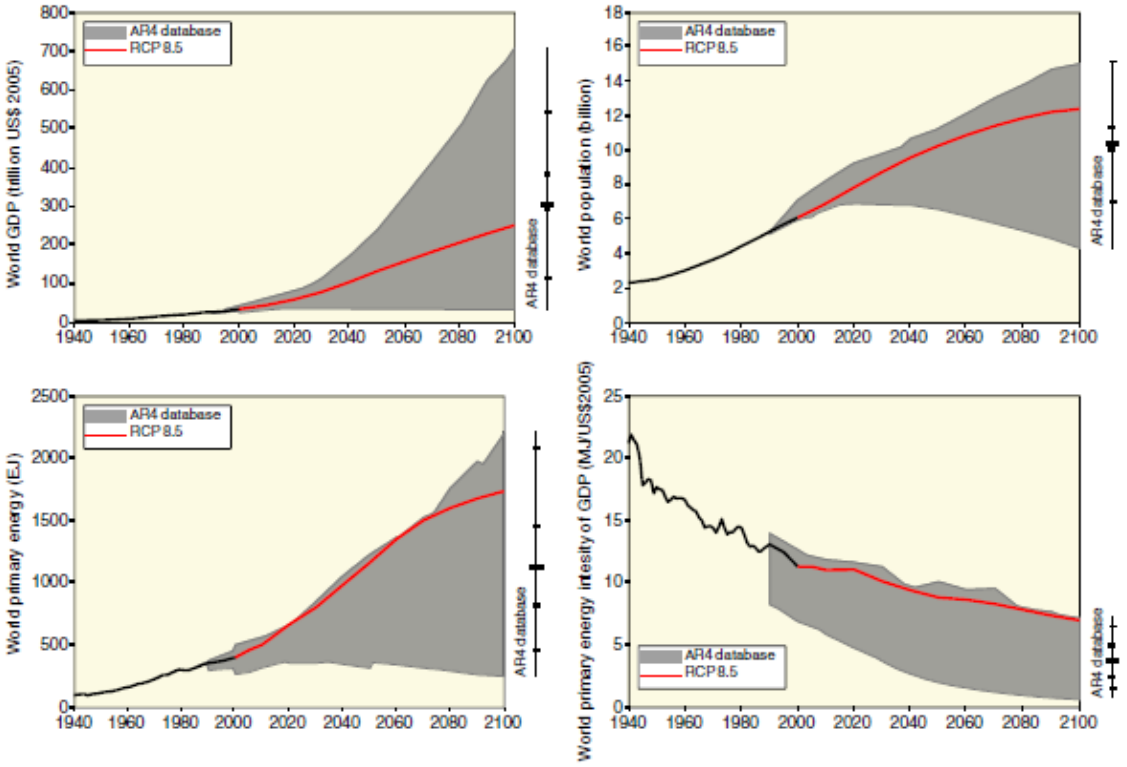

IAMs
Processing & Completion
RCP repository
Land use & cover data:
- Selection from multi-gas literature (2005-2100)
- Harmonisation
- Downscaling
Socio-economic scenarios
Land Use & Cover Data
Emission data
Concentration & Climate data
Gridded Emissions
AIM GCAM
RCP Extensions
Meinshausen et al.
GHG
Step 1: Select 4 scenarios from the literature that cover the full range of RF futures in the literature; review and update
Step 3: Harmonize land use output (start from one common set of base year data at 0.5 x 0.5 grid; provide consistent output set)
Step 2: Downscale all results to 0.5 x 0.5 grid
Step 6: Run emissions of long-lived GHGs in MAGICC to create concentration data
Step 7: Extend scenarios to 2300 using simple algorithms
Step 5: Run emissions of short-lived species in atmospheric chemistry model to create concentration fields
- Atmospheric Chemistry
- Transport
Concentration Fields
CAM 3.5
Ozone and Aerosol conc. Fields
Historical Emissions
Grainer et al.
Step 4: Harmonize emissions with 1 base year set (for 12 species; 10 sectors and at 0.5x0.5 degree) (develop data set)
Step 8: Make all data available for download at RCP-IIASA database

# IAM Models Preparing the RCPs

| Model | Home Institution | |
|---|---|---|
| AIM<br>Asia Integrated Model | National Institutes for Environmental Studies, Tsukuba Japan |  |
| GCAM<br>Global Change Assessment Model | Joint Global Change Research Institute, PNNL, College Park, MD |  |
| IMAGE<br>The Integrated Model to Assess the Global Environment | PBL Netherlands Environmental Assessment Agency, Bildhoven, The Netherlands |  |
| MESSAGE<br>Model for Energy Supply Strategy Alternatives and their General Environmental Impact | International Institute for Applied Systems Analysis; Laxenburg, Austria |  |

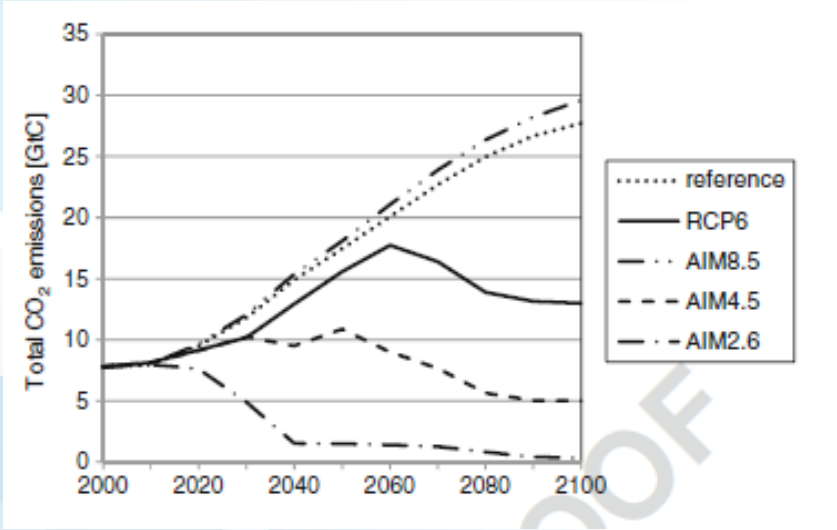

- Selection from multi-gas literature (2005-2100)
- Review
- Harmonisation
- Downscaling
1
2
Socio-economic scenarios
Land Use & Cover Data
Emission data
Concentration & Climate data
4
Gridded Emissions
RCP3PD: Vuuren et al.
RCP4.5: Thomson et al.
RCP6: Fujino et al.
RCP8.5: Riahi et al.
MESSAGE AIM GCAM IMAGE
4
Historical Emissions
Grainer et al.
Land use & cover data:
Historical LUC data
- Harmonisation
- Gridding
Land Use data
3
Hurtt et al.
GLM
Well-mixed greenhouse gases:
Hist. Conc-entrations
- Harmonisation
- Gas-cycle & climate
- RCP Extensions
GHG Concentrations
RCP Extensions
5
6
Meinshausen et al.
MAGICC 6
Reactive Gases & Aerosols:
- Atmospheric Chemistry
- Transport
Concentration Fields
6
Lamarque et al.
CAM 3.5
- Provision of data for
a) Historical period
b) RCP period (2005-2100)
c) Extension (2100-2300)
Land Use data
Harmonized GHG Emissions
GHG Concentrations
Gridded Reactive Gas Emissions
Ozone and Aerosol conc. Fields
7
RCP Database http://www.iiasa.ac.at/web-apps/tnt/RcpDb

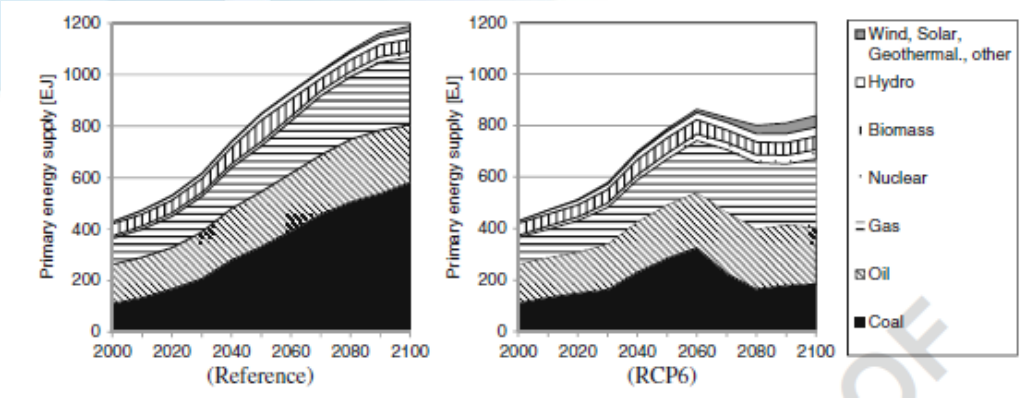
# RCP8.5 (Riahi et al. 2011) IIASA




Shows how emissions may develop in a highly populated, slow technology progress, and fossil fuel oriented world.

# RCP6.0 (Masui et al. 2011) NIES

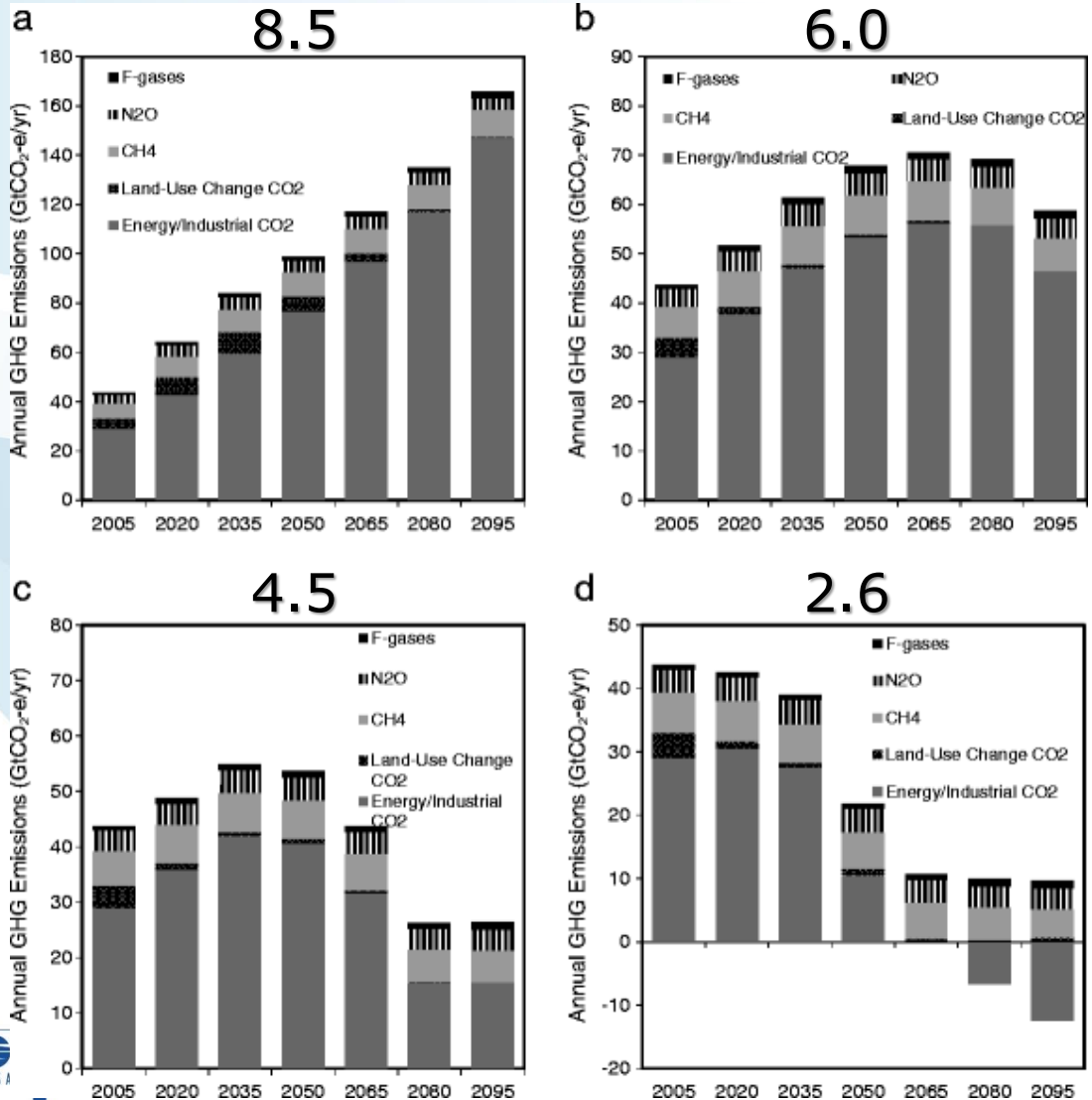



Shows the consequences of a modest climate target (reductions in 2nd half century; mostly by reducing coal use)

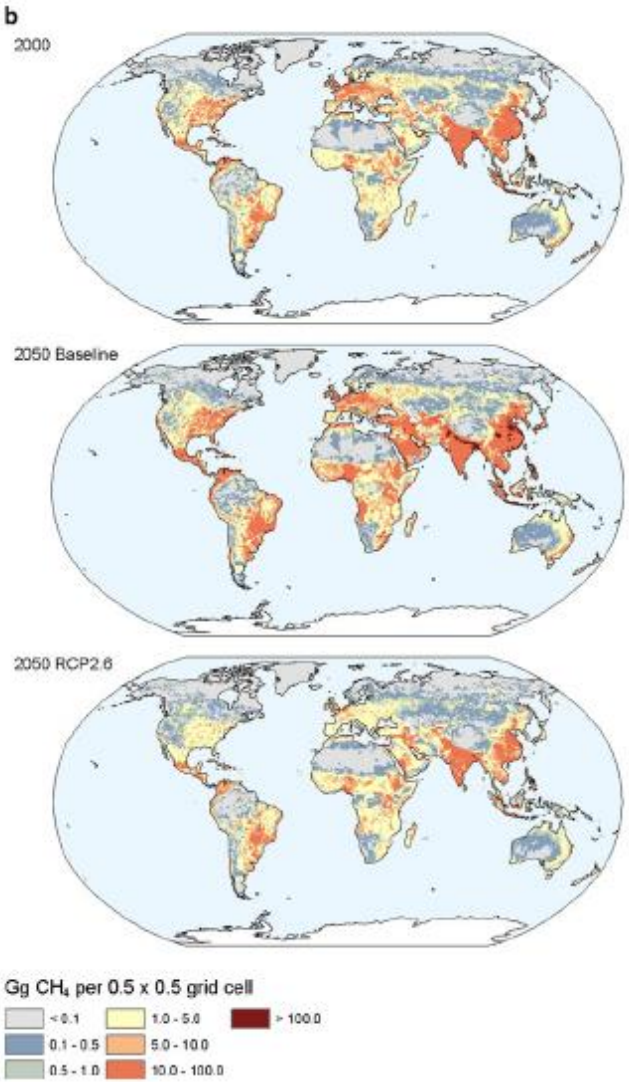
[in terms of radiative forcing, concentrations – this scenario can also be interpreted as a medium/low baseline]

# RCP4.5 (Thomson et al. 2011) JGCRI




Shows the consequences of medium stringent climate policy – and particular the possible role of the terrestrial carbon for mitigation

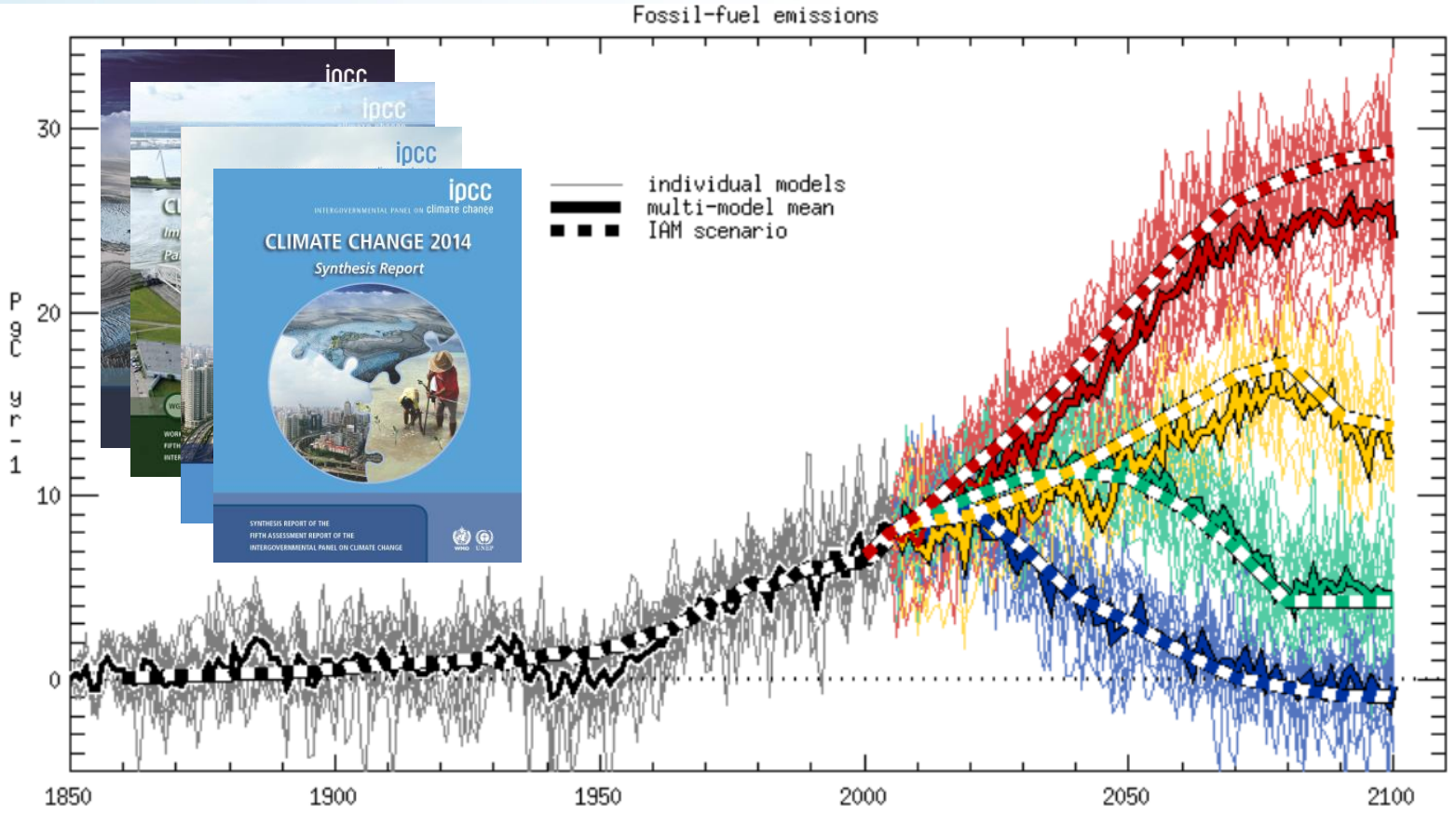
# RCP2.6 (van Vuuren et al. 2011) PBL




Shows the consequences of stringent climate policy (role of negative emissions)

Interaction between climate policy, land use, air pollutant emissions

# RCPs were run by climate models and assessed in AR5




MESSAGE (IIASA)

AIM (NIES)

GCAM (PNNL)

IMAGE (PBL)

# Shared Socioeconomic Pathways (SSPs)

# Basic Elements and IAM Scenarios for the SSP (GEC, 2017)

- Community-wide effort
  - Economists
  - Demographers
  - Impact & Vulnerability
  - Integrated Assessment Modellers

Contents lists available at ScienceDirect

Global Environmental Change

journal homepage: www.elsevier.com/locate/gloenvcha

The Shared Socioeconomic Pathways and their energy, land use, and greenhouse gas emissions implications: An overview

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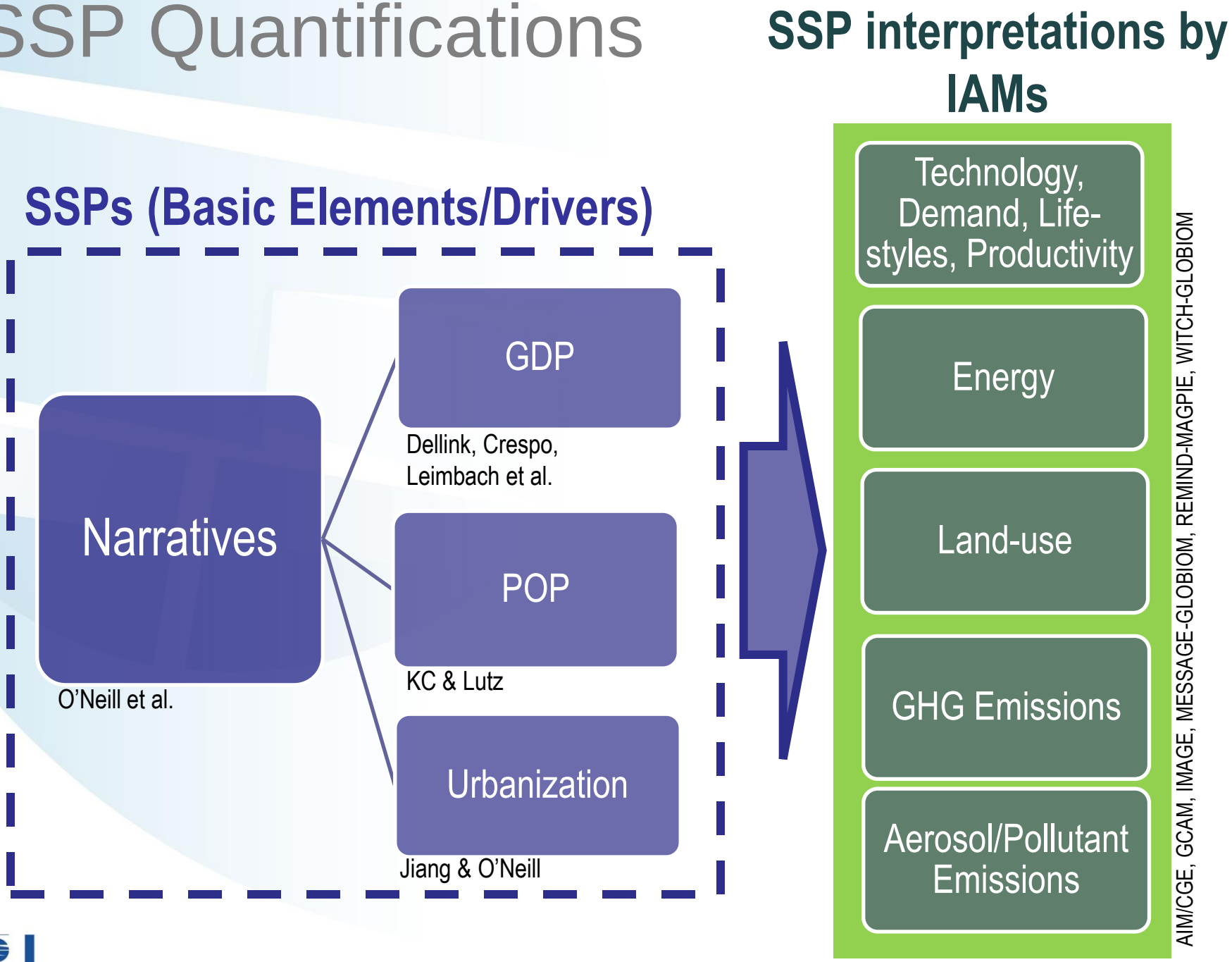
- **Global Environmental Change Special Issue**
  - Overview (Riahi et al. 2017)
  - Demographic projections (KC & Lutz 2017)
  - GDP projections (OECD, IIASA, PIK 2017)
  - Urbanisation projections (Liang & O'Neill 2017)
  - Quantifications of SSPs (6 global IAM teams)
  - Cross-cutting papers on energy, land and air pollution

Scenario data available at SSP database: https://tntcat.iiasa.ac.at/SspDb/

# SSP Quantifications



# The Scenario Matrix Architecture

Challenge to mitigation

**SSP5: Fossil fueled development**

- Rapid growth, free trade
- High technology development,
- Environment and social goals not a priority: adaptive, technology-fix
- Focus on economic growth

Markets first

Clash of civilisations

**SSP3: Regional rivalry**

- Competition among regions
- Low technology development
- Environment and social goals not a priority
- Focus on domestic resources
- High population growth
- Slow economic growth dev. countries

SSP2:
**Middle of the Road**

**SSP1:Sustainability**

- Global cooperation
- Rapid technology dev.
- Strong env. policy
- Low population growth
- Low inequity
- Focus on renewables and
- efficiency
- Dietary shifts
- Forest protection

UN world

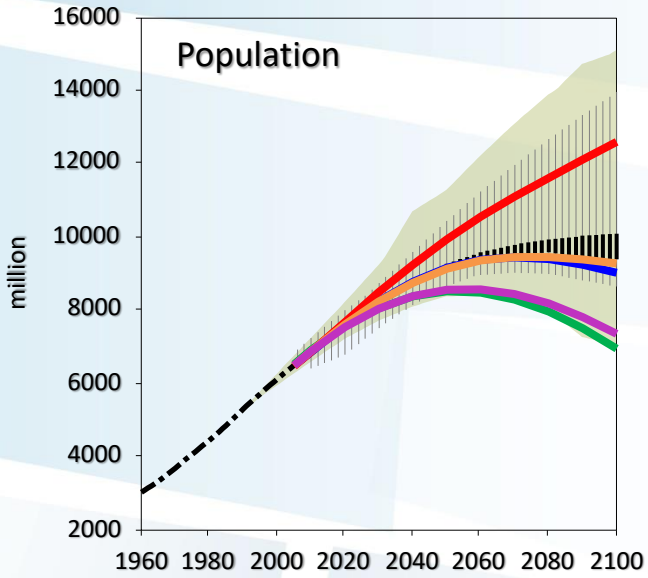
Have's and have not's

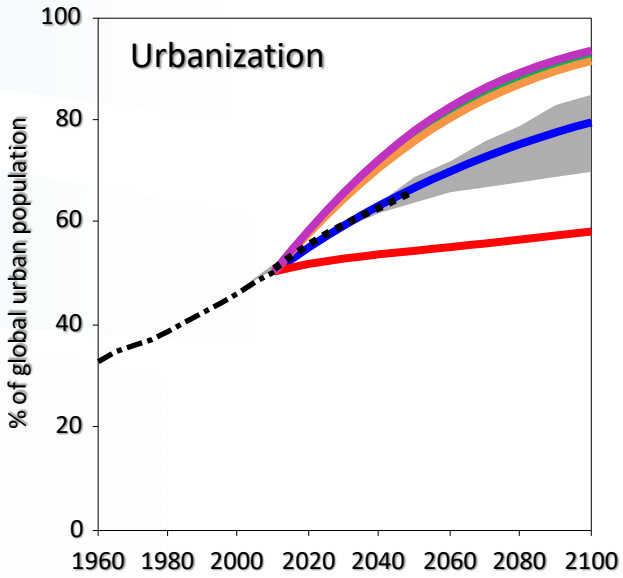
**SSP4: Inequality**

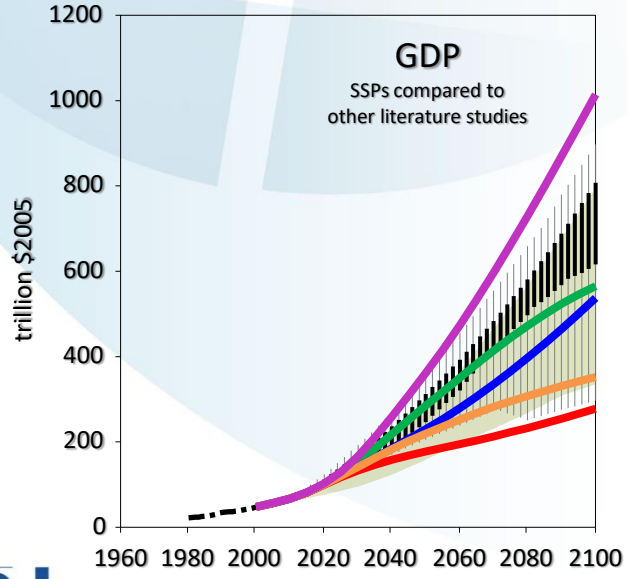
- Inequality across and within regions
- Low technology development
- Environment priority for those that can afford
- Limited trade

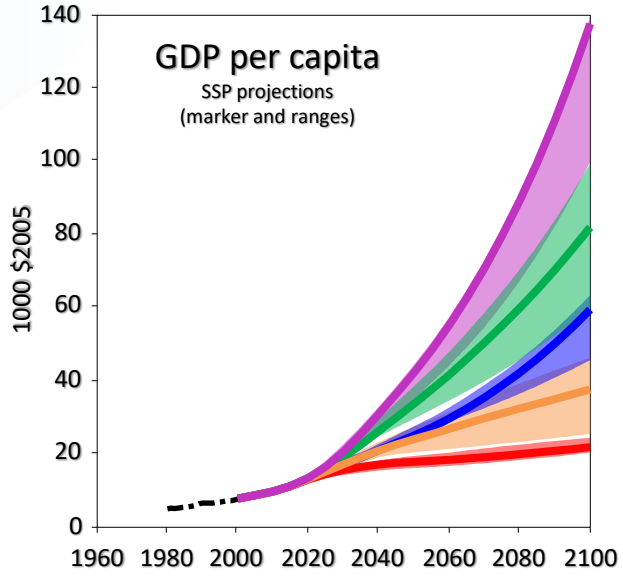
Challenge to adaptation

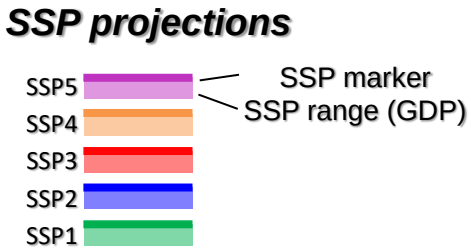
# Economic & Demographic Change: five SSPs

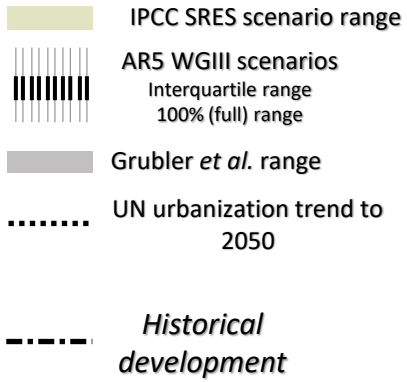


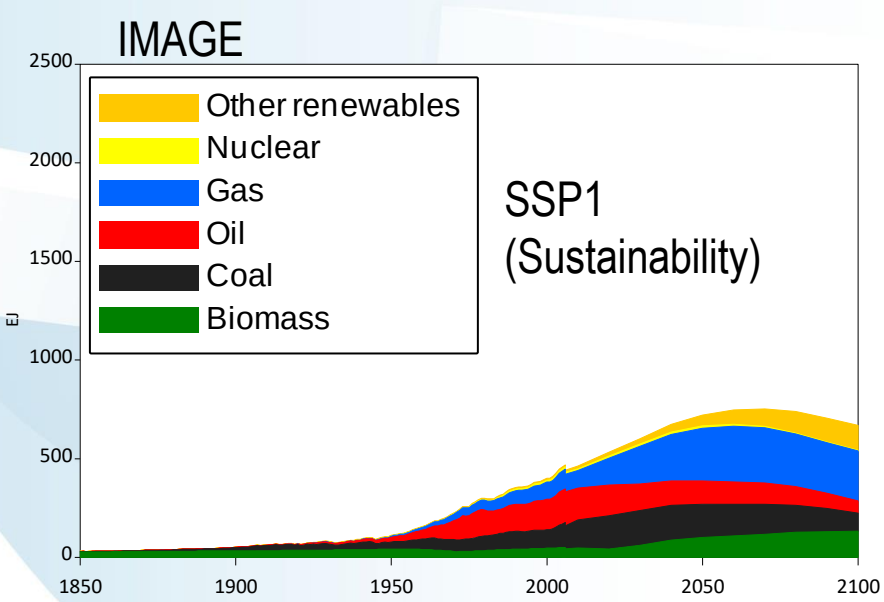

Sources: Overview: Riahi et al, 2017, GDP: Dellink et al, 2017; Urbanization: Jiang and O'Neill et al, 2017, Population: KC and Lutz, 2017

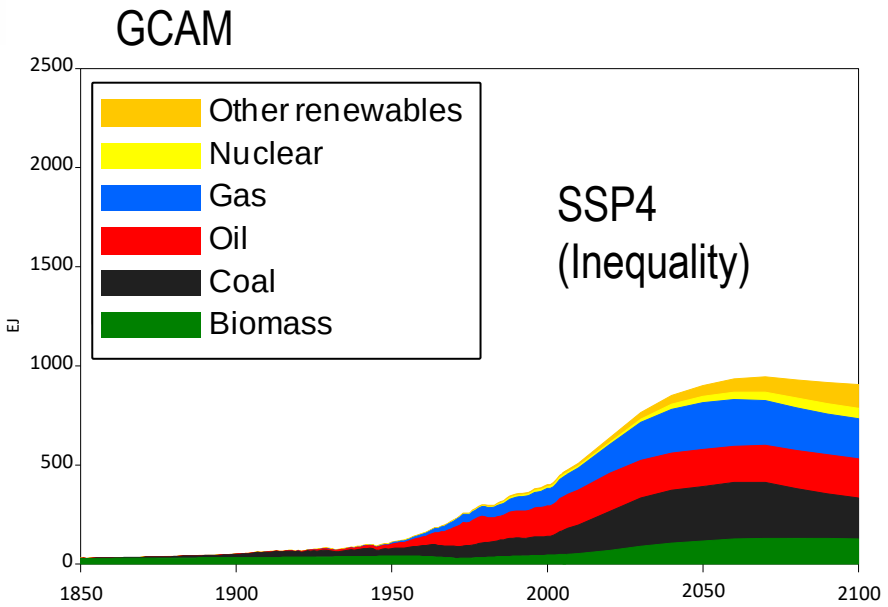
# Reference SSP (IAM) Scenarios
(no climate policy beyond those in place today)

- Six IAM teams
- Five SSPs
- One representative Marker Scenario for each SSP
- For each SSP there are multiple IAM runs depicting uncertainty ranges

# Energy – SSP Reference Cases

**Two marker scenarios where mitigation is relatively easy**



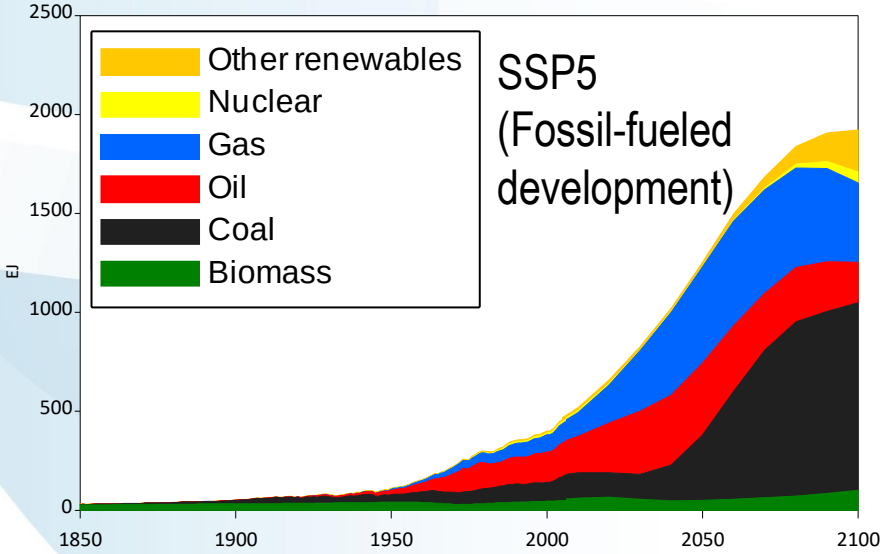

Transition away from coal/oil
Low demand

High share of poor with low emissions
Low/intermediate demand
Technology available to the “elite”

# Energy – SSP Reference Cases

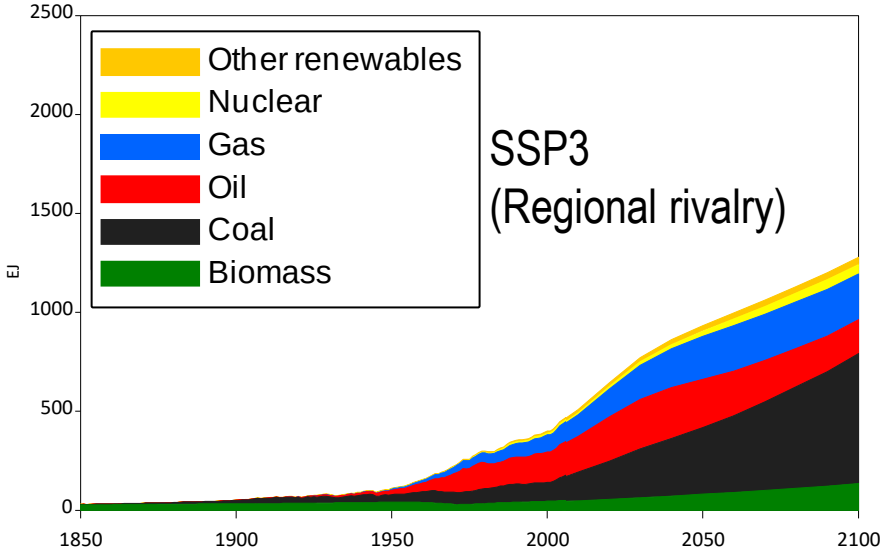
**Two marker scenarios where mitigation is relatively difficult**

REMIND-MAGPIE




Coal-intensive development
Very high demand

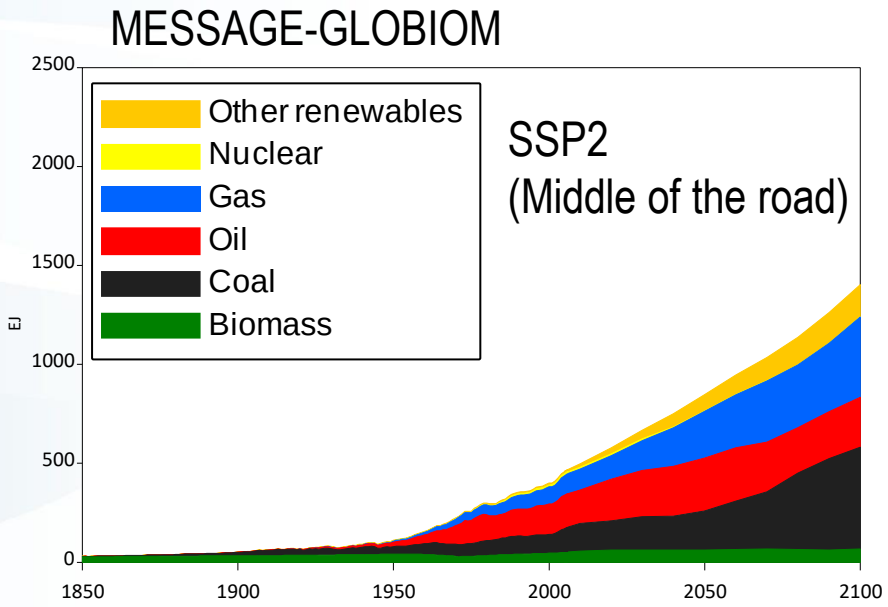
AIM




Fossil-intensive
High poverty
Slow technological change
Strong fragmentation

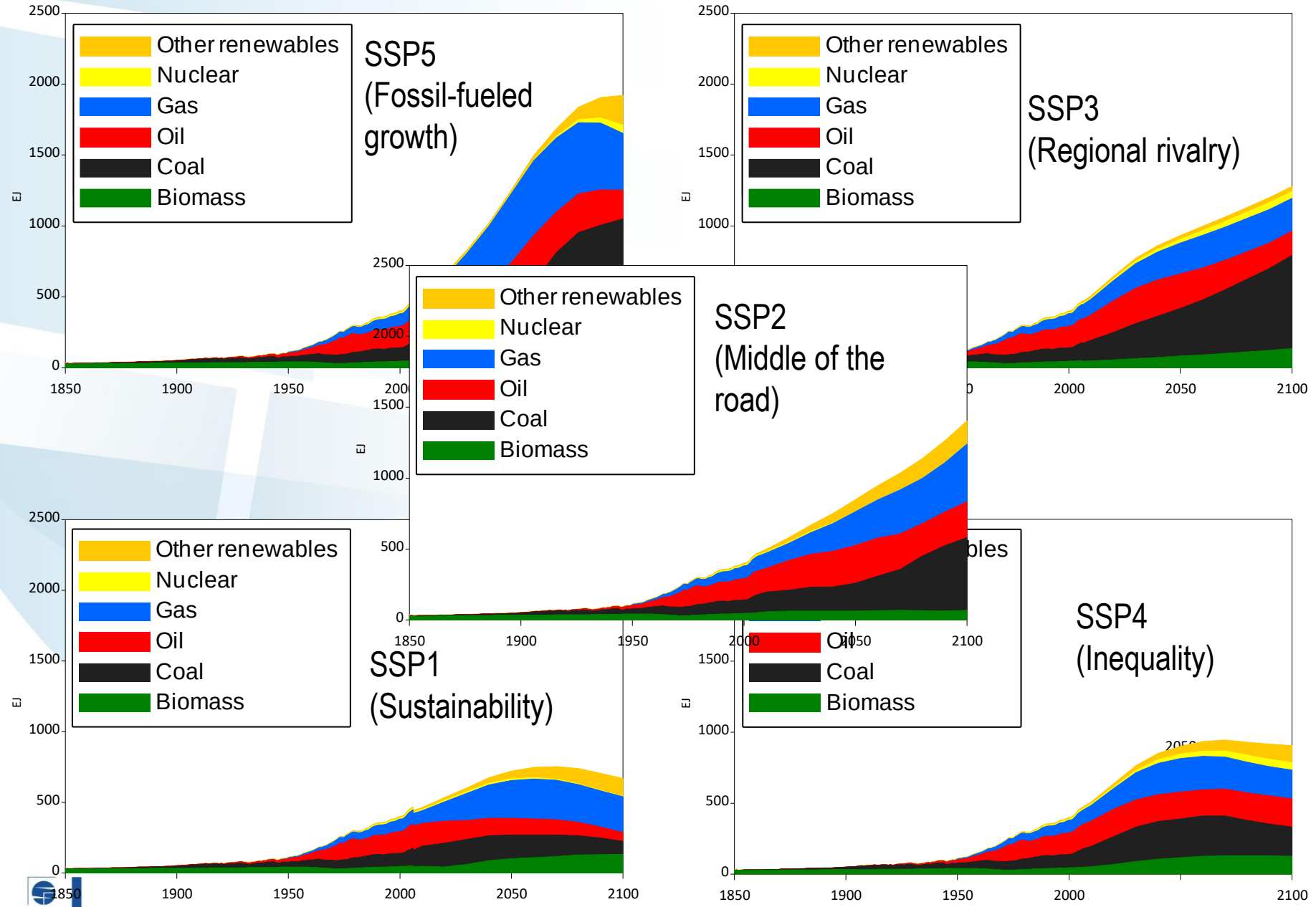
# Energy – SSP Reference Cases

**A central marker scenario with intermediate mitigation challenge**




Balanced Technology
Intermediate demand

# Primary Energy – SSP Reference Cases



# How were these pathways created?

## Storylines

**SSP5: Fossil fueled development**

- Rapid growth, free trade
- High technology development,
- Environment and social goals not a priority: adaptive, technology-fix
- Focus on economic growth

**SSP1:Sustainability**

- Global cooperation
- Rapid technology dev.
- Strong env. policy
- Low population growth
- Low inequity
- Focus on renewables and efficiency
- Dietary shifts
- Forest protection

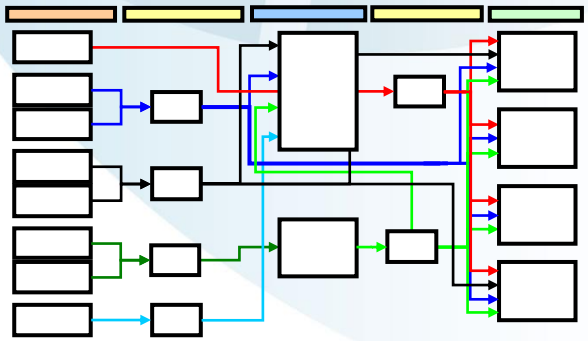
## Qualitative assumptions

Table A.1: Qualitative assumptions for energy demand across SSPs

| | 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 |
| 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 | | | | | | | | | | | |

Community

## IAM



Modeling Team

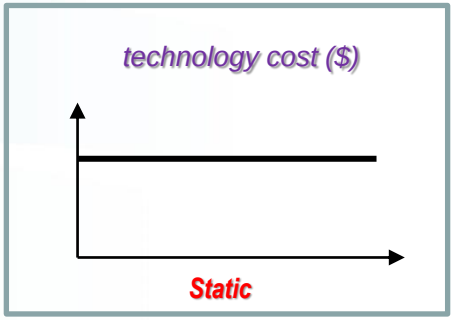
## Quantitative assumptions

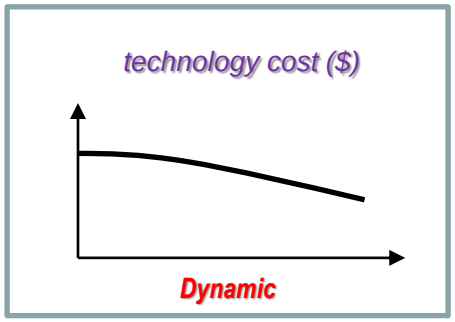
| | A | B | C | D | E | F | G | H | I | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | MODEL | SCENARIO | REGION | VARIABLE | UNIT | 2010 | 2015 | 2020 | 2025 | 2030 | 2035 | 2040 | 2045 | 2050 |
| 2 | AIM/E-India [IIMA] | Reference | India | Capital Cost\|Electricity\|Biomass | US$2010/kWe | 2284.664 | 2284.664 | 2284.664 | 2284.664 | 2284.664 | 2284.664 | 2284.664 | 2284.664 | 2284.66 |
| 3 | AIM/E-India [IIMA] | Reference | India | Capital Cost\|Electricity\|Coal\|IGCC | US$2010/kWe | 2263.432 | 2263.432 | 2263.432 | 2263.432 | 2263.432 | 2263.432 | 2263.432 | 2263.432 | 2263.43 |
| 4 | AIM/E-India [IIMA] | Reference | India | Capital Cost\|Electricity\|CSP | US$2010/kWe | 7189.384 | 7189.384 | 7189.384 | 7189.384 | 7189.384 | 7189.384 | 7189.384 | 7189.384 | 7189.38 |
| 5 | AIM/E-India [IIMA] | Reference | India | Capital Cost\|Electricity\|Gas\|CC | US$2010/kWe | 1276.799 | 1276.799 | 1276.799 | 1276.799 | 1276.799 | 1276.799 | 1276.799 | 1276.799 | 1276.79 |
| 6 | AIM/E-India [IIMA] | Reference | India | Capital Cost\|Electricity\|Gas\|CT | US$2010/kWe | 526.7987 | 526.7987 | 526.7987 | 526.7987 | 526.7987 | 526.7987 | 526.7987 | 526.7987 | 526.798 |
| 7 | AIM/E-India [IIMA] | Reference | India | Capital Cost\|Electricity\|Hydro | US$2010/kWe | 3074.07 | 3074.07 | 3074.07 | 3074.07 | 3074.07 | 3074.07 | 3074.07 | 3074.07 | 3074.0 |
| 8 | AIM/E-India [IIMA] | Reference | India | Capital Cost\|Electricity\|Nuclear | US$2010/kWe | 4086.623 | 4086.623 | 4086.623 | 4086.623 | 4086.623 | 4086.623 | 4086.623 | 4086.623 | 4086.62 |
| 9 | AIM/E-India [IIMA] | Reference | India | Capital Cost\|Electricity\|PV | US$2010/kWe | 4648.405 | 4648.405 | 4648.405 | 4648.405 | 4648.405 | 4648.405 | 4648.405 | 4648.405 | 4648.40 |
| 10 | AIM/E-India [IIMA] | Reference | India | Capital Cost\|Electricity\|Wind\|Offshore | US$2010/kWe | 3103.509 | 3103.509 | 3103.509 | 3103.509 | 3103.509 | 3103.509 | 3103.509 | 3103.509 | 3103.50 |
| 11 | AIM/E-India [IIMA] | Reference | India | Capital Cost\|Electricity\|Wind\|Onshore | US$2010/kWe | 1693.652 | 1693.652 | 1693.652 | 1693.652 | 1693.652 | 1693.652 | 1693.652 | 1693.652 | 1693.65 |
| 12 | AIM/E-India [IIMA] | Reference | India | OM Cost\|Fixed\|Electricity\|Biomass | US$2010/kWe/yr | 22.82728 | 22.82728 | 22.82728 | 22.82728 | 22.82728 | 22.82728 | 22.82728 | 22.82728 | 22.8272 |
| 13 | AIM/E-India [IIMA] | Reference | India | OM Cost\|Fixed\|Electricity\|Coal\|IGCC | US$2010/kWe/yr | 44.64246 | 44.64246 | 44.64246 | 44.64246 | 44.64246 | 44.64246 | 44.64246 | 44.64246 | 44.6424 |
| 14 | AIM/E-India [IIMA] | Reference | India | OM Cost\|Fixed\|Electricity\|Coal\|PC | US$2010/kWe/yr | 44.64246 | 44.64246 | 44.64246 | 44.64246 | 44.64246 | 44.64246 | 44.64246 | 44.64246 | 44.6424 |
| 15 | AIM/E-India [IIMA] | Reference | India | OM Cost\|Fixed\|Electricity\|CSP | US$2010/kWe/yr | 117.8658 | 117.8658 | 117.8658 | 117.8658 | 117.8658 | 117.8658 | 117.8658 | 117.8658 | 117.865 |
| 16 | AIM/E-India [IIMA] | Reference | India | OM Cost\|Fixed\|Electricity\|Gas\|CC | US$2010/kWe/yr | 13.69637 | 13.69637 | 13.69637 | 13.69637 | 13.69637 | 13.69637 | 13.69637 | 13.69637 | 13.6963 |
| 17 | AIM/E-India [IIMA] | Reference | India | OM Cost\|Fixed\|Electricity\|Gas\|CT | US$2010/kWe/yr | 11.07591 | 11.07591 | 11.07591 | 11.07591 | 11.07591 | 11.07591 | 11.07591 | 11.07591 | 11.0759 |
| 18 | AIM/E-India [IIMA] | Reference | India | OM Cost\|Fixed\|Electricity\|Hydro | US$2010/kWe/yr | 35.48955 | 35.48955 | 35.48955 | 35.48955 | 35.48955 | 35.48955 | 35.48955 | 35.48955 | 35.4895 |
| 19 | AIM/E-India [IIMA] | Reference | India | OM Cost\|Fixed\|Electricity\|Nuclear | US$2010/kWe/yr | 99.52695 | 99.52695 | 99.52695 | 99.52695 | 99.52695 | 99.52695 | 99.52695 | 99.52695 | 99.5269 |
| 20 | AIM/E-India [IIMA] | Reference | India | OM Cost\|Fixed\|Electricity\|PV | US$2010/kWe/yr | 105.0605 | 105.0605 | 105.0605 | 105.0605 | 105.0605 | 105.0605 | 105.0605 | 105.0605 | 105.060 |
| 21 | AIM/E-India [IIMA] | Reference | India | OM Cost\|Fixed\|Electricity\|Wind\|Onshore | US$2010/kWe/yr | 50.47305 | 50.47305 | 50.47305 | 50.47305 | 50.47305 | 50.47305 | 50.47305 | 50.47305 | 50.4730 |
| 22 | AIM/Enduse[Japan] | JPN_MILES2_INDC80 | Japan | OM Cost\|Fixed\|Electricity\|Wind\|Onshore | US$2010/kWe/yr | 59.50295 | 59.50295 | 59.50295 | 59.50295 | 59.50295 | 59.50295 | 59.50295 | 59.50295 | 59.5029 |
| 23 | AIM/Enduse[Japan] | JPN_MILES2_INDC80 | Japan | Capital Cost\|Electricity\|Biomass | US$2010/kWe | 3524.209 | 4007.529 | 4007.529 | 4007.529 | 4007.529 | 4007.529 | 4007.529 | 4007.529 | 4007.52 |
| 24 | AIM/Enduse[Japan] | JPN_MILES2_INDC80 | Japan | Capital Cost\|Electricity\|Coal\|IGCC | US$2010/kWe | 2894.886 | 2894.886 | 2894.886 | 2894.886 | 2894.886 | 2894.886 | 2894.886 | 2894.886 | 2894.88 |
| 25 | AIM/Enduse[Japan] | JPN_MILES2_INDC80 | Japan | Capital Cost\|Electricity\|Coal\|PC\|1 | US$2010/kWe | 2498.782 | 2498.782 | 2498.782 | 2498.782 | 2498.782 | 2498.782 | 2498.782 | 2498.782 | 2498.78 |
| 26 | AIM/Enduse[Japan] | JPN_MILES2_INDC80 | Japan | Capital Cost\|Electricity\|Coal\|PC\|2 | US$2010/kWe | 2315.909 | 2517.292 | 2517.292 | 2517.292 | 2517.292 | 2517.292 | 2517.292 | 2517.292 | 2517.29 |
| 27 | AIM/Enduse[Japan] | JPN_MILES2_INDC80 | Japan | Capital Cost\|Electricity\|Gas\|CC\|ACC | US$2010/kWe | 1213.256 | 1213.256 | 1213.256 | 1213.256 | 1213.256 | 1213.256 | 1213.256 | 1213.256 | 1213.25 |
| 28 | AIM/Enduse[Japan] | JPN_MILES2_INDC80 | Japan | Capital Cost\|Electricity\|Gas\|CC\|ACC-High | US$2010/kWe | 1547.214 | 1547.214 | 1547.214 | 1547.214 | 1547.214 | 1547.214 | 1547.214 | 1547.214 | 1547.21 |
| 29 | AIM/Enduse[Japan] | JPN_MILES2_INDC80 | Japan | Capital Cost\|Electricity\|Gas\|CC\|CC | US$2010/kWe | 1152.593 | 1152.593 | 1152.593 | 1152.593 | 1152.593 | 1152.593 | 1152.593 | 1152.593 | 1152.59 |

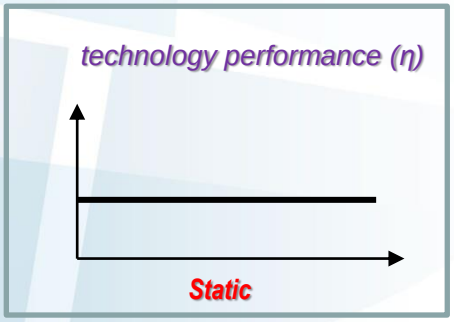
reference | data | tech_variants

Source: Riahi et al. 2017, Krey et al. 2019

# Projecting techno-economic parameters

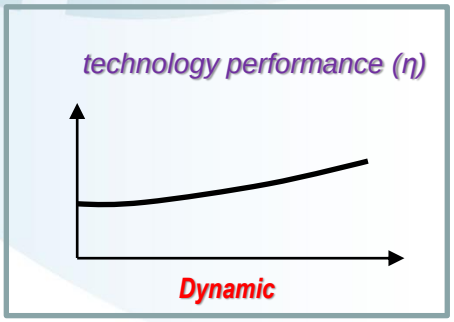



- AIM/Enduse[Japan]
- AIM/E-India [IIMA]
- India MARKAL

- BLUES
- MESSAGEix-GLOBIOM_1.0




- REMIND 1.6
- WITCH-GLOBIOM 4.4

- DNE21 +V.12A
- DNE21+ V.MILES
- GCAM 4.2_ADVANCE
- IMAGE 3.0
- POLES MILES
- IPAC-AIM/technology_V1.0
- PRIMES_V1

(using coal power plants as the example)

Source: Krey et al. 2019

# Qualitative Assumptions: Demand

Table A.1: Qualitative assumptions for energy demand across SSPs

| | 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** |
| **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 | | | | | | | | | | | |

Source: Riahi et al. 2017

# Qualitative Assumptions: Fossil Fuels

Table A.2: Qualitative assumptions for fossil energy supply across SSPs

| | SSP1 Sustainability | SSP2 Middle of the Road | SSP3 Regional Rivalry | | SSP4 Inequality | | | SSP5 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 |

Source: Riahi et al. 2017

# Qualitative Assumptions: Conversion

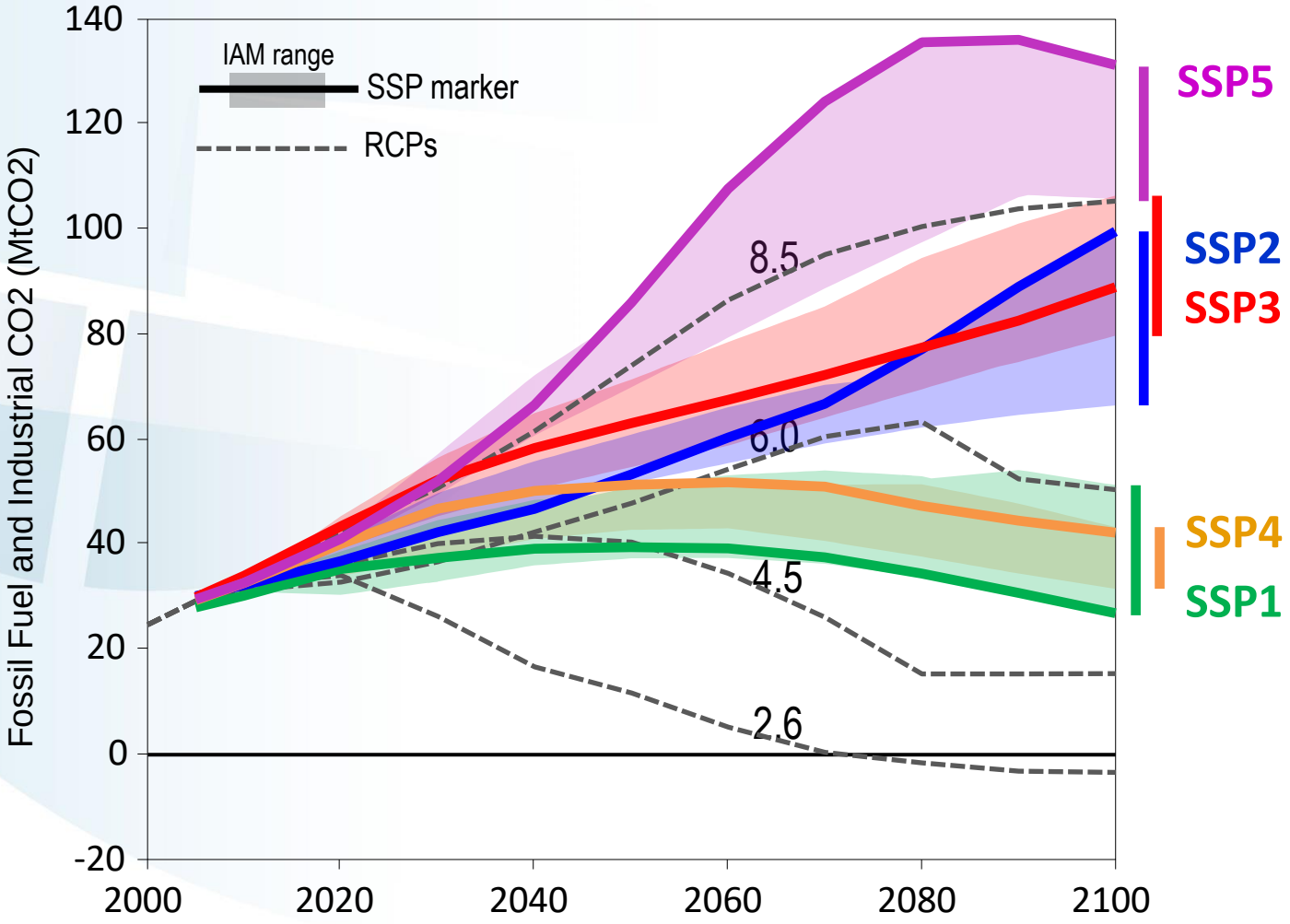
Table A.3: Qualitative assumptions for energy conversion technologies SSPs

| | 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 | |

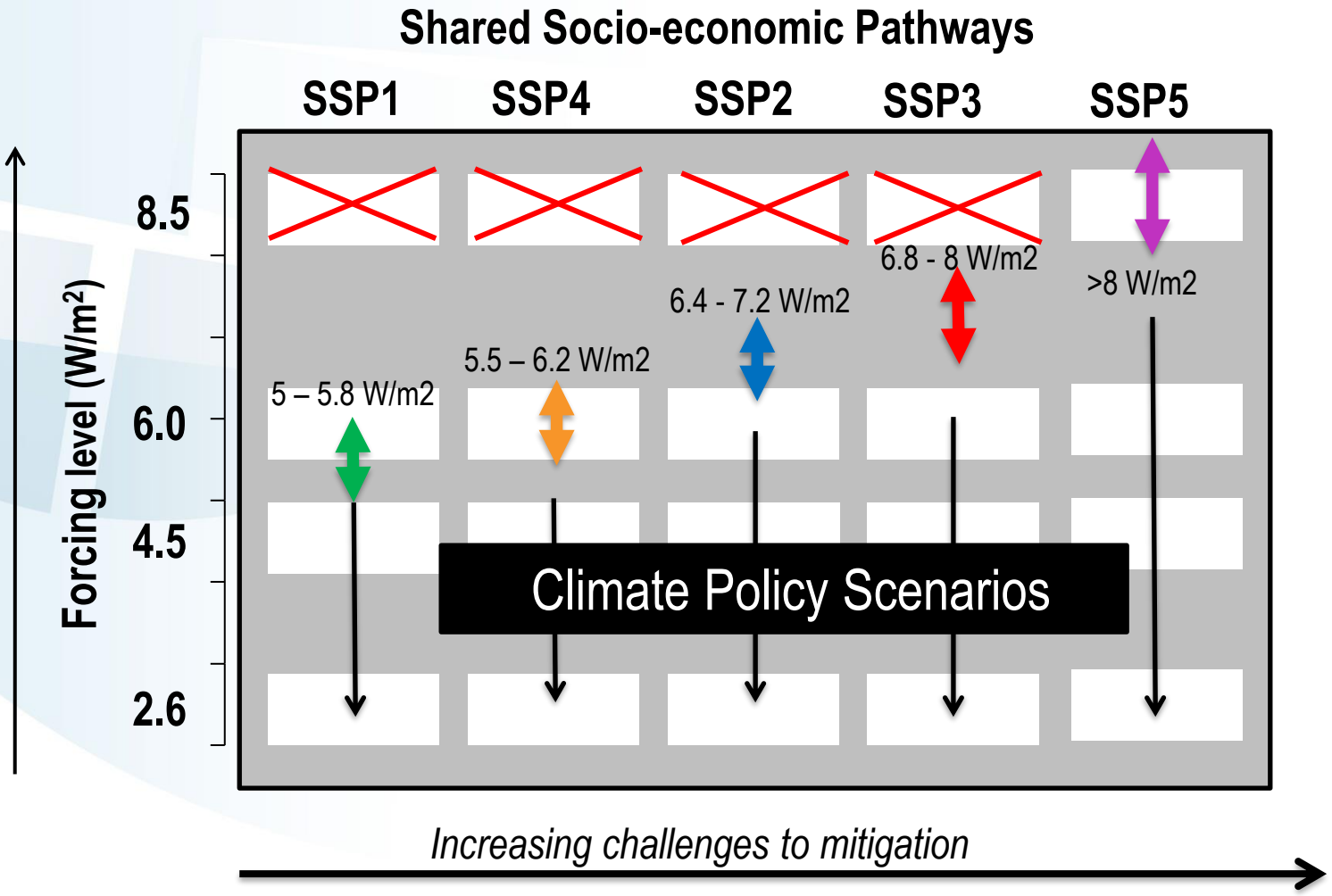
Source: Riahi et al. 2017

# Global $CO_2$ Emissions

(SSP Reference scenarios and RCPs)



# SSP/RCP combinations based on reference IAM scenarios



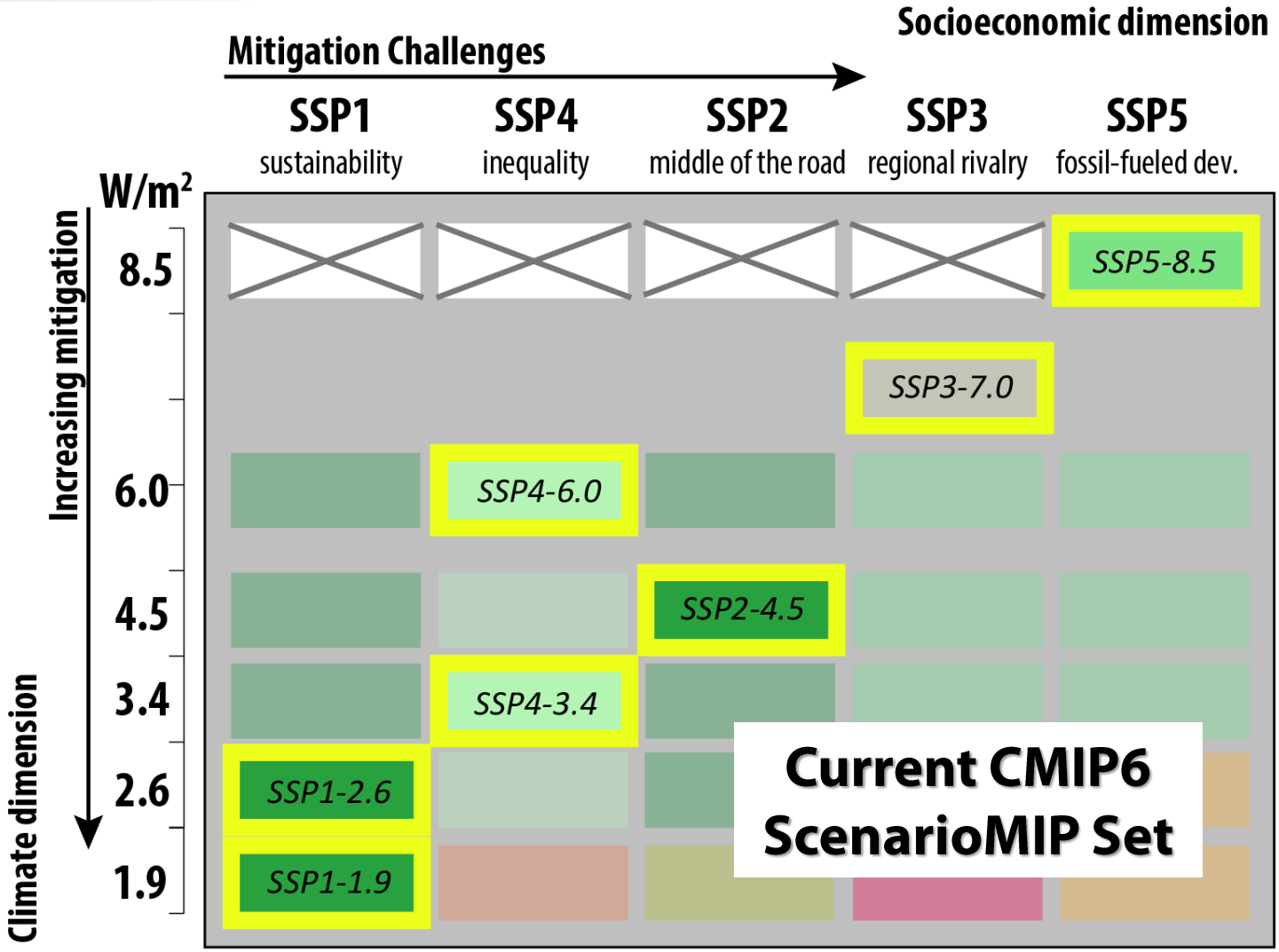
# Shared Policy Assumptions (SPAs)

SPAs describe policy assumptions consistent with the widely different challenges to mitigation across the SSP due to, e.g., fragmentation, lack of institutions, inequity, lack of technology, governance, etc..

Two main SPA dimensions

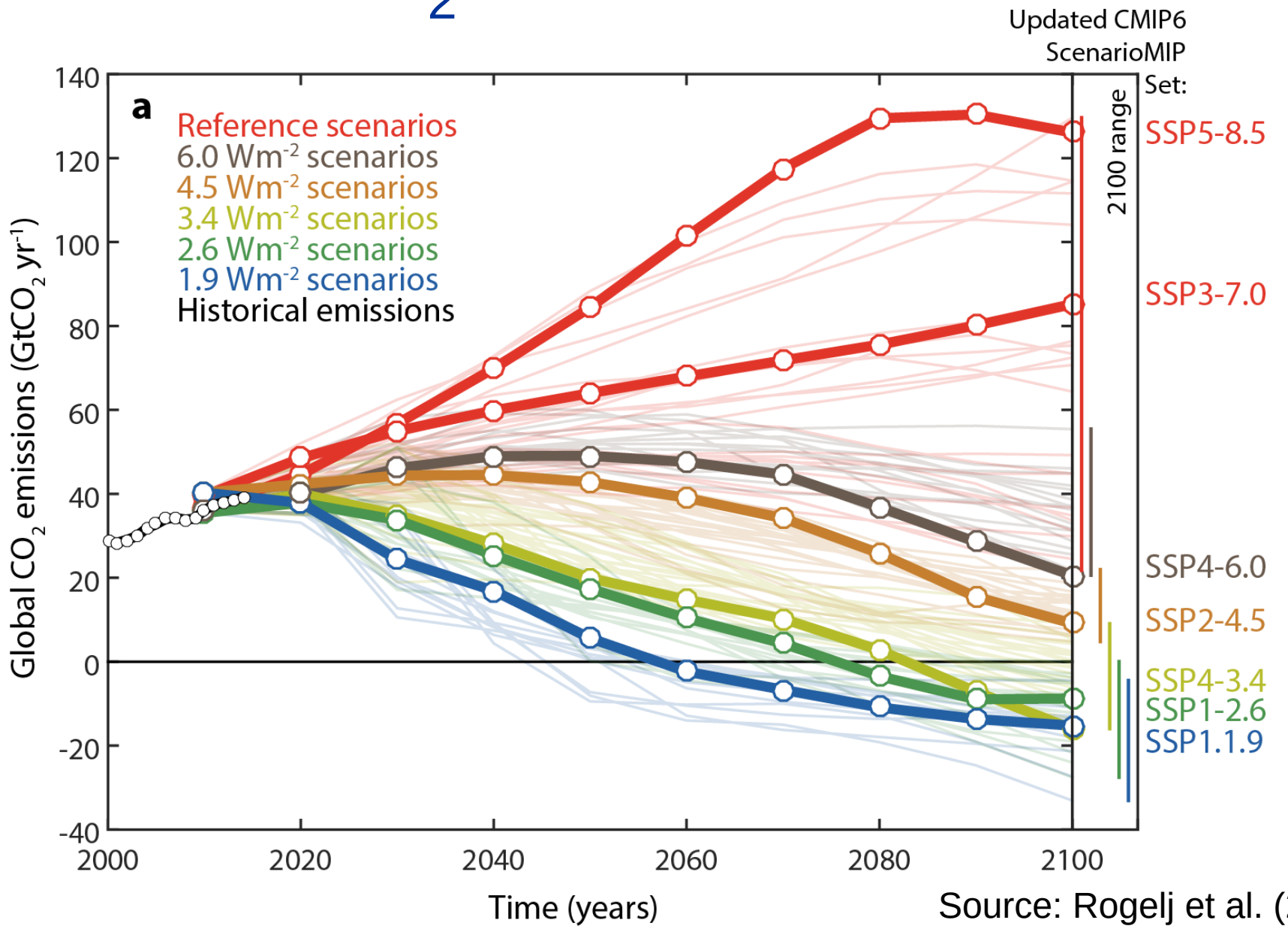
| Accession rule and timing of regional participation | Effectiveness of land policies |
|---|---|
| ***SSP1, SSP4***<br>Early accession will global collaboration as of 2020 | ***SSP1, SSP5***<br>Highly effective |
| ***SSP2, SSP5***<br>Some delays with low-income regions joining in 2040 | ***SSP2, SSP4***<br>Intermediately effective (limited REDD) |
| ***SSP3***<br>Late accession - rich regions join as of 2020 and poor regions join at a certain income level | ***SSP3***<br>Low effectiveness (implementation failures and high transaction costs) |

# RCP-SSP Matrix including mitigation pathways down to 1.9W/m$^2$



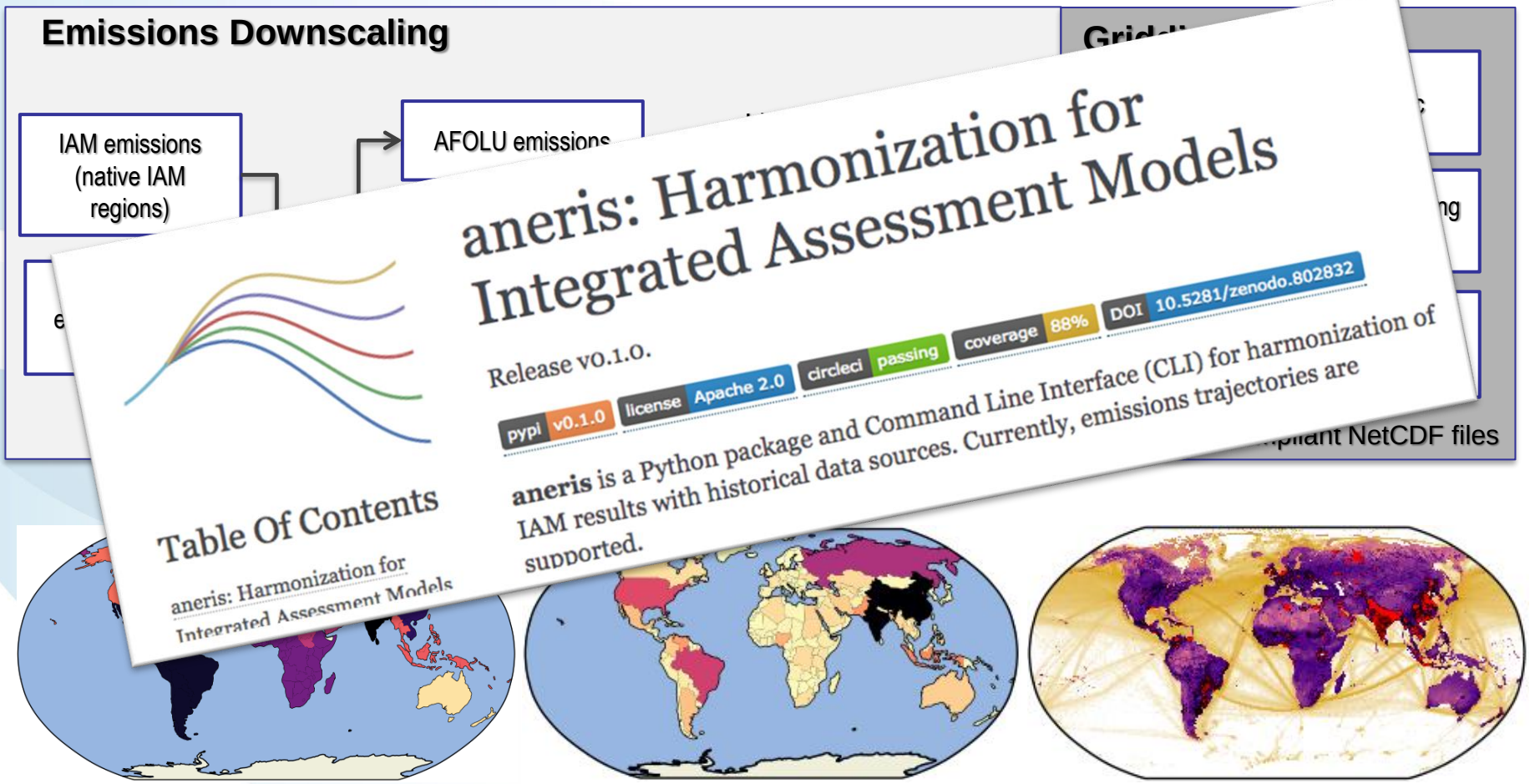

Source: Riahi et al. 2017, Rogelj et al. 2018

# Global $CO_2$ Emissions



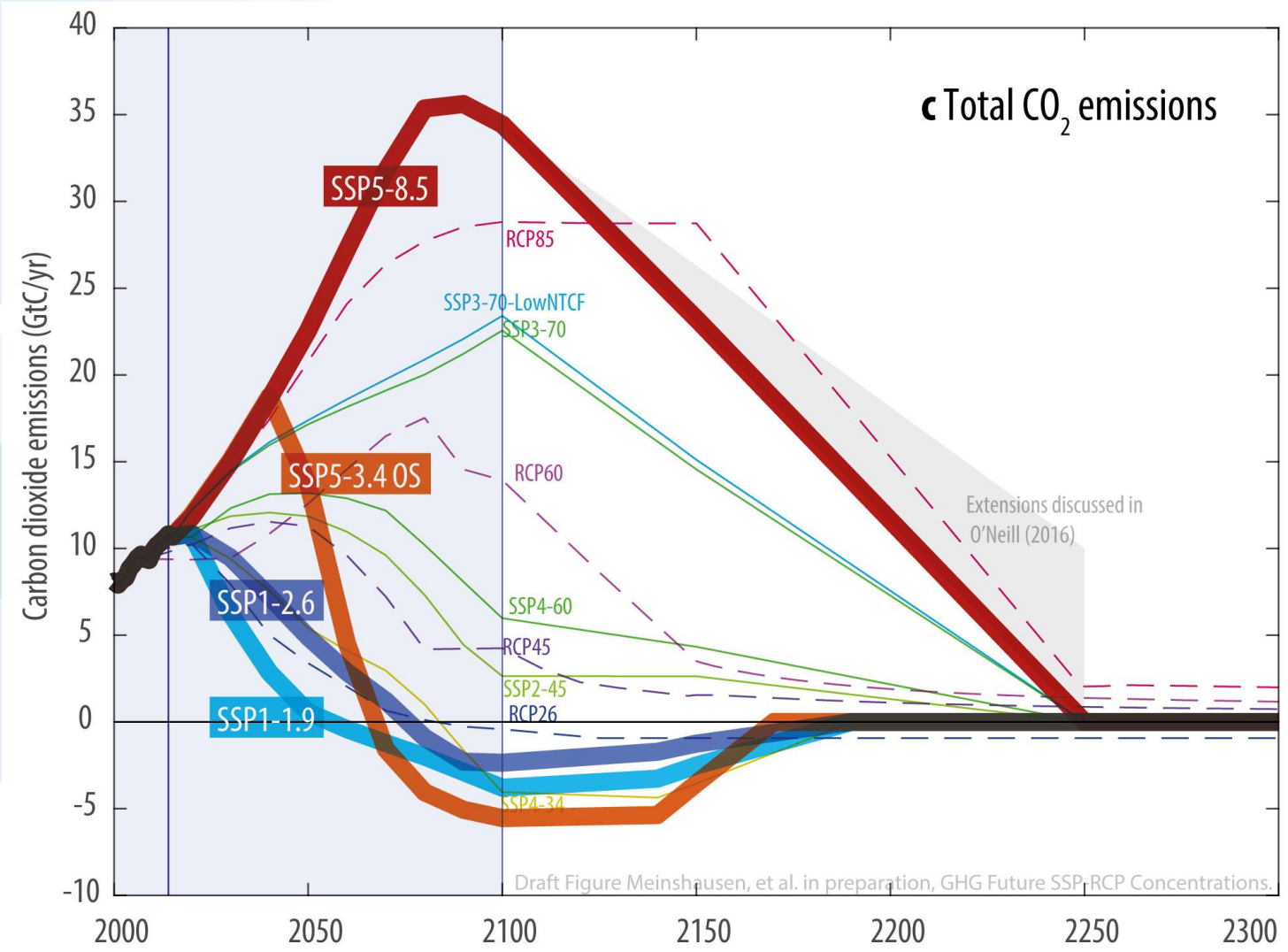

Source: Rogelj et al. (2018)

# Harmonization and Downscaling of Emissions and Land-use for ESMs



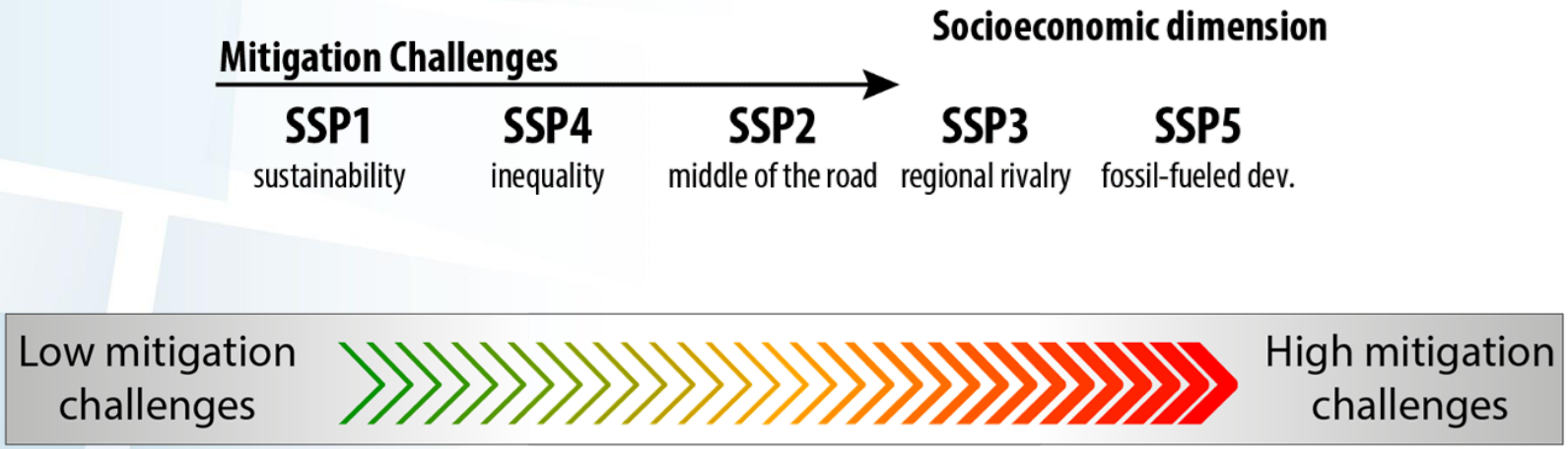

Source: Gidden et al. (2019) https://doi.org/10.5194/gmd-12-1443-2019, Feng et al. (2020) https://doi.org/10.5194/gmd-13-461-2020, Hurtt et al. (2019) https://doi.org/10.5194/gmd-13-5425-2020

# Extension of the CMIP6 Emissions beyond 2100



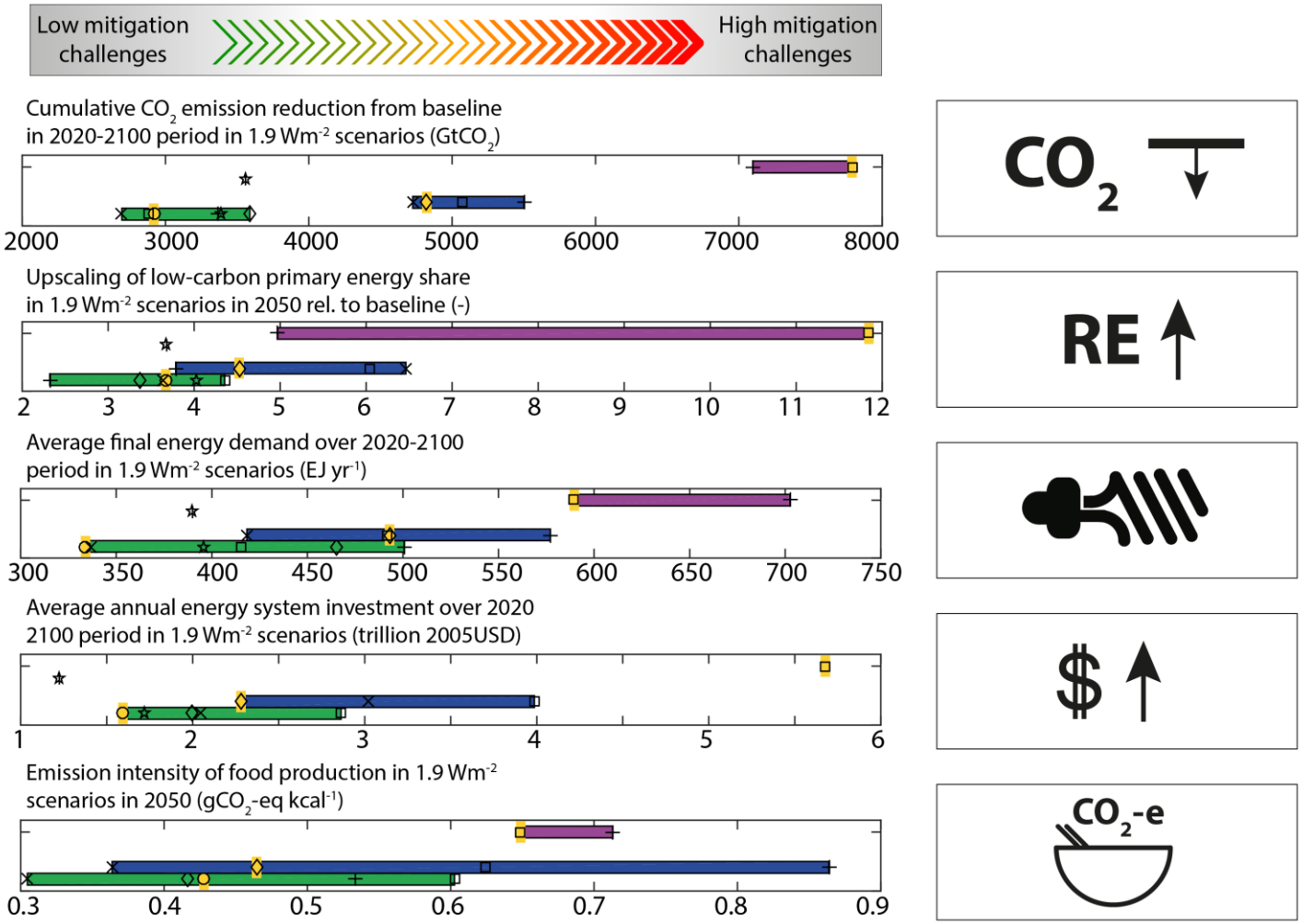

Source: Meinshausen et al. (2020), https://doi.org/10.5194/gmd-13-3571-2020

# Differential mitigation challenges




Source: Rogelj et al. (2018)

# Differential mitigation challenges



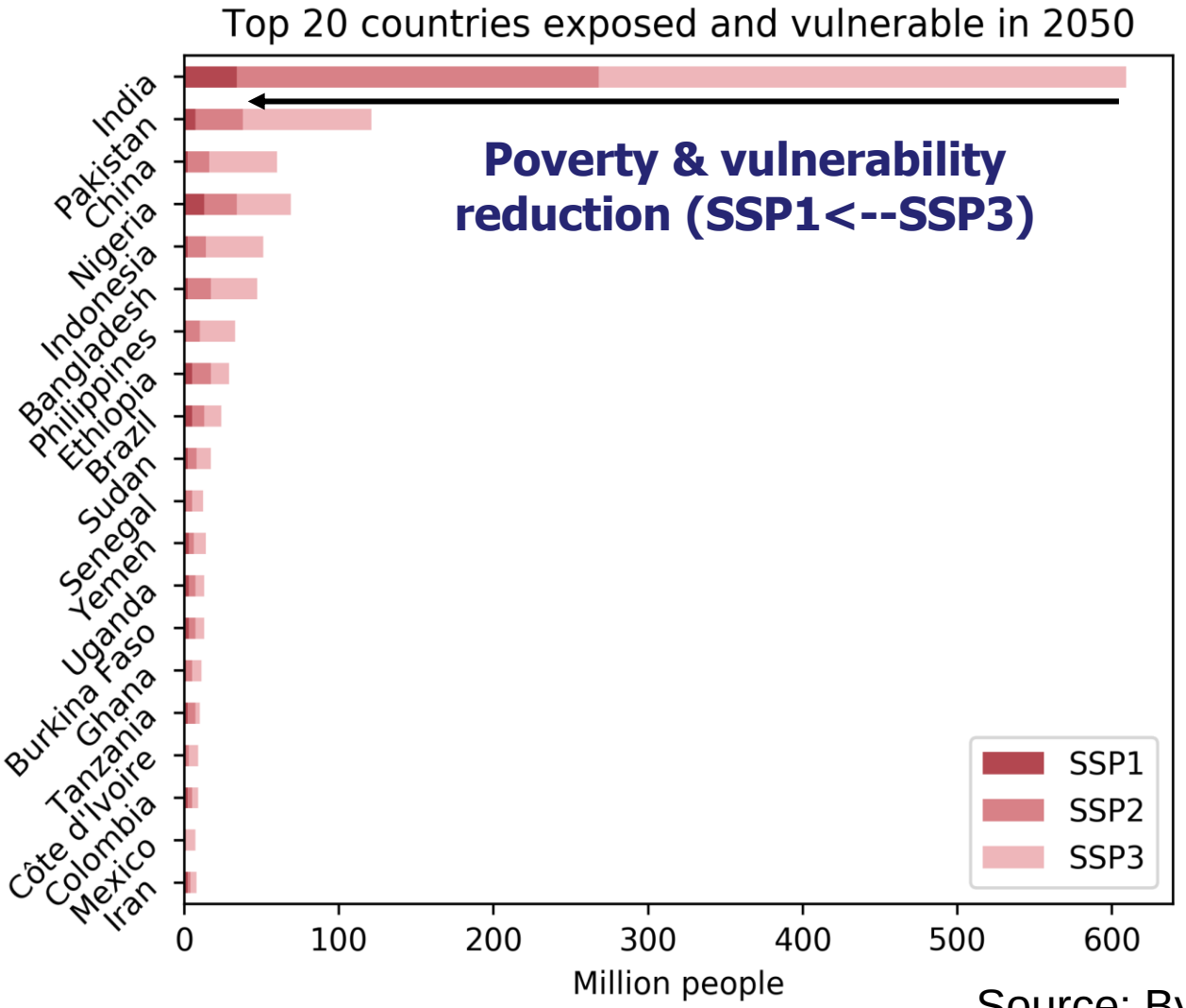

**SSP1** **SSP2** **SSP4** **SSP5**

**Models**: X : AIM/CGE (A); + : GCAM4 (G); O : IMAGE (I);
◊ : MESSAGE-GLOBIOM (M); □ : REMIND-MAGPIE (R); ☆ : WITCH-GLOBIOM (W)

SSP marker:

Source: Rogelj et al. (2018)

# Benefits of development, reducing vulnerability to climate extremes




Source: Byers et al. (2018)

# Thank you!

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