# A guide to Representative Concentration Pathways

The Representative Concentration Pathways (RCP) is the latest generation of scenarios that provide input to climate models.

Scenarios have long been used by planners and decision makers to analyse situations in which outcomes are uncertain. In climate research, emissions scenarios are used to explore how much humans could contribute to future climate change given uncertainties in factors such as population growth, economic development, and development of new technologies. Projections and scenarios of future social and environmental conditions are also used to explore how much impact lesser or greater amounts of climate change would have on different possible states of the world, for example futures with greater or lesser amounts of poverty. The purpose of using scenarios is not to predict the future, but to explore both the scientific and real-world implications of different plausible futures.

Over time, a variety of approaches to scenarios in climate research have been used, from stylised representations of annual percentage increases in global average concentrations of greenhouse gases to advanced representations of emissions of many gases and particles affecting climate and derived from detailed socioeconomic and technology assumptions. An overview of several of the most prominent sets of emissions scenarios is provided in table 1.

History of scenarios

| Year | Name | Used in |
|---|---|---|
| 1990 | SA90 | First Assessment Report |
| 1992 | IS92 | Second Assessment Report |
| 2000 | SRES – Special Report on Emissions and Scenarios | Third and Four Assessment Report |
| 2009 | RCP – Representative Concentration Pathways | Fifth Assessment Report |

Climate models are essentially computer programmes which describe the most important components, processes and interactions in the climate system, such as the frequency and magnitude of monsoons, El Niños and other climate modes. In order to calculate how human activities could affect the climate system, scientists insert greenhouse gas concentrations, pollution, and changes in land use and land cover to their models. These factors influence the Earth's climate. How much emissions and land use change scientists should add depends on future social and economic development, including economic growth, technological change, innovation, population growth and urbanization. This information is provided by scenarios produced by the integrated assessment models. (These models integrate knowledge from two or more domains e.g. the environment and economics, into a single framework.)

A climate projection is usually a statement about the likelihood that something will happen several decades to centuries in the future if certain influential conditions develop. Scenarios however, are not projections or predictions, but rather represent alternative, possible ways in which the future may unfold.

**How are the RCPs different from previous scenarios?**
In preparation for the Fifth Assessment Report (AR5), researchers developed a new approach for creating and using scenarios in climate change research. This new approach was motivated by the changing information needs of policy makers. For example the increasing interest in exploring different approaches to achieving specific climate change targets (such as limiting change to 2°C), and growing interest in a "risk management" approach that combines reductions in emissions and adaptation to reduce climate change damages.

Scientific advances also dictated the need for new scenarios. Since the Fourth Assessment Report (AR4) important improvements in climate models have been made. As the climate models became more sophisticated, more detailed input was needed. Simultaneously, models that are used in the production of scenarios have improved and more advanced input can therefore be provided.

**What is radiative forcing?**
Radiative forcing, expressed as Watts per square metre, is the additional energy taken up by the Earth system due to the enhanced greenhouse effect. More precisely, it can be defined as the difference in the balance of energy that enters the atmosphere and the amount that is returned to space compared to the pre-industrial situation. Total radiative forcing is determined by both positive forcing from greenhouse gases and negative forcing from aerosols. The dominant factor by far is the positive forcing from $CO_2$. As the radiative forcing increases, the global temperature rises. However, the precise relationship between these factors is not fully known.

The new approach is built around the concept of Representative Concentration Pathways (RCPs). RCPs are time and space dependent trajectories of concentrations of greenhouse gases and pollutants resulting from human activities, including changes in land use. RCPs provide a quantitative description of concentrations of the climate change pollutants in the atmosphere over time, as well as their radiative forcing in 2100 (for example, RCP 6 achieves an overall impact of 6 watts per square metre by 2100). The word "representative" signifies that each RCP provides only one of many possible scenarios that would lead to the specific radiative forcing pathway. Radiative forcing is a measure of the additional energy taken up by the Earth system due to increases in climate change pollution (see box on radiative forcing).

**How were the RCPs developed and how are they used in climate research?**
Each RCP was developed by a different modelling group. Since the RCPs had been developed with different, independent models, they are not directly comparable. By fixing the pathways for the radiative forcing and the concentrations, climate modellers could already begin with their simulations and analyse the results for the Fifth Assessment Report (published in September 2013). In a parallel process, the scenario community is developing a set of consistent socio-economic scenarios with storylines to guide mitigation, adaptation, and mitigation analysis. These are called shared socioeconomic pathways (SSPs) and will be assessed in the IPCCs AR5 Working Group 3 Report released in March 2014.

A key difference between the new RCPs and the previous scenarios is that there are no fixed sets of assumptions related to population growth, economic development, or technology associated with any RCP. Many different socio-economic futures are possible leading to the same level of radiative forcing. This enables researchers to test various permutations of climate policies and social, technological, and economic circumstances. For example, at a global scale, higher population or increased energy consumption could be compensated by a higher fraction of renewable energy. So rather than prescribing the economic development and calculate climate change, researchers could pick an RCP scenario that is compatible with the 2°C target, for example, and then assess various technology and policy options to achieve the emissions consistent with that pathway and target. In previous scenarios, for example the SRES, analysis started with a socio-economic storyline from which emission trajectories and climate impacts were assessed. This essentially 'locked in' the options for socio-economic change and made such explorations difficult.

Gases and pollutants included in the RCPs

Greenhouse gases: $CO_2$, methane, nitrous oxide, several groups of fluorocarbons and sulphur hexafluoride.

Aerosols and chemically active gasses: Sulphur dioxide, soot, organic carbon, carbon monoxide, nitrogen oxides, volatile organic compounds, ammonia

Another key difference is that the RCPs are spatially explicit and provide information a global grid at a resolution of approximately 60 kilometres. This gives the spatial and temporal information about the location of various emissions and land use changes. This is an important improvement as the location of some emissions affects their warming potential.

**Who developed the RCPs and how were they chosen?**

A global community of integrated assessment modelling groups formed the Integrated Assessment Modelling Consortium to develop the RCPs, based on a peer-reviewed research process and community-wide discussion. The pathways are freely available online, and peer-reviewed articles describing their development are also available (http://www.iiasa.ac.at/web/home/research/researchPrograms/TransitionstoNewTechnologies/RCP.en.html).

## The RCPs used in AR5

The four RCPs are consistent with certain socio-economic assumptions. These will later be replaced by the Shared Socio-economic Pathways which will provide flexible descriptions of possible futures within each RCP.

**RCP 8.5 – High emissions**

This RCP is consistent with a future with no policy changes to reduce emissions. It was developed by the International Institute for Applied System Analysis in Austria and is characterised by increasing greenhouse gas emissions that lead to high greenhouse gas concentrations over time.

Comparable SRES scenario A1 F1

This future is consistent with:

- Three times today's $CO_2$ emissions by 2100
- Rapid increase in methane emissions
- Increased use of croplands and grassland which is driven by an increase in population
- A world population of 12 billion by 2100
- Lower rate of technology development
- Heavy reliance on fossil fuels
- High energy intensity
- No implementation of climate policies

**RCP 6 – Intermediate emissions**

This RCP is developed by the National Institute for Environmental Studies in Japan. Radiative forcing is stabilised shortly after year 2100, which is consistent with the application of a range of technologies and strategies for reducing greenhouse gas emissions.

Comparable SRES scenario: B2

This future is consistent with:

- Heavy reliance on fossil fuels
- Intermediate energy intensity
- Increasing use of croplands and declining use of grasslands
- Stable methane emissions
- $CO_2$ emissions peak in 2060 at 75 per cent above today's levels, then decline to 25 per cent above today

**RCP 4.5 – Intermediate emissions**

This RCP is developed by the Pacific Northwest National Laboratory in the US. Here radiative forcing is stabilised shortly after year 2100, consistent with a future with relatively ambitious emissions reductions.

Comparable SRES scenario: B1

This future is consistent with:

- Lower energy intensity
- Strong reforestation programmes
- Decreasing use of croplands and grasslands due to yield increases and dietary changes

- Stringent climate policies
- Stable methane emissions
- $CO_2$ emissions increase only slightly before decline commences around 2040

**RCP 2.6 – Low emissions**

This RCP is developed by PBL Netherlands Environmental Assessment Agency. Here radiative forcing reaches 3.1 W/m2 before it returns to 2.6 W/m2 by 2100. In order to reach such forcing levels, ambitious greenhouse gas emissions reductions would be required over time.

Comparable SRES scenario: None

This future would require:

- Declining use of oil
- Low energy intensity
- A world population of 9 billion by year 2100
- Use of croplands increase due to bio-energy production
- More intensive animal husbandry
- Methane emissions reduced by 40 per cent
- $CO_2$ emissions stay at today's level until 2020, then decline and become negative in 2100
- $CO_2$ concentrations peak around 2050, followed by a modest decline to around 400 ppm by 2100

# Further reading


- The representative concentration pathways: an overview by Detlef P. van Vuuren et al which appeared in the November 2011 issue of Climate Change. http://link.springer.com/article/10.1007%2Fs10584-011-0148-z

- The next generation of scenarios for climate change research and assessment by Richard H. Moss et al which appeared in the February 2010 issue of Nature. http://www.nature.com/nature/journal/v463/n7282/abs/nature08823.html (pay wall)



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