AVOID 2
Can we avoid dangerous climate change?

How does climate impacts research make use of IPCC scenarios?

Like most climate impacts research results, the AVOID 2 findings are usually stated with reference to a small set of future scenarios. There are separate scenarios for atmospheric greenhouse gas concentration (the Representative Concentration Pathways, or RCPs) and for socioeconomic development (the Shared Socioeconomic Pathways, or SSPs). This policy card explains what the RCPs and SSPs are, and how they are combined in climate impact assessment studies.

Representative Concentration Pathways

These are physical scenarios designed to explore **a plausible range of future climate forcings**, expressed in terms of the effect of human activities on the earth's radiation balance.

There are four RCPs defining plausible changes in forcing through the 21st century, named according to the anthropogenic radiative forcing level in 2100. For example, RCP8.5 reaches a radiative forcing of 8.5 Wm^{-2} (Watts per square metre) in 2100. The RCPs are used as input to climate simulation models, which estimate their effects on temperature and other climate variables.

The RCPs do not specify emissions of greenhouse gases, but do define specific patterns of land use change which are important for climate.

As scenarios, the RCPs do not have a 'chance of occurrence' – all are conceptually possible. However, the middle scenarios (RCP4.5 and RCP6.0) imply emissions levels which are broadly more plausible than the extreme scenarios (RCP2.6 and RCP8.5).

Shared Socioeconomic Pathways

These scenarios are designed to explore **a plausible range of future socioeconomic development patterns** in terms of GDP, population density and distribution, policies and energy use, etc.

There are five SSPs, each accompanied by a narrative. They are differentiated in terms of the socioeconomic challenges to mitigation and adaptation. Each also has a set of core quantitative projections, defining basic demographic and economic assumptions such as global population and average income.

The SSPs make no assumptions about the effects of climate change and do not themselves define emissions.

As scenarios, the SSPs do not have a 'chance of occurrence' – all are conceptually possible.

Combining climate and socioeconomic scenarios

Any combination of RCP and SSP is theoretically possible. For a given SSP, a wide range of future emissions could be projected by making different assumptions about the uptake of energy technologies and policy support. Similarly, different SSPs can result in the same future emissions. Estimates of future emissions and land cover change for a given SSP and set of policy and energy technology assumptions are made using energy models or Integrated Assessment Models (IAMs).

Some combinations of RCP and SSP are more feasible than others. For example, some IAMs fail to simulate emissions consistent with the RCP2.6 stringent mitigation forcing with the socioeconomic assumptions in SSP3, within feasible constraints on the speed of deployment of new energy technologies. At the other extreme, some IAMs fail to generate the high emissions consistent with RCP8.5 under some SSPs.

Assessing climate impacts using a matrix approach

The impacts of climate change can be assessed under any combination of climate forcing (RCP) and socioeconomic scenario (SSP). A complex climate model is used to estimate the physical hazard under each RCP, such as the incidence of extreme heat in a particular region. The SSP gives the population and level of GDP in this region, which shows the level of vulnerability – the people who will be affected. An IAM is then used to combine a simplified climate model with socio-economic information to estimate the level of damage in the changed climate. By estimating impacts under different combinations of RCP and SSP, it is possible to assess the relative effect of climate and socioeconomic change on future impacts and the effectiveness of adaptation options.

Read more

Reports from Work Package B of AVOID 2 consider climate impacts under alternative scenarios. These are available on our website *www.avoid.uk.net*

What are the four Representative Concentration Pathways (RCPs)?

The RCPs are chosen to cover the range of plausible outcomes in 2100, from a scenario requiring very stringent mitigation (RCP2.6) to a scenario with continued rapid increase of atmospheric greenhouse gas levels (RCP8.5). The other two scenarios (RCP4.5 and RCP6.0) are intermediate in nature.

Because the RCPs only specify greenhouse gas concentrations, the global temperature change and emissions pathway consistent with each RCP are estimated using climate models. Different climate models give different outputs, so there is a range of possible outcomes for each scenario.

We should not expect observed forcings to follow any of the RCP trajectories exactly, so it does not make sense to ask which one we are 'on' at the moment. In the first decades of the scenarios, there is little observable difference between the trajectories anyway, with greater divergence later in the century.

Figure 1: The four Representative Concentration Pathways (RCPs)

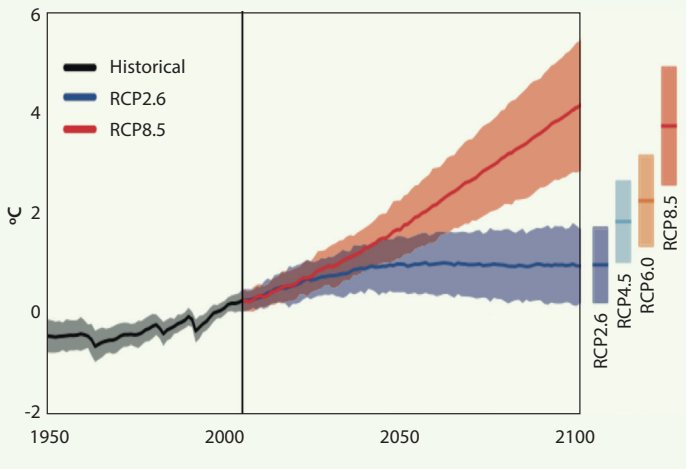
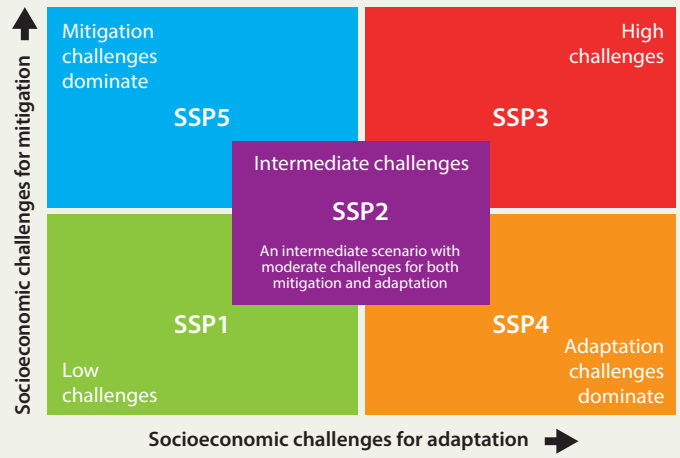


Figure 2: The five Shared Socioeconomic Pathways



What are the five Shared Socioeconomic Pathways (SSPs)?

SSP1: **Sustainable development proceeds at a reasonably high pace, inequalities are lessened**, technological change is rapid and directed toward environmentally friendly processes, including lower carbon energy sources and high productivity of land. Global population 6.8 billion in 2100 (the global population as of 2016 was approaching 7.5 billion).

SSP2: **The most commonly used scenario.** It is intermediate in nature and has been used by AVOID 2 work package B. It has medium challenges for both mitigation and adaptation and a global population of 9 billion people in 2100.

SSP3: **Unmitigated emissions are high** with a rapidly growing population, and slow technological change in the energy sector. **Inequality is high**, a regionalised world leads to reduced trade flows, leaving **large numbers of people vunerable to climate change** and low adaptive capacity. Global population 12.6 billion in 2100.

SSP4: **Rapid technological development in low carbon energy sources**. However, in some regions, development proceeds slowly, **inequality remains high**, and economies are isolated, leaving these regions highly vulnerable to climate change with limited adaptive capacity. Global population 9.3 billion in 2100.

SSP5: In the absence of climate policies, **energy demand is high**, and most of this demand is met with carbon-based fuels. Nonetheless, **economic development is rapid**, with **more equitable distribution of resources**, stronger institutions, and slower poulation growth, leading to a less vulnerable world better able to adapt to climate impacts. Global population 7.4 billion in 2100.

Read more

Reports from Work Package C of AVOID 2 consider the feasibility of stringent mitigation scenarios and look at the assumptions and requirements for this to occur. Reports from Work Package D examine the feasibility of rapid, large-scale BECCS deployment. These reports are available on our website *www.avoid.uk.net*

O'Neill et al, 2014, *A new scenario framework for climate change research: the concept of shared socioeconomic pathways*, Climate Change 122:387-400 (Open Access).

Some frequently asked questions

What is a climate forcing?

The drivers of climate change are measured in terms of radiative forcing measured in watts per square metre, which is the amount of extra energy captured or lost as a result of the change. Changing the concentration of greenhouse gas in the atmosphere causes a forcing. Land use change can also result in a forcing due to the change in the amount of energy reflected from the surface of the earth (e.g. when snow is replaced by tree cover). Forcings can have a warming or cooling effect depending on whether incoming solar energy is captured or lost.

What is a scenario?

Scenarios are not intended to be predictions of what will happen. They are intended to cover a range of plausible possibilities, with the expectation that the true outcome will be somewhere within that range.

How were the Representative Concentration Pathways (RCPs) chosen?

A small set of scenarios were needed in order to be able to run different climate models and compare the outputs. They were chosen to span an expected feasible range of the total climate forcing at the end of the century – one low (RCP2.6), one high (RCP8.5), and two in the middle (RCP4.5 and 6.0). The actual outcome does not have to exactly follow one of the four. It could reach a different forcing at the end of the century or take a different pathway to the same forcing.

What is 'business as usual' (BAU)? Is RCP8.5 a BAU pathway?

In many cases we would like to know what outcomes would result from the 'do-nothing' or BAU option. However, to define a BAU climate we must define a whole set of reference projections of GDP, population, climate policy, energy technology development, etc. There are differences of opinion about what kinds of climate policy would be expected in a BAU world. So there cannot be a single BAU pathway to compare. None of the RCPs were designed as a BAU pathway.

Is the RCP2.6 pathway achievable in practice?

The feasibility of achieving this level of radiative forcing by 2100 depends on many other factors. In a socioeconomic pathway with high challenges for both mitigation and adaptation, very ambitious technological improvements would be required to stay on the RCP2.6 pathway. In a less challenging socioeconomic pathway, the required level of technological development and implementation is easier to achieve.

Is the RCP2.6 pathway the only way to stay below 2°C?

First, note that all temperature projections are estimates. It is possible that even if the RCP2.6 pathway were to be followed exactly, the temperature rise could still exceed 2°C, if the climate sensitivity (Earth's climate response to atmospheric GHG concentration) turns out to be at the high end of the plausible range. The main determinant of global temperature change is the cumulative greenhouse gas emission level. There are many different possible pathways that could achieve less than 2°C by 2100.

How were the Shared Socioeconomic Pathways (SSPs) chosen?

The socioeconomic storylines of the SSPs were selected, like RCPs, by the IPCC and are designed to cover the range of possible challenges for mitigation and adaptation. The level of challenge for mitigation is determined by emissions reduction policies and by the rate of technological development. The level of challenge for adaptation is determined by the strength of institutions and by equitable sustainable development, which improve both resilience and the timeliness and effectiveness of responses to climate change.