# 2. Scenarios for climate change and sea-level rise

NZ SEA RISE
TE TAI PARI O AOTEAROA

Sea-level rise is accelerating in a delayed response to global greenhouse-gas emissions over the past several decades. We have been able to measure the rise in sea level so far using tide gauges and satellites. But as with climate change generally, the most wide-ranging impacts lie ahead of us. We can't pin down (predict) exactly how sea-level rise will track for the rest of this century and beyond, as it mainly depends on how much global greenhouse gas emissions are reduced and how quickly. That introduces a widening uncertainty looking into the future.

While future impacts and implications of climate change are uncertain, they are not entirely unknowable[1]. For instance, we know sea level will continue rising for centuries – it's how quickly it rises and the final peak level it reaches (and when), which are uncertain. Like estimating future population or GDP growth/decline, we need to use different possible scenarios for our projections to anticipate and plan for plausible climate-shaped futures e.g., sea-level rise or temperature. Using scenarios for projections better encompasses future uncertainties, where there could be surprises either way (worse or better than we expect), rather than a conventional way of choosing a single prediction to plan for e.g., a most likely prediction or a worst case.

The Intergovernmental Panel on Climate Change (IPCC) and climate researchers worldwide previously used storylines called Representative Concentration Pathways (RCPs) to represent plausible climate futures. These futures were focused on a radiative forcing of warming that could be reached by 2100, going from 2.6, 4.5, 6.0 to 8.5 Watts per square metre of additional energy trapped in the climate system by the greenhouse effect.

IPCC's latest assessment reports (published 2021-22) shifted to a new core set of future representative scenarios, based on Shared Socio-economic Pathways (SSPs). Climate change is not happening in isolation, but in tandem with other processes of environmental, social, technical, economic, and cultural change[1]. These SSP narratives comprise different assumptions about possible changes in social and economic systems that influence future emissions. SSP scenarios span a wide range of plausible societal and climate futures from an aspirational goal of only 1.5°C warming to over 4°C warming by 2100. The switch to SSP scenarios recognises there are varying pathways to reaching global warming levels, such as different trajectories of $CO_2$ and non-$CO_2$ greenhouse-gas emissions, aerosols, population trends, income inequality, energy use and land use from different social and economic settings.[2] The new SSPs offer five different narratives of how the world could become (Figure 1) that also combine RCPs (end number) related to increases in global mean temperature.

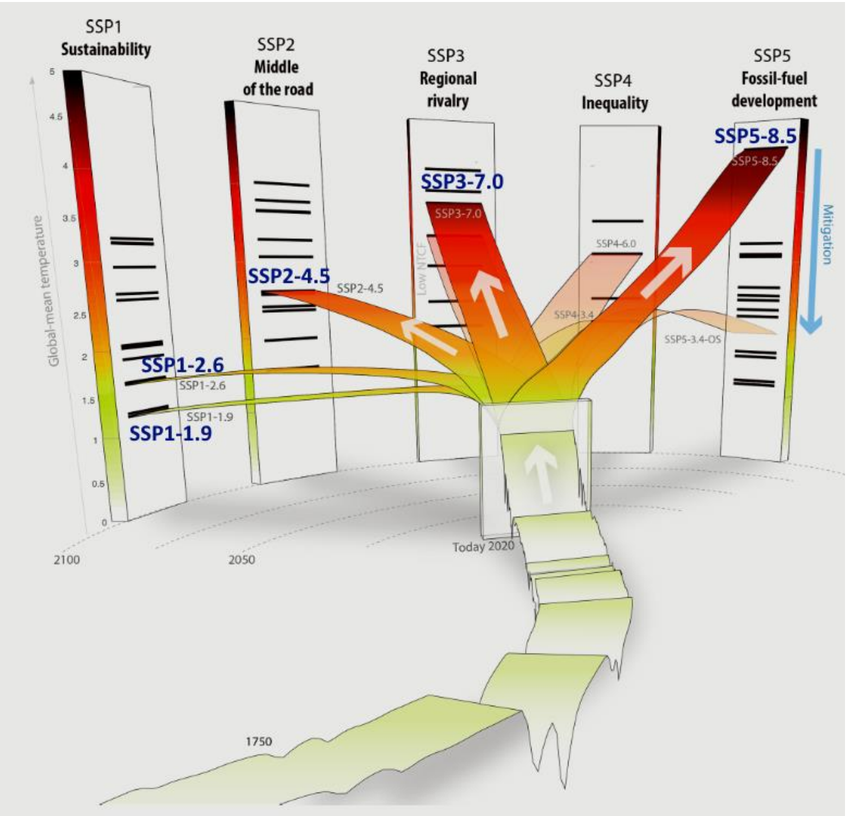


**Figure 1:**

Global mean temperature in relation to a core suite of five Shared Socio-economic Pathways (SSP) narratives that incorporate RCP energy imbalances. Vertical axis is global mean temperature increase, coinciding with less mitigation of greenhouse gases.

These SSPs were the scenarios used for the NZ SeaRise projections for Aotearoa www.searise.nz/maps-2

*Source: Meinshausen et al. (2020).*[2]

Compared to previous RCP scenarios, these SSPs offer a broader view of possible future changes than just assuming "business as usual" socio-economic settings, by considering how might we respond to a changing climate in the way we live, move about and do business. The SSPs also show that it would be easier to both mitigate greenhouse gases and adapt to climate change in some socio-economic settings than in others (e.g., SSP1 or SSP2 – Figure 1).

### Which scenario should we use?

A common question. It arises from the conventional "predict-then-act" stance for making decisions, selecting either a most-likely sea-level rise, or picking a worst case to cover "most eventualities". However plausible sea-level rise projections for different SSP scenarios spread further apart over time (see Primer #1) and we can't assign a probability of occurring to any of the scenarios as it depends on how global emissions track. Take two examples at the national scale (excluding vertical land movement): 1) scenarios for sea-level rise at a specific time e.g., 2100, may range from 0.4 to 1.1 m; or, 2) for a specific sea-level rise that may define a local adaptation threshold, say a threshold of an 0.8 m rise, then there is a long ~100-year window from 2085 to 2180 when that specific rise will occur. So, choosing a specific scenario could easily lead to an over- or under-stated design or timing of an adaptation decision. Rather we need to keep our future options open to change.

Retaining a suite of scenarios, which describe potential climate futures, allows us to explore questions like "What can happen?" (for example Figure 2) and then "What can we do about it?" that help illustrate impacts under a variety of climate-related outcomes. Further, storylines and scenario planning of the wider implications of sea-level rise can highlight interactions and cascading impacts across human and physical systems that generate risks that are not evident from just looking in isolation at different climate impact projections[3,4]. Using scenarios means we can test various adaptation options or actions for how flexible they are in coping with a range of future conditions and implications. Monitoring the headway as sea level continues to rise (and the impacts it causes) means combinations or pathways of options can be implemented as and when needed locally by the community and infrastructure providers.

### Scenarios for coastal hazard assessments

Sea-level rise projections will change over time as new information and Earth System modelling evolves considering how globally we are tracking with emissions. Each new IPCC assessment report brings a revised set of projections e.g., the latest 2021 report projects sea-level rise by 2120 to be 0.03–0.14 m higher for Aotearoa. The new NZ SeaRise projections (Primer #1) also have introduced local estimates of vertical land movement rates, which may also change over time.

To avoid having to regularly redo coastal hazard and risk assessments, a scenario-neutral approach of using sea-level rise increments of 0.1 or 0.2 m helps steer around this operational issue[5]. Thereafter, the suite of sea-level rise scenarios then provides the time span over which that rise will be reached. Any future updates of projections or local vertical land movement rates can then be linked to the nearest equivalent increment of sea-level rise in the hazard assessment. Using increments also matches better with local adaptation thresholds, which often may be expressed as a specific sea-level rise by which a switch to another option is needed. Figure 2 shows an example of two sea-level rise increments (0.5 and 0.9 m) for the Whitianga–Cooks Beach area using the Waikato Regional Council's coastal inundation tool: https://coastalinundation.waikatoregion.govt.nz/

**Figure 2:** Coastal flood inundation hazard maps for different increments of sea-level rise that are not time bound (blues – direct flooding; green – indirect flooding).


[1] https://climatescenarios.org/primer/
[2] Lee et al. (2021). https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_04.pdf
[3] Lawrence et al. (2018). https://deepsouthchallenge.co.nz/resource/climate-change-the-cascade-effect/
[4] Simpson et al. (2021). https://doi.org/10.1016/j.oneear.2021.03.005
[5] Section 6.5.4, MfE coastal hazard guidance. https://environment.govt.nz/publications/coastal-hazards-and-climate-change-guidance-for-local-government/