

## **Extending the Shared Socioeconomic Pathways for impacts and risks related to higher-end European scenarios**

### **Summary (~150 words):**

In spite of high-end scenarios being increasingly plausible, potential climate change impacts, adaptation and vulnerabilities (CCIAV) studies face two major limitations: understanding uncertainty in long-term socioeconomic changes and oversimplification with single scale approaches. A key aspect in understanding the potential consequences of high-end climate change is the exploration of uncertainty in long-term socioeconomic futures in the form of alternative scenarios. In this study, we argue that the flexible design of the Shared Socioeconomic Pathways (SSPs) can be regionally extended to produce sub-global socioeconomic storylines for application in CCIAV studies for Europe and Scotland. The downscaled European SSPs feature an innovative participatory approach and build on the global SSPs that are used as boundary conditions. In addition to assessing challenges and opportunities associated with SSPs for sub-global extension, this study aims at generating a set of internally consistent qualitative and quantitative elements, and integrated storylines for Europe and Scotland.

### **Extended abstract (600-1200 words):**

The climate system is getting unequivocally warmer (IPCC, 2013). Although the United Nations Framework Convention on Climate Change warns that the increase in global temperature should remain below 2°C above pre-industrial levels to avoid severe impacts (UNFCCC, 2011), projections based on current emission trends point to much more substantial warming, with possible increases of 4°C or more in the long-term unless there is radical action to cut emissions (Peterson et al., 2003).

Notwithstanding increased plausibility of such high-end climate projections, few studies simultaneously assess the potential climate change impacts, adaptation and vulnerabilities (CCIAV) and the potential synergies and trade-offs with mitigation (New et al., 2011). A key aspect to understanding the potential consequences of high-end climate change impacts is the exploration of uncertainty in long-term alternative socioeconomic futures (Field et al., 2014). Global scenarios are the most common approach to explore this uncertainty in future climate and societal conditions. Traditionally, however, global socioeconomic scenarios have lacked an integrated perspective on mitigation, adaptation and residual climate impacts (Field et al., 2014). In addition to this, the sub-global scale of CCIAV methods do not match the global scale at which socioeconomic narratives are framed. Therefore, the scientific community has developed Shared Socioeconomic Pathways (SSPs) with the aim to providing pathways of key socioeconomic drivers along the dimensions of challenges to mitigation and to adaptation which are scalable to different regional contexts (Kriegler et al., 2012). The new insight of the SSPs, compared to previous global scenarios such as the SRES scenarios, is that the magnitude and pattern of greenhouse gas emissions are derived independently of demographic and socioeconomic development. In other words, multiple socioeconomic development pathways can lead to any particular emission scenario. Therefore, demographic and socioeconomic development pathways do not include explicit assumptions about future emissions; these assumptions have been elaborated in the Representative Concentration Pathways (RCPs). SSPs and RCPs may be combined using a matrix architecture into a broader range of scenarios than was possible with the SRES (Ebi et al., 2014). The design of the global storylines of the SSPs is thus suitable for the development of consistent cross-scale global and sub-global socioeconomic storylines (O'Neill et al., 2014, Ebi et al., 2014).

In this study, we present a European and Scottish extension of the global SSP to develop a set of high-end scenarios. The European extension of the SSPs are constructed within the broader context of a set of multi-sectoral and multi-scale case studies. The final aim of the European and Scottish SSPs is to enable their implementation in subsequent CCIAV studies to explore the implications of alternative sub-global socioeconomic futures for the creation of transition pathways that aim to build resilience in the face of uncertainty related to these high end scenarios.

Similar to the global SSPs, the European and Scottish SSPs consist of a set of internally consistent qualitative storylines; tables with a structured overview of the key assumptions and uncertainties; and a limited set of quantitative (model) parameters. These were subsequently linked to RCP4.5 and RCP8.5 to yield integrated storylines. The methods that were used are highly participatory, having stakeholders and experts develop regional extensions of the global SSPs. The final products were a mix between extended developments from the global SSPs and regional developments and assumptions taken from existing regional scenarios. Particularly innovating is the fact that quantitative estimates include ranges of uncertainty as indicated by stakeholders that can be converted to probability density functions. The advantages of in-depth engagement with stakeholders are particularly important for higher-end scenario analyses, where credibility and uncertainty challenges will need to be addressed pro-actively. In addition to this, the broadness and flexibility of the SSP framework allows for the development of consistent assumptions in key variables and modelling analysis at both European (continental) and Scottish (national) scale.

We argue that the participatory process designed to extend the global SSPs, although complex, results in an effective toolkit that addresses the need for more reliable and more credible scientific knowledge on highly uncertain but plausible and important socio-economic futures. The multi-scale and multi-sector approach facilitates further research and assessment possibly characterising the range of complexity in mitigation and adaptation efforts, and in residual impacts of climate change. This research may also include potential synergies across scales from local to continental and to global and trade-offs between mitigation and adaptation towards sustainable pathways.

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