TITLE: Optimising sectoral contributions for Paris-compatible emission budgets over multiple SDG trade-offs

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SUMMARY

Achieving Paris-compatible mitigation levels to keep global temperature increase to well-below-2°C requires deep transformations in every economic sector. Nevertheless, the sectoral allocation of mitigation effort remains a widely debated issue, showcasing considerable variance in the scenario literature. Meanwhile, there emerge critical interactions between climate change mitigation and progress in other sustainable development goals (SDGs). To evaluate how to optimally allocate mitigation effort across sectors, this study assesses the impacts of sectoral mitigation on poverty, health, water, economy, and land-related SDG indicators, and shows how sectoral allocation of mitigation effort depends on which SDG is prioritised in the context of mitigation.

ABSTRACT

In 2015, world leaders acknowledged the urgent need for an ambitious agenda fostering human well-being within planetary boundaries by adopting two landmark international agreements: (1) the Paris Agreement's goal to prevent dangerous anthropogenic climate change by limiting global temperature increase by 2100 to well-below-2°C and pursue efforts to stay below 1.5°C (UNFCCC, 2015), and (2) the Sustainable Development Goals (SDGs) to accelerate sustainable development across the world (UN, 2015). Several SDGs have been shown to interact significantly with climate change (SDG13) (Tagomori et al., 2024), including but not limited to indicators related to land (SDG2 related to food and SDG15 on terrestrial biodiversity, which has strong relations with climate impacts and climate action), water (SDG6 on water use), health (SDG3 on air pollution-driven mortality) and the economy (SDG8 on economic growth that is affected by climate change and/or climate action). These domains are highly interconnected and dependent on one another, with a range of interactions implying both potential trade-offs and synergies between individual SDGs.

At the same time, achieving Paris-compatible mitigation levels to keep global temperature increase well-below-2°C and ideally below 1.5°C requires deep transformations in virtually every sector. Nevertheless, the actual contribution by sector has been a widely debated and unsolved issue. Specifically, the contributions of the main energy end-use sectors (industry, buildings, and transport), the energy supply sector, and the AFOLU sector differ widely between existing mitigation scenarios (Hermville et al., 2022). Both the energy supply sector and the AFOLU sector have a negative emission potential to offset emissions in end-use sectors (Fuhrman et al., 2024). Nevertheless, these negative emission potentials, achieved through either bioenergy combined with carbon, capture and storage (BECCS) or afforestation/reforestation of large land areas, do not come without risks and potential impacts (Heck et al., 2018; Hirata et al., 2018; Stenzel et al., 2021). Therefore, a numerical assessment of co-benefits and trade-offs from mitigation in each of these five different sectors can give valuable insights for the contributions of each sector in future mitigation strategies.

This study explores the sectoral distribution of ramping up mitigation efforts from a pathway based on current national policies and short-term pledges, which largely remain incompatible with achieving the Paris targets according to the latest assessments (UNEP 2023; Van de Ven et al, 2023), towards 1.5°C-, 1.7°C-, and 2°C-compatible futures. The analysis assesses the marginal impact of mitigation in each sector on 5 variables representative of different SDGs:

- Average food basket bill as indicator for SDG 2: "Zero Hunger"
- Premature mortality due to ambient air pollution as indicator for SDG 3: "Good Health & Wellbeing"
- Physical water scarcity index as indicator for SDG 6: "Clean Water & Sanitation"
- GDP per capita growth as indicator for SDG 8: "Decent Work & Economic Growth"
- Proportion of natural land in total land as indicator for SDG 15: "Life on Land"

To provide a policy-relevant decision tool, the study applies an established combination between an integrated assessment model and portfolio analysis (Forouli et al., 2020) to estimate optimal allocations of sectoral mitigation efforts depending on the prioritised SDGs. We break our analysis down into three steps: i) identification of the maximum potential for mitigation in each sector and the total mitigation required to achieve specific temperature goals; ii) simulation of individual scenarios with gradually varying sectoral allocations of mitigation effort using GCAM; and iii) synthesis of optimal portfolios using AUGMECON-R.

In the first step, we attempt to take stock of the role of different sectors in existing scenarios, to identify the maximum potential of each sector towards mitigation targets, relative to their average CO_2 emission paths in existing scenarios based on current and/or national policies (NPi). We use the AR6 database (Byers et al., 2022) to quantify model-average emission pathways (Figure 1). We then calculate the full area between sectoral NPi pathways and their maximal mitigation potential, from 2020 (harmonised based on observed emissions by sector) and 2050, and divide it in blocks of 5 Gt.

In the second step, we apply the Global Change Analysis Model (GCAM) (Calvin et al., 2019) to run multiple incremental scenarios, increasing mitigation in one sector in steps of 5 Gt up to their maximum mitigation potential, while keeping CO_2 emissions in all other sectors on their NPi level. At each level, we identify the relative impacts in each of the 5 SDG indicators (Figure 2).

In the final step, we identify Pareto-optimal portfolios of mitigation effort using AUGMECON-R (Nikas et al., 2022) based on emission budgets compatible with 2°C (300 Gt "additional" mitigation between 2020 and 2050 relative to NPi), 1.7°C (415 Gt), and 1.5°C (560 Gt), which optimise sectoral efforts on a 5-dimensional scale towards each of the above-mentioned 5 SDGs (Figure 3). This provides a picture on which sector policymakers select to prioritise in terms of mitigation depending on which SDGs they deem most relevant and/or urgent.

The results indicate that there is considerable conflict between mitigation in different sectors depending on the SDG that is optimised to the maximum potential. For example, mitigation in the Transportation sector is most effective towards progress from a Health perspective, but it also affects the selected Economy- and Water-related SDG indicators the most, while the impact is largely reverse when mitigating the AFOLU sector. Overall, the results show that around 50% (or more) of mitigation is attributed to the energy supply sector, which is the largest emitting sector nowadays and also has the highest potential for reduction. Nevertheless, part of this potential is realised by negative emissions through BECCS, and the analysis does not take into account the different risks of depending on carbon removals and direct abatement.

Overall, the results show that deeper mitigation stretches the limits in most sectors, decreasing flexibility in optimising sectoral mitigation over SDGs. In general, deeper mitigation affects our selected set of SDGs related to Hunger and Economy most negatively, while improving progress in those related to Health and Land. Meanwhile the effect for the examined water-related SDG is ambiguous.

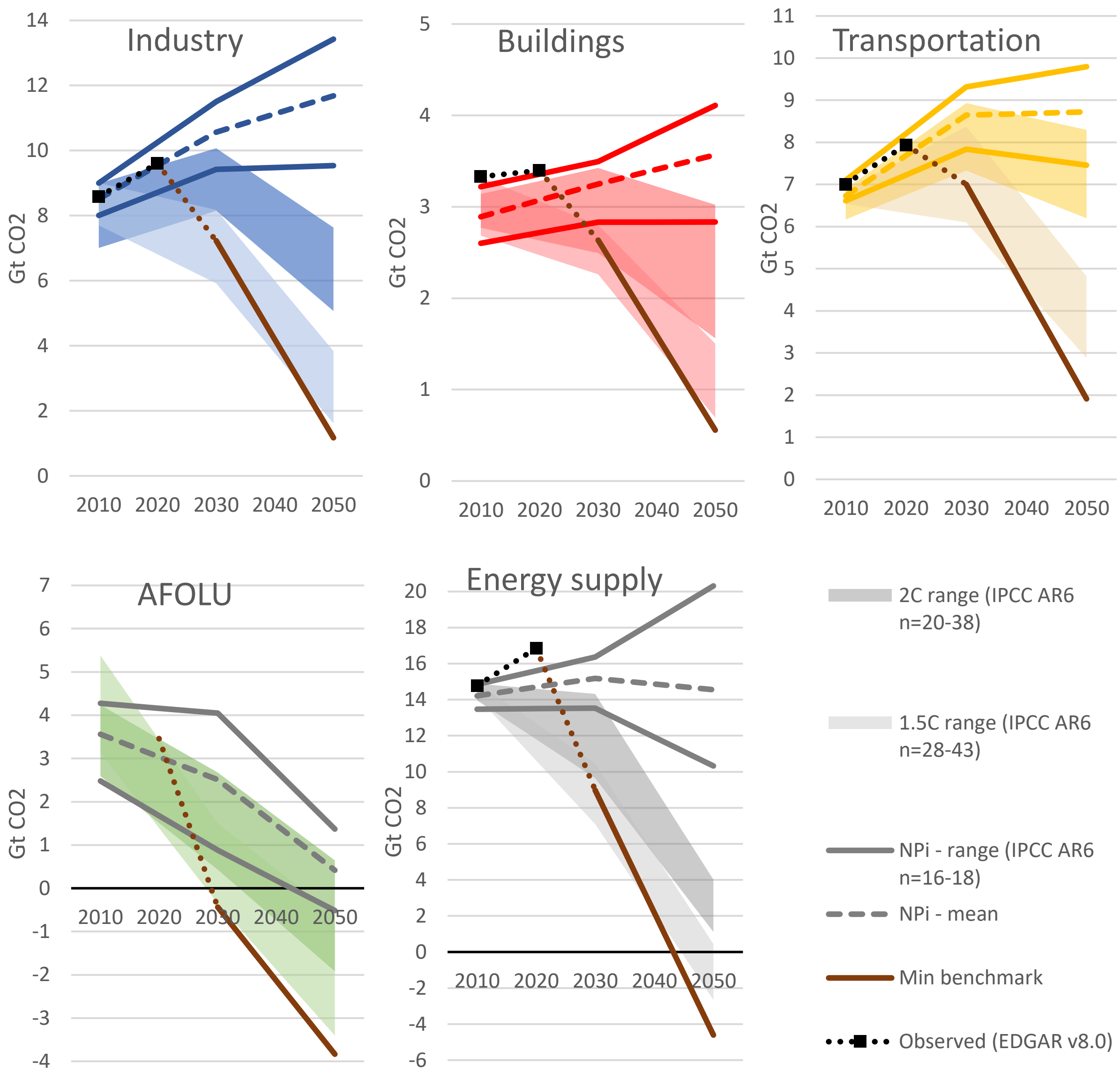

Figure 1: Sectoral emission stocktake for 2010, 2030 and 2050 for NPi baselines, 2ºC and 1.5ºC scenarios from IPCC AR6 (n values reflect number of models reporting, taking mean of all relevant scenarios from the same model), observed values in 2010 and 2020 (taken as average between 2019 and 2021 emissions to avoid Covid-19 distortions, no value available for AFOLU sector), and applied "minimal benchmark" in this study.

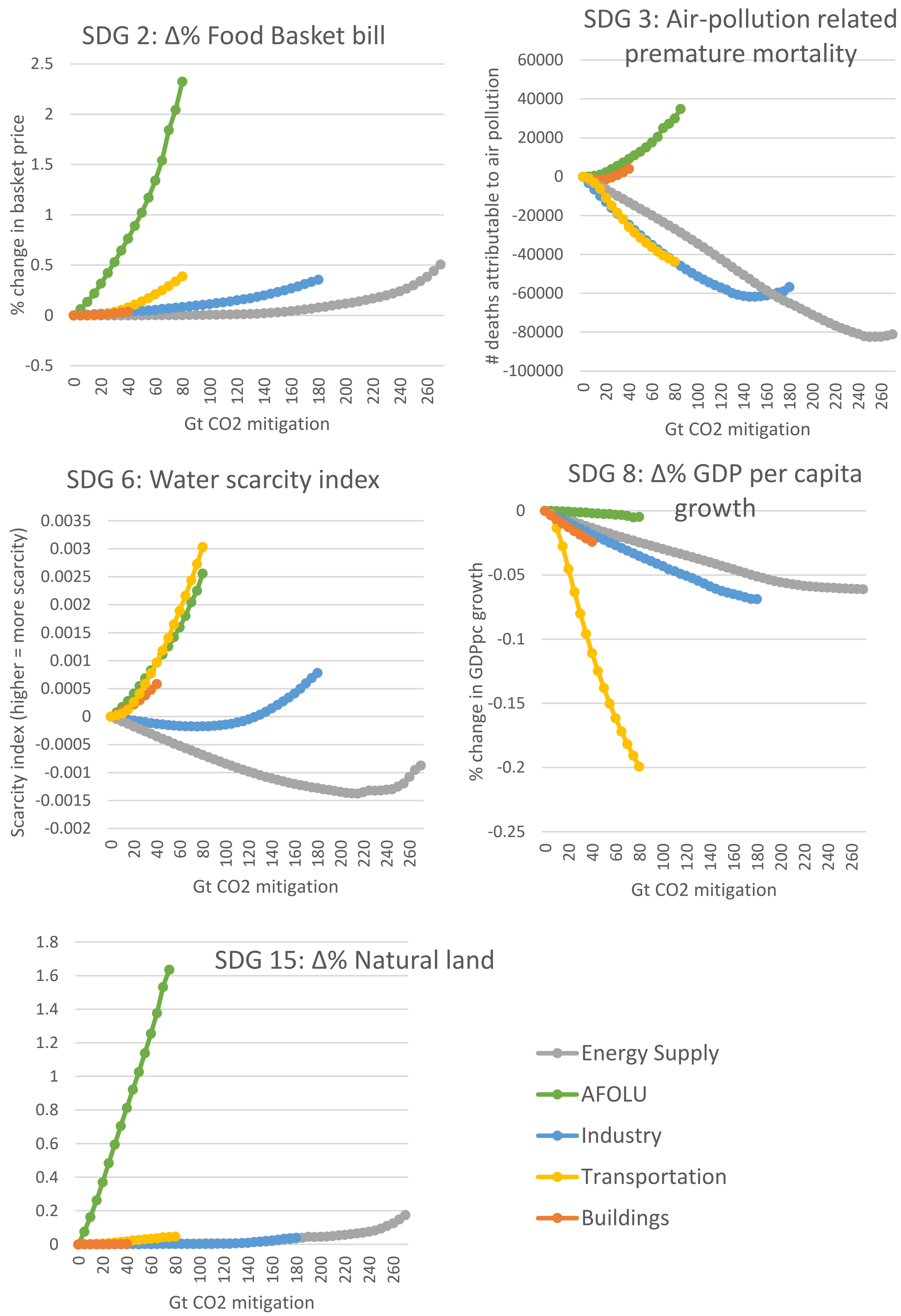

Figure 2: Impact of incremental sector mitigation to each of 5 SDGs

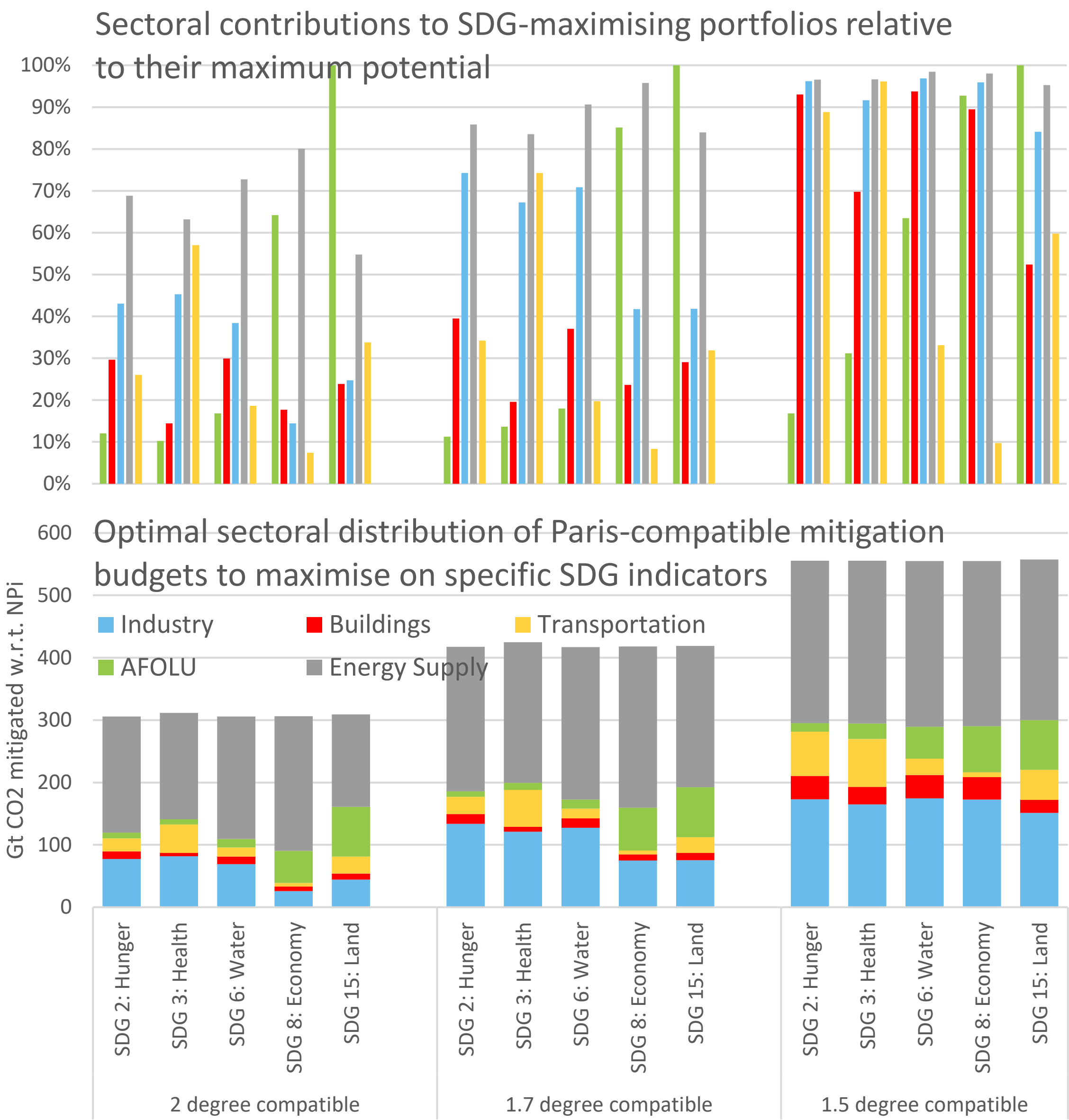

Figure 3: For top 10% best performing portfolios for each SDG, the sectoral contribution relative to their maximum mitigation potential (2.0, 1.7, and 1.5ºC compatibility) (upper graph) and the average sectoral portfolio of mitigation efforts (lower graph).

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