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Climate crisis and sustainability – the impact of climate change on SDG indicators in Germany

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Table of Contents

Abstract

Climate crisis and sustainability – the impact of climate change on SDG indicators in Germany

The impacts of climate change and extreme weather events are becoming more and more evident in Europe and warming is occurring much faster than previously thought. Despite the necessary mitigation and decarbonisation efforts, the global warming that has already started and the associated climate change will inevitably lead to more extreme weather events and climate damages. The assessment of damages from climate change is mainly based on GDP losses. By focusing on GDP as the central indicator, other sustainability aspects are ignored.

The aim of this study is to take a broader view of the impact of climate change on society and the economy and therefore to look at other sustainability indicators in addition to GDP.

The impact of climate change on the German economy was determined using a model-based scenario analysis. Key climate impacts were translated into monetary values and the economic consequences were estimated using the national macroeconomic input-output model INFORGE. The impact of climate change was caclucalted as losses in GDP and supplemented by changes in the UN Sustainable Development Goals (SDGs).

The results show that climate change has a clear negative impact on economic development: price-adjusted GDP losses will total €660 billion by 2050. At the same time, the effects of climate change also have a negative impact on the SDGs. SDG2 Zero Hunger in particular is worsening due to rising food prices. Overall, it is becoming apparent that considering the climate costs in relation to sustainability goals highlights other important issues that would otherwise be overlooked.

3 Introduction

Climate change impacts are already evident today and are expected to intensify in the future (IPCC 2023). Especially in Europe warming is occurring twice as fast as the global average, so that Europe is becoming the fastest-warming continent on Earth (C3S and WMO 2025). The associated climate change will inevitably lead to more extreme weather events and climate damages. The increasing frequency and intensity of extreme weather events, such as floods, droughts, and heatwaves, pose significant challenges to societies and economies worldwide (Joint Research Centre 2020).

Assessments of climate change damage often focus on GDP or aggregate welfare losses using integrated assessment models (IAMs) such as the well-known DICE model developed by William Nordhaus. Using GDP as the central indicator at the aggregate level ignores other relevant aspects such as inequality. This has led to growing criticism of IAMs and the underlying equilibrium theory, as they cannot adequately represent the complexity of climate change (Keen 2020; Roos and Hoffart 2021; Rising et al. 2022). Climate change not only has negative effects on infrastructure and economic growth, but also carries the risk of exacerbating conflicts and tensions worldwide, which can increase inequality within a society and weaken its resilience (Gomolka et al. 2025).

Recent research has highlighted that climate change affects not only economic growth but also sustainable development more broadly. The IPCC (2018) concludes that climate change severely hinders achieving sustainability goals and reducing inequality. This is particularly evident in the impacts on various UN Sustainable Development Goals (SDGs), including SDG 1 (No Poverty), SDG 2 (Zero Hunger), and SDG 10 (Reduced Inequalities) (Fuso Nerini et al. 2019).

Recent empirical evidence from Germany shows that rising food prices already affect about 28% of consumers significantly, with lower-income households showing particularly strong engagement in saving behaviors and reduced food expenditure (Hempel 2024).

For Germany specifically, a number of recent studies examine the effects of climate change on the economy (Peter et al. 2021; Philip et al. 2021; Flaute et al. 2022; Lutz et al. 2025). These analyses primarily concentrate on GDP losses, structural changes and the effect on economic activities, leaving gaps in understanding the broader societal impacts. Additional assessments at the European level provide some insights through downscaled results to country level (Joint Research Centre 2020; COACCH 2021), but a comprehensive analysis of climate change impacts beyond GDP for Germany is still lacking.

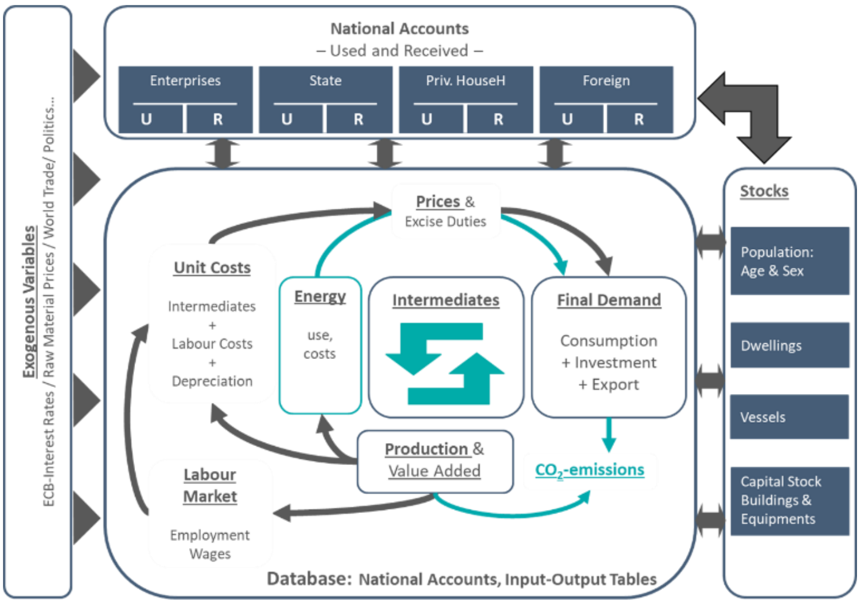
This paper provides an update to the analysis conducted by Reuschel and Stöver (2023). While the methodological framework, consisting of a scenario analysis using the INFORGE model (Becker et al. 2022), was retained, the economic data, conditions and foreseeable influencing factors were updated. The costs of climate change were evaluated in relation to GDP and the SDGs. This allows us to gain a more comprehensive understanding of the impact of climate change on both the economic and social dimensions in Germany.

The paper is structured as follows: The next section provides a methodological overview. In section 3, we describe the results, which are discussed in section 4. Section 5 concludes the paper.

4 Method

The costs of climate change were estimated using a scenario-analysis based on the macroeconometric model INFORGE. The model is designed for assessments of economic, energy, climate and environmental policies with a time horizon up to 2050. It follows the INFORUM philosophy (Almon 1991) of building bottom-up and fully integrated econometric input-output models. Like CGE models, it belongs to the group of input-output-based macroeconomic models, in which interactions, indirect effects and other interdependencies are mapped at a high sectoral level of detail (Becker et al. 2022). In contrast to CGE models, INFORGE is not based on neoclassic theory but on approaches from evolutionary economics, explaining developments through estimated equations and parameters based on historical data. As shown in Figure 1, prices are determined considering market imperfections triggered by incomplete competition, partially rigid prices and market dependencies. The production quantity is determined by both supply and demand side impacts, with companies setting prices based on their cost situation and competing import prices (Lehr and Lutz 2020). This triggers demand reactions that in turn determine the production quantity. Technological change is represented through modes of production, labor productivity, and capital intensity. Current technological developments that do not yet have a sufficient temporal foundation are integrated by setting assumptions.

Figure 1: Overview of the design and structure of the model INFORGE / PANTA RHEI



Source: Own illustration, adapted from Becker et al. (2022)

The scenario analysis compares two scenarios: a 'reference' scenario, in which climate change remains at the 2025 level and does not progress further; and a 'climate change' scenario, in which climate change continues to progress and increasingly frequent and intense extreme weather events occur. Based on extreme weather events caused by climate change, the most significant climate impacts for Germany were identified and the resulting direct effects were derived from the literature. The selection of impacts, based on the national Climate Impact and Risk Assessment study (UBA 2021), considered urgency, economic relevance, degree of certainty in projections, and feasibility of monetary valuation. The identified key climate impacts were yield losses in agriculture and forestry, fishing, groundwater level and groundwater quality in water management, navigability of inland waterways during low water levels, damage to buildings and infrastructure caused by heavy rain and flooding, effects on health and the healthcare system. These key climate impacts were translated into economic impacts using impact chains (Fritzsche et al. 2014; Zebisch et al. 2017; Zebisch et al. 2022), focusing on monetisable effects that can be represented in an economic model. These direct climate change costs at the sectoral level trigger further indirect and induced effects in the model through various channels such as production cost structure changes, productivity impacts, final demand adjustments, investment patterns, public expenditure shifts, and export price effects. The impact of climate change are modelled as continuous effects over time. This approach acknowledges that exact timing and location of future extreme weather events cannot be predicted. A detailed description of the scenario structure can be found in Stöver et al. (2025).

Comparing both scenarios we can assess the costs and impacts of climate change for GDP, different economic sectors and economic structures. Additionally, we can calculate selected SDG indicators and hence show the impact of climate change on sustainability. With that, we take a welfare perspective that considers both 'benefits and costs of present activities', going beyond pure GDP measurement.

The selected SDG indicators align with the model's capabilities. The SDG indicators we can compute from the model results are shown in Table 1. They cover aspects of SDG 1 (No Poverty), SDG 2 (Zero Hunger), SDG 3 (Good Health and Well-Being), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation and Infrastructure), and SDG 10 (Reduced Inequalities). The selection of the SDG indicators allows a more comprehensive assessment of climate change impacts on society, addressing both economic and social sustainability aspects.

Table 1: Description of selected SDG-indicators

SDG	Indicator
No Poverty	Poverty-oriented public social expenditure (%)
Zero Hunger	Food prices relative to total inflation
Good Health and Well-Being	Proportion of population with high health care expenditures
Affordable and Clean Energy	Share of renewables in total final energy consumption
Affordable and Clean Energy	Energy intensity (primary energy in relation to GDP)

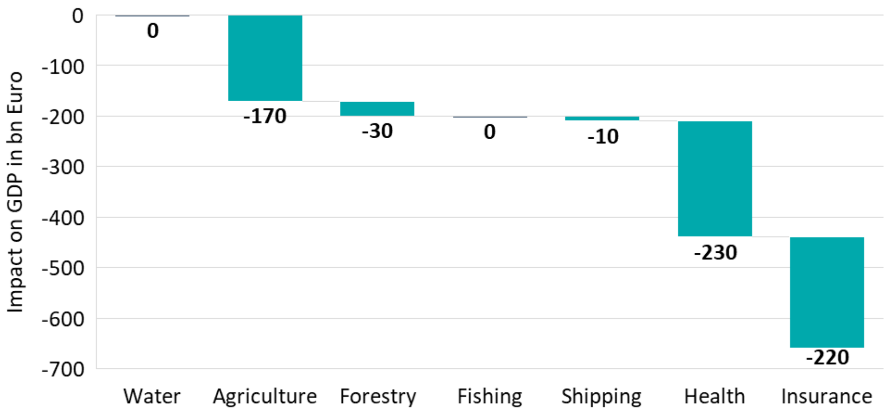
	Decent Work and Economic Growth	Per capita growth rate of real GDP
	Decent Work and Economic Growth	Productivity growth (GDP per employee)
	Industry, Innovation and Infrastructure	Value added of manufacturing in relation to GDP
	Reduced Inequalities	Labour income as a share of GDP

Source: Own elaboration based on https://sdg-indikatoren.de/en/

5 Results

Between 2025 and 2050, climate change is expected to result in a total loss in value added (measured in terms of price-adjusted GDP) of around €660 billion. As Figure 1 shows, the greatest losses will be incurred in the areas health, insurance and agriculture.

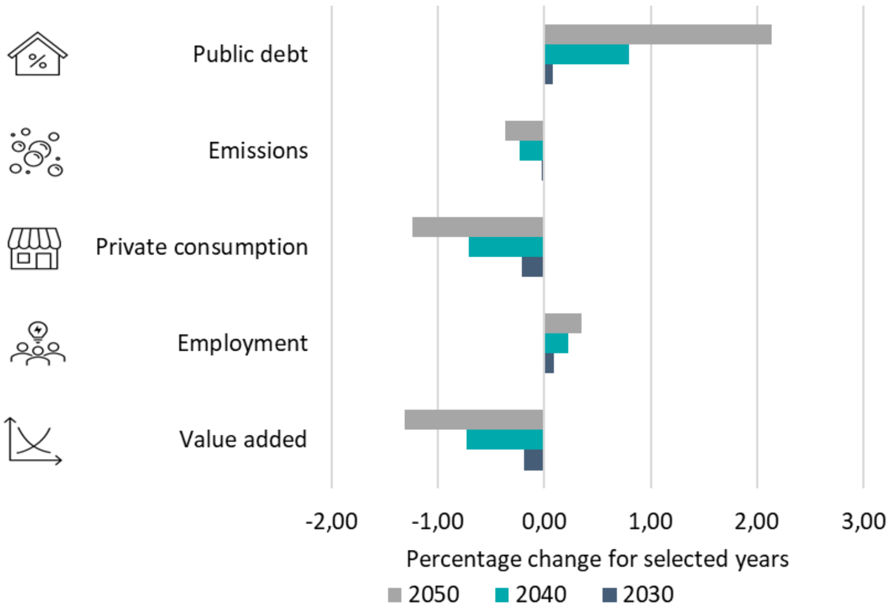
Figure 1: Accumulated losses of climate change in real GDP



Source: Scenario analysis with INFORGE.

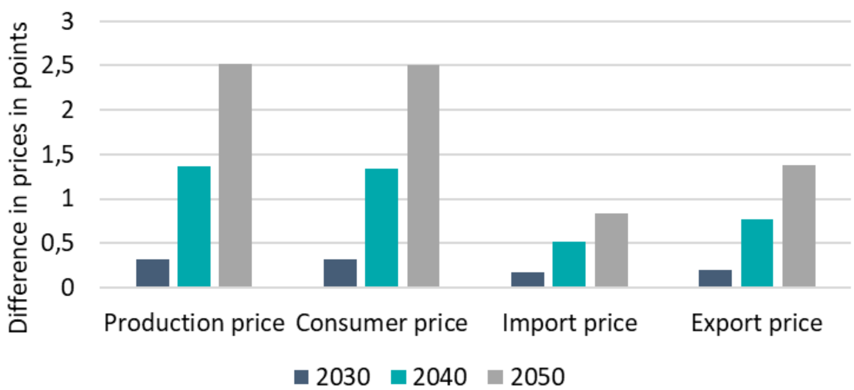
Focusing on the economic consequences of climate change in specific areas reveals that private consumption is considerably lower. In 2050 private households consume 1.2% less than without climate change (Figure 2). One reason for this is a lower propensity to consume caused by inflationary pressure, which is triggered in various production sectors, particularly agriculture. Wherever possible, higher production costs are passed on and ultimately manifest themselves in higher consumer prices. As a result, the consumer price index in 2050 will be 2.5 points higher than it would be without advancing climate change (Figure 3).

Figure 2: Impact of climate change on different economic sectors



Source: Scenario analysis with INFORGE.

Figure 3: Climate change impacts on price indices



Source: Scenario analysis with INFORGE.

These structural changes and shifts, which are below the aggregate level of GDP, suggests that sustainability will also be affected by climate change.

Table 1 shows, in column 2, the future development of sustainability goals that would result without advancing climate change. Column 3 shows the impact of climate change. Even without advancing climate change, some goals in Germany are not developing positively. This is the case for SDG1 (no poverty), SDG2 (zero hunger), and SDG3 (good health and wellbeing): Poverty-oriented social welfare benefits are increasing, food prices are rising faster than inflation, and the proportion of the population with high healthcare costs is growing. Environmental indicators (SDG7) are developing particularly positively, i.e., the contribution of renewables to final energy consumption is increasing and energy intensity is decreasing. The economic indicators (SDG8) as well as SDG9 (industry, innovation, and infrastructure) and SDG10 (reduced inequality) remain relatively unchanged. This unfavorable development of sustainability goals is exacerbated by the effects of climate change. Social spending (SDG1) and food prices (SDG3) are rising even more sharply, energy intensity is higher (SDG8), and the previously neutral development of SDG8 and SDG9 is now trending in a negative direction.

Table 1: Development of SDGs 2025-2050 without advancing climate change and impact of climate change

SDG	Indicator	Change 2025-2050	Climate change impact
1	Poverty-oriented public social expenditure (%)	⬆	+ 1%
2	**Food prices relative to total inflation**	⬆	**+ 5%**
3	Proportion of population with high health care expenditures	⬈	--
7	Share of renewables in total final energy consumption	⬆	--
7	Energy intensity (primary energy in relation to GDP)	⬊	+ 1%
8	Per capita growth rate of real GDP	⇘	- 0,1%-points
8	Productivity growth (GDP per employee)	⇘	- 0,1%-points
9	Value added of manufacturing in relation to GDP	⇨	- 0,1%-points
10	Labour income as a share of GDP	⇨	+0,2%-points

Source: Scenario analysis with INFORGE.

The strongest climate change impact on sustainability is observed in food prices (SDG2), with a 4.6% difference by 2050. In particular because of rising world market prices due to the loss of agricultural yields, food prices rise more sharply than prices overall, leading to a deterioration in the indicator for SDG 2. This finding is supported by Kotz et al. (2024), who found that an increase in the monthly average temperature leads to higher overall inflation, which could amount to an additional 0.8–0.9 percentage points per year by 2035. These model-based findings are supported by recent empirical evidence on consumer responses to rising food prices in Germany. In a survey of 1000 German consumers, Hempel (2024) found that about 28% of respondents were significantly affected by rising food prices, showing strong engagement in saving behaviors and reduced food expenditure. These consumers were characterized by lower incomes, less full-time employment, and higher levels of pessimism about their economic situation. The study demonstrates that price increases disproportionately affect vulnerable groups, potentially exacerbating existing socioeconomic inequalities. This aligns with our model predictions about the distributional effects of climate-induced price changes.

The variations across different SDGs demonstrate the multifaceted nature of climate impacts identified by UBA (2021) in their Climate Impact and Risk Assessment study. The results particularly align with Joint Research Centre (2020) findings regarding the complex interplay between direct climate impacts and indirect socioeconomic effects. As noted by Philip et al. (2021), even conservative estimates indicate substantial economic costs, with our analysis showing these effects extend into social dimensions.

6 Discussion

Our findings show that the socioeconomic impacts of climate change can be significant and go far beyond traditional GDP indicators. Furthermore, the observed developments in SDG indicators reveal complex interactions between climate change and sustainable development in Germany. The approach thus helps to go beyond traditional GDP-oriented analyses and broaden the perspective to include additional aspects of climate change impacts and costs.

Nevertheless, this approach has some weaknesses and disadvantages. Scenario analysis and economic modelling can only take into account variables that can be expressed in economic or quantitative terms. This applies both to the costs of climate change and to the selection and presentation of SDG indicators. The results therefore most likely represent only a lower limit, as several climate impacts cannot (yet) be sufficiently quantified and taken into account in the SDGs. The fact that only monetisable impacts of climate change can be considered in the model means that costs arising, for example, from a deterioration in quality of life or social cohesion are neglected. The results should therefore be regarded as an initial rather than a comprehensive assessment.

Furthermore, the scenario analysis is based on several kinds of uncertainties. First, there are uncertainties regarding the development of climate change and the intensity and frequency of extreme weather events. Second, it remains uncertain where and when climate change-induced effects occur. However, the specific occurrence is decisive for the extent of the damages. While price-related events tend to occur over larger areas, social impacts are usually highly localized. Third, depending on the climate impact, there are more or less pronounced uncertainties regarding the specific impacts on systems and groups, as well as regarding the interactions between climate impacts and the respective responses to them. Fourth, the development of inequality is uncertain, but structural changes in income distribution can significantly affect the magnitude of the results. Fifth, uncertainties regarding the quantification of social impacts remain. Even if there are qualitative descriptions of impact chains and interrelations, the quantification in socioeconomic terms is associated with assumptions.

Finally, while our model is well suited for analyzing national costs of climate change, global effects via trade might not be sufficiently considered. Rather, the effects of climate change on international relations were included using assumptions regarding price and distribution effects. For a more in-depth analysis, it would be appropriate to extend the modelling approach by combining it with global social accounting models.

7 Conclusion

This study demonstrates that climate change poses a significant threat to both the economic prosperity and sustainable development of Germany. Through a comprehensive scenario analysis utilizing the INFORGE model, we project substantial GDP losses of €660 billion by 2050. However, framing climate change solely as an economic issue, measured by GDP, provides an incomplete picture. Our analysis, critically, extends beyond this conventional metric to reveal the detrimental impacts on several UN Sustainable Development Goals. Specifically, we found that rising food prices, driven by climate-induced agricultural losses, will disproportionately impact vulnerable populations and significantly worsen progress towards SDG 2 (Zero Hunger). This finding aligns with recent empirical evidence demonstrating increased financial strain on German consumers and highlights the potential for exacerbated socio-economic inequalities. The results underscore the importance of a holistic assessment of climate change costs, one that considers the complex interplay between economic damages and broader societal well-being. By integrating SDG indicators into our analysis, we identified cascading effects impacting areas like poverty (SDG 1), health (SDG 3), whereas the share of renewable energy (SDG 7) is increasing.

While our study represents a significant step towards a more comprehensive understanding, it is important to acknowledge inherent limitations. The necessary reliance on quantifiable data and economic modelling means that certain qualitative impacts, such as diminished quality of life or eroded social cohesion, remain underrepresented. Furthermore, uncertainties surrounding the future trajectory of climate change, the precise timing and location of extreme events, and the dynamics of global trade introduce unavoidable complexities.

Despite these limitations, the findings presented here reinforce the urgent need for ambitious mitigation and adaptation strategies. Future research should focus on refining modelling approaches to incorporate a wider range of non-monetizable impacts, exploring the complex interactions between climate change and international relations through integrated global modelling frameworks, and continually updating assessments with the latest climate science and socio-economic data. Ultimately, a truly sustainable response to the climate crisis requires a paradigm shift – one that prioritizes not just economic growth, but also equitable and resilient societies capable of thriving in a changing world.

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