

Evaluating the Potential and Risks of Carbon Dioxide Removal (CDR) and Storage (CCS) Strategies in Global Climate Mitigation: An Integrated Assessment Modeling Approach

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DIRECT AIR CARBON CAPTURE (DACC)



END-OF-PIPE CARBON CAPTURE (CC)

Objective

This study aims to model a range of carbon dioxide removal (CDR) and carbon capture and storage (CCS) methods within the IAM FRIDA as global-scale climate mitigation strategies. The analysis assesses the mitigation potential of CDR technologies under different climate scenarios and examines the role of bioenergy with carbon capture and storage (BECCS) as a negative emissions technology. Shares for the years 2030, 2050 and 2100 were derived from projections reported by the International Energy Agency about CCUS.

Introduction

FRIDA is a feedback-intensive IAM built to map the co-evolution of human and natural systems. Its latest iteration, FRIDA v2.1 (Schoenberg et al., 2025), establishes bi-directional links between socioeconomic drivers such as demographics, energy and human behaviour, and biophysical climate shifts, effectively closing the loop between human activity and Earth system processes.

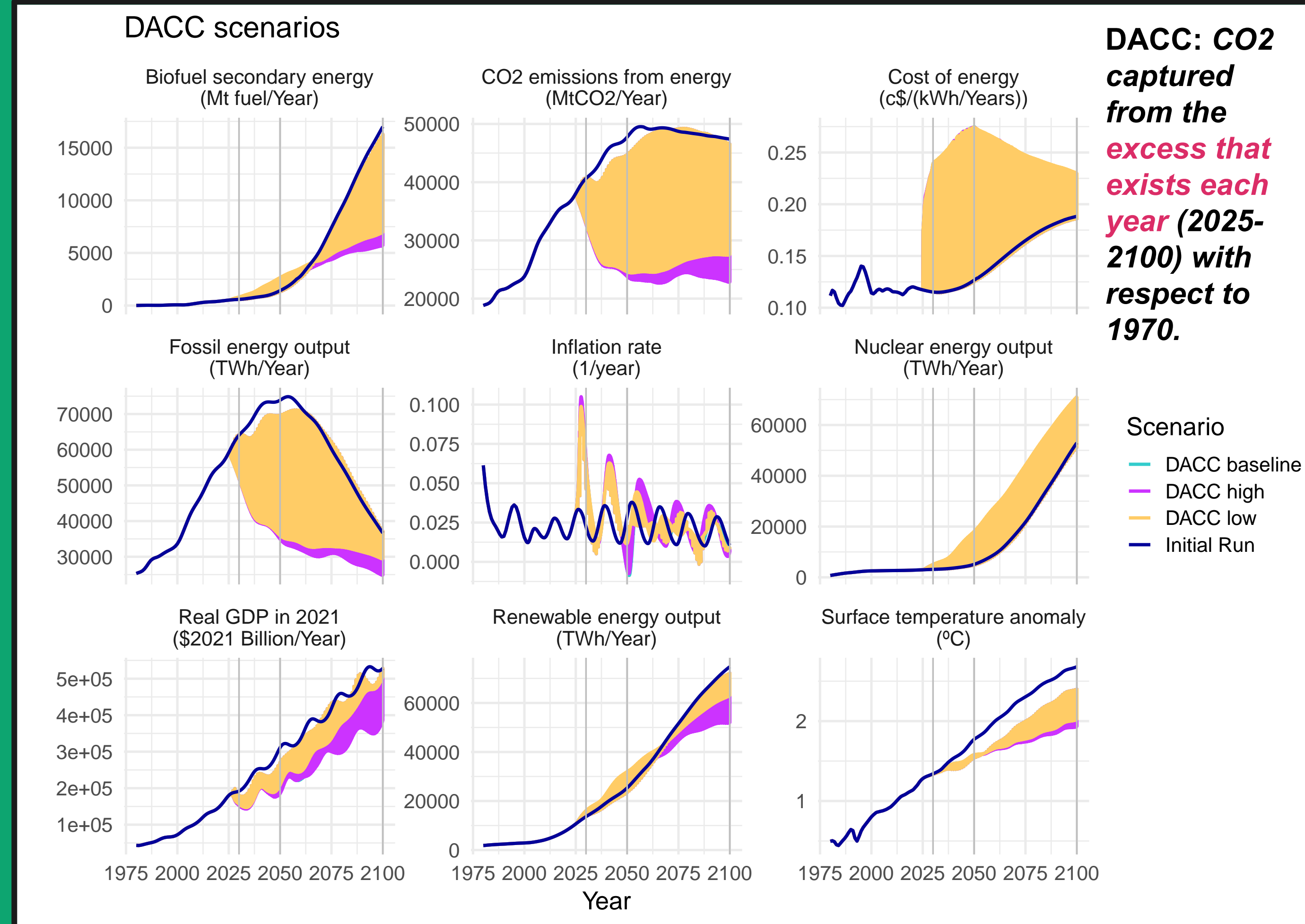


Figure 2. Projections of biofuel, nuclear, fossil and renewable energy production, CO2 emissions from energy, land use for crops, Real GDP in reference to the year 2021, and surface temperature anomaly for a low, baseline and high development scenarios of DACC.

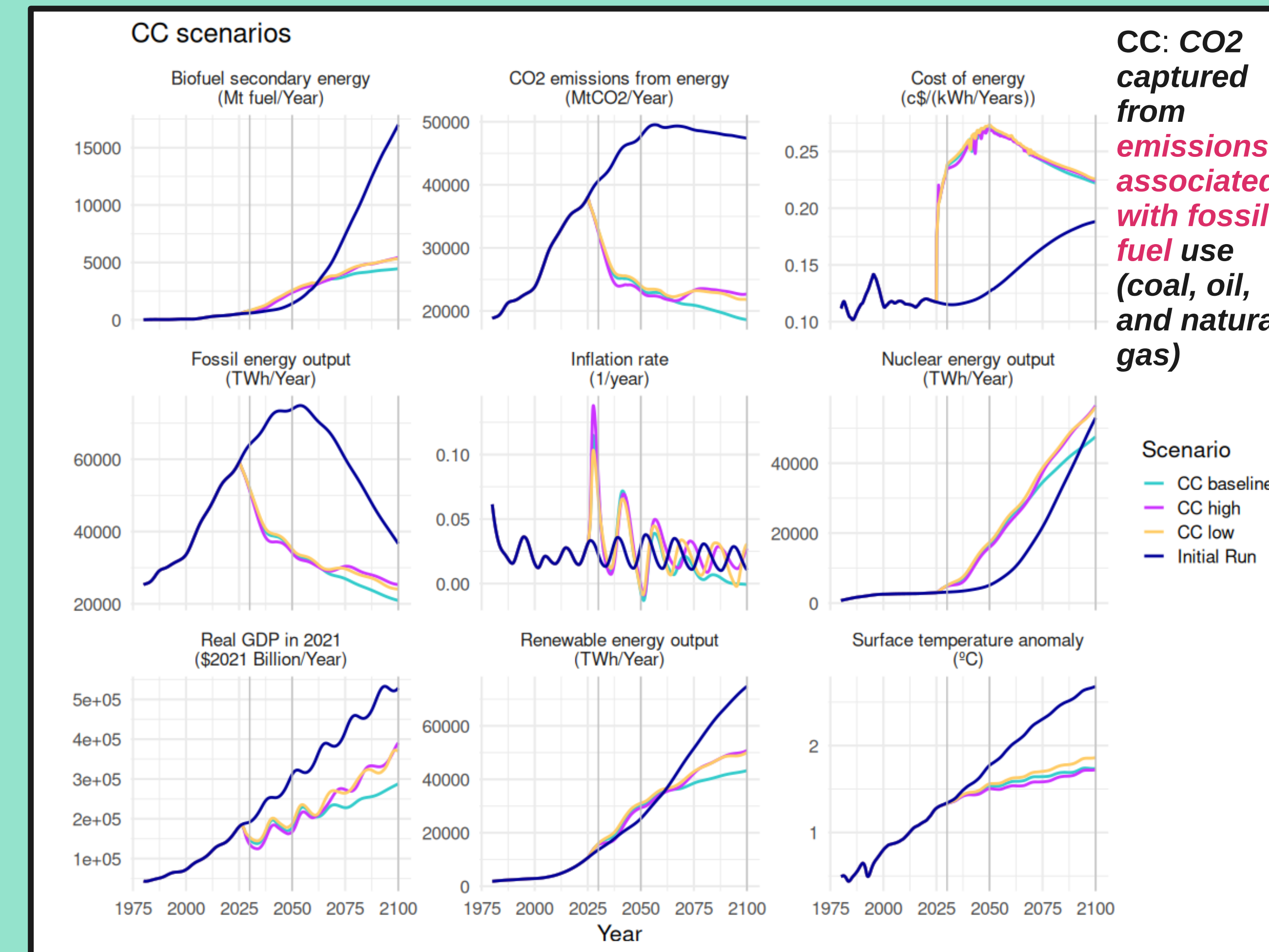


Figure 3. Projections of biofuel, nuclear, fossil and renewable energy production, CO2 emissions from energy, inflation rate, Real GDP in reference to the year 2021, and surface temperature anomaly for a low, baseline and high development scenarios of carbon capture.



BIOENERGY WITH CARBON CAPTURE (BECC)

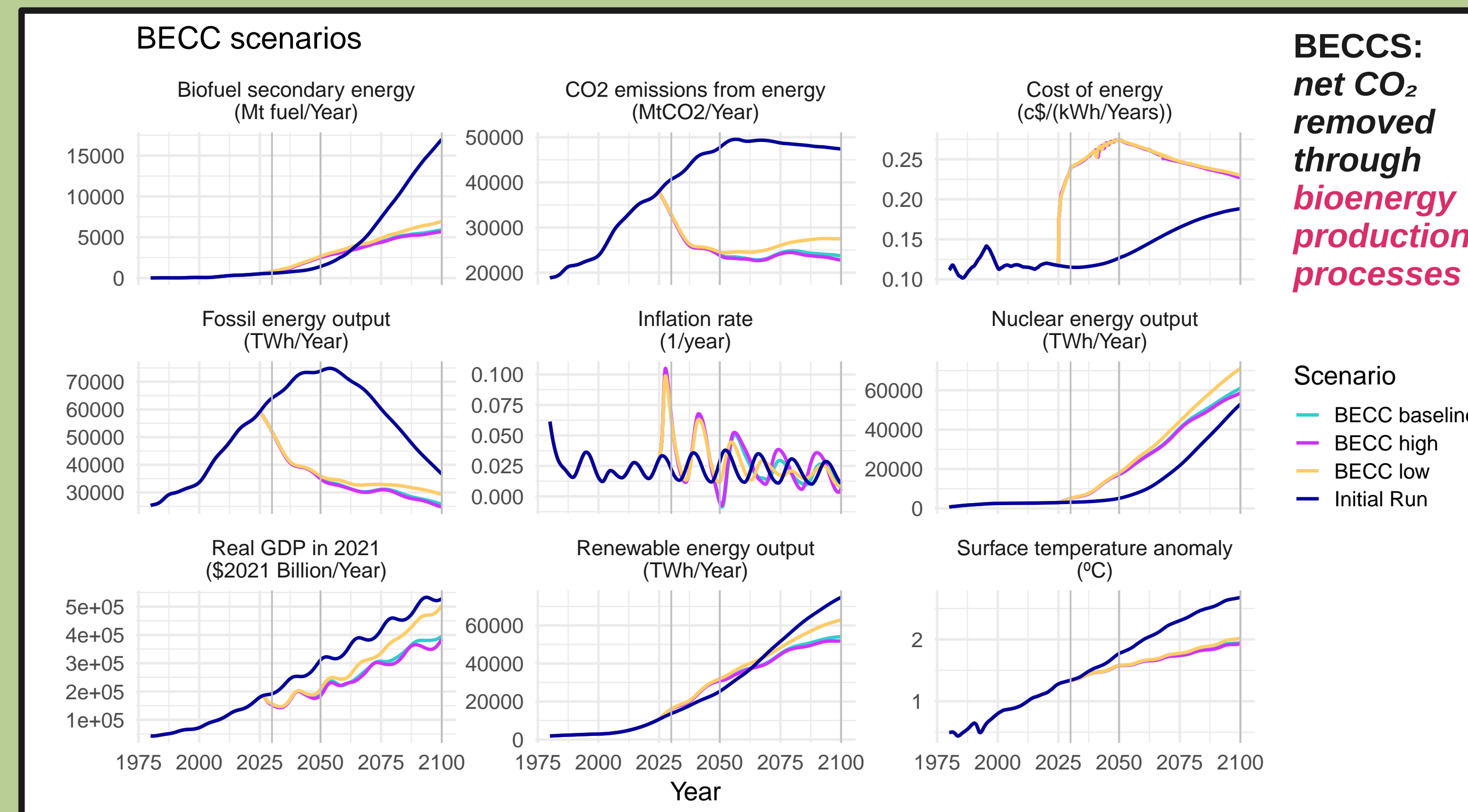


Figure 4. Projections of biofuel, nuclear, fossil and renewable energy production, CO2 emissions from energy, land use for crops, Real GDP in reference to the year 2021, and surface temperature anomaly for a low, baseline and high development scenarios of BECCs.

Conclusions

Climate Goal: Thermal stabilization < 2°C achieved through direct CO2 removal.
Structural Change: Accelerated replacement of fossil fuels with a marked increase in nuclear power production. The deployment of BECCS boosts the production of biofuels and renewable energy
Economic Cost: Achieving a substantial reduction in emissions from 2040 onward and limiting global warming to 2°C by 2100 is associated with a corresponding rise in inflation. This reflects a trade-off between deep decarbonization and long-term price stability. Overall, the structural transition has a moderate impact, leading to a slight decline in GDP and increased inflationary pressure compared to the inaction scenario (Initial Run).

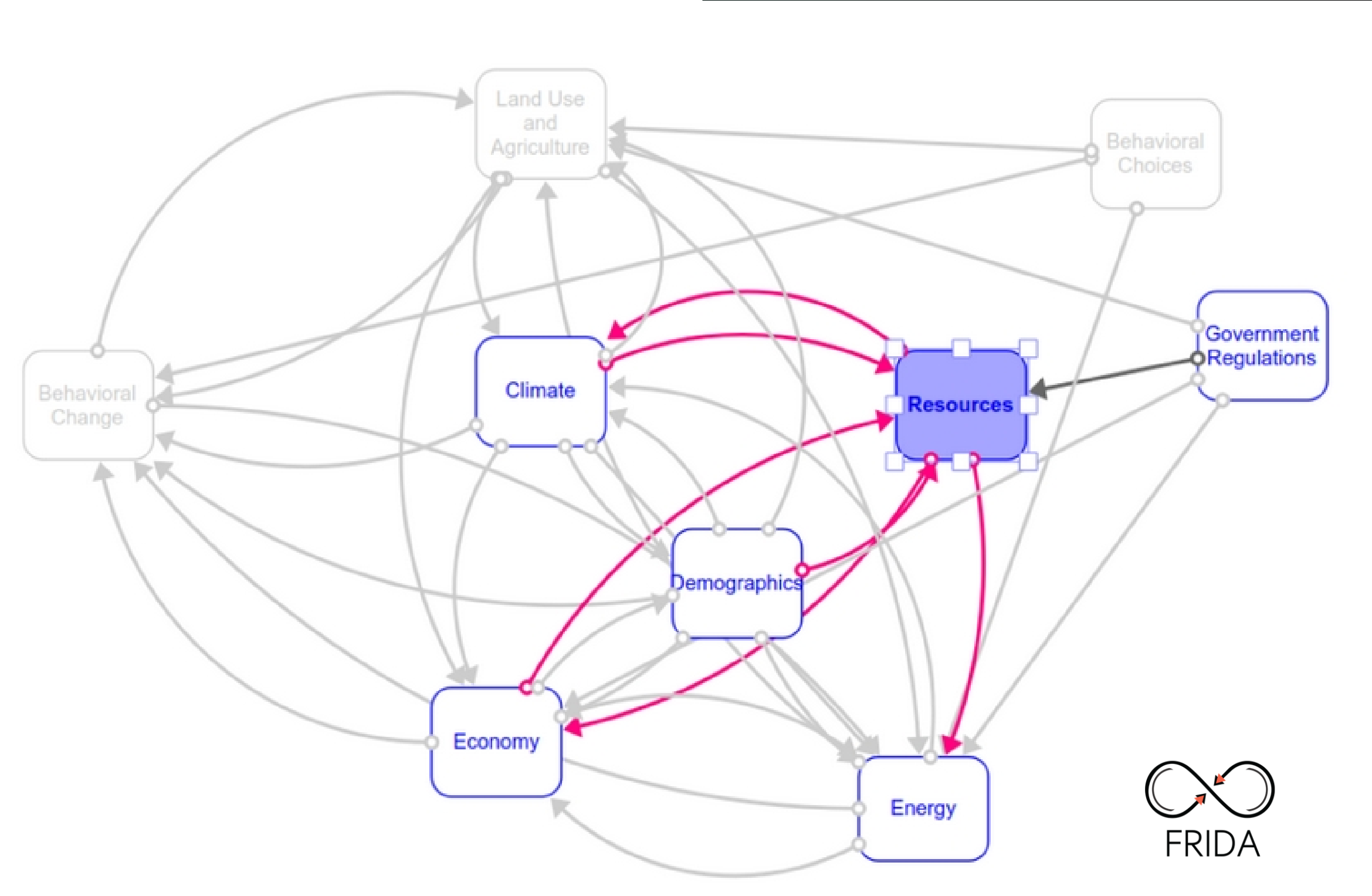


Figure 1: The modules making up FRIDA's representation of CDR/CCS Resources. The causes and impacts are highlighted in red.