Achieving sustainable development in Eastern Africa: a portfolio-based integrated assessment modelling analysis among different Shared Socioeconomic Pathways

Akaterini Forouli 1, Alexandros Nikas 1, Dirk-Jan Van de Ven 2, Jon Sampedro 2, Haris Doukas 1

1 Decision Support Systems Laboratory, School of Electrical and Computer Engineering, National Technical University of Athens, Iroon Politis 9, 157 80, Athens, Greece
2 Basque Centre for Climate Change, Edificio Sede 1-1, Parque Científico de UPV/EHU, 48940, Leioa, Spain

Introduction
We introduce a two-level integration of integrated assessment modelling and portfolio analysis in order to simulate the technological evolution of climate policies with implications for multiple Sustainable Development Goals (SDGs), across different socioeconomic trajectories and considering different levels of uncertainty.

Materials and Methods
**GCAM**
- the Global Change Assessment Model (GCAM), we simulated for Eastern Africa the following scenarios for 2020, 2030, 2040:
  - Three Shared Socioeconomic Pathways (SSPs)
    - SSP 2 ("Middle of the Road")
    - SSP 3 ("Regional Reality")
    - SSP 5 ("Tack-Sustainable Development")
- Six Technological Pathways:
  - Liquidated Petroleum Gas (LP), photovoltaics (PV), Biogas, Ethanol, Charcoal, and Fuelwood
- Two land policy pathways:
  - A baseline without options to increase sustainable forest output and
  - A land policy that assumes policy actions focused on increasing sustainable forest supply.

First GCAM – PA link
The GCAM outputs translating into progress parameters relevant to different SDGs, are fed into a portfolio analysis (PA) model.

Portfolio Analysis
Indicators relevant to the three SDGs constitute the evaluation criteria of the PA model:
- Maximisation of GHG emission reductions
- Maximisation of energy access increase
- Maximisation of avoided premature deaths

The alternative options are the six technological pathways.
The PA model is examined under two different budget constraints: a strict one with a low budget, and a higher one.

Uncertainty
Deterministic uncertainty: The resulting optimal portfolios are compared across the policy and SSP evaluation.
Stochastic uncertainty: Incorporate into the model by running a Monte Carlo simulation.
- A mean socioeconomic scenario is also introduced and stress-tested against uncertainty in terms of an SSP robustness score.

Second link PA-GCAM
The portfolio analysis results are fed back into GCAM, to verify if the mean scenario (mid-SSP) portfolios lead to more robust solutions.

Results
Comparison among SDGs
- Differences on the technological performances among the SSPs are mainly observed in SSP 5 for the years 2030 and 2040:
  - In the baseline scenario:
    - SSP 5 can prove more progressive-friendly in achieving the three SDGs in the short term.
    - In the medium- and long-term, SSP 1 leads to better results for the energy access and health criteria.
  - In the land policy scenario:
    - The energy access and premature mortality levels are higher for SSP 3
    - SSP 2 outperforms the other pathways in reducing GHG emissions
  - SSP 5 preserves the lowest contribution to the optimisation objectives in both the baseline and the land policy scenario.

Mean socioeconomic scenario

Figure 5: Technology subsidy portfolios for a "low" budget that are Pareto-optimal in terms of simultaneously avoiding GHG emissions, premature deaths and improving energy access for the land policy scenarios in 2030 and 2040. Size of dots illustrates robustness against stochastic modelling parameters uncertainty.

Notes
- Results for 2020, 2030 and 2040 come from the same scenarios in GCAM, just at another time point. Therefore, subsidies applied in 2020 might somewhat affect the outcomes in 2030, for example in the case of subsidising PV systems which have a lifespan of 30 years (although costs and thus subsidies are annualised).
- We also see a temporal correlation effect with forest revegetation by subsidizing technologies that avoid the use of fuelwood or by applying a land policy in 2030, the available "unsustainable fuelwood" resources in 2040 increase, as this is seen an exhaustible stock—everything not consumed in one year is available to consume in a later year.
- This is specifically the reason why the results in the baseline scenario are worse in 2040 as fuelwood is getting scarce, consumers will switch to other (and usually cheaper) alternatives, even without subsidies. Therefore, the impact of subsidies is lower, as they essentially represent a "waste" of money on subsidising for example LPG, while many households would have been using LPG anyway (but now it is simply cheaper for them).

Acknowledgement
This work was supported by the H2020 European Commission Project "PARIS REINFORCE" under grant agreement no. 838646. The sole responsibility for the content of this paper lies with the authors; the paper does not necessarily reflect the opinions of the European Commission.

Table 1: Total impact and contributions per technology for robust Pareto optimal subsidy portfolios in the "mid-SSP" model.

Table 2: Decrease in CO2 output ranges between SSPs for each of the three SDGs and policy scenarios in the "low" budget case when selecting a portfolio of higher robustness score.

**Acknowledgement**
This work was supported by the H2020 European Commission Project “PARIS REINFORCE” under grant agreement No 838646. The sole responsibility for the content of this paper lies with the authors; the paper does not necessarily reflect the opinions of the European Commission.

**Table 1: Total impact and contributions per technology for robust Pareto optimal subsidy portfolios in the “mid-SSP” model.**

**Table 2: Decrease in CO2 output ranges between SSPs for each of the three SDGs and policy scenarios in the “low” budget case when selecting a portfolio of higher robustness score.**

**Notes**
- Results for 2020, 2030 and 2040 come from the same scenarios in GCAM, just at another time point. Therefore, subsidies applied in 2020 might somewhat affect the outcomes in 2030, for example in the case of subsidising PV systems which have a lifespan of 30 years (although costs and thus subsidies are annualised).
- We also see a temporal correlation effect with forest revegetation by subsidizing technologies that avoid the use of fuelwood or by applying a land policy in 2030, the available “unsustainable fuelwood” resources in 2040 increase, as this is seen an exhaustible stock—everything not consumed in one year is available to consume in a later year.
- This is specifically the reason why the results in the baseline scenario are worse in 2040 as fuelwood is getting scarce, consumers will switch to other (and usually cheaper) alternatives, even without subsidies. Therefore, the impact of subsidies is lower, as they essentially represent a “waste” of money on subsidising for example LPG, while many households would have been using LPG anyway (but now it is simply cheaper for them).