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Analysing the Trade-offs between Mitigation and Development Objectives for South Africa using a Linked Modelling Framework

Bruno Merven[1], Faaiqa Hartley[1*], Sherman Robinson[2], and Channing Arndt[2]

Key Messages

- A hard-linked energy-economic model is developed to identify energy abatement options and simultaneously assess the impacts on economic development.
- Substantial emissions reduction occurs under least-cost optimization without environmental constraints. By 2050, renewable energy accounts for 80% of total power generation.
- Further abatement implies costs, but available improvements in energy efficiency assist in reducing these costs.

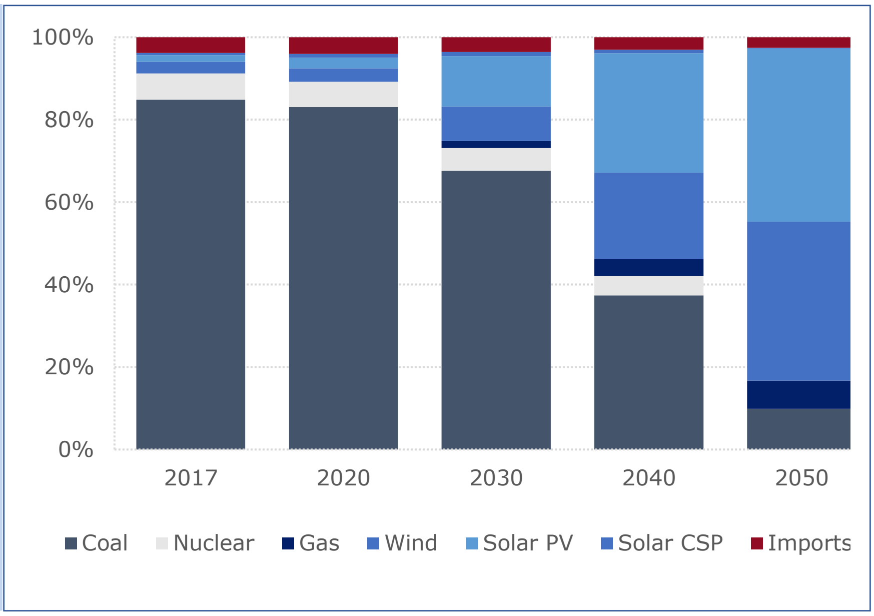

Figure 1: Least-cost power generation mix for South Africa (UE scenario)

Introduction

The Paris Agreement calls for reductions in global emissions to reach a well below 2-degree climate future. To assess options for South Africa, we deploy a detailed analytical framework that includes all major energy consuming sectors and provides a complete picture of abatement options and costs to reduce greenhouse gas emissions related to energy use while, simultaneously and consistently, assessing economic and developmental impacts.

In South Africa, a historically coal dependent country, new technologies [1] and ageing coal capacity imply that large declines in emissions from the power sector are fully compatible with economic development. A clean energy transformation of the power sector should begin now. Environmental concerns and international climate commitments may stimulate further abatement, which comes at a cost. Available improvements in energy efficiency can assist in reducing these costs.

This brief also highlights the value of the linked modelling framework as a promising analytical tool for climate mitigation assessment.

A linked system of energy and economic models

A system of two linked models, one of the energy system and a second of the national economy, is built. The models are hard-linked, as such information exchanges occur automatically within the model runs with information flows both to and from each model. The energy model (SATIM) is a bottom-up integrated energy systems model [2]. The economic simulation model (eSAGE) is a dynamic recursive, economy-wide, multisector, computable general equilibrium (CGE) model [3]. The linked system is called SATIMGE [4].

SATIM is used to compute the least-cost energy technology mix both on the supply (Power and Refineries) and demand side (Industry, Buildings, and Transport) and an associated investment plan given technologies and polices. The technology mix in SATIM is incorporated into the production function of sectors in eSAGE to capture changes in efficiency, fuel mix, and capital and labour use. eSAGE is thus able to assess the impact on the economy considering the technology changes taking place in energy production and use. The updated economic projection from eSAGE is then used to update the projected energy demand in SATIM. The models are run iteratively until convergence is achieved and a consistent and optimal energy path is determined.

Transitioning to clean energy in South Africa

Five scenarios are considered (see **Table 1**). The model is run from 2017 to 2050 and the scenario with unconstrained emissions (UE) is treated as the reference case to which other scenarios are compared.

The energy model finds the least-cost path for a given greenhouse gas emissions constraint. All existing petroleum and power plants are allowed to endogenously retire (based on cost). In capped scenarios, a cumulative CO_2 emissions cap is placed on the energy and industrial processes and product use (IPPU) sectors over the 2020–2050 period.

Scenario	Description
UE	No emissions cap.
9GT	Cumulative 9GT cap on energy and IPPU emissions.
8GT	Cumulative 8GT cap on energy and IPPU emissions.
7GT	Cumulative 7GT cap on energy and IPPU emissions.
7GT+EE	Cumulative 7GT cap on energy and IPPU emissions plus demand side energy efficiency improvements.

Table 1: Modelled scenarios

Unconstrained emissions

Under the UE scenario, energy emissions in South Africa decline over the period, reaching 208 $MtCO_2$-eq by 2050 (486 in 2017). The declining trend is driven by much lower coal use in power generation which is replaced by renewable energy because of lower costs. Under UE, renewable energy accounts for 80% of total power generation while coal only accounts for 10% by 2050 (see **Figure 1**).

Energy sector changes under further abatement

Under constrained energy and IPPU emissions scenarios, emissions in the power sector decrease further as more renewable energy sources replace coal use. Under the 7Gt scenario, renewable energy accounts for 90% of power generation by 2050, with no coal being used. The shift to renewable energy assists in decarbonizing other sectors as the uptake of cleaner technologies increase. As emission caps become more ambitious, earlier and larger clean energy investments are required (the decline in power emissions requires more investment in renewable energy capacity) along with increased mitigation in non-power sectors (see **Figure 2**).

Economic costs of further abatement

Further abatement imposes a cost to the economy as new investment and higher CO_2eq prices are needed. This can be

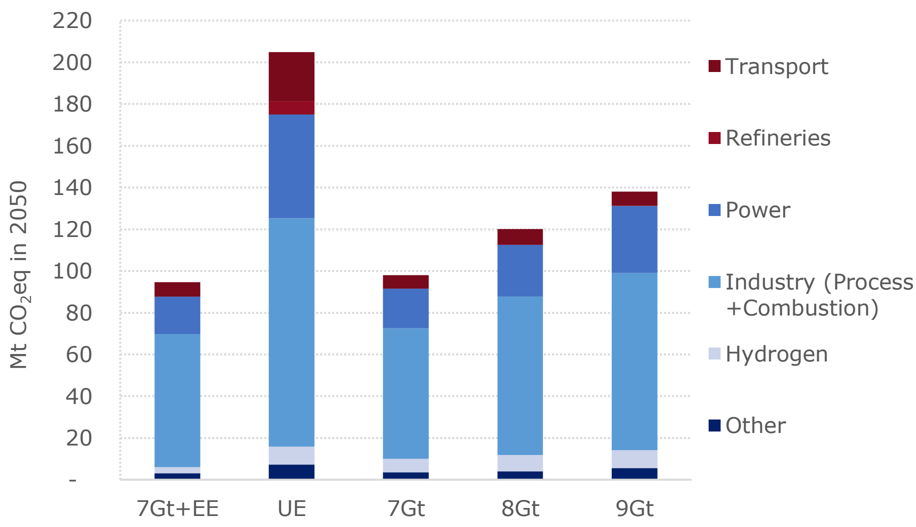

Figure 2: Energy and IPPU emissions by sector, 2050

seen by scenario 9Gt in **Figure 3**, which shows that reducing energy emissions by 67Mt or 32% by 2050 (relative to UE) reduces Gross Value Added (GVA) in 2050 by about 1%. GVA is a key indicator of the state of a nation's economy. Under a 7 Gt cumulative cap, reductions in GVA reach 5% by 2050 (without energy efficiency improvements). The GVA impact is driven largely by the assumption that the savings rate and thus the total amount of capital available to the economy is fixed across scenarios. It is possible that if this constraint were to be relaxed (e.g., with climate finance) that the negative impact on GVA would be lower. This is left for future work.

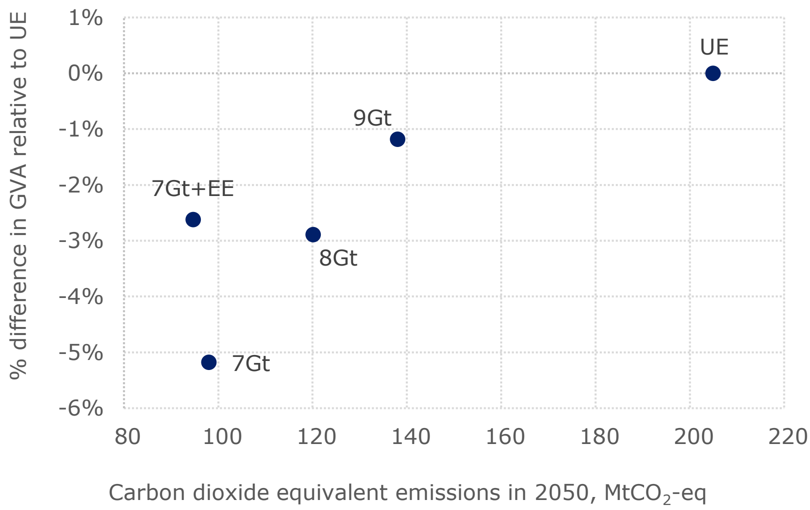

Figure 3: GVA impact and Energy and IPPU emissions by scenario, 2050

Reducing the costs to the economy

Improvements in energy efficiency can reduce the negative impact of increased greenhouse gas mitigation on the economy. This is shown by the GVA improvement between the 7Gt and 7Gt+EE scenarios (Figure 3). Available energy efficiency improvements in the transport, industry, and building sectors (see [5] and [6]) are included in the 7Gt+EE scenario up to 2030 as defined by policy.

Increased energy efficiency reduces energy demand, directly reducing emissions and indirectly reducing the need for new energy investment, lessening the need for the earlier retirement of existing generation assets.

While not modelled in as much detail, development of efficient and low emissions technologies in currently hard to mitigate sectors (see Figure 2) could allow these sectors to emulate the electricity sector.

Recommendations

- A transition to a clean energy economy should begin now, with a focus on the electricity sector. Penetration of renewable energy to up to 80% of power supply by 2050 is fully compatible with economic growth and development objectives.
- Further mitigation efforts, in line with objectives of keeping global temperature rise well below 2 degrees, should be facilitated by measures to enhance energy efficiency to minimize costs to the economy. New, low emissions technologies in currently hard to mitigate sectors are also desirable.
- The linked modelling framework deployed is valuable from analytical, institutional, and political perspectives. Analytically, it provides a much more comprehensive and rigorous empirical analysis than has been possible to date, drawing from the strengths of each model. Institutionally, it permits independent development and maintenance of respective models, greatly facilitating model maintenance and upgrading. Politically, it produces the results demanded by key decision makers. This approach should be replicated in other coal dependent developing countries such as Indonesia and Colombia.

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Notes

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Author Information

Affiliations

[1] Energy Systems Group, University of Cape Town.

[2] Environment and Production Technology Division, International Food Policy Research Institute.

*Corresponding author
Email: faaiqa.hartley@uct.ac.za