**Introduction**

South Africa is one of the most carbon intensive countries in the world. About 78.9% of total emissions are from energy supply and use (DEAT, 2009). These emissions have largely been due to the extensive use of coal in the generation of electricity, as well as the conversion of coal into liquid by Sasol.

The South African government made a voluntary commitment during the 15th Conference of Parties in 2009 to reduce emissions by 34% and 42% below "business as usual" by 2020 and 2030 respectively, provided they receive the necessary international support (DEA, 2010).

There is however limited understanding of the socio-economic implications of carbon taxes, as well as mitigation actions such as the expansion of renewable energy and nuclear.

**Policy questions addressed**

Around 96% of South Africa’s electricity is generated by the state-owned national utility Eskom (Eskom, 2013), which operates 27 power stations with a total nominal capacity of 41.9GW, of which 85% of the capacity is coal-fired. The balance of capacity is provided by nuclear, open-cycle gas turbines, hydro and pumped-storage plants (ESKOM, 2013).

The government developed its 2010 Integrated Resource Plan (IRP) in order to meet South Africa’s future electricity demand by moving towards less carbon intensive generation. The IRP’s stated objectives were to balance the cost solution with other pressing requirements including CO₂ mitigation, local job creation and energy security. The energy supplied by different sources in the IRP is illustrated in Figure 1 below, with the policy-adjusted scenario informed the preferred plan.

**Methodology**

For this study, we build on the previous work started through a collaboration with the ERC and UNU-WIDER on the linking of two models - SATIM (SA TIMES energy model) and e-SAGE (energy extension to SA CGE model). This provides both detail on energy technologies and information on overall economic effects, and thus can give information useful in answering the policy questions. Alternate runs of SATIM and e-SAGE are performed from 2006 to 2040, with the exchange of information about fuel prices, demand, investment (capital growth), and electricity production by technology group and electricity price. Given an initial demand, TIMES computes an investment plan, and a resulting electricity price projection, which is passed onto e-SAGE to see the impact, if any that this new price projection has on the demand and fuel prices, which then go back to TIMES in the next iteration.

As a demonstration of the linked models for the purpose of evaluating mitigation actions, the following scenarios are run:

**A set of TIMES runs without the CGE model**
- A Reference case of the power sector without any mitigations actions
- A CO2 tax runs with a CO2 price trajectory starting at $7 (R48) ton CO2eq (40% of 120) in 2015, increasing to $117 (R723)ton CO2eq in 2025 at a rate of 10% per annum
- A Nuclear Program ramping up from 2023, aiming to reach 20% share of centralized generation by 2030 and 30% in 2040, which approximates the REIPPPP, though an exact replication would need further work.

The same set of runs as above but this time with the linked CGE and TIMES models.

**Results**

Carbon Tax Sensitivities

<table>
<thead>
<tr>
<th>Total GDP</th>
<th>agriculture</th>
<th>industry</th>
<th>services</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Deviation from Reference (Scenario %)</td>
<td>-3.08</td>
<td>-3.52</td>
<td>-3.70</td>
</tr>
</tbody>
</table>

Conclusions and Further Work

Linking the energy model to the economic models helps quantify the socio-economic impacts of energy sector mitigation policies. Preliminary results seem to indicate the costs are not insignificant, however still much work is needed on the models:

- The economic model is struggling to solve past 2025 without imposing a lot of relatively steep electricity, which explains the sudden economic growth recovery and drop in CO2 emissions in the period 2025-2040.
- Once fixed, several further sensitivities are needed around:
  - Growth
  - Recycling options for CO2 taxes
  - Technology and fuel costs

Other aspects that need further model development:

- More coherence between models (discount rates, cost of labour and energy prices)
- Better modelling of the demand side by including the demand side in the energy model.

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