DOES ACCOUNTING FOR INDIRECT EMISSIONS AFFECT ENERGY SYSTEM DECARBONISATION PATHWAYS?

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Abstract

Energy efficiency, electrification and the decarbonisation of electricity are at the forefront of UK and other G20 countries' climate policy: Radical changes to the current energy system will be required in order to meet a challenging commitment to reduce 2050 GHG emissions by 80% compared with a 1990 baseline. Technology explicit energy system models are used in the UK and internationally to define pathways to meeting such low carbon pathways, but these models only account for the emissions associated with energy combustion and do not include emissions arising from infrastructure, manufacturing, construction, land use and transport associated with different low-carbon energy technologies and fuels. We address this shortcoming and for the first time explicitly model the full lifecycle emissions of all energy technologies within an energy system model: We estimate the supply chain emissions across current and future energy technologies for the UK and apply these to the UK MARKAL energy system model. Results demonstrate how the least cost energy mix for the UK up to 2050 changes when all lifecycle emissions are taken into account. We also differentiate between lifecycle emissions produced in the UK and those produced internationally, and thereby measure the carbon leakage associated with different energy system pathways and accounting methods.

(1) Overview

Analytical energy models are widely used to map out ranges of future energy systems which meet carbon reduction targets at least cost. MARKAL (MARKet Allocation) is one such well-established bottom-up, dynamic, linear programming (LP) model for energy systems developed by IEA and ETSAP (Energy Technology Systems Analysis Programme)[1]. Bottom-up, technology-oriented models such as MARKAL are designed to consider the energy sector in great detail and minimize the cost of meeting energy service demands, subject to technological and policy constraints. Exogenous inputs to the model include the topology of the energy system in terms of technologies and fuel flows, taxes, emissions limits, energy service demands, technology characteristics and costs. The optimization process selects the optimal energy and technology mix subject to these assumptions and constraints. Energy system models are commonly used to inform policy: The IEA's authoritative Energy Technology Perspectives is underpinned by TIMES, an energy system model in the MARKAL model family, for example, and the UK MARKAL model has underpinned successive UK government policy papers and assessments of national emissions targets (Strachan et. al., 2009).

Energy system models choose least cost fuel and technology pathways for carbon constrained futures on the basis only of the direct emissions as a result of energy combustion. Indirect emissions arising from the infrastructure, manufacturing, construction, land use and transport associated with different energy technologies and fuels are not counted. At the technology level, including only the direct emissions from combustion processes leads to an underestimate of total lifecycle emissions, as renewable energy technologies are not carbon free on a lifecycle basis. Therefore, evidence supporting or hindering alternative energy technologies based only on direct carbon emissions may currently mislead policy decisions (Minx et al., 2009).

Additionally there are global implications when modelling the national energy system. Provision of energy to meet UK demand is a driving force for emissions elsewhere in the world. The UK imports resources and manufactured products from abroad to provide the energy infrastructure and energy supply to domestic industries and households. Under current territorial legislation requirements, the UK is not responsible for emissions released abroad in the extraction, manufacture and transportation of these products. This becomes a particular issue when considering global emissions and carbon leakage. As the costs for energy intensive products produced in the UK rises due to more stringent environmental legislation, demand may shift abroad to cheaper, less policy ambitious countries.

This research looks at the impact of counting full lifecycle GHG emissions from every energy technology and fuel on energy system scenarios for the UK. Life-cycle emissions have been applied to energy system models already by adding externality costs (see for example Rafaj et al. (2007)); however, it is our understanding that the inclusion of indirect emissions is unique. By isolating the indirect component we can assess the influence in shaping the national

[1] http://www.iea-etsap.org/web/index.asp

energy system pathways and in particular, how the favoured low carbon technology mix is affected. Additionally, this allows us to explore the UK national energy system within the global context in terms of carbon leakage.

(2) Methods

This research brings together the UK cost-optimisation energy system model MARKAL (Usher et. al., 2012) with life cycle analysis. MARKAL, selected for its energy system completeness, is an established model used in UK climate and energy policy. Life cycle analysis was favoured for the estimation of indirect emissions due to its inclusion of upstream processes. Process-based life-cycle analysis, input-output life-cycle analysis or a combination of the two have been applied to estimating the life-cycle impacts of different energy technologies, including wind, solar, biomass, nuclear, NGCC, IGCC and CCS. Process-based analysis collects data on the direct and indirect energy and material inputs (and the consequent greenhouse gas emissions embodied in these) to each process in the life-cycle of an energy technology, such as raw material extraction, transportation, manufacturing, operation and disposal. Input-output analysis converts monetary flows to physical flows (for example greenhouse gas emissions) between sectors in an economy and uses the composition of purchases for an average economic sector from a country's National Accounts to estimate the environmental impact along the full supply-chain of a product.

For all energy technologies in MARKAL, a domestic and imported value for CO_{2e}/ kWh is obtained. This study uses LCA results from an environmentally extended input–output (EEIO) model which has been used to assess the role of material efficiency measures in reducing UK GHG emissions by 2050 (Barrett & Scott, 2012). Where the EEIO model does not cover a particular energy technology, we obtain lifecycle emissions from the literature. To balance domestic indirect emissions as a result of industrial processes and transport, we identify and remove the activity in those sectors associated with the energy system. This ascribes all GHG emissions as a result of energy demand to the given energy technology and so avoids double counting.

We run the UK MARKAL model to 2050 with the 80% GHG reduction target with the following three scenarios:

i. A Reference scenario, where only direct emissions are counted towards the target
ii. Domestic indirect emissions are also counted as part of the 2050 target
iii. Both domestic and international indirect emissions are counted as part of the 2050 target.

(3) Results

A set of modeling results and resulting policy implications will be presented for each scenario above, and will focus on:

- Cost of achieving the 2050 target;
- Energy mix for each sector;
- In what sectors and fuels are indirect emissions most significant?
- Carbon leakage (international indirect emissions).

(4) Conclusions

The IPCC's latest Special Report on Renewable Energy Sources and Climate Change Mitigation recognises the important contribution life-cycle analysis can play in informing the evidence base for climate change mitigation policy. A key issue explored in this research is how important lifecycle emissions are for the feasibility of stringent emissions targets. A second key issue is in the relative costs imposed on an OECD country like the UK under a fuller emissions accounting. A third key issue is in the robustness of the optimal decarbonisation pathways and results energy mix under full accounting.

References

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