Sustainable Energy Technologies and Assessments 30 (2018) 1–10

Contents lists available at ScienceDirect

Sustainable Energy Technologies and Assessments

journal homepage: www.elsevier.com/locate/seta

A comparative analysis of substituting imported gas and coal for electricity with renewables – An input-output simulation

Mitra Kamidelivand[a,b,*], Caiman Cahill[c], Maria Llop[d], Fionn Rogan[a,b], Brian O'Gallachoir[a,b]

[a] Energy Policy and Modelling Group, MaREI Centre, Environmental Research Institute (ERI), University College Cork, Ireland
[b] School of Engineering, University College Cork, Ireland
[c] International Energy Research Centre (IERC), Cork, Ireland
[d] Universitat Rovira i Virgili and CREIP, Department of Economics, Tarragona, Spain

ARTICLE INFO

Keywords:
Input-output simulations
Disaggregation
Fossil-fuel substitution
Renewable electricity
Net socioeconomic effects

ABSTRACT

For many countries, the leading energy system decarbonisation strategy is to decrease reliance on imported fossil-fuel by developing renewable electricity. This paper offers insights on the net effects of transition to low fossil-based electricity by adapting an input-output (I-O) substitution model. Firstly, it addresses a common challenge with national I-O tables, namely how to isolate figures for inhomogeneous products like 'electricity' and 'gas' aggregated into one sector for a case study of Ireland. Secondly, it applies an extended I-O model to compare the net impacts on energy and non-energy sectors when substituting imported fossil fuels for electricity with renewable resources. Within the framework of the I-O model, for each 1% GHG reduction of the gas substitution scenario, there are increases of 26.2 net jobs and €5.1 m net value-added. These impacts are lower by 73–78% for coal substitution scenarios. Without taking account of the lost jobs and value-added from the economy, the job creations and value-added of renewable electricity would be overestimated by 17%–35% and 25%–50%, respectively. As well as giving insights into the net benefits of renewable electricity, the study provides techniques that could be applied to I-O tables for other jurisdictions to enable improved analysis of energy scenarios.

Introduction

The 2030 agenda for Sustainable Development Goals (SDGs) in the area of energy and climate (i.e., SDG 7 and SDG 13) outlines actions to ensure access to sustainable energy for all members and to combat climate change and its impacts [1]. Supporting renewable energy is associated with key sustainability benefits for the environment, resource sustaining, improvements to the local economy (use of local materials and labour), and energy security (reduced dependency on imported fuel). The latter, particularly, is important in countries that are highly dependent on imported fossil fuels for their electricity generation especially since the price of fossil fuels influences the price of electricity [2].

Given the benefits of renewables, the EU and non-EU countries have set targets to promote renewable energy. To date, most of the achieved gross reduction in CO_2 emissions in Europe has taken place in energy-intensive sectors under the EU Emissions Trading Scheme (ETS) due to increased renewable electricity and reduced reliance on fossil fuels [3]. In late 2016, the Renewable Energy Directive (RED) increased the target share of renewables in final energy consumption of the EU to 27% by 2030 [4]. Despite the benefits of this target, its achievement could be a challenge for some of the member states including Ireland who are even likely to miss their 2020 goals [3]. The target for Ireland is to have 40% of electricity demand from renewable energy [5] by 2030. As present, Ireland has 27% of its electricity demand from renewables, which is over half way to the target. Among European countries, in 2016, Ireland had one the highest overall dependencies for electricity generation on imported fossil fuels at 62%, followed by Greece at 71%, Poland at 84%, Cyprus at 91% and Malta at 92% [6]. This implies that renewable electricity requires more policy supports.

Effective policy making requires a full understanding of the implications of setting such targets on the environment and on the wider economy [7]. Methods need to be developed to assist policy makers to increase that understanding. It requires the integration of all three sustainability dimensions: environment, economy and society [8]. Studies that address this issue in the literature, for instance, do so by adapting a Life-cycle-Assessment and Life-Cycle-Cost (LCA and LCC) approach for power sustainability assessments through scenario

* Corresponding author at: Energy Policy and Modelling Group, MaREI Centre, Environmental Research Institute (ERI), University College Cork, Ireland.
E-mail address: mitra.kamidelivand@ucc.ie (M. Kamidelivand).

https://doi.org/10.1016/j.seta.2018.08.003
Received 7 March 2018; Received in revised form 3 July 2018; Accepted 22 August 2018

analyses, see [9–11] and through multi criteria decision analysis (MCDA), see [12–14], or through an integration of LCA and MCDA, see [8], among others.

In transition to low-carbon energy, an important question is whether decarbonized energy will be sustainable in economy-wide considerations, for instance with respect to net jobs in the economy [15] or GDP creation [16]. A growing body of literature has adapted an input-output (I-O) analysis to examine the socio-economic impacts of a transition to clean energy [15–23]. I-O models which have macroeconomic implications, provide a useful framework for policy and are appropriate for the short-term evaluation of regionally-specific impacts [24].

There are many advantages of I-O models: they have simple assumptions[1], can easily be replicated, use the official national accounts [15], and can be extended to include the physical outputs of the economy such as emissions, pollutions, land-use, energy, and employment [26]. The strength of this approach is that it considers the relationship between sectors, measures the linkage effects [22] and, thus, gives an estimate of the overall economic effect of, for instance, additional investments in renewables [20] or shifting from fossil to renewable electricity [15].

Despite the advantages of I-O models as discussed above, they sometimes fail to address the ecological-economic impacts of energy simulation scenarios for related policy targets. This is because either the energy sectors are aggregated in the original I-O tables or because the sectors for which energy and environmental data is available do not match the economic sectors defined in the I-O tables [26,27]. The electricity sector is one of those sectors that is combined with gas in a single sector in many national published I-O tables.

There have been growing attempt in the recent literature to address this issue. Reference [18] has disaggregated the electricity sector into the subsectors of generation technologies and business services by using the coefficients of a previous I-O table and extra data for the Spanish economy. In an alternative approach to disaggregating the electricity sector, a synthetic industry approach for renewable energy industries is adapted in which the existing data in the U.S. national account is used and a vector of demand for the goods and services making up each synthetic renewable industry is created in the I-O table [15].

The disaggregation of energy sectors can be a challenge in small economies, where disaggregated information is not readily available or cannot be published because of the small number of actors that comprise the disaggregated sectors and the potential breach in confidentiality that publication of such data could cause. Ireland is a typical example of this, where for instance, electricity and gas are aggregated, making it more difficult to apply the national I-O table to studies examining the total impact of energy use on the environment and economy. Understanding the economic impacts of decarbonisation for countries that import renewable energy technology like Ireland is also important. Ireland, like many countries, makes policy decision with a greater emphasis on economic growth than on decarbonisation. This is partly because there is little reference to the evidence of how these two can be linked.

This study contributes to solving this problem and will assist further research by providing disaggregated data. As mentioned earlier, Ireland significantly depends on imported fossil-fuels for electricity generation, and needs this research to understand the implication of substituting renewable for fossil-fuels. In addition to the disaggregation approach by which gas and conventional and renewable electricity are split, an I-O model is developed where the economy-wide impacts of three indicators of energy scenarios are compared. The model compares the relative relationship between GHG emission reductions and changes in employment, as well as value-added of the economy for substituting gas and coal for electricity with renewable sources. As per the authors' knowledge, there is not a similar I-O substitution model in the literature.

The study proposes applicable methods to estimate the disaggregating weighting factors and uses data sources which can be obtained in other countries as well. This will enable other researchers to build appropriate energy related I-O models to provide a better understanding of the regional economy-wide impacts of related energy policies. It can also be expanded to an energy-oriented Social Accounting Matrix (SAM) which is the basis for Computing General Equilibrium models. The rest of this paper presents the data acquisition and I-O substitution model in "Material and methods", discusses the results in "Results and discussion", and concludes in "Conclusion".

Material and methods

The study proposes methods to estimate the weighting factors across the different energy sectors and then applies an extended I-O substitution analysis [28] to compare the effect of two substitution scenarios on selected environmental-economic indicators. A summarized outlook of the model, in Fig. 1, shows the common approach of splitting the I-O elements and the I-O substitution model to compare the sustainability impacts of low-carbon electricity generation scenarios. The approach includes:

i) Disaggregating joint figures for gas and electricity (NACE 35) in the Irish input-output table into gas and electricity separately, and then disaggregating electricity into fossil-electricity and renewable-electricity. Data acquisition and calculations are detailed in "Data construction and disaggregation";
ii) Disaggregating GHG emissions to match the disaggregated sectors above ("Disaggregation of GHG emissions");
iii) Disaggregating employment numbers to match the disaggregated sectors above ("Disaggregation of employment numbers"), and
iv) Conducting an I-O substitution model to compare substituting fixed percentages of imported gas for electricity with renewables (gas scenarios) and substituting fixed percentages of imported coal for electricity with renewables (coal scenarios) ("I-O substitution").

Gas scenarios (1–5) substitute each time 2% of the value of imported gas which was to be used for electricity with renewable electricity at five intervals. The coal scenarios (1–5) are similar to the gas scenarios, but the substitution occurs for imported coal which was to be used for electricity with renewable electricity. The economy-wide sustainability of the developed scenarios is compared for GHG emissions, employment numbers, value-added, and energy imports (Fig. 1). Prior to an I-O analysis of the electricity scenarios, it was necessary to disaggregate gas and electricity sector (NACE-35) in the national I-O table along with the disaggregated GHG emissions and employment numbers of sectors.

The main data sources of the study are collected from the national Central Statistics Office (CSO), the Sustainable Energy Authorities of Ireland (SEAI), the Commission for Regulation of Utilities (CRU), the Environmental Protection Agency (EPA), as well as published papers and literature which are referenced where they appear in the text. The latest I-O table of 2010 (from CSO) is used which contains 58 industry and service sectors, including an aggregated gas and electricity sector (NACE 35). The sectoral environmental GHG emissions are available for 19 sectors (from CSO and EPA) while employment numbers are published for 45 sectors (from the CSO database of Business Demography NACE Rev 2).

Data construction and disaggregation

The disaggregation approach is summarized in Fig. 1. In general,

[1] The assumptions to obtain a high level of aggregation could also be a disadvantage of I-O models [22]. Some further drawbacks of this model are discussed by [25].