



# The critical role of the industrial sector in reaching long-term emission reduction, energy efficiency and renewable targets



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## HIGHLIGHTS

- A new industrial modelling approach in a whole energy systems model is developed.
- The contribution of UK industry to long-term energy policy targets is analysed.
- Emission reductions of up to 77% can be achieved in the UK industry until 2050.
- The UK industry sector is essential for achieving the overall efficiency commitments.
- UK industry can make a moderate contribution to the expansion of renewable energies.

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## ABSTRACT

This paper evaluates the critical contribution of the industry sector to long-term decarbonisation, efficiency and renewable energy policy targets. Its methodological novelty is the incorporation of a process-oriented modelling approach based on a comprehensive technology database for the industry sector in a national energy system model for the UK (UKTM), allowing quantification of the role of both decarbonisation of upstream energy vectors and of mitigation options in the industrial sub-categories. This enhanced model is then applied in a comparative policy scenario analysis that explores various target dimensions on emission mitigation, renewable energy and energy efficiency at both a national and European level. The results show that ambitious emission cuts in the industry sector of up to 77% until 2050 compared to 2010 can be achieved. Moreover, with a reduction in industrial energy demand of up to 31% between 2010 and 2050, the sector is essential for achieving the overall efficiency commitments. The industry sector also makes a moderate contribution to the expansion of renewable energies mostly through the use of biomass for low-temperature heating services. However, additional sub-targets on renewable sources and energy efficiency need to be assessed critically, as they can significantly distort the cost-efficiency of the long-term mitigation pathway.

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## 1. Introduction

In recent years, the number of national greenhouse gas (GHG) emissions mitigation targets and strategies has increased considerably accompanied by a trend to implement these targets through a mix of different, often sector-specific, policy instruments [1]. In addition to limits on GHG emissions, many countries have formulated targets for the use of renewable energies and progress in energy efficiency making the issue of target and policy coordination essential [2]. Within the global effort of keeping the temperature rise below 2 °C, the UK introduced the Climate Change Act in 2008. Through this legally binding framework the UK has

formally committed to a GHG emission reduction of 80% by 2050 compared to the level in 1990 and a portfolio of instruments, including an electricity market reform, energy taxes as well as incentive measures for renewable heat and energy efficiency in buildings has been introduced [3,4].

In many past analyses on the possible pathways to reach these targets, a strong focus has been put on the evaluation of the mitigation potentials on the energy supply side, particularly the decarbonisation of the electricity sector. Demand-side analyses and modelling has generally focused on the more homogenous transport and buildings sectors. Yet, it is essential to consider the industrial sector in its contribution to energy policy goals and its interactions with the rest of the energy system.

At the global level, the industrial sector is responsible for over a third of energy demand and a slightly higher emissions share [5,6].

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In its 5th Assessment Report, the IPCC placed the industrial sector as the most pollutant end-use sector, even before buildings and transport [7]. In the UK, the industrial sector currently accounts for about a quarter of total greenhouse gas emissions (including indirect emissions from electricity use) and almost a fifth of final energy consumption with the most energy-intensive subsectors (iron and steel, cement and other non-metallic minerals, non-ferrous metals, pulp and paper, chemicals) being responsible for more than two thirds of these emissions [8]. In the future, the industry sector will face the dual challenge of implementing low energy and low carbon technologies while simultaneously maintaining international competitiveness. In addition to the national energy and climate policy, the future development of the UK industry sector is also affected by the EU-wide legislation which, in addition to emission reduction, sets explicit targets for the progress in energy efficiency and the use of renewable energies across the whole energy system [9,10].

As discussed in detail in Section 2, assessing the possible contribution of the industry sector to a multi-faceted energy transition poses a considerable challenge given the heterogeneity of the sector in terms of the manufactured products, the production processes and technologies applied, all within a systems context of competing resources and alternate end-use applications of energy vectors. Bottom-up energy system models constitute powerful tools to analyse long-term emission reduction pathways in a systematic manner with the advantages of including a high level of technological detail and taking all interactions within the energy system into account. In this context, detailed modelling of actual production processes and accounting for the substantial differences between industrial subsectors is a bespoke process that can yield fresh insights on the role of the industry sector in the low-carbon transition.

This paper has two primary objectives:

- (1) to present a novel process-oriented modelling approach for the industry sector (the disaggregated hybrid module or DHM), integrating a comprehensive bottom-up technology database into a newly developed national energy system model (UK TIMES Model or UKTM); and
- (2) to assess the UK industry sector's possible long-term contribution to system-wide targets within the scope of a comparative scenario analysis with overlapping policies for decarbonisation, efficiency and renewable energy.

Section 2 provides a review on the current modelling representation of the industry sector in an energy system context. Taking the UK as a modelling and policy exemplar, and after a short description of UKTM, the new methodology for representing the industry sector in a more disaggregated and process-oriented manner is presented in Section 3. Section 4 outlines the overlapping policy analysis and the comparative scenario assumptions. The main results of the scenario analysis, focusing on the industry sector, are outlined in Section 5. The paper concludes with a discussion of findings and policy implications in Section 6.

## 2. Modelling of the industry sector in an energy system context<sup>1</sup>

Since the industry sector is a highly heterogeneous sector in terms of its energy use, modelling the future development of

industrial energy demand as well as policy design is a substantial challenge [17]. Other energy end-use sectors, especially the residential and transport sector are in comparison more homogenous with respect to their energy service demands, such that modelling approaches in whole system models are generally more straightforward (cf. for example [18–20] for the residential sector; and [21–23] for the transport sector).

A variety of recent studies have evaluated the energy savings and emission reduction potentials of different industrial subsectors from a sector-specific perspective (cf. for example [24–30]). These analyses explore the industrial production routes in great detail, but look at the industrial subsectors in isolation. However, in order to evaluate the industry sector's long-term contribution to emission mitigation and other energy policy targets, a more comprehensive modelling approach is required.

On the other hand, bottom-up energy optimisation models which cover the entire energy system have long been applied to determine cost-efficient and consistent long-term pathways for a low-carbon energy transition and to analyse interactions and the competition for resources as well as low-carbon energy vectors in the system. Yet, given the scope and complexity of these models, traditionally a relatively simple modelling approach for the industrial sector based on the different types of energy service or end-use demands has often been chosen (see for example the representation in UK MARKAL [31] or in the global ETSAP-TIAM model [32]).

This approach is generally characterised by the use of abstract process technologies which provide different types of energy services (like low or high temperature heat, motor drive, drying, etc.). That means that instead of representing the actual production steps and specific technologies required to produce a certain final product, the energy service demands and their potential provisions through different fuels are represented in a generic manner (usually using the same cost and technology assumptions for each sub-sector). Each process technology has one specific fuel as input which is used to produce one specific energy service. In a second step, a dummy demand technology (not representing an actual production process) aggregates the various energy service demand categories (usually with fixed shares for each category) in order to produce the final end-use demand (usually specified in units of useful energy). Fig. 1 provides a stylized representation of this approach.

The advantage of modelling by end-use demands is that the sector can be represented through a small number of components, while still allowing for the characterisation of energy uses and cross-sectoral substitutions. This approach is mainly suited to evaluate the potential for fuel switching in the industry sectors. However, several shortcomings need to be taken into account when applying this methodology:

- Given that the actual process technologies in the various industrial subsectors are not explicitly modelled, important technological constraints can often not be accounted for or only approximated with this approach. For example, the use of the electric arc furnace route in steel-making is limited by the availability of metal scrap.
- This also implies that radical technological changes in the production processes, which are especially needed in the case of ambitious emission reduction targets, cannot directly be included in the model approach. This drawback becomes particularly evident when thinking about the specifics of industrial manufacturing technologies with carbon capture and storage (CCS).
- In addition, if the actual process technologies are not modelled, it is difficult to account for process emissions and, more importantly, to include mitigation options for these emissions.

<sup>1</sup> This short review focuses on the representation of the industrial sector in technology-oriented, bottom-up energy system models. There are two additional main thrusts of industrial energy modelling that are important but are not the focus of this paper. Firstly, multi-regional input-output models analysing issues of direct versus indirect emissions and the possible offshoring of energy use and resultant emission leakage (cf. for example [11–13]). Secondly, macroeconomic modelling approaches focusing on the wider macro-economic implications of changed prices in the industrial subsectors and potential restrictions on industrial output (cf. for example [14–16]).

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