Applied Energy 156 (2015) 374–389

Contents lists available at ScienceDirect

Applied Energy

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

Heat recovery using heat pumps in non-energy intensive industry: Are Energy Saving Certificates a solution for the food and drink industry in France?

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HIGHLIGHTS

- First non-energy intensive bottom-up analysis for heat recovery with heat pump.
- Decrease of 12% and 9% of energy consumption and emissions in 2020 compared to 1990.
- Almost 40% additional energy savings could be achieved with incentive policies.
- A drop of 15% of the gas price could stop the heat pump deployment.
- With higher gas prices we could observe heat pump deployment or inter-energy substitutions.

ARTICLE INFO

Article history:
Received 3 February 2015
Received in revised form 25 June 2015
Accepted 15 July 2015

Keywords:
Non-energy intensive industry
Energy Savings Certificate
Heat recovery
Heat pumps
Bottom-up modeling
Food & drink industry

ABSTRACT

Saving energy is crucial for all sectors following the new framework presented by the European Commission to drive continued progress towards a low-carbon economy. Many studies focus on the residential sector, transport and energy-intensive industries, but there is a lack of tools to help decision makers in non-energy intensive industry (NEI). This paper presents the first bottom-up energy model developed for this sector. This prospective modeling enables us to analyze the impact of heat recovery using heat pumps (HP) in industrial processes up to 2020 in the French food and drink industry (F&D), the biggest NEI sector. The technology has high potential in this sector and may be eligible for Energy Saving Certificates. Our model determines the differentiated cost for energy savings in response to incentive policies under the ESC mechanism at a 4-digit level of NACE classification. Sensitivity analyses also show how gas prices and electricity carbon footprints impact on HP penetration. Our study of this particular sector shows that the model could be a useful decision-making tool for assessing potential energy savings and could be extended to other sectors of NEI industry for more efficient subsectoral screening.

1. Introduction

This paper focuses on the analysis of non energy intensive (NEI) industries, where, contrary to Energy Intensive (EI) industries, there is a lack of scientific energy analysis work despite the significant number of publications and books about energy.

A survey of the topic highlights that the share of NEIs has increased in final energy consumption and industrial added value (80% of the industrial added value) [1,2], making them a priority target for energy suppliers in France. Energy suppliers like EDF (Electricité de France) have an obligation to achieve energy savings over a given period in France to avoid penalties according to the Energy Savings Certificates (ESC) or "white certificates" mechanism established by the program law of July 13th 2005, which lays down policy guidelines on energy. Since the ESC cannot be applied to sectors subject to the national quota allocation (PNAQ in French), which are generally EIs, NEIs are expected to be more important in the drop of the industrial energy intensity to avoid double counting with the European Emission Trading Scheme (EU ETS). Thus, the promotion of a bottom-up energy model (technology rich base) for non-energy intensive industries at a very detailed disaggregation (4-digit level of NACE[1] classification) could be a useful decision-making tool for energy operators. The heterogeneity and the disparity of the NEI explained the scarcity

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[1] NACE: Statistical Classification of Economic Activities in the European Community. The 4-digit level is the most disaggregated level.

http://dx.doi.org/10.1016/j.apenergy.2015.07.048
0306-2619/

of models in this group of sectors. Then, the development of this first bottom-up energy model, by using TIMES model (MARKAL family model), will allow assessing the energy efficiency potential of the non-energy intensive industry. In this article, to follow on a previous work on heat recovery by HP [3], we focus on an economic analysis by applying incentive policies to achieve the maximal potential depending on the penalties of the ESC mechanism. This analysis could be helpful for the strategic department of energy operators to know at which level to invest in the industry and promote efficient technologies. Sensitivity analysis will also be done on the impact of gas prices or electricity carbon footprint. So, this paper is broken down as follows: Section 2 succinctly describes, as a reminder to set the context, the structure and some assumptions of the NEI bottom-up model within TIMES with a study case assessment of heat recovery using heat pumps in the food & drink industry up to 2020 [3]; Section 3 is subdivided into two parts, the first of which analyzes the impact on energy savings of incentive policies using ESC mechanisms, and the second providing a sensitivity analysis on the evolution of HP penetration in food & drink, with the natural gas price and the electricity sector's carbon footprint.

2. Methods

2.1. Non-energy intensive "bottom-up" model

We have developed the first bottom-up model for an energy prospective exercise for non-energy intensive industry at the 4-digit level of NACE classification for future energy planning, subject to different constraints (energy price evolution, energy efficiency policies, environmental constraints, etc.) up to 2020 using the TIMES framework [4–15] (Fig. 1). However, contrary to our previous article [3] based on energy prospective with technology spreads; we analyze these results in an economic point of view with incentives for policy makers. This is one of the strength of prospective models based on an optimization paradigm.

TIMES[2] is a "Bottom up" techno-economic model which provides a technology rich basis for estimating energy dynamics over a multi-period time horizon. It is based on a Reference Energy System (RES) which is a network describing the flow of commodities through various and numerous processes. The objective function is the criterion that is minimized by the TIMES model. It represents the total discounted cost of the system over the selected planning horizon. The components of the cost of the system are expressed in each year of the study horizon (and even for some years off horizon) in contrast to the constraints and variables that are related to period. This choice allows a more realistic representation of payments flows performed in the energy system.

Each year, the total cost includes the following elements:

- The investment costs incurred for investing into processes.
- Fixed and variable annual costs.
- Costs incurred for exogenous imports.
- Revenues from exogenous exports.
- Delivery costs for required commodities consumed by processes.
- Taxes and subsidies associated with commodity flows and process activities or investments.

The representation of the technologies calls for precise knowledge of the industrial installations in each sector. The existing and future technologies in the sectors over a given time horizon are considered with techno-economic parameters (capacity, energy intensity, efficiency, availability factor, investment costs, fixed and variable costs, economic and technical life, etc.) and their related strategic orientation parameters (taxes, subsidies, etc.).

In the NEI model, the CO_2 emissions of a fossil fuel f could be also calculated using the following equation

$$Emi_{CO_2}^{f} = EC_f * EF_f$$

where EC_f: the quantity of fossil fuel f consumed by the sources of combustion, EF_f: The emission factor of the fossil fuel f.

The total CO_2 emissions could be deduced from the addition of all fossil fuel emissions. Emission factors (EF) used in this model are the specific emissions given by the ADEME (French Environment and Energy Management Agency) on the verification and quantification of emissions reported under the exchange system quotas of emissions of greenhouse gases in its guide of emission factors [16].

Fossil fuel	EF (tCO_2/MW h)
Coal	0.343
Heavy fuel oil (FOL)	0.282
Light fuel oil (FOD)	0.271
Natural gas	0.206
LPG	0.231

For an impact more adapted to global environmental constraints, CO_2 emissions allocated to the production of electricity have been taken into account in the model in order to observe the impact of the power generation energy mix. In France, according to ADEME/EDF R&D [16], it is estimated at around 55g CO_2/kW h in the industry. These emissions are not added in the global calculation of the emissions from industry, they will only account for the effect of a tax on CO_2.

The RES will allow us to obtain the optimal technology path according to an energy/environmental scenario, such as the potential for industrial energy efficiency and CO_2 emissions reduction in relation to France's commitments to meet the EU climate change targets across sectors, based on least cost criteria. It is a partial equilibrium model because it provides no feedback on sector changes in other economies. However these impacts are of secondary importance in most developed economies like France [17].

Several methods/tools were indeed developed for the energy efficiency of industrial sector. However, these methodologies are done in an isolated depiction of specific processes in a specific industrial manufacture which do not facilitate the implementation of a coherent global frame that takes into account all interactions between the decisions of economic, public and private agents [18]. Moreover, in the case of the NEI industry, it is more relevant to generalize then pass the decision to individuals, in which case this bottom-up model for an energy prospective analysis could provide individual decision-making support. The question is therefore not to "think individually to act globally" but rather to take the initiative "to think globally with a view to acting individually". Then, unlike individualized studies on specific processes in a specific manufacture, it would represent the best way to motivate industrialists with very low energy costs in the case of non-energy intensive industries (one of their principle characteristics) to make energy savings [3].

Furthermore, the methodologies of energy modeling used for energy intensive sectors are not suitable for NEI. The energy description of Energy intensive industry (e.g. Iron and steel, pulp and paper, etc.) is done through the main manufactured product,

[2] The Integrated Markal-Efom System was developed by the Energy Technology Systems Analysis Programme (ETSAP), an implementing agreement under the aegis of the International Energy Agency (IEA), in 1997 as the successor of the former generators MARKAL and EFOM with new features for understanding and greater flexibility.