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Heat recovery with heat pumps in non-energy intensive industry: A detailed bottom-up model analysis in the French food & drink industry

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ABSTRACT

Rising energy prices and environmental impacts inevitably encourage industrials to get involved in promoting energy efficiency and emissions reductions. To achieve this goal, we have developed the first detailed bottom-up energy model for Non-Energy Intensive industry (NEI) to study its global energy efficiency and the potential for CO_2 emissions reduction at a 4-digit level of NACE classification. The latter, which is generally neglected in energy analyses, is expected to play an important role in reducing industry energy intensity in the long term due to its economic and energy significance and relatively high growth rate. In this paper, the modelling of NEI is done by energy end-use owing to the unsuitability of the end-product/process approach used in the Energy Intensive industry modelling. As an example, we analysed the impact of heat recovery with heat pumps (HP) on industrial processes up to 2020 on energy savings and CO_2 emissions reductions in the French food & drink industry (F&D), the biggest NEI sector. The results showed HP could be an excellent and very promising energy recovery technology. For further detailed analysis, the depiction of HP investment cost payments is given per temperature range for each F&D subsector. This model constitutes a useful decision-making tool for assessing potential energy savings from investing in efficient technologies at the highest level of disaggregation, as well as a better subsectoral screening.

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1. Introduction

Energy plays an important role in the European economy and is a major concern of the 21st century. According to the IPCC, based on current trends, we must reduce the level of carbon in energy sources in order to stem the inexorable growth of greenhouse gas emissions [1] and avoid catastrophic consequences. European Union (EU) prepared to pursue a genuinely sustainable approach to using energy that would satisfy present needs without compromising the capacity of future generations to satisfy their own [2].

In spite of the increase in R&D investments on renewable energy resources and clean technologies, the EU's energy demand is likely to be dominated by fossil fuels for many years. Uncertainties which remain on fossil fuel supply (production, price) with the increasing demand are particularly burdensome for consumers. The EU 25's total energy dependence is set to increase from 56% in 2006 (respectively 82% and 62% for oil and natural gas) to 65% in 2030 (93% for oil and 84% for natural gas) [3–6]. All of these highlight the vulnerability of the EU on the energy issue.

The energy system is at a crossroads and, under increasing environmental pressure, the EU needs to define an energy strategy that strikes a balance between sustainable development, competitiveness and supply security, and involves all branches of industry. A long-term vision of monitoring climate change no doubt requires a deep questioning of many of our current practices [7]. Nevertheless, it is difficult to assess the consequences and impacts of strategic choices on the basis of expert opinion in an increasingly complex energy and environmental context. In this world of uncertainty, which has a negative effect on future investments, prospective analysis is useful for decision-makers to investigate the possible future and highlight on the consequences of today's decisions and choices by dealing with various constraints (e.g. emissions quotas, lack of resources, etc.) [8].

Energy prospective exercises employ various types of model with very different functions and levels of aggregation according to their use. Several works on prospective modelling have already been done on all or part of the economy (e.g. electricity production sector, industry, residential sector and transport) for France and other countries [7,9–26]. In our paper we focus on the industry sector in France. It could subdivide into two big families with relevant indicators based on energy and economic characteristics for each sector: Energy Intensive industry (EI) and Non-Energy Intensive industry (NEI). Under the Energy Savings Certificates (ESC) mechanism established by the program law of July 13th 2005 laying down policy guidelines and energy, energy suppliers like EDF

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(Electricité de France) have an obligation to achieve energy savings over a given period in France. A failure to achieve these objectives incurs penalties. To avoid double counting with the European ETS (Emission Trading Scheme, or mechanism for trading emissions of CO_2), the ESC cannot be applied to sites that come under the national quota allocation plan (PNAQ), which are generally the EIs. NEIs are thus a priority target for energy operators like EDF. Over recent years, NEI's importance has increased in the total final energy (TFE) consumption and value added (VA) of industry [10]. They are expected to play an important role in reducing the aggregate energy intensity of industry in the long term because of their economic importance (80% of value added in French industry) and have relatively high growth rate. However, these sectors have been neglected in energy analyses, despite the continuing policy focus on energy efficiency and the many reports and books written on the topic. So, we have developed the first detailed bottom-up energy model for Non-Energy Intensive industry (NEI) to study its global energy efficiency and the potential for CO_2 emissions reduction at a 4-digit level of NACE classification. All industrial modelling relied mainly on EI industries due to the complexity of NEIs. This bottom-up energy model is developed within TIMES model (MARKAL family model) with a technology-rich basis to be useful as a good decision-making tool for energy operator like EDF, to study global energy efficiency potential for NEI industry. Then it analyses the potential for CO_2 emissions reduction from technology and identify policies that could result in adopting these options. Furthermore, this analysis assesses the impact of non-energy intensive industry in achieving the 20/20/20 EU targets on climate change. The paper is broken down as follows: Section 2 gives an analysis of the energy positioning of industry, and more specifically NEI; Section 3 describes the overall structure of the NEI bottom-up model, and the specific features and choices engaged for a detailed subsectorial analysis. Finally, Section 4 presents some results using the model with a study case, the assessment of heat recovery potential using Heat Pump systems (HP) in the French food & drink industry up to 2020.

2. Industrial energy use

Europe plays an important role in the international energy market. Energy demand in the EU is on an upward trend, which became more marked after EU expansion without significant additional energy resources. Energy prices are rising, and increasing dependence on imports because of decreasing reserves represents a threat for supply security and European competitiveness. Industry's TFE represents 27% on average for 20% of GDP, which is the second most significant sector of the economy behind the transport sector. In France, industry's TFE is slightly lower than the EU average at 22%, or 36 MToe (an increase of 17.4% compared to the 1990s) for 14% of GDP. It remains a very important component and is the energy efficiency leader in the French economy. NEI encompass 85.2% sectors of the French industry such as food & drink, textiles, electrical & electronic equipment, transport equipment etc. [10]. French NEI is more developed than the European average with around 45% of TFE for 80% of the total industrial VA. It illustrates its importance in the French economy, as well as in Europe. However, it has been neglected in energy analyses, despite the continuing policy interest in energy efficiency and the many reports and books written on the topic.

Over the last 13 yrs, French industry has been generally energy efficient. Between 1995 and 2008, we note an improvement in energy intensity of about 23%, which is a reduction of about 2% per year (Fig. 1). This energy performance allowed dropping energy consumption by 2.9% while increasing of VA by 25.5%.

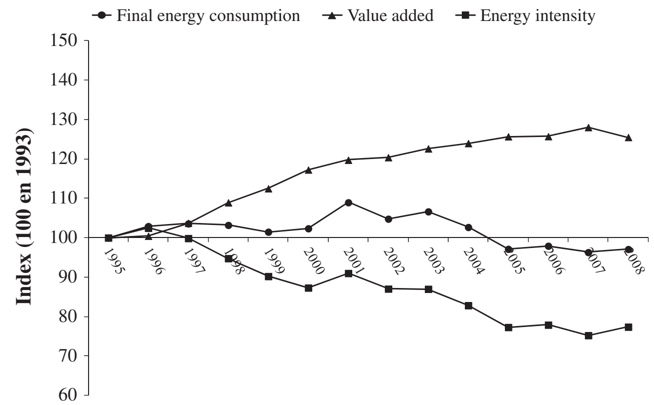

Fig. 1. Evolution of energy intensity, value added and final energy use for industry in France.

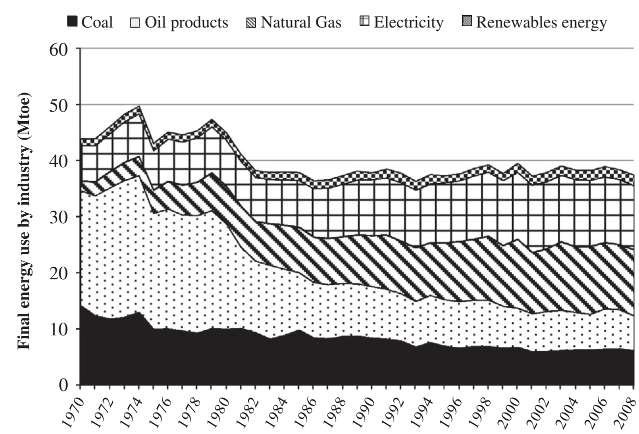

Fig. 2. Evolution of final energy use by French industry.

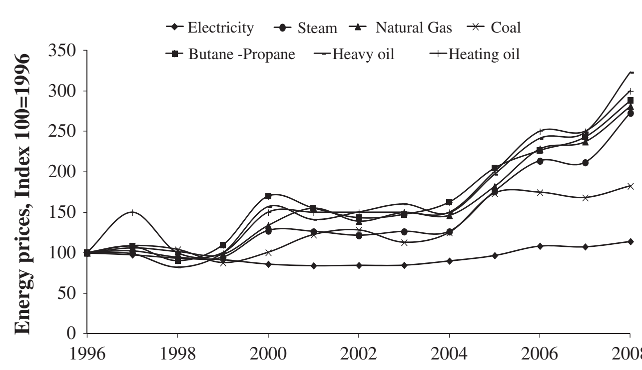

Fig. 3. Evolution of French industrial energy prices.

This energy performance can be explained partly by the use of new efficient energy technologies and partly by a 55% level of structural changes within French industry between 1995 and 2008.

These changes were the result of NEI industries' dynamic economic action, to the detriment of EI industries, combined with a rise in energy prices and other factors (Figs. 2 and 3). This increase in energy prices from 1999, combined with those of electricity on the deregulated market and the effect of introducing the CO_2 quota, had a particularly strong impact on EI industries because of the very high proportion of energy costs in their production costs, unlike NEI industries.

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