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Methodologies to estimate industrial waste heat potential by transferring key figures: A case study for Spain

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HIGHLIGHTS

- Three transferable methods to assess industrial waste heat potential are used.
- The methods based on either the energy consumption or CO_2 emissions.
- To investigate in how far transferring figures to different countries is sensible.
- A case study presented: the Spanish manufacture industry.
- The Spanish annual industrial waste heat potential ranges from 54.3 to 151.1 PJ.

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ABSTRACT

In the current European energy context, the use of recovered industrial waste heat provides an attractive opportunity to substitute primary energy consumption by a low-emission and low-cost energy carrier. In the case of industrial waste heat, this potential is currently not only largely untapped, but also unaccounted for. In order to achieve a widespread use of recovered industrial waste heat, assessments with a large scope and high spatial resolution are needed. Three methods published in the period 2002–2010 have been found in the literature, which are potentially transferable to other regions. These three methods are based on either the energy consumption of each manufacturing sector or the individual site CO_2 emissions. The scope of this analysis is, first, to investigate in how far a transfer of the figures to different countries or regions is sensible in comparison to former studies in the literature. In the process, some uncertainties when transferring methods were identified (different definitions of industry, different standard industrial activities classifications or no standard at all, etc.). The second goal is, once the methodology is accepted, to apply it to a case study, in this case the industrial sector in Spain and two of its counties (Catalonia and the Basque Country) for the years 2001, 2009, 2010 and 2013. In this period, and based on the different approaches employed, the Spanish annual industrial waste heat potential ranges from 54.3 to 151.1 PJ, Catalonia from 8.6 to 29.7 PJ, and from 7.2 to 11.9 PJ for the Basque Country. The methods are considered highly transferable but uncertainties inevitably arise in the case that the source and destination industrial sectors are very different.

1. Introduction

Since the industrial sector continues implementing efforts to improve its energy efficiency, recovering industrial waste heat (IWH) provides an attractive opportunity for a low-emission and low-cost energy source. This heat can be recovered and reused in other processes onsite (to preheat incoming water or combustion air, preheating furnace loads, etc.), or transformed into electricity, cold or other type of heat. Many technologies are available for

Abbreviations: IWH, industrial waste heat; EPA, Environmental Protection Agency; SIC, Standard Industrial Classification; IDAE, Instituto para la Diversificación y Ahorro de la Energia; ICAEN, Institut Català d'Energia; EVE, Ente Vasco de la Energia; SNI, Swedish Standard Industrial Classification; NACE, Nomenclature statistique des activités économiques dans la Communauté européenne; Q_{IWH}, industrial waste heat potential; E_{FUEL}, fuel consumption per sector; f, waste heat per fuel consumption ratio; E-PRTR, European Pollutant Release and Transfer Register; M1, Method 1; M2, Method 2; M3, Method 3.

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IWH recovery: Brueckner et al. [1] proposed and classified these technologies into active and passive technologies depending on whether the heat is being used directly at the same or at lower temperature level or whether it is transformed to another form of energy or to a higher temperature. Moreover, in that paper an economic analysis taking into account the maximum acceptable investment cost for each technology is estimated and compared with the current investment cost depending on the operating hours of the systems proposed.

Before taking advantage of recovered IWH, its characteristics (amount, thermophysical properties, type of potential, etc.) and its location should be known. Regarding its characteristics, Brueckner et al. [2] proposed differentiating between theoretical, technical and economic potential when assessing IWH potentials and suggests a categorization of the methods to account IWH found in the literature along three dimensions: study scale, data collection, and approach (bottom–up and top–down). Regarding the location of the heat source, Miró et al. [3] reviewed and identified the IWH potential for 33 countries worldwide taking into account scientific and other dissemination sources.

However, site-specific data on annual waste heat volumes rejected from industrial facilities is very rare, which makes the exploitation of this energy source difficult. Existing assessments often do not specify the methodology used, in some cases apparently making expert assumptions that are not scientifically justified [3]. Moreover, in some regions the manufacturing industry is a very secretive economic sector and their energy related parameters are not reported. This situation urges the employment of alternative data parameters to assess excess heat availabilities [4]. One of these alternatives may be the adaptation and transfer of key figures originally developed for another region. Three medium precise IWH assessments have been found in the literature, in which transferrable figures are available (developed by Brueckner et al. [5], Land et al. [6] and Persson et al. [4] respectively) and are applied here to assess the potential in other regions. These three methods combine bottom–up and top–down approaches and are either based on the energy consumption of each manufacturing sector or their CO_2 emissions.

Other studies defining methodologies to estimate the IWH potential have been found in the literature. However, they cannot be transferred due mainly to the mismatch between the classification of the industry in the applied region and in the original study. Latour et al. [8] assessed in 1982 the industrial waste heat from the 10 Environmental Protection Agency (EPA) regions from the US considering 19 selective industrial sectors and the percentage of the annual purchased fuels and electricity discharged as waste heat was presented. Although they classified the industrial sectors according to the Standard Industrial Classification (SIC) valid at that moment, the conversion to the current standard classifications was not possible. In Korea, Chung et al. [9] presents in 2010 the most recent ratios of recovery potential and energy purchased, however the exact definition and boundaries of each industrial sector considered by the authors is not available. Pehnt et al. [10] combined studies from Vienna, Norway and the US and the therein derived key figures to estimate the waste heat potential for Germany in 2010, however some of the key figures were not published, only the final results. In the Ecoheatcool project [11] the heat demand in Europe were investigated by Euroheat&Power, a pan-European district heating association [12]. To evaluate the economically feasible waste heat potential for all 32 European states the energy factors derived from Land et al. (Method 1 [6]) were also used. McKenna et al. [13] estimates the IWH recovery potentials in the UK industry based in the CO_2 emitted in the different industrial sites involved in the European Union Emissions Trading System. McKenna et al. [13] study is more detailed, taking into account specific subsector parameters like the combustion emission fraction, the load factor, etc. which implies a huge effort in collaboration with industrial trade groups which was not possible in the case of Spain. This study was later used by Hammond and Norman [14] to estimate the technical potential of various heat recovery technologies, also in the UK. Finally, Miró et al. [15] updated and transferred McKenna et al. [13] approach to the non-metallic mineral industry in Europe for the period 2007–2012.

Most of the industries worldwide neither record not publish their waste streams. The general aim of this study is to apply and to discuss the suitability of transferring three IWH potential evaluation methods identified in the literature to a different region than the original. The specific objectives are (1) to evaluate if transferring key figures is a suitable methodology to perform a first approach in terms of evaluating the industrial waste heat potential, and (2) once the methodology is accepted, to apply it to a case study, in this case Spain. This region is selected since in that region the potential expected is high (due to a high presence of energy-intensive sectors) and the fact that the Spanish manufacturing industry is a very secretive economic sector and, therefore it is not possible to apply more accurate methods to estimate the IWH potential. The results obtained are compared, when available, to former studies in the investigated regions. Moreover, the suitability of transferring these methods is verified by applying them to Sweden and to the German non-metallic minerals sector, since former IWH potential assessments have been performed in these two cases and comparison and discussion is possible. Once the use of these methods is accepted, a case study is selected, in this case the Spanish manufacturing industry, as well as two of the most industrialized Spanish regions: Catalonia and The Basque Country.

The structure of this article is organized as follows: first of all in this article the three methods selected are presented and their adaptation to be transferrable to the scope of the study is described. Then, the validation of their transference is assessed and, finally, the results obtained for Spain, Catalonia and the Basque Country are shown and widely discussed.

2. Methods

Methods to estimate IWH can be classified by accuracy in three different categories: rough methods, using few statistical data, medium precise estimate, with more detailed literature data and coefficients, and high precision methods, with measured data. In order to estimate the IWH for a region, it is very difficult and time consuming to collect or measure individual site data. That is why high precision methods have not been considered by the authors. Similarly, rough methods are not considered because their high uncertainty. Thus, Three medium precise estimation methods from the literature have been selected as they can be transferred, assuming some uncertainties, to other regions. Two of the methods are based on waste heat per industrial fuel consumption ratios, the other considers individual CO_2 emissions of the industrial sites.

In case of the first two methods (Method 1 and Method 2) based on waste heat per fuel consumption ratios (f), the data needed from the studied region is the fuel consumption per industrial sector. The different sources of fuel consumption used are IDAE [16] and Eurostat [17] for Spain, ICAEN [18] for Catalonia and EVE [19] for the Basque Country. All of them use their own non-standard industrial classifications in order to report the energy consumption. For that, both the fuel consumption and the industrial classification have been adapted to match with the key figures from the original methods. In this process, experts from the institutions which publish these data have contributed. The resulting equation to obtain the sectors ratios and their IWH potential (Q_{IWH})