Renewable and Sustainable Energy Reviews 95 (2018) 23–37

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

Uses of industrial energy benchmarking with reference to the pulp and paper industries

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ARTICLE INFO

Keywords:
Paper and pulp industry
Energy benchmarking
Comparisons of industry benchmarks, energy saving technology in paper making

ABSTRACT

Plant operators and policy makers frequently use energy benchmarking to assess the potential for reducing energy consumption from industrial plants. As benchmarking studies require considerable resources and the cooperation of plant operators it is tempting to try to merge or compare data from different studies. This paper reviews published benchmarks and energy-saving estimates from the paper and pulp industries to explore how comparable data from independent studies are. A literature review was conducted which identified that benchmarks were either produced through a top-down process using annual production and fuel consumption data or through a bottom-up process from process-level data. It was concluded that top-down benchmarks are useful in measuring national trends but are of little value to individual plants. For common process such as Kraft pulp production it is possible to compare values from different studies but only if sufficient information is given in the original studies to confirm that their scope is identical. However, it is unlikely that improvement rates in energy use can be inferred from the difference between studies that use different sources, as the degree of disagreement between contemporary studies is of the same order as the identified potential energy savings. Benchmarking studies were found to provide good summaries of potential technological improvements although there is some inconsistency in estimations of potential impacts.

1. Introduction

Energy Benchmarking is the process of comparing the performance of a plant with that of a similar plant or its own performance at an earlier time. It is an important tool to help identify potential energy savings. Benchmarking studies can be influential in the setting of policies, regulations and targets. The benchmarking process can be useful in highlighting where improvements can be made and in the case of temporal benchmarking identify the need for, or effectiveness of, maintenance work [1–4]. Benchmarks can be produced through a top-down approach using annually reported energy-use and production data or through a bottom-up approach using plant level energy-audit and production data. The top-down approach is useful for estimating national trends and assessing the impact of policies. The bottom-up approach is useful for comparing the performance of specific plants. Bottom-up studies need the participation of the major mills within the geographic areas being considered and entail considerable effort from the plant operational staff. Top-down studies use commercially sensitive production and cost data. Both approaches require significant commitment from the participant organisations. As such they represent a considerable investment. As an alternative to conducting a new benchmarking exercise it would be useful to be able to compare studies from different geographic locations and earlier time periods as an aid in assessing regional differences or progress in reducing energy consumption. Examples where benchmark studies of the same industry are compared appear to be missing from the literature. This paper examines when benchmarks from different sources can be compared and the value of comparing them.

This study is based on published academic literature and official reports. These documents used a mixture of original benchmark surveys, updated benchmark surveys and stakeholder consultations. A single industrial sector was chosen for the current study to bring focus and clarity to the approach, whilst acting as an exemplar for the wider questions concerning the value of benchmarking.

The paper and pulp industry was selected for the detailed analysis of benchmarks because it is an established global industry and a major energy consumer. As a sector it has the third highest carbon intensity (measured as t CO_{2e} per £k GVA) of any industry [5], with energy representing an average of 16% of the industry's costs [6,7]. This means there is a significant incentive for companies to examine their energy use and take part in benchmarking studies. The processes involved in paper production are well documented in the literature and described in Appendix A.

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https://doi.org/10.1016/j.rser.2018.06.019
Received 22 August 2016; Received in revised form 11 June 2018; Accepted 11 June 2018

Studies were identified that are representative of the type of benchmarking studies available. These are reviewed in Section 2. Four studies were selected for detailed comparison and are discussed in Section 3. Given the amount of data included in the selected studies it was decided to put the results of the comparison into three appendices. Appendix B aligns the product descriptions used in different studies. Appendix C lists the specific energy demands for electricity and steam converted into GJ per dry-tonne of paper. Appendix D identifies the Best Available Technology (BAT) and emerging technologies from the wider range of studies. The detailed comparison highlights the importance of having identical process boundaries and product definitions when comparing benchmarks. The identification of BAT and emerging technologies are comparable across studies but estimations of their potential impact differ between studies.

As the focus of this paper is on energy benchmarking, it is not intended to provide a comprehensive review of the literature on the potential for energy efficiency improvements in the paper and pulp industry. Recent reviews of emerging technology have been published [2,8]. Several of the benchmarking studies also include assessments of emerging technology and these are discussed in Sections 3.4 and 3.5.

2. Published benchmarks in the paper and pulp industry

The reviewed benchmark studies have been grouped by geographic regions.

2.1. Global benchmarks

The Ernest Orlando Lawrence Berkeley National Laboratory produced a report titled 'World Best Practice Energy Intensity Values for Selected Industrial Sectors' for the US Department of Energy [9]. This report used survey data for the pulp and paper industry [10–12]. The report provides separate figures for electricity use, energy used for steam generation, total energy used, and primary energy used for several products from both separate and integrated mills. As the report's purpose is to give BAT values, the ranges of reported specific energy values are not given. Data from the report are used by the Institute for Industrial Productivity (IIP) in order to provide benchmarks for some energy intensive industries on their web site.[1]

The International Energy Agency (IEA) published a report on 'Energy Technology Transition for Industry' [13], this report covers specific energy consumption data for industries in different countries and estimates the potential scope for improvement. It acknowledges that there are inconsistencies in the way that countries report the use of Black Liquor (a by-product of the widely used Kraft sulphate chemical pulping process) and industrial combined heat and power generation (CHP). Consequently, they relied on national energy and trade data to produce national average specific energy requirements rather than the reported specific energy consumption of plants within each country. The report summarises BAT benchmarks for electricity and heat use for different processes provided in other work [10,14–16].

In 2016 the IEA published a report on Energy Efficiency Indicators for member countries [17]. It used a top-down approach and adopts MJ/$_{US} to measure energy intensity. Although this gives an indication of the economic value generated per unit of energy it gives little indication of actual energy use as it can be influenced by changes in currency exchange rates and product mix as well as improvements in energy efficiency. An Energy Efficiency Index (EEI) for different countries can be calculated by comparing the aggregated energy use for a sector within a country with that which would be required by the 10% least energy intensive plant in the country to achieve the same production [18]. EEIs have been used to estimate the potential energy savings achievable by improving energy efficiency by using data from [13] (discussed above) to calculate the EEIs for the paper and pulp sectors [18].

2.2. North american benchmarks

The US Department of Energy commissioned 'Energy Bandwidth' reports into the potential for energy-efficiency improvements in different sectors. These studies assess the energy demand for the following classifications: Current Technology (CT), using median data from survey return; State of the Art (SOA), using the latest commercially implemented technology; Practical Minimum (PM), which includes identified potential improvements from other studies; and Thermodynamic Minimum (TM), which gives absolute minimum values from the laws of thermodynamics. The TM estimate is used as a baseline to estimate savings. The original study into the pulp and paper industries was carried out in 2006 [19]. This was updated in 2015 [20]. These reports cover a range of products and feedstocks. They give data for individual processes and products rather than complete mills. Losses associated with on-site electricity generation, and steam supply are covered in separate sections of the reports.

The US Environmental Protection Agency ran a series of energy reduction programs under the "Energy Star" initiative [4,21]. The paper and pulp industries were covered by one such study [22]. An Energy Performance Index (EPI) was used rather than specific energy consumption. The EPI uses a formula that relates energy use to the specific production process, product made, and feedstocks used. The coefficients used in this formula are arrived at by regression analysis from confidential survey data. The computed value of energy demand is then compared with the actual value to produce an Energy Performance Score with 100 representing the score of the most efficient plant. This approach has the advantage that it can deal with mills that make more than one grade of product. However, the use of the EPI prevents a direct comparison with other studies as it does not allow energy use or emissions to be calculated.

Natural Resource Canada (NRC) published a benchmarking report in 2006 [23]. It gives detailed breakdowns of the energy use for each production phase taken from Canadian mills giving the energy consumption for the 25th percentile, median, 75th percentile and figures for "modern" mills to reflect the latest developments. The report gives values for specific electricity and thermal energy consumption.

2.3. European benchmarking

The EU Industrial Emissions Directive 2010/75/EU (Integrated Pollution Prevention and Control) requires the preparation of 'Best Available Techniques Reference Documents' to be produced for industrial sectors. Several studies have used the 2001 version of this document [10], which was revised in 2015 [24]. These reports contain data on energy use, emissions and BAT. They use specific energy figures for different feedstocks taken from a 2007 survey of German mills [25], which reported on the range of energy used in existing plants. BAT values were calculated using a bottom-up approach utilising proven leading technology. The document also gives an assessment of emerging technologies in pulp and paper manufacturing.

The European Emission Trading System (EU ETS) is a cap and trade industrial emissions reduction scheme. It only covers direct emissions i.e. those that occur from the processes carried out onsite and onsite combustion of fuels. It excludes emissions that arise from the generation of grid electricity or the production of fuels. Under the scheme, installations that could lose business to competitors who are in countries that are not members of the scheme are given free allowances equivalent to the emissions that would be emitted by the least polluting 10% of plants in the same sector. Benchmarking has been used to identify the least polluting 10% of plants [5,26,27]. The EU ETS covers site-level emissions, so it is not possible to calculate the energy use for individual processes from these data.

The Climate Strategy research organisation produced a status report on the European pulp and paper industry in 2016 [28]. This report used

[1] http://ietd.iipnetwork.org/content/pulp-and-paper#benchmark.