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The Potential Energy Efficiency Improvements for the Italian Pulp and Paper Industry

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Pulp and paper production is an energy intensive process, that accounts for about 9 % of industrial final energy use in Italy in 2016. While the energy intensity of the total manufacturing sector has decreased by 51 % over the last twenty years, pulp and paper industry has shown a slower improvement, of only 4 %. The sector presents wide opportunities for improving energy efficiency and, for this purpose, adequate knowledge of the energy saving potentials and their costs are essential prerequisites to design effective policies. In this paper, after assessing the current technologies and energy performance of the Italian pulp and paper industry, we identify the technical and economic potentials for fuel and electricity savings in the sector. While many studies in this field use data on efficient technologies from available literature, surveys or even theoretical estimates, the added value of this paper is the use of real data coming from 110 energy efficiency measures implemented in the field by the pulp and paper companies under the Italian White Certificates Scheme.
The analysis indicates that the energy saving potentials, under conservative technology penetration rates, amount to 0.88 TWh for electricity and 4.47 TWh for fossil fuels consumption: such savings equal 12.6 % and 18.6 % of the sector electricity and fuel demand, and can be translated into mitigated CO_2 emissions of 353 kt.

1. Introduction

Energy efficiency plays a fundamental role in promoting and supporting the development of a low carbon economy, as well as optimizing the use of energy carriers in the different sectors. The industrial sector is responsible for about a quarter of the energy consumption of the European Union (EU) in 2018 (EUROSTAT, 2018) and consequently an important contribution to European energy efficiency target is expected.
This commitment, however, is made particularly complex by the fact that the desired reduction of energy consumption must be combined with business competitiveness, which is strongly influenced by many variables, including environmental constraints, costs and volatility of energy prices (Fais et al., 2016). Studies conducted on this topic in the period 1995 - 2009 reveal that an increase of 1 % in the cost of energy sources can lead to a reduction of about 1.6 % in the export competitiveness (EURELECTRIC, 2014). Moreover, since 2007, the global economic crisis has slowed down the overall process of energy efficiency improvement in European industry: from 2007 to 2013 the rate of energy efficiency improvement was 0.9 % per year, compared to the 1.9 %/y recorded in the period 2000 - 2007 (ADEME, 2015). In fact, it is estimated that, since 2007, only a quarter of energy savings in industry is attributable to energy efficiency, while more than half is the direct consequence of the decrease in production.
The relevance of energy efficiency in business activity has been widely investigated in economic sciences literature. There is in fact strong empirical evidence that the adoption of efficient technologies to reduce energy consumption represents an optimum for all the stakeholders involved (Allcott et al., 2012). However, despite the potential benefits of adopting Energy Efficiency Measures (EEM) are high, such measures are often ignored by companies (Gillingham et al., 2009).
A more in-depth investigation into barriers to energy efficiency was conducted on a sample of over 220 manufacturing SMEs located in Italy (Trianni et al., 2016): in particular, they showed that, although there is usually a great attention to energy efficiency and efforts towards a more efficient production are present,

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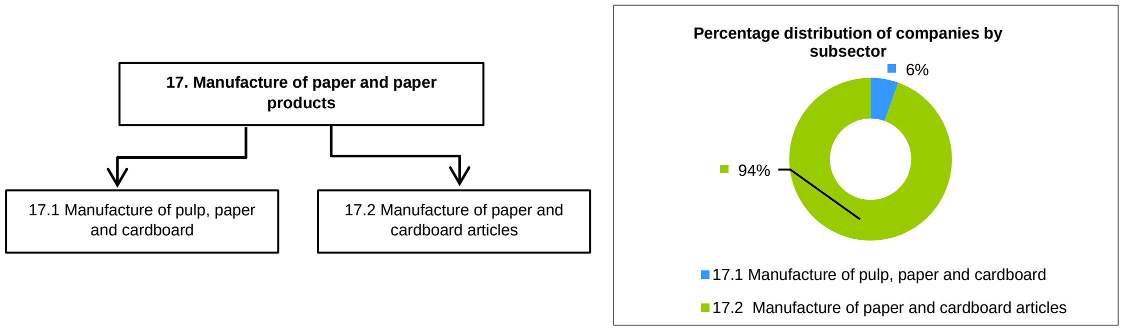
however awareness and behavioural issues emerge as critical in these companies; this affects the very first steps of the decision-making process, related to the punctual identification and evaluation of plausible EEM.
Given the above mentioned barriers, it is not surprising that energy efficient technologies spread more slowly than expected on the basis of merely rational economic assumptions. It is fundamental to understand, from an empirical point of view, the potential impact of EEM, in order to support policy makers in designing possible actions to correct such distortions.
This paper contributes to the existing literature by focusing specifically on energy efficiency, in order to identify the technical and economic potentials for fuel and electricity savings. The added value is the use of real data coming from real EEM implemented by Italian industries under the Italian White Certificates Scheme in the pulp and paper sector. Such sector is highly energy-intensive, strongly export-oriented and also sensitive to the issue of competitiveness on national and international markets.
The paper is organised as follows: first, the current technologies and energy performance of the pulp and paper industry are analysed and presented; second, the data used are described and explained; subsequently, the technical and economic potentials for fuel and electricity savings in the sector are identified and discussed; finally, the main conclusions are drawn.

2. The pulp and paper sector

The pulp and paper sector represents a relevant reality in the Italian industrial landscape. With a turnover of about 22 G€/y, the sector employs 197,000 workers (about 5 % of Italian manufacturing employment), according to the Italian National Statistical Institute (ISTAT) in 2017. The sector is identified by the National Association of Corrosion Engineers code (NACE) C17 and is divided in two main categories: the manufacture of pulp, paper and cardboard (NACE C17.1) and the manufacture of products through further processing and converting (NACE C17.2), as shown in Figure 1. The dimension of companies is typically small, with a number of employees of less than 50 units in over 90 % of cases.



(a) (b)

Figure 1: Composition of the pulp and paper sector (a) and distribution of companies by subsector (b).

Although less representative in terms of number of companies, NACE C17.1 is the most affected by the EEM implemented in the sample of analysed companies. Therefore, the study focused on this subsector and in particular on papermaking factories.
The sector is energy intensive, being the fourth industrial sector for energy consumption. Energy supply accounts for 20 - 30 % of total production costs and represents usually the second cost item. The thermal energy use in the sector was 19 TWh in 2014, almost exclusively attributable to natural gas. As for electricity, the 2014 consumption amounts to 7.01 TWh, of which 76 % were self-produced through cogeneration solutions powered by natural gas (CEPI, 2016).
The production process of a paper mill can be summarized as shown in Figure 2, where the material flows and distribution of energy in the various phases are highlighted (Fais et al., 2016), in order to understand “where” and “how” energy is currently used in the production process and which technologies are involved.
Natural gas represents over 70 % of process energy use in paper mills. It is largely used for steam production, typically through CHP plants. The steam is then distributed to the users of the plant, in particular towards drying: this is the most energy-consuming section and consumes 80 - 90 % of the steam produced in the paper mill.

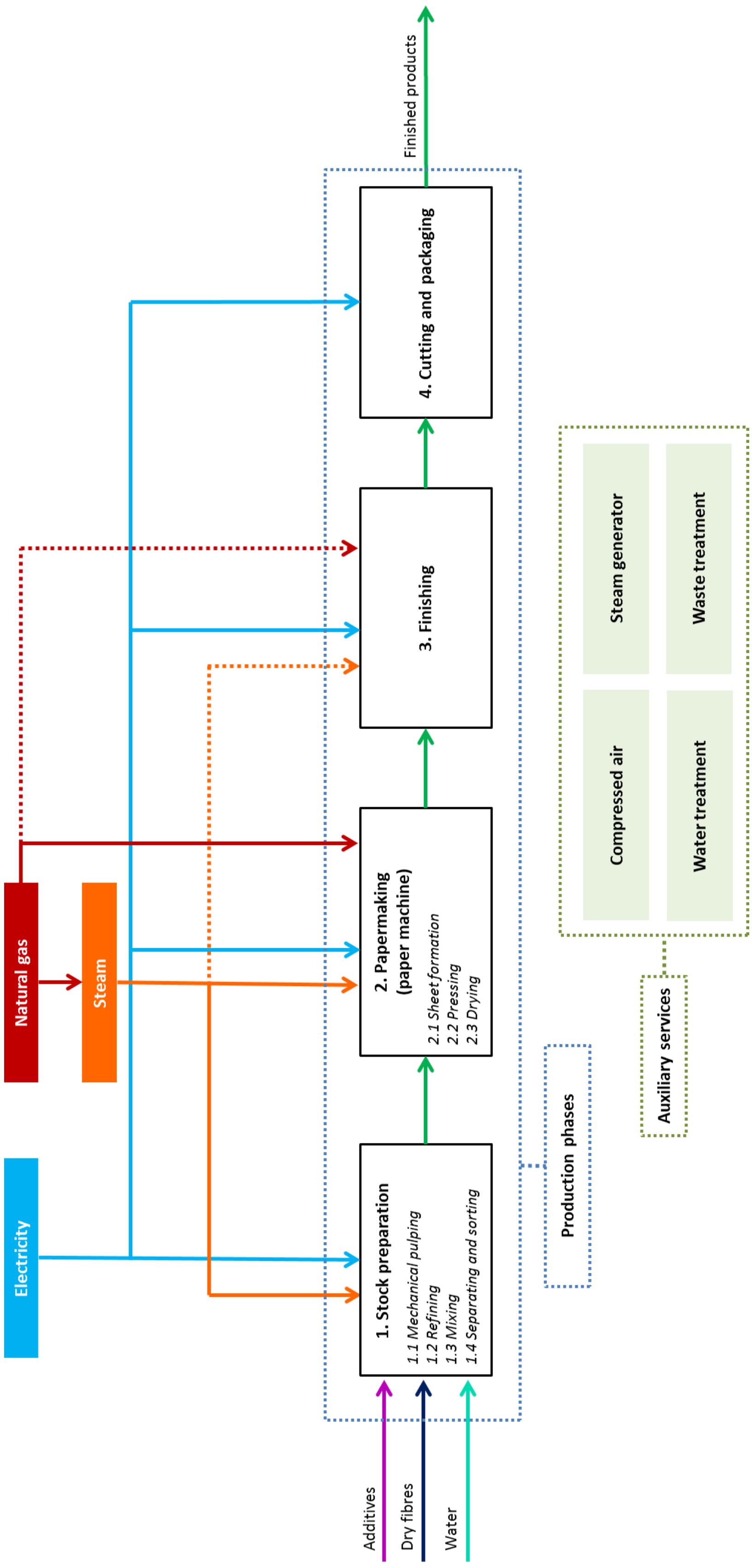


Figure 2: Typical production layout of a paper mill.

3. Description of the data used in the analysis

The goal of the analysis is to explore the energy saving potentials that an industrial sector is still able to express in order to reduce the energy intensity of production processes. The starting point are the data about companies that have implemented EEM in their factories and which have been collected under the White Certificate Mechanism in Italy in the decade 2005 - 2015. These EEM are real interventions realized by industrial firms. The great amount of data collected was analysed, organized and finally structured in a catalogue of specific measures implemented in order to reduce energy consumption. Each intervention was examined and defined under various parameters and different types of information were extracted. The result of this intense process of collecting and sorting useful data is the creation of a database of EEM implemented by a significant sample of companies in each sector. The analysis sample consists of 110 EEM, implemented in 82 plants, 95 % of which are paper mills belonging to the 17.1 subsector. These plants are owned by 66 different companies, which have been examined in order to assess their placement in the general sector framework. Although not very relevant in terms of numbers, the observed companies represent a quite significant slice of the economic activity of the sector as a whole (Table 1).

Table 1: Summary of the economic representativeness of the sample.

Economic characteristics	Sector 17.1 Manufacture of pulp, paper and cardboard	Sample of companies implementing EEMs	Representativeness
Number of enterprises	2,474	66	2.7 %
Revenues [M€]	21,000	7,000	34 %
Number of employees	62,000	16,000	25 %
Labour profitability, [€/employee]	344,000	458,000	(>33 %)

With reference to the year 2015, 34 % of the revenues of the entire sector were realized by the companies of the sample. Moreover, these companies employ around 25 % of the total employees in the sector and also have a productivity value per employee of 33 % higher than the sector. This information suggests that the companies observed in the sample are on average larger and more productive than the associated industry average. As regards energy consumption, a measure of the representativeness of the sample was possible in comparison to the subsector 17.1 only, since finding reliable and agreed data for the whole sector was difficult. Table 2 shows a representativeness of 65 % in terms of energy consumption.

Table 2: Summary of the energy and economic representativeness of the sample.

Energy consumption	Sector 17.1 Manufacture of pulp, paper and cardboard	Sample of companies implementing EEMs	Representativeness [%]
Electricity [ktoe]	1,310	847	65
Natural gas [ktoe]	2,058	1,330	65
Total [ktoe]	3,368	2,177	65

4. Evaluation the energy saving potential achievable by the pulp and paper sector

The evaluation of energy saving potential is conducted starting from the sample of plants which have implemented EEM: the energy savings achieved at the specific plant level are subsequently scaled up to the national level, based on the number of plants present in the sector that have not yet realized EEM.

This bottom-up assessment relies on the concept of replicability, i.e. the degree at which EEM can be theoretically reproduced on other plants within the same sector. The replicability degree results from the evaluation of different factors that can affect the implementation of EEM: after a merely technical analysis, economic feasibility criteria are added, as well as considerations on market penetration and acceptability by the industry. The energy saving potential estimated for the sector is therefore both a technical and economic potential, since it quantifies the level of energy savings that would occur if all industrial processes and equipment in the country are upgraded with EEM that are replicable according to the above mentioned criteria. This

represents a more conservative and realistic scenario compared to the optimistic and theoretic projections that would result from the implementation of exclusively Best Available Technologies (BAT).
The sample of EEM realized in the pulp and paper sector consists of 110 interventions carried out between 2005 and 2015 as part of the White Certificates Scheme. Most of the EEM were implemented on the core process phases (68 %), while the remaining portion mainly involved auxiliary services. Each measure was analysed and catalogued according to the parameters in Table 1. Then the interventions have been organized in clusters, based on the type of technology used and the process phase involved. For each cluster the thermal and electricity savings indexes were identified, that is the average savings achieved by implementing the interventions in the cluster itself. The results of these elaborations are shown in Table 3.

Table 3: Clusters of EEM implemented in the pulp and paper industry sample and related indexes of thermal and electricity saving.

Energy saving potentials		Number of EEM	Electricity Saving Index [%]	Thermal Saving Index [%}
1	Inverters and high efficiency motors	14	4.5	-
2	Heat recovery	16	-	4.9
3	Revamping of drying hoods	13	0.9	3.8
4	Revamping or new production line	18	6.5	11.9
5	Revamping or replacement of the steam generator	5	1.6	4.3
6	Revamping or replacement of the stock preparation line	10	6.6	6.5
7	Revamping or replacement of the press section	13	5.0	6.7
8	Revamping of the drying section	21	4.5	5.9

After an assessment of the replicability of the clusters on each production plant in the pulp and paper sector, the savings indexes are applied to the thermal and electrical consumption of the industry. The results of this operation are the energy savings potentials achievable by the sector through the implementation of the clusters (Figure 3). In particular, for each cluster two components of these potentials are identified:

- the share of savings already achieved by the by the EEM in the cluster;
- the share of savings still to be achieved, net of what already accomplished by the EEM in the cluster.

The highest savings, both of thermal energy and electricity, can be reached in correspondence with actions on the entire production line (cluster 4). Significant saving opportunities are possible also in correspondence with the pressing and drying phases (clusters 7 and 8), which are indeed the most energy intensive processes.
By combining the clusters and replicating them on the entire sector, according to reasonable criteria of co-existence and accumulation of the EEMs on each production plant, the global potentials for electricity and thermal savings are obtained for the pulp and paper sector (Table 4).

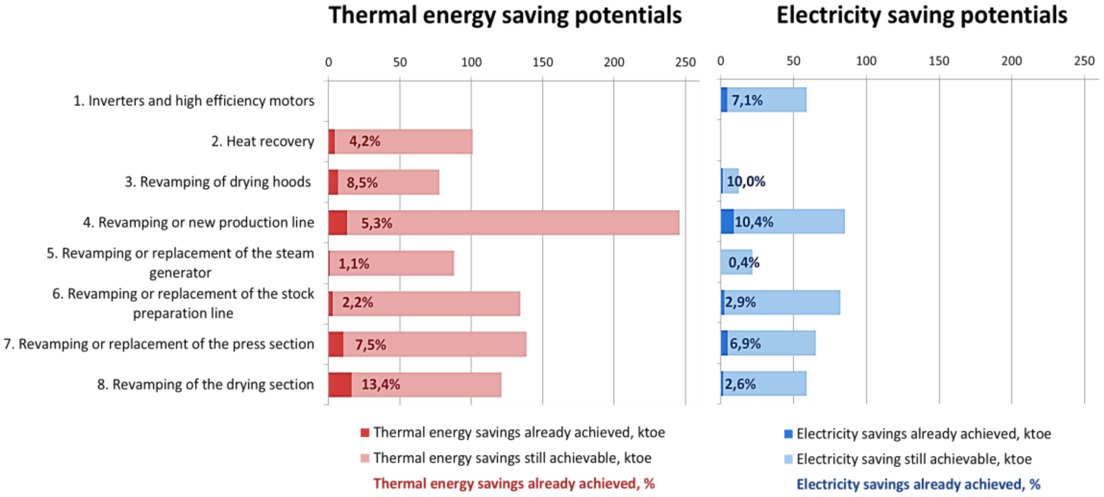
Table 4: Energy saving potentials for the pulp and paper sector.

Energy saving potentials	%	TWh	ktoe
Electricity	12.6	0.88	165
Thermal energy	18.6	4.47	382
Total	16.2	5.34	547

Overall, the potential for savings of 16.2 % on total energy consumption is estimated for the pulp and paper sector. The savings potentials obtained are net of the savings already achieved by the sector in the decade 2005-2015 as part of the White Certificates mechanism, so they are potentials still achievable by the sector.

5. Conclusions

The present study assesses the energy efficiency potentials that can be followed by the Italian industry in the pulp and paper sector. Starting from the analysis of 110 interventions overall implemented by the sector in the decade 2005 - 2015, it was possible to define an estimate of the energy savings achievable by the sector. These savings potentials are obtained according to criteria of reasonable replicability, technical feasibility and economic sustainability and are net of energy savings already achieved: the estimated saving potentials are 12.6 % for electricity and 18.6 % for thermal energy. These results represent an important contribution to national policies towards energy efficiency and decarbonisation, in particular as regards the National Energy Strategy developed by the Italian Government (SEN, 2017). In fact, the study shows the feasibility of energy efficiency targets on the basis of technical and economic criteria, which reflect the real decision making processes faced by industrial companies in everyday business. The presented study reveals that in the sector some EEM have been successfully implemented by a large number of companies, while other technologies show a low penetration rate, although being convenient in terms of energy savings. To bridge this gap, it could be useful to address specific energy policy measures. Considering that industry plays a central role in the achievement of EU decarbonisation goals, it is crucial, for policy-makers, that the support for the adoption of EEM should be tailored around a broader range of business characteristics, such as size, productivity, energy intensity, manufacturing sector, in order to most effectively tackle the resistances to the implementation of energy efficient technologies.



(a) (b)

Figure 3: Electricity (a) and Thermal (a) saving potential for the clusters in the pulp and paper sector: split between the shares already achieved and still achievable (RSE elaboration).

Acknowledgments

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