sEEnergies

QUANTIFICATION OF SYNERGIES BETWEEN ENERGY EFFICIENCY FIRST PRINCIPLE AND RENEWABLE ENERGY SYSTEMS

D3.7 Report on the non-energy impacts of energy efficiency in the industry sector

Project

Acronym	**sEEnergies**
Title	Quantification of Synergies between Energy Efficiency First Principle and Renewable Energy Systems
Coordinator	Brian vad Mathiesen, Aalborg Universitet
Reference	846463
Type	Research and Innovation Action (RIA)
Programme	HORIZON 2020
Topic	LC-SC3-EE-14-2018-2019-2020 - Socio-economic research conceptualising and modelling energy efficiency and energy demand
Start	01 September 2019
Duration	34 months
Website	https://seenergies.eu/
Consortium	**Aalborg Universitet (AAU)**, Denmark **Hogskolan i Halmstad (HU),** Sweden **TEP Energy GmbH (TEP),** Switzerland **Universiteit Utrecht (UU),** Netherlands **Europa-Universität Flensburg (EUF),** Germany **Katholieke Universiteit Leuven (KULeuven),** Belgium **Norges Miljø- og Biovitenskapelige Universitet (NMBU),** Norway **SYNYO GmbH (SYNYO)**, Austria **Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V. (Fraunhofer),** Germany

Deliverable

Number	**D3.7**
Title	**Report on the non-energy impacts of energy efficiency in the industry sector**
Lead beneficiary	Utrecht University
Work package	WP3
Dissemination level	Public
Nature	Other
Due date	30.06.2021
Submission date	30.06.2021
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Document history

Version	Date	Comments
1	04-06-2021	Internal draft to reviewers
2	30-06-2021	Final report

Acknowledgement: This project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No 846463.

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Acronyms & Abbreviations

Term	Description
CO	Carbon monoxide
CO_2	Carbon dioxide
EE	Energy efficiency
GDP	Gross Domestic Product
GHG	Greenhouse gases
GVA	Gross value added
IEA	International Energy Agency
MEBs	Multiple energy benefits
NEBs	Non-energy benefits
NOx	Nitrogen oxides
PJ	Petajoule
PM	Particulate matter
PM2.5	Particulate matter with a diameter less than 2.5 µm
PM10	Particulate matter with a diameter less than 10 µm
RCA	Revealed Comparative Advantage
SOx	Sulphur oxides
TJ	Terajoule

1 Introduction

Energy efficiency (EE) plays a key role in the ongoing efforts for a clean energy transition in the industry sector and for meeting the global climate and sustainability goals. So far, analyses of energy efficiency measures and technologies focus mostly on the direct energy saving and the greenhouse gas (GHG) saving potentials. However, many of these energy efficiency measures except for reducing final energy use they can also provide other benefits, non-energy benefits (NEBs), which can play a definitive role for the uptake of energy efficiency in industries.

Non-energy benefits, also commonly named in literature multiple energy benefits (MEBs), can provide several enhancements to the industrial operation, such as increased competitiveness and increased security of supply while technological innovation is boosted, and climate change is limited. Lilly and Pearson (1999) assessed the benefits of energy efficiency on the operation and maintenance costs in industries. In other studies (Pye and McKane, 2000; Finman and Laitner 2004, Worrell et al. 2004), more NEBs were identified and partly quantified such as improved productivity, improved product quality, decrease in materials, reduced pollution and waste, increased process reliability and improved working environment, and workforce satisfaction. Such benefits, because they refer to the firms' particular benefits, are identified as individual benefits (IEA, 2012). NEBs related to the industrial productivity and asset values are identified as sectoral benefits, while NEBs related to the benefits to the entire economy, such increased employment, reduced pollution concentration levels, impact on Gross Domestic Product (GDP), increased energy security and reduced energy prices are identified as national benefits (IEA, 2012).

For the industrial sector, the quantification and monetisation of non-energy benefits and their inclusion in cost-benefit analyses can lead to significant increase in profitability and reduced payback periods (IEA, 2014). In addition, according to survey responses, when stakeholders make investment decisions, the NEBs of energy efficiency and not the direct energy savings may, in certain cases, be the most important decision parameters (Reinaud et al., 2012). In a cost analysis made for the iron and steel industry, the inclusion of enhanced productivity was shown to significantly affect the profitability of the investments, doubling the overall cost-effective savings potential and cutting by half the payback period (from about 4 years to less than 2) for the measures that increase productivity (Worrell et al., 2004). Thus, incorporating NEBs of energy efficiency measures in the cost assessments can strengthen the incentives for their adoption.

In this analysis, we aim to translate the energy efficiency potentials identified in Deliverable 3.6 (Kermeli and Crijns-Graus, 2020) to the NEB potentials for the EU 28 industry. Because the individual NEBS, are industry and measure specific and hard to quantify, we limited this analysis into creating a list with the most important NEBs per industry specific measure for two industrial sectors, the iron and steel and the cement industries. In the following paragraphs instead of the term NEBs we use the term "non-energy impacts". This is to demonstrate and to capture, where possible, that some measures might also have some drawbacks (e.g. increase of a certain pollutant or increased maintenance costs). The structure of the report is as follows. Section 2 outlines the methods used for calculating the non-energy impacts, and Section 3 presents the results. Lastly, Section 4 discusses the main uncertainties and limitations of the analysis and presents the main conclusions.

2 Methods and approach

The potentials for energy efficiency improvements in the EU industrial sector under different scenarios, broken down per different industrial sub-sectors and EU countries, were estimated in earlier analysis (Kermeli and Crijns-Graus, 2020). It was found that energy efficiency improvements can decrease the industrial energy demand in the EU28 by 1,630 PJ in a “High efficiency scenario”, while in a “High efficiency and high recycling scenario” final energy demand can decrease by 3,300 PJ by 2050.

The wide adoption of energy efficiency measures can have several economic, social, environmental, policy and energy market impacts. While also impacts will be present on an individual/sectoral level, such as productivity gains, reduced maintenance, increased workforce satisfaction. The industry sector is complex with many different industrial processes used to manufacture a variety of industrial goods. The EE measures and technologies that could be adopted are also many and diverse and can have different impacts. Others can reduce the noise level inside the factory, others can reduce the need for maintenance, others can reduce employment, others can reduce industrial productivity while the impact will be different in the different industrial sectors. This makes the individual/sectoral impacts very industry and measure specific and hard to quantify for the whole EU industry.

In this analysis we use two approaches:

With the first approach we calculate the economic, social, and environmental impacts the EE potentials identified in Kermeli and Crijns-Graus (2020) can have in the EU28. We do this based on the methods identified and presented in Reuter et al. (2020) after making some adjustments. The analysis from Reuter et al. (2020) was chosen due to its i) simplicity, most methods are non-data and non-modelling intensive that directly link the direct energy savings potentials to the non-energy impacts of EE and ii) ability to show the additional impacts for the whole EU industry, although the impacts are also calculated at a more disaggregated level (per industrial sub-sector, EE measure and EU country).

The second approach is industry, technology, and measure specific. Here, we identify the EE measures with significant non-energy impacts with a focus on two industries, cement and iron and steel. This approach relies on available literature concerning details on EE, primarily technical reports, case studies and scientific articles.

2.1 Environmental, social, and economic impacts

In Reuter et al. (2020), the additional impacts offered by EE improvements are broken down into three main categories: environmental, social, and economic. Table 1 shows the identified additional impacts that are relevant to the industry sector.

Table 1 Additional benefits to energy efficiency measures for the industry sector (adjusted from Reuter et al., 2020)

	#	Sub-category	Indicator	Derive from EE potentials?
Environemntal		***Energy/Resource Management***		
	1	Energy savings	Annual energy savings (top-down/bottom-up)	yes
	2	Savings of fossil fuels	Annual fossil fuels saved due to EE	yes
	3	Impacts on RES targets	Lowering of RES targets due to EE	yes
		Global and Local Pollutants		
	4	GHG savings	Annual CO2 savings linked to EE	yes
	5	Air pollution	Avoided pollutants (PM2.5, PM10, CO, NOx, and SOx)	yes
Social		***Quality of life***		
	6	Health and well-being	Health impacts	yes
Economic		***Innovation/Competitiveness***		
	7	Innovation impacts	Revealed Patent Advantage (RPA)	no
	8	Competitiveness	Revealed Comparative Advantage (RCA)	no
	9	Turnover of EE goods	Investments linked to energy savings	yes
		Macro-economic		
	10	Impact on GDP	Impacts of Energy savings on GDP growth	yes
	11	Employment effects	Additional FTE linked to energy savings	yes
	12	Potential impact on energy prices	Lower energy prices due to changes in consumption based on price elasticities	yes
	13	Impact on public budgets	Additional income tax revenue from additional employment based on energy savings	yes
		Micro-economic		
	14	(Industrial) productivity	Change of productivity due to lowered production costs	yes
		Energy Security /Energy Delivery		
	15	Energy security 1	Lower import dependency	yes
	16	Energy security 2	Larger supplier diversity	yes
	17	Impact on integration of RES	Demand response potential per country	no

In the following paragraphs we describe the methods and the data used for the calculation of the non-energy impacts for the EU industrial sector. We focus on the impacts that can be directly linked to the energy savings (for more information on the impacts not directly linked to the energy savings please see Reuter et al., (2020)). The energy savings represent the difference in the energy consumption between different scenarios for the same year. The energy savings have been analysed for three different scenarios i) BAT ("high efficiency scenario"), ii) BAT+incremental recycling ("high efficiency+ incremental recycling") and iii) BAT+high recycling ("high efficiency+recycling") (Kermeli and Crijns Graus, 2020). The energy savings used to calculate the non-energy impacts in this analysis will be the energy savings identified in the BAT+high recycling scenario (representing the difference between the frozen efficiency and the BAT+high recycling scenario).

In addition, it makes more sense to calculate certain additional impacts on an EU level and for all end-use sectors (i.e., buildings, industry, and transport). An example of such an impact is the "Potential impact on energy prices" where although a strong reduction in industrial energy consumption could potentially decrease the energy prices, the reductions only in one end-use sector or only in one EU country will not have a prominent effect. Such impacts are identified, and a method is suggested, however they are not calculated here.

2.1.1 Environmental impacts

The environmental impacts include the direct impacts of the diffusion of energy efficiency technologies, namely final and primary energy savings, and the savings of GHG and other emissions. Here, we only focus on final energy savings, the reduction of CO_2 emissions and the reduction of NOx, SOx, CO and PM emissions.

Energy savings

To calculate the energy savings, a direct impact of energy efficiency improvements, first the different technologies that could offer significant energy savings (both in the form of fuel and/or electricity) were identified and the current diffusion technologies were determined. Information was gathered on the fuel and electricity savings, defined in GJ/tonne product. The future implementation rate was determined from information found in literature. The annual energy savings per country and industrial sub-sector ($ES_{i,j}$) are calculated according to the formula:

$$ES_{i,j} = \sum_{x} P_{i,j} * DR_{x,j} * ES_x \qquad \text{(Eq. 1)}$$

where *i* is a certain industrial product, *j* is a European country, $DR_{x,j}$ is the diffusion rate of technology *x* in country *j*, and ES_x are the energy savings the technology *x* can offer. For more details on the method, data (e.g. production levels, technologies, diffusion rates) please see Kermeli and Crijns-Graus (2020).

Savings of fossil fuels

This represents the quantity of fossil fuels saved due to EE improvements. The energy savings are allocated to the various types of fuels (coal, oil, biomass, gas) used in the different industries and in the various EU countries. This is based on the breakdown of energy consumption per energy carrier for the different industries and countries from IEA statistics (IEA, 2016). Multiplying the energy savings ($ES_{i,j}$) with the fuel share and by multiplying with the energy content of the fuels, the quantity of fuel savings per fuel (FQ_f) can be determined.

$$FQ_f = \sum_{i,j} ES_{i,j} * FS_{i,j,f} * LCV_f^{-1} \quad \text{(Eq. 2)}$$

where, $FS_{i,j,f}$ is the fuel share of fuel f in country j and industrial sub-sector i, and LCV_f is the net calorific value of fuel f. This method does not consider the fossil fuel savings from EE measures that decrease electricity use as it is outside the boundaries of this analysis. However, for energy efficiency measures that decrease electricity use these indirect fuel savings can be significant.

Impact on RES targets

By decreasing the energy demand in industries, the RES targets can be achieved with lower efforts. According to the European Commission, the RES targets for 2030 are: 40% GHG emission reduction, at least 32% increase of the share of renewable energy, and at least 32.5% reduction of the total energy consumption in the EU (EC, 2018; EC, 2019). The RES target, for the share of renewable energy, is the ratio between the renewable energy consumed and the total gross final energy consumption. To meet this RES target, the absolute amount of energy that will need to be supplied by renewable sources will be lower in an EE scenario than in a frozen efficiency scenario. The difference between the supplied renewable energy (ΔRE) in different scenarios shows how much easier the target can be reached. The ΔRE and can be calculated with the following formula:

$$\Delta RE = RES_{target} * GTFEC_{FE\ scenario} - RES_{target} * GTFEC_{EE\ scenario} \quad \text{(Eq. 3)}$$

where, RES_{target} is the renewable energy target for a certain year for the EU, $GTFEC_{FE\ scenario}$ is the gross total final energy consumption in the frozen efficiency scenario and $GTFEC_{EE\ scenario}$ in an energy efficiency scenario. The $GTFEC$ includes all end-use sectors (buildings, transport, industry, and energy use in transformation industries) on an EU level. It is therefore not possible to calculate this non-energy impact just for the industry sector and it is advisable to calculate it when the EE impact is determined for all end-use sectors in the EU (possibly in WP6).

Avoided CO_2 emissions

By multiplying the fuel savings (see non-energy impact "Savings of fossil fuels") with the default CO_2 emission factor per fuel, the avoided CO_2 emissions can be calculated ($CO_{2,saved}$). The formula is:

$$CO_{2,saved} = \sum_f ES_f * emf_f \quad \text{(Eq. 4)}$$

where, ES_f is the quantify of fuel f saved due to energy efficiency improvements (in tonnes) in the EU, and emf_f is a default CO_2 emission factor for fuel f. In this analysis we do not consider the indirect CO_2 emissions from power and heat generation processes.

Avoided air pollution

Like the impact above, the avoided air pollutants (NO_x, SO_x, PM2.5, PM10, and CO) generated from the combustion of fuels can be calculated by multiplying the fuel savings with the default emission factor per fuel. The formula is:

$$P_{saved,k,j} = \sum_f ES_{f,j} * emf_{k,f} \quad \text{(Eq. 5)}$$

where, $P_{saved,k,j}$ is the amount of pollutant *k* saved in country *j* (in ktonnes), $ES_{f,j}$ is the quantity of the fuel *f* saved in country *j*, and $emf_{k,f}$ is the default emission factor for fuel *f* and pollutant *k*. Indirect pollutant emissions from heat and power generation are not calculated. Data on emission factors are taken from EEA's Guidebook on the fuel combustion in manufacturing processes (EEA, 2016). For more accurate results however, and when technology stratified production data are available, a Tier 2 instead of Tier 1 method should be used.

2.1.2 Social impacts

Social impacts are the direct impacts of EE improvements, both positive and negative, on people's quality of life, health, work, and environment. Here we focus on the health and well-being.

Health and well-being

When fuel combustion reduces due to energy efficiency improvements, less pollutants are released into the atmosphere. We focus on two pollutants. The fine particles, particles with a diameter of less than 2.5 μikrometers (PM2.5), and the NOx emissions, both of which have serious health impacts, especially the PM2.5.

The health impacts are estimated in the form of avoided premature deaths related to the reduction of NOx and PM2.5. The decrease in emissions due to EE will result in a decrease in pollutant concentrations into the atmosphere (in µg/m3) and thereby less avoided deaths. EEA reports the concentration of these two pollutants and the resulting deaths per 1,000 inhabitants in each EU country (EEA, 2020). To calculate the avoided deaths per country the following formula is used:

$$AD_{k,j} = PC_{k,j,Frozen\ efficiency} * DR_{k,j} - PC_{k,j,EE\ efficiency} * DR_{k,j} \quad \text{(Eq. 6)}$$

where, $AD_{k,j}$ are the avoided deaths from the reduction in pollutant *k* in country *j*, $PC_{k,j,Frozen\ efficiency}$ is the concentration of pollutant *k* in country *j* in the frozen efficiency scenario (in µgr/m^3), and $DR_{k,j}$ is the rate of the number of deaths per concentration level of pollutant *k* in country *j*. $PC_{k,j,EE\ efficiency}$ is the pollutant concentration in an energy efficiency scenario.

It must be noted that this approach is only suitable for small changes in air pollution concentration, where a linear relationship can be assumed with avoided deaths. Since industry only accounts for a share of the total air pollution emissions and the energy efficiency only reduces a small to moderate share of these emissions, this approach can be considered suitable here.

The concentration of pollutant *k* in country *j* ($PC_{k,j}$) due to fuel combustion in industries can be calculated from the sum of pollutants released from each type of fuel burned divided by the applied air volume. The formula is:

$$PC_{k,j} = \sum_f FQ_{f,j} * (AV_{k,j})^{-1} \quad \text{(Eq. 7)}$$

where, $FQ_{f,j}$ is the quantity of fuel *f* consumed in country *j*. $AV_{k,j}$ is a fixed value of the applied air volume (in 10^9 m^3) of country *j* and pollutant *k* deriving from EEA Tables (by dividing the absolute pollutants, PM2.5 and NOx with the observed concentration level of each pollutant) (EEA, 2020).

This formula gives a rough indication of pollutant concentrations and for better estimates models should be used that take into account factors such as specific plant locations, wind speeds and rainfall.

2.1.3 Economic impacts

The adoption of EE measures can have macroeconomic impacts. It can for example improve competitiveness and boost the economic activity, lead to increased employment, and reduce energy prices.

Turnover of EE goods

The wide investment in implementing energy efficiency measures may promote innovation in this field and may offer additional economic benefits to the country. The turnover of energy efficiency measures/technologies can be calculated by multiplying the energy savings offered by all technologies with the corresponding investment cost made. The formula is:

$$TO_j = \sum_{tech} ES_{tech,j} * Inv_{tech} \qquad \text{(Eq. 8)}$$

where, TO_j is the turnover of energy efficiency goods in country *j*, $ES_{tech,j}$ is the energy savings a certain technology can offer in country *j*, and Inv_{tech} is the investment required (in €/GJsaved) in offering the energy savings. Both the $ES_{tech,j}$ and $Inv_{tech}$where estimated in Deliverable 3.6 (Kermeli and Crijns-Graus, 2020).

Impact on GDP

The GDP by industry is the contribution of the industrial sector to the overall GDP of the country. The industry GDP is also referred to as gross industrial value added (GVA) and it is equal to the difference between the gross output (e.g. product sales, other incomes) and cost of all inputs (e.g. raw materials, energy, and purchased services). To account for the impact on industrial GDP due to the reduction in energy costs the following formula is used:

$$GVA_j^1 = GVA_j^0 + \sum_{c} ES_{c,j} * p_c \qquad \text{(Eq. 9)}$$

where, GVA_j^0 is the gross valued added of the industry in country *j* without and GVA_j^1 with EE improvements. $ES_{c,j}$ are the energy savings of energy carrier *c* in country *j* and p_c the price of the energy carrier *c*.

Please note that a positive impact on GDP is only achieved if cost-effective energy-efficiency (EE) measures are implemented. For larger EE changes, that also include EE effects with additional net costs, a more sophisticated approach needs to be adopted (e.g. Input-Output tables or macro-economic models), as the relationship between EE and GVA is non-linear.

Employment effects

The wide employment of EE measures can impact employment primarily by the following two mechanisms: i) investments in EE measures and technologies that can increase the employment in industries that supply the EE technologies and, ii) energy reductions that can decrease the employment in energy suppliers and distributors (Reuter et al., 2020). Another indirect impact can be related to the increased disposable income, in case the EE measures are cost-effective, that could be invested into productivity expansions and increases in employment. Studies have shown (Laitner, 2013; Wei et al., 2010), that EE improvements could likely lead to a net increase in the level of employment. According to Cambridge Econometrics (2015), 0.07-0.27 jobs are generated per GWh saved due to EE in the industry sector, or when related to investments, about 9-11 jobs per million Euros invested. In a more recent study, IEA (2020), it was estimated that about 10-18 jobs are created per million dollars invested in EE.

In this analysis we follow a simple approach for calculating the impact of EE on employment (AE_j) in country *j*, based on the formula:

$$AE_j = TO_j * 13\, jobs/m\$ \qquad \text{(Eq. 10)}$$

where, TO_j is the investment on EE measures in country j, and 13 is a fixed number of the jobs generated per 1 million € invested in EE according to the latest literature.

Please note that this is a simple approach that ignores nonlinearities and is especially sensitive to the balance of cost effective versus non cost-effective EE measures.

Potential impact on energy prices

The wide adoption of EE measures will reduce the energy purchases, and since energy markets are characterised by an increasing supply curve, when energy demand would fall the energy prices should also fall. Energy efficiency can also enable lower energy prices by reducing the need to add expensive new power generation or transmission systems, pressure on energy resources and GHG emissions. In a U.S. study, a 1% reduction in gas demand from EE was found to be generally associated with a 1–1.5% reduction in gas prices (Chernick and Plunkett, 2014). As most energy sources (such as oil) are global commodities; change in demand in only one country or one sector is not expected to have an impact on energy prices. It would thus, make sense to make this analysis on an EU level, considering all end-use sectors. The formula that can be used is the following (Reuter et al., 2020):

$$\frac{(p_{c,2} - p_{c,1})}{p_{c,1}} = n_c * \frac{(Q_{c,2} - Q_{c,1})}{Q_{c,1}} \qquad \text{(Eq. 11)}$$

where, $p_{c,1}$ and $p_{c,2}$ represent the energy prices of energy carrier *c* before and after the EE, respectively. $Q_{c,1}$ and $Q_{c,2}$ represent the total consumption in the EU28 level of the carrier *c* before and after the EE improvements, respectively. While, n_c is the price elasticity for the whole EU.

Impact on public budgets

The public budgets can be affected by EE improvements in several ways. A positive impact would be related to the new jobs created due to EE and thereby by the additional income taxes collected. This can be calculated with the formula:

$$IT_j = AE_j * Inc_j * I_{r,j} \qquad \text{(Eq. 12)}$$

where, IT_j is the additional income tax in country *j*, AE_j are the additional jobs generated in country *j*, Inc_j is the average income of the jobs generated and $I_{r,j}$ the income tax level in country *j*.

Impact on industrial productivity

Improving energy efficiency allows for the manufacture of the same product volumes but at a lower energy use. The energy intensity for product manufacture (in GJ/tonne) decreases reducing thereby the company's energy expenditures. This will influence the productivity expressed as added value per unit of energy consumed (Reuter et al., 2020). The impact on industrial productivity (ΔP_i) in a certain country can be calculated from the formula:

$$\Delta P_j = P_j^1 - P_j^0 = \frac{GVA_j^1}{FEC_j^1} - \frac{GVA_j^0}{FEC_j^0} = \frac{GVA_j^0 + \sum_c ES_{c,j} * p_c}{FEC_j^1} - \frac{GVA_j^0}{FEC_j^0} \qquad \text{(Eq. 13)}$$

where, P_j^1 is the industrial productivity for country *j* with EE and P_j^0 without EE. GVA_j^1 is the valued added of the industry in country *i* with and GVA_j^0 without EE. FEC_j^1 is the final energy consumption in country *i* with and FEC_j^0 without EE. Lastly, p_c is the energy price of energy carrier *c*. The impact on productivity is reported in million euro per peta joule [M€/PJ].

Impact on energy security

EE improving measures can help countries limit their reliance on other countries for energy avoiding in this way possible disruptions and thereby increasing their energy security. The impact of EE on energy security (ΔID_j) in country *j*, can be calculated with the formula (Reuter et al., 2020):

$$\Delta ID_j = ID_j^0 - ID_j^1 = \left(\frac{net\ imports}{GTFEC_j + bunkers_j}\right) - \left(\frac{net\ imports}{GTFEC_j + bunkers_j + PES_j}\right) \qquad \text{(Eq. 14)}$$

where, ID_j^0 and $ID_j^1$is the import dependency in country *j* before and after the EE, respectively. $GTFEC_j$ is the gross total final energy consumption and PES_j the primary energy savings in country *j*.

Table 2 shows which results on non-energy impacts will be presented in this Deliverable (as part of the work in WP3).

Table 2 Non-energy impacts calculated in this analysis

#	Non-energy impacts	**Results presented in:**
1	Energy savings	WP3 (this report)
2	Savings of fossil fuels	WP3 (this report)
3	Impacts on RES targets	possibly WP6
4	GHG savings	WP3 (this report)
5	Air pollution	WP3 (this report)
6	Health and well-being	WP3 (this report)
9	Turnover of EE goods	WP3 (this report)
10	Impact on GDP	WP3 (this report)
11	Employment effects	WP3 (this report)/WP6
12	Potential impact on energy prices	possibly WP6
13	Impact on public budgets	possibly WP6
14	(Industrial) productivity	WP3 (this report)
15	Energy security	possibly WP6

2.2 Industry/Measure specific

For the individual non-energy impacts, who as explained earlier are industry and measure specific, we follow a different approach. Here, we identify all the non-energy impacts of industry specific measures[1] mentioned in main technical reports and also list available data on the impact level. We focus on the non-energy impacts that would affect the operational costs of industries, such as increased productivity, change in materials/inputs needed, and lower emissions that could translate into reduced pollution control. With extra data to fill the gaps and additional analysis, the cost impacts could be integrated in the Cost of Conserved Energy (CCE) calculations to check the impact on profitability.

The clustering of non-energy impacts is based on Worrell et al. (2004) (see Table 3). Only differences are that we include recycling and efficient use of waste or by-products in the Waste group. And we also present the material reduction in a separate column.

Table 3 Additional benefits of energy efficiency (Worrell et al., 2004)

Waste	Emissions	Operation and Maintenance
Use of waste, fuels, heat, gas	Reduced dust emissions	Reduced need for engineering controls
Reduced product waste	Reduced CO, CO2, NOx, SOx emissions	Lowered cooling requirements
Reduced wastewater		Increased facility reliability
Reduced hazardous waste		Reduced wear and tear on equipment/machinery
Materials reduction		Reduction in labour requirements
Production	**Working environment**	**Other**
Increased product output/yields	Reduced need for personal protective equipment	Decreased liability
Improved equipment performance	Improved lighting	Improved public image
Shorter process cycle times	Reduced noise levels	Delaying or reducing capital expenditures
Improved product quality/purity	Improved temperature control	Additional space
Increased reliability in production	Improved air quality	Improved worker morale

[1] The non-energy impacts of EE improvements on cross-cutting equipment such as motors, pumps and fans are not addressed.

3 Results

Here, we present the results in two sections. Section 3.1 shows the environmental, social, and economic impacts of Energy Efficiency measures in the EU28 industry. The results are calculated, in most cases, per EU country and industrial sector. Section 3.2 shows the main impacts industry specific energy efficiency measures can have on two industrial sub-sectors, the iron and steel and the cement industries. Where possible, these technology/measure specific impacts are quantified.

As mentioned in Section 2: Methods and approach, there are a number of limitations to the indicators used. The results mentioned here should therefore be interpreted with caution and seen as rough indications. Without more detailed study and enhanced approaches, few hard conclusions can be drawn as to the comparison of the NEBs in terms of their importance. However, the results in terms of industrial sub-sector comparisons are more reliable, which will be highlighted in Section 4: Discussion and conclusion.

3.1 Results on environmental, social, and economic impacts

The results presented in these following paragraphs are calculated using the methods described in Section 2.1.

3.1.1 Results on environmental impacts

Figure 1 shows the final energy demand in the EU28 per industrial sub-sector in the base year (2015) and in 2030 and 2050 under two scenarios: a frozen efficiency scenario and an energy efficiency scenario (BAT with high recycling). The energy savings potentials are calculated at 1,630 PJ in 2030 and they increase to 3,300 PJ in 2050.

As shown in Figure 2, most savings are achieved in the production of pig iron (697 PJ), cement (228 PJ), rolled steel (67 PJ), primary aluminium (39 PJ), ammonia (38 PJ) and ethylene (36 PJ). In certain sub-sectors the energy demand increases, driven by increased activity as compared to the Frozen Efficiency scenarios due to the higher recycling levels. Such an industry is the steel making from scrap industry (EAF steel) where the energy use is 27% higher compared to the Frozen Efficiency scenario.

The countries with the most energy savings are Germany, France, the UK, Italy, and Spain.

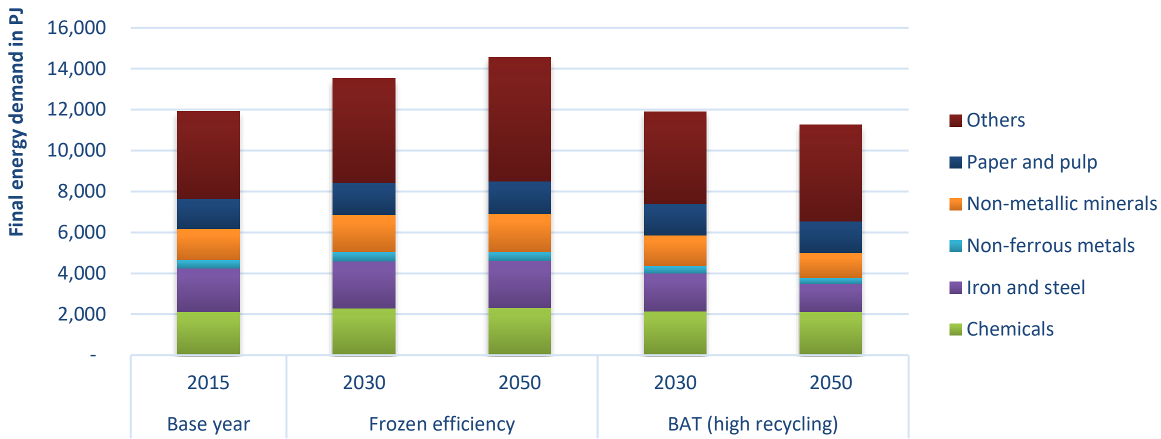

Figure 1 Final industrial energy demand in the EU28 in a frozen efficiency and in an energy efficiency scenario (Kermeli and Crijns-Graus, 2020)

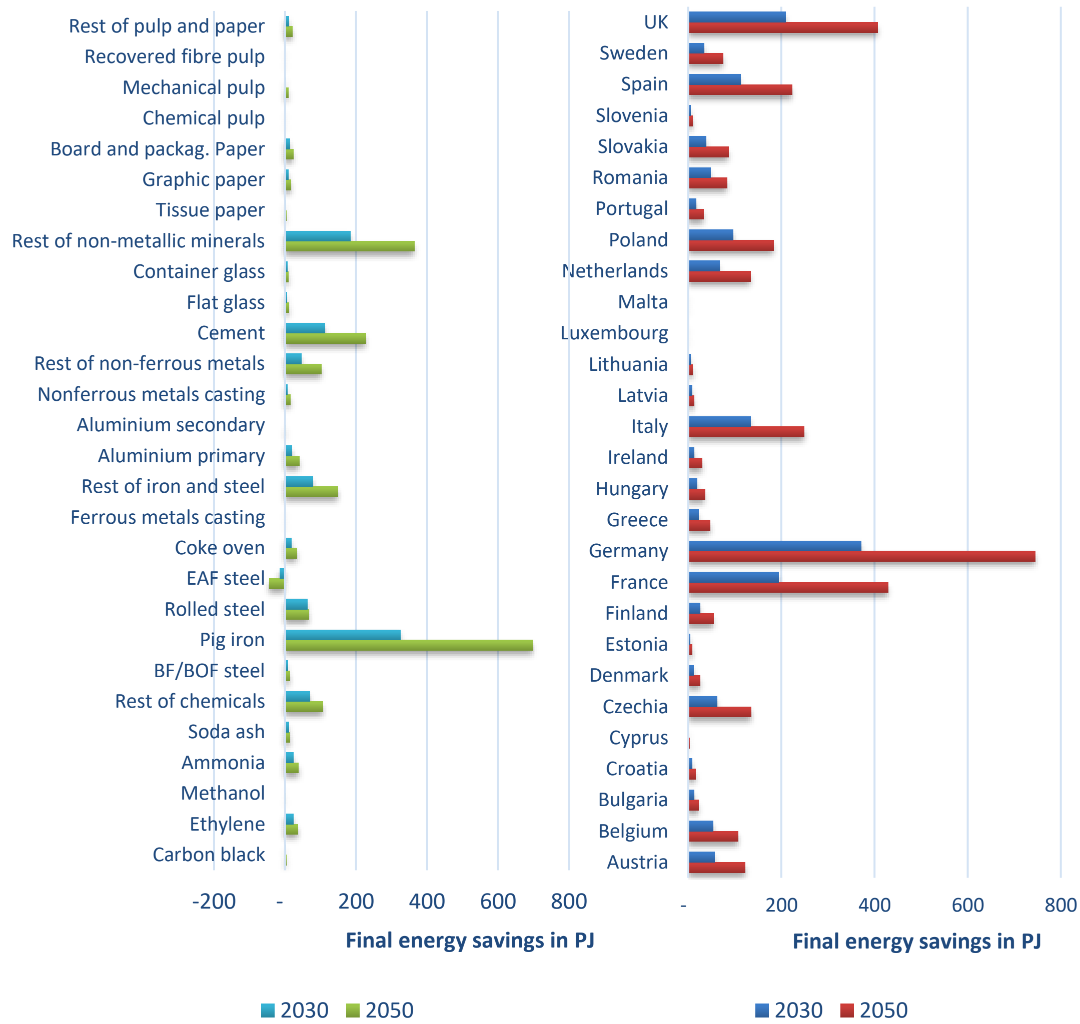

Figure 2 Final energy savings from energy efficiency improvements and increased recycling per industrial sub-sector (left figure) and per EU country (right Figure)

About 85% of the total final energy savings are fuel savings with the rest being electricity savings. Fuel consumption decreases by about 1,400 PJ in 2030 and 2,800 PJ in 2050. This is translated into 54 Mtonnes of fuel saved in 2030 and 111 Mtonnes of fuel saved in 2050. Figure 3 shows the avoided fuel consumption per type of fuel. About 50% of the avoided fuel used is coal, 22% is natural gas, 15% biofuel and waste, 10% oil products, and 4% heat.

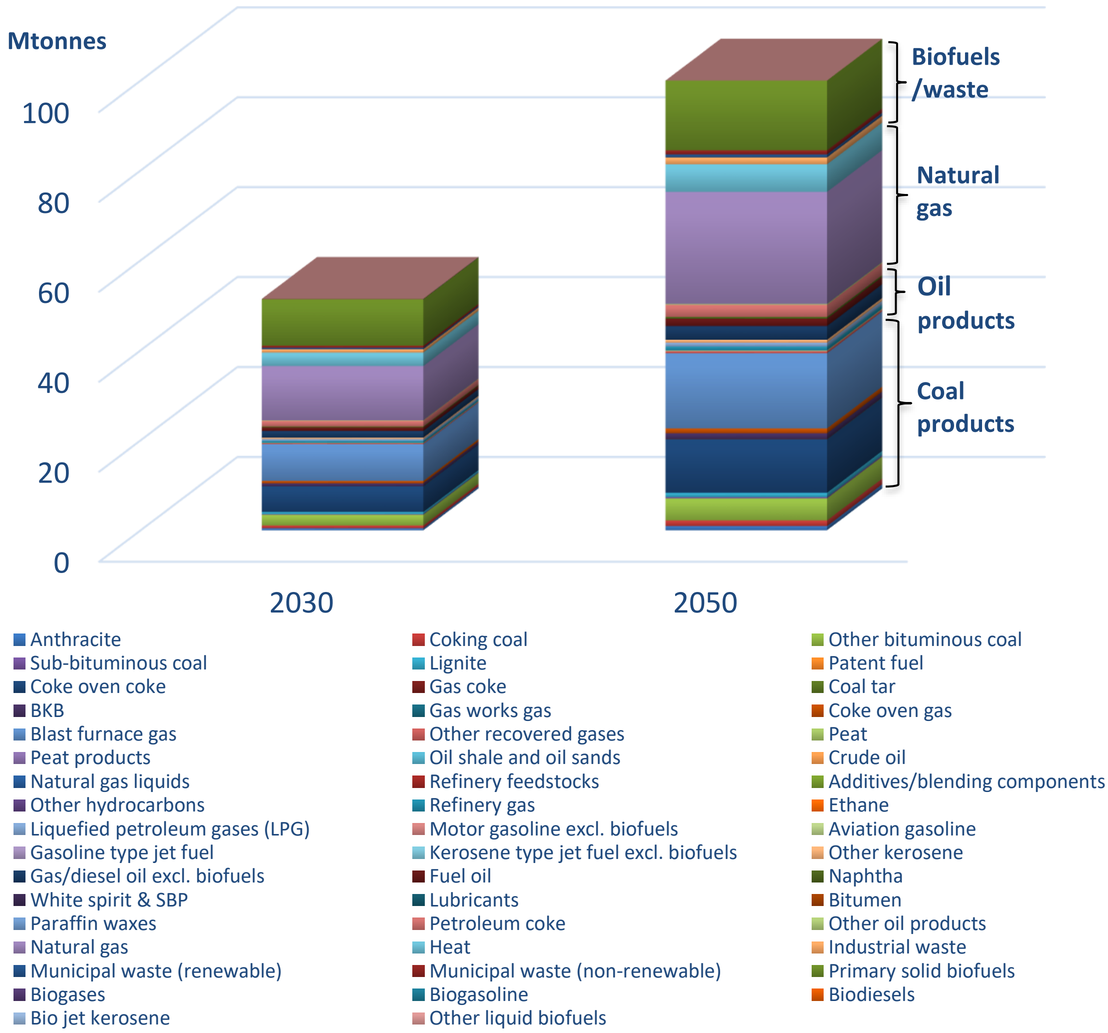

Figure 3 Fuel consumption avoided in the EU28 from energy efficiency improvement measures, plus increased recycling.

Figure 4 shows the savings in fuel used in the industrial sector per EU country. Most savings are identified for Germany and follow France and the UK.

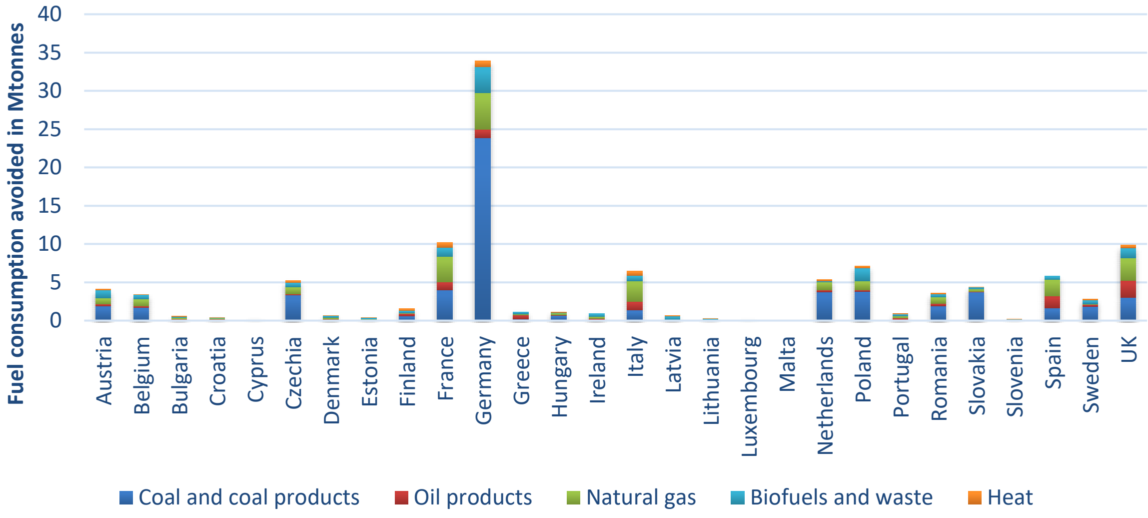

Figure 4 Fuel consumption avoided er EU country from energy efficiency improvements and increased recycling

Figure 5 shows the CO_2 emissions (from energy combustion) in the different scenarios (Johannsen et al., 2020). The CO_2 emissions that can be saved in 2050 from increased EE and recycling are estimated at about 60 Mtonnes.

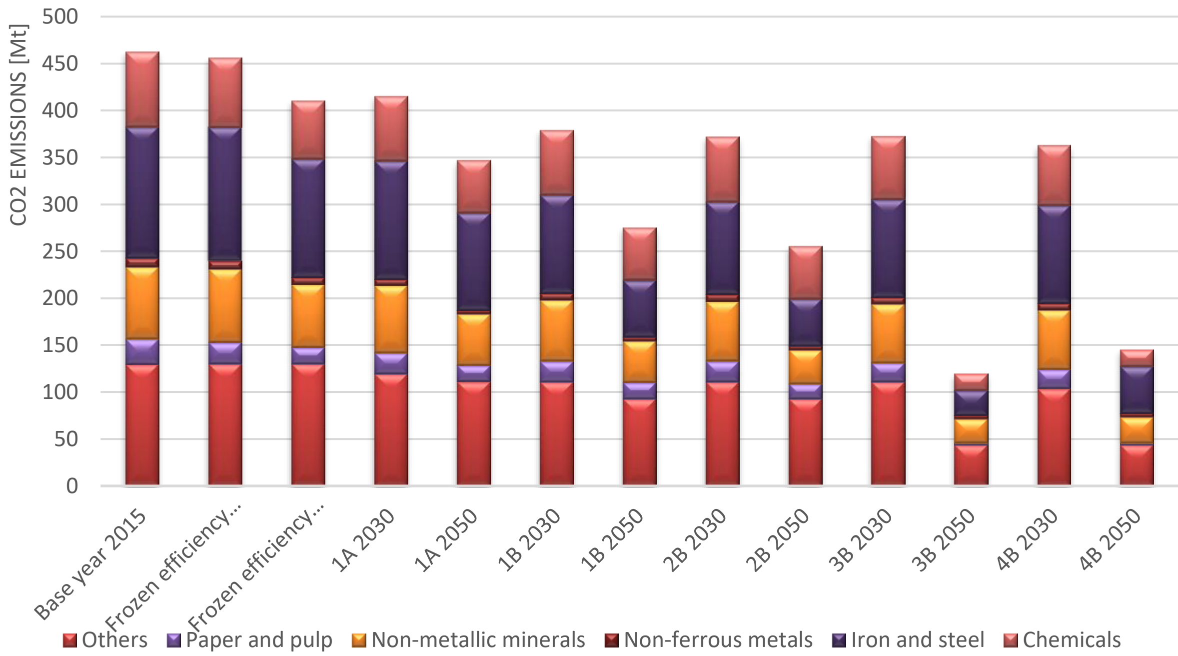

Figure 5 CO_2 emissions in the different scenarios in IndustryPLAN (scenarios 1A: BAT with no extra recycling scenario, 1B: BAT with extra recycling scenario, 2B: BAT with extra recycling and innovative EE technologies, 3B: electrification scenario, 4B: hydrogen scenario) (Johannsen et al., 2020)

The air pollutants released during the combustion of fuels in industries are estimated to increase if no energy efficiency improvements are adopted. Figure 6 shows the level of emissions from fuel combustion in the EU industries in the base year and the emission development when energy efficiency measures are adopted and when not. It is calculated that the 2050 CO emissions could decrease by about 1,000 ktonnes, SOx emissions by about 790 ktonnes, NOx by about 400 ktonnes, PM10 by about 140 ktonnes and finally PM2.5 by about 130 ktonnes.

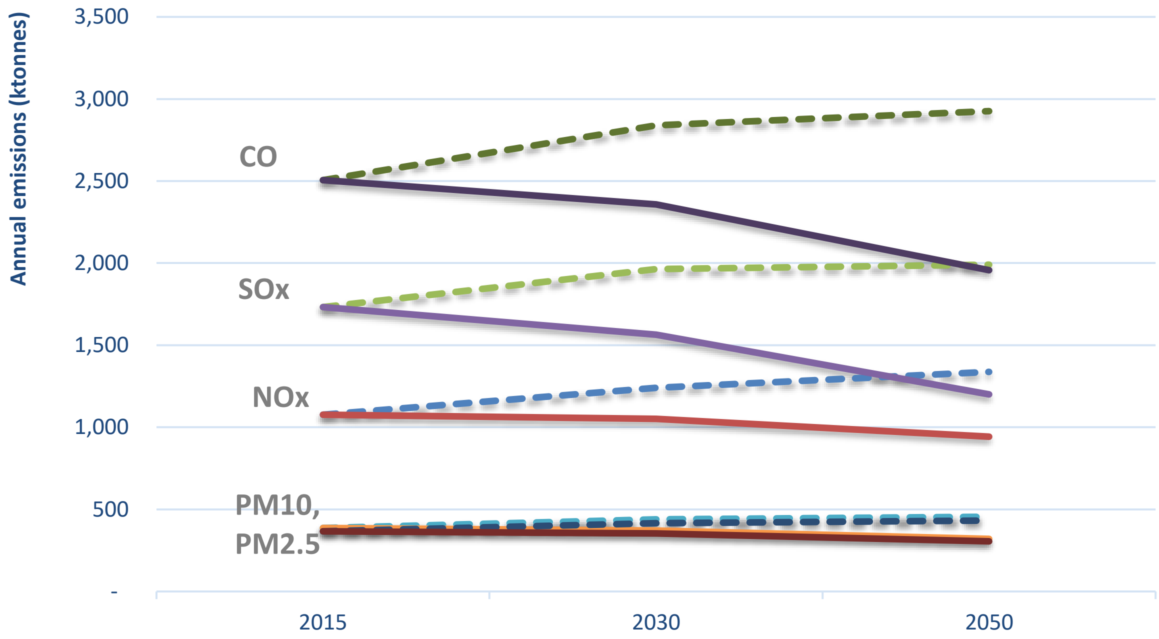

Figure 6 Emissions generated by the EU industry when energy efficiency improvements are adopted (normal lines) and without energy efficiency improvements (dashed lines)

Most of the Sulphur oxide savings take place in the iron and steel industry (see Figure 7). This is because SOx emissions depend on the Sulphur content in fuels (it is the highest in coal 900g/GJ). In the case of Nitrogen oxides, energy efficiency measures in sectors with not such a heavy reliance on coal, but on other fuels such as oil are responsible for most of the pollution savings. Again, most PM emission savings are highest in the iron and steel industry (again the PM emission factor is higher for solid fuels and biomass).

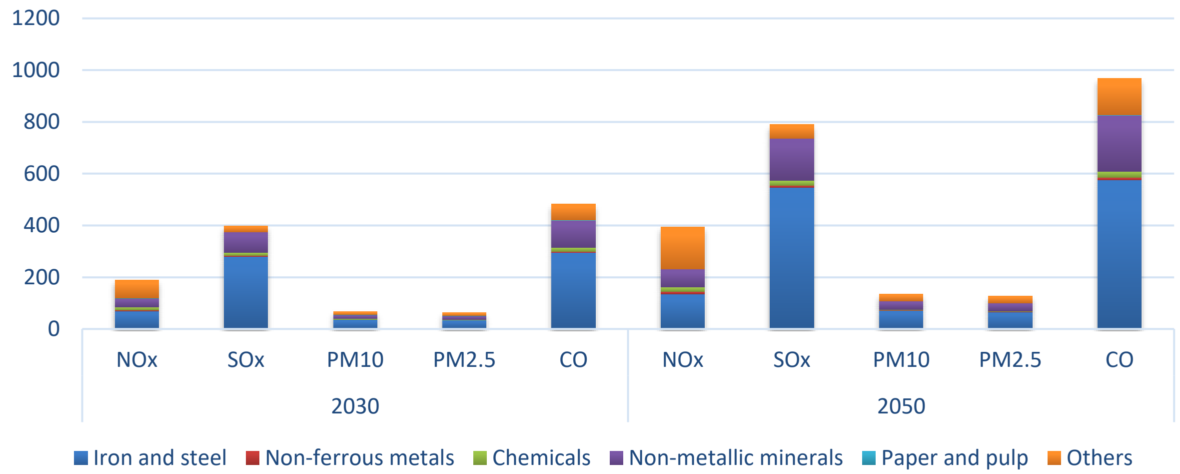

Figure 7 Emissions avoided due to energy efficiency improvements and increased recycling in the EU industry

3.1.2 Results on social impacts

Regarding the social impacts of energy efficiency, we addressed in this analysis the number of avoided deaths from decreased pollution. We focused on two pollutants, PM2.5 and NOx that are generated from burning fuels in industries. Improvements in energy efficiency will decrease the fuel use and pollution, indirectly decreasing the number of deaths associated with these pollutants. It is estimated (see Figure 8) that the wide of adoption of energy efficiency measures and recycling in 2050 will prevent 48,000 and 2,700 premature deaths due to the avoided PM2.5 and NOx emissions, respectively.

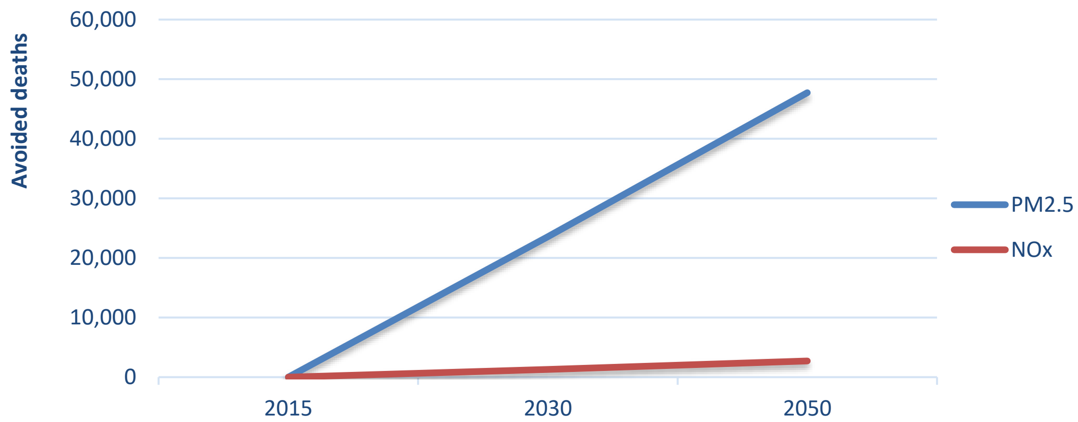

Figure 8 Number of prevented deaths from improvements in energy efficiency and increased recycling

The number of deaths depends on the activity of the industrial sub-sectors, the types of fuels used and the country population density. Certain fuels, such as coal are high on PM2.5 and PM10. This means that countries with industries relying heavily on coal will have more particulate matter released.

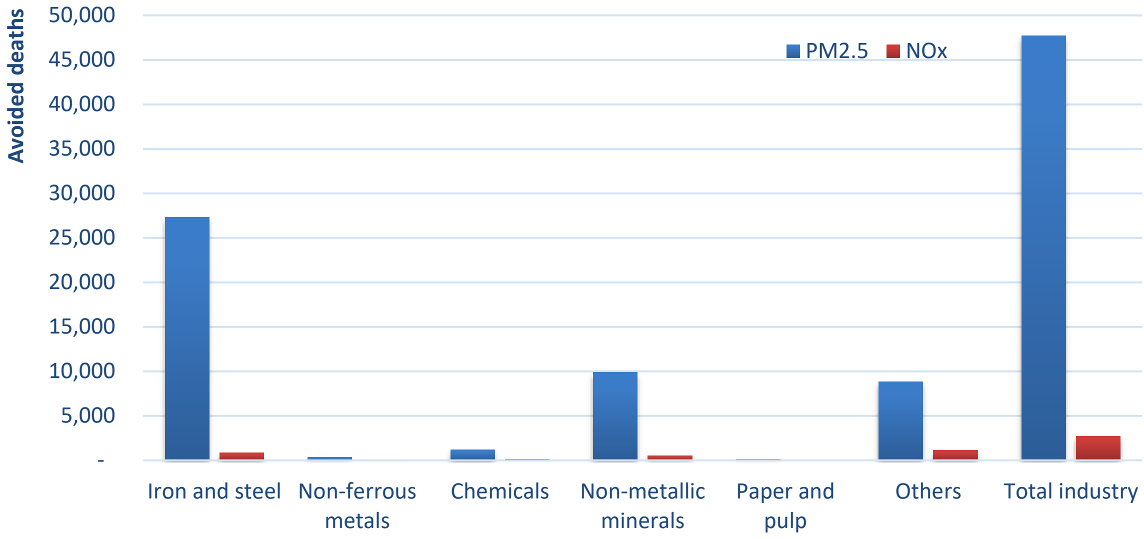

Figure 9 Avoided deaths due to the lower PM2.5 and NOx emissions from increased energy efficiency and recycling per EU industrial sector

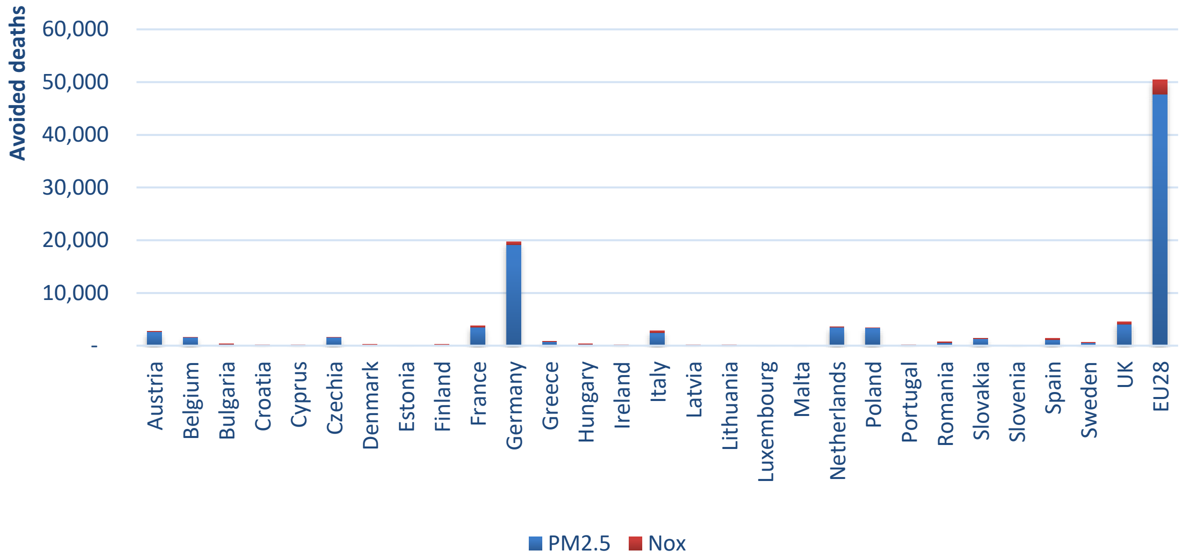

Figure 10 Avoided deaths due to the lower PM2.5 and NOx emissions from increased energy efficiency and recycling per EU country

Boundaries play a role. The EEA that reports PM2.5 and PM10 emissions for the EU28, but the coke ovens used in steel making are reported under the energy transformation sector while blast furnaces are mostly under the industrial processes that accounts for emissions from industrial processes but not from fuel combustion.

3.1.3 Results on economic impacts

In this section we present two economic impacts of energy efficiency improvements.

The annual turnover with energy efficiency measures for different industrial sub-sectors in the EU28 is shown in Figure 11. The turnover in 2030 and 2050 is estimated at 16,400 M€ and 29,011 M€, respectively, generating a total turnover for the energy efficiency improvements identified at 45,500 M€. The turnover is the highest for the cement industry. This is because the Investment for a couple of measures (e.g., addition of precalciner) is high but also the energy savings potentials are high.

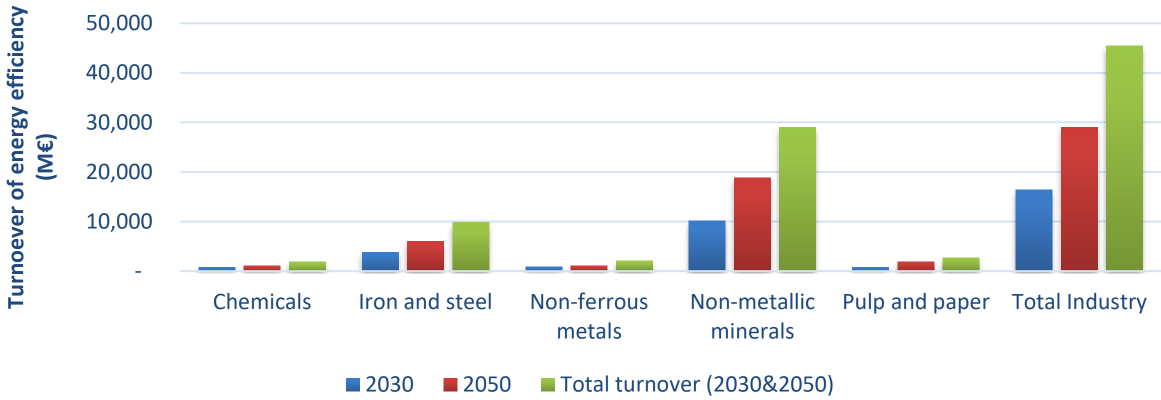

Figure 11 The turnover of energy efficiency per industrial sub-sector in the EU28 for 2030, 2050, and the total turnover (2030&2050)

Figure 12 shows the impact of energy efficiency on the economic growth of each EU country and in the EU28. In 2050, the GDP is estimated to increase by 0.6% in 2030 (from 2,160 to 2,175 bln€) and by 1.0% in 2050 (from 2,665 to 2,690 bln€). In 2050, the greatest absolute increase in industrial GDP is identified for Germany (0.8% growth), France (1.1% growth), UK (1.4% growth), Italy (0.7% growth) and Spain (0.9% growth). The industrial sub-sectors that achieved the greatest share of additional economic growth are the Others sector (50%), the non-metallic minerals (20%), the iron and steel (12%), the chemicals (8%), the non-ferrous metals (6%), and the paper and pulp (4%) sub-sectors.

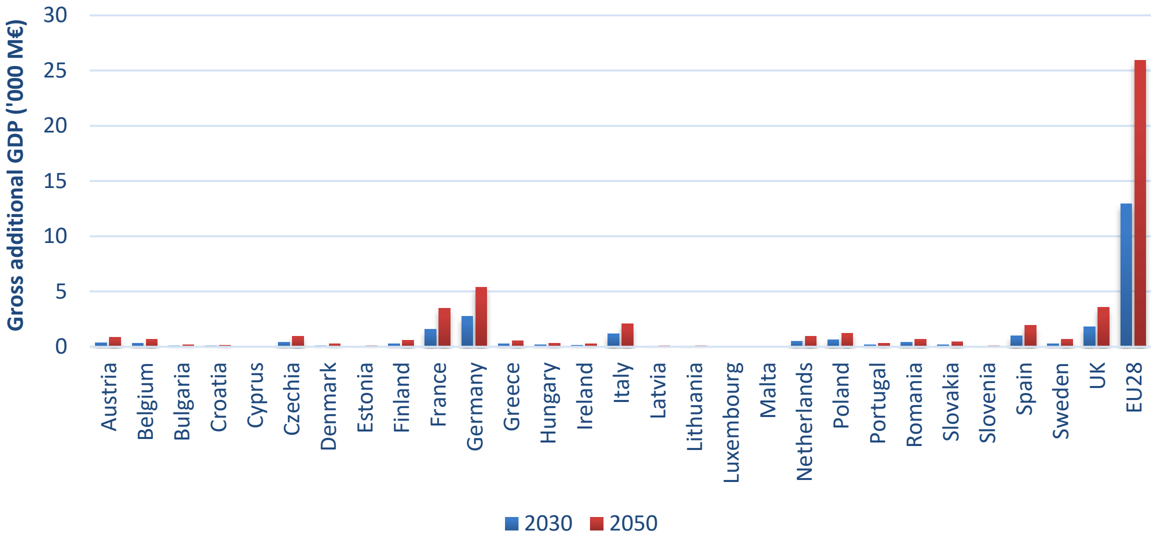

Figure 12 Change on GDP per EU country due to energy efficiency and recycling

The impact on industrial productivity is shown in Figure 13 and in Figure 14. It is calculated that energy efficiency improvements and recycling will increase industrial productivity in the whole EU industry by 180M€/PJ in 2030 and 240 M€/PJ in 2050. This is an increase of 14% and 30% in 2030 and 2050, respectively.

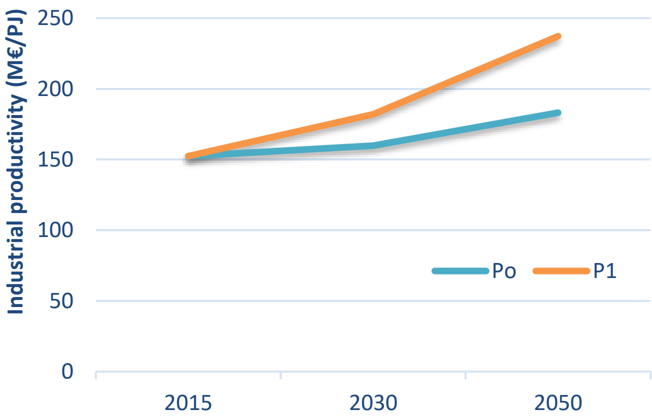

Figure 13 The EU industrial productivity with (P^1) and without energy efficiency improvements (P^0)

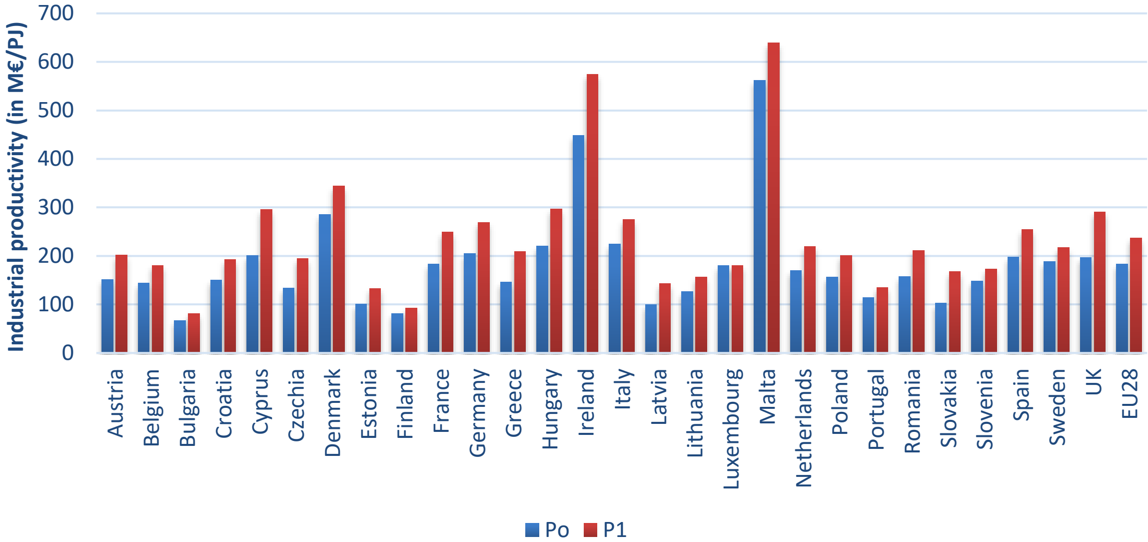

Figure 14 The EU industrial productivity with (P^1) and without energy efficiency improvements (P^0) in the different EU countries

Figure 15 shows that in 2030 EE measures and increased recycling could generate about 200,000 and in 2050 about 380,000 jobs. In 2015 about 34 million people were occupied in the EU28 industry (Eurostat, 2021).

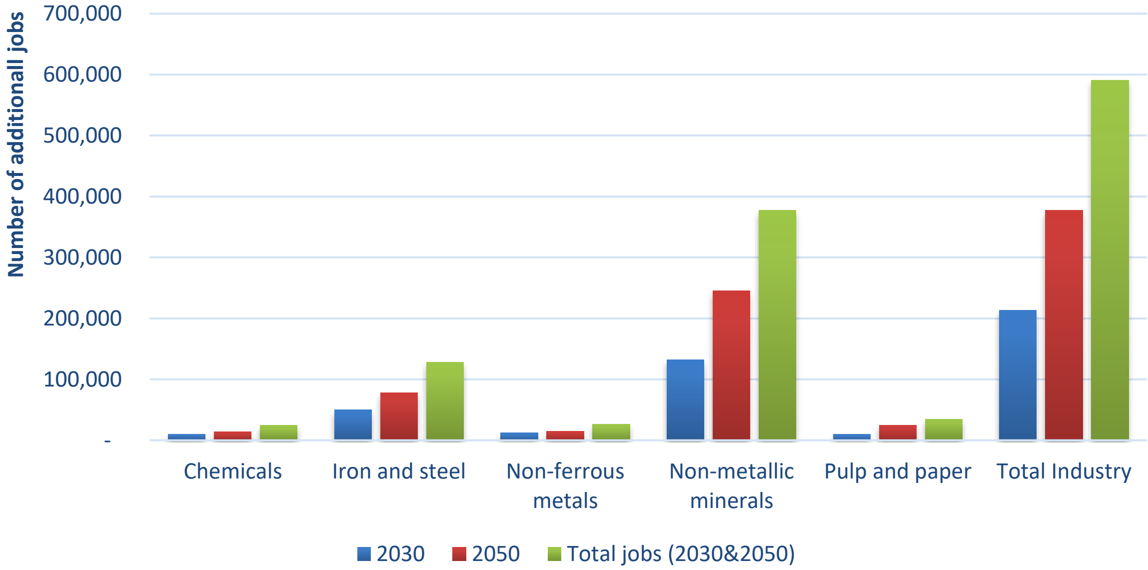

Figure 15 Contributions to additional employment per industrial sub-sector in the EU28.

3.2 Industry/Measure specific results

In this Section we list all the non-energy impacts of EE measures mentioned in main technical reports. Table 4 lists the non-energy impacts for the iron and steel industry and Table 5 for the cement industry.

Table 4 Non energy impacts of energy efficiency measures specific to the iron and steel industry (Worrell et al., 2013b; JRC, 2013a; IIP, 2014)

Measures	Impact on production	Impact on emissions	Impact on operation and maintenance	Impact on waste	Impact on working environment	Impact on materials/inputs	Other impacts
Coke making							
Coal moisture control	- improves productivity (~10%); improves coke quality (1.7%)						
Coke dry quenching		- reduces dust emissions			--> improves the air quality	- decreases the coking coal quality requirements	
Single chamber system	- improves productivity; improves coke quality						
Non-recovery coke ovens		- eliminates air pollution; likely increases NOx emissions	--> reduces the need for coke oven gas and wastewater treatment; increases needs for NOx abatement	- eliminates waste water			
Coke Stabilization Quenching (CSQ) (IIP)	- improves coke quality (coke moisiture~2%)	- reduces dust emissions (down to 6gr/tonne coke)			--> improves the air quality		
Next generation coke making technology	- improves productivity (by up to 240%)	- reduces Nox emissions (by ~30%)	--> decreases the needs for NOx abatement			- flexible in coal resources--> increase in use of non-dust binding coking coal (20-50% share)	
Sintering							
Emission Optimized Sintering		- reduces the off-gases (by 40-65%), minimizes NOx, SOx, CO and CO2 emissions			--> improves the air quality		
Iron making (Blast furnace-BF)							
Improved blast furnace control	- improves productivity						
Injection of Pulverized Coal (PCI)		--> reduces emissions (from reduced coke demand)	- increases the BF maintenance, and the needs for oxygen and coal grinding			- reduces coke demand (up to 3.3 tonnes of coke saved per tonne hot metal)	
Injection of Natural Gas	- improves productivity	--> reduces emissions (from reduced coke demand); reduces CO2 emissions				- reduces coke demand (substituting 0.9 and 1.15 tonne natural gas/tonne coke)	
Injection of Pulverized Oil		--> reduces emissions (from reduced coke demand); reduces CO2 emissions				- reduces coke demand (1 tonne of coke can be replaced with 0.8 tonnes of oil)	

Measures	Impact on production	Impact on emissions	Impact on operation and maintenance	Impact on waste	Impact on working environment	Impact on materials/inputs	Other impacts
Injection of Plastic Waste		--> reduces emissions (from reduced coke demand); increases dioxine emissions	--> increases the needs for flue gas control equipment necessary	- promotes plastic recycling		reduces coke demand (1 tonne of coke can be replaced with 1.3 tonnes of plastic)	
Charging Carbon Composite Agglomerates (CCB)				--> promotes resource recycling		- use of non-coking coal, and iron bearing dust and sludge	
BOF Bottom Stirring (IIP)	- improves yield (decreased slag formation) by 0.5%; improves product quality (lower oxygen and carbon content)		- increases vessel life; extra efforts for maintaining good stirring				
Improved hot stove control			- increase the reliability of the operation; increases stove lifetime				
Improvement of process monitoring and control	- improves productivity						
Improved process control in EAFs	- improves productivity (by 8%); improves yield (by 1-2%)		- reduces refractory wear			'- reduces electrode consumption (by 3.5-16%)	
Scrap preheater	- improves productivity (tap-to-tap times decrease by 10-15 minutes)	- increases dust, dioxin and mercury emissions	--> increases the need for downstream emission abatement		--> deteriorates the air quality		
Increase power	- improves productivity (by 8 tonnes per hr)		- increases refractory wear making cooling needs necessary; higher process stability (electric arc)				
Foamy slag practices	- improves productity						
Oxy-Fuel Burners/Lancing	- improves productity		- reduces electrode consumption; Lowers maintenance costs (there are fewer or no moving parts)				
Post-Combustion of the Flue Gases	- improves productivity (tap-to-tap time reduction of 3-11%)		- reduces baghouse emissions				
Waste Injection in EAFs	- improves productivity			--> promotes resource recycling (e.g., plastic tires)		- decreases the needs for coke and coal (30%)	
Direct Current (DC) Arc Furnaces	- improves productivity					- reduces electrode consumption by 50% (1-2 kg/tonne steel)	
Optimal charge calculation (IIP)						--> decreases scrap needs (by 5-10%)	
Contiarc® Furnace		- reduces waste gas and dust volumes	--> reduces the needs for gas cleaning		--> improves the air quality	- decreases electrode consumption (0.8 kg/t less than a typical AC furnace)	
Comelt Furnace	- improves productivity (tap-to-tap times of less than 45 minutes)	- reduces off-gases			--> improves the air quality; reduces the noise level (by	- decreases electrode consumption (by 30%)	

Measures	Impact on production	Impact on emissions	Impact on operation and maintenance	Impact on waste	Impact on working environment	Impact on materials/inputs	Other impacts
					up to 15 dB(A))		
Tundish Heating	- improves product quality				reduces the noise and heat levels	- increases tundish lifetime lids (90%)	
Near net shape casting	- improves productivity; improves yield (by 95%)		- integration of several production steps			- decreases the needs for consumables (e.g. mould, rolling cylinders)	
Process Control in Hot Strip Mill	- improves yield (rejects decrease from 1.2 to 0.2%); improves productivity (downtime reduces from 50 to 6%)						
Hot Charging	- improves material quality; improves yield; improves productivity (by 6%)					- may reduce slab stocking	
Automated Monitoring and Targeting System		- reduces effluent					
Continuous Annealing	- improves productivity		- integration of several production steps				

- Main non-energy impact
→ side effect of the non-energy impact

Table 5 Non-energy impacts of energy efficiency measures specific to the cement industry (Worrell et al., 2013a; JRC, 2013b; IIP, 2014)

Measures	Impacts on production	Impact on emissions	Impact on O&M	Impact on waste	Impact on working environment	Impacts on inputs needed or "Impact on materials"	Other impacts
Raw material preparation							
Use pneumatic conveyors	- possibly increases productivity (due to lower downtime)		- increases reliability; reduces wear; decreases the needs for dedusting (by 60%)		--> improves air quality		
Homogenizing	-increases productivity (by 5%)						
Advanced raw meal grinding	-increases productivity; increases raw meal fineness		- can combine grinding, drying and separation; improves flexibility by allowing larger mass flow rate variations (30-100% mill capacity)				
Separate raw meal grinding	- improves product quality		- improves flexibility				
Pre-grinding to ball mills	- increases productivity (50-100%)						
Raw meal process control	- increases productivity (6-8%)						
Vibration control in vertical mills	- increases productivity		- decreases disruptions				
High efficiency classifiers	- improves productivity (up to 15%); improves product quality						
Fuel preparation							
Efficient mills			- reduces the need for pre-crushing; improves flexibility (can manage fuel variations)				
High efficiency classifiers for coal grinding	- improves productivity						
Clinker production							
Process Control	- improves product quality (e.g., grindability, reactivity); improves productivity (2.5-5%)	- decreases Nox emissions	- helps stabilze kiln operation; helps stabilize the use of alternative fuels; decreases the needs for NOx abatement			- increases refractory life (5-100%)	
Process control clinker cooler	- improves productivity (10%); improves product quality (free lime reduces by 30%)	- decreases Nox emissions (20%)	--> decreases the needs for NOx abatement				
Kiln combustion system improvements	- improves productivity (by 5-10%)	- decreases Nox emissions (30-70%)	--> decreases the needs for NOx abatement				
Mineralized clinker	- could negatively affect product quality	- decreases NOx emissions (10-50%) and kiln dust	--> decreases the needs for NOx abatement; '- improved kiln operation			- increases refractory life; allows the use of fuels with high sulfur content	

D3.7 Non-energy impacts of EE in the industry sector

Measures	Impacts on production	Impact on emissions	Impact on O&M	Impact on waste	Impact on working environment	Impacts on inputs needed or "Impact on materials"	Other impacts
Indirect firing	- improves productivity (5-10%)	- reduces NOx emissions	- flame optimization (good operation varying fuel mixes); decreases the needs for NOx abatement				
Oxygen enrichment	- improves productivity (25-50%)	- increases Nox emissions	--> increases the needs for NOx abatement; increases the refractory wear/damage			- allows the use of fuels with low calorific value	
Mixing air technology		- decreases SO2 and NOx emissions	- improves kiln stability; fuel substitution can increase by 4-15%; decreases the needs for NOx abatement				
Kiln shell heat loss reduction			-improves kiln reliability; reduces kiln start ups				
Conversion to efficient clinker cooler	- improve productivity (20%)						
Upgrade clinker cooler	- improve productivity (4%)	- could increase emissions	- reduces maintenance				
Low Pressure Drop Cyclones	- improve productivity (3%)		- could increase the dust carry over				
Convert dry kilns to multistage preheater kilns	- improves productivity (up to 50%)						
Cement Suspension Preheater Calcining Technology with High Solid-Gas Ratio	- improves productivity	- decreases the NOx and SO2 contents in the exhaust to less than 200 ppm and 50 ppm, respectively	--> decreases the needs for gas treatment				
Add preheater stages	- improves productivity (3%)						
Add precalciner	- improves productivity (80-100%)	- reduces Nox emissions (45%)	--> decreases the needs for NOx abatement				
Long dry to preheater/precalciner	- improves productivity (40%)						
Finish grinding							
Process control	- improves product quality (lower deviation, increased strength, product Blaine); improves productivity (3-9%)						
Replace ball mills with vertical roller mills	- increase product fineness; decreases quality (higher particle variations)						
Use High-Pressure Roller Presses With/Without Ball Mills	- improves productivity (100%)						
High pressure roller press as pre-grinding to ball mill	- improves productivity (30%)					- allows for increased use of clinker substituting materials	- requires less space (30%)
High efficiency classifiers	- improves product quality; improves productivity (10-25%)		- increases operation reliability				
Improved grinding media			- reduces wear				

Measures	Impacts on production	Impact on emissions	Impact on O&M	Impact on waste	Impact on working environment	Impacts on inputs needed or "Impact on materials"	Other impacts
Clinker flow regulator			- reduces wear				
Product changes							
Blended cements	- affects product quality (typically higher long-term strength and lower short-term strength)	- decreases NOx, SO2, CO2 and PM emissions	- increases grinding needs, and possibly handling and drying of clinker substitutes			- contributes to the effective utilization of by-products generated in other industries (e.g., fly ash and blast furnace slag)	
Limestone Portland cement		- decreases NOx, SO2, CO2 and PM emissions					
Feedstock changes							
Use of steel slag	- improves productivity (5%)	- decreases NOx emissions (9-60%); decreases process CO2 emissions					
Use of cement kiln dust	- improves productivity (2%)	- decreases process CO2 emissions	- alkali compounds can negatively affect the kiln operation making CKD treatment necessary	- decreases CKD disposal needs			
Reduce the lime saturation factor	- at shares higher than 10% decreases product quality (low early strength and slow setting times)	- decreases process CO2 emissions	--> the decrease in product quality can be restricted with increased grinding			- reduces the use of limestone or allows the use of materials with a lower limestone content; the decrease in product quality can be restricted with the use of additives	

- Main non-energy impact
→ side effect of the non-energy impact

4 Discussion and conclusion

This analysis addressed only the non-energy impacts of EE from the implementation of best available technologies (BATs) and increased recycling. Innovative measures needed to be widely implemented in the coming years to achieve the decarbonisation targets, can also achieve significant energy savings (Kermeli and Crijns-Graus, 2020). However, the non-energy impacts from innovative measures has not been assessed here.

Only the non-energy impacts from final energy savings were assessed. However, reducing electricity use through increased energy efficiency will further reduce fossil fuel consumption in power plants and would thereby result in additional non-energy benefits, in reduced pollution and associated deaths for example.

The increase of industry GDP (industrial value added) was estimated from the reduction in energy costs. However, a country's GDP could also increase from the increased productivity that some EE also offer, but also from the increased activity in industries producing the EE technologies, and maintaining the technologies.

For the estimation of the CO, NOx, SOx, PM2.5 and PM10 pollutants avoided, a Tier 1 method was used, which was based on energy consumption data and default emission factors per energy carrier. The emission factors used are considered representative to the fuel combustion in industrial facilities and they differ from the ones for the fuel combustion in power plants. For more accurate results, a Tier 2 or 3 method should be used that considers the types of technologies employed in the different industries and that also takes into account the level of pollution control. Comparing our results for the total EU industry to the emission data reported from EEA (after excluding the energy used in coke ovens as in EEA the emissions from coke ovens are reported in the transformation sector) our estimates are about 39% higher on PM2.5 emissions, 27% lower on PM10 emissions, 1% lower for NOx emissions, 127% higher for SOx emissions, and 50% lower on CO emissions. In this analysis we used fixed emission factors per fuel type. In reality however the emissions generated will depend on the fuel quality (e.g. low sulphur coal will release significantly less SOx emissions), the combustion conditions and the reactions between raw materials and fuel. This is the reason a Tier 3 method that considers specific industrial processes and technologies individually, would have been more accurate. In addition, pollution control units, such as the desulphurization units applied when burning coal, can greatly limit the emissions released into the atmosphere. The above reasons and the use of potentially different fuel breakdowns could explain the deviations between this analysis and EEA data.

The individual/sectoral non-energy impacts identified in Section 3.2 should be monetised to fully understand their impact on profitability (Pye and McKane, 2000). This has not been performed in this analysis. An intermediate step was taken instead, of identifying and quantifying, where possible, the non-energy impacts for each industry specific measure.

In addition, the non-energy impacts quantified in Tables 4 and 5, are only indicative as they are based on available information retrieved from technical reports and case studies. The actual impacts will be case specific and will need to be individually assessed.

Concerning the impact of EE improvements on energy prices, there is significant skepticism about the actual degree of price suppression, focusing on two considerations: i) whether consumers are actually exposed to market prices, and ii) whether the market will respond in ways that will offset or eliminate the price change (Chernick and Plunkett, 2014).

According to literature (Wei, 2010; Sorrell et al., 2009; Nadel, 2012; Saunders, 2003), the gains from the implementation of EE measures can be lower as consumption and expenditures can increase because of increased profitability and competitiveness. For example, when an industry installs an energy efficient technology, its competitiveness can increase (due to the lower production costs) which can lead to higher product demand that will result in a higher than before energy consumption. There is no consensus in literature with rebound effects ranging from high, to medium and low. In general, rebound effects are expected to be modest when the cost of energy is low compared to the overall production costs (van den Bergh, 2011). This means that the level of the rebound effect could differ between industries with energy intensive industries that experience lower production costs due to EE likely showing a higher rebound effect. Because the actual degree of the rebound effect is however unclear this was not taken into account in the analyses.

Conclusion

Because of the limitations discussed in this section and in Section 2: Methods and approach, the results should be interpreted with caution. More detailed study and enhanced approaches are needed to get a better idea of the actual non energy impacts in terms of their size and how they compare to each other. We have shown though that interesting results can be obtained with relatively simple indicators, which clearly point in direction of substantial NEBs related to industrial energy savings. For the ones assessed, we see a positive impact in all areas. The strong uptake of EE and recycling (especially the increased use of scrap in the iron and steel industry) in the EU, could in 2050 avoid up to 50,000 deaths (optimistic estimate that does not consider the presence of pollution control systems), can potentially increase GDP by 1% while it can also be beneficial for industrial producers who could experience increased productivities of about 30%. The results in terms of industrial sub-sector comparisons are conclusive and point in the direction of the sectors where most NEBs can be achieved, which are iron and steel and non-metallic minerals (mainly cement).

Finally, we focused on calculating NEBs that are linked directly to energy savings, but other NEBs are present as well, as shown in section 3.2. This section shows that a wide variety of non-energy benefits are to be realized by industrial facilities, if they adopt EE. These benefits are very sector, measure and site specific and difficult to estimate on a country level.

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