Sustainable Growth Pillar within the Europe 2020 Index. A Sector level's Decomposition

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A Sector level's Decomposition

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Executive summary

This work deals with different sectors' performances towards achieving the Sustainable growth pillar's objectives from the Europe 2020 strategy. First, we determine the objectives at the sectoral level according to the country-level set objectives. Then we define a composite index for the whole Sustainable growth pillar and finally propose a decomposition of that composite index. This decomposition provides important insight, by differentiating between three different components of the Sustainable growth pillar: sector-, group-, and objective-specific indexes. The decomposition, therefore, allows for a better understanding of the realisation of the set objectives at the sectoral level, since the composite index alone leads to confusion about all plausible reasons explaining the given outcome. Applying the methodology to 8 sectors within the 27 European Union countries for the period 2004-2018, we found that while performances have increased over time, compelling efforts are still required to achieve the Europe 2020 Sustainable growth pillar objectives, especially the Energy efficiency and the Renewable energy share targets, as portrayed by the objective-specific index results. The decomposition allows us to emphasise the important patterns and challenges for each sector at the three levels.

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0. Introduction

Today, the world is facing an enormous double challenge: to supply humanity with the necessary energy to support its continued development and to address global warming through the reduction of greenhouse gas (GHG) emissions (Lesourne, 2008). This challenge comes from the human activities that have been developing in the last decades.

While Agriculture, Forestry and Land use contributes for 18.4% to the world GHG emissions, Energy does for 73.2%, Direct Industrial Processes for 5.2%, and Waste for 3.2% (OurWorldinData.org, 2020). Note that with respect to usage by sector, Energy's emissions are attributed to Industry (24.2%), Transport (16.2%), Buildings (17.5%) Agriculture and Fishing (1.7%) etc.

At the beginning of the EU in 1951, coal was considered as the heart of its economic growth, which it stayed up to 2012 in some countries. Kanellakis et. al. (2013) argue that divergent visions between the Member States led to an energy policy at the national state level in the 1960s as most European governments were promoting nuclear power development as a substitute to their increased dependency on imports of oil, coal and/or natural gas. Renewable energy attracted very little interest, due to the high initial cost, with exception of hydropower in countries endowed with significant potential. In the early 1970s, following the 1973 oil crisis and the 1974 Copenhagen summit meeting, the first push for a common energy policy was launched with a declaration on energy policy, adopting guidelines concerning energy supply and demand (Kanellakis, et al., 2013).

In 1991, Germany introduced the first feed-in tariff for renewables[1]. The same year, Denmark installed the world's first offshore wind farm. Europe increasingly uses and produces renewables and continues to be a frontrunner in the domain (European Comission, 2020). The Green Paper on Renewable of 1997 had as objective to achieve a 12% contribution by renewable sources of energy to the Union's gross inland energy consumption by 2010 (European Commission, 1997). The EU share of renewable energy in gross final energy consumption increased from 9.6% in 2004 to 18.9% in 2018, less than 2% of the 2020 target. The Renewable Energy Directive (2009/28/EC) established national targets for EU member countries. This was considered as a "novelty act". Now, 173 countries have similar targets across the world (European Comission, 2020).

In 2018, the 2009 directive was revised and adopted as part of the Clean energy for all Europeans package. It includes a new renewable energy target of at least 32% by 2030 (European Comission, 2020). This ambitious target matches with the European Commission's proposal to cut greenhouse gas emissions by at least 55% by 2030. The objectives are mainly to achieve climate neutrality by 2050, stimulate the creation of green jobs while cutting greenhouse gas emissions, and encourage international partners to increase their ambition to limit the rise in global temperature to 1.5°C and avoid consequences of climate change (European Commission, 2020).

The EU updated its energy policy framework to facilitate the transition from fossil fuels towards cleaner energy and to meet the EU's Paris Agreement commitments for reducing greenhouse gas emissions (European Comission, 2020).

[1] A feed-in tariff is a renewable law that obliges energy suppliers to buy electricity produced from renewable sources at a fixed price, usually over a fixed period. The legal guarantees ensure investment security, and the support of all viable renewable energy technologies (Mendonca, 2012)

Despite the good conditions for expanding renewable energy, some European countries hardly meet the policy goals or limit their ambition due to several reasons, such as the dependency of their economies on (fossil) energy (Holmgren, et al., 2019), their position in the EU or their economic situation (Walheer, 2018).

As mentioned above, the agricultural sector is also one of the key aspects of the Europe's objectives success. The number of farms keeps declining every year, there were 10.5 million agricultural holdings in the EU in 2016. At the same time EUR 59.9 billion was invested in agricultural capital in the EU in 2018, which was an estimated increase of EUR 2.3 billion compared to the previous year (Eurostat, 2019). Agriculture created a (gross) added value of EUR 188.5 billion and contributed 1.2% to the EU's GDP and accounted for 7.4% of total international trade in goods in 2017 (Eurostat, 2018). The agricultural sector remains one of the main land users in Europe and mostly in rural areas (European Environment Agency, 2020). This shows that the agricultural sector of the EU is still a substantial one, even though it is small related to other economic sectors.

Conceived in 1962 (European Commission, 2017) and launched in 1966 (European Commission, 2020) it is the Common Agricultural Policy (CAP) that sets the scene for the agricultural sector. It is a partnership between agriculture and society, and between Europe and its farmers. The aims are to support farmers and improve agricultural productivity, ensure a stable supply of affordable food and a reasonable living to farmers, help tackle climate change and allow for the sustainable management of natural resources, maintain rural areas and landscapes across the EU, and finally keep the rural economy standing by promoting jobs in farming, agri-foods industries and associated sectors. A long list of goals that clearly demonstrates the comprehensiveness of the CAP, one of the most important supranational policies of the EU. Within the CAP we can also distinguish a double goal: ensuring the development of the agricultural sector, while also reducing the negative ecological impact of the sector.

Unlike most other public policies that are financed principally by the Member States, the CAP is supported mainly by the Union, requiring about 40% of the EU budget, the equivalent of 1% of all public expenditure (European Commission, 2017).

The agricultural sector has been losing its weight in the economy over decades in most EU countries (Eurostat, 2019). However, the sector is in fact a large polluter. In the EU, its share in total GHG emissions is 12,7% (2017) even though its contribution to renewable energy production accounts for more than 26 million tons of oil equivalent (toe) (12.1%) (European Commission, 2020).

To ensure a long-term economic growth, the European Union adopted in 2010 the Europe 2020 strategy. The 2020 objectives rely on three pillars: Smart growth, Sustainable growth and Inclusive growth. The first pillar proposes developing the economy based on knowledge and innovation; the second implies the promotion of a more resource-efficient, greener and more competitive economy and the last one entails fostering a high-employment economy delivering economic, social and territorial cohesion (European Commission, 2010).

Many studies analysed the efficiency of the 2020 objectives from different angles and perspectives. The added value of this work is to bring more clarity in sectors directly involved in the sustainability pillar of the EU 2020 strategy.

While many sectors saw good efficiency improvement in most countries, others did not. A study conducted by Walheer in 2018 reveals that in Europe, depending on countries and sectors, efficiency outcome can be different. The study reports that Agriculture and electricity, Gas and water sectors are the most inefficient sectors (Walheer, 2018).

Analyzing not only those two sectors but also those that are directly or indirectly linked to them might help detecting barriers to success of the strategy to adapt policies and improve performances for the coming years. To do so, our research focuses on the Sustainability pillar, which mainly involves Agriculture, Energy supply, Industry, Waste, Domestic transport, Residential and commercial, International shipping and International aviation sectors.

Therefore, our research question is: **What are the performances of sectors towards achieving the Europe 2020 strategy objectives on the Sustainable Growth Pillar?**

1. Literature review

In this chapter, we outline the Europe 2020 strategy and what it entails, and then we describe some conceptual notions about sustainability relevant to the Europe 2020 strategy.

1.1. The Europe 2020 strategy

To cut GHG and other gas emissions, to improve the energy use and production's efficiency and sustainability as suggested by the Europe 2020 strategy, action needs to be taken in the sectors and economic activities emitting the most GHG and other polluting gases. Yet, authors' opinions diverge when it comes to measuring the progress of European countries into achieving the 2020 strategy objectives.

Analyzing the EU's possibility to achieve the Europe 2020 strategy by using regressions, Liobikiene et al. (2017) for instance foresaw that, assuming the growth of the economy and primary energy consumption stimulate GHG emissions, the target of reducing GHG emission by 20% by 2020 compared to 1990 would still be achieved. These previsions were supported by the tendencies of economic growth, energy consumption and the change of renewable energy share changes on the period 2005-2012 (Liobikiene, et al., 2017).

However, more recently, using the MULTIMOORA method and the Shannon Entropy Index, Fedajev et al. (2019) suggested that the EU strives to ensure sustainable growth and development by 2020. They measured the inequality in the performances of the Member States in each strategic priority and found that some countries like Sweden, Denmark and Austria were the best performers while others like Belgium, Bulgaria, Spain or Italy had an unfavourable position in the final ranking (Fedajev, et al., 2019).

Likewise, Beckr et al. (2020), through a multidimensional indicator analysis of the Europe 2020 strategy, show that although the EU has made some improvements as a whole, some specific regions have lagged behind or even moved backwards, and within some countries, regions are moving further away from one another. Moreover, the analysis concludes that more effort is needed in the environmental dimensions (Becker, et al., 2020).

Carvalho (2012) considered the EU 2020 renewable energy target as very ambitious, but achievable. Even though in general the policy had good results (Eurostat, 2020), the revised directive which is related to the policy remains challenging (Lowitzsch, et al., 2020) and requires an important shift in the emerging energy renovation market from a step-by-step market and inconsistent energy renovation financed by grants to the market industrialised and holistic energy renovation leading to zero energy building financed by long-term loans (Saheb, et al., 2018).

Analysing specific aspects of the energy production and use could help to improve the sector's efforts into achieving the renewable energy policy efficiency.

Ozdemir et al. (2020) suggest that subsidies of energy output are cost-effective for achieving renewable energy targets in the short run, while Pe'er and Lakner (2020) argue that the EU's CAP has failed in meeting the environmental targets due to inefficient spending among other reasons. This could have been avoided through a strong green architecture and more interaction between the EU and its Member States, to achieve a more efficient spending of public payments on farmers. In this perspective, Lambin et al. (2020) suggest that to achieve durable impacts and sustainability, policies must include all relevant actors and private action.

Therefore, Scown, et al. (2020) imply that to contribute to sustainable agriculture, the CAP payments need to be distributed from supporting income in regions where farming is already profitable to supporting farmers to implement environment-and climate-friendly practices.

Many works have analysed the energy efficiency with respect to environmental targets. Examples include Bertoldi and Mosconi (2020), Malinauskaite et al. (2020), Malinauskaite et al. (2019), Vehmas et al. (2018), Ó Broin et al. (2015), Filippini et al. (2014), Rehmatulla et al. (2015), Ziolkowska and Ziolkowski (2015), Ó Broin et al. (2013) and Pardo et al. (2011). These works take into account different sectors in the analysis, but they all have in common the use of energy as an efficiency measure linked to the policy. The results depend on several factors, such as the type and the size of the sector, but also the technology used by the sector. It is obvious, according to those studies, that a sector will gain efficiency if it uses less energy. The problem with this conclusion is that many sectors cannot vary easily the amount of the needed energy for their respective activities. And since the type of used energy depends on its availability in every country, increasing the renewables share in the total use of energy can be more complex.

Our research instead focuses on the energy-related objectives that include both the share of energy deriving from renewable sources and the energy efficiency level. Although these two aspects of energy are connected, a difference can be observed with respect to the destination and the use of energy across different activities and sectors of the economy.

One of the major differences is that in the mentioned works, a sector can be considered energy efficient by using less energy with no consideration of the type or the source of the energy. This study completes the energy performance with the share of renewable energy. Thus this study's aim is to explain the success in using more renewable energy and increasing energy efficiency, by the direct and indirect characteristics of the sector, and in this case the characteristics of the sectors using intensively energy in their activities. This is the same understanding of efficiency as mentioned by Walheer (2018). Through a non-radial multi-sector non-parametric production-frontier analysis, the author found that different levels of countries' efficiency behaviour can be met depending on different variables such as being a member of the EU12 group and/or the G7 group, the renewable energy target of the EU 2020 strategy for the country, the energy use or the 2008 economic crisis. The same study shows that the agricultural sector and the sector of water, gas and energy are the most inefficient in achieving the set target in the considered sectors of the EU (Walheer, 2018).

While the variables in Walheer's study were related to the country level taking into account the three pillars, this study will restrict the analysis to the Sustainable growth pillar at the sector's level.

1.2. Sustainability

Sustainability is defined by the World Bank as "a requirement of our generation to manage the resource base such that the average quality of life that we ensure ourselves can potentially be shared by all future generations" (Asheim, 1994). Likewise, the United Nations describe the concept as meeting the needs of the present without compromising the ability of future generations to meet their own needs (United Nations, 1987). And so, the Sustainable growth Pillar as advocated by the European Commission is about the promotion of a more resource-efficient, greener and more competitive economy by production with lower emissions, constrained resources to prevent environmental degradation, biodiversity loss and unsustainable use of resources (European Commission, 2010). This notion can be considered as part of the Sustainable Developments Goals (United Nations, 2015). In fact, sustainability has taken a central place on the global agenda on development policies and financing (World Bank, 2018) and is widely discussed through different angles and points of view.

Discussing the Sustainable growth criteria, Spangenberg et al. (2002) argued that there are no simple criteria developed to assess the sustainability for a given growth pattern. Analysing the German context with an application of transdisciplinary sustainability scenarios, they found that there are indeed trade-offs between economic growth and environmental impacts, and a positive correlation of growth and employment. However, they still considered it possible to develop organised strategies that combine economic competitiveness, low unemployment rates and softening the pressure on the environment (Spangenberg, et al., 2002).

An analysis of the environmental sustainability of European production and consumption assessed by the use of life cycle impact assessment-based planetary boundaries (Sala, et al., 2020) suggests that in 2010, global environmental impacts surpassed several boundaries and that the impact of EU's consumption was close to or already transgressed the global environmental boundaries, while the EU accounts for less than 10% of the world population. Sala et al.'s analysis certainly does not take into account the specific aspect of targets, policy assessments or implementations across countries.

In fact, sustainability schemes can differ from a country to another (Su, et al., 2020) regardless of economic similarities. Investigating the influence of resource dependence factors and factors of sustainable growth on the economic growth of the net oil and gas exporting countries, Filimonova et al. (2020), found that the impact of resource dependence factor is not significant in some hydrocarbons exporting countries while most countries' economy's growth depends significantly on factors of sustainable growth. Therefore, resource-dependent countries need more diversified economies and revenues (Filimonova, et al., 2020).

Moreover, although the notion is differently perceived according to each country's context (Matschoss, et al., 2019), many authors have in fact looked into the link between sustainability achievement or failure and several economic activities or sectors. In this respect, amongst others, Su et al. (2020), Wang & Zhan (2019), Marques et al. (2019) and Khan et al. (2021) explore the link between the energy sector and sustainability by emphasising energy's involvement in achieving a sustainable growth with respect to its type, its use, its inputs or its related-run time, while others use the same criteria to investigate the issue with respect to the agricultural sector, see Franco (2021), Davies (2020), Fabiani et al. (2020), Zaman (2020) and Möckel (2015)), Transport (see Mugion et al. (2018), Malasek (2016) and Eliasson & Proost (2015)), Industry (see Kumar et al. (2020) and Garetti & Taish (2012)) etc.

While all these findings mostly portray either causality or linkages between sustainability and different sectors, this research focuses on the objective that is set by the EU for every sector, and how each of the latter performed for the set objectives.

2. Methodology

If there are M countries pursuing K objectives to achieve at the latest at period P, and each objective k has a specific and quantifiable target for every country m, denoted by $x_{m,k}^{P}$, and we observe the achievement of every country at period p, denoted by $x_{m,k}^{p}$, two situations can be observed. Either countries seek an increase in their current target level to achieve the objective, or they seek a decrease in their current level to reach the objective. In the first case, the objective k is achieved for country m if: $x_{m,k}^{p} \geq x_{m,k}^{P}$, for $p \geq P$. This corresponds to a "positive target". In the second case, the objective k is achieved for country m if: $x_{m,k}^{p} \leq x_{m,k}^{P}$, for $p \leq P$. This corresponds to a "negative target".

To find out the performance level of specific sectors related to the Sustainability growth pillar of the EU 2020, the decomposition of the composite index as developed by Walheer is a useful methodology. Referring to Walheer (2018), we develop in the next subsections the decomposition of the composite index to apply to the Europe 2020 strategy (Walheer, 2018).

2.1. Constructing the Europe 2020 Sector-level objectives

While the European Union designed the Europe strategy objectives on the country level regardless of the specificities in sectors, this research analyses the targets on the sector level.

Therefore, we make some assumptions to design the sector's target according to its underlying weight. We propose the weighting of sectors due to the lack of data for all variables of interest by sector for the studied countries.

The weight of the sector will correspond to its contribution in GHG emissions measured in tons of carbon dioxide equivalent (CO_2e):

$$Weight_{j,m,p} = \frac{\mathrm{CO_2e}_{j,m,p}}{\mathrm{CO_2e}_{m,p}} \tag{1}$$

With:
j: Sector
m: Country
p: Period

Knowing that the total GHG emissions of a country equal to the sum of all sectors' emissions.

The Objective by sector by period will be given by:

$$OBJECTIVE_{j,p} = OBJECTIVE_{m,p} * Weight_{j,m,p} \tag{2}$$

Then we consider that there are J sectors for which Europe pursued K objectives to achieve at the latest at period P. We assume that each objective k has a specific and quantifiable target for every sector j, denoted by $x_{j,k}^{P}$, and we observe the achievement of every sector at period p, denoted by $x_{j,k}^{p}$, two situations can be observed. Either sectors have to increase in their current target level to achieve the objective, or they seek a decrease in their current level to reach the objective. In the first case, the objective k is achieved for sector j if: $x_{j,k}^{p} \geq x_{j,k}^{P}$, for $p \geq P$. This corresponds to a "positive target". In the second case, the objective k is achieved for sector j if: $x_{j,k}^{p} \leq x_{j,k}^{P}$, for $p \leq P$. This corresponds to a "negative target".

2.2. The Europe 2020 Composite Index

To define the composite index, the first step is to normalise the indicators $x_{j,k}^{p}$. However, the units of indicators $x_{j,k}^{p}$ might be different depending on every k and that difference in measurement units can lead to some issues for the constructed indexes. A useful tool to address this issue is the *min-max* normalisation technique.

For each sector j at period p for objective k, the normalised indicators are defined by:

$$NX_{j,k}^{p} = \frac{X_{j,k}^{p} - X_{m,k}}{X_{M,k} - X_{m,k}}, \text{for a positive ambition,} \quad (3)$$

$$NX_{j,k}^{p} = \frac{X_{M,k} - X_{j,k}^{p}}{X_{M,k} - X_{m,k}}, \text{for a negative ambition,} \quad (4)$$

The *min-max* normalisation technique is used in diverse domains such as social and development studies (see for instance the aggregation of the dimensional indices used to formulate the Human Development Index by the United Nation Development Programme (United Nations Development Programme, 2016)), Engineering and technology research (Saranya & Manikandan, 2013), Management (Cricelli, et al., 2014) or Economics (Carrino, 2016). The process is also used in similar analysis by Pasimeni and Pasimeni (2016) and Walheer (2018) to construct the 2020 Index. According to Walheer (2018), "while the min-max transformation gives normalised indicators, it does not take the values of the targets into account". It is therefore necessary to simply modify this transformation to get the target levels. We obtain:

$$NXP_{j,k}^{p} = \frac{X_{j,k}^{p} - X_{m,k}}{X_{j,k}^{P} - X_{m,k}}, \text{for a positive target,} \quad (5)$$

$$NXP_{j,k}^{p} = \frac{X_{M,k} - X_{j,k}^{p}}{X_{M,k} - X_{j,k}^{P}}, \text{for a negative target,} \quad (6)$$

Where $X_{m,k}$ and $X_{M,k}$ are, respectively, the minimum and the maximum, of the indicators $X_{j,k}^{p}$ for all periods and all sectors. The attributed values are: $X_{m,k} = min_{j,p}\left\{X_{j,k}^{p}\right\}$ and $X_{M,k} = max_{j,p}\left\{X_{j,k}^{p}\right\}$. Indeed $NXP_{j,k}^{p}$ could exceed one since there is no ranking between $X_{j,k}^{p}$ and $X_{j,k}^{P}$. If for a positive target we have that $X_{j,k}^{P} > X_{j,k}^{p}$ before the last period, and $X_{j,k}^{p}$ increases with an increase in p, at some period, the objective could be reached ($X_{j,k}^{P} = X_{j,k}^{p}$) and then overstepped ($X_{j,k}^{p} > X_{j,k}^{P}$).

In fact, we can have three possible outcomes: $NXP_{j,k}^{p} < 1$ when the objective is not reached at period, $NXP_{j,k}^{p} = 1$ when the objective is obtained, and $NXP_{j,k}^{p} > 1$ when the objective is surpassed.

To construct our normalised indicators with respect to the target level, we can define our composite index, denoted by CI_{j}^{P} for sector j at period p. Referring to Walheer (2018) and Pasimeni (2013), we rely on the geometric weighted aggregation method. Formally, with $\omega^p_{j,k} \geq 0$ and $\sum_{k=1}^{K} \omega^p_{j,k} = 1$, we obtain:

$$CI^p_j = \prod_{k=1}^{K} \left(NXP^p_{j,k}\right)^{\omega^p_{j,k}} \tag{7}$$

We can interpret the composite index as follows: CI^P_j is a positive function of the indicators $NXP^p_{j,k}$. The higher the indicators $NXP^p_{j,k}$ are evaluated, the better will be the performance, implying greater CI^P_j. CI^P_j will be equal or equal to one if all objectives are reached or surpassed by all sectors ($NXP^p_{j,k} \geq 1$), but the opposite is not true. This problem known as the compensability implies that greater indicators $NXP^p_{j,k}$ will compensate for lower indicators $NXP^p_{j,k}$ in the composite index CI^P_j. This is important since, as mentioned before, by definition, the indicators $NXP^p_{j,k}$ are unbounded from above.

We have now to select the weights of objectives corresponding to the chosen weighted aggregation method. There are two possible types: exogenous and endogenous weights. The first type is defined by the practitioner or expert. This implies a subjective judgement. The second type consists of computing a geometric average. It corresponds to $\omega^p_{j,k} = \frac{1}{K}$. (Note that this weighing is different from the sector's weighing discussed in 2.1).

2.3. Decomposition of the Europe 2020 Composite Index

It is necessary to identify the specific reasons that explain the better or worse performances indicated by $NXP^p_{j,k}$ and CI^P_j. For policymakers, it is crucial to detect factors for which relevant strategies and action need to be applied to reach the objectives. We demonstrate in this part how to decompose $NXP^p_{j,k}$ into three parts: (1) a sector-specific index justifying how each sector performs with respect to the best performer for each period, (2) a group-specific index that indicates how the group of sectors operates for every period, and (3) a Sustainable growth pillar oriented objective-specific index that reveals if the targets are reachable for the period. Note that this analysis considers two groups of sectors according to their level of performance: (1) high-performance sector: the one with the best performance towards the objective/target and (2) low-performance sector: the one with the worst performance towards the objective/target. Such classification is realised by Heras-Saizarbitoria, et al. (2015).

Constructing our decomposition of $NXP^p_{j,k}$, we clearly separate those three constituents. The decomposition can be used to test whether specific policies, strategies, events, or shocks have affected the performances at the sector level, the group level or objective level for CI^P_j.

Before we formally develop the decomposition of $NXP^p_{j,k}$, we introduce the notion of maximal value for a specific period (year): $X^p_{M,k} = max_j\,\{X^p_{j,k}\}$. Constructing on this new concept, we can easily decompose the equation (5) into three parts by multiplying top and bottom by $X^p_{M,k} - X_{m,k}$ and $X_{M,k} - X_{m,k}$:

$$NXP^p_{j,k} = \frac{X^p_{j,k} - X_{m,k}}{X^P_{j,k} - X_{m,k}}, \tag{8}$$

$$= \frac{X^p_{j,k} - X_{m,k}}{X^P_{j,k} - X_{m,k}} * \frac{X^p_{M,k} - X_{m,k}}{X^p_{M,k} - X_{m,k}} * \frac{X_{M,k} - X_{m,k}}{X_{M,k} - X_{m,k}}, \tag{9}$$

$$= \frac{X_{j,k}^{p} - X_{m,k}}{X_{M,k}^{p} - X_{m,k}} * \frac{X_{M,k}^{p} - X_{m,k}}{X_{M,k} - X_{m,k}} * \frac{X_{M,k} - X_{m,k}}{X_{j,k}^{P} - X_{m,k}}, \tag{10}$$

$$= SECTOR_{j,k}^{p} * GROUP_{k}^{p} * OBJECTIVE_{j,k}\ , \tag{11}$$

$SECTOR_{j,k}^{p}$ indicates how sector j performs in period p for objective k compared to the best practice of that period (captured by $X_{M,k}^{p}$). Since $X_{j,k}^{p} \leq X_{M,k}^{p}$, this index is bounded from above by one, with unity means that the sector *j* is the best performer. When the sector could perform better in a period, the values will be lower. Some factors such as a particular event or a certain policy implementation might affect the performance and lead to a sub-optimal level. This index is very similar to the standard *min-max* normalisation index; the single difference is that, in fact, the maximal value depends on the period.

$GROUP_{k}^{p}$ represents the performance of the group in period p for objective k by comparison between the best practice of the same period (captured by $X_{M,k}^{p}$) and the highest value of the indicators for all periods (captured by $X_{M,k}$). This index is also clearly bounded from above by one as $X_{M,k}^{p} \leq X_{M,k}$. Lower values of the index could be caused by some issues or factors related to the group.

$OBJECTIVE_{j,k}$ similarly informs if objective k is, by definition, reachable for sector *j* by comparing the highest value of the indicators for all periods (captured by $X_{M,k}$) to the objective target of sector *j* (captured by $X_{j,k}^{P}$). This index is not bounded because there is no natural ranking between $X_{M,k}$ and $X_{j,k}^{P}$. If the value is smaller than one, that means the objective cannot be achieved for the period. If it is equal or greater than one, that means the opposite. This index grants the identification of problems linked to the sustainable growth-related objectives so that investigation can be made to make sure the targets are well set and achievable.

For a negative target, with $X_{m,k}^{p} = min_{j}\ \{X_{j,k}^{p}\}$, the minimal value of period p in the sector, a similar decomposition of $NXP_{j,k}^{p}$ by multiplying the top and the bottom of the equation (6) by $X_{M,k} - X_{m,k}$ and $X_{M,k}^{p} - X_{m,k}$ gives:

$$NXP_{j,k}^{p} = \frac{X_{M,k} - X_{j,k}^{p}}{X_{M,k} - X_{j,k}^{P}}, \tag{12}$$

$$= \frac{X_{M,k} - X_{j,k}^{p}}{X_{M,k} - X_{j,k}^{P}} * \frac{X_{M,k} - X_{m,k}^{p}}{X_{M,k} - X_{m,k}^{p}} * \frac{X_{M,k} - X_{m,k}}{X_{M,k} - X_{m,k}}, \tag{13}$$

$$= \frac{X_{M,k} - X_{j,k}^{p}}{X_{M,k} - X_{m,k}^{p}} * \frac{X_{M,k} - X_{m,k}^{p}}{X_{M,k} - X_{m,k}} * \frac{X_{M,k} - X_{m,k}}{X_{M,k} - X_{j,k}^{P}}, \tag{14}$$

$$= SECTOR_{j,k}^{p} * GROUP_{k}^{p} * OBJECTIVE_{j,k}, \tag{15}$$

Obviously, the interpretation of the three components is parallel to the decomposition in equation (11); the unique distinction is that the latter is based on minima instead of maxima.

When taking into account the geometric weighted aggregation, we find similarly from the equation (7), the following decomposition of the composite index:

$$CI_{j,k}^{p} = \prod_{k=1}^{K} \left(NXP_{j,k}^{p}\right)^{\omega_{j,k}^{p}} \tag{16}$$

$$= \prod_{k=1}^{K} \left(SECTOR_{j,k}^{p} * GROUP * OBJECTIVE_{j,k} \right)^{\omega_{j,k}^{p}} \quad (17)$$

$$= \prod_{k=1}^{K} \left(SECTOR_{j,k}^{p} \right)^{\omega_{j,k}^{p}} * \prod_{k=1}^{K} \left(GROUP_{j,k}^{p} \right)^{\omega_{j,k}^{p}} * \prod_{k=1}^{K} \left(OBJECTIVE_{j,k} \right)^{\omega_{j,k}^{p}} \quad (18)$$

$$= SECTOR_{j}^{p} * GROUP_{j}^{p} * OBJECTIVE_{j}^{p}. \quad (19)$$

While in (11) and (15) the three components of the decomposition depend on the objectives, it is not the case in (19). This is due to the aggregation over objectives when we compute the composite index. Naturally, objectives are set for all sectors of European countries as a whole.

Furthermore, we can also notice that, the sector-specific component depends on j and that the objective-specific component depends on p, while this is not the case for the indicators in (11) and (15). The difference is explained by the weights $\omega_{j,k}^{p}$ generally being dependent on j and p, which makes the three components also depend on them. We could consider for exogenous weights that some components can only depend on either j or p.

2.4. The case of the Europe 2020 Sustainable growth pillar's objectives Index formalization

We will apply our methodology to the case of the Europe 2020 objectives and more specifically on the Sustainable growth pillar's level.

This pillar contains quantitative targets presented in table 1:

Table 1: Sustainable growth pillar objectives

Objective	Explanation	Target type
Greenhouse gas (GHG) emissions	Cut greenhouse gas emissions by 20%	Negative
Energy efficiency	Increase energy efficiency by 20%	Negative[2]
Renewable energy	Use 20% of its energy needs from renewable sources	Positive

Note that this analysis is more restrictive because of the focus on one pillar and the sectors related to it, compared to the global Europe 2020 analysis that includes the three pillars.[3]

[2] Increasing the energy efficiency implies that the EU's final energy consumption should be lowered by 20% in 2020 (European Commission, 2014). In other terms the amount of consumed energy in million tons of oil equivalent (TOE) should be 80% of that of 1990.

[3] See Walheer (2018)

3. Results and Discussion

After presenting the data and descriptive statistics, we delineate in this chapter the composite index results, the decomposition results and the relative relevance of the objectives.

3.1. Data and Descriptive Statistics

For the European Union of 27, we choose the data from Eurostat (the official institution of the European Union)[4]. To set the sectoral objectives and achievements, according to the technique explained in 2.1., we use the data from the European Environment Agency[5]. The period of interest is 2004-2018. However, with respect to the country-level targets, the sectoral objectives are set on with 1990 as the base year.

As mentioned in 2.2., we first construct our indexes by normalizing the indicators by using the *min-max* process adapted to take the objective level into consideration. The Europe 2020 Sustainable growth pillar's objectives account for two negative targets and one positive target (see 2.4. for formal definitions). The descriptive statistics which contain the minimum, the median, the average, the maximum, and the standard deviation (SD) presented in *table 2*, provide a summary of both raw and normalised indicators by specifying the type of the target (negative or positive).

These descriptive statistics reveal important information regarding performances between 2004 and 2018. At least one sector has reached and even surpassed the GHG emissions reduction and the renewable energy share targets for which the maximum value is greater than one, while at least one of them approached the Energy efficiency target for which the maximum value is 0.99. Medians and averages portray different achievements for each objective. They are relatively higher for GHG emissions than for Energy efficiency and Renewable energy share. Even though these descriptive statistics are based on a 15 year-long period for all sectors cannot be conclusive, they portray interesting results. Going deeper with detailed results is the purpose of the next section.

Table 2: Descriptive statistics

Variable	Normalization	Minimum	Median	Mean	Maximum	SD
GHG emissions per capita	Raw	0.20	1.05	1.21	3.38	0.90
(Negative)	Index	0.00	0.99	1.03	2.23	0.32
Energy efficiency	Raw	19.53	112.39	124.95	324.02	92.52
(Negative)	Index	0.00	0.81	0.81	0.99	0.24
Renewable energy share	Raw	0.10	1.59	1.84	5.91	1.50
(Positive)	Index	0.00	0.76	0.80	2.26	0.37

[4] https://ec.europa.eu/eurostat/web/main/data/database: GHG emissions per capita is given by the total emissions of greenhouse gases, including carbon dioxide (CO_2) and other gases all expressed in CO_2e (availability: 1990-2018); Energy efficiency is measured as the evolution of final energy consumption in million TOE (availability: 1990-2019); Renewable energy is given by the share of renewable energy in final energy consumption (availability: 2004-2019)

[5] https://www.eea.europa.eu/data-and-maps/data/data-viewers/greenhouse-gases-viewer: GHG emissions by sector (availability: 1990-2018)

3.2. Results

In this section, we first give the results for the composite index for the Sustainable growth pillar and then we decompose that index into three components: sector-, group-, and objective-specific indexes. We present the main results using graphs. Detailed results are given in the "Appendix" for every sector and every year.

3.2.1. The Sustainable growth pillar composite index Results

As described in 2.2., for the objectives we use exogenous weights defined by $\omega_{j,k}^{p} = \frac{1}{K}$ which corresponds to the geometric average. This method reflects a natural attribution of the same importance to both objectives in the aggregation. In this matter, Walheer (2018) suggests that the chosen weights do not impact the decomposition index, meaning that for any weighting method, the composite index can still be decomposed into three parts (see *3.2.3*). Furthermore, for some sectors, the composite index can theoretically be zero when the sector has the worst value for at least one indicator. The recommended mean to address this is to set the value of the normalised indicator to the smallest value of all the normalised ones. In this study's case, it is 0.16. Both the exogenous weighting and the technique to address the zero value have also been used by Pasimeni & Pasimeni (2016) in their comparative analysis of national performances towards the Europe 2020 strategy.

a) Whole Sustainable growth pillar results

The results of the Sustainable growth pillar composite index are presented in *Table 3* in which we plot the composite index and the descriptive statistics (minimum, median, average, maximum, and standard deviation) for each sector in each period. Likewise, we present in *Figure 1* each sector's index and their average to show the performance evolution over time.

The first information we observe is that on average the performances have increased over time. Initially, the average level was 1.65 (median 0.74) in 2004 while it was 1.07 (median 1) in the final year. These scores imply that the Sustainable growth-related targets were globally met in 2018 (since 2014 if we consider the average scores for the three previous years). However, there is still more effort to be done by the Domestic transport, the Residential and commercial, the Agriculture and the Waste sectors for which the respective composite indexes are 0.88; 0.97; 0.92 and 0.95.

In 2010, the maximum was 1. This means that for the first time, there was at least one sector that reached the target. It was the Industry sector. At the same angle, the best performer in 2004 reached 0.8 while in 2018, the best one reached 1.39. This was the International aviation sector.

Table 3: Sustainable growth pillar composite index

Period	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Sector															
Energy supply	0.16	0.23	0.26	0.26	0.43	0.74	0.66	0.70	0.76	0.92	1.12	1.11	1.18	1.23	1.24
Industry	0.75	0.75	0.77	0.78	0.83	1.00	0.98	1.00	1.04	1.06	1.07	1.05	1.02	1.02	1.03
Domestic transport	0.60	0.61	0.64	0.66	0.68	0.74	0.73	0.75	0.81	0.83	0.85	0.86	0.86	0.86	0.88
Residential and commercial	0.75	0.78	0.78	0.85	0.82	0.85	0.85	0.88	0.90	0.90	0.94	0.96	0.95	0.96	0.97
Agriculture	0.80	0.81	0.82	0.84	0.84	0.86	0.87	0.87	0.90	0.90	0.93	0.91	0.91	0.90	0.92
Waste	0.79	0.81	0.82	0.85	0.86	0.89	0.90	0.90	0.93	0.95	0.97	0.96	0.96	0.96	0.95
International shipping	0.74	0.75	0.77	0.81	0.83	0.85	0.88	0.92	0.98	1.00	1.05	1.08	1.11	1.13	1.17

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
International Aviation	0.64	0.66	0.72	0.78	0.83	0.91	0.94	0.98	1.10	1.21	1.28	1.28	1.26	1.31	1.39
Minimum	0.16	0.23	0.26	0.26	0.43	0.74	0.66	0.70	0.76	0.83	0.85	0.86	0.86	0.86	0.88
Median	0.74	0.75	0.77	0.79	0.83	0.86	0.88	0.89	0.91	0.94	1.01	1.01	0.99	0.99	1.00
Average	0.65	0.67	0.70	0.73	0.76	0.86	0.85	0.88	0.93	0.97	1.03	1.03	1.03	1.04	1.07
Maximum	0.80	0.81	0.82	0.85	0.86	1.00	0.98	1.00	1.10	1.21	1.28	1.28	1.26	1.31	1.39
SD	0.21	0.19	0.19	0.20	0.15	0.09	0.11	0.10	0.11	0.12	0.14	0.13	0.14	0.16	0.18

We can observe a stress (irregularity) in the evolution in 2009. From 2009 to 2010 some sectors' performance decreased. Only Agriculture, Waste, International shipping and International Aviation kept an increase in their scores. The 2009 period also correspond to the smallest dispersion captured by a standard deviation of 0.09, relatively fewer than the 0.15 average standard deviation. In other terms, sectors converged in their performances. This could be explained by the fact that due to the financial crisis of 2008-2009, most sectors could not innovate easily to keep reducing the GHG emissions, increasing the energy efficiency and the renewable share of their used energy.

It is also noticeable that with respect to every sector's initial situation, some have made more improvement than others. Even though International aviation is the best performer in 2018 compared to its initial score of 0.64 in 2004, the change is not as impressive as for the Energy supply sector. From the last position with 0.16 initially, the sector was second with 1.24 in 2018. This corresponds to a 675% improvement from the first to the last year.

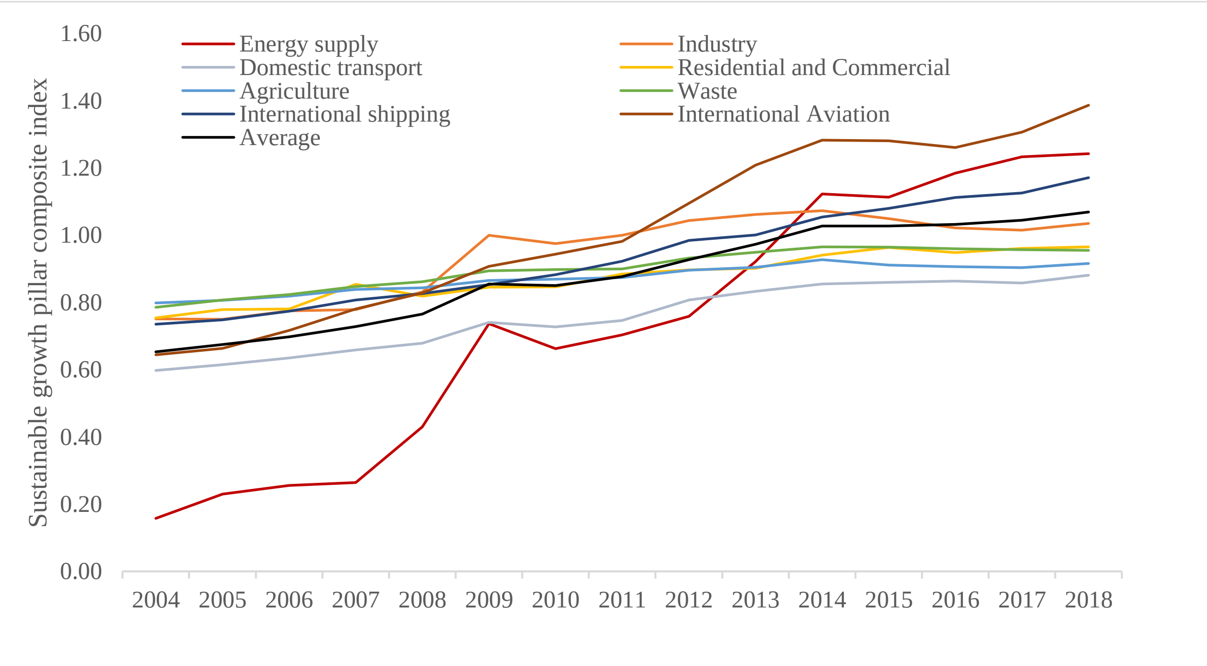


Figure 1: Composite index

To better observe these improvements and to investigate changes over time, we plot in *Figure 2* the composite index levels of all sectors for initial and final periods.

No sector had a score larger than one for the initial year. In the final year, Energy supply, Industry, International aviation had already reached and surpassed the target while Domestic transport, Agriculture and Waste still had scores that are lower than the unity but relatively close to meeting the targets. Domestic transport is the sector that has to make the most effort to achieve the target.

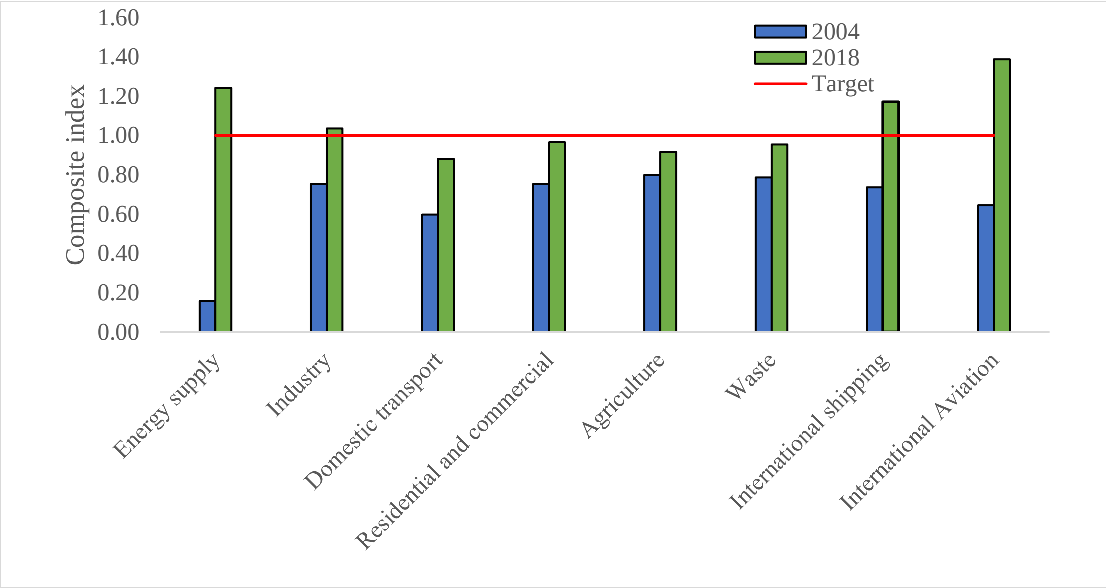


Figure 2: Sustainable growth pillar Composite index: 2004 vs 2018 scores

b) Objectives results

In *Figure 3* and *Figure 4* we present the same type of analysis for all objectives of the Sustainable growth pillar taking into account each of them separately to observe different performances of every objective. Detailed results and descriptive statistics are in the Appendix (see *Table 4* for GHG emissions, *Table 5* for Energy efficiency and *Table 6* for Renewable energy).

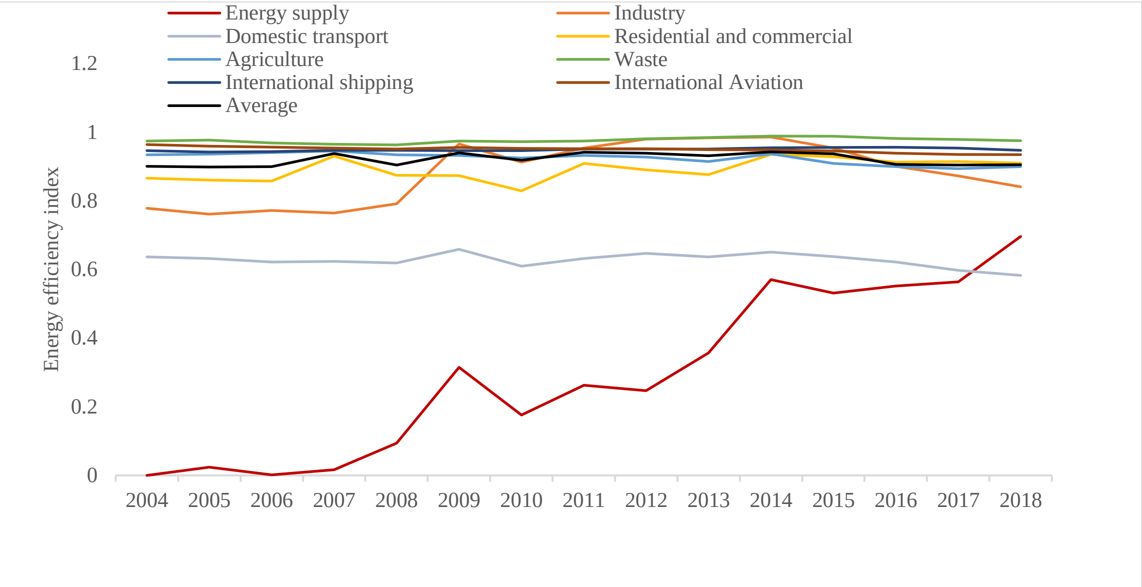
Note that for this part of the analysis the method mentioned earlier to avoid having a value of zero for a given index at some point is not applicable. In fact, since computations are made for each objective and each period, the *min-max* normalization technique will lead to a value of zero for the period in which the minimal value of the positive target performance (respectively maximal value of the negative target performance) is located (see 2.2. for detailed explanation). These the minimal performances being located in the initial period for each target and each objective, on *Figure 4*, there is at least one sector having a zero value for 2004.

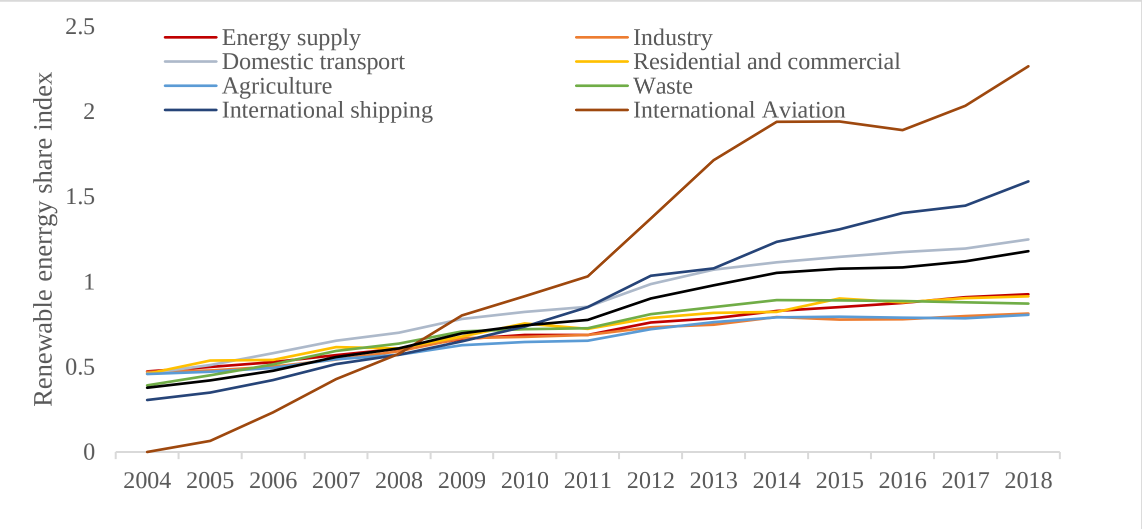
Even though the whole Sustainable growth pillar index globally evolves in an positive direction, we observe that performance pathways are different for every objective over time.

First, the Greenhouse gas emissions index was relatively high and did not evolve much for most sectors. Only Energy supply had a score of zero the initial year and had impressively increased its performance which reached 2.1 in the last period. This explains why the average passed from 0.82 in the first year to 1.18 in the last year even though most sectors could barely attain 1. Additionally, 62.5% of sectors met this objective's target in 2018.

Second, for the Energy efficiency index, while some sectors such as Waste, International shipping and Agriculture had relatively high scores, other like Industry, Domestic transport, and Energy supply had lower scores. The latest had even a zero-value score in 2004. We observe a progressive decrease in the standard deviation (see *Table 5*), which means that sectors become more and more homogeneous. In fact, no sector managed to reach the target for the whole period. Some have even decreased their performance from the initial year to the last for this specific objective. This is the case of Domestic transport, Agriculture and International Aviation for which scores passed respectively from 0.64 to 0.58; 0.93 to 0.9; 0.96 to 0.93 between the initial and the final period. For this objective, again Energy supply was improved the most by going from zero to 0.7.

Finally, for the Energy renewable share index, all performances were less than 0.5 in the initial period for all sectors. Both of them made improvements and in the final year, three surpassed the target. In 2018, Domestic transport scored 1.25, International shipping 1.59 and International Aviation, which was the last in the initial period, was the first in the last period with over 2.26.





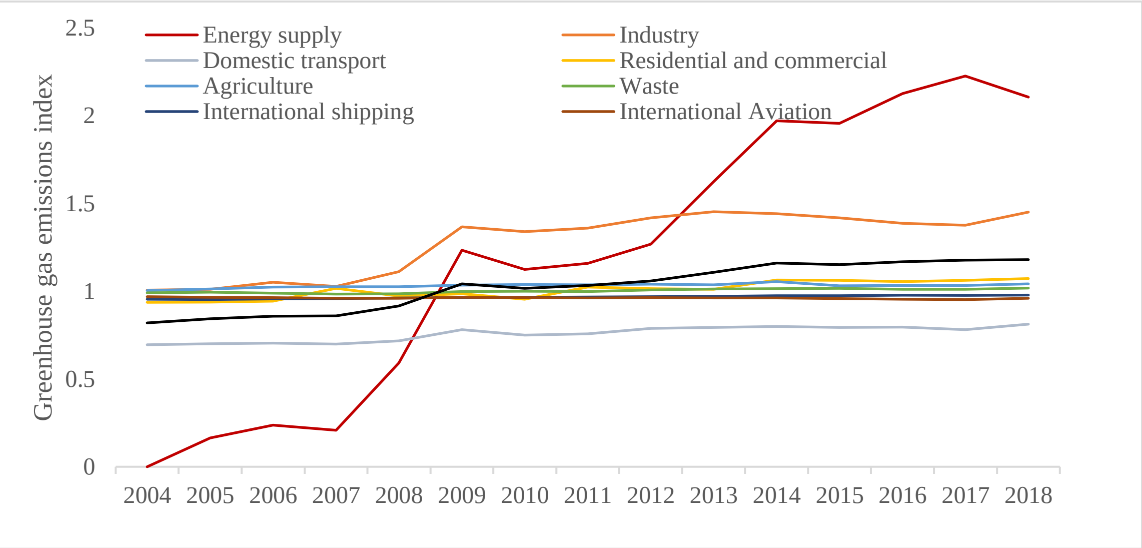


Figure 3: Objective index

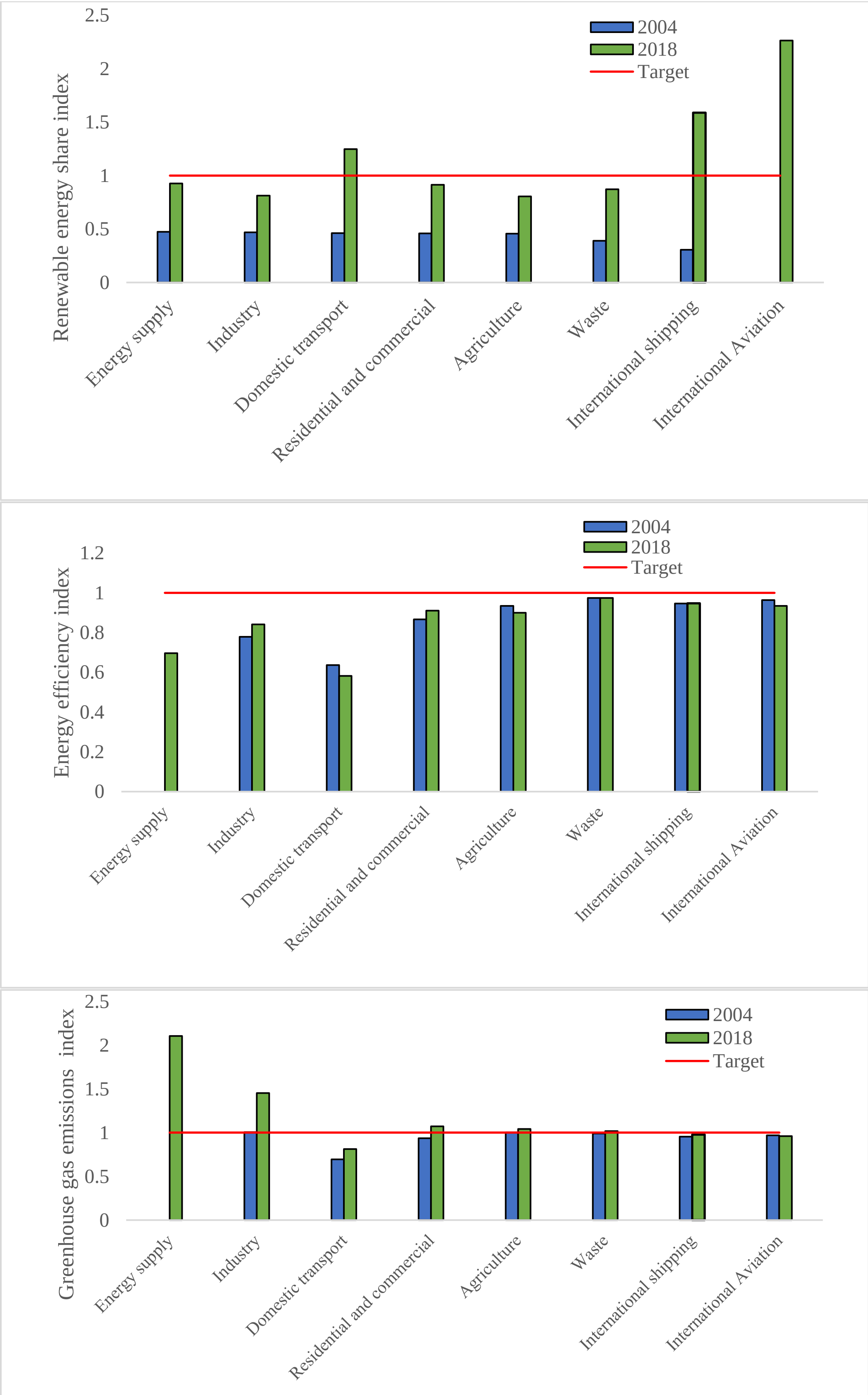


Figure 4: Objective index: 2004 vs 2018 scores

From what precedes, we make two observations. First, the whole performance in the Sustainable growth pillar's goal depends on individual performances within every component (target) of the goal. Second, the level of achievements and improvements for every sector depends on their initial situation in the first year. In this regard, International aviation was the best performer for the Composite index with 1.39 in the last period because it made tremendous evolution in the Renewable energy target and because it had in the same target a score of zero the first period (2.26 in the last one). In the same perspective, Energy supply's performances are explained by its important shifts from zero to 2.1 in GHG emissions target and from 0 to nearly 0.7 in Energy efficiency.

3.2.2. Decomposition Results

The composite index helps to take into account the target levels so that the additional performance needed from each sector to attain the Sustainable growth pillar related objectives can be measured. Despite the relevance of these results, additional details are important to understand the explanations of the best/worst achievements.

As wondered by Walheer (2018) in his national level Decomposition of the Europe 2020 strategy, best/worst performance might be explained by multiple potential reasons such as particular events that affect all countries (economic crisis or policy implementation, regulations at the European level) or that only affected specific countries (too high or too low targets of some countries, the difference in the effort needed to reach targets, (in)existence of enough inefficiencies for some countries or at the European level). For all these plausible reasons it might be confusing for countries to rely only on the composite index, since the impact of these reasons might have an influence at the sector's level too. This is why we also isolate the composite index in three components: sector-, group-, and objective-specific index.

Starting by presenting the decomposition results in *Table 4*, we present the averages for the initial and the final period.

A first finding is that Sector-specific indexes have increased on average for every objective. As such, sectors become more homogeneous and converge by improving their performances with respect to best practice. While Group-specific indexes have slightly decreased for GHG emissions and energy efficiency, they have globally increased as shown by the Sustainable growth pillar decomposition. This implies that being a member of a group of sectors in the context of group performance also improves over time.

The more important improvement of the Renewable share energy is explained by an increase of Sector- and Group-specific indexes. While other objectives the target is already reached (more than 1 in 2018), for the Energy efficiency, there is still some room for improvement to reach the target. This objective's relatively poorer performance is explained by smaller performances of both Sector-, Group- and Objective levels for which scores were below the unity (0.68; 0.97; and 0.81) in the last period.

Finally, the Objective-specific index only attains the target for the GHG emissions objective for the period of 2004-2018. Based on this index, one cannot make conclusions that the targets are well set, reachable or not.

Table 4: Decomposition, average results

Objective	Period	Composite index	Sector	Group	Objective
Sustainable growth pillar	2004	0.65	0.55	0.84	0.88
	2018	1.07	0.60	0.99	0.88
GHG emissions	2004	0.82	0.64	1.00	1.03
	2018	1.18	0.73	0.99	1.03
Energy efficiency	2004	0.76	0.64	1.00	0.81
	2018	0.85	0.68	0.97	0.81
Renewable energy share	2004	0.38	0.37	0.51	0.80
	2018	1.18	0.39	0.98	0.80

For more detailed results of the decompositions, we now consider descriptive statistics for each period, and levels of the indexes for the initial period and the final one.

a) Whole Sustainable growth pillar sector-specific index

We begin with the sector-specific indexes. They are computed for each sector and period for the Sustainable growth pillar objective. They show how each sector performs compared to the best practice. We present in *Figure 5* the index levels for each sector and each period and in *Figure 6* the index levels for every sector for the initial and the final period. Numbers and descriptive statistics are in *Table 8* in the Appendix.

If the index is equal to one for a given sector, this implies that that sector has the same performance as the best practice of the sample for a specific period. For the Sustainable growth pillar, averages are below one, meaning that sectors could, in principle, increase their performance for the period. The sector-specific index has, on average, increased over time but there is still progress to be made. The maximum and minimum have also increased over time, which is positive. The standard deviation explaining the dispersion decreases as well, meaning that the sample becomes more homogeneous. All sectors improved their performances except Agriculture. This can in fact be now explained by the sector-specific events/policies/factors. The specific-level index goes in favour of better performances but not enough to meet the target. The best sectors are Waste, International shipping and International aviation. Poor performers include Energy supply, Domestic transport and Industry. These results show the presence of underestimation and overestimation of the performances by the composite index for some sectors. While Waste has been underestimated, Industry and Energy supply were overestimated by the composite index. For these sectors, the sector-specific index seems not to be the key explanation of the previous results found for the composite index. However, this index relatively accurately measures the performances of International shipping and International aviation.

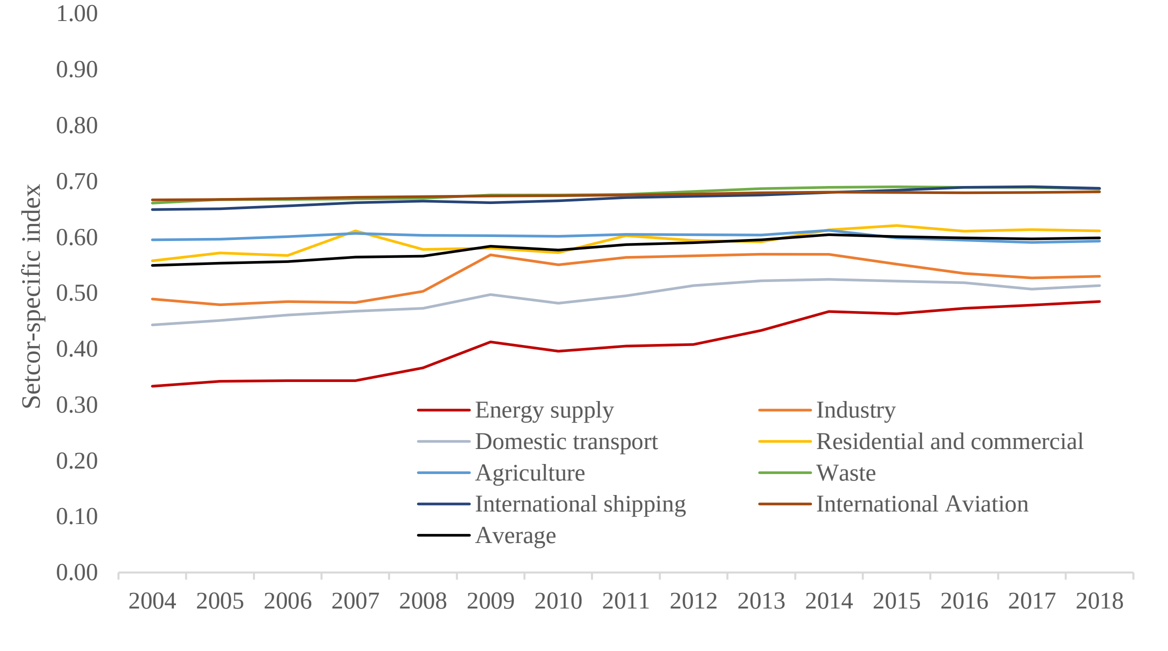


Figure 5: Sector-specific index for the Sustainable growth pillar

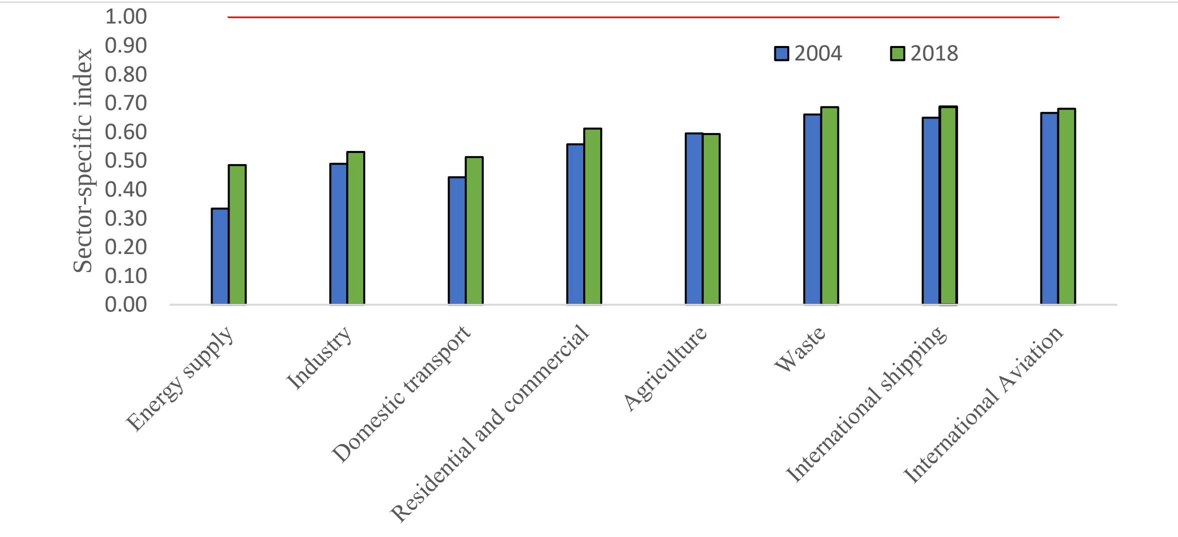
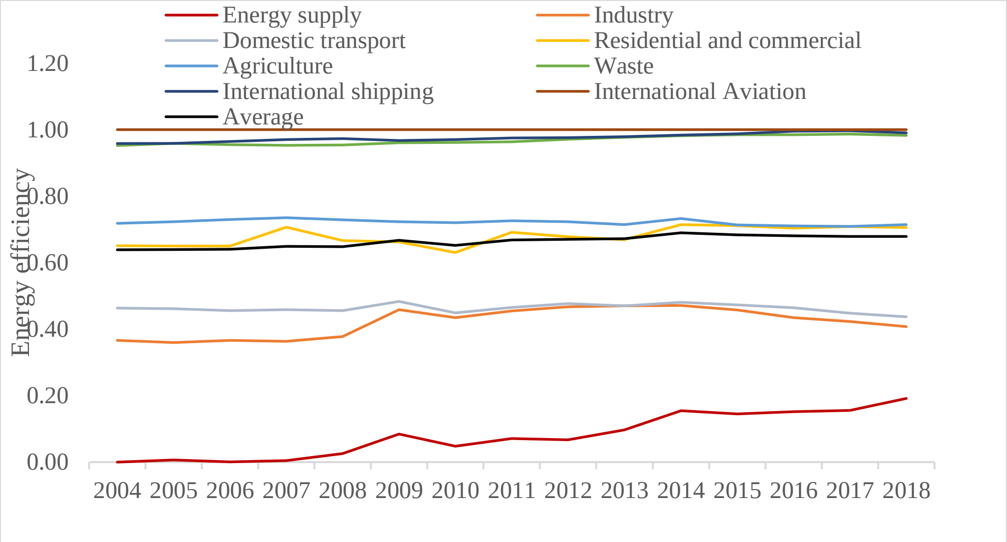


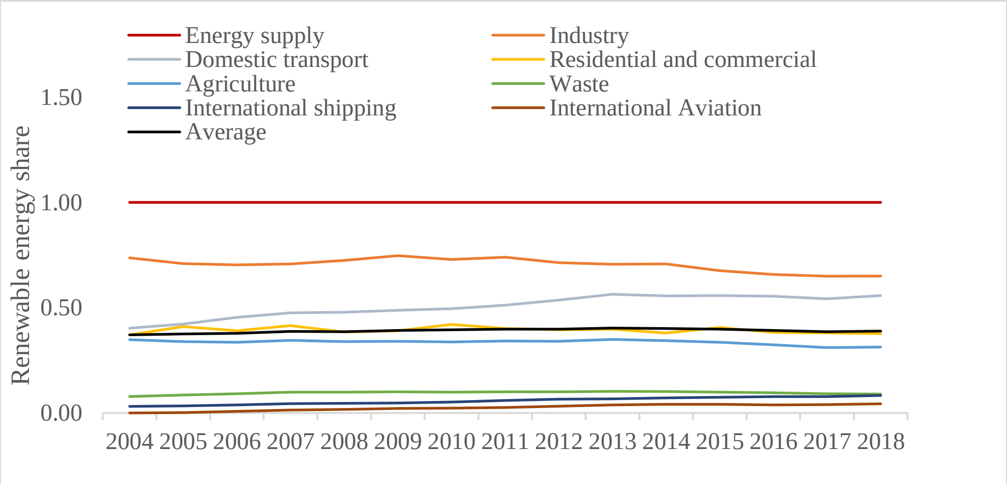
Figure 6: Sector-specific index for the Sustainable pillar: 2004 vs 2018 scores

b) Objectives sector-specific index

We plot for each sector and period for the three objectives of the Sustainable growth pillar sector-specific indexes that show how each sector performs compared to the best practice. In *Figure 7* the index levels for the whole period and in *Figure 8* the index levels for the initial and the final period are found. Detailed numbers and descriptive statistics are in *Tables 9,10* and *11* in the Appendix. Having a value of an index that is equal to one for a given sector implies that that sector has the best performance for a specific period. For all three objectives, the averages are far from one. The implication of these low values is that sectors could, in principle, increase their performances for all periods.

For the GHG emissions objective, all sectors improved their performances in general, as shown by the average. International aviation was the best sector followed by International shipping and Waste. Energy supply which remained the last performer for this objective went from 0 in 2004 to 0.26 in 2018. Next, for the Energy efficiency objective, most sectors improved their performances but Domestic transport and Agriculture's scores went down between the first and the final period. The best performers for this objective are International aviation, International shipping and Waste. This explains the high performances for International aviation and International shipping shown in the composite index, but with a less expected level for Waste. As such, the performance of this sector is probably underestimated. Finally, for the Renewable energy share objective, the mean portrays a relatively low performance of sectors. Significant effort is still needed at sector's level to reach the target. The best performers are Energy supply, Industry and Domestic transport. Poorer performances are observed for International aviation, International shipping and waste. In this matter, the composite index has clearly overestimated performances from the International shipping and the International aviation.





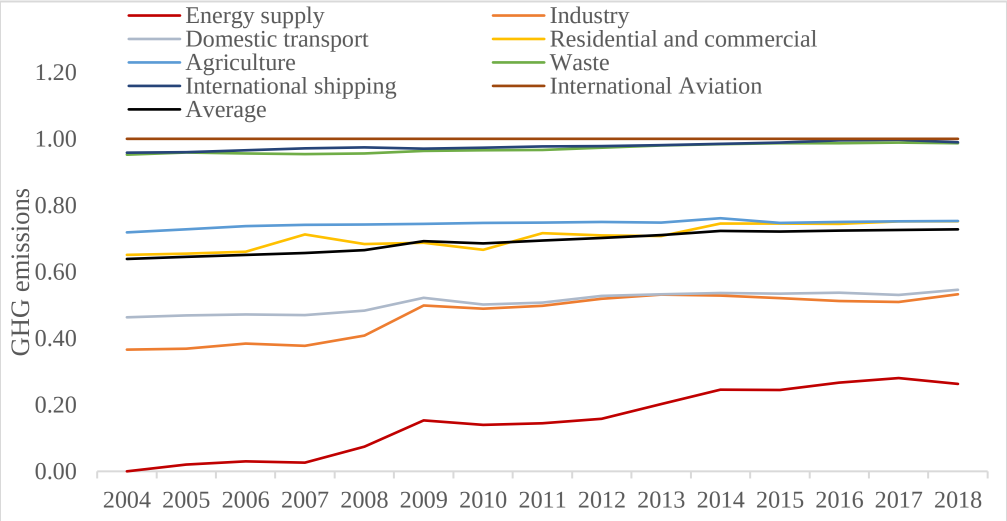


Figure 7: Sector-specific index for the three objectives

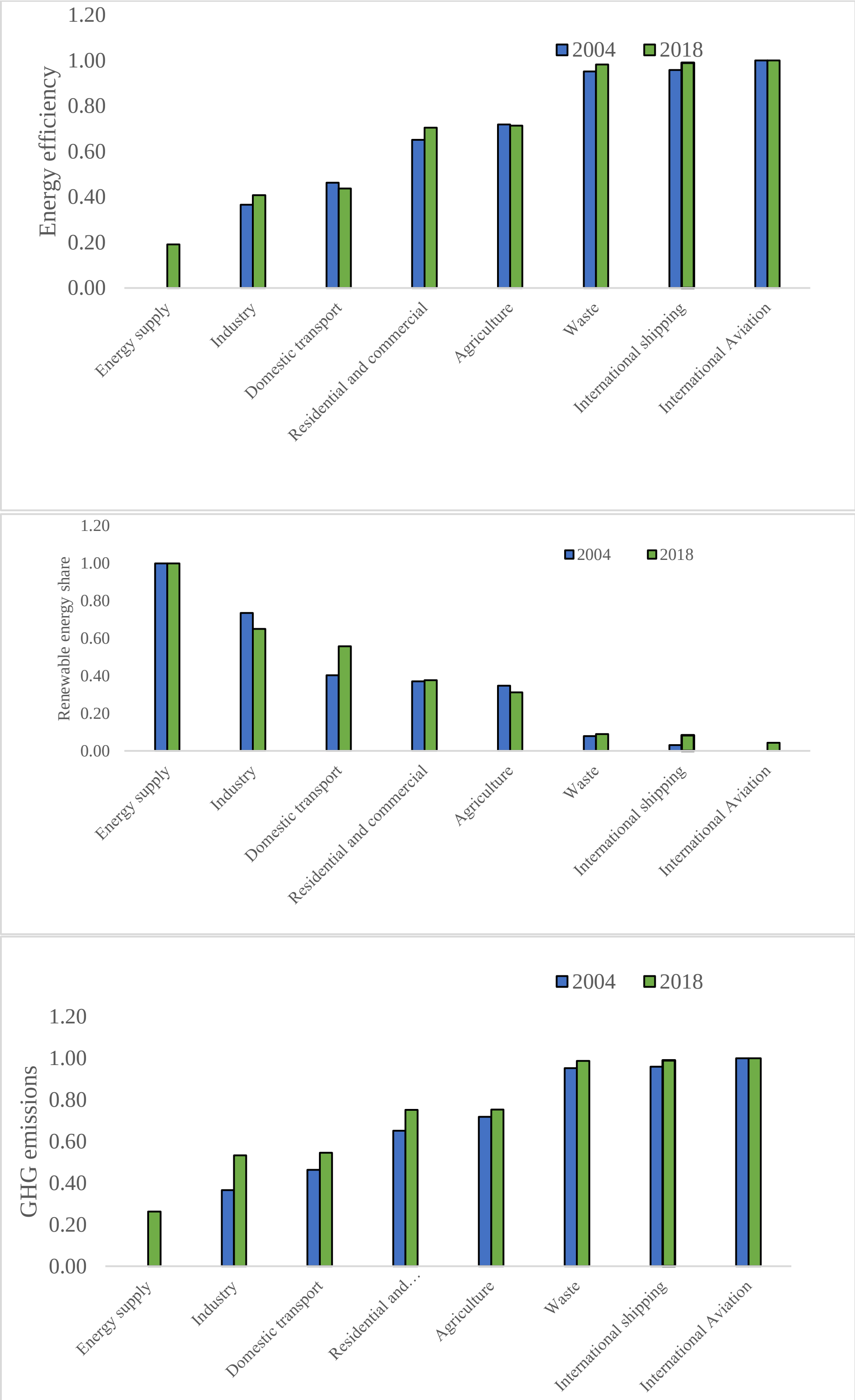


Figure 8: Sector-specific index for the three objectives: 2004 vs 2018 scores

c) Group-specific index

The group-specific indexes depend on time alone and are thus the same for every sector. They represent how the performances of the group have changed. This is relevant to measure whether being a member of a high-performance group (see 2.3. for group definition) has a positive or negative impact on the achievement of the targets. We plot in *Figure 9* the group-specific indexes for the three objectives and the Sustainable growth pillar objective overall. Detailed numbers are given in *Table 12* (Appendix).

When this index is one, that means the group has the best performance for the period. A first observation is that the index values are relatively high. Next, the initial levels are the same for GHG emissions and Energy efficiency, but different for Renewable energy share which was the lowest (0.51). The Sustainable growth pillar's level increased over time. Energy efficiency and GHG emissions' levels being already high did not change much (minor fluctuations) while Energy renewable's level increased over time. We observe a convergence between the three objectives over time. Policy at group-level may have been necessary for the Renewable share target to reach the one value in 2018. For the Sustainable growth pillar index, the increase is almost linear for all periods and has reached 0.99 for the final period, due to the relative diminishing worse performance of the Renewable energy share objective.

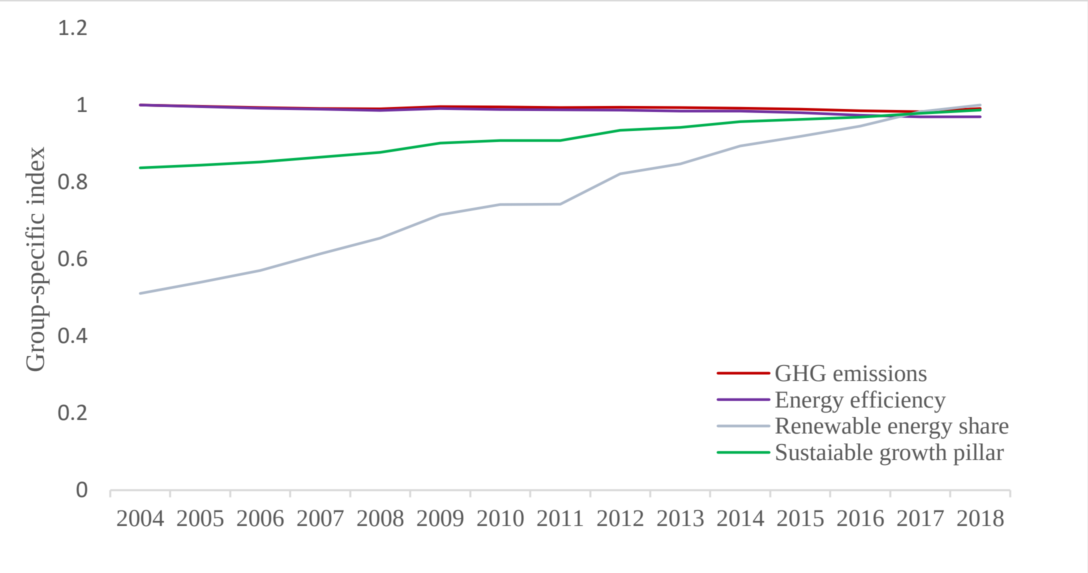


Figure 9: Group-specific index for the Sustainable growth pillar

d) Objective-specific index

The third and last reason for the best/worst performances might be due to the objective target itself. This last part of our decomposition responds to the question if the targets are reachable for the whole considered period. Intrinsically, this index is time-independent and only depends on the sector (and on the objective). We plot descriptive statistics of those indexes in *Figure 10*. Detailed numbers are in *Table 13* (Appendix).

The graph reveals that sectors could on average exceed 0.8 but not reach 1 except for the GHG emissions objective. Some sectors could exceed 1 for GHG emissions and Renewable energy share targets as portrayed by the Maximum numbers. In fact, as indicated in *Figure 4* we have seen that some sectors have reached and surpassed some objectives. Next, the graph also reveals again the relatively poor performances of the Energy efficiency and Energy renewable share targets on average. The minimum value is very low for Energy efficiency objective. This shows once more how difficult it is to reach that objective for sectors. We saw in previous results (see *Figure 4*) that no sector managed to reach this target for the whole period. Therefore, on average more effort is still needed for the Energy efficiency objective and the Energy renewable share target. Finally, the minor standard deviation confirms our previous observation of convergence and homogeneous sector groups over time. The results of the Sustainable growth pillar confirm our findings. The targets are, in principle, achievable, if more efforts are applied to improve performances for Energy efficiency and Energy renewable share objectives.

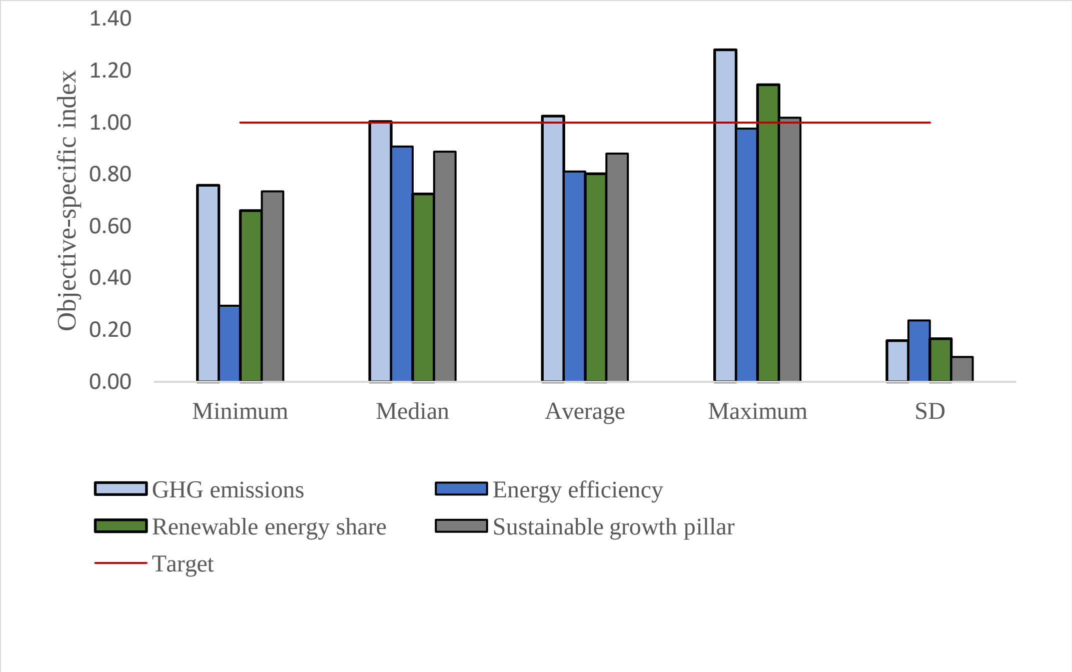


Figure 10: Objective specific index

3.2.3. The relative relevance of the Objectives

As discussed above, we consider all objectives having the same importance. This is the reason why we used the exogenous weights corresponding to the geometric average for all three objectives. That is to say each objective weights 1/3. However, one could consider that for a policy or political purpose, the importance attributed to each specific objective is differentiated and policymakers could assign different weights in accordance with their relative importance. The difference in weighing has an impact on the composite index.

If for instance the GHG emissions, the Energy efficiency and the Renewable energy share objectives are provided weights of respectively 1/5, 2/5 and 2/5, the composite index will change. For all sectors, the median and the average of 2018 vary from 1 and 1.07 to 0.95 and 1.05. Naturally, when poorly performed objectives are provided more relevance (weight) than better-performed ones, the composite index is negatively affected.

However, the difference in objectives' weighing does not have any impact on the decomposition results.

Attained (✓) and non-attained (✗) targets in 2018:

(De)composition Index	Sector	Sustainable growth pillar	GHG emissions	Energy efficiency	Renewable energy share
Composite	Energy supply	✓	✓	✗	✗
	Industry	✓	✓	✗	✗
	Domestic transport	✗	✗	✗	✓
	Residential and commercial	✗	✓	✗	✗
	Agriculture	✗	✓	✗	✗
	Waste	✗	✓	✗	✗
	International shipping	✓	✗	✗	✓
	International Aviation	✓	✗	✗	✓
Sector-specific	Energy supply	✗	✗	✗	✓
	Industry	✗	✗	✗	✗
	Domestic transport	✗	✗	✗	✗
	Residential and commercial	✗	✗	✗	✗
	Agriculture	✗	✗	✗	✗
	Waste	✗	✗	✗	✗
	International shipping	✗	✗	✗	✗
	International Aviation	✗	✓	✓	✗
Group-specific	All sectors	✗	✗	✗	✓
Objective-specific	Energy supply	✓	✗	✗	✗
	Industry	✓	✗	✗	✗
	Domestic transport	✗	✗	✗	✗
	Residential and commercial	✓	✗	✗	✗
	Agriculture	✓	✗	✗	✗
	Waste	✓	✗	✗	✗
	International shipping	✗	✗	✗	✗
	International Aviation	✗	✗	✓	✓

4. Conclusion

Using the composite index presents advantages given its relatively easy way to construct and interpret. It is also a useful tool to compare and benchmark sectors. In this analysis, we determined objectives at the sectoral level according to the country-level set objectives, after which we have defined a composite index for the Sustainable growth pillar of the Europe 2020 strategy and finally proposed a decomposition of that composite index. This decomposition provides important insight, by differentiating between three different components of the Sustainable growth pillar: sector-, group-, and objective-specific indexes. The decomposition, therefore, allows for a better understanding of the realisation of the set objectives at the sectoral level, since the composite index alone leads to confusion about all possible reasons explaining the given outcome. Applying our methodology to 8 sectors within the 27 European Union countries for the period 2004-2018, we found that while performances have increased over time, compelling efforts are still required to achieve the Europe 2020 Sustainable growth pillar objectives, especially the Energy efficiency and the Renewable energy share targets, as portrayed by the objective-specific index results. All in all, the decomposition allowed us to emphasise the important patterns and challenges for each sector at the three levels.

The policy implication of this thesis' results is that it would allow policymakers to focus on relevant policy aspects to improve performances so that the Europe 2020 objectives can be reached. As such, they could choose the level that induces the most the outcome of the objective. These levels can be the sector, the group of sectors or the objectives themselves. In other words, when unsatisfying results are denoted from one of the given levels, enhancement policy could be assessed accordingly. While the composite index depicts relatively satisfying results from 2014 to 2018 (scores above 1), we saw that these results underestimate the sector-specific index. For the same period of time, the latter only reached 0.60. In this perspective, policymakers could refer to the sector level to improve the whole outcome. The sectors-specific index indicates sectors that should increase their performances in different objectives: Energy supply, Industry and Domestic transport in both GHG emissions and Energy efficiency objectives; and International aviation, International shipping, Waste, Residential and commercial, and Agriculture in Energy renewable share objectives. Furthermore, from a group perspective, low-performance sectors should be incited to become more competitive to reach the level of high-performance sectors, especially for the Energy efficiency objective. Finally, the Objective-specific index reveals performances that are clearly overestimated by the composite index, especially for the Energy efficiency and Energy renewable share objectives. The relatively poor performances in these objectives are explained by the too high level of the targets. Theoretically, this can be addressed by lowering the targets. This not being the point, policymakers could consider empowering sectors by different means such as subsidies or other tools, to allow them to reach the objectives easier. Considering these implications could help to attain satisfactory results in the Europe 2030 climate and energy framework for which the ambition is to cut at least 40% of GHG emissions, to reach at least a 32% share for renewable energy and improve energy efficiency by at least 32.5%.

This work of course has some limitations. The principal one is the lack of all types of data. The real weights of sectors might be different across countries. All variables' data for each sector within each country of the EU 27 not being available, the weighing method allowed us to set the objectives and performances to make a sectoral level analysis. Further research providing more specific data for each sector in each country could help to have more precise results.

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6. Appendix

Table 5: Greenhouse gas emissions index

Period	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Sector															
Energy supply	0.00	0.17	0.24	0.21	0.59	1.23	1.12	1.16	1.27	1.62	1.97	1.96	2.13	2.23	2.10
Industry	1.01	1.01	1.05	1.03	1.11	1.37	1.34	1.36	1.42	1.45	1.44	1.42	1.39	1.37	1.45
Domestic transport	0.69	0.70	0.70	0.70	0.72	0.78	0.75	0.76	0.79	0.79	0.80	0.79	0.79	0.78	0.81
Residential and commercial	0.94	0.94	0.94	1.02	0.97	0.99	0.95	1.02	1.01	1.01	1.06	1.06	1.05	1.06	1.07
Agriculture	1.00	1.01	1.02	1.02	1.03	1.04	1.04	1.04	1.04	1.04	1.05	1.03	1.03	1.03	1.04
Waste	0.99	0.99	0.99	0.98	0.98	1.00	1.00	1.00	1.01	1.01	1.02	1.02	1.01	1.01	1.02
International shipping	0.95	0.95	0.96	0.96	0.96	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.98	0.98	0.98
International Aviation	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.95	0.95	0.96
Minimum	0.00	0.17	0.24	0.21	0.59	0.78	0.75	0.76	0.79	0.79	0.80	0.79	0.79	0.78	0.81
Median	0.96	0.96	0.96	0.97	0.97	0.99	0.98	1.01	1.01	1.01	1.03	1.02	1.02	1.02	1.03
Average	0.82	0.84	0.86	0.86	0.92	1.04	1.02	1.03	1.06	1.11	1.16	1.15	1.17	1.18	1.18
Maximum	1.01	1.01	1.05	1.03	1.11	1.37	1.34	1.36	1.42	1.62	1.97	1.96	2.13	2.23	2.10
SD	0.35	0.29	0.27	0.28	0.17	0.18	0.17	0.17	0.20	0.28	0.37	0.37	0.42	0.45	0.42

Table 6: Energy efficiency index

Period	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Sector															
Energy supply	0.00	0.02	0.00	0.02	0.09	0.32	0.18	0.26	0.25	0.36	0.57	0.53	0.55	0.56	0.70
Industry	0.78	0.76	0.77	0.76	0.79	0.97	0.91	0.95	0.98	0.98	0.99	0.95	0.90	0.87	0.84
Domestic transport	0.64	0.63	0.62	0.62	0.62	0.66	0.61	0.63	0.65	0.64	0.65	0.64	0.62	0.60	0.58
Residential and commercial	0.87	0.86	0.86	0.93	0.87	0.87	0.83	0.91	0.89	0.88	0.94	0.93	0.91	0.91	0.91
Agriculture	0.93	0.94	0.94	0.95	0.93	0.93	0.92	0.93	0.93	0.91	0.94	0.91	0.90	0.89	0.90
Waste	0.97	0.98	0.97	0.97	0.96	0.97	0.97	0.97	0.98	0.99	0.99	0.99	0.98	0.98	0.97
International shipping	0.95	0.94	0.94	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.96	0.96	0.95	0.95
International Aviation	0.96	0.96	0.96	0.95	0.95	0.96	0.95	0.95	0.95	0.95	0.95	0.95	0.94	0.93	0.93
Minimum	0.00	0.02	0.00	0.02	0.09	0.32	0.18	0.26	0.25	0.36	0.57	0.53	0.55	0.56	0.58
Median	0.90	0.90	0.90	0.94	0.90	0.94	0.92	0.94	0.94	0.93	0.94	0.94	0.91	0.90	0.91
Average	0.76	0.76	0.76	0.77	0.77	0.83	0.79	0.82	0.82	0.83	0.87	0.86	0.85	0.84	0.85
Maximum	0.97	0.98	0.97	0.97	0.96	0.97	0.97	0.97	0.98	0.99	0.99	0.99	0.98	0.98	0.97
SD	0.33	0.32	0.33	0.33	0.30	0.23	0.27	0.25	0.26	0.22	0.16	0.17	0.16	0.16	0.14

Table 7: Renewable energy index

Period	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Sector															
Energy supply	0.47	0.50	0.53	0.57	0.61	0.66	0.69	0.69	0.76	0.78	0.83	0.85	0.88	0.91	0.93
Industry	0.47	0.48	0.50	0.54	0.59	0.67	0.68	0.69	0.73	0.75	0.79	0.78	0.78	0.80	0.81
Domestic transport	0.46	0.51	0.58	0.65	0.70	0.78	0.82	0.85	0.99	1.07	1.11	1.15	1.17	1.20	1.25
Residential and commercial	0.46	0.54	0.54	0.62	0.61	0.68	0.75	0.72	0.79	0.82	0.82	0.90	0.88	0.90	0.91
Agriculture	0.46	0.47	0.49	0.54	0.57	0.63	0.64	0.65	0.72	0.76	0.79	0.79	0.79	0.79	0.81
Waste	0.39	0.45	0.51	0.59	0.64	0.71	0.72	0.73	0.81	0.85	0.89	0.89	0.89	0.88	0.87
International shipping	0.31	0.35	0.42	0.52	0.57	0.65	0.74	0.85	1.04	1.08	1.23	1.31	1.40	1.45	1.59
International Aviation	0.00	0.07	0.23	0.43	0.58	0.80	0.91	1.03	1.37	1.71	1.94	1.94	1.89	2.03	2.26
Minimum	0.00	0.07	0.23	0.43	0.57	0.63	0.64	0.65	0.72	0.75	0.79	0.78	0.78	0.79	0.81
Median	0.46	0.47	0.51	0.56	0.60	0.67	0.73	0.72	0.80	0.83	0.86	0.90	0.88	0.91	0.92
Average	0.38	0.42	0.48	0.56	0.61	0.70	0.74	0.78	0.90	0.98	1.05	1.08	1.08	1.12	1.18
Maximum	0.47	0.54	0.58	0.65	0.70	0.80	0.91	1.03	1.37	1.71	1.94	1.94	1.89	2.03	2.26
SD	0.16	0.15	0.11	0.07	0.04	0.06	0.09	0.13	0.22	0.32	0.39	0.39	0.39	0.43	0.51

Table 8: Sector-specific index for the Sustainable growth pillar

Sector-specific index	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Sector															
Energy supply	0.33	0.34	0.34	0.34	0.37	0.41	0.40	0.41	0.41	0.43	0.47	0.46	0.47	0.48	0.48
Industry	0.49	0.48	0.48	0.48	0.50	0.57	0.55	0.56	0.57	0.57	0.57	0.55	0.54	0.53	0.53
Domestic transport	0.44	0.45	0.46	0.47	0.47	0.50	0.48	0.49	0.51	0.52	0.52	0.52	0.52	0.51	0.51
Residential and commercial	0.56	0.57	0.57	0.61	0.58	0.58	0.57	0.60	0.59	0.59	0.61	0.62	0.61	0.61	0.61
Agriculture	0.60	0.60	0.60	0.61	0.60	0.60	0.60	0.61	0.60	0.60	0.61	0.60	0.59	0.59	0.59
Waste	0.66	0.67	0.67	0.67	0.67	0.68	0.68	0.68	0.68	0.69	0.69	0.69	0.69	0.69	0.69
International shipping	0.65	0.65	0.66	0.66	0.66	0.66	0.67	0.67	0.67	0.68	0.68	0.68	0.69	0.69	0.69
International Aviation	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Minimum	0.33	0.34	0.34	0.34	0.37	0.41	0.40	0.41	0.41	0.43	0.47	0.46	0.47	0.48	0.48
Median	0.58	0.58	0.58	0.61	0.59	0.59	0.59	0.60	0.60	0.60	0.61	0.61	0.60	0.60	0.60
Average	0.55	0.55	0.56	0.56	0.57	0.58	0.58	0.59	0.59	0.60	0.60	0.60	0.60	0.60	0.60
Maximum	0.67	0.67	0.67	0.67	0.67	0.68	0.68	0.68	0.68	0.69	0.69	0.69	0.69	0.69	0.69
SD	0.12	0.12	0.12	0.12	0.11	0.09	0.10	0.10	0.09	0.09	0.08	0.08	0.08	0.09	0.08

Table 9: Sector-specific index for GHG emissions objective

Sector-specific index	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Sector															
Energy supply	0.00	0.02	0.03	0.03	0.07	0.15	0.14	0.14	0.16	0.20	0.25	0.24	0.27	0.28	0.26
Industry	0.37	0.37	0.38	0.38	0.41	0.50	0.49	0.50	0.52	0.53	0.53	0.52	0.51	0.51	0.53
Domestic transport	0.46	0.47	0.47	0.47	0.48	0.52	0.50	0.51	0.53	0.53	0.54	0.53	0.54	0.53	0.55
Residential and commercial	0.65	0.65	0.66	0.71	0.68	0.69	0.67	0.72	0.71	0.71	0.75	0.75	0.74	0.75	0.75
Agriculture	0.72	0.73	0.74	0.74	0.74	0.74	0.75	0.75	0.75	0.75	0.76	0.75	0.75	0.75	0.75
Waste	0.95	0.96	0.96	0.95	0.96	0.96	0.97	0.97	0.97	0.98	0.98	0.99	0.99	0.99	0.99
International shipping	0.96	0.96	0.97	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.99	0.99	1.00	1.00	0.99
International Aviation	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Minimum	0.00	0.02	0.03	0.03	0.07	0.15	0.14	0.14	0.16	0.20	0.25	0.24	0.27	0.28	0.26
Median	0.68	0.69	0.70	0.73	0.71	0.72	0.71	0.73	0.73	0.73	0.75	0.75	0.75	0.75	0.75
Average	0.64	0.64	0.65	0.66	0.67	0.69	0.69	0.69	0.70	0.71	0.72	0.72	0.72	0.73	0.73
Maximum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SD	0.35	0.34	0.34	0.34	0.33	0.29	0.30	0.30	0.29	0.28	0.27	0.27	0.27	0.27	0.27

Table 10: Sector-specific index for Energy efficiency objective

Sector-specific index	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Sector															
Energy supply	0.00	0.01	0.00	0.00	0.03	0.08	0.05	0.07	0.07	0.10	0.15	0.14	0.15	0.16	0.19
Industry	0.37	0.36	0.37	0.36	0.38	0.46	0.43	0.45	0.47	0.47	0.47	0.46	0.43	0.42	0.41
Domestic transport	0.46	0.46	0.46	0.46	0.46	0.48	0.45	0.47	0.48	0.47	0.48	0.47	0.46	0.45	0.44
Residential and commercial	0.65	0.65	0.65	0.71	0.67	0.66	0.63	0.69	0.68	0.67	0.71	0.71	0.70	0.71	0.71
Agriculture	0.72	0.72	0.73	0.74	0.73	0.72	0.72	0.73	0.72	0.71	0.73	0.71	0.71	0.71	0.71
Waste	0.95	0.96	0.95	0.95	0.95	0.96	0.96	0.96	0.97	0.98	0.98	0.98	0.98	0.99	0.98
International shipping	0.96	0.96	0.96	0.97	0.97	0.97	0.97	0.98	0.98	0.98	0.98	0.99	0.99	1.00	0.99
International Aviation	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Minimum	0.00	0.01	0.00	0.00	0.03	0.08	0.05	0.07	0.07	0.10	0.15	0.14	0.15	0.16	0.19
Median	0.68	0.69	0.69	0.72	0.70	0.69	0.68	0.71	0.70	0.69	0.72	0.71	0.71	0.71	0.71
Average	0.64	0.64	0.64	0.65	0.65	0.67	0.65	0.67	0.67	0.67	0.69	0.68	0.68	0.68	0.68
Maximum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SD	0.35	0.35	0.35	0.35	0.34	0.32	0.33	0.32	0.32	0.32	0.30	0.31	0.31	0.31	0.31

Table 11: Sector-specific index for Energy renewable share objective

Sector-specific index	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Sector															
Energy supply	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Industry	0.74	0.71	0.70	0.71	0.72	0.75	0.73	0.74	0.71	0.71	0.71	0.68	0.66	0.65	0.65
Domestic transport	0.40	0.42	0.45	0.47	0.48	0.49	0.49	0.51	0.54	0.56	0.56	0.56	0.55	0.54	0.56
Residential and commercial	0.37	0.41	0.39	0.41	0.38	0.39	0.42	0.40	0.40	0.40	0.38	0.41	0.38	0.38	0.38
Agriculture	0.35	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.34	0.35	0.34	0.34	0.32	0.31	0.31
Waste	0.08	0.09	0.09	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09
International shipping	0.03	0.03	0.04	0.04	0.05	0.05	0.05	0.06	0.07	0.07	0.07	0.07	0.08	0.08	0.08
International Aviation	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04
Minimum	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04
Median	0.36	0.37	0.36	0.38	0.36	0.37	0.38	0.37	0.37	0.37	0.36	0.37	0.35	0.35	0.34
Average	0.37	0.38	0.38	0.39	0.39	0.39	0.39	0.40	0.40	0.40	0.40	0.40	0.39	0.39	0.39
Maximum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
SD	0.35	0.35	0.35	0.34	0.35	0.35	0.35	0.35	0.34	0.34	0.34	0.34	0.33	0.33	0.33

Table 12: Group-specific index

Objective	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
GHG emissions	1.00	1.00	0.99	0.99	0.99	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.99
Energy efficiency	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.98	0.98	0.98	0.97	0.97	0.97

Renewable energy share	0.51	0.54	0.57	0.61	0.65	0.72	0.74	0.74	0.82	0.85	0.89	0.92	0.95	0.98	1.00
Sustaiable growth pillar	0.84	0.84	0.85	0.86	0.88	0.90	0.91	0.91	0.93	0.94	0.96	0.96	0.97	0.98	0.99

Table 13: Objective-specific index

	GHG emissions	Energy efficiency	Renewable energy share	Sustainable growth
Energy supply	1.20	0.29	0.71	0.73436869
Industry	1.28	0.88	0.67	0.94398377
Domestic transport	0.76	0.63	0.89	0.75703621
Residential and commercial	1.01	0.89	0.73	0.87595304
Agriculture	1.03	0.92	0.66	0.87195165
Waste	1.00	0.98	0.72	0.89991421
International shipping	0.97	0.95	0.90	0.93838175
International Aviation	0.96	0.95	1.15	1.01916242
Minimum	0.76	0.29	0.66	0.73
Median	1.00	0.91	0.73	0.89
Average	1.03	0.81	0.80	0.88
Maximum	1.28	0.98	1.15	1.02
SD	0.16	0.24	0.17	0.10