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A composite assessment of the stringency of national climate and low-carbon energy policies

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ABSTRACT

The Paris Agreement requires countries to put in place climate change actions in line with the objective to keep the increase of the global temperature well below 2°C, with efforts to stay below 1.5°C, compared to pre-industrial levels. It is, therefore, of crucial importance to track and evaluate the policies and measures that national governments are implementing toward these objectives. National policies to reduce greenhouse gas (GHG) emissions include a wide variety of instruments aimed at deploying low-carbon energy sources, decarbonizing industrial processes, as well as commercial and residential sectors. New initiatives recently started to emerge to keep track of climate actions over time, covering various spatial and thematic areas. They also offer different levels of detail about climate policy measures, including both qualitative and quantitative information.

This study aims at gathering quantitative information from publicly available databases to monitor the progress of emission reduction policy measures, focusing on six main dimensions: policy density, carbon pricing, fossil fuel subsidy removal, energy efficiency, renewable energy and energy research and development (R&D) as aspects of interest for the research. These are used as the framework for a comparison across countries of the stringency of their climate and low-carbon energy policies. The approach is based on the construction of a composite indicator, namely the ACTION Index, which aggregates the six selected single indicators. Subsequently, the robustness of the proposed systematic measure is tested through the comparison of results with the Environmental Policy Stringency scores published by the OECD. The research covers emission reduction policy efforts in 26 countries throughout 11 years, from 2010 to 2021. Findings show that the stringency of mitigation policy measures increased over the last decade, reporting an overall positive trend for all the countries under analysis. Individual performance varies greatly among countries, with Norway and other Northern European nations showing the highest scores of the ACTION Index and a positive evaluation in all dimensions of climate policy considered. On the opposite side, Mexico is the main laggard, reporting the lowest score mainly due to inconsistent policy decisions and changes that, although an initial increment, contributed to the poor performance of the country in some dimensions such as carbon pricing and fossil fuel subsidy removal. On the whole, breaking down the ACTION Index into its components allows to delve into national dynamics with a finer eye: this part of the research uncovers remarkable heterogeneity, offering a granular evaluation of the factors driving the overall composite measure and those contributing the least. These results highlight the importance of

implementing comprehensive climate policy mixes, addressing together major sources of emissions, key polluting sectors and inefficient economic incentives.

Methodologically, the analysis confirms that assessing and comparing the stringency of national emission reduction efforts is a daunting task, challenged by limited data availability as well as by the variety and complexity of climate policy tools to be considered. This notwithstanding, the advancements proposed by the ACTION Index in terms of broader geographic and climate policy coverage compared to previous studies, will contribute to identify and fill the gaps in the scientific literature regarding the main issues related to policy stringency evaluation and it will allow to translate scientific evidence into thought-provoking policy recommendations and interesting guidelines for further improvement and research.

FOREWORD

By establishing challenging long-term goals and stressing on the urgent need to ramp up ambition to tackle the climate crisis, the Paris Agreement has spurred near-universal climate action at all levels, from local to global (UNFCCC, 2015). However, while the urgency to face environmental challenges, primarily climate change, and their detrimental effects is growing at an increasingly rapid pace, the endeavors to fulfil the Agreement's objectives are still lacking across several domains. To this regard, from the outcome of the first global stocktake (UNFCCC, 2023b), which officially concluded at COP28 in Dubai, and that evaluated the aggregated efforts toward the Paris Agreement's objectives, it is clear that Parties are persistently struggling in delivering effective measures and fall short in adopting a comprehensive and synergic approach. As a matter of fact, the reported efforts are still fragmented, focused on specific sectors, and unevenly distributed. On the contrary, still being mindful of the differentiated responsibilities and capabilities determined by the different national contexts, the last Conference of the Parties calls for accelerating emission reduction by pursuing global efforts such as tripling renewable energy capacity and doubling the average annual rate of energy efficiency by 2030, as well as eradicating harmful subsidies and gradually phasing out fossil fuels in energy systems; it thus underlines its commitment to multilateralism, in the development and implementation of fair and equitable regulations for sustainable climate action.

Existing gaps in policy action include weak long-term political vision, lack of financial and technical support to the implementation of climate measures, together with deficits in the assessment and reporting of national progress. As a direct consequence, in light of these deficiencies in implementing, supporting and collectively evaluating domestic endeavors, the last Conference of the Parties urges continuous monitoring and accountability from each country (UNFCCC, 2023b). Along with that, the countries are encouraged to facilitate the sharing and enhancement of knowledge and of good practices, to fill important shortcomings in capacity: in other words, the international community is called upon to meaningfully engage other actors such as technical experts and stakeholders, in order to develop innovative methodologies and tools for assessing the stringency and effectiveness of implemented efforts. In this regard, the scientific community agrees on the undeniable need for more robust comparative measures and more thorough cross-country research, to promote exchange of experiences and best practices (UNFCCC, 2023b). This would enhance transparency and comparability of domestic climate policy efforts, with important implications for the ambition of the global climate action as well as its credibility, equity, and public acceptance (Aldy et al., 2016).

Scientific studies often tend to narrow their focus on a particular aspect of regulatory stringency; while their approach enables to deliver detailed considerations ad in-depth examination of specific aspects, it often falls short in comprehensively addressing the multidimensional nature of the phenomenon and understanding the interrelated challenges it presents.

In this context, the present research stems from a compelling need to contribute to the advancement of climate policy evaluation and cross-country analysis in a more holistic way. Indeed, it represents a pioneering effort to integrate dimensions indicative of policy stringency that have not been considered jointly before, in other comparative assessments in the scientific literature. The creation of the ACTION Index draws inspiration from the research activities conducted within the framework of the project ACTION – Assessing Climate TransItion OptioNs: policy VS impacts (Davide & De Cian, 2023), at CMCC (Centro Euro-Mediterraneo sui Cambiamenti Climatici), ECIP (Economic analysis of Climate Impacts and Policy) Division, in Venice. Spanning 11 years and encompassing 26 countries from 2010 to 2021, the composite measure offers a unique opportunity to delve into national performances and their evolution across various indicators. The dimensions constituting the ACTION Index consider the key elements of an emission reduction strategy, such as the number of mitigation policies implemented, the carbon price, the removal of fossil fuel subsidies, the support to energy efficiency and renewable energy sources and the expenditure in energy research and development (R&D).

Achieving the ambitious and long-term objectives established by the Paris Agreement hinges upon the effective integration of the aforementioned dimensions. While the ACTON Index allows to spotlight leaders and to point out shortcomings of laggards from a high-level perspective, the accompanying indicators facilitate a more granular and refined assessment, for exploring peculiar measures and initiatives implemented nationally in recent years and for proposing noteworthy policy insights, including targeted intervention or improvement in particular areas.

On the whole, the following research sheds light on the multifaceted nature of climate action efforts worldwide and it explores the several challenges arising from policy stringency evaluation. It also provides the chance to gain interesting insights on the complex world of composite indicators, stressing on their pivotal role in delivering clear and straight-forward information to enhance public awareness and to help stakeholders and policymakers in effectively tracking the implementation of climate policies and enhance continuous commitment to progress.

Table of contents

Annexes

Figures

Tables

List of abbreviations

BOD – Benefit Of the Doubt

CCS – Carbon Capture and Storage

CPI – Carbon Pricing Dashboard

CPLC – Carbon Pricing Leadership Coalition

CPD – Climate Policy Database

ELV – Emission Limit Value

EPS – Environmental Policy Stringency

ETS – Emissions Trading System

EW – Equal Weighting

FA – Factor Analysis

FITs – Feed-In Tariffs

GDP – Gross Domestic Product

GHG – Greenhouse Gas

ICAP – International Carbon Action Partnership

IEA – International Energy Agency

IISD – International Institute for Sustainable Development

IMF – International Monetary Fund

JRC – Joint Research Centre

LCOE – Levelized Cost Of Electricity

MBI – Market Based Instruments

NDCs – Nationally Determined Contributions

NMBI – Non-Market Based Instruments

OECD – Organization for Economic Co-operation and Development

PM – Particulate Matter

R&D – Research and Development

RISE – Regulatory Indicators for Sustainable Energy

1. Introduction and literature review

The Paris Agreement requires countries to put in place climate change actions in line with the objective to keep the increase of the global temperature well below 2°C, with efforts to stay below 1.5°C, compared to pre-industrial levels (UNFCCC, 2015). Along with that, in the endeavor to curtail emissions' growth, governments must face the raising concerns about the pollution plague, primarily caused by anthropogenic emissions. To this regard, the role of policies is crucial in delivering concrete mitigation actions. Notwithstanding, the efforts to assess the effectiveness of those regulations at cross-country level have always been limited by the lack of accurate and comparable measures of policy stringency (Botta & Koźluk, 2014). This study aims at filling this gap in the scientific literature, by proposing a new composite quantitative measure and assessing its robustness through the comparison with a similar empirical proxy proposed by the Organisation for Economic Co-operation and Development (OECD), i.e. the Environmental Policy Stringency (EPS) Index. This will allow to determine the extent to which researchers can rely on the former for future assessments.

The research is structured as follows. The introductory sections will entail literature review on climate policy stringency and on the different existing approaches to measure it. A specific focus will be on the use of composite indices, as a powerful tool in policy analysis and public debate. Furthermore, the Environmental Policy Stringency (EPS) Index will be described in depth, in terms of aggregation structure and scoring system; some of its empirical applications will be explored and the main limitations will be mentioned, to elucidate the reasons for constructing the ACTION Index. Secondly, the methodological section will help illustrate the approach followed for the construction of the quantitative measure of country performance. Along with that, the steps followed to test the reliability of the composite indicator, through the comparison with the EPS Index scores, will be described in detail. Section 3 will cover the main findings and results obtained from the analysis, whereas the last paragraph will be devoted to their discussion and to the identification of possible limitations and gaps. This will enable to draw conclusions and explore policy recommendations, as well as guidelines for further improvement.

1.1. Defining climate policy stringency

As reported in the "Handbook on constructing composite indicators: methodology and user guide" (European Commission, Joint Research Centre & Organisation for Economic Co-operation and Development, 2008), "what is badly defined is likely to be badly measured". It is, indeed, of primary importance to give a clear definition of policy stringency before considering how to assess it. The OECD refers to policy stringency as "the degree to which environmental policies put an explicit or implicit price on polluting or environmentally harmful behavior" (OECD, 2023). The concept can be applied to single policy instruments, as well as to overall environmental policy: its interpretation is unequivocal if related to environmental taxes for example, since a higher price on a unit of pollutant is synonym of higher stringency; likewise, when considering stricter emission limits. R&D expenditures or investments in clean technology options, or feed-in tariffs contribute to an increase in the strictness of a country's policy portfolio as well (Botta & Koźluk, 2014). Conversely, fossil fuels subsidies, for instance, have the opposite effect on environmental policy stringency: they do not only represent the cause of economic inefficiencies, but they are also responsible of hampering the clean energy transition (Schwanitz et al., 2014).

There are three main reasons supporting the need for tools to measure policy stringency: first of all, countries have to constantly keep track of progress toward meeting their national targets and adjust or improve their emission reduction policy measures in light of that. Secondly, on a broader scale, benchmarking country performance is essential to identify the most performing actors and those who must strengthen their policy action. Last but not least, the empirical evaluation of policy stringency allows to understand the impacts that environmental policies have on different sectors and players (e.g. workers, firms and households); this is particularly useful to prevent or solve undesirable regressive policy implications on specific groups (Kruse et al., 2022).

1.2. Measuring climate policy stringency

Existing cross-country studies on the topic often focus exclusively on a specific aspect of policy stringency: this certainly allows to deliver detailed considerations and in-depth evaluation of particular aspects. Nevertheless, narrowing the research scope usually hinders from identifying interconnections between various dimensions and from assessing the overall effectiveness and coherence of regulatory measures.

Nascimento et al. (2022), for instance, concerning policy density, developed an extensive analysis of the evolution in number and sectoral coverage of climate change mitigation policies implemented by G20 countries over the past two decades; the main research objective was to identify areas of improvement of the mitigation potential of national policy portfolios and solve misalignments due to policy gaps.

Regarding carbon pricing instead, Best et al. (2020) investigate the efficacy of carbon pricing regulations implemented in 142 countries over twenty years in contrasting emissions growth over time. Similarly, Finch & Van den Bergh (2022) evaluate the authenticity of countries' carbon prices by comparing them with national and sectoral advertised prices for 31 countries. In other words, the authors assess the reliability of carbon pricing policies in representing factual national policy influence on emissions. Furthermore, Best & Zhang (2020), explore key drivers (such as climate change awareness, education, control of corruption and participation in political globalization) determining variations in the adoption and implementation of carbon pricing policies among different countries. In the same vein, Skovgaard et al. (2019) through a mapping and clustering analysis illustrate the main economic, political and environmental considerations influencing the implementation of carbon pricing frameworks globally. Moreover, Linsenmeier et al. (2022) discuss possible challenges and opportunities arising from the different strategic order of implementing carbon pricing measures. Carhart et al. (2022) instead, propose a methodology for quantifying comprehensive carbon prices of domestic climate laws, by considering both explicit mechanisms, i.e. carbon taxes and ETS, and implicit priced included in various policy instruments, such as regulations or subsidies.

Concerning fossil fuel subsidies, Harring et al (2023) present a comprehensive evaluation of public attitudes and the reasons behind them (e.g. socio-demographic aspects or eco-consciousness), toward the removal of harmful incentives across five different developing countries, exploring people's perceptions and preferences through cross-national survey data. Along with that, Schwanitz et al. (2014) explore the consequences of phasing out harmful subsidies on the long-term and evaluate different scenarios and policy pathways for subsidy reform and assess their beneficial effects on reaching climate objectives.

Related to the energy sector, the study conducted by Carley et al. (2018) for instance, offers empirical insights on the effectiveness of renewable energy portfolios standards in promoting strong green energy deployment, depending on their design and stringency. Another detailed evaluation by Wang et al. (2022), by focusing on the BRICS economies, clarifies the relationship between the promotion of environmental policy stringency and the shift to clean energy sources, to mitigate carbon emissions, and their subsequent positive effects on ecological sustainability indicators. Regarding energy research and development, Johnstone et al. (2012) explore the interrelation between environmental policy stringency and technological innovation. In particular, through survey data and patent counts from 77 countries, the authors assess whether companies are eager to develop innovative technologies and processes to curtail environmental effects, in light of new regulatory frameworks.

Having listed some of the countless research in the scientific literature on climate policy stringency, the following study aims at conveying that a more holistic approach is needed to achieve a systemic and broader awareness of the dynamics involved in policy stringency enhancement and seek for robust and targeted policy intervention.

1.2.1. Challenges of assessing an elusive variable

Considering the complexity of this multidimensional variable, measuring policy stringency is not trivial and various are the challenges of assessing it in the most comprehensive way. Botta & Koźluk (2014) identify four main issues in evaluating the stringency of environmental policies: multidimensionality, sampling, identification (and enforcement), and the lack of data.

Multidimensionality can be interpreted in two ways: on the one hand, environmental multidimensionality refers to the fact that regulations aim at improving environmental quality by controlling the concentration of different pollutants (SO_x, NO_x, Hg, etc) in different environmental spheres (air, water, soil, etc). On the other hand, the concept of policy design multidimensionality entails the variety of environmental policy instruments (e.g. market-based instruments, command-and-control regulation, voluntary approaches, etc) and their multiple design features, as well as their application in different sectors. Regarding design characteristics, Botta & Koźluk (2014) consider the extent of differentiation in instrument design, based on factors such as vintage, size and type of technology used in production processes: countries often set different air emissions standards for coal and gas-fired power plants. Again, there is great variation of policy stringency for old and newly built infrastructure. Moreover, Kruse et al. (2022) highlight the risk of assessing only partially the stringency of national policies in a cross-country analysis, due to the diverse array of policy tools they employ: as a matter of fact, to address climate and energy concerns, some might lean more on market-based instruments such as environmental taxes, whereas others might show a preference for non-market based mechanisms like emission limits or standards. Besides, each of these policy mechanisms vary in terms of political acceptability, effectiveness, and dynamic efficiency (Galeotti et al., 2020). According to Botta & Koźluk (2014), a further aspect to consider is the role that each level of government plays in the environmental legislation of a country. Bearing in mind the challenge of multidimensionality, attaining an exhaustive assessment of the stringency of a national policy portfolio implies the aggregation of all these dimensions.

Sampling is another crucial aspect mentioned by Botta & Koźluk (2014) and it is implicitly related to multidimensionality. Issues may arise when considering that a sample on which a research study is conducted may not include specific sectors (e.g. in a service-based economy) indirectly affected by stringent environmental regulations (e.g. through high electricity prices). Furthermore, policies often determine the industrial composition of a country: a higher stringency may be related to a lower share of polluting firms.

Identification further complicates the measurement of policy stringency: it is defined as "the difficulty in correctly assessing the degree to which the expected consequences of stricter regulations (e.g. abatement expenditures by firms or observed pollution intensity) can be actually attributed to environmental policy stringency" (Botta & Koźluk, 2014). As a matter of fact, others can be the factors playing a role in that, such as specific traits of a country (like its level of development, market imperfections in its economic structure, technological access, and capability, outsourcing etc), policy uncertainty or provisions that aim to ease the transition. To this regard, Galeotti et al. (2020) refer to the industrial composition of a nation, or its economic structure as contextual time-varying characteristics that deeply influence the evolution of policies over time. Hence, measuring their stringency needs to account for their dynamic nature. In some cases, the impact of a policy might not be immediately observable, leading to time lags in its outcomes. This temporal gap makes the assessment even more intricate. Along with that, the same authors argue that countries facing more severe pollution challenges could potentially adopt stricter measures. Failing to consider this aspect would result in a biased representation of environmental policy stringency. Moreover, all the aforementioned characteristics are interrelated, and this makes it hard to establish a clear link between indicators of relative environmental performance (or pollution reduction expenses) and the actual mix of environmental regulations in place. Indeed, they can interact in unexpected ways, leading to synergies or conflicts that are difficult to capture. In addition to that, law enforcement issues, especially in nations with weak institutional power or unofficial economies, makes the measurement of the effects of regulations even more complicated (Botta & Koźluk, 2014).

Lastly, *the lack of data* represents the fourth remarkable challenging aspect underlined by Botta & Koźluk (2014): gathering reliable and consistent information on policy implementation and its outcomes can be difficult, particularly in countries with varying levels of transparency. The lack of data, according to the authors, is frequently conceived as a rationale for favoring a certain measure of policy stringency over another one. In the following section, the main existing measurement approaches will be explained in detail.

1.2.2. Approaches to its measurement

Several are the approaches adopted by the scientific community to measure policy stringency. Even though they vary in multiple aspects, Botta & Koźluk (2014) provide a clear and straightforward categorization, according to the context in which the stringency assessment is applied. To be more

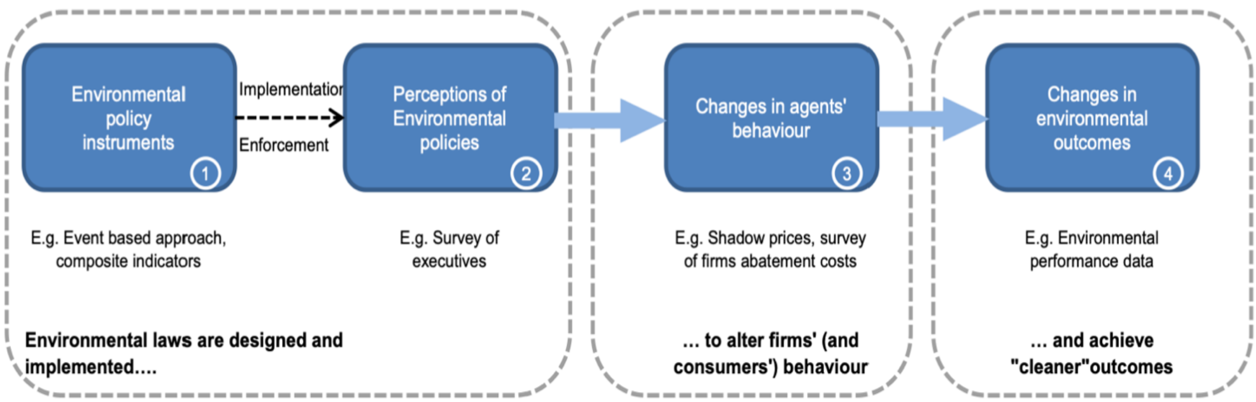

Figure 1. Approaches to the measurement of policy stringency
Source: Botta & Koźluk (2014)

precise, the following diagram elaborated by the authors (Figure 1), shows the four dimensions in which the measures can be included and the flow linking the design and implementation of environmental regulations to their desired outcomes:

The authors identify six main methods to assess environmental policy stringency:

- *single policy events measures* are useful for studying the direct impacts of policy introduction or changes in environmental regulations, especially at a micro-level. If the purpose of the research is highly specific, such as examining the effects of a single policy, this type of measures can simplify the analysis and overcome the problem of multidimensionality. Notwithstanding, this simplification comes at the expense of drawing more generalized conclusions, and it limits the representation of an overall environmental stringency assessment. One of the main advantages in empirical applications is that they allow to link policies to their effects directly, solving the challenge of identification. One limitation is that they are often binary variables, which makes it challenging to test the specific influence of various characteristics of policy change, like design aspects or interactions with other regulations.
- *composite measures*, instead, are a powerful method of summarizing complex information sets into a simple and representative measure, based on an underlying theoretical framework which includes more than one indicator. For this reason, they are strongly influenced by multidimensionality; yet, they are able to provide a comprehensive overview of a specific phenomenon. However, their creation is critical, especially in terms of weighting and aggregation; in fact, if poorly built, composite measures can be highly misleading and they can also fail to highlight important dimensions of policy instruments that are difficult to perceive and assess. As regards the issue of identification, similarly to single policy event measures, they are based on directly observable features. Nevertheless, another aspect to consider is that composite indicators may exhibit low variance across nations, often due to international policy directives promoting homogenization of laws. Conversely, policies can still differ in the process of implementation. Another strong point of this type of measures is that they hold a remarkable potential for reconstructing trends over time based on past and present regulations.

- *surveys of perceived stringency* entail other types of challenges; this category of measurement approaches is indirectly affected by various factors. Sampling, for example, is a crucial issue: respondents may give more (or less) importance to policy instruments, or pollutants depending on their personal experience. Even building a sample of participants randomly could be arguable, because many of them may not directly experience environmental regulations. Along with that, the problem of identification is remarkable as well: depending on the performance of a country's economy, survey-respondents may describe the national policy portfolio as more (or less) stringent. People's judgement may also be affected by the overall quality of a country's institutions, rather than just focusing on environmental strictness. When performing a cross-country analysis through surveys, it is taken for granted that respondents are aware of the current stringency of environmental laws in the international context; however, answers could be just a reflection of people's viewpoint of domestic policy stringency. In this case, it is of fundamental importance to be aware of and account for specific variations in national contexts, as well as taking into consideration the size of a given country's economy to scale properly. Lastly, surveys allow to cover a relatively long period of time, but they cannot provide historical data.
- *firm or plant surveys* are highly influenced by multidimensionality, due to the fact that companies are asked to report all environmental expenditures. Additionally, in terms of identification, this type of measures does not allow to analyze separately the effects of environmental regulations and other factors related to the business of the firm (e.g. investments in capital and R&D for energy efficiency or for profitability, that lead as secondary outcome to an improvement in the company's environmental performance as well); moreover, knock-on effects (such as the outsourcing of emissions due to stricter domestic environmental regulations) are often overlooked. Sampling is the third factor affecting firm surveys: on the one hand, countries heavily relying on polluting firms report higher pollution levels and higher expenditures on pollution control technologies. On the other hand, service-based economies usually show lower pollution levels and lower investments in environmental measures, even if the same standards are set. Last but not least, data availability is not the same across countries and years, hence a comparative analysis may be difficult and weak. In addition to that, if environmental policy stringency influences the industrial composition of a

nation, the outcomes of firm surveys will refer only to existing companies, hence, they will result in a biased characterization of the phenomenon.

- *shadow prices* represent "the opportunity cost of abating pollution in the form of reduced output" (Dang & Mourougane, 2014). Botta & Koźluk (2014) argue that the issue of multidimensionality, in this case, emerges only implicitly because this type of measure focuses on the outcomes, rather than on the several dimensions of policy instruments implemented to achieve the desired effects. However, it is worth highlighting that these outcomes are determined by other aspects (e.g. market imperfections or the interplay with other policies like labor or product market regulations), and this makes the stringency assessment tough. The challenge of lack of data in this context is not relevant, because there is usually full availability of information and historical trends can be built easily.
- *measures based on environmental outcomes,* like relative pollution intensity, reduce multidimensionality in terms of policy instruments and industrial composition, by looking at the effective role of a single pollutant in a specific environmental medium. Nonetheless, to conduct a comprehensive assessment of environmental stringency, the analysis of the contribution of several pollutants in various media is essential and multidimensionality needs to be addressed as well. On a global scale, these measures are generally easy to compare (e.g. for studying GHG emissions), whereas they may have limited relevance if used to evaluate the aggregation of local pollutants intensity. Like in the case of shadow prices, also this type of measurement approach cannot clearly identify the contribution of other policies, as well as production costs (such as energy, labor, and capital) and other issues like technological progress and market structures. Lastly, even if data availability is in some cases limited (especially for developing countries), measures based on environmental outcomes offer the possibility of building and studying historical trends.

On the whole, each of the measurement approaches described in the previous paragraph implies pros and cons. Depending on where to gauge the level of stringency, the magnitude of the challenging issues explained in Section 1.2.1. varies consistently. For example, assessing the strictness of environmental laws directly entails the risk of overlooking significant differences regarding what the regulation dictates (*de jure*) and how it is concretely enforced (*de facto*). At the same time, if the stringency is assessed directly through the laws themselves, problems related to identification can be avoided. Conversely, when the assessment is conducted after the implementation of regulations, policy effects become more tangible, and their multiple interactions emerge more clearly. Nonetheless, issues regarding sampling (especially in the case of surveys) and identification of the actual role of policies (among the multitude of factors influencing a specific outcome) may be tricky.

The next section will be dedicated to a specific focus on composite indicators and on their potential in measuring multidimensional and elusive concepts in policy analysis and on their ability in delivering straightforward information for dissemination, communication, and public debate. There is no universal acceptance on the methodology used to build them, hence, possible limitations in their application or critics on their construction will be explored as well.

1.3. Composite indicators

Generally speaking, an indicator is "a quantitative or qualitative measure derived from a series of observed facts that can reveal relative positions (e.g. of a country) in a given area. When evaluated at regular intervals, an indicator can point out the direction of change across different units and through time." (European Commission, Joint Research Centre & Organisation for Economic Co-operation and Development, 2008). Composite indicators are built through the aggregation of several indicators into a single index according to a theoretical framework or an underlying model. As already stated, this type of measurement approach has to deal with multidimensionality, that can be simplified by selecting single measures (indicators) of a certain phenomenon and analyzed on the whole when grouped together.

1.3.1. Advantages

In the field of policy analysis, indicators represent powerful tools for summarizing and depicting complex and multidimensional entities in the clearest way. This is particularly helpful for decision-making purposes of political leaders: especially in cross-country analysis, they can help in tracking progress over time and in benchmarking nations' performance on a given issue. As a matter of fact, they are easier to understand than the whole set of sub-indicators they are built on and they still keep the underlying information base, while reducing the quantity of data into a single value or score. Furthermore, they are ideal means for creating simple and effective strategic communication with the general public, including citizens and media. In fact, they allow to draw attention to specific topics, and they help build narratives around them, not only for academic circles, but also for ordinary people

(European Commission, Joint Research Centre & Organisation for Economic Co-operation and Development, 2008).

1.3.2. Methodological limitations

Having described the main strong points in the use of indices, it is appropriate to shed light on the possible limitations their application comes with. It is highly recommended to deal with methodological issues transparently, before proceeding with the construction of the composite measure in order to avoid manipulation and possible misinterpretation of data. As reported in the "Handbook for constructing composite indicators: methodology and user guide" (European Commission, Joint Research Centre & Organisation for Economic Co-operation and Development, 2008), the methodology behind their construction has to be carefully selected and applied, because if poorly built, this type of measure can lead to misleading results or simplistic outcomes. As a direct consequence of this, there is the risk of a wrong elaboration and misinterpretation of policy recommendations. Moreover, if the conceptual framework at the base of the composite indicator is not clearly described, the measure may be misused and applied wrongly (e.g. to support a specific policy). It is also worth noting that the creation of indices relies more on the choices and "artistry" of the modeler, rather than on universally established scientific guidelines for encoding. This is particularly true in the case of newly emerging policy areas, e.g. innovation, sustainable development and competitiveness, considering that the research in this fields is still premature and offers great potential to be developed in the following years. When it comes to models, the validation of a composite indicator depends on its suitability for the specific purpose it serves and on its approval among peers. To this regard, it is clear that the scientific community will never attain a shared opinion on the selection of indicators and weighting procedure, because it often involves personal judgement, that can potentially introduce bias: another critical issue, in fact, it that these factors can be the subject of political debate. Another frequently discussed topic is whether aggregating or not the several indicators into a single measure: on the one hand, aggregators claim that obtaining a representative summary statistic can be simple and effective in capturing the core meaning of an investigated issue; according to them, this will also better catch the eye of policy makers and arouse media and people's interest. On the other hand, non-aggregators argue that it is more convenient to analyze a suitable set of indicators once identified, without proceeding to create a composite index that may probably be meaningless and responsible of overlooking some information on the way.

1.3.3. The Environmental Policy Stringency Index

Created in 2014, the Environmental Policy Stringency Index is regarded as "a first tangible effort to measure environmental policy stringency internationally over a relatively long-time horizon." (Botta & Koźluk, 2014). It represents a country-specific and internationally comparable measure that has gained widespread popularity as a valuable tool for policy analysis (Kruse et al., 2022).

1.3.3.1. Structure and description

Heretofore, it has been developed for 40 nations (of which 34 OECD countries) and it covers a period of three decades, from 1990 to 2020. It can be easily updated and expanded when new data become available. As regards its structure, this composite index has been constructed through the aggregation of information related to 13 selected environmental policy instruments, with a specific focus on climate change and air pollution mitigation policies, for which data is most comprehensively available. As a matter of fact, as explained in the last updated Working Paper – No. 1703 – by OECD (Kruse et al., 2022), it has been necessary to strike a balance between the maximum possible coverage in terms of countries and period of time, and data that could be always consistently available and of high quality. Generally speaking, this is a crucial choice to ensure that variations in data quality do not affect the robustness of the index itself.

The latest version of the index, namely EPS21, is characterized by a specific aggregation structure, based on three equally weighted sub-indices, divided into market-based, non-market based and technology support policies.

- *Market-based instruments*

Among the market-based instruments (MBI), the authors group measures that put a price on pollution: firstly, *CO2 trading schemes*, which stringency is gauged by the average annual permit price. It is obvious that the higher is the price and the stricter is the regulation. As regards regional trading schemes, the prices are subject to aggregation at national scale. Subsequently, the values in national currency are converted to USD/tonne of CO_2, to facilitate comparisons. Secondly, *Renewable Energy Trading Schemes* are included in the study to estimate the percentage of electricity that comes from green sources; also in this case, the higher is this value and the more it helps increase the stringency. The third indicator refers to *CO_2 taxes*, which value in national currency is converted in USD/tonne of

CO_2 as well. The same conversion is applied to *Nitrogen Oxides (NOx) taxes*, and *Sulphur Oxides (SOx) taxes*. Lastly, the stringency of *Fuel Taxes (Diesel)* is assessed by dividing the diesel tax by the national pre-tax price paid by industries for diesel. Then the values are converted to USD/litre.

- *Non-Market-based instruments*

The second sub-index brings together non-market-based instruments (NMBI) tackling with pollution limits and emission standards: the first three indicators are *Emission Limit Value (ELV) for Nitrogen Oxides (NO_x)*, *ELV for Sulphur Oxides (SO_x)*, *ELV for Particulate Matter (PM)* which respectively measure the maximum levels of nitrogen dioxide emissions, sulphur dioxide emissions and particulate matter emissions allowed for a recently constructed coal-fired power plant. It is implicit that lower values indicate stricter policy directives. These values are measured in mg/m^3. The fourth indicator, namely *Sulphur Content Limit for Diesel,* is representative of the maximum concentration of sulphur allowed in diesel for cars. Also in this case, more stringent policies are associated with lower values of this variable. The unit of measure is parts per million (ppm).

- *Technology support policies*

The third sub-index regards measures fostering innovation in clean technologies and their adoption. It is further divided into upstream and downstream technology support measures: the former category concerns *Public Research and Development Expenditure (R&D)*, which refers to the national investments in R&D related to low-carbon energy technologies (including innovative clean solutions that might not yet be commercially deployable), like carbon capture and storage (CCS), hydrogen and fuel cells, renewable energy sources etc. This indicator is obtained by the ratio of the public R&D expenditure to the nominal GDP of countries. This result is then multiplied by 1000 to be better read. The second indicator, instead, refers to *Renewable Energy Support for Solar and Wind* and it gauges the level of financial support given to solar and wind energy technologies through mechanisms such as feed-in tariffs (FIT) and renewable energy auctions. It is evaluated relatively to the global levelized cost of electricity (LCOE), to consider the recent declining costs of renewable energy production over time. The value is the ratio, expressed in USD per kilowatt-hour (USD/kWh), comparing the price support to the LCOE. This third category has been added to the latest version of the EPS Index (EPS21), while the previous one (EPS16) did not account for it. This was done in light of the increasing interest in clean innovation solutions in recent years and also because investments in R&D and feed-in tariffs function differently compared to market-based and non-market-based policies. In particular, while these last two categories of regulations primarily address the external costs of emissions, the technology support dimension measures also positive externalities of Research, Development and Demonstration (RD&D). The authors declare that the updated version of EPS makes it possible to conduct a more granular assessment of the impacts of environmental laws.

The whole aggregation structure of the revised EPS index is represented as follows (Figure 2):

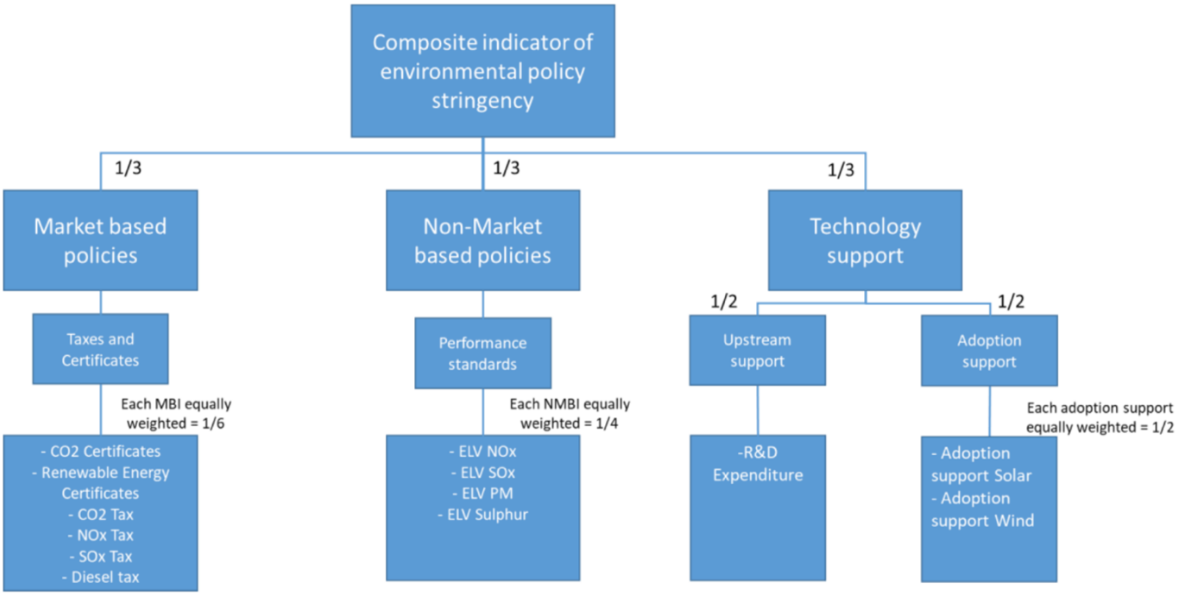

Figure 2. Theoretical framework of the EPS21
Source: Kruse et al. (2022)

Equal weights are assigned to each of the three sub-indices, bearing in mind that the policy set that each country deploys to manage emissions varies contextually. Along with that, within each sub-index, the sum of policy weights equals one; by doing so, each of the three instrument dimensions can be a stand-alone measure, that can be used to assess policy effects independently from the other two. As regards the scoring system, the EPS Index ranges from 0 (not stringent) to 6 (highest degree of stringency): considering each of the 13 policy tools, the raw data is reorganized in ascending order. The lowest value (0) is assigned when there are no regulations in place. Subsequently, the level of stringency is assigned looking at the distribution of observations. The maximum value (6) is given to observations that fall above the 90th percentile. The other scores (from 1 to 5) are decided by dividing the range between the 90th and the 10th percentiles into five equal segments, which establish the thresholds for the remaining values. In the case of highly skewed distributions, a value of stringency equal to 6 is associated to data falling above the 75th percentile, not to let that extreme values affect the threshold levels remarkably. The same way, the other thresholds stem from the difference between the 75th percentile and the 25th percentile, divided into five (Kruse et al., 2022).

1.3.3.2. Empirical applications of the EPS Index and policy stringency implications

Kruse et al. (2022) illustrate several environmental measures, which have been selected for a comparison of results with the EPS21: the main objective of the analysis is to understand relationships between the variables and to assess the extent and the direction of their correlation, in order to gain new insights about possible policy patterns. For example, among other measurement approaches of policy stringency, the EPS Index scores have been compared to industry energy prices (measured in USD/tonne of oil equivalent (toe)), that are regarded as widely utilized metrics for monitoring the impacts of pricing regulations on industrial sectors and companies. Nevertheless, it is essential to acknowledge their limitations: the authors argue that they can only provide a partial assessment of market-based policies and they are also influenced by non-environmental determinants, such as business cycles. In contrast, the EPS Index offers a distinct advantage by assessing the environmental policy effectiveness across a wider spectrum. The second relationship analyzed focuses on the World Economic Forum (WEF) Commitment to Sustainability Index, a parameter assessing how much effort countries put into promoting sustainable development. The score is composed by three sub-indices, which respectively measure countries' energy efficiency laws, renewable energy laws and the number of signed environmental treaties. In this case, it has been demonstrated that countries with more stringent environmental policies, as reflected in the OECD EPS Index, tend to exhibit a higher commitment to sustainability, as reported by the WEF Index. Furthermore, regarding other dimensions of environmental policies, a cross-sectional assessment between the EPS21 and the DEEP (Design and Evaluation of Environmental Policies) indicator has been conducted: developed by the OECD, it evaluated the possible economic burdens in OECD countries. It encompasses four key components: a) administrative costs of procedures required for permits and licenses in firms, b) impediments to competition for new companies entering the market and dealing with more stringent environmental rules than established firms, c) evaluation procedures related to new environmental regulations and their economic effect and d) transparency and rigor in evaluating the economic impacts of existing environmental policies. Considering the weak correlation between the two composite indicators, the authors argue that more rigorous environmental policies do not necessarily lead to increased challenges for businesses and in more in general for the economy. On the contrary, these findings suggest that certain barriers arising from environmental laws can be alleviated without compromising environmental goals. In the same paper (Kruse et al., 2022), the scores of the EPS21 are also analyzed in relation to various environmental outcomes: for instance, the Yale Environmental Performance Index (EPI) ranks countries' performance in 11 environmental dimensions, like climate change, air pollution, like the EPS; it also covers issues like sanitation and drinking water, biodiversity and ecosystem services, as dimensions of interest for environmental health and ecosystem vitality. Apart from differences in policy coverage, the Yale EPI evaluates concrete outcomes after the implementation of environmental laws, whereas the EPS Index deals with policy stringency, that may have effects on country's performance as a consequence. However, results suggest that a higher level of stringency denoted by the EPS aligns with better environmental performance; in fact, it is clear that stricter regulations contribute to emission reduction and better environmental performance. Furthermore, a negative correlation (which does not involve a cause-effect relationship) between the EPS scores and CO_2 emissions intensity and PM2.5 exposure has been detected: in line with existing evidence, it has been demonstrated that stricter regulations have a substantial impact on both reducing GHG emissions and improving air quality. An interesting point is that India and China represent outliers, due to their highly populated and strongly polluted cities; in fact, these two countries are characterized by the highest exposure to air pollutants and mediocre levels of stringency. Another remarkable but complex comparison relates the EPS Index to the Ecological Footprint (EF) indicator: the latter quantifies a country's utilization of ecological resources, relative to the Earth's capacity to produce goods and to absorb waste. In particular, the EF of consumption accounts for domestic resources and ecosystem service demand, as well as the export of goods exploited in other nations and the imported resources for domestic use. An alternative way of representing this parameter is the "Planet Equivalents", i.e. the number of Earths needed to sustain the humans' overall footprint, if everyone on the planet adopted the same consumption pattern as the people of a specific territory. High values of EF of consumption are indicative of greater demand of goods and unsustainable consumption. The correlation between the EPS21 and this variable is positive, meaning that nations showing high policy stringency tend to exhibit larger ecological footprints. It is worth noting that the current set of environmental laws is still insufficient to resize (or at least restrict) our consumption habits in relation to the limits that our planet poses in terms of goods and services. Additional and stronger policies are required to bring countries' needs down to sustainable levels. In addition to that, the EPS has been compared to a sub-measure of the EF, that is the Carbon Footprint indicator (measured in hectares per person): it is representative of the extent of the area of land required to absorb a country's carbon dioxide emissions. Even in this case, the values go hand in hand, showing a positive correlation. However, as stated by the authors, the values of these two measures may also follow different trends: on the one hand, the EPS Index focuses on production-based emissions, whereas the Carbon Footprint indicator gauges the consumption-based carbon footprint; having said that, it can be possible that the practice of emissions offshoring could lead to increased imports of carbon-intensive resources in nations with high levels of policy stringency. Lastly, in terms of innovative clean technologies and policy support, changes in the EPS Technology Support Sub-Index across time has been analyzed together with the share of climate change mitigation patents: both trends are similar, characterized by a growing trajectory until 2011, followed by a decline until 2015; after that, the share of climate change mitigation patents still experiences a decrease, whereas the policy support in clean technologies and R&D begins to rise again, even though still below the peak registered in 2011. The analysis of the interdependence between the two variables is essential to stress on the need for the introduction of new and well-designed laws aimed at spurring more innovation and greater advancements in the green transition. Additionally, the EPS has been employed in other empirical studies with the common objective of assessing the impacts of policy stringency on various economic outcomes: for instance, Albrizio et al. (2014) assess the relationship between national productivity growth in OECD countries and the stringency of their policies; the authors demonstrate that the observed tightening environmental regulations do not have a clear and strong impact on aggregate productivity growth, fostering essentially only short-term adjustments. Nevertheless, they provide new insights on differentiated impacts depending on the size of the firm: small and newly established companies experience a decline in productivity, whereas technologically advanced industries show a modest and temporary increase. Furthermore, Koźluk & Timiliotis (2016) delve into the Pollution Heaven Hypothesis (which argues that companies may opt to relocate their production plants in countries with laxer environmental regulations and lower energy costs, to circumvent the higher expenses associated with stringent environmental standards) and implement the EPS Index to investigate whether countries with stricter environmental laws are penalized in terms of competitiveness and exports. Overall, their research study reveals that there is no evidence that stringency has negative effects on global value chains. However, the authors underline its significant impact on trade specialization: in fact, more stringent policies affect the most polluting sectors, leading to reduced exports, hence lower competitiveness. Conversely, they grant a competitive advantage for less polluting firms, which can promote their exports. Similarly, Sauvage (2014) highlights the importance of environmental policies in shaping trade dynamics and identifies a significant positive relationship between regulatory environmental stringency and international trade in environmental goods. From the empirical analysis, it is stated that those countries with more stringent laws, are the ones that tend to excel in the export of goods designed for environmental protection and sustainability. Lastly, De Santis & Lasinio (2015) include the EPS Index in their study, to test possible positive effects on innovation activities within the EU. In particular, the research reveals that countries showing robust environmental regulations tend to stimulate greater innovation efforts, especially in green technologies and practices. The research studies described in this section are just some of the various examples of assessments, in which the EPS Index has been taken into account to explore the connections between policy stringency, economic efficiency and innovation efforts.

1.3.3.3. Limitations and critics

After having explored the several applications of the composite indicator and the great interest it has received in the scientific literature, it is worth mentioning some of the limitations it entails. As stated before, the EPS index mainly focuses on policies targeting the reduction of GHG emissions and local air pollution; one of his drawbacks is that, within this group of laws, this measure does not encompass regulations across all sectors of the national economies: for instance, it does not take into consideration policies related to the agricultural sector. This is particularly critical for countries (e.g. New Zealand and Brazil) where agriculture contributes significantly to carbon emissions in the atmosphere; furthermore, the composite indicator overlooks other environmental domains such as policies regarding water, biodiversity, or waste management, for which data is not accessible in a broad cross-country framework. To cite a representative example, water and waste management regulations are often implemented at regional or municipal scale, and this is the main reason why they cannot be included in national assessments. Other policies are not measured continuously (i.e. a national water management plan) and cannot be part of cross-country comparisons. Having said that, to this regard, Kruse et al. (2022) admit that the EPS Index may not fully represent the overall environmental policy portfolio and that to address this limitation future efforts could expand the index to cover additional dimensions.

2. Methodology

2.1. The ACTION Index

The elaboration of the ACTION Index aims at deepening the understanding of the main challenges related to policy stringency evaluation, as well as exploring interesting outputs through a cross-country comparison. By doing so, the main methodological steps required for the construction of the quantitative measure will be listed and each of them will be described as exhaustively as possible in a dedicated paragraph. An important contribution for the development of this part of the research has been given by the "Handbook on constructing composite indicators: methodology and user guide" (European Commission, Joint Research Centre & Organisation for Economic Co-operation and Development, 2008), as it represents one of the most complete sources of information about composite indicators which compare and rank country performance in different thematic areas and about up-to-date and well-established procedures implemented to build them. In particular, it provides a useful set of technical guidelines to make the most appropriate methodological choices and to ensure the quality of results. Based on that, Figure 3 shows the methodological steps on which the research is based.

2.1.1. Theoretical framework

The theoretical framework defines the underlying conceptual structure or set of principles that guides the selection, combination, and interpretation of individual variables into a meaningful measure. First of all, to ensure that the selected components or dimensions align effectively with the intended purpose of the analysis, it is essential to have and convey a clear understanding of the concept to be measured, together with the goals of the study: in practical terms, the "fitness-for-purpose" principle is respected when the selected variables are relevant and appropriate in relation to the specific objectives of the research, so that the composite indicator can be well-suited to serve its intended function. To this regard, the "Handbook on constructing composite indicators: methodology and user guide" (European Commission, Joint Research Centre & Organisation for Economic Co-operation and Development, 2008) highly recommends establishing a clear link between the framework and the structure of the composite measure, bearing in mind that, in some cases, when the multi-dimensional phenomenon is complex or difficult to evaluate, it could rise disagreement among stakeholders. For this reason, the process should include, as much as possible, the critical thinking of different experts in the field and the practical feedback of users once they have implemented the measure for their own research purposes. As a second step, to deal with the challenge of multidimensionality, it is worth determining possible sub-groups, to build a nested structure: this will not only allow to better study linkages between the selected factors, but it will also help the user to easily understand the relative contribution (in terms of weight) of each of them. Subsequently, a list of selection criteria is required to clearly distinguish between indicators to be incorporated in the overall composite measure and those which should be excluded because they are not relevant for the analysis.

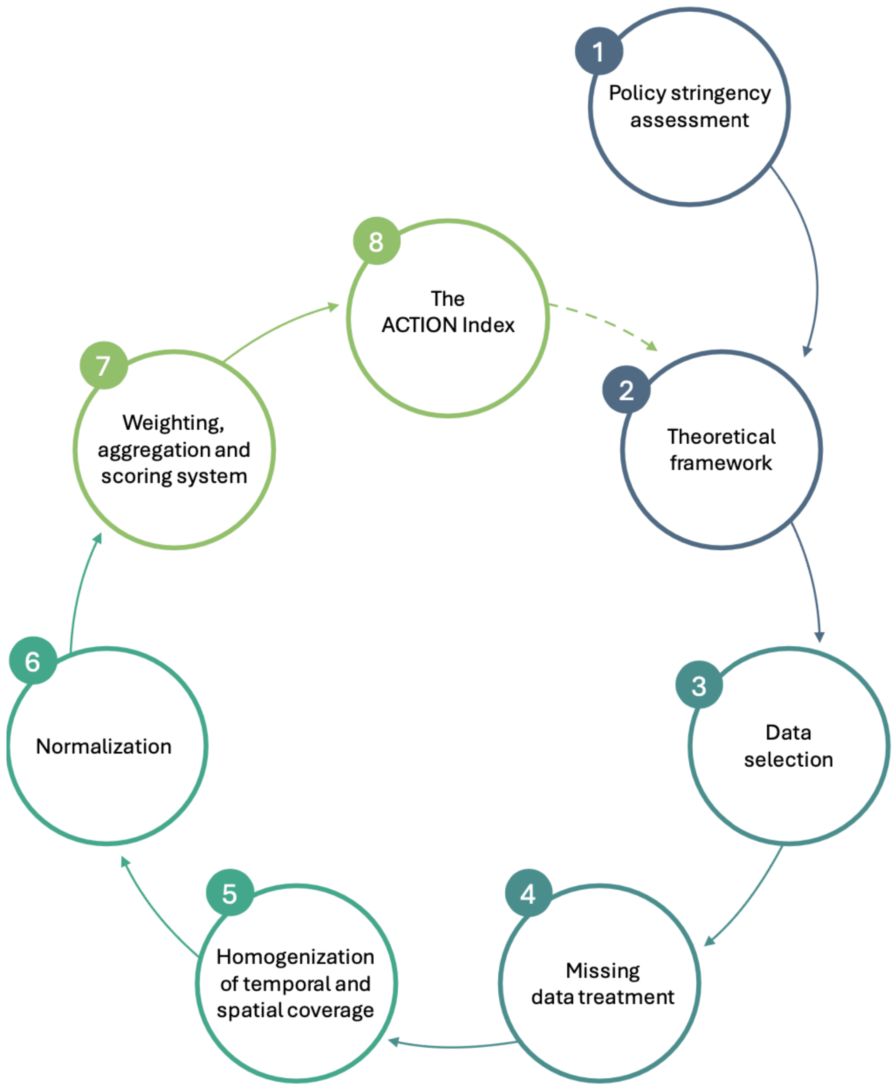

Figure 3. Methodological steps for the construction of the ACTION Index

Having said that, in this specific case, the definition of policy stringency and the purpose of the study have been deeply explored in the first paragraphs. A comprehensive evaluation of policy stringency, considering its multidimensional nature, would require indicators for each sector covered by policies. However, this assessment specifically focuses on climate and clean energy policies; bearing in mind this, Figure 4 shows the structure of the ACTION Index, that has been elaborated after a careful analysis of the scientific literature: the colored circles refer to the six main dimensions that have been regarded as crucial to defining the stringency of national regulations.

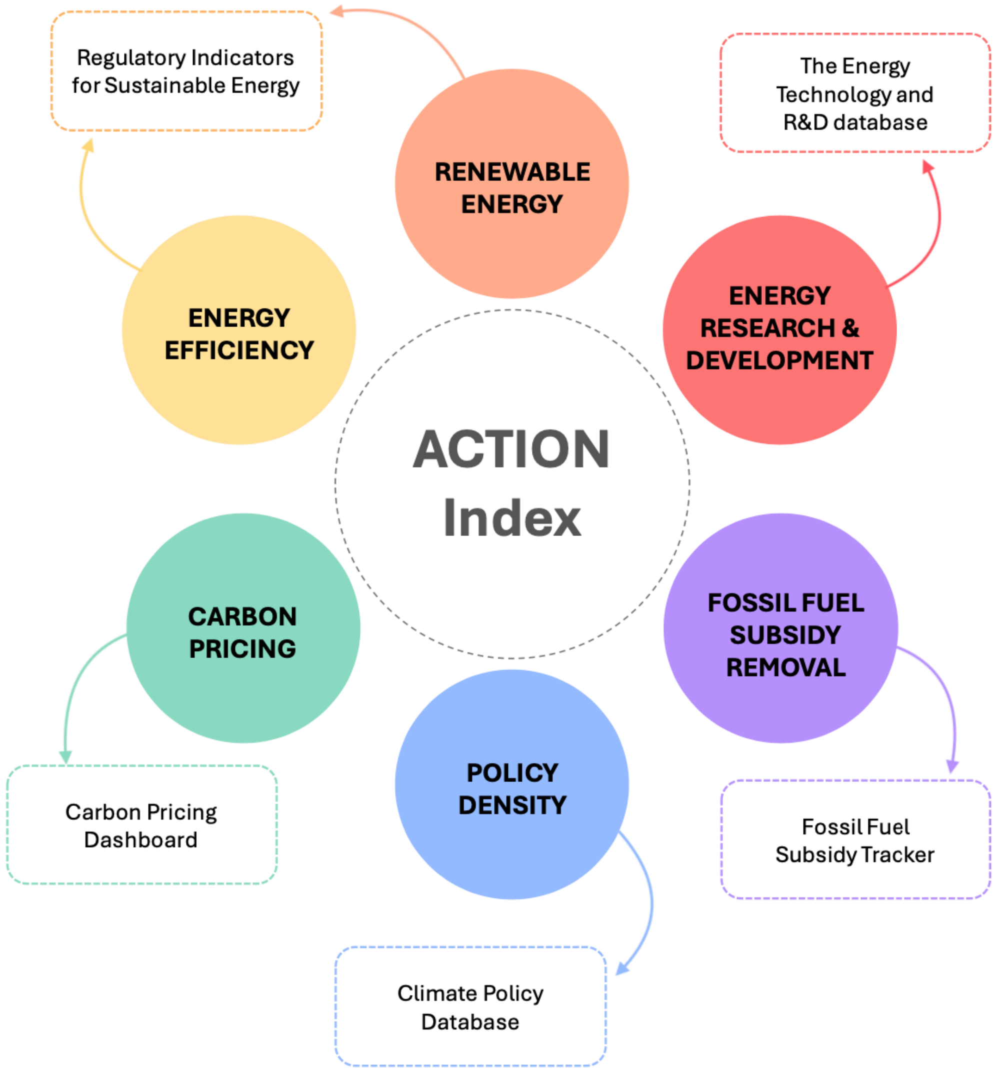

Figure 4. Theoretical framework of the ACTION Index and its dimensions

2.1.2. Data selection

The process of data gathering and selection for the construction of an index involves careful consideration of various factors: some of the ideal criteria that a researcher should take into account when dealing with eligible indicators are relevance, timeliness, accessibility and analytical soundness (European Commission, Joint Research Centre & Organisation for Economic Co-operation and Development, 2008); nonetheless, this step is usually influenced by subjective choices that confirm in most of the cases that there is no single definitive set of variables, but rather multiple options. Additionally, there are other issues that deserve the attention of the reader: considering the lack of internationally comparable quantitative (hard) measures, qualitative (soft) data collected from surveys or policy reviews is often chosen as the best alternative, resulting in a less rigorous assessment. As a matter of fact, some people may perceive qualitative measures as less precise than quantitative research, which could impact its acceptance in academic and professional circles. Moreover, to overcome the problem of scarcity of data, or when cross-country comparisons are limited, proxies may represent a good option, even though they should not be taken for granted. The last remarkable aspect that arises regards the need of an appropriate process of scaling of the various variables: this should be done to guarantee an accurate and reliable interpretability of results from comparisons. It ensures a more valid and meaningful assessment of differences and similarities across countries, indeed.

Based on the identified dimensions, the dashed boxes represented in Figure 4 refer to the five databases selected to conduct the analysis: namely the *Carbon Pricing Dashboard*[2], the *Climate Policy Database*[3], the *Energy Technology and R&D Database*[4], the *Fossil Fuel Subsidy Tracker*[5] and the *Regulatory Indicators for Sustainable Energy Database*[6]. The information provided by each of them is summarized in Table 1 and it is further explored in the next sections. In particular, the countries and time period covered by each database has been specified. Along with that, only quantitative data, whether discrete or continuous, has been exploited and its unit of measurement has been identified.

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[2] New Climate Institute, Climate Policy Database, https://climatepolicydatabase.org
[3] The World Bank Group, Carbon Pricing Dashboard, https://carbonpricingdashboard.worldbank.org/map_data
[4] IEA, Energy Technology RD&D Statistics, https://doi.org/10.1787/enetech-data-en
[5] OECD & IISD, Fossil Fuel Subsidy Tracker, https://fossilfuelsubsidytracker.org
[6] The World Bank Group, Regulatory Indicators for Sustainable Energy, https://rise.esmap.org/indicators

Database	Temporal coverage	Spatial coverage	Type of data considered in the research		Unit of measurement
Carbon Pricing Dashboard	1990 - 2022	47 national jurisdictions	Quantitative - continuous	Weighted price (based on the share of covered emissions)	US$/tCO2e
Climate Policy Database	1927 - 2022	198 countries	Quantitative - discrete	Number of policies	-
The Energy Technology and R&D Database	1974 - 2023	31 IEA countries and EU, Brazil, Chile	Quantitative - continuous	Total national RD&D	Nominal national currencies per thousand units of GDP
Fossil Fuel Subsidy Tracker	2010 - 2022	192 countries	Quantitative - continuous	Grand Total (coal, end-use electricity, natural gas, petroleum)	USD, nominal
Regulatory Indicators for Sustainable Energy	2010 - 2021	140 countries	Quantitative - discrete	Indicators	Scores (0-100)

Table 1. Overview of the databases included in the research

a) Carbon Pricing Dashboard

The Carbon Pricing Dashboard (CPI) is an international dataset launched in 2017 by the World Bank Group, supported by the International Carbon Action Partnership (ICAP) and the Carbon Pricing Leadership Coalition (CPLC). It represents an up-to-date source of information on carbon pricing initiatives implemented from 1990 to 2022 in 47 national jurisdictions and 36 subnational jurisdictions (The World Bank Group, 2023a, 2023c). It relies on annual data and analyses reported in the "State and Trends of Carbon Pricing" report series. It distinguishes between carbon taxes and emissions trading schemes (ETSs), specifying the status of the initiatives (implemented, scheduled, under consideration etc); it also includes details on policy coverage in terms of GHG emissions covered and carbon price levels. The transparency and effectiveness of carbon pricing mechanisms can vary from one country to another and may change over time as policies evolve. It is crucial to analyze the specific design and implementation of carbon pricing in each jurisdiction to understand how prices are determined and whether they align with the advertised rates. Referring to the dataset, Finch & van den Bergh (2022) argue that the advertised prices of carbon taxes can be highly misleading, because it may not always represent the actual price paid by emitters, due to possible exemptions or other factors. On the other hand, the authors also affirm that ETS mechanisms can offer more transparency for determining the price of emissions allowances, as it is driven by market forces. Overall, The CPI can be a valuable resource for tracking these developments and understanding the nuances of carbon mechanisms worldwide. Carbon price raw data (carbon taxes or ETS carbon prices) included in the dataset has been used to obtain a unique annual carbon price measure (in US$/tCO2e) per country. Precisely, the "emissions-weighted" carbon price has been calculated by multiplying the annual price by the emissions covered by the initiative in terms of annual share. This allows to compare different carbon prices across countries, considering their coverage and the varying levels of carbon intensity from sector to sector. For countries that have implemented both a carbon tax and an ETS system, both prices has been considered. Regarding the EU ETS, carbon price has been disaggregated to obtain a price for each of the EU member states, considering the year they officially obtained the membership.

b) Climate Policy Database

The Climate Policy Database (CPD) elaborated and developed by the NewClimate Institute, in collaboration with PBL Netherlands Environmental Assessment Agency and Wageningen University and Research, is regarded as one of the most complete packages on national climate mitigation policies: the data it contains has been retrieved from different sources of information, such as Climate Watch, the IEA/IRENA Policy Database, and the Climate Change Laws of the World Database (Schaub et al., 2022). Covering an observation period from 1927 to 2022, it includes more than 6000 policies and it spans over 198 countries; overall, it can be generally considered comprehensive for G20 economies and 18 other countries (NewClimate Institute, 2023); as a matter of fact, the coverage and the depth of information available on climate policies is generally wider for large emitters and countries that are obliged to systematically report in-depth on their policy implementation. Moreover, for those countries, the CPD has undergone a process of validation with several stakeholders and policy experts, to ensure data quality and consistency (Nascimento et al., 2022). Conversely, there is less available information regarding the non-G20 nations, which are mostly emerging economies in Europe, Asia and Latin America. On the whole, the database offers a comprehensive policy coverage: it does not only allow to measure policy density over time, but also to assess the degree of policy dismantling, indicating a decrease in policy density; as a matter of fact, it provides information about the year of adoption, as well as the year in which a policy has been repealed. For each regulation, different details are provided, mainly related to policy objectives, administrative level, instrument types, and targeted sectors. The six main sectors included in the database are electricity and heat, industry, land transport, buildings, agriculture and forestry, and general (this last category covers cross-sectoral policies which do not belong to a particular sector, and which may offer a framework for the implementation of other sector-specific laws). The key policy instruments gathered in the database are codes and standards, direct investments, voluntary approaches, market-based instruments, and fiscal and financial incentives. This variety reflects the existence of a multi-sector and multi-instrument approach to climate policies across countries. A significant drawback highlighted by Schaub et al. (2022) is that the CPD does not differentiate the types of policy; to be more precise, it is not possible to discern between binding laws and non-binding acts; to gather this type of information, the short description provided for each policy can be consulted. According to the scope of this research, filters have been applied to the original database to select only national regulations in force, which have mitigation as policy objective and that are related to climate and low-carbon energy sectors.

c) The Energy Technology and R&D Database

The Energy Technology and R&D Database is part of the IEA Energy Technology RD&D Statistics, published by the International Energy Agency (IEA) and it represents a useful source of information for tracking trends on energy technology and R&D expenditures, both in the private and public sector. It includes data that encompasses a broad spectrum of dimensions such as energy efficiency, renewable energy sources, fossil fuels, hydrogen technologies and more. It covers a period spanning around 50 years: starting from 1974 and it has always been updated, twice a year, usually in May and October (IEA, 2023a; IEA, 2023b). Its geographical coverage is broad, including 31 IEA countries, four IEA regions, the European Union, Brazil and Chile. It is structured in six main datasets: a) "Detailed Country RD&D Budgets", b) "Summary Country RD&D Budgets", c) "Estimated RD&D Budgets by Region", d) "RD&D Indicators", e) "RD&D Budgets per GDP" and f) "Summary RD&D Private Sector by Country". Considering the purpose of the study, to allow an easy comparison of results, the "RD&D Budgets per GDP" dataset has been considered: it contains annual data on the total RD&D in nominal national currencies divided by GDP in nominal national currencies at market prices and volumes, measured in thousand units of GDP. It covers 30 countries and one indicator (IEA, 2023c).

d) Fossil Fuel Subsidy Tracker

The Fossil Fuel Subsidy Tracker (OECD & IISD, 2023) stems from the research efforts of the OECD, together with the International Institute for Sustainable Development (IISD) and it provides a complete framework on global estimates of the financial support that fossil-fuel industry is still receiving nowadays. Fossil fuel subsidies can act as a barrier to the development and implementation of stringent climate policies. Thus, redirecting public financial flows, through the removal of harmful incentives, and promoting cleaner technologies represents a remarkable policy lever to achieve climate and low-carbon energy goals. With the aim of ensuring comparability of data and facilitating country reporting, the platform allows to keep track of wasteful subsidies, from both a global and a country-specific perspective. It covers 192 economies around the world and different support mechanisms (direct budgetary transfers, tax expenditures and induced transfers) and it is updated once a year. Data is collected from three databases owned by the major international organizations engaged in gathering data on the support for fossil fuels transparently: the OECD Inventory of Support Measures for Fossil Fuels, the IEA Energy subsidies database, and the IMF Fossil Fuel Subsidies database. As specified in the methodological section on the official website, the three sources offer complementary information: on one hand, the IEA, along with the IMF database, presents an overview of the explicit fossil fuels subsidy estimates as induced transfers to consumers. On the other hand, the OECD Inventory is a useful source of data on direct budgetary transfers and tax expenditures that encourage fossil-fuel production and consumption instead of green alternatives. Furthermore, it covers initiatives that set favorable conditions for the growth of the fossil-fuel sector, including producers, consumers and general services. It is worth mentioning a possible limitation: the Fossil Fuel Subsidy Tracker may include under-estimates of the actual overall subsidy totals, due to a partial quantification performed by the three single databases or because they may not have captured some aspects of the several support measures. The Fossil Fuel Subsidy Tracker provides specific national subsidies for coal, end-use electricity, natural gas and petroleum, as well as the grand total; this last information, measured in USD (nominal) has been included in the study.

e) Regulatory Indicators for Sustainable Energy

Lastly, the Regulatory Indicators for Sustainable Energy (RISE) database represents a useful reference point for policymakers, researchers, and private investors to evaluate national policy support for sustainable energy sources and identify opportunities to foster green investments in the sector (RISE, 2022; The World Bank Group, 2023b). The database consists of more than 30 indicators and 85 sub-indicators based on four main pillars of sustainable energy development:

a) Access to electricity
b) Access to clean cooking
c) Energy efficiency
d) Renewable energy

Representing over 98% of the global population, the RISE database comprises scores (ranging from 0 to 100) for 140 countries, and it provides a comprehensive overview of the strength and quality of governments' contribution in supporting actions to achieve national sustainable energy goals. It tracks changes in policies over time, from 2010 to 2021, allowing to monitor progress in each country through the timeseries. The numerical scoring system, ranging from 0 to 100, is sub-divided into three categories, according to a "traffic light system" which reflects the grade of ambition: green is used for strong performing countries, scoring from 67 to 100, demonstrating a mature and developed policy and regulatory environment. Secondly, the yellow group identifies countries' scores from 34 to 66, indicating a quite developed policy framework, which needs to be improved. Instead, red scores from 0 to 33 are representative of those countries which require a strong improvement in policy design and adoption, still at its premature stage. The survey methodology through which the scores are obtained consists of a questionnaire composed of several yes/no questions; depending on the responses, the scoring system assigns 0 points to negative answers and a positive value for affirmative answers. This criterion is applied to each sub-indicator that contributes to the final score of the several indicators. The research focuses on two of the four categories listed above:

- Energy Efficiency scores

This pillar includes the following indicators: *national energy efficiency planning*, *energy efficiency entities*, *incentives and mandates – industrial and commercial end users, incentives and mandates – public sector*, *incentives and mandates – energy utility programs*, *financing mechanisms for energy efficiency*, *minimum energy efficiency performance stardards*, *energy labeling system*, *building energy codes*, *transport sector energy efficiency* and lastly, *carbon pricing and monitoring*.

- Renewable Energy scores

The seven indicators falling within this category are *legal framework for renewable energy*, *planning for renewable energy expansion*, *incentives and regulatory support for renewable energy*, *attributes of financial and regulatory incentives*, *network connection and use*, *counterparty risk* and again *carbon pricing and monitoring*.

Like the other sources of information, this database has its own limitations: a country's RISE score refers to regulations that have been enacted, without ensuring that they have been effectively implemented in some cases. In other words, the database cannot fully represent the quality of the content of the regulations it considers, since it is a highly specific issue, and it may give rise to subjective considerations. It is therefore obvious that assessing the quality and enforcement of laws remains challenging. Nonetheless, considering the holistic perspective on which it is based, the RISE database offers a good potential to be exploited for several research purposes.

2.1.3. Missing data treatment

The absence of data frequently undermines the creation of robust composite indicators. Several can be the reasons and the three main patterns of missing values are illustrated as follows (European Commission, Joint Research Centre & Organisation for Economic Co-operation and Development, 2008):

- *Missing Completely at Random* (MCAR): in this scenario, the absence of values is unrelated to the variable of interest or any other variable in the dataset.
- *Missing at Random* (MAR): in this case, missing values are independent of the variable of interest but are influenced by other variables in the dataset.
- *Not Missing at Random* (NMAR): as regards this third category, missing values are contingent on the values themselves.

As reported in the handbook, it is often difficult to assess whether values are missing randomly or systematically. However, most imputation methods presume a "missing at random" mechanism (either MCAR or MAR). On the contrary, when a "non-random missing pattern" is assumed, it necessitates explicit modeling and inclusion in the analysis. The entire process could be intricate, involving ad hoc assumptions that might significantly impact the overall outcome of the analysis. Having said that, the choice of how missing data is handled can strongly impact the results. It is essential to be transparent in this sense, because different data treatment methods may lead to different conclusions and interpretations; the three general methods that are usually considered when facing missing data are:

- *Case deletion* (or case analysis) that allows to simply exclude missing records from the analysis. Nevertheless, applying this method implies the assumption that missing values are a random sub-sample of the original sample (MCAR assumption); if the statement does not hold, it may lead to biased estimated, and the standard errors tend to be larger in a reduced sample.
- *Single imputation* methods such as mean, median or mode substitutions, regression imputation, hot-and-cold deck imputation, and expectation-minimization imputation, involve replacing missing data with a single imputed value.
- *Multiple imputation* consists in replacing missing values with several imputed records, through the Markov Chain Monte Carlo algorithm for example.

In these last two cases, missing data are treated as an integral part of the analysis and are not discarded, as for the case deletion. This allows to minimize bias that could potentially arise when excluding values; at the same time, it is essential to reflect the uncertainty in imputed data, that may be different from real data: this can be done through variance estimates. While single imputation tends to underestimate the variance because it only partially reflects imputation uncertainty, multiple imputation, by providing several values, better represents this ambiguity. It is important to note that no imputation model is without assumptions, and the results should be rigorously checked for statistical properties, such as distributional characteristics.

As regards the analysis, different approaches for the single databases have been applied. As regards the RISE Database, there was only one missing value (for the year 2016), among the renewable energy scores; it has been treated through a single imputation based on average substitution considering the overall scores of the previous and the following year (2015 and 2017). Regarding the Fossil Fuel Subsidy Tracker, as reported in the methodological section of the official website, "blank cells should be considered as values that have not been estimated and not as zero" (OECD & IISD, 2023). Therefore, case deletion has been chosen as the best method, hence, small countries (especially islands such as Aruba) have been excluded because not relevant enough for the analysis, considering all the missing information. Lastly, the IEA Guide to Reporting Energy RD&D Budget/Expenditure Statistics (IEA, 2011) specifies for the Energy Technology and R&D database how to treat missing information contained in the database: for the cases indicated with "--", budgets or expenditures are nil, thus through single imputations, values equal to 0 have been assigned.

2.1.4. Homogenization of temporal and spatial coverage

Temporal coverage	2010-2021
Spatial coverage	Austria
	Belgium
	Canada
	Chile
	Czech Republic
	Denmark
	Finland
	France
	Germany
	Greece
	Hungary
	Ireland
	Italy
	Japan
	Korea
	Mexico
	Netherlands
	New Zealand
	Norway
	Poland
	Portugal
	Slovak Republic
	Spain
	Sweden
	Switzerland
	United Kingdom

Table 2. Temporal and spatial coverage of the analysis (Objective 1)

Considering the data availability of the six databases, the homogenization of both temporal and spatial coverage has been determined through an overlap procedure. Overall, the sample for the analysis includes 26 countries, which performance in terms of policy stringency is tracked over a period of 11 years, from 2010 to 2021. Table 2 shows the nations included in the research.

2.1.5. Descriptive statistics

Carbon Pricing Dashboard		Fossil Fuel Subsidy Tracker	
Mean	11.12	Mean	3,685,398,822.82
Standard Error	2.35	Standard Error	1,023,824,969.44
Median	6.48	Median	1,880,419,025.81
Standard Deviation	11.97	Standard Deviation	5,220,503,497.66
Minimum	0.00	Minimum	3,637,893.30
Maximum	75.16	Maximum	29,012,927,829.60
N	26	N	26
Climate Policy Database		**Regulatory Indicators for Sustainable Energy - EE scores**	
Mean	2.26	Mean	59.76
Standard Error	0.54	Standard Error	2.58
Median	1.17	Median	63.00
Standard Deviation	2.76	Standard Deviation	13.14
Minimum	0	Minimum	4.00
Maximum	13	Maximum	87.00
N	26	N	26
The Energy Technology and R&D Database		**Regulatory Indicators for Sustainable Energy - RE scores**	
Mean	0.36	Mean	64.86
Standard Error	0.06	Standard Error	2.55
Median	0.33	Median	66.79
Standard Deviation	0.29	Standard Deviation	13.00
Minimum	0.00	Minimum	11.00
Maximum	1.67	Maximum	94.00
N	26	N	26.00

Table 3. Descriptive statistics of the databases after the homogenization of temporal and spatial coverage

After the process of data cleaning, the six descriptive statistics tables have been built to have a general overview of the content of each database (Annex A). In particular, the considered parameters are the mean, the standard error, the median, the standard deviation, the minimum and maximum values and N (which represents the number of countries included in each database); it is worth remembering that N may not coincide with the total number of countries reported in Table 1, considering the filters applied at the beginning of the process of data selection and the nations that have been excluded because of several missing values. Another important remark is that for the Climate Policy Database, the overall descriptive statistics refers to the period 1990-2022 and does not cover the entire period 1927-2022. As a matter of fact, 1990 represents the first relevant year in which at least 10 policies in total have been implemented by countries according to the available information. The previous years (from 1927 to 1989) lack of data continuity, and this would have affected the parameters shown in Table 1 for the CPD negatively. Instead, Table 3 has been built after the identification of the 26 countries included in the analysis and it considers the same parameters.

2.1.6. Normalization

Normalization is a necessary step before aggregating data, considering that indicators within a dataset often differ in measurement units; there is plenty of methods cited in the scientific literature (European Commission, Joint Research Centre & Organisation for Economic Co-operation and Development, 2008; Freudenberg, 2003). An overview of the most commonly used ones is provided as follows:

- *Ranking* represents the most straightforward method; it is not influenced by outliers, and it is optimal when the objective of the research is to track countries' performance over a temporal scale by focusing on their relative position. Nonetheless, when it comes to evaluating national performance in absolute terms, this technique falls short as it loses information on specific levels.
- *Standardization* (or *z-score transformation*) transforms indicators onto a unified scale, characterized by a mean of 0 and a standard deviation of 1. In this case, it is obvious that indicators with outliers wield a stronger influence on the composite measure. This may not be ideal if the goal is to reward exceptional performances, i.e., achieving remarkably positive outcomes on a few indicators is considered more valuable than numerous average scores. To weaken this effect, adjustments can be made during the aggregation process. For instance, this can involve excluding the highest and lowest individual indicator values from the index or assigning different weights based on the perceived "desirability" of each individual indicator score.
- *Min-Max normalization* is used to standardize indicators to a common range [0,1] by subtracting the lowest value and dividing by the indicator value range. Even in this case, this method is susceptible to distortion, when dealing with extreme values or outliers. At the same time, the Min-Max allows to expand the range of indicators confined to a small interval, and its impact on the final composite measure may be more pronounced compared to the z-score transformation.
- *Distance to a reference* is another normalization method that allows to identify a reference point against which the relative position of a specific indicator can be measured. The reference might represent a specific target to achieve within a designated timeframe, e.g. the Kyoto Protocol's 8% reduction goal for CO_2 emissions by 2010 for all EU member states. Alternatively, it might be an external benchmark country, like United States and Japan, that are often

considered when constructing composite indicators within the framework of the EU Lisbon agenda. An alternative option is to set as reference the average country within a group, which has a value of 1, with other countries being assigned a score based on their deviation from this average. It is clear that indicators exceeding 1 are representative of countries with performances above the group average. Similarly, the leading country may be assigned the value of 1 and the others may receive scores relative to their distance from the leader. It is worth bearing in mind that this technique relies on extreme values, which could potentially represent dubious outliers.

- *Categorical scales* are used to assign values to indicators by categorizing or classifying them into discrete groups or categories based on specific criteria. The indicators can take the form of numerical values, or qualitative terms like "fully accomplished", "partly accomplished" or "not accomplished". The choice of categories depends on the nature of the indicators and the purpose of the assessment. As following step, typically, the scores are determined according to the indicator's distribution: in a numerical scale, 1 could represent a low level of achievement, while 3 might represent a high level of achievement. Regarding a qualitative scale, "fully achieved" might correspond to the highest score, "partly achieved" to a medium value, whereas "not achieved" to the lowest score. Often, the scores are determined based on the percentile rank of the indicator's value within a distribution: this means that the performance of a country or entity is compared to others in a similar context. For instance, across different countries, the top 5% of performers can get a score of 100, whereas those falling between the 85^{th} and 95^{th} percentiles get a score of 80, and so on, down to 0 points. The exact percentile ranges and scores can vary depending on the specific methodology. This approach allows to give a good visibility to the most performing countries and to penalize the worst ones. Categorical scales aim to maintain consistency over time. This implies that the same percentile or distribution-based scoring method is applied to the indicator across different years. This helps ensure that changes in the definition of the indicator over time do not impact the transformed variable, making it possible to track changes in performance across time. However, categorical scales have limitations, as they omit a significant amount of information about the indicator's variance, reducing it to a few discrete categories. Furthermore, when there's little variation within the original scores, the percentile-based categorization may not accurately reflect the underlying distribution. One potential alternative is to adjust the percentile brackets for each individual indicator to create transformed categorical variables with distributions that resemble a normal curve.

- *Indicators above and below the mean* represent another way of normalizing data: this transformation technique is founded on the mean-centered approach; this is such that values close to the mean (used as reference point) are assigned a score of 0, whereas those exceeding or falling below a specific threshold are assigned scores of 1 and -1, respectively. This valuable method is straightforward and is not influenced by outliers; nonetheless, it often faces criticism due to the arbitrary nature of the chosen thresholds for categorizing entities as above or below average. This can significantly impact the results. Another drawback consists of the omission of absolute level information regarding each indicator, with the risk of losing the magnitude of existing differences. For instance, if a particular indicator for an entity is three times higher than the mean, and the indicator for a second entity is 25% above the mean, both would be categorized as "above average" when using a 20% around the mean as threshold.
- The last normalization technique listed in this section is based on the *percentage of annual differences over consecutive years*: this transformation is ideal if the set of indicators is accessible for several years and it reflects the growth percentage of the considered values in comparison to the previous year.

The methods listed above are all valuable; however, the choice of the most appropriate one requires careful consideration of the characteristics of the available data, as well as of the objectives of the composite indicator, and more in general of the purpose of the research. As regards the set of data collected for this analysis, for comparative purposes, the normalization technique proposed for the elaboration of the EPS Index by Kruse et al. (2022) has been taken as a reference: for each dimension, the normalization process is based on the classification of the values (x_n) of the database into discrete intervals; eleven categories have been identified for each indicator, and to each of them, through a nested function, a score (from 0 to 10) has been associated. A score equal to 0 is associated to values of $x = 0$. On the contrary, the highest score (10) is given to observations with values above the 90th percentile. Subsequently, the amplitude of the frequency ranges for the remaining scores has been determined through this formula, considering the 90th and the 10th percentile of each distribution (Table 4):

$$(90^{th}\, percentile\ - 10^{th} percentile)/9$$

The resulting value represents the increment from one threshold to the following one, as shown in Table 5. A score of 1 corresponds to a low degree of policy stringency and so on, up to the maximum score of 10, associated with the highest performances of the single indicators in terms of strictness of regulations. It is worth specifying that the only database that has been subjected to the opposite ranking is the Fossil Fuel Subsidy Tracker, for which the score 10 has been assigned to values of $x = 0$, indicative of absence of subsidies for the fossil fuel sector. On the contrary, those countries with the highest values of harmful incentives receive a low score up to 0, since their financial support to the fossil-fuel industry is a synonym of low policy stringency. Moreover, Kruse et al. (2022) specify that for highly skewed distributions (with a standard deviation 1.5 times larger than the mean of the considered variable), the same method is performed, but considering the 75th and the 25th percentile. As regards this research, this criterion has been checked and none of the six dimensions have a standard deviation, which is greater than 1.5 times the mean.

	10th percentile	90th percentile
Carbon Pricing Dashboard	0.75	28.08
Climate Policy Database	0	6
The Energy Technology and R&D Database	0.03	0.71
Fossil Fuel Subsidy Tracker	267,449,408.80	11,128,903,969.64
RISE - EE scores	36.10	81.90
RISE - RE scores	37.00	84.90

Table 4. 10th and 90th percentile of each distribution

Score	Carbon Pricing Dashboard	Climate Policy Database	The Energy Technology and R&D Database	Fossil Fuel Subsidy Tracker	RISE - EE scores	RISE - RE scores
0	x = 0	x = 0	x = 0	11,128,903,969.64 < x ≤ 29,012,927,829.60	x = 0	x = 0
1	0 < x ≤ 3.78	0 < x ≤ 0.67	0 < x ≤ 0.11	9,922,075,685.10 < x ≤ 11,128,903,969.64	0 < x ≤ 41.19	0 < x ≤ 42.32
2	3.78 < x ≤ 6.82	0.67 < x ≤ 1.33	0.11 < x ≤ 0.18	8,715,247,400.56 < x ≤ 9,922,075,685.10	41.19 < x ≤ 46.28	42.32 < x ≤ 47.64
3	6.82 < x ≤ 9.86	1.33 < x ≤ 2.00	0.18 < x ≤ 0.26	7,508,419,116.03 < x ≤ 8,715,247,400.56	46.28 < x ≤ 51.37	47.64 < x ≤ 52.97
4	9.86 < x ≤ 12.90	2.00 < x ≤ 2.67	0.26 < x ≤ 0.33	6,301,590,831.49 < x ≤ 7,508,419,116.03	51.37 < x ≤ 56.46	52.97 < x ≤ 58.29
5	12.90 < x ≤ 15.93	2.67 < x ≤ 3.33	0.33 < x ≤ 0.41	5,094,762,546.95 < x ≤ 6,301,590,831.49	56.46 < x ≤ 61.54	58.29 < x ≤ 63.61
6	15.93 < x ≤ 18.97	3.33 < x ≤ 4.00	0.41 < x ≤ 0.48	3,887,934,262.41 < x ≤ 5,094,762,546.95	61.54 < x ≤ 66.63	63.61 < x ≤ 68.93
7	18.97 < x ≤ 22.01	4.00 < x ≤ 4.67	0.48 < x ≤ 0.56	2,681,105,977.88 < x ≤ 3,887,934,262.41	66.63 < x ≤ 71.72	68.93 < x ≤ 74.26
8	22.01 < x ≤ 25.05	4.67 < x ≤ 5.33	0.56 < x ≤ 0.63	1,474,277,693.34 < x ≤ 2,681,105,977.88	71.72 < x ≤ 76.81	74.26 < x ≤ 79.58
9	25.05 < x ≤ 28.08	5.33 < x ≤ 6.00	0.63 < x ≤ 0.71	0 < x ≤ 1,474,277,693.34	76.81 < x ≤ 81.90	79.58 < x ≤ 84.90
10	28.08 < x ≤ 75.16	6.00 < x ≤ 13	0.71 < x ≤ 1.67	x = 0	81.90 < x ≤ 87	84.90 < x ≤ 94

Table 5. Threshold distribution and scoring system of the ACTION Index

2.1.7. Weighting, aggregation and scoring system

Weighting and aggregation come right after the normalization process and represent another critical step in the construction of composite indicators: these procedures can wield a significant impact on both the final outcomes and the rankings of countries included in the benchmarking framework. Some weighting methods encompass statistical models, while others mainly rely on participatory techniques used to explore experts' opinion. However, regardless the chosen methodology, assigning weights essentially involves making value judgements; here is a summary of three common weighting schemes and related considerations (European Commission, Joint Research Centre & Organisation for Economic Co-operation and Development, 2008; Freudenberg, 2003):

- *Equal weighting* (EW) – by relying on this method, all variables or sub-indicators are given the same weight: this holds the assumption that they are equally important, as components of the index. It is a straightforward and transparent technique; however, it is often criticized because applying equal weights may be caused by a lack of an empirical basis, for instance when there is little awareness of the existing causal relationships between the variables; if so, this may not accurately reflect the actual importance of each indicator. On the contrary, the choice of adopting this method may also be justified by a preference for simplicity and avoidance of subjective judgements. In any case, attributing equal weights is not a synonym of "no weights", but it implicitly means that all indicators hold equal significance in the composite measure. Furthermore, when variables are structured into dimensions that are subsequently included in the index, the use of equal weights for the single values may result in an unequal weighting of dimensions within the composite measure. Another critical issue arises when variables with a remarkable degree of correlation are combined: this can lead to a form of double counting, with weights w_1 and w_2 summed in the composite measure. It is often advisable to analyze the statistical correlation between variables and prefer the ones which show a low degree. Another solution could be the adjustment of weights, e.g. by attributing a lower value to highly correlated indicators. Moreover, double counting should not only be faced from a statistical perspective, but also through a more qualitative approach: the composite itself should be compared to each single indicator to investigate if each of them is representative of the phenomenon the analysis aims to capture.

- *Statistical Models* – such as the principal components analysis (PCA), or the factor analysis (FA), as well as the "benefit of the doubt" (BOD) approach, are data-driven approaches that are based on the statistical relationship between variables. They ensure objective weighting, grounded in the inherent data patterns and they help to uncover the underlying data structure. The first two techniques can be applied only if there is correlation between the variables in play; they allow to reduce the dimensionality of the data, by identifying the most important dimensions or factors to construct more parsimonious and informative composite measures. Alternatively, the BOD approach is particularly useful when there is uncertainty about the appropriate weights for the index, or when it is important to respect the diverse needs and priorities of the different considered entities: in other words, a notable feature of this technique is that it provides country-specific weights, based on national priorities, together with policy objectives and specific circumstances. Moreover, it represents a parsimonious approach, under which all indicators are initially given equal weight, unless there is evidence suggesting the contrary, based on the available data. The main drawback is the potential instability in weights due to changes in data or issues related to data quality or availability.
- *Participatory Methods* – they involve the investigation of experts' considerations or stakeholders' preferences into the weighting process: to this regard, it is important to distinguish between the relevance of each specific indicator according to the participants and the immediacy or the degree of political intervention required within the specific dimension associated with that indicator. By doing so, the composite indicator usually aligns with specific policy priorities or objectives. Several are the participatory techniques, such as budget allocation processes (BAP), or analytic hierarchy processes (AHP), or conjoint analysis (CA) as well; they all allow people to express their opinion of the relative importance they attribute to variables or specific components. These methods are especially useful when performing national policy evaluations based on a well-defined basis; however, for international comparisons, such clear references are often lacking or may yield conflicting results. The BAP methodology, for instance, allows experts to allocate *N* points across a set of individual indicators, based on the relevance they attribute to each of them. It is worth noting that this method is most effective when applied to a small set of indicators, typically no more than 10 or 12, to avoid inconsistencies in results.

Transparency in documenting the weighting methodology is pivotal, as it helps ensure credibility in the development of composite indicators. It is common in practice to combine objective (statistical) and subjective (from experts or stakeholders) weighting methods to create indices that strike a balance between data-driven objectivity and policy relevance. Another key factor to consider is the time element: in some cases, it is preferable to keep the same weights over the years, for instance when the research is conducted to assess how specific variables evolve over time. On the contrary, if the goal of the analysis is to establish best practices or prioritize certain aspects, then weights should necessarily adapt and vary progressively.

Aggregation methods show great variety as well; the main issue to account for is the interpretation and meaning of weights in the context of the composite index. While weights are usually conceived as a measure of the importance of the associated variable, the actual effect of those weights in linear and geometric aggregations allows for compensability between indicators; in other words, this means that when some indicators perform poorly or have low scores, other indicators with higher scores can make up for these deficiencies, leading to a more favorable overall assessment. Instead, a multi-criteria approach may be more complex and structured, but it ensures to enhance the intrinsic importance of each weight, because it does not allow any kind of trade-off between indicators:

- *Linear aggregation* – it combines individual indicators through a linear sum, where each measure is assigned a weight, and the results are simply summed together. It represents a straightforward additive approach. According to this method, compensability remains constant, meaning that a country with low scores on one indicator needs a proportionally high score on others to enhance its overall performance.
- *Geometric aggregation* – conversely, it is based on a non-linear function, such as the geometric mean, that is implemented to combine the single indicators. In this case, the compensability is lower for indicators with low values; hence, an increase in a low absolute score has a more significant impact on the index than the same increase in a high absolute score. Therefore, in benchmarking exercises, countries are incentivized to focus on the improvement of low-performing sectors and activities, as this offers better opportunities to improve their rankings.
- *Multi-criteria approach* – it involves a more comprehensive and structured process. It evaluates and compares indicators based on multiple criteria and uses decision-making

methods to assign weights and rank indicators. It is usually implemented when the analysis focuses on data covering completely different dimensions (e.g. social, economic and environmental). It is obvious that a low economic performance cannot be compensated by high levels of social cohesion or enhanced environmental protection. One of the main limitations is that this technique may become computationally complex and time-consuming when dealing with a larger number of nations, as the number of permutations increases exponentially.

To sum up, the lack of a clear and universal approach for establishing weights and aggregation procedures does not compromise the validity of the composite measure, as long as the entire process is characterized by transparency. Considering all advantages and disadvantages of the weighting and aggregation methods described above, the most suitable option to lead a straightforward and effective process has been the following: all the six dimensions have been given the same weight because they are regarded as equally important in contributing to the ACTION Index overall score. Similarly to what mentioned by Kruse et al. (2022), the equal weighting of the sub-indices ensures a fair assessment that considers the different strategies and dimensions that countries may employ to contribute to national policy stringency. Subsequently, a linear aggregation of the scores has been performed: through this additive approach, the maximum score that a country can get once the ACTION Index is built is 60, corresponding to the best performance of policy stringency. The last step of this part of the research deals with the rescaling of the score of the index to make it more interpretable and to allow an easy comparison with the EPS Index: considering that the latter ranges from 0 (not stringent) to 6 (highest stringency level), the same values has been assigned to the ACTION Index.

3. Results and analysis

3.1. Objective 1 – Aggregate stringency assessment

3.1.1. Changes in the ACTION Index over time

This paragraph presents the evolution of the ACTION Index across time for the 26 countries included in the research (Figure 5). On average, the index progressively increased, ranging in 2010 from 4 to 33, up to 2021, varying from 20 to 52, thus showing an overall positive trend for all the countries. This is also represented in Table 6: the green – yellow – red colored scale applied as conditional formatting allows to clearly observe the progress that each country has made throughout the years. To have a more precise overview of the scores that have been assigned to each dimension contributing to the ACTION Index, it is worth referring to Annex B. The raw data of each database corresponding to the yearly scores per country for the six indicators has been collected in tables after the process of data cleaning and it can be consulted in the Annex C. The evolution of each of the six indicators for the countries will be further explored in Section 3.1.2, to highlight how the six thematic areas independently affect the stringency represented by the ACTION Index, as a single score. To this regard, the lowest stringency score of 4 is assigned to Mexico in 2010, whereas Norway is characterized by the highest score of the index 54, in 2018. None of the 26 nations ever got the maximum score within the scoring system, corresponding to 60. Despite being representative of the lowest value in 2010, Mexico, for instance, shows a substantial increment over the first years (especially between 2010 and 2014), reaching a score of 19 in 2014. This growth, however, does not seem to be constant for the further period since the curve alternates peaks and troughs. On the contrary, Norway has the highest scores among the sample, (except for the year 2014, when Denmark performs better, with a score of 40) and it is characterized by an increasing trend. Figure 5 also depicts a quite steady pattern for some nations: New Zealand for example increased its ACTION Index score at a slow rate but constantly, shifting from 16 (in 2010) to 29 (in 2021). Similarly, Portugal, the Netherlands and Ireland exhibit constant trends, but starting from a higher basis and with greater scores over time with respect to New Zealand. On the other hand, values regarding for instance Switzerland and Chile seem to be representative of discontinuous trends over time: the former shows a relevant increase in the ACTION Index score from the year 2015, up to the maximum score in 2018, and then decreases slightly in the following year, whereas the latter's curve witnesses an abrupt and steep change in the composite measure in 2016. Besides, some nations exhibit irregular series: this is the case of United Kingdom for instance; the index falls substantially in 2012 (shifting from a score of 25 in 2011 to a score of 12 the next year), and from 2014 its trend flattens. Likewise, Spain experiences a trough in the score in 2012, as well as in 2016. Lastly, there is Korea, reaching its lowest value (23) in 2014 and progressively increasing in its performance in the following years. Furthermore, Figure 6 shows the difference between the score assigned to countries in 2010 and the score they got in 2021: the fact that each of them improved their performance in terms of stringency is further confirmed; however, there are remarkable differences in the trends detected. The countries which made the greatest progress over the eleven years covered by the analysis are Germany, Spain, Switzerland, and Chile: respectively, Germany strengthened its stringency, shifting from a score of 20 in 2010 to 46 in 2021; similarly, Spain's ACTION Index increased of 25 points, from 16 in 2010 to 41 in 2021. Chile and Switzerland experienced the same change of 23 points in their scores, improving respectively from 13 to 36 and from 21 to 44. Conversely, Italy shows the lowest variation in the score between 2010 and 2021, from 23 to 25, meaning that it has not substantially improved its stringency performance. To be more precise, analyzing again Figure 5, the country shows a downward trend between 2011 and 2013 and an upward one between 2016 and 2020. Lastly, Figure 7 shows the average stringency performance of all countries, for the period 2010-2021, based on the ACTION Index scores per year. The most performing nation is Norway, with an average value of 44.08; followed by Denmark and Finland with respectively 38.75 and 37.67, it is the only country of the sample showing an average index above the threshold of 40. Instead, the lowest scores are attributed to Mexico (15.92), Poland (17.50) and New Zealand (19.92). Most of the other countries have scores ranging from 28 to 35 on average.

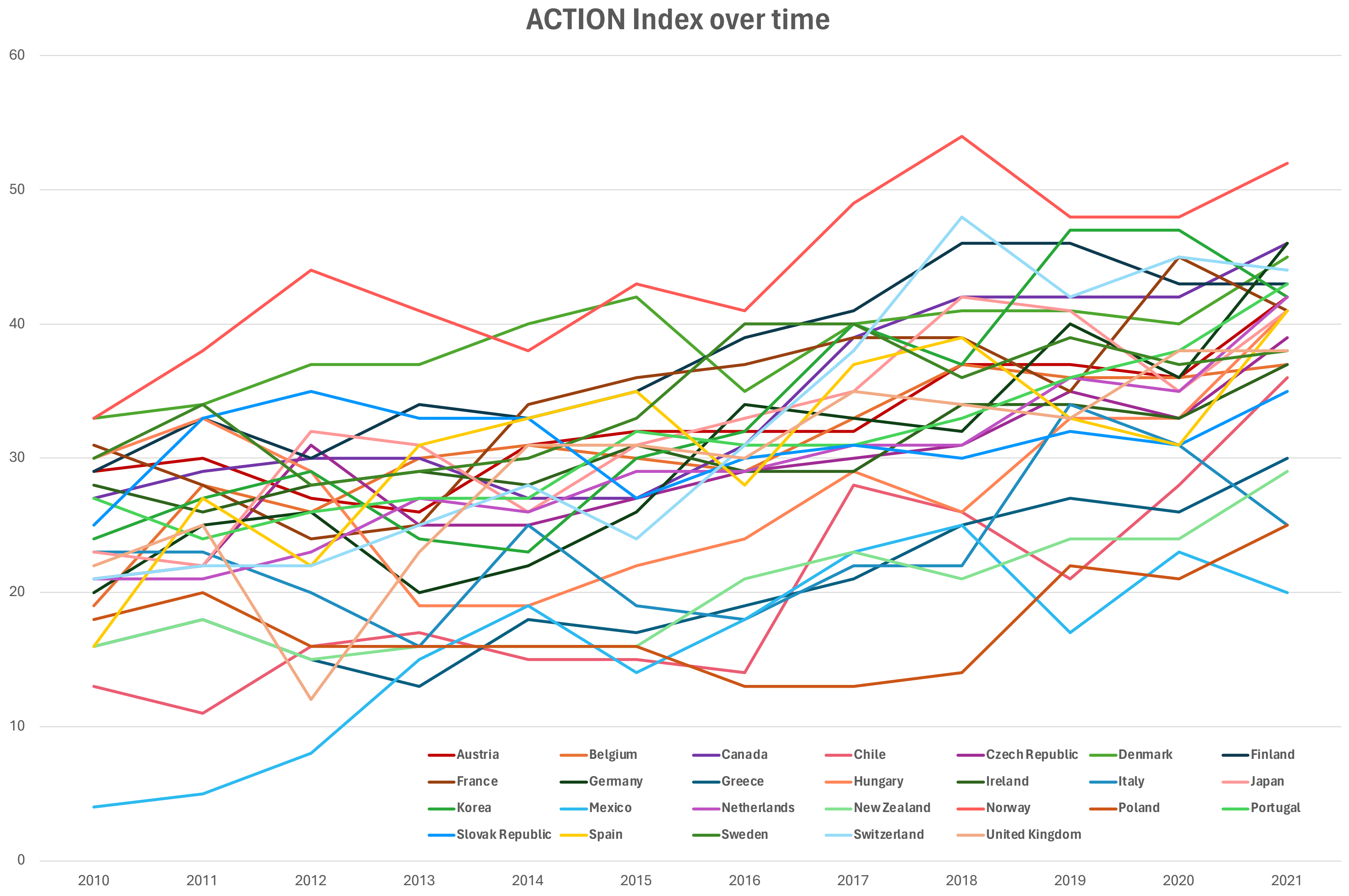


Figure 5. Evolution of the ACTION Index per country between 2010 and 2021

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Austria	29	30	27	26	31	32	32	32	37	37	36	42
Belgium	19	28	26	30	31	30	29	33	37	36	36	37
Canada	27	29	30	30	27	27	31	39	42	42	42	46
Chile	13	11	16	17	15	15	14	28	26	21	28	36
Czech Republic	21	22	31	25	25	27	29	30	31	35	33	39
Denmark	33	34	37	37	40	42	35	40	41	41	40	45
Finland	29	33	30	34	33	35	39	41	46	46	43	43
France	31	28	24	25	34	36	37	39	39	35	45	41
Germany	20	25	26	20	22	26	34	33	32	40	36	46
Greece	16	18	15	13	18	17	19	21	25	27	26	30
Hungary	30	33	29	19	19	22	24	29	26	33	33	41
Ireland	28	26	28	29	28	31	29	29	34	34	33	37
Italy	23	23	20	16	25	19	18	22	22	34	31	25
Japan	23	22	32	31	26	31	33	35	42	41	35	41
Korea	24	27	29	24	23	30	32	40	37	47	47	42
Mexico	4	5	8	15	19	14	18	23	25	17	23	20
Netherlands	21	21	23	27	26	29	29	31	31	36	35	42
New Zealand	16	18	15	16	16	16	21	23	21	24	24	29
Norway	33	38	44	41	38	43	41	49	54	48	48	52
Poland	18	20	16	16	16	16	13	13	14	22	21	25
Portugal	27	24	26	27	27	32	31	31	33	36	38	43
Slovak Republic	25	33	35	33	33	27	30	31	30	32	31	35
Spain	16	27	22	31	33	35	28	37	39	33	31	41
Sweden	30	34	28	29	30	33	40	40	36	39	37	38
Switzerland	21	22	22	25	28	24	31	38	48	42	45	44
United Kingdom	22	25	12	23	31	31	30	35	34	33	38	38

Table 6. ACTION Index scores per country (2010-2021)

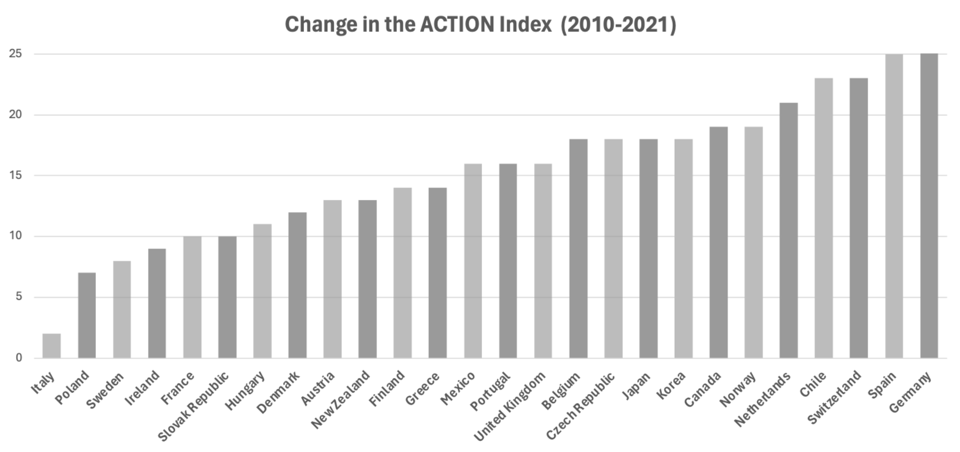


Figure 6. Change in the ACTION Index per country between 2010 and 2021

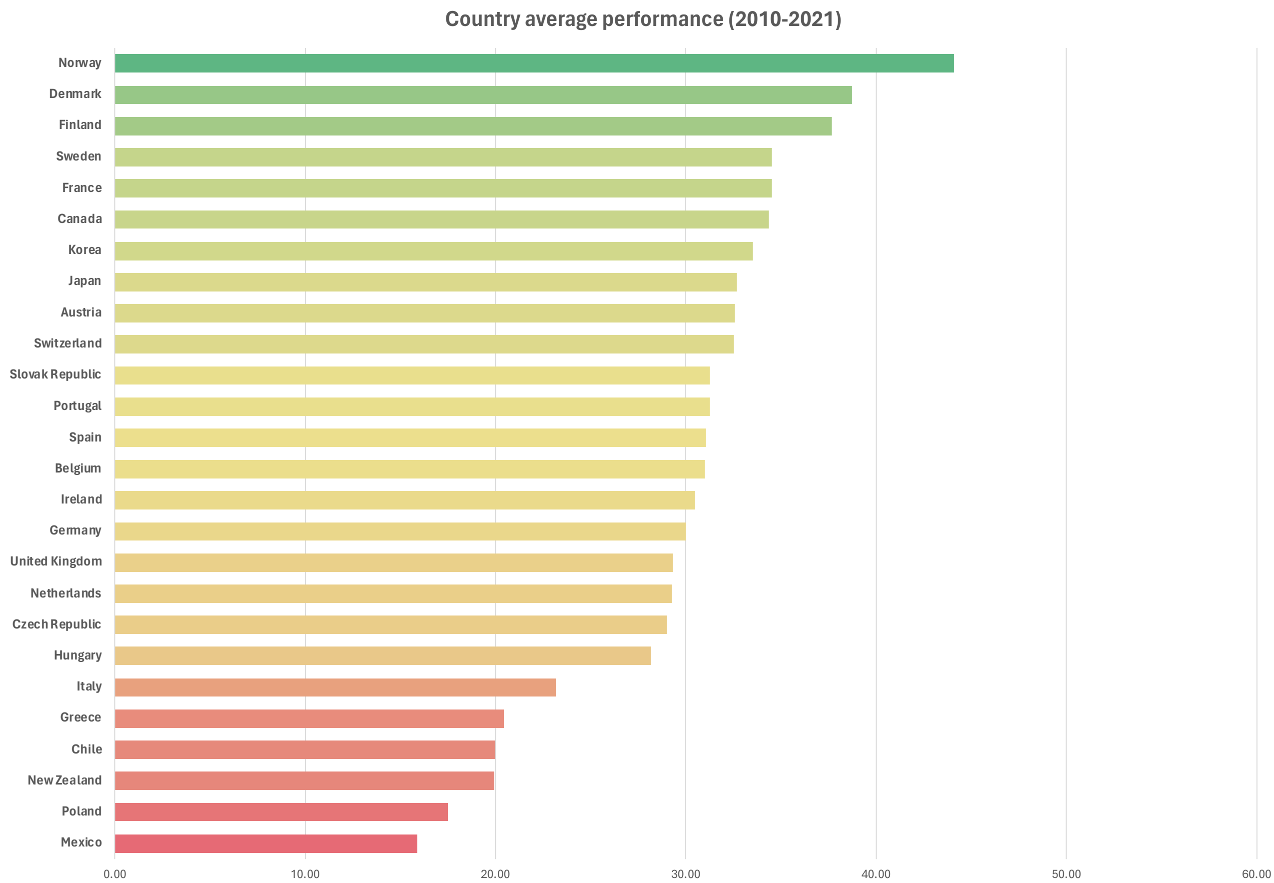


Figure 7. Average ACTION Index score per country (2010-2021)

3.1.2. Changes in policy stringency by indicators

After having described the most evident variations of the ACTION Index over time for the countries included in the analysis, in this section, the research focuses on the deconstruction of the composite measure in its individual parts: analyzing the evolution of each indicator over time can offer a deeper and more sophisticated perception of the stringency of national policies, as well as which variables contribute the most to its value. The main aim is to reveal the heterogeneity that is usually masked by the single score of the index: in other terms, which are the driving elements to be refined and enhanced and which are the areas of improvement for each country. Generally speaking, this represents a valuable and granular approach to promote transparency and accountability, and to facilitate targeted interventions and policy development or iterative improvement. Additionally, focusing on the individual components can contribute to a more holistic understanding of the overall performance of a specific country. As a matter of fact, the process provides an overarching view of the various dimensions at play, allowing for a more informed and well-rounded assessment.

Carbon pricing

From Figure 8, it can be observed that the most performing country regarding carbon pricing mechanisms is Sweden, with a score of 10 during the whole considered period. Among the front runners, there is also Finland, fluctuating between 8 and 9 for the period 2012-2017 and reaching the highest score in 2018 and Norway, which shows a remarkably good performance during the same time as well, with slightly lower scores between 2015 and 2017.

These three countries are indeed the first to have implemented a national carbon tax, with Finland starting in 1990, followed one year later by Norway and Sweden. They later also joined the EU Emission Trading System (EU ETS), broadening the scope of their carbon reduction measures. Their carbon price rates have constantly been the highest historically also due to the wide share of emission covered. In particular, between 2010 and 2021, Sweden shows a weighted carbon price starting at about 42 US$/ton$CO_2$e and increasing up to 75 US$/ton$CO_2$e in 2021, the most ambitious price rate in the CPD database (see Annex C, Table 1). Similarly, Finland and Norway report weighted carbon price rates that range between 17 and 45 US$/ton$CO_2$e.

On the contrary, the laggards for this dimension are Japan, Mexico, Canada, and Chile, constantly shifting between 0 and 1, and never exceeding the threshold score of 2. Figure 9 illustrates the change that each country experiences comparing the scores in 2010 and 2021. As regards carbon pricing, the only country which decreased minimally its score is United Kingdom, passing from 3 to 2. On the contrary, France, Germany and Portugal significantly increased their performance regarding this dimension: starting with a score of 3, the three nations share as common feature a positive change of 7 points. Germany for instance, although being part of the EU ETS since the beginning, has only recently adopted a complementary carbon tax, in 2021, and led to the steep increase in the indicator score compared to the year before that can be observed in Figure 8.

Policy density

Countries in this case are evaluated based on the number and comprehensiveness of national policies in the climate and low-carbon energy sector. Notably, the evolution of the scores is highly variable and none of them is characterized by a steady path: values show fluctuations, suggesting a dynamic and changing pattern. However, on average, the main countries standing out for their positive performance through the years (2010-2021) are Canada, with an average score of 8.0, United Kingdom with 7.58 and Japan with 7.08. The worst performers can be more easily identified looking at the trends shown in Figure 8: Czech Republic and Hungary for example are associated with a downward trend, with scores equal to 0 respectively from the years 2013 and 2012 up to 2021. From Figure 9, it is worth noting that six out of 26 countries did not experience any change in the score of policy density, others improved it, while the remaining ones worsened it: Japan distinguishes itself for being the one which did the greatest advancement (+7). Its irregular curve is characterized by three major troughs in 2011, 2014 and 2020, while for the other years the scores are between 8 and 10. Italy shows the worst negative change (-8) instead, starting from a score of 8 and ending up with a score of 0.

Energy research and development

The cross-country comparison for the dimension of energy R&D reveals significant variations in national investments and commitment to advancing clean energy technologies. On this front, as shown in Figure 8, Finland and Norway represent two major players, with the highest performances through the years. The Norwegian government, for example, included among the R&D support measures the Hydrogen Strategy in June 2020. Exactly one year later, in view of the 2030 Climate Action Plan, published a white paper with a specific focus on outlining strategies for value creation in the energy sector: the main targets on the long-term are, as already mentioned, hydrogen and offshore wind energy, together with improvements in the use of power grids and further investigation on CCS technologies. Steps ahead are coordinated by Enova, a body under the control of the Ministry of Climate and Environment, fostering innovative research for the introduction of new low-emissions solutions (IEA, 2023d). Going back to Figure 8, similarly, with slightly lower scores, there is France, which witnesses a quite regular development of the indicator's score, between 8 and 10. Considering other nations which did significant strides in energy R&D, Spain and Portugal show the greatest progress over time (+5 and +4, as illustrated by Figure 9), starting with low values and increasing their national investments, up to scores equal to 7 and 5 in 2021. Instead, the worst scorers for this dimension are Chile, Greece, and New Zealand, maintaining the indicator between 0 and 2 for the whole eleven years included in the analysis. Finally, Hungary and Italy, with a negative change equal to-4, represent the countries which diminished the most their energy R&D efforts: despite the same change in the indicator between 2010 and 2021, the two countries show quite different curves; on the one hand, Hungary starts with a score of 10 which drops dramatically to 1 twice during the eleven years, reaching only at the end of the timeseries the score 6. On the other hand, Italy keeps a more constant development of the indicator between 3 and 5 with a downward trend, reaching a score equal to 0 in 2021.

Fossil fuel subsidy removal

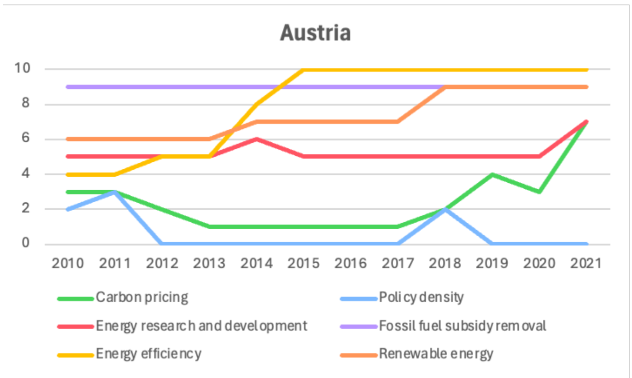
This dimension is representative of the elimination or reduction of national financial support provided to harmful energy sources: the maximum average score is 9.0 and it belongs to several countries, such as Austria, Czech Republic, Hungary, Netherlands, New Zealand, Norway, Portugal and Slovak Republic. Other nations showing outstanding performances are Denmark, which is characterized by a decrease of one unit in the score only for the last year, Switzerland, with a constant score of 8 during the whole time period, Finland and Poland, both shifting between 8 and 9. From Figure 9, the most evident variation between 2010 and 2021 is the dramatic decrease in the score (-6) experienced by France, changing from 7 to 1. Conversely, other countries distinguished themselves for progressing constantly over time: Korea, for example, increased its score from 8 to 9, Spain from 6 to 8 and so on. The nations which should improve their strategies to transition to a more sustainable and low-carbon energy system are Italy, which shows very low values over time, as well as Mexico, which maintains its curve around 0, except for the year 2014, in which reaches a score of 4 and the United Kingdom, with a poor performance of the indicator, equal to 0, from 2013 to 2021, which witnesses a rise in fossil fuel subsidies over the year. To this regard, the country has historically been reliant on oil and gas for a significant portion of its energy needs (IEA, 2023e) and from 2015 to 2021, the support provided by the government to fossil fuel companies amounted to USD 110.6 billion (see Annex C, Table 4). Recent research conducted by the House of Commons Library (Horton H., 2023), revealed that since 2015, the UK government funneled around £20 billion (USD 25.2 billion) of public money into the fossil fuel industry more than the amount allocated for clean-energy sources. The same study found that around a fifth of the incentives provided directly to fossil fuel companies were earmarked for exploration for new extraction and mining activities in the North Sea. These policy decisions hold by the Oil and Gas Authority (OGA) were strongly criticized, especially by environmental campaigners, who protested against the government making it a real legal case, namely the "Paid to pollute" case (Paid to pollute, 2023).

Energy efficiency

From both Figure 8 and Figure 9, it is evident that many countries did great advancements in their commitment to improving energy efficiency. This involves coordinated efforts across production, transformation, and consumption of goods, as well as the delivery of services using the least amount of energy possible (IEA, 2011). On the whole, each of them did a positive change between 2010 and 2021 in the indicator's score, and this is indicative of a commendable progress over time in fostering the reduction of energy consumption and the optimization of energy use. The most outstanding performances for this indicator are represented by Portugal, with the highest average score of 8.33 over the eleven years; besides, Denmark, Hungary and Spain display the greatest change over time (+9), reaching the highest score of 10 respectively in 2017, 2019 and 2020. By contrast, the nation with the lowest change between 2010 and 2021 is New Zealand, keeping its rating between 2 and 4. Ultimately, the most disappointing performance is the one of Poland, with an average score of its indicator of 1.67; only in the last three years, the country shows an upward trend, reaching a score of 4 just in 2020 and 2021.

Renewable energy

This last indicator shows the greatest improvements among the six (Figure 9): none of the 26 countries show a negative change over time, meaning, like for the energy efficiency scores, that over time a growing attention regarding the promotion of renewable energy sources has been shared by all the nations. Examining the top-performing countries, Chile, Korea, Mexico, Switzerland, and United Kingdom display a change of +9; among them, Switzerland and United Kingdom have the steepest curves, both starting from 1 and reaching an asymptotic curve (approaching the score of 10) respectively from 2018 and 2017. From Figure 9, it can be seen that other five nations, i.e. Finland, Greece, Netherlands, Norway, and Spain, witness a positive variation of 8 points, comparing the scores in 2010 and in 2021. On the contrary, the most modest change in the indicator belongs to Slovak Republic (+2); despite the slow growth over time, the country owns the highest average score (8.67): its graph depicts a steady trend, with values remaining relatively constant over the observed period; starting from a rating of 7 in 2010, the curve reaches consequently the maximum score (10) from 2013 onwards. On the contrary, Poland holds the lowest average score (2.08) of this indicator. Its curve keeps a score of 1 until 2018 and improves minimally until reaching a score of 4 in 2020. The poor performance in the renewable energy indicator is evidently due to the Polish domestic energy mix, which is still dominated by traditional energy sources. In fact, according to the latest IEA Energy Policy Review (IEA, 2023d), Poland's energy sector has always been predominantly reliant on fossil fuels, which in 2020 represented up to the 85% of the Total Energy Supply (TES) for the country, with coal contributing around 40%, followed by oil (28%) and natural gas (17%). Despite being a major player in the national energy system and economy, coal has witnessed a decline from 2010 to 2020. Nevertheless, in 2020, the IEA reports that Poland still stands out among the other member countries for the greatest share of coal in various energy metrics, such as energy production, TES, Total Final Consumption (TFC) and electricity generation. There is considerable work ahead for the country in terms of development, promotion, and integration of renewable initiatives. However, an important step has been taken in 2016, with the replacement of the green certificate system with an auction scheme, regulated by the Renewable Energy Act (IEA, 2020). This policy measure underwent several amendments through the years: for instance, it introduced technology baskets for different energy sources, such as onshore and offshore wind energy, solar energy, biogas and hydropower; additionally, in 2018, the so called "rule of enforcing competition" was established to guarantee fair competition and preventing all bids from winning regardless of the specified energy value. This Renewable Energy Act contributed positively to an increase in the quantity of electricity generated from renewable sources, which nearly tripled, marking a significant growth in its proportion within the national power mix, from 7% to 18% (IEA, 2022).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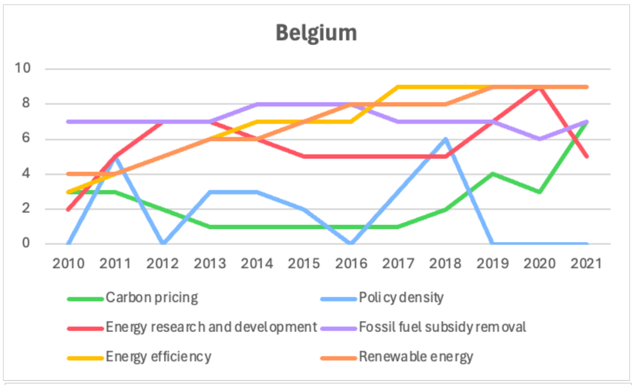
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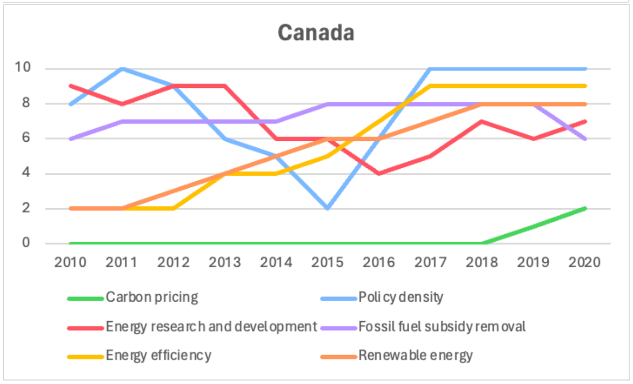
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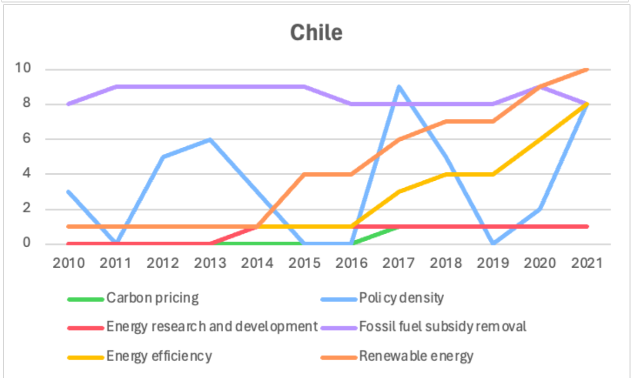
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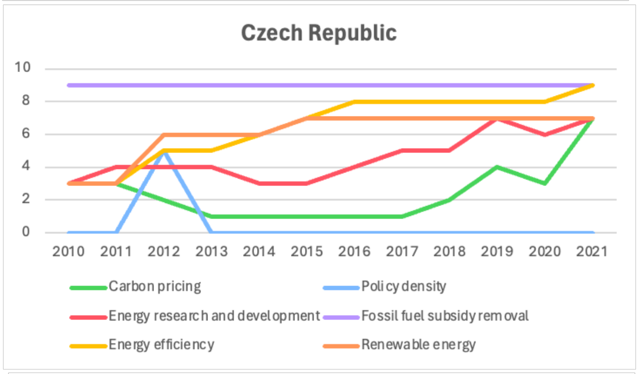
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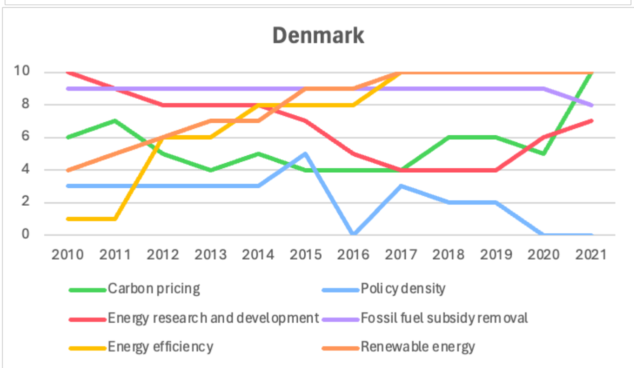
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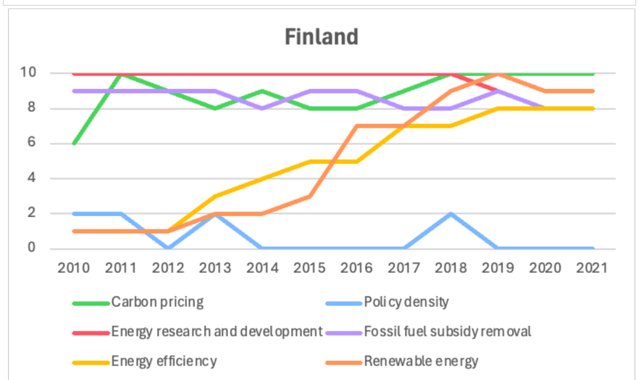
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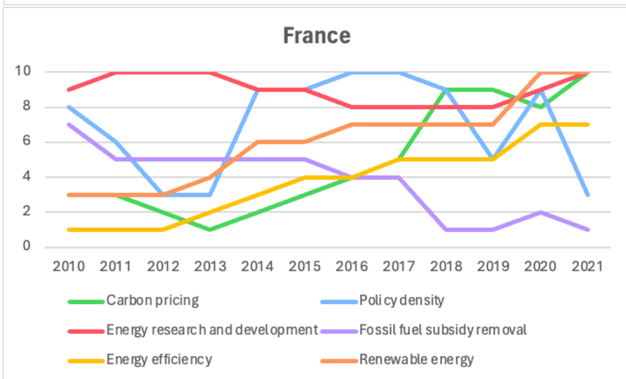
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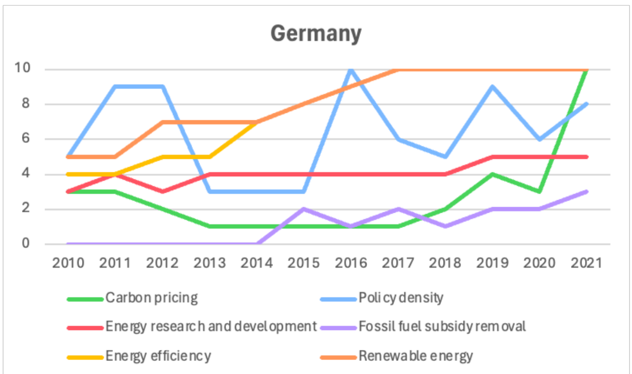
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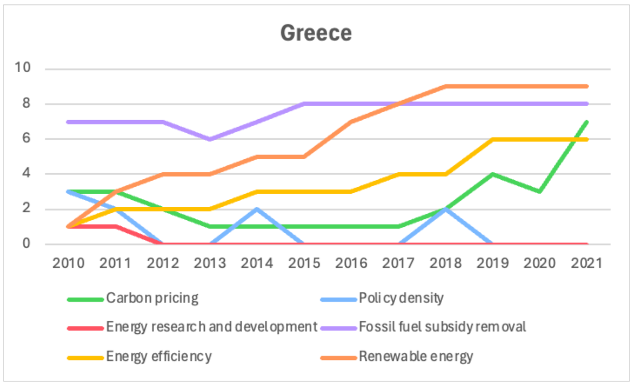
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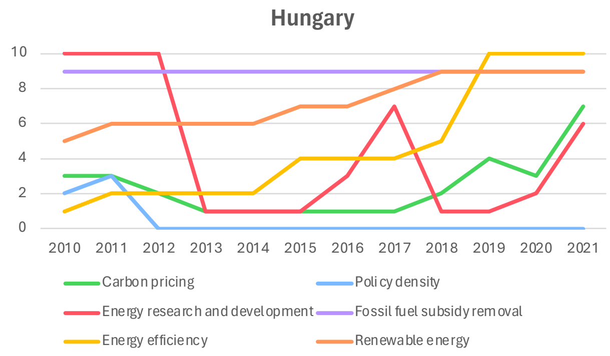
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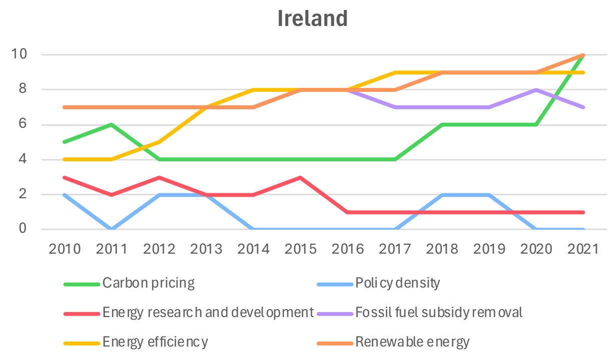
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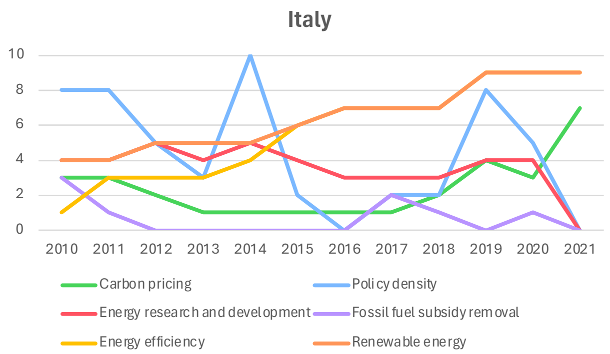
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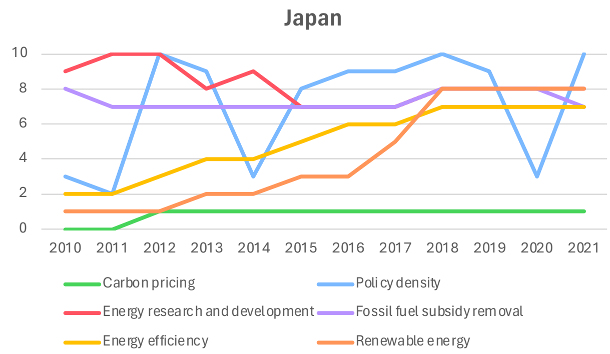
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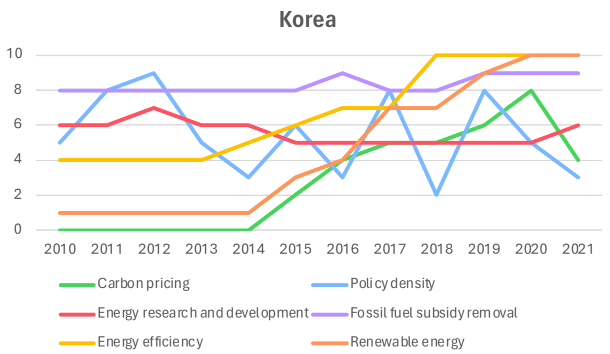
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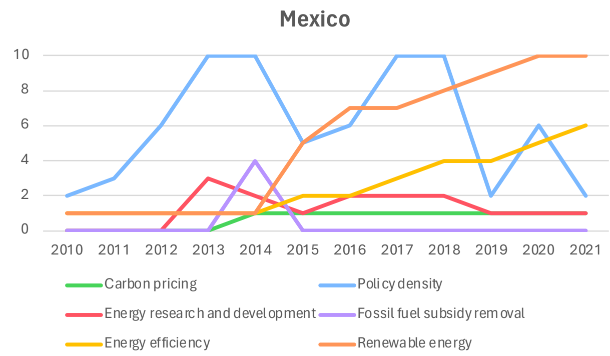
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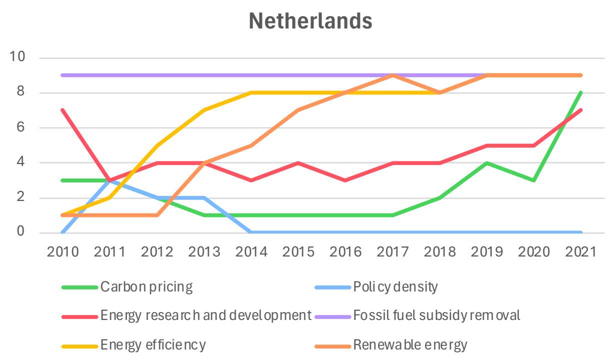
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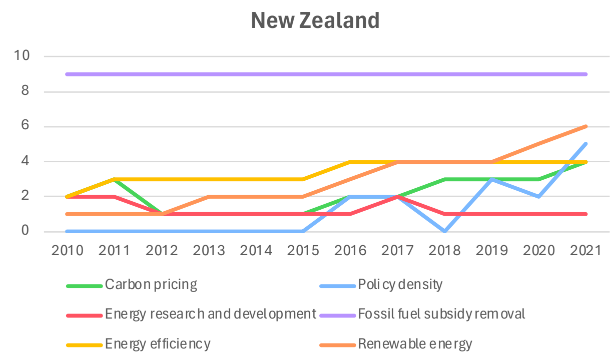
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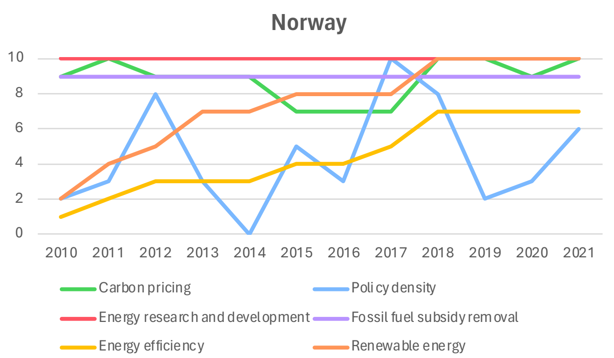
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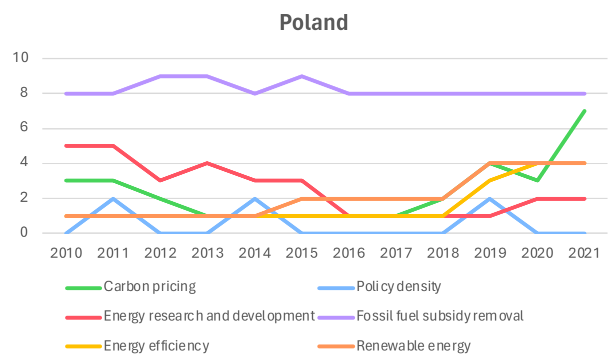
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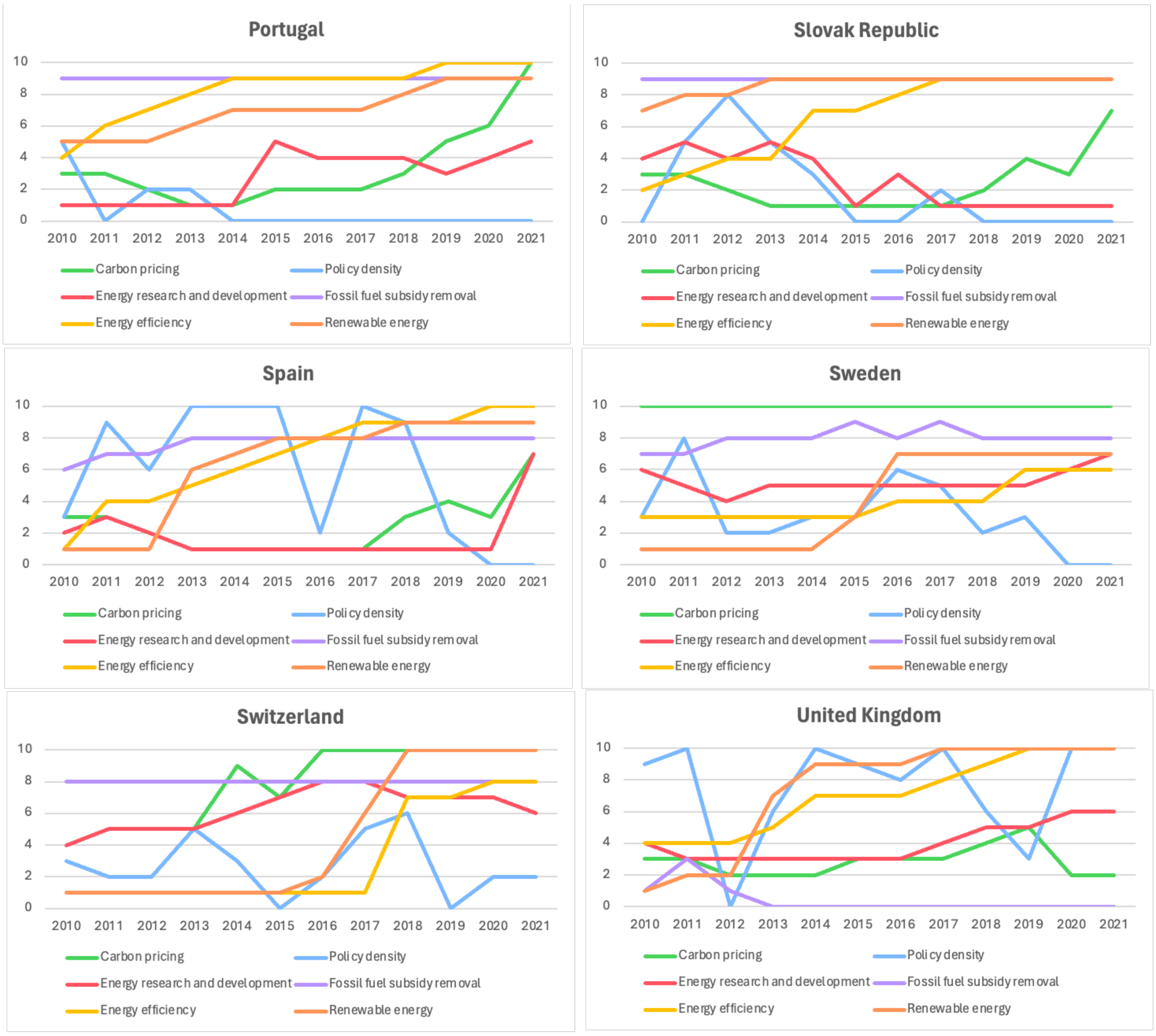

Figure 8. Changes in policy stringency by indicator (2010-2021)

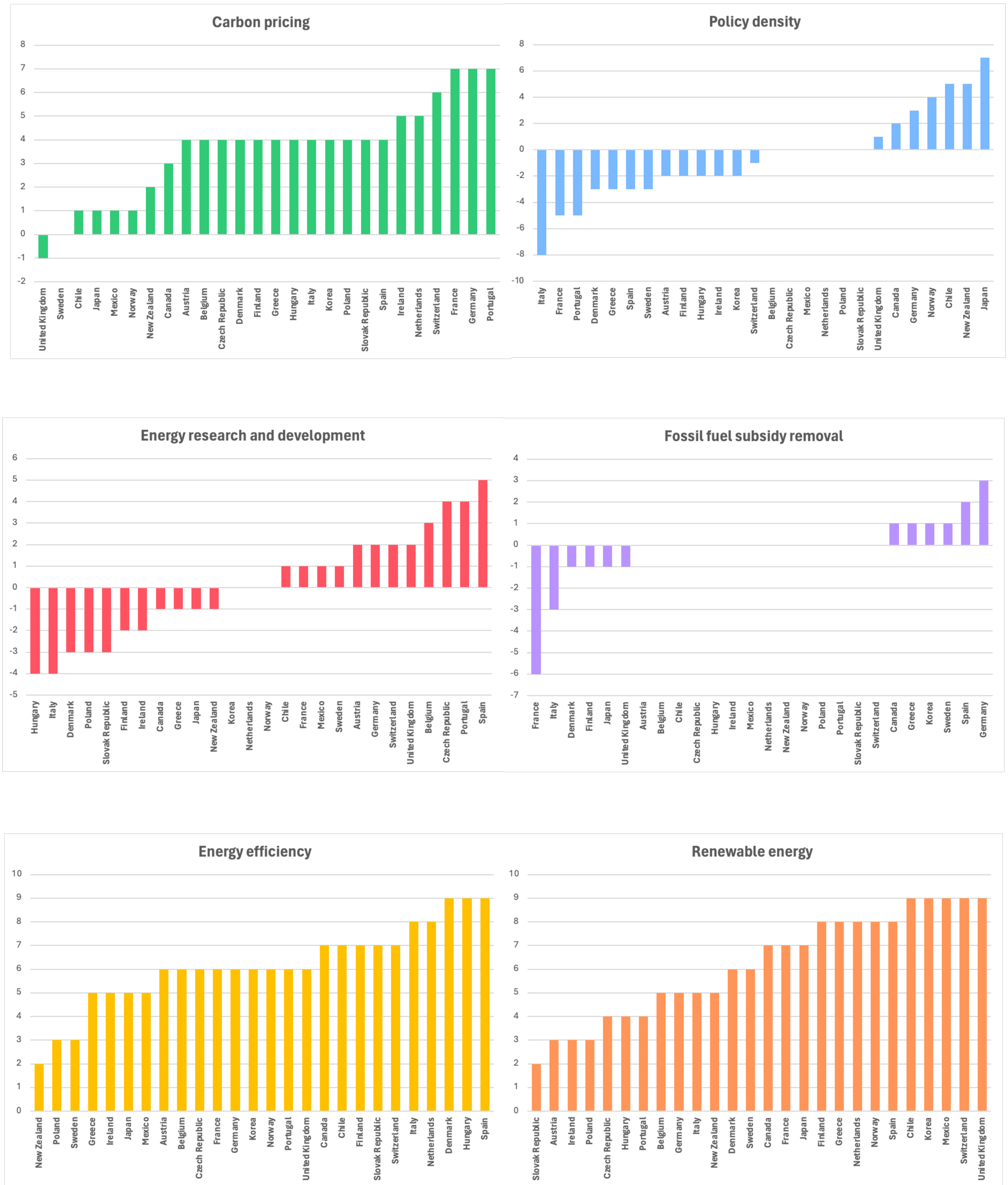

Figure 9. Change in indicators' scores per country between 2010 and 2021

Figure 10 further illustrates the average national stringency performances shown by Figure 7, based on the average scores of the ACTION Index and it highlights the contribution of each indicator over time, for the years between 2010 and 2021. As already cited, this is particularly useful to assess which areas have the major impact on a country's overall index performance and which are the dimensions that should be better enhanced through policy intervention and strategic planning. For instance, Norway tops the average score ranking, showing a strong performance across nearly all dimensions tracked by the ACTION Index. Being the leading country, it performs better on average in carbon pricing mechanisms, in energy research and development, in fossil fuel subsidy removal and in renewable energy strategies than in the policy density and in the energy efficiency dimensions. Notwithstanding, as already shown in Figure 8, over time the country has made relevant improvements in the energy efficiency score, while the indicator of policy density has not been constant or in continuous progress, but it has undergone several variations over time. Regarding carbon pricing mechanisms, the polluter-pays principle represents a cornerstone for the country: being one of the first nations in the world to introduce a carbon tax in 1991 and maintaining its rate and emission coverage among the highest over the years (see Annex C, Table 1), Norway also joined the European Union Emissions Trading System (EU-ETS) in 2008, pursuing ambitious emission reduction targets. According to our data (The World Bank Group, 2023a), the share of emissions covered by the two mechanisms is one of the highest of the world, averaging 63% of national emissions. More recently, in June 2017, the Government passed an important regulation, i.e. the Climate Change Act, which established Norway's aim to attain climate neutrality by 2050, with a desirable 50-55% GHG emissions reduction by 2030 compared to 1990. Along with that, the Storting allocated a budget of NOK 10.5 billion to the Ministry of Climate and Environment (Climate Analytics & NewClimate Institute, 2023; IEA, 2023d). On the opposite side of the ranking, there is Mexico, which registers a good relative performance in policy density and in the renewable energy and energy efficiency indicators. Instead, points of improvement should be sought within the carbon pricing, the energy research and development and the fossil fuel subsidy removal thematic areas. As a matter of fact, despite the high number of climate and energy-related regulations that the country has put in place over the years, Mexico's climate efforts persistently move in a regressive direction, especially since Lopez Obrador's election in 2018, due to a strong prioritization of fossil fuel incentives with a specific focus on the energy and on the transport sector. The dismantling of climate change governance in recent years is another evidence of the underplayed significance of climate related issues: the Climate Change Fund for instance has been dissolved in 2020, as well as the National Institute for Climate Change a year later (Climate Analytics & NewClimate Institute, 2023). It is evident that on average, between 2010 and 2021, the countries which showed the most underperforming results in the carbon pricing dimension are Canada, Japan, Chile and Mexico. As regards policy density instead, several are the nations which should improve their policy portfolio, in terms of extent and comprehensiveness of regulations in the climate and low-carbon energy sector. Among the list, the worst results belong to Poland, Greece, Hungary, Czech Republic, Netherlands, and Austria. Another evident aspect that emerges by analyzing the laggards in the graph is that Greece shows the poorest contribution in its average score within the whole sample, in terms of energy research and development. Furthermore, especially Germany, United Kingdom, Italy, and Mexico should foster targeted intervention in phasing out subsidies to the fossil fuel industry and in renewable energy investments, due to their insufficient performances. Lastly, the energy efficiency and renewable energy average scores of most of the nations are worthy of recognition in terms of contribution on the ACTION Index average score: one of the countries which could perform far way better in those two sectors is Poland.

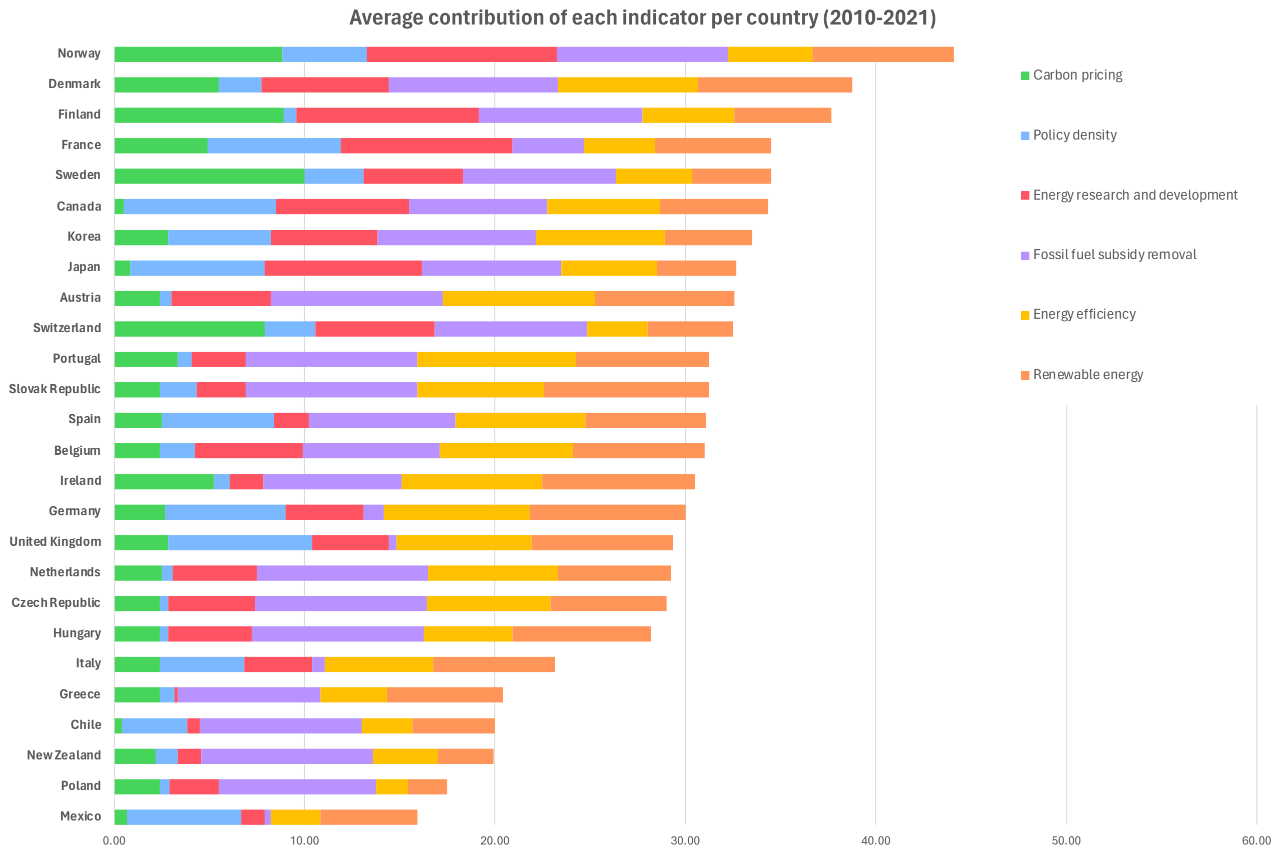

Figure 10. Deconstruction of the ACTION Index in its dimensions per country

Figure 11 and Figure 12 show two spider charts that have been created to support the ranking represented in Figure 7 and Figure 10 and to better compare the first five top-performing countries and the five laggards based on the average ACTION Index scores. These graphs allow to plot the set of indicators' scores in a visually intuitive way and to better perform the benchmarking focusing on a smaller group of countries, based on common characteristics or specific criteria.

From Figure 11, it can be observed that the country performing better in carbon pricing mechanisms is Sweden (with an average score of 10), followed by Finland (8.92) and Norway (8.83). Instead, in terms of policy density, there are consistent differences between the five nations: the worst score belongs to Finland (0.67), followed by Denmark (2.25), Sweden (3.08), and Norway (4.42). Conversely, France distinguishes itself if compared to the other four countries, with an average score of 7. As regards energy research and development, the highest indicator's score is 10 and belongs to Norway, while Sweden is the lowest performing one (5.25). Furthermore, in terms of fossil fuel subsidy removal, the only country which is lagging behind the others is France, with a mediocre score of 3.75. The remaining ones have ratings ranging between 8 and 9. Considering energy efficiency, Denmark stands out over the other nations, with a score of 7.33. On the other hand, Norway, Finland, France, and Sweden show similar performances between 3.75 and 4.83. Lastly, considering the renewable energy indicator, Denmark displays also in this case the best score (8.08), followed by Norway (7.42). The bottom-tier country on this front is Sweden with 4.17.

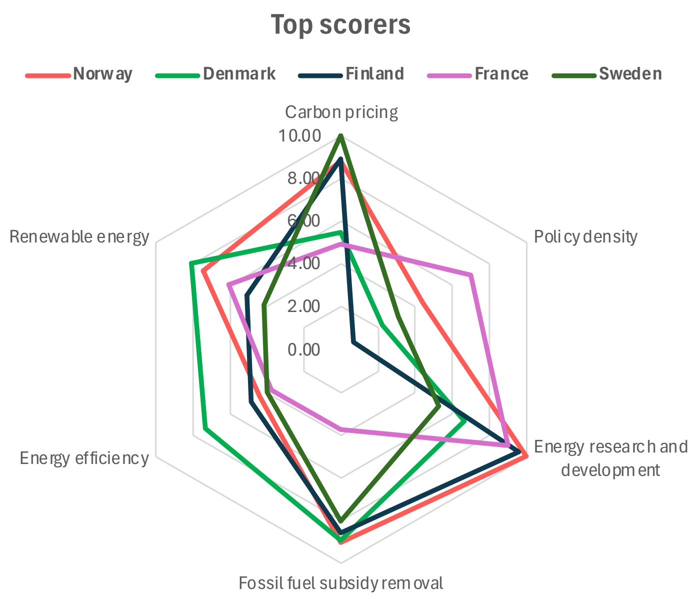

Figure 11. Average contribution of each dimension of the ACTION Index for the most performing countries

Considering the lowest average scores of the six indicators, the five most underperforming nations are Chile, Greece, Mexico, New Zealand, and Poland. Regarding carbon pricing mechanisms, all the countries show less-than-optimal scores, especially Chile with an average value of 0.42 and Mexico with 0.67. Looking at the policy density dimension, the only exception to the rule is Mexico, which shows a satisfactory score of 6.0; the remaining four are characterized by inadequate results, especially Poland (0.50) and Greece (0.75). Furthermore, the sample has the poorest rating in the energy research and development, meaning that this dimension needs to be prioritized through advocating for the development and implementation of targeted policies and strategies for the sector. As regards the indicator representing the fossil fuel subsidy removal dimension, apart from Mexico, which displays the weakest average performance within the group of 26 countries (with a score of 0.33), the other four exhibit noteworthy outcomes, between 7.50 (for Greece) and 9 (for New Zealand). Lastly, the energy efficiency and renewable energy average scores are indicative of modest but not exceptional outcomes, especially regarding the former dimension. However, from the graphs shown in Pictures 8 and 9, it is worth noting that on one side Greece, Chile and Mexico did remarkable progress over time, while, on the other side, New Zealand and Poland still have plenty of room for improvement.

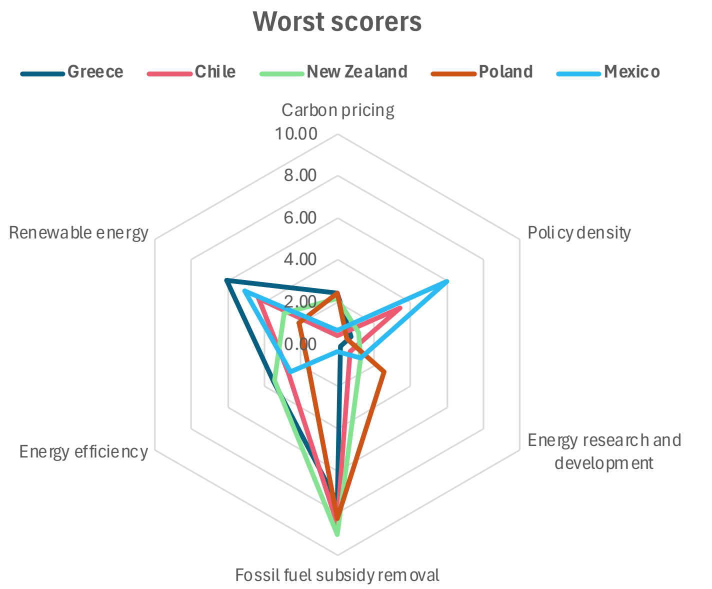

Figure 12. Average contribution of each dimension of the ACTION Index for the worst performing countries

3.2. Objective 2 – ACTION Index VS EPS Index

A further contribution that this research aims at achieving is identified under the "Objective 2": to test the explanatory power of a composite measure, it is often advisable to compare the index with another quantitative measure that is linked to it. In the context of composite indicators, the *explanatory power of an index* is defined as its ability to effectively capture and illustrate the concept or the phenomenon it is designed to measure. Simplistically, it is representative of its robustness and reliability for the intended purpose. Concretely, as already explained, the EPS Index is regarded as "a first tangible effort to measure environmental policy stringency internationally over a relatively long-time horizon." (Botta & Koźluk, 2014). Similarly, the ACTION Index aims at capturing the same phenomenon, but with a less pervasive scope, since it considers only climate and low-carbon energy policies. Nevertheless, the composite elaborated within this study explores two dimensions which are not covered by the EPS Index, i.e. policy density and fossil fuel subsidy removal. It is therefore interesting to compare the two indices and assess if the outcomes analyzed under the "Objective 1" are in line with another measure of policy stringency.

As already explained in the methodology (Section 2.1.7), before starting with this part of the analysis, the ACTION Index has been rescaled, from 0 to 6, to make it more easily comparable with the EPS Index. Subsequently, another overlap procedure has been performed (considering once again the temporal and spatial coverage of both samples, namely the ACTION Index and the EPS Index), and the following 23 countries have been included in this part of the research, covering the years 2010-2020 (Table 7); Chile, Mexico and New Zealand have been excluded from the original group of countries (Table 2), because the EPS Index does not account for them.

Before proceeding with the comparison of the two indices, it is worth commenting Figure 13, which depicts the evolution of the EPS Index scores for each country during the considered period. On the whole, likewise the ACTION Index scores, the values for this composite measure progressively increased over time, varying in 2010 from 2.31 to 4.00, and in 2020 from 2.50 to 4.89. The lowest EPS Index score (2.11) in the 10 years is assigned to Portugal in 2014, whereas France reports the highest value among the countries (4.89) in 2020. On average, the growth of the scores of the EPS Index is slightly less noticeable in Figure 13, if compared to the scores of the ACTION Index shown in Figure 5 (without considering, in this case, the three countries which have been excluded for this second part of the study and bearing in mind that the y axis for this graph ranges from 0 to 60). Another remarkable aspect is that the range of the ACTION Index is wider than the one shown for the EPS Index, and the curves of the countries vary more in terms of development, alternating peaks and troughs for several nations. Instead, from a general perspective, the EPS Index values are more constant over time. As shown in Table 8, thanks to the conditional formatting, countries can be grouped based on their performance over time: Portugal and Spain for example, show similar trends, reaching the minimum score (2.11 and 2.22) respectively in 2014 and 2013 and slightly improving in their path during the subsequent years. Likewise, despite starting from a quite good basis (with a score of 3.61), Canada exhibits a drop in its curve between 2013 and 2016 and maintains a mediocre performance over the remaining years. On the contrary, France and Switzerland are the most performing nations for the EPS Index in terms of progress over the temporal scale: both countries show in Figure 13 an upward trend, standing out from the others, especially from 2017 onwards, and reaching the highest scores in 2020 (4.89 and 4.50). The majority of the other performances of the sample are represented by quite steady curves, with a gradual increase of the single scores, especially focusing on the last years of the considered period.

Temporal coverage	2010-2020
Spatial coverage	Austria
	Belgium
	Canada
	Czech Republic
	Denmark
	Finland
	France
	Germany
	Greece
	Hungary
	Ireland
	Italy
	Japan
	Korea
	Netherlands
	Norway
	Poland
	Portugal
	Slovak Republic
	Spain
	Sweden
	Switzerland
	United Kingdom

Table 7. Temporal and spatial coverage of the analysis (Objective 2)

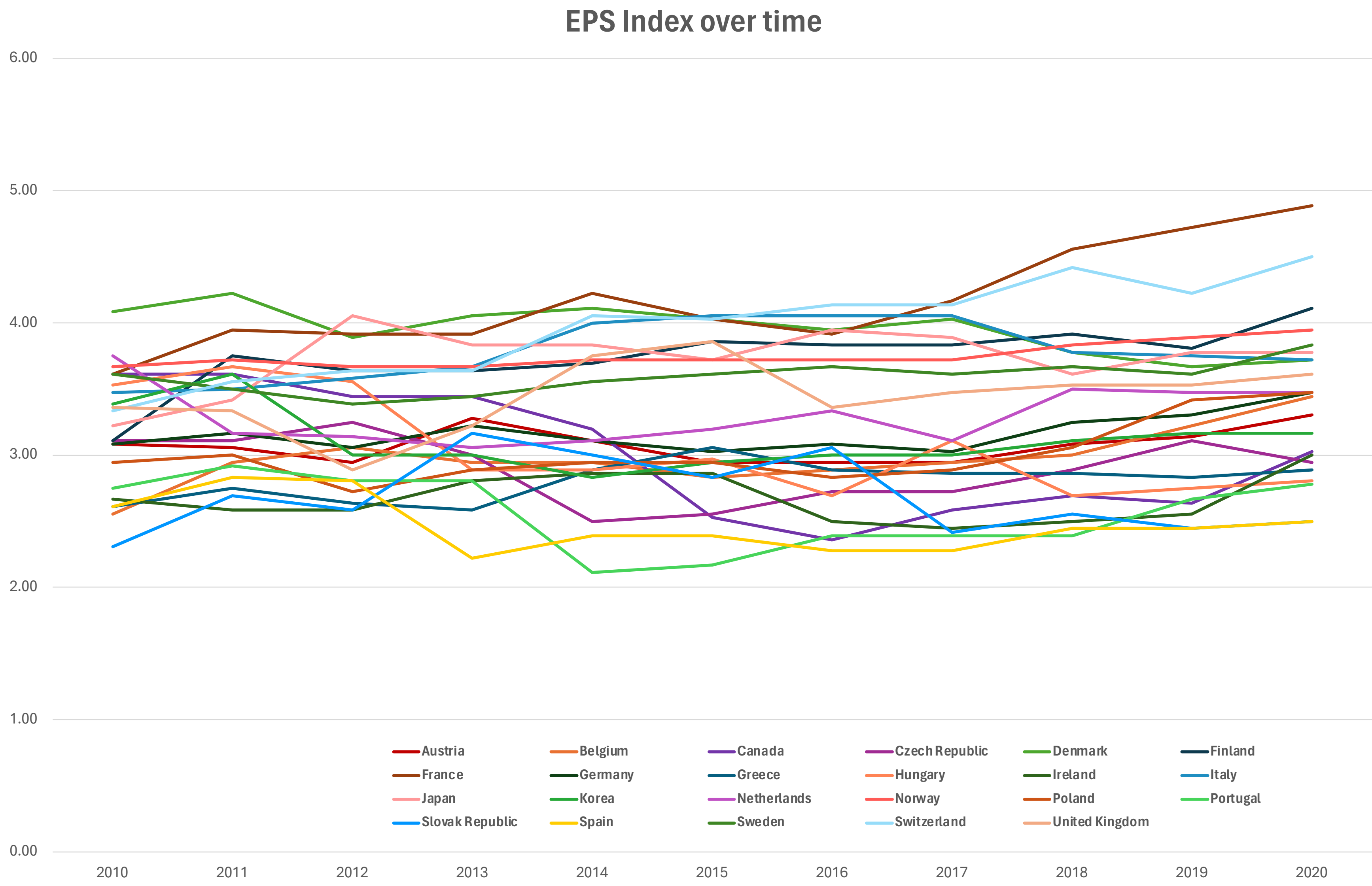

Figure 13. Evolution of the EPS Index per country between 2010 and 2020

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Austria	3.08	3.06	2.94	3.28	3.11	2.94	2.94	2.94	3.08	3.14	3.31
Belgium	2.56	2.94	3.06	2.94	2.94	2.83	2.89	2.94	3.00	3.22	3.44
Canada	3.61	3.61	3.44	3.44	3.19	2.53	2.36	2.58	2.69	2.64	3.03
Czech Republic	3.11	3.11	3.25	3.00	2.50	2.56	2.72	2.72	2.89	3.11	2.94
Denmark	4.08	4.22	3.89	4.06	4.11	4.03	3.94	4.03	3.78	3.67	3.72
Finland	3.11	3.75	3.64	3.64	3.69	3.86	3.83	3.83	3.92	3.81	4.11
France	3.61	3.94	3.92	3.92	4.22	4.03	3.92	4.17	4.56	4.72	4.89
Germany	3.08	3.17	3.06	3.22	3.11	3.03	3.08	3.03	3.25	3.31	3.47
Greece	2.61	2.75	2.64	2.58	2.89	3.06	2.89	2.86	2.86	2.83	2.89
Hungary	3.53	3.67	3.56	2.89	2.89	2.97	2.69	3.11	2.69	2.75	2.81
Ireland	2.67	2.58	2.58	2.81	2.86	2.86	2.50	2.44	2.50	2.56	3.00
Italy	3.47	3.50	3.58	3.67	4.00	4.06	4.06	4.06	3.78	3.75	3.72
Japan	3.22	3.42	4.06	3.83	3.83	3.72	3.94	3.89	3.61	3.78	3.78
Korea	3.39	3.61	3.00	3.00	2.83	2.94	3.00	3.00	3.11	3.17	3.17
Netherlands	3.75	3.17	3.14	3.06	3.11	3.19	3.33	3.11	3.50	3.47	3.47
Norway	3.67	3.72	3.67	3.67	3.72	3.72	3.72	3.72	3.83	3.89	3.94
Poland	2.94	3.00	2.72	2.89	2.94	2.94	2.83	2.89	3.06	3.42	3.47
Portugal	2.75	2.92	2.81	2.81	2.11	2.17	2.39	2.39	2.39	2.67	2.78
Slovak Republic	2.31	2.69	2.58	3.17	3.00	2.83	3.06	2.42	2.56	2.44	2.50
Spain	2.61	2.83	2.81	2.22	2.39	2.39	2.28	2.28	2.44	2.44	2.50
Sweden	3.61	3.50	3.39	3.44	3.56	3.61	3.67	3.61	3.67	3.61	3.83
Switzerland	3.33	3.56	3.64	3.64	4.06	4.03	4.14	4.14	4.42	4.22	4.50
United Kingdom	3.36	3.33	2.89	3.22	3.75	3.86	3.36	3.47	3.53	3.53	3.61

Table 8. EPS Index scores per country (2010-2020)

Afterwards, the average scores of both composite measures (ACTION Index and EPS Index) for the same period (2010-2020) have been calculated and included in the next sections. After a first basic comparative assessment considering the average performances of each country for both samples, a more detailed statistical analysis will be conducted, and the most relevant outcomes will be described and commented.

Table 9 reports the average scores calculated for the 23 countries, for both ACTION Index and EPS Index. Along with that, Figure 14 is a graphical representation of the national rankings according to both composites, ordered from the highest to the lowest ACTION Index performances during the considered decade. In Table 9, two of the scores highlighted in green belong to Norway (4.34) and France (4.17), which have the most top-tier positions in the ranking, respectively for the ACTION Index and the EPS Index. Furthermore, in the case of the ACTION Index, Norway is followed by Denmark and Finland, which, as already mentioned, have noteworthy positions in terms of average scores as well. As regards the EPS Index, the other two nations with a commendable standing are Switzerland and Denmark. At the lower end of the ranking instead, the worst scorers for the ACTION Index, highlighted in red, are Poland (1.68), together with Greece (1.95) and Italy (2.30). Instead, according to the average EPS Index, the three bottom-ranked countries are Spain, with a score of 2.47, Portugal (2.56) and Ireland (2.67). In terms of average range, the ACTION Index has a higher value (2.65) than the EPS Index (1.70), considering their maximum and minimum average scores.

An interesting highlight that emerges by observing Figure 14 is that, if for some countries both ACTION Index and EPS Index scores are similar, for others there is a notable difference: the cross-country analysis suggests for instance, that France leads the ranking in the EPS Index, with a balanced contribution of the three sub-indices' scores, i.e. technology support policies, market based policies, and non-market based policies in 2020 (see Figure 6, Kruse et al. 2022), whereas for the ACTION Index it remains in the fifth position. The lower performance concerning the latter index, indeed, is mainly determined by the fossil fuel subsidy removal indicator; as it can be seen from Figure 8, the French country has experienced a progressive reduction of the indicator's score, which is associated with higher incentives for the fossil fuel industry, especially in the last years: indeed, they saw an increase of 2.5 times from 2010, amounting to USD 9.3 billion in 2020 (see Annex C, Table 4). Analogously, Switzerland has an excellent placement regarding the EPS Index scale, whereas for the ACTION Index it is placed midway in the ranking. Regarding the ACTION Index, the dimension contributing the least to the overall average score is policy density, which, as already explained, is not encompassed by the EPS Index analysis. In this regard, Figure 8 shows a highly variable development of the indicator over time, with modest scores per year, meaning low climate policy coverage, which in turns reflects the need for strategic policy prioritization for the Swiss Confederation. This may represent the main reason driving the difference in the two composites' scores. Another aspect that catches the attention for Switzerland relates to the low average scores in energy efficiency and renewable energy, which could have further influenced the inferior performance with respect to the EPS. Figure 8 clearly marks a great improvement in the two indicators starting from 2017, when the government announced the will to phase out nuclear power, through the Energy Strategy 2050. Switzerland is still undergoing a challenging transition, which requires its alignment with the European electricity market to address forthcoming energy demand and widen the pool of environmentally friendly energy sources (IEA, 2023d). Going back to Figure 14, the highest difference between the two average scores (1.49) is showcased by Italy, which performs far way better in the EPS Index, whereas it has a disappointing score for the ACTION Index, being the last third country. The disaggregation of the ACTION Index shown in Figure 8 with respect to Italy clearly points out that the unsatisfactory performance is mainly due to its failing score in fossil fuel subsidy removal, again, a dimension left out by Kruse et al. (2022). Indeed, the country still has a long way to go in this sense: in 2021, it granted USD 12.4 billion, the third highest sum of money allocated to non-renewable energy sources among the countries included in the sample (see Annex C, Table 4). The IEA (2023d) strongly claims for a revision of the National Energy and Climate Plan, especially to overhaul the country's energy supply, which is still heavily reliant on fossil fuels imports from the Russian Federation. Being the dominant component of Italy's total energy supply (TES), in 2021, natural gas bought from Russia represented the 41% of the total imports of this energy source. By 2025, the nation is committed to eradicate its dependance on the Russian country, by relying more on liquefied natural gas (LNG) and imports through pipelines, as well as by counting on new gas supply routes. The same way, Poland is the last country lagging behind regarding the ACTION Index average scores, whereas it has a respectable position for the EPS Index. On the whole, this can be justified by the fact that the only dimension in which the country shows a top-notch performance is fossil fuel subsidy removal: between 2010 and 2021 Poland never exceeded USD 2.4 billion for incentivizing the fossil fuel industry. The remaining five dimensions covered by the ACTION Index are characterized by unsatisfactory scores, showing that there is still plenty of room for improvement in climate policy stringency. With respect to the EPS Index, the graph shown by Kruse et al. (2022) under Figure 6, which represents the contribution of the three sub-indices to the overall index score across countries for the year 2020, reveals that the dimension which necessitates further enhancement regards technology support policies: the authors highlight that opportunities for progress should be sought in R&D expenditures (upstream support) and further emphasis should be also put on the adoption of solar and wind energy (downstream support). This is in line with the findings highlighted by Figure 8, for Poland's energy efficiency, renewable energy and energy R&D scores of the ACTION Index. As already said, a major goal for the Polish energy sector is the reduction of its reliance on coal, which still represents the highest percentage in the energy mix, and the promotion of reforms for a more conducive environment for green energy expansion. By looking again at Figure 14, on the contrary, there are nations performing better in the ACTION Index average score than in the other composite measure: this is the case of Slovak Republic, Spain, and Portugal, showing ACTION Index average scores which are neither exceptional nor poor; in the case of the EPS Index instead, they belong to the group of the least-well performing countries. In this regard, Kruse et al. (2022) emphasize that the dimensions which necessitate the strongest intervention in 2020 for the three countries regard market-based policies and technology support policies.

Moreover, Figure 15 summarizes the performances of the 23 countries for both indices in one average score developing over time. The two composites are characterized by different curves: starting from a lower basis than the EPS Index in 2010 (2.46 vs 3.19), the ACTION Index shows a notable upswing, indicating considerable progress, especially from 2017 onwards. As shown before, the ACTION Index improvement in stringency could be mainly due to the increasing emphasis on energy efficiency placed by roughly all the countries through the years and across various sectors, spanning from industry to transportation and commercial end-use. Another important contribution to the increase in the ACTION Index score is represented by the gradual and notable growth in renewable energy adoption.

Conversely, regarding the EPS Index, its overall performance is steadier, showing marginal advancements in the last few years. Looking in further detail at policy trends represented by the three groups of indicators contributing to the EPS overall score, the main variations have been registered for technology support measures: R&D investments, together with FITs expenditures for solar and wind power, decreased in the first part of the 2010s, while ramping up again for the second half of the decade. Conversely, within non-market based policies, each of the four sub-indices (ELV for NO_x,

SO_x, PM, and Sulphur) has been roughly increasing at the same pace during the considered decade. Lastly, with regard to market-based instruments, different trends have been registered: the diesel tax has been constantly stringent over time, whereas sub-indices of renewable energy certificates, NO_x, SO_x and CO_2 taxes progressively improved in their scores. Lastly, carbon certificates between 2012 and 2017 may have negatively influenced the EPS stringency performance, due to their price volatility: that historic period in fact was characterized by significant fluctuations, with EU ETS prices never exceeding EUR 10 per tonne of CO_2. In the following three years instead, the prices of emission permits increased up to EUR 20-30 per tonne of CO_2 and this has brought benefits in terms of regulatory stringency (Kruse et al. 2022).

	ACTION Index	EPS Index
Norway	4.34	3.75
Denmark	3.82	3.96
Finland	3.72	3.74
Sweden	3.42	3.59
France	3.39	4.17
Canada	3.33	3.01
Korea	3.27	3.11
Japan	3.19	3.73
Austria	3.17	3.08
Switzerland	3.15	3.97
Slovak Republic	3.09	2.69
Belgium	3.05	2.98
Portugal	3.02	2.56
Spain	3.02	2.47
Ireland	2.99	2.67
Germany	2.85	3.16
United Kingdom	2.85	3.45
Czech Republic	2.81	2.90
Netherlands	2.81	3.30
Hungary	2.70	3.05
Italy	2.30	3.79
Greece	1.95	2.81
Poland	1.68	3.01

Table 9. Average scores per country over time (2010-2020)

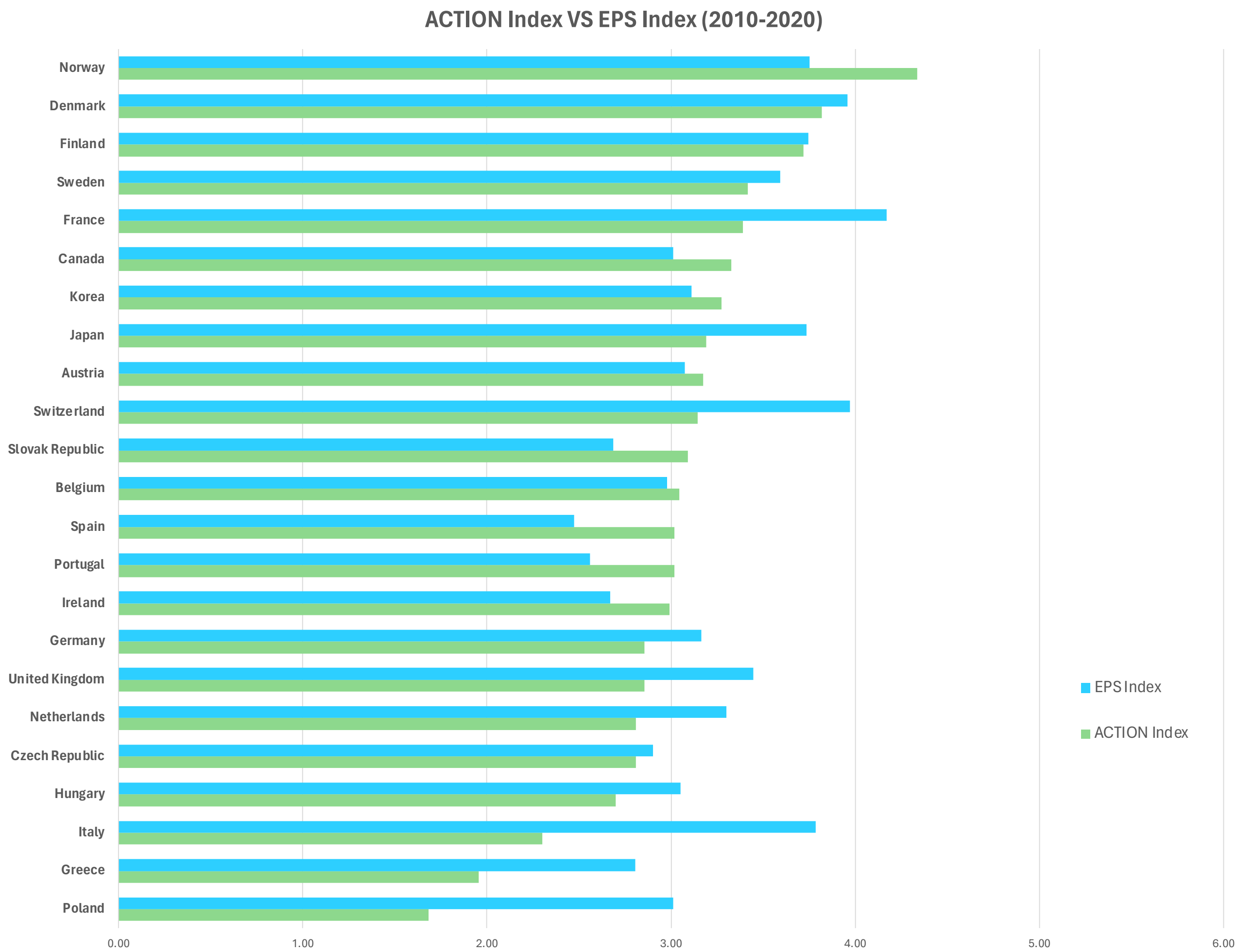

Figure 14. Average ACTION Index and EPS Index scores per country (2010-2020)

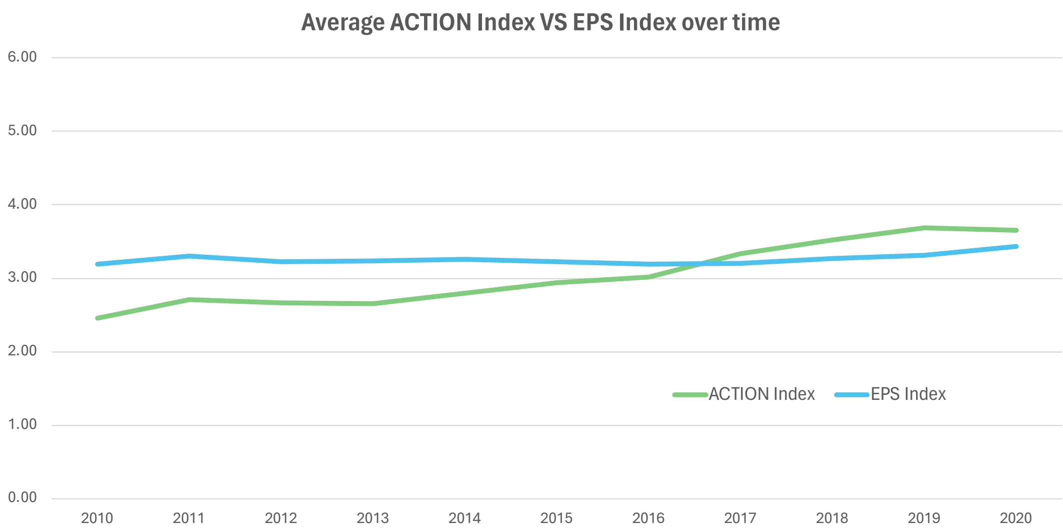

Figure 15. Evolution of the ACTION Index and EPS Index average scores between 2010 and 2020

From a statistical point of view, Table 10 shows the descriptive statistics elaborated for both composite measures, after the steps explained in Section 2.1.7. The main summary measures, i.e. the mean, the median, the standard error, the standard deviation, the maximum and minimum values, the interquartile range, and the Yule-Kendall's coefficient are reported and compared. Along with that, the distributions of both samples (Figure 16) will be analyzed to determine which is the most suitable correlation method to choose (whether Person's correlation or Spearman's correlation) in order to perform the intended analysis. In particular, the overall pattern of both distributions will be commented, focusing on the shape, the center, and the spread. Finally, the boxplot for both samples will be represented (Figure 17) to evaluate possible deviations from the overall pattern, such as the presence of outliers.

ACTION Index		EPS Index	
Mean	3.04	Mean	3.26
Standard Error	0.12	Standard Error	0.10
Median	3.05	Median	3.11
Standard Deviation	0.57	Standard Deviation	0.49
Minimum	1.68	Minimum	2.47
Maximum	4.34	Maximum	4.17
Interquartile Range	0.47	Interquartile Range	0.79
Yule & Kendall Coefficient	0.06	Yule & Kendall Coefficient	0.49
N	23	N	23

Table 10. Descriptive statistics of the samples after the homogenization of temporal and spatial coverage

The scores of both samples have been plotted and the histograms of their distribution are represented as follows (Figure 16):

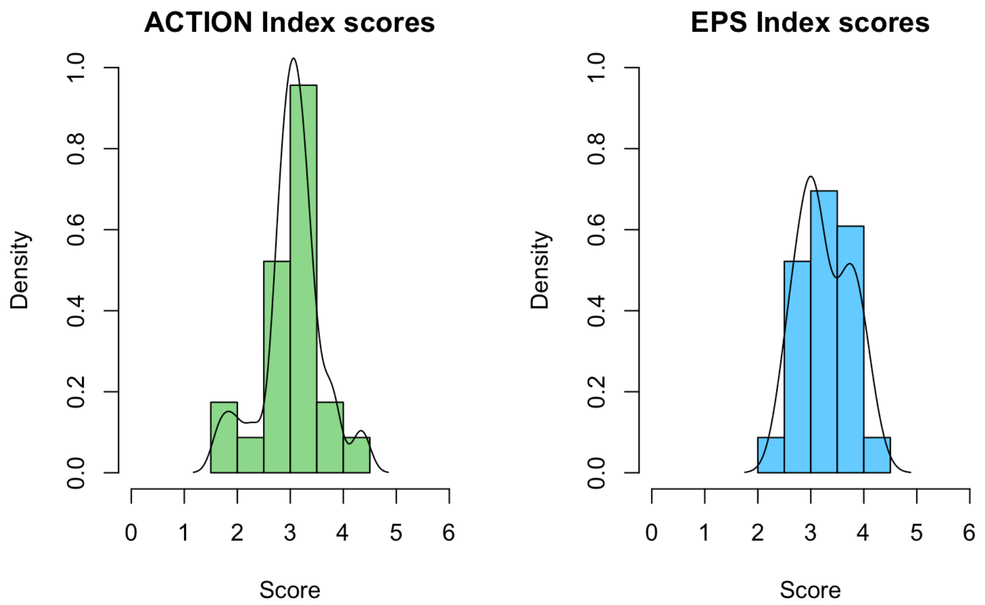

Figure 16. Distribution of data

As it can be observed, the distributions are slightly different: on the one hand, the curve representing the ACTION Index scores appears roughly symmetric and data seem to be normally distributed; there is one major peak and two smaller peaks on both sides, along the tails. On the other hand, as regards the sample of the EPS Index scores, the distribution seems positively skewed, and it is characterized by one major peak and a smaller one on the right. These assumptions are further confirmed by the summary statistics (Table 10), according to which for the first sample ("ACTION Index scores") the mean and the median are almost coincident, whereas regarding the second one ("EPS Index scores") the mean is greater than the median. The Yule-Kendall's coefficient allows to evaluate the skewness of the two distributions: for the ACTION Index sample the measure is almost equal to 0, confirming that the curve is approximately symmetric, whereas for the EPS Index subsample, the coefficient is positive (0.49), meaning that the curve spreads toward the right, hence it is positively skewed. Therefore, the dispersion of both curves is analyzed: by comparing the standard deviation values for both samples, it can be observed that the ACTION Index sample has a greater value (0.57) than the EPS Index sample (0.49). This result can be observed also graphically, since the observations of the former are a little more dispersed around the mean than the observations of the latter, where the values appear more concentrated around the mean. Finally, regarding the interquartile range values, it is worth noting that the spread of the 50% of the values belonging to the EPS Index sample is greater (0.79) than the one of the ACTION Index (0.47). The larger value means that the central portion of data belonging to the former sample spreads out further, hence the dispersion of data is wider than the second one. Conversely, the smaller value for the ACTION Index sample proves that the middle values cluster more tightly.

The spread of data can also be highlighted by plotting the boxplots for both samples:

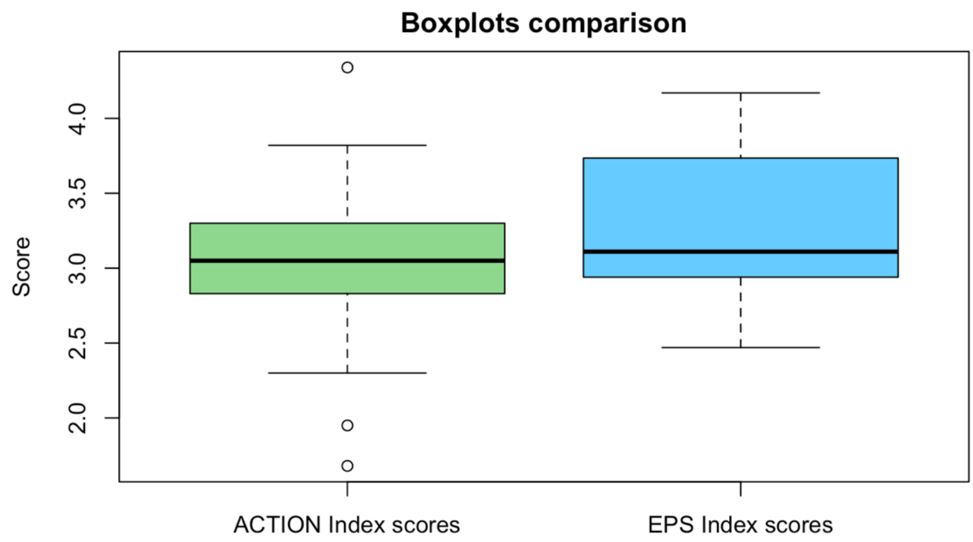

Figure 17. Boxplots of the two samples

From this graph (Figure 17), it is worth noting the presence of three data points located outside the whiskers of the boxplot on the right. They represent outliers for the ACTION Index sample, corresponding to average scores equal to 1.68 (Poland), 1.95 (Greece) and 4.34 (Norway). On the contrary, regarding the EPS Index scores, no outlier has been detected.

Before performing the correlation test, in the following paragraph, a statistical inference will be conducted to better understand the characteristics of the two samples. Since the score of both indices can be considered a continuous variable, the related distribution is a density function. Therefore, the next goal is to evaluate whether the two samples follow a Gaussian or a Gamma distribution. For the parameters' estimation, the Maximum Likelihood Method will be implemented. Subsequently, the Goodness of fit of both distributions will be assessed both numerically and graphically. As a matter of fact, to further verify which distribution better represents the data, the shape of a Quantile-Quantile plot (for both samples) will be analyzed. Moreover, the Kolmogorov-Smirnov test will be performed and the lowest value for the test will be considered to determine the best distribution for the two samples and judge the adequacy of the given statistical model.

The following table shows the aforementioned parameters:

	ACTION Index	EPS Index
Gaussian_mu	3.040000	3.258696
Gaussian_sigma_squared	0.555643	0.4833156
Gamma_alpha	26.99501	45.666800
Gamma_beta	8.88002	14.01394

Table 11. Estimated parameters for the Gaussian and the Gamma distribution

Afterwards, as already explained, the histograms and the theoretical densities of the distributions of both samples are plotted (Figure 18) to graphically assess which distribution (Gaussian or Gamma) better fits the data:

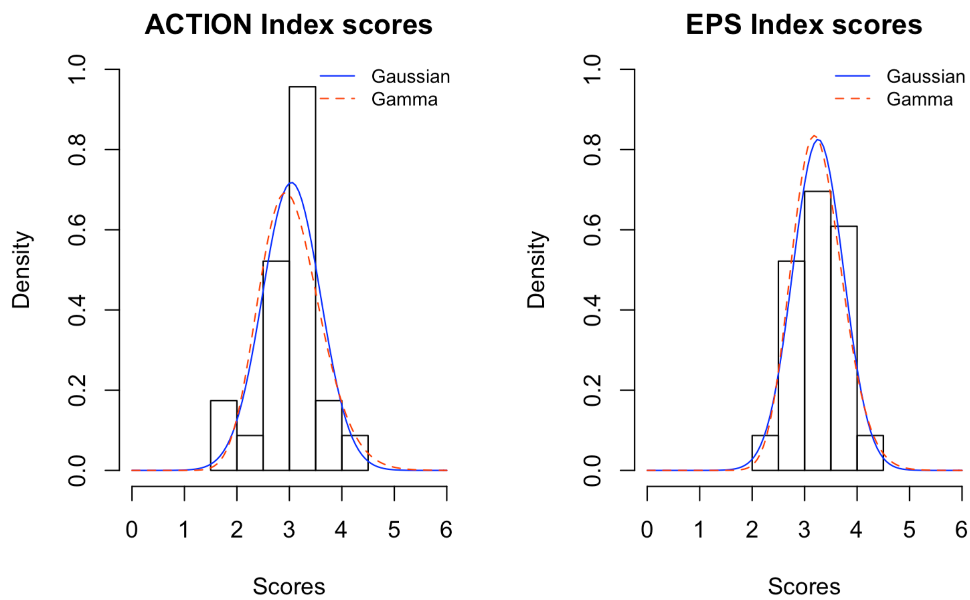

Figure 18. Histograms and theoretical densities of the distributions of both samples

Furthermore, the quantile-quantile plots for both samples are shown to make a further comparison:

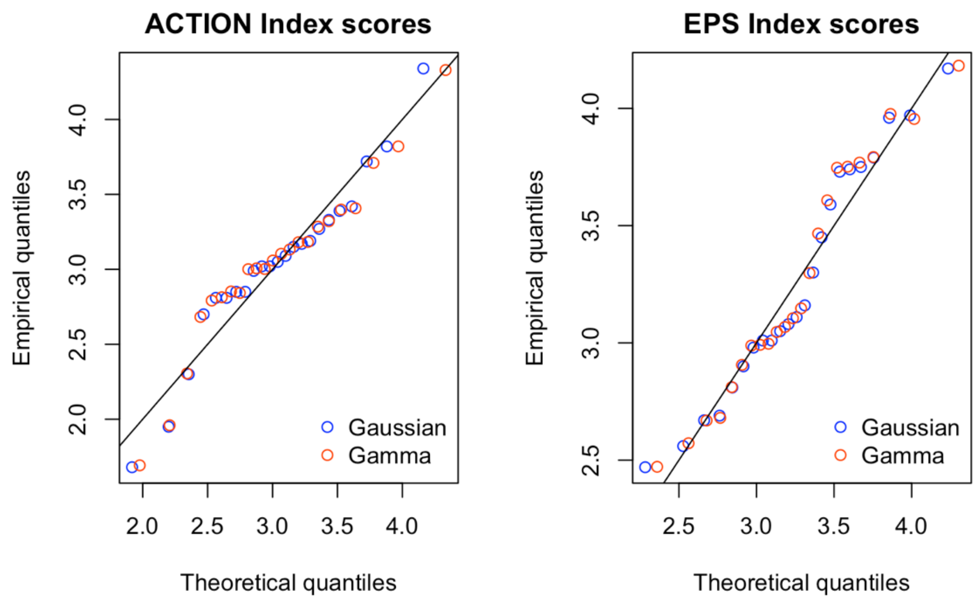

Figure 19. Q-Q plots of the distributions of both samples

By observing the empirical and theoretical density functions, the difference between the two distributions is not readily noticeable. However, the Gaussian distribution seems to better fit the data regarding the ACTION Index sample. Conversely, as regards the EPS Index sample, the Gamma and the Gaussian distributions are quite similar, and it is difficult to graphically assess which one seems to have a better agreement with the data. This feature can be highlighted also by looking at the Q-Q plot of the sample on the right: both red and blue points are almost equally distant from the 1-1 line.

To further comment the previous assumptions, the Goodness of fit statistics is calculated. The Kolmogorov-Smirnov test (which compares the distance between the empirical distribution function of the sample and a continuous distribution of known form) is considered: as regards the first distribution related to the ACTION Index scores, the values resulting from the testing procedure are **ks_Gaussian = 0.166** and **ks_Gamma = 0.193**. The best distribution is the one that presents the lowest value: therefore, in this case, the best fit is the Gaussian distribution. Regarding the EPS Index sample, the values resulting from the Kolmogorov-Smirnov test for the Gaussian and Gamma distribution are respectively **ks_Gaussian = 0.146** and **ks_Gamma = 0.141**. In this case, the two scores are slightly different; however, the Gamma distribution has a lower result, which means that it represents the best fit. These values confirm the previous suppositions based on the Q-Q plots.

The relationship between the two indices is displayed through the scatterplot shown hereunder:

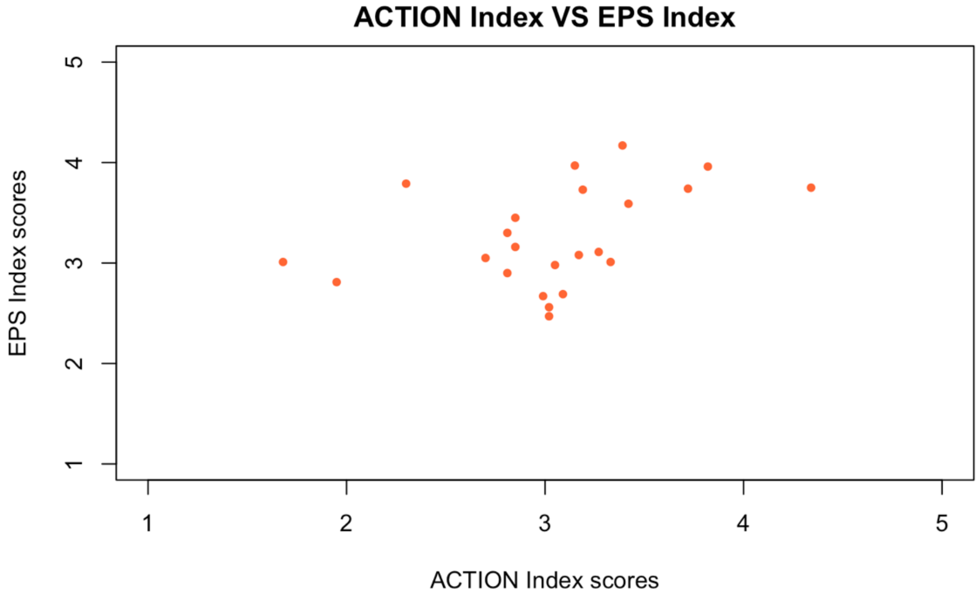

Figure 20. Relationship between the ACTION Index and the EPS Index scores

From Figure 20, it is not easy to discern a clear trend in the data since the points do not cluster tightly and perfectly together. Indeed, the strength of the relationship or correlation between the two variables increases as the data points approach as close as possible a straight line. Nonetheless, in this specific case, despite the dots are widely spread out over the graph, it is possible to affirm that there seem to be a weak trend in the data.

As last part of this analysis, considering all the comments and assumptions made before, the most suitable method to measure the strength and direction of the possible relationship between the two samples is the Spearman's correlation test. As a matter of fact, if compared to the Pearson's correlation test, the former is based on less rigid assumptions: first of all, this non-parametric method does not require the variables to be normally distributed. Indeed, as confirmed before through the Kolmogorov-Smirnov test, if the ACTION Index scores seem to satisfy this condition, the Gamma distribution represents the best fit for the EPS Index sample instead. Moreover, the Spearman's correlation test is less sensitive to the presence of outliers, and three of them has been detected for the ACTION Index sample through the representation of its boxplot. Last but not least, the method is often implemented to evaluate the strength and direction of a monotonic relationship between two variables, when a linear relationship between them may not be certain. To this regard, this has been analyzed through the representation of the scatterplot. Having said that, the first step to follow when performing a Spearman correlation test is to formulate the hypotheses: the null hypothesis H_0 states that there is no correlation between the two variables, i.e. the ACTION Index scores and the EPS Index scores, whereas the alternative hypothesis H_A assumes that there is a significant correlation between them. The values obtained from the test are the following: a **p-value = 0.0303521** (< 0.05) allows to reject H_0, which is not consistent with data and accept H_A. Moreover, the obtained correlation coefficient $\boldsymbol{\rho}$ **= 0.4520278** indicates that a positive systematic relationship between the data of the two samples exists. Therefore, the overall conclusion is that there is a certain level of positive monotonic relationship between the scores of both indices.

4. Discussion

By setting ambitious long-term objectives and emphasizing the urgent need to chart a better course forward against the climate crisis, the Paris Agreement, has prompted widespread engagement in climate initiatives at all levels, from local to global (UNFCCC, 2015). However, the first global stocktake (UNFCCC, 2023b), at the core of COP28 in Dubai, unveils persistent challenges faced by countries in effectively implementing impactful measures and in achieving a synergic approach. Having said that, the Conference of the Parties calls for an urgent course correction, stressing on the point that "*the window for meaningful change is closing and the time to act is now*" (UNFCCC, 2023a). It is evident that efforts thus far have been fragmented, confined to certain sectors, and disproportionally allocated. Acknowledging the different responsibilities and capabilities shaped by the various national contexts, the scientific community emphasizes the importance of international collaboration and active participation in advancing global endeavors. The Conference of Parties also reaffirms its dedication to multilateralism in fostering collective decision-making and joint action for achieving the common goals. Furthermore, given the existing shortcomings in the implementation, support, and collective evaluation of national initiatives, strengthening monitoring and detailed reporting in line with the Transparency Framework under the Paris Agreement is essential. Moreover, nations are urged to promote the exchange and enhancement of knowledge and best practices to address capacity gaps effectively. Additionally, there is consensus within the scientific community on the need for stronger comparative metrics and comprehensive cross-country investigations to gather relevant research findings regarding policy strategies and their effectiveness. As a matter of fact, as mentioned in the introductory section, existing comparative studies narrow their focus to a specific facet of regulatory stringency; by doing so, they certainly allow for a more in-depth assessment of a specific aspect, delving into intricacies and detailed implications, which may be overlooked in a broader study. On the other hand, they often fail in capturing the multidimensionality of the phenomenon and in delivering a holistic understanding of the interconnected challenges it implies.

To this end, the present study and the ACTION Index itself have originated from the urge of contributing to this purpose and have offered the opportunity to evaluate policy stringency performances from different points of view.

From a macro perspective, the ACTION Index has provided a snapshot of the progress that each country has achieved between 2010 and 2021: on average, the composite progressively increased over the considered period, witnessing advancements for all countries included in the analysis. The

different curves, some characterized by steadier paths and others alternating peaks and troughs, have sparked the interest of delving into national dynamics with a finer eye.
In other words, the overall quantitative measure also proved to hide remarkable heterogeneity, if analyzed from a micro perspective: breaking down the ACTION Index into its components has allowed to assess which factors drive its score and which have a less impactful contribution for each nation. Indeed, as shown through the analysis of the single indicators, each country has proved to have its own strong points and weaknesses. The granular evaluation of each dimension has brought to light interesting insights and has offered the opportunity to explore examples of peculiar policy measures implemented nationally in recent years. The analysis of the stand-alone indicators has created prospects for some empirical evaluations: results show that the main improvements in policy stringency between 2010 and 2021 have been determined by an increasing emphasis on energy efficiency policies and measures implemented or reinforced nationally. The other indicator through which the countries exhibited the greatest improvements is the renewable energy one, meaning that over time, the commitments in the promotion of cleaner and environmentally friendly energy sources has been more and more pervasive and shared by all nations. Still, bearing in mind that the progress made by each of them has been highly variable, it is important to highlight that none of the countries included in the sample has weakened its overall performance in terms of energy efficiency and renewable energy promotion after the eleven years. On the contrary, there are marked differences in national performance across the remaining indicators, i.e. carbon pricing, policy density, energy research and development and fossil fuel subsidy removal; for this reason, it is hard to discern common patterns driving the whole sample in one direction.
Finally, the empirical comparison between the ACTION Index and the EPS Index served to validate the reliability and robustness of the former, in capturing the studied phenomenon. The presence of a certain level of positive monotonic relationship between the average scores has confirmed that there exists a consistent and systematic association between the indices. The different scope of the two measures has also been crucial in identifying possible causes of discrepancies or divergent findings in national performances, which need further investigation.

4.1. Limitations, gaps identification and guidelines for further improvement

Considering the limited scope of this research, in terms of both spatial and temporal coverage, it would be stimulating to broaden it, to validate the robustness of the outcomes and to unveil new perspectives and considerations.

A wider temporal analysis could be performed to better catch the evolution of the scores over a longer time span. A comparison between historical dynamics and more recent policy stringency developments will thus probably uncover greater fluctuations.

Another possible improvement, in terms of spatial coverage, could consist in the inclusion of a sample of developing countries, which have not been covered by the assessment due to overlap issues between the considered databases. Given the vulnerability that distinguishes these nations in tackling the detrimental effects that climate change brings with it, it might be engaging to explore if, in some cases, despite disadvantaged conditions, developing countries have achieved unexpected and enlightening results after implementing certain regulatory measures covered by one of six dimensions on which the ACTION Index is grounded. Expanding the research in this sense would also represent the occasion to reflect upon the need for mobilization of financial resources, defined by the Conference of Parties (UNFCCC, 2023b) as one of the "critical enablers" of implementation and support of strong nationally determined contributions (NDCs) of developing countries. This support should come from developed nations, in light of the principles of international cooperation, coordination of efforts and equitability.

It is also worth remembering that the focus of this research are mitigation policies. This allows to pinpoint another important remark: in the future, it would be stimulating to broaden the scope of the study by including national adaptation strategies and initiatives, to understand how countries are taking action to adjust to actual or expected climate stimuli and their negative effects on societies, ecosystems and economies worldwide.

Methodological improvements of the present research, instead, would consist in performing an uncertainty or a sensitivity analysis for example. From the "Handbook on constructing composite indicators: methodology and user guide" (European Commission, Joint Research Centre & Organisation for Economic Co-operation and Development, 2008), both approaches are explored deeply. The application of first technique is more frequent and allows to determine how overall uncertainty spreads through the entire structure of the quantitative measure and its underlying model. On the other hand, a sensitivity analysis is conducted with the purpose of identifying all sources of uncertainty and assessing the extent to which they influence outcomes' variance. It is also argued that the combination of the two methods in the construction of an index can greatly improve its structure. Furthermore, both techniques could further improve transparency and make the analysis and the findings more reliable. Examples of concrete applications on different methodological steps concern using different values in the weighting procedure, applying alternative aggregation techniques, or even taking into account or exclude single indicators, to detect potential outcomes' variations (European Commission, Joint Research Centre & Organisation for Economic Co-operation and Development, 2008).

4.2. Conclusion and policy recommendations

The empirical research in this thesis has essentially brought to light the fundamental role of policy stringency, in shaping and enhancing countries' overall commitment to effective mitigation actions. The need for more holistic and comprehensive quantitative measures gave birth to the ACTION Index, which allowed to translate scientific evidence into thought-provoking policy recommendations. In-depth comparative studies such as the one proposed in this paper should be conducted and their scientific and policy relevance should be exploited at its fullest potential by policymakers and governmental bodies to lead informed and powerful decision-making and promote comparison of best practices with other countries.

The way foreword is clear: immediate and synergic action to shift development pathways toward sustainability and effective emissions reductions is a must. At the same time, the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement acknowledges that "this does not imply peaking in all countries within this time frame, and that time frames for peaking may be shaped by sustainable development, poverty eradication needs and equity and be in line with different national circumstances" (UNFCCC, 2023b). Multilateralism and knowledge-sharing are strongly needed, considering that climate change impacts are not confined to a single country or region, but extended beyond borders and involving intertwined challenges.

Annexes

Annex A – overall descriptive statistics

Carbon Pricing Dashboard		Fossil Fuel Subsidy Tracker	
Mean	6.05	Mean	3,838,980,438.83
Standard Error	1.24	Standard Error	821,491,964.85
Median	4.69	Median	277,644,962.26
Standard Deviation	8.34	Standard Deviation	10,742,401,373.10
Minimum	0.00	Minimum	-1,437,926,280.90
Maximum	139.88	Maximum	269,710,880,791.70
N	45	N	171
Climate Policy Database		**Regulatory Indicators for Sustainable Energy - EE scores**	
Mean	0.60	Mean	32.07
Standard Error	0.11	Standard Error	1.84
Median	0.00	Median	28.33
Standard Deviation	1.41	Standard Deviation	21.78
Minimum	0	Minimum	0.00
Maximum	19	Maximum	87.00
N	161	N	140
The Energy Technology and R&D Database		**Regulatory Indicators for Sustainable Energy - RE scores**	
Mean	0.25	Mean	37.78
Standard Error	0.05	Standard Error	1.82
Median	0.15	Median	35.25
Standard Deviation	0.28	Standard Deviation	21.55
Minimum	0.00	Minimum	0.00
Maximum	1.67	Maximum	94.00
N	31	N	140

Table 1A. ACTION Index: overall descriptive statistics

Annex B – indicators' scores (2010-2021)

Carbon Pricing Dashboard

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Austria	3	3	2	1	1	1	1	1	2	4	3	7
Belgium	3	3	2	1	1	1	1	1	2	4	3	7
Canada	0	0	0	0	0	0	0	0	0	1	2	3
Chile	0	0	0	0	0	0	0	1	1	1	1	1
Czech Republic	3	3	2	1	1	1	1	1	2	4	3	7
Denmark	6	7	5	4	5	4	4	4	6	6	5	10
Finland	6	10	9	8	9	8	8	9	10	10	10	10
France	3	3	2	1	2	3	4	5	9	9	8	10
Germany	3	3	2	1	1	1	1	1	2	4	3	10
Greece	3	3	2	1	1	1	1	1	2	4	3	7
Hungary	3	3	2	1	1	1	1	1	2	4	3	7
Ireland	5	6	4	4	4	4	4	4	6	6	6	10
Italy	3	3	2	1	1	1	1	1	2	4	3	7
Japan	0	0	1	1	1	1	1	1	1	1	1	1
Korea	0	0	0	0	0	2	4	5	5	6	8	4
Mexico	0	0	0	0	1	1	1	1	1	1	1	1
Netherlands	3	3	2	1	1	1	1	1	2	4	3	8
New Zealand	2	3	1	1	1	1	2	2	3	3	3	4
Norway	9	10	9	9	9	7	7	7	10	10	9	10
Poland	3	3	2	1	1	1	1	1	2	4	3	7
Portugal	3	3	2	1	1	2	2	2	3	5	6	10
Slovak Republic	3	3	2	1	1	1	1	1	2	4	3	7
Spain	3	3	2	1	1	1	1	1	3	4	3	7
Sweden	10	10	10	10	10	10	10	10	10	10	10	10
Switzerland	4	5	5	5	9	7	10	10	10	10	10	10
United Kingdom	3	3	2	2	2	3	3	3	4	5	2	2

Climate Policy Database

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Austria	2	3	0	0	0	0	0	0	2	0	0	0
Belgium	0	5	0	3	3	2	0	3	6	0	0	0
Canada	8	10	9	6	5	2	6	10	10	10	10	10
Chile	3	0	5	6	3	0	0	9	5	0	2	8
Czech Republic	0	0	5	0	0	0	0	0	0	0	0	0
Denmark	3	3	3	3	3	5	0	3	2	2	0	0
Finland	2	2	0	2	0	0	0	0	2	0	0	0
France	8	6	3	3	9	9	10	10	9	5	9	3
Germany	5	9	9	3	3	3	10	6	5	9	6	8
Greece	3	2	0	0	2	0	0	0	2	0	0	0
Hungary	2	3	0	0	0	0	0	0	0	0	0	0
Ireland	2	0	2	2	0	0	0	0	2	2	0	0
Italy	8	8	5	3	10	2	0	2	2	8	5	0
Japan	3	2	10	9	3	8	9	9	10	9	3	10
Korea	5	8	9	5	3	6	3	8	2	8	5	3
Mexico	2	3	6	10	10	5	6	10	10	2	6	2
Netherlands	0	3	2	2	0	0	0	0	0	0	0	0
New Zealand	0	0	0	0	0	0	2	2	0	3	2	5
Norway	2	3	8	3	0	5	3	10	8	2	3	6
Poland	0	2	0	0	2	0	0	0	0	2	0	0
Portugal	5	0	2	2	0	0	0	0	0	0	0	0
Slovak Republic	0	5	8	5	3	0	0	2	0	0	0	0
Spain	3	9	6	10	10	10	2	10	9	2	0	0
Sweden	3	8	2	2	3	3	6	5	2	3	0	0
Switzerland	3	2	2	5	3	0	2	5	6	0	2	2
United Kingdom	9	10	0	6	10	9	8	10	6	3	10	10

The Energy Technology and R&D Database

Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Austria	5	5	5	5	6	5	5	5	5	5	5	7
Belgium	2	5	7	7	6	5	5	5	5	7	9	5
Canada	9	8	9	9	6	6	4	5	7	6	7	8
Chile	0	0	0	0	1	1	1	1	1	1	1	1
Czech Republic	3	4	4	4	3	3	4	5	5	7	6	7
Denmark	10	9	8	8	8	7	5	4	4	4	6	7
Finland	10	10	10	10	10	10	10	10	10	9	8	8
France	9	10	10	10	9	9	8	8	8	8	9	10
Germany	3	4	3	4	4	4	4	4	4	5	5	5
Greece	1	1	0	0	0	0	0	0	0	0	0	0
Hungary	10	10	10	1	1	1	3	7	1	1	2	6
Ireland	3	2	3	2	2	3	1	1	1	1	1	1
Italy	4	4	5	4	5	4	3	3	3	4	4	0
Japan	9	10	10	8	9	7	7	7	8	8	8	8
Korea	6	6	7	6	6	5	5	5	5	5	5	6
Mexico	0	0	0	3	2	1	2	2	2	1	1	1
Netherlands	7	3	4	4	3	4	3	4	4	5	5	7
New Zealand	2	2	1	1	1	1	1	2	1	1	1	1
Norway	10	10	10	10	10	10	10	10	10	10	10	10
Poland	5	5	3	4	3	3	1	1	1	1	2	2
Portugal	1	1	1	1	1	5	4	4	4	3	4	5
Slovak Republic	4	5	4	5	4	1	3	1	1	1	1	1
Spain	2	3	2	1	1	1	1	1	1	1	1	7
Sweden	6	5	4	5	5	5	5	5	5	5	6	7
Switzerland	4	5	5	5	6	7	8	8	7	7	7	6
United Kingdom	4	3	3	3	3	3	3	4	5	5	6	6

Indicator	Country	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Fossil Fuel Subsidy Tracker	Austria	9	9	9	9	9	9	9	9	9	9	9	9
	Belgium	7	7	7	7	8	8	8	7	7	7	6	7
	Canada	6	7	7	7	7	8	8	8	8	8	6	7
	Chile	8	9	9	9	9	9	8	8	8	8	9	8
	Czech Republic	9	9	9	9	9	9	9	9	9	9	9	9
	Denmark	9	9	9	9	9	9	9	9	9	9	9	8
	Finland	9	9	9	9	8	9	9	8	8	9	8	8
	France	7	5	5	5	5	5	4	4	1	1	2	1
	Germany	0	0	0	0	0	2	1	2	1	2	2	3
	Greece	7	7	7	6	7	8	8	8	8	8	8	8
	Hungary	9	9	9	9	9	9	9	9	9	9	9	9
	Ireland	7	7	7	7	7	8	8	7	7	7	8	7
	Italy	3	1	0	0	0	0	0	2	1	0	1	0
	Japan	8	7	7	7	7	7	7	7	8	8	8	7
	Korea	8	8	8	8	8	8	9	8	8	9	9	9
	Mexico	0	0	0	0	4	0	0	0	0	0	0	0
	Netherlands	9	9	9	9	9	9	9	9	9	9	9	9
	New Zealand	9	9	9	9	9	9	9	9	9	9	9	9
	Norway	9	9	9	9	9	9	9	9	9	9	9	9
	Poland	8	8	9	9	8	9	8	8	8	8	8	8
	Portugal	9	9	9	9	9	9	9	9	9	9	9	9
	Slovak Republic	9	9	9	9	9	9	9	9	9	9	9	9
	Spain	6	7	7	8	8	8	8	8	8	8	8	8
	Sweden	7	7	8	8	8	9	8	9	8	8	8	8
	Switzerland	8	8	8	8	8	8	8	8	8	8	8	8
	United Kingdom	1	3	1	0	0	0	0	0	0	0	0	0
RISE - EE scores	Austria	4	4	5	5	8	10	10	10	10	10	10	10
	Belgium	3	4	5	6	7	7	7	9	9	9	9	9
	Canada	2	2	2	4	4	5	7	9	9	9	9	9
	Chile	1	1	1	1	1	1	1	3	4	4	6	8
	Czech Republic	3	3	5	5	6	7	8	8	8	8	8	9
	Denmark	1	1	6	6	8	8	8	10	10	10	10	10
	Finland	1	1	1	3	4	5	5	7	7	8	8	8
	France	1	1	1	2	3	4	4	5	5	5	7	7
	Germany	4	4	5	5	7	8	9	10	10	10	10	10
	Greece	1	2	2	2	3	3	3	4	4	6	6	6
	Hungary	1	2	2	2	2	4	4	4	5	10	10	10
	Ireland	4	4	5	7	8	8	8	9	9	9	9	9
	Italy	1	3	3	3	4	6	7	7	7	9	9	9
	Japan	2	2	3	4	4	5	6	6	7	7	7	7
	Korea	4	4	4	4	5	6	7	7	10	10	10	10
	Mexico	1	1	1	1	1	2	2	3	4	4	5	6
	Netherlands	1	2	5	7	8	8	8	8	8	9	9	9
	New Zealand	2	3	3	3	3	3	4	4	4	4	4	4
	Norway	1	2	3	3	3	4	4	5	7	7	7	7
	Poland	1	1	1	1	1	1	1	1	1	3	4	4
	Portugal	4	6	7	8	9	9	9	9	9	10	10	10
	Slovak Republic	2	3	4	4	7	7	8	9	9	9	9	9
	Spain	1	4	4	5	6	7	8	9	9	9	10	10
	Sweden	3	3	3	3	3	3	4	4	4	6	6	6
	Switzerland	1	1	1	1	1	1	1	1	7	7	8	8
	United Kingdom	4	4	4	5	7	7	7	8	9	10	10	10
RISE - RE scores	Austria	6	6	6	6	7	7	7	7	9	9	9	9
	Belgium	4	4	5	6	6	7	8	8	8	9	9	9
	Canada	2	2	3	4	5	6	6	7	8	8	8	9
	Chile	1	1	1	1	1	4	4	6	7	7	9	10
	Czech Republic	3	3	6	6	6	7	7	7	7	7	7	7
	Denmark	4	5	6	7	7	9	9	10	10	10	10	10
	Finland	1	1	1	2	2	3	7	7	9	10	9	9
	France	3	3	3	4	6	6	7	7	7	7	10	10
	Germany	5	5	7	7	7	8	9	10	10	10	10	10
	Greece	1	3	4	4	5	5	7	8	9	9	9	9
	Hungary	5	6	6	6	6	7	7	8	9	9	9	9
	Ireland	7	7	7	7	7	8	8	8	9	9	9	10
	Italy	4	4	5	5	5	6	7	7	7	9	9	9
	Japan	1	1	1	2	2	3	3	5	8	8	8	8
	Korea	1	1	1	1	1	3	4	7	7	9	10	10
	Mexico	1	1	1	1	1	5	7	7	8	9	10	10
	Netherlands	1	1	1	4	5	7	8	9	8	9	9	9
	New Zealand	1	1	1	2	2	2	3	4	4	4	5	6
	Norway	2	4	5	7	7	8	8	8	10	10	10	10
	Poland	1	1	1	1	1	2	2	2	2	4	4	4
	Portugal	5	5	5	6	7	7	7	7	8	9	9	9
	Slovak Republic	7	8	8	9	9	9	9	9	9	9	9	9
	Spain	1	1	1	6	7	8	8	8	9	9	9	9
	Sweden	1	1	1	1	1	3	7	7	7	7	7	7
	Switzerland	1	1	1	1	1	1	2	6	10	10	10	10
	United Kingdom	1	2	2	7	9	9	9	10	10	10	10	10

Table 1B. Indicators' scores

Annex C – raw data of the six databases (2010-2021)

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Carbon Pricing Dashboard	Austria	7.03	9.67	3.78	2.47	2.75	3.13	1.99	2.54	6.66	9.97	7.54	20.26
	Belgium	7.03	9.67	3.78	2.47	2.75	3.13	1.99	2.54	6.66	9.97	7.54	20.26
	Canada	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.30	4.64	9.23
	Chile	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.47	1.47	1.47	1.47	1.47
	Czech Republic	7.03	9.67	3.78	2.47	2.75	3.13	1.99	2.54	6.66	9.97	7.54	20.26
	Denmark	16.81	20.17	13.88	12.35	13.54	11.70	10.95	12.12	16.07	18.54	15.93	29.32
	Finland	16.92	30.03	25.36	22.11	25.83	22.88	24.49	28.05	34.33	33.23	30.18	44.57
	France	7.03	9.67	3.78	2.47	6.13	8.59	10.58	15.15	26.01	27.51	24.62	38.60
	Germany	7.03	9.67	3.78	2.47	2.75	3.13	1.99	2.54	6.66	9.97	7.54	32.01
	Greece	7.03	9.67	3.78	2.47	2.75	3.13	1.99	2.54	6.66	9.97	7.54	20.26
	Hungary	7.03	9.67	3.78	2.47	2.75	3.13	1.99	2.54	6.66	9.97	7.54	20.26
	Ireland	15.11	18.15	11.78	12.74	11.02	11.73	10.92	11.99	16.58	18.96	17.61	36.00
	Italy	7.03	9.67	3.78	2.47	2.75	3.13	1.99	2.54	6.66	9.97	7.54	20.26
	Japan	0.00	0.00	0.86	0.76	1.39	1.19	2.12	1.97	2.05	1.95	2.01	1.96
	Korea	0.00	0.00	0.00	0.00	0.00	6.65	11.06	13.24	14.98	17.12	23.93	11.60
	Mexico	0.00	0.00	0.00	0.00	0.91	0.80	0.66	0.72	0.74	0.74	0.60	0.78
	Netherlands	7.03	9.67	3.78	2.47	2.75	3.13	1.99	2.54	6.66	9.97	7.54	24.38
	New Zealand	6.09	7.53	2.82	0.82	1.32	2.42	6.39	6.59	7.46	8.59	7.01	12.62
	Norway	27.96	32.78	26.51	26.03	26.19	21.10	19.30	21.41	28.09	29.69	25.15	43.32
	Poland	7.03	9.67	3.79	2.47	2.75	3.13	1.99	2.54	6.66	9.98	7.55	20.26
	Portugal	7.03	9.67	3.78	2.47	2.75	5.10	4.67	5.45	9.72	15.13	16.84	30.41
	Slovak Republic	7.03	9.67	3.78	2.47	2.75	3.13	1.99	2.54	6.66	9.97	7.54	20.26
	Spain	7.03	9.67	3.78	2.47	3.27	3.53	1.99	2.54	7.12	10.29	7.85	20.59
	Sweden	42.23	52.85	46.30	45.79	46.28	44.67	54.19	58.47	62.31	60.69	55.32	75.16
	Switzerland	11.29	14.94	15.27	14.53	27.25	21.76	29.42	29.41	34.13	32.59	34.81	37.88
	United Kingdom	7.03	9.67	3.78	4.04	6.09	8.74	6.97	7.53	12.01	14.93	4.68	5.21
Climate Policy Database	Austria	1	2	0	0	0	0	0	0	1	0	0	0
	Belgium	0	3	0	2	2	1	0	2	4	0	0	0
	Canada	5	7	6	4	3	1	4	9	8	10	13	9
	Chile	2	0	3	4	2	0	0	6	3	0	1	5
	Czech Republic	0	0	3	0	0	0	0	0	0	0	0	0
	Denmark	2	2	2	2	2	3	0	2	1	1	0	0
	Finland	1	1	0	1	0	0	0	0	1	0	0	0
	France	5	4	2	2	6	6	8	8	6	3	6	2
	Germany	3	6	6	2	2	2	13	4	3	6	4	5
	Greece	2	1	0	0	1	0	0	0	1	0	0	0
	Hungary	1	2	0	0	0	0	0	0	0	0	0	0
	Ireland	1	0	1	1	0	0	0	0	1	1	0	0
	Italy	5	5	3	2	7	1	0	1	1	5	3	0
	Japan	2	1	8	6	2	5	6	6	10	6	2	8
	Korea	3	5	6	3	2	4	2	5	1	5	3	2
	Mexico	1	2	4	9	8	3	4	8	8	1	4	1
	Netherlands	0	2	1	1	0	0	0	0	0	0	0	0
	New Zealand	0	0	0	0	0	0	1	1	0	2	1	3
	Norway	1	2	5	2	0	3	2	9	5	1	2	4
	Poland	0	1	0	0	1	0	0	0	0	1	0	0
	Portugal	3	0	1	1	0	0	0	0	0	0	0	0
	Slovak Republic	0	3	5	3	2	0	0	1	0	0	0	0
	Spain	2	6	4	13	8	7	1	10	6	1	0	0
	Sweden	2	5	1	1	2	2	4	3	1	2	0	0
	Switzerland	2	1	1	3	2	0	1	3	4	0	1	1
	United Kingdom	6	8	0	4	9	6	5	8	4	2	9	11

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
The Energy Technology and R&D Database	Austria	0.41	0.39	0.38	0.38	0.43	0.37	0.39	0.38	0.39	0.38	0.41	0.55
	Belgium	0.15	0.40	0.55	0.50	0.41	0.39	0.39	0.36	0.38	0.50	0.63	0.36
	Canada	0.71	0.58	0.70	0.70	0.47	0.45	0.33	0.37	0.52	0.46	0.53	0.56
	Chile	0.00	0.00	0.00	0.00	0.04	0.03	0.02	0.03	0.03	0.03	0.01	0.01
	Czech Republic	0.20	0.30	0.30	0.26	0.23	0.24	0.32	0.34	0.35	0.51	0.41	0.50
	Denmark	0.73	0.68	0.59	0.62	0.56	0.54	0.35	0.29	0.28	0.29	0.46	0.49
	Finland	1.43	1.29	1.16	1.14	1.05	1.13	0.87	0.95	0.82	0.66	0.62	0.56
	France	0.70	0.73	0.72	0.74	0.70	0.66	0.62	0.58	0.58	0.58	0.69	0.73
	Germany	0.24	0.27	0.26	0.29	0.29	0.30	0.30	0.33	0.31	0.33	0.36	0.37
	Greece	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Hungary	0.89	0.90	0.87	0.09	0.06	0.08	0.23	0.53	0.09	0.04	0.12	0.42
	Ireland	0.24	0.12	0.20	0.16	0.15	0.23	0.07	0.07	0.06	0.07	0.06	0.06
	Italy	0.29	0.33	0.35	0.33	0.34	0.29	0.25	0.25	0.26	0.28	0.31	0.00
	Japan	0.70	0.76	0.77	0.59	0.67	0.55	0.51	0.48	0.57	0.56	0.59	0.57
	Korea	0.47	0.43	0.48	0.47	0.43	0.40	0.37	0.35	0.34	0.34	0.38	0.42
	Mexico	0.00	0.00	0.00	0.20	0.16	0.09	0.13	0.14	0.12	0.04	0.03	0.02
	Netherlands	0.55	0.23	0.30	0.28	0.23	0.27	0.24	0.27	0.30	0.35	0.37	0.48
	New Zealand	0.17	0.12	0.10	0.09	0.09	0.09	0.06	0.11	0.10	0.10	0.09	0.06
	Norway	1.40	1.16	0.99	0.83	1.22	1.12	0.95	0.97	0.85	1.67	1.04	1.11
	Poland	0.36	0.39	0.26	0.27	0.23	0.19	0.10	0.10	0.09	0.10	0.15	0.18
	Portugal	0.01	0.01	0.02	0.06	0.05	0.33	0.32	0.31	0.32	0.25	0.31	0.34
	Slovak Republic	0.28	0.35	0.33	0.34	0.27	0.04	0.23	0.02	0.05	0.04	0.10	0.08
	Spain	0.14	0.26	0.16	0.07	0.09	0.10	0.08	0.07	0.08	0.08	0.08	0.55
	Sweden	0.42	0.35	0.33	0.37	0.39	0.39	0.39	0.36	0.37	0.36	0.45	0.51
	Switzerland	0.32	0.37	0.38	0.38	0.46	0.52	0.58	0.59	0.55	0.55	0.56	0.46
	United Kingdom	0.32	0.21	0.19	0.23	0.19	0.20	0.24	0.31	0.34	0.37	0.44	0.46
Fossil Fuel Subsidy Tracker	Austria	1,103,313,048.00	1,227,421,220.00	1,004,379,746.00	895,563,618.00	875,237,134.00	1,219,688,172.00	1,199,489,296.00	1,202,804,148.00	1,308,974,100.00	1,320,370,170.00	852,671,762.00	970,775,762.00
	Belgium	2,842,040,376.00	2,863,207,042.00	2,686,544,075.00	3,018,478,854.80	2,561,275,115.70	2,454,768,446.00	2,582,461,748.10	2,961,533,284.00	3,351,884,028.00	3,548,573,029.50	3,921,453,674.20	3,750,790,770.40
	Canada	4,598,659,349.10	2,892,285,914.20	3,181,484,164.40	3,223,177,193.40	3,310,268,470.70	2,202,598,744.80	2,429,171,698.50	2,481,091,387.40	2,205,406,594.20	2,251,615,133.30	3,924,167,525.80	3,189,711,634.00
	Chile	1,787,059,648.00	614,328,336.00	628,128,428.10	672,854,656.00	980,984,560.00	1,423,229,320.00	1,669,689,576.00	1,867,206,248.00	1,523,355,520.00	1,645,858,000.00	1,420,186,224.00	1,936,212,048.00
	Czech Republic	381,786,972.00	407,036,112.00	364,880,988.00	324,879,536.00	288,324,408.00	248,736,634.00	223,055,132.00	259,942,533.00	275,576,182.00	357,636,728.00	361,579,432.00	407,357,606.00
	Denmark	1,303,877,184.00	1,452,310,848.00	1,139,409,056.00	1,188,502,304.00	1,189,316,608.00	886,945,408.00	859,764,480.00	1,155,780,484.00	1,308,114,716.00	1,307,443,624.00	1,418,642,960.00	1,516,219,536.00
	Finland	1,027,866,033.60	1,045,703,069.00	1,067,010,352.00	1,243,169,984.00	1,707,128,376.00	1,359,680,166.10	1,443,164,390.40	1,491,186,233.50	1,645,520,105.00	1,469,063,287.40	1,545,319,544.00	1,510,351,832.00
	France	3,620,891,643.60	5,989,699,747.60	6,181,467,770.50	6,249,062,920.90	6,023,596,150.10	5,568,010,158.50	6,347,847,604.30	7,424,758,774.50	10,145,496,837.00	10,100,705,425.00	9,269,442,950.00	9,946,763,632.90
	Germany	13,619,097,056.00	12,752,951,108.00	11,913,314,546.00	11,465,717,108.00	11,833,102,848.00	9,669,413,868.00	10,277,582,232.00	9,614,238,024.00	9,958,148,884.00	8,798,977,976.00	9,643,050,420.00	7,862,532,396.00
	Greece	3,101,422,850.20	3,099,777,797.50	3,837,029,465.70	4,053,013,939.50	3,208,787,465.80	2,381,684,623.40	2,059,413,844.30	2,372,655,121.10	2,333,527,010.90	2,139,471,047.30	1,922,512,257.30	2,124,660,590.50
	Hungary	452,075,186.40	485,628,010.60	399,823,026.80	403,874,966.80	396,387,908.00	425,633,224.50	300,514,537.10	335,011,248.70	362,074,392.40	301,031,033.40	358,304,186.80	238,705,391.80
	Ireland	3,010,166,742.30	3,032,081,194.50	2,851,133,003.10	2,859,750,919.10	3,054,000,089.80	2,603,537,676.80	2,545,432,308.80	2,741,258,672.50	3,138,093,654.80	2,976,206,822.50	2,424,291,060.30	2,756,052,698.50
	Italy	7,659,063,191.50	9,986,237,096.50	11,942,384,953.40	12,903,570,282.50	13,266,690,015.00	11,475,996,320.90	11,138,200,799.10	9,707,548,402.60	11,045,232,504.50	11,353,427,668.90	10,283,757,893.90	12,416,576,015.60
	Japan	2,176,213,196.00	2,937,225,315.00	3,567,994,668.00	3,775,094,172.00	2,882,241,674.00	2,871,291,289.00	3,315,643,801.00	2,684,929,810.00	2,201,890,111.50	2,385,585,252.00	2,233,996,064.00	3,251,981,053.00
	Korea	1,913,183,366.20	2,051,909,407.40	1,975,719,734.80	2,134,187,930.20	2,101,444,943.90	1,829,070,463.40	1,470,535,531.30	1,491,325,172.90	1,477,433,362.80	1,380,958,107.20	1,403,663,119.30	1,464,810,484.80
	Mexico	17,764,115,215.70	29,012,927,829.60	27,698,095,153.10	17,155,060,323.20	7,405,346,541.60	11,929,593,213.60	27,305,603,340.80	14,269,383,190.90	16,679,739,413.00	18,646,525,584.80	11,530,515,921.00	23,440,248,929.70
	Netherlands	432,983,520.00	510,805,360.00	416,303,056.00	155,678,960.00	196,577,148.00	173,199,392.00	528,435,142.30	845,858,343.10	881,925,704.50	871,185,920.00	1,202,807,744.00	1,413,590,384.00
	New Zealand	34,960,954.00	34,004,288.00	43,016,031.00	14,208,534.10	17,624,372.70	11,869,802.20	11,852,909.00	3,637,893.30	6,800,861.90	13,884,542.60	15,731,574.80	19,002,687.10
	Norway	457,981,887.50	534,059,911.50	357,275,965.80	625,340,600.50	579,582,827.00	521,763,606.50	482,117,070.50	451,059,882.00	392,871,702.00	373,235,933.00	327,520,551.90	361,225,962.10
	Poland	1,747,068,086.50	1,793,068,348.00	1,428,148,944.00	1,410,995,584.00	1,494,793,368.00	1,383,852,062.00	1,631,424,272.00	2,064,494,200.00	2,390,708,963.00	1,692,199,450.00	1,996,350,968.00	2,109,503,539.00
	Portugal	233,193,557.50	510,585,278.50	173,318,014.50	207,186,453.00	215,615,734.00	266,948,920.00	319,120,336.00	496,380,648.00	533,942,339.00	614,927,547.00	686,654,360.30	639,744,385.30
	Slovak Republic	281,382,137.00	223,892,699.90	239,616,224.00	270,249,136.00	278,427,420.00	238,047,612.00	241,212,384.00	245,297,484.00	277,401,508.00	267,138,328.00	225,431,924.00	251,139,696.00
	Spain	4,674,259,362.00	3,461,592,576.00	2,951,723,837.10	2,615,670,878.20	2,398,414,977.10	2,144,377,745.10	1,973,059,168.70	1,884,451,704.00	2,032,162,248.00	1,807,473,114.60	1,734,688,328.00	1,683,823,120.00
	Sweden	3,392,288,480.00	3,213,961,808.00	2,296,645,472.00	1,929,011,984.00	2,047,658,760.00	1,439,132,728.00	1,573,034,794.00	1,423,178,852.00	1,565,800,355.00	1,697,454,196.00	2,123,321,280.00	2,677,728,460.00
	Switzerland	1,932,513,563.00	2,459,427,427.50	2,370,270,537.00	2,323,121,833.80	2,467,890,340.00	2,455,407,546.80	2,489,906,116.60	2,430,667,015.80	2,530,099,636.30	2,571,491,107.90	1,540,069,760.40	1,656,969,844.70
	United Kingdom	10,107,476,360.00	8,479,482,226.00	10,644,372,968.00	27,179,543,276.00	25,176,757,416.00	23,181,113,976.00	14,835,935,561.00	16,338,596,736.00	15,216,521,152.00	14,496,258,865.40	12,114,926,713.80	14,385,481,856.00

		2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
RISE - EE scores	Austria	53	56	57	61	73	83	83	83	83	83	83	84
	Belgium	50	53	61	64	68	68	68	78	78	78	78	78
	Canada	45	46	46	53	55	59	71	77	77	79	79	79
	Chile	11	14	19	28	29	37	39	47	56	56	64	74
	Czech Republic	48	49	58	60	65	69	73	75	75	76	76	77
	Denmark	35	35	64	64	75	75	75	82	82	83	83	83
	Finland	32	33	40	47	56	58	61	67	71	76	76	76
	France	32	32	36	44	51	53	54	61	61	61	69	69
	Germany	52	52	57	57	67	75	77	83	83	83	83	83
	Greece	40	42	43	44	47	50	50	52	52	63	65	65
	Hungary	41	46	46	46	46	53	54	55	57	84	84	85
	Ireland	53	55	59	67	74	76	76	79	80	80	80	80
	Italy	39	49	49	51	55	63	70	71	71	80	80	80
	Japan	46	46	51	53	53	58	64	64	68	68	68	68
	Korea	52	52	52	52	57	66	69	69	84	87	87	87
	Mexico	15	17	29	32	37	46	46	47	53	54	60	64
	Netherlands	40	43	57	71	72	74	75	75	76	79	80	80
	New Zealand	46	47	49	49	49	50	53	55	55	55	56	56
	Norway	36	42	49	49	49	52	56	57	67	67	68	68
	Poland	19	25	28	29	32	36	36	38	38	51	55	55
	Portugal	54	62	68	75	77	78	78	78	81	83	84	84
	Slovak Republic	46	50	53	55	69	70	72	79	79	81	81	81
	Spain	30	52	56	61	63	70	73	80	80	80	83	83
	Sweden	49	50	50	50	50	50	52	52	52	64	64	64
	Switzerland	4	6	11	15	15	17	17	39	69	70	73	73
	United Kingdom	52	52	56	58	68	68	69	73	78	82	82	82
RISE - RE scores	Austria	67	67	67	67	69	74	70	74	81	82	81	81
	Belgium	58	58	59	64	67	69	75	76	78	83	84	84
	Canada	43	43	48	54	63	64	66	74	78	78	78	84
	Chile	22	22	26	29	37	54	58	67	70	70	81	88
	Czech Republic	48	48	65	65	65	69	69	69	71	74	72	72
	Denmark	58	62	64	72	72	80	84	86	87	93	93	94
	Finland	38	38	38	44	47	51	72	72	80	85	82	82
	France	48	51	51	58	66	68	69	71	70	70	88	88
	Germany	61	61	71	71	74	75	83	86	87	89	89	92
	Greece	42	49	54	54	60	63	74	77	81	82	83	83
	Hungary	61	65	66	66	66	69	69	78	81	84	81	81
	Ireland	69	71	71	71	71	75	75	77	81	81	82	88
	Italy	53	58	62	63	63	64	69	70	71	84	82	82
	Japan	23	25	39	44	46	49	50	61	76	79	78	78
	Korea	29	29	31	31	32	50	54	74	73	81	87	87
	Mexico	11	12	15	15	34	61	69	72	78	84	91	91
	Netherlands	41	41	42	54	62	72	77	80	79	83	82	82
	New Zealand	39	41	42	43	43	45	50	53	53	53	62	65
	Norway	47	58	63	71	72	76	77	77	92	92	88	88
	Poland	33	35	37	38	40	45	45	45	47	54	54	54
	Portugal	59	63	63	64	72	72	72	73	76	83	83	83
	Slovak Republic	74	77	78	80	80	80	83	83	83	83	82	82
	Spain	34	39	39	64	71	76	76	79	82	84	81	81
	Sweden	34	34	34	34	34	48	70	70	69	73	73	73
	Switzerland	19	20	20	23	26	32	44	65	87	88	87	87
	United Kingdom	23	44	47	69	81	81	83	85	87	91	92	92

Table 1C. Raw data for each database after the process of data cleaning

References

Albrizio, S., Botta, E., Koźluk, T., & Zipperer, V. (2014). Do Environmental Policies Matter for Productivity Growth? Insights from New Cross-Country Measures of Environmental Policies. OECD Economics Department Working Papers No. 1176. https://doi.org/10.1787/5jxrjncjrcxp-en

Aldy, J., Pizer, W., Tavoni, M. et al. (2016). Economic tools to promote transparency and comparability in the Paris Agreement. *Nature Clim Change* 6, 1000-1004. https://doi.org/10.1038/nclimate3106

Best, R., Burke, P. J., & Jotzo, F. (2020). Carbon Pricing Efficacy: Cross-Country Evidence. *Environmental and Resource Economics*, 77(1), 69–94. https://doi.org/10.1007/s10640-020-00436-x

Best, R., & Zhang, Q. Y. (2020). What explains carbon-pricing variation between countries? *Energy Policy*, 143. https://doi.org/10.1016/j.enpol.2020.111541

Botta, E., & Koźluk, T. (2014). Measuring Environmental Policy Stringency in OECD Countries: A Composite Index Approach. OECD Economics Department Working Papers No. 1176. https://doi.org/10.1787/5jxrjnc45gvg-en

Carhart, M., Litterman, B., Munnings, C., & Vitali, O. (2022). Measuring comprehensive carbon prices of national climate policies. *Climate Policy*, 22(2), 198–207. https://doi.org/10.1080/14693062.2021.2014298

Carley, S., Davies, L. L., Spence, D. B., & Zirogiannis, N. (2018). Empirical evaluation of the stringency and design of renewable portfolio standards. *Nature Energy*, 3(9), 754–763. https://doi.org/10.1038/s41560-018-0202-4

Climate Analytics & NewClimate Institute. (2023). Climate Action Tracker – Countries: policies and action. Available at: https://climateactiontracker.org

Davide, M. & De Cian, E. (2023). ACTION – Assessing Climate TransItion OptioNs: policy vs impacts – project. CMCC, Economic analysis of Climate Impacts and Policy Division. Accessed at: https://www.cmcc.it/projects/action-assessing-climate-transition-options-policy-vs-impacts

De Santis, R., & Lasinio, C. J. (2015). Environmental Policies, Innovation and Productivity in the EU. LSE 'Europe in Question' Discussion Paper Series No. 100/2015

Dang, T. & Mourougane, A. (2014). Estimating Shadow Prices of Pollution in Selected OECD Countries. OECD Green Growth Papers No. 2014-02. OECD Publishing, Paris. https://doi.org/10.1787/5jxvd5rnjnxs-en

European Commission, Joint Research Centre., & Organisation for Economic Co-operation and Development. (2008). Handbook on constructing composite indicators: methodology and user guide. OECD Publishing, Paris. https://doi.org/10.1787/9789264043466-en

Finch, A. & van den Bergh, J. (2022). Assessing the authenticity of national carbon prices: A comparison of 31 countries. *Global Environmental Change*, *74*. https://doi.org/10.1016/j.gloenvcha.2022.102525

Freudenberg, M. (2003). Composite Indicators of Country Performance: A Critical Assessment. OECD Science, Technology and Industry Working Papers No. 2003/16 https://doi.org/10.1787/405566708255

Galeotti, M., Salini, S., & Verdolini, E. (2020). Measuring environmental policy stringency: Approaches, validity, and impact on environmental innovation and energy efficiency. *Energy Policy*, 136. https://doi.org/10.1016/j.enpol.2019.111052

Harring, N., Jönsson, E., Matti, S., Mundaca, G., & Jagers, S. C. (2023). Cross-national analysis of attitudes towards fossil fuel subsidy removal. *Nature Climate Change*, *13*(3), 244–249. https://doi.org/10.1038/s41558-023-01597-5

Horton, H. (2023) Fossil fuels received £20bn more UK support than renewables since 2015. *The Guardian*. Accessed at: https://www.theguardian.com/environment/2023/mar/09/fossil-fuels-more-support-uk-than-renewables-since-2015

IEA. (2011). IEA Guide to Reporting Energy RD&D Budget/Expenditure Statistics. Accessed at: https://iea.blob.core.windows.net/assets/3432ae79-1645-4cf1-a415-faa3588e6f29/RDDManual.pdf

IEA. (2020). Renewable Energy Act of Poland (Amended). International Energy Agency, Paris. Accessed at: https://www.iea.org/policies/5737-renewable-energy-act-of-poland-amended

IEA. (2022). Poland needs a stronger push to reduce emissions and ensure secure energy supplies, new IEA policy review says. Press release, International Energy Agency. Accessed at: https://www.iea.org/news/poland-needs-a-stronger-push-to-reduce-emissions-and-ensure-secure-energy-supplies-new-iea-policy-review-says

IEA. (2023a). Energy Technology RD&D Statistics. *OECD iLibrary*. Available at: https://doi.org/10.1787/enetech-data-en

IEA. (2023b). Energy Technology RD&D Budgets. Available at: https://www.iea.org/data-and-statistics/data-product/energy-technology-rd-and-d-budget-database-2

IEA. (2023c). Energy Technology RD&D Budgets, October 2023 Edition, Database documentation. Accessed at: https://iea.blob.core.windows.net/assets/03a20101-5d0d-466b-9c0f-e4d1e8ac024e/RDD_Documentation.pdf

IEA. (2023d). IEA Energy Policy Reviews. International Energy Agency, Paris. https://doi.org/10.1787/8550daed-en

IEA. (2023e). IEA 2023 Country profiles. International Energy Agency, Paris. Accessed at: https://www.iea.org/countries

Johnstone, N., Haščič, I., Poirier, J., Hemar, M., & Michel, C. (2012). Environmental policy stringency and technological innovation: Evidence from survey data and patent counts. *Applied Economics*, 44(17), 2157–2170. https://doi.org/10.1080/00036846.2011.560110

Koźluk, T., & Timiliotis, C. (2016). Do environmental policies affect global value chains? A new perspective on the pollution haven hypothesis. OECD Economics Department Working Papers No. 1282. OECD Publishing, Paris. https://doi.org/10.1787/5jm2hh7nf3wd-en

Kruse, T., Dechezleprêtre, A., Saffar, R., & Robert, L. (2022). Measuring environmental policy stringency in OECD countries: An update of the OECD composite EPS indicator. OECD Economics Department Working Papers No. 1703. https://doi.org/10.1787/90ab82e8-en

Linsenmeier, M., Mohommad, A., & Schwerhoff, G. (2022). Policy sequencing towards carbon pricing among the world's largest emitters. *Nature Climate Change*, 12(12), 1107–1110. https://doi.org/10.1038/s41558-022-01538-8

Nascimento, L., Kuramochi, T., Iacobuta, G., den Elzen, M., Fekete, H., Weishaupt, M., van Soest, H. L., Roelfsema, M., Vivero-Serrano, G. De, Lui, S., Hans, F., Jose de Villafranca Casas, M., & Höhne, N. (2022). Twenty years of climate policy: G20 coverage and gaps. *Climate Policy*, 22(2), 158–174. https://doi.org/10.1080/14693062.2021.1993776

New Climate Institute. (2023). Climate Policy Database. Available at: https://climatepolicydatabase.org

OECD. (2023). Environmental Policy Stringency Index. Available at: https://stats.oecd.org/Index.aspx?DataSetCode=EPS

OECD & IISD. (2023). Fossil Fuel Subsidy Tracker. Available at: https://fossilfuelsubsidytracker.org

Paid to pollute. (2023). The Case Against Public Money for Oil and Gas. Official website. Accessed at: https://paidtopollute.org.uk

Sauvage, J. (2014). The stringency of Environmental Regulations and Trade in Environmental Goods. OECD Trade and Environment Working Papers. No. 2014/03. https://doi.org/10.1787/5jxrjn7xsnmq-en

Schaub, S., Tosun, J., Jordan, A., & Enguer, J. (2022). Climate Policy Ambition: Exploring A Policy Density Perspective. *Politics and Governance*, 10(3). https://doi.org/10.17645/pag.v10i3.5347

Schwanitz, V. J., Piontek, F., Bertram, C., & Luderer, G. (2014). Long-term climate policy implications of phasing out fossil fuel subsidies. *Energy Policy*, 67, 882–894. https://doi.org/10.1016/j.enpol.2013.12.015

Skovgaard, J., Ferrari, S. S., & Knaggård, Å. (2019). Mapping and clustering the adoption of carbon pricing policies: what polities price carbon and why? *Climate Policy*, 19(9), 1173–1185. https://doi.org/10.1080/14693062.2019.1641460

The World Bank Group. (2023a). Carbon Pricing Dashboard. Available at: https://carbonpricingdashboard.worldbank.org/map_data

The World Bank Group. (2023b). Regulatory Indicators for Sustainable Energy. Accessed at: https://rise.esmap.org/indicators

The World Bank Group. (2023c). State and Trends of Carbon Pricing 2023. Open Knowledge Repository Beta. http://hdl.handle.net/10986/13334

UNFCCC. (2015). Adoption of the Paris Agreement, 21st Conference of the Parties. https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement

UNFCCC. (2023a). Why the Global Stocktake is Important for Climate Action this Decade. UNFCCC official website. Accessed at: https://unfccc.int/topics/global-stocktake/about-the-global-stocktake/why-the-global-stocktake-is-important-for-climate-action-this-decade#What-happens-next

UNFCCC. (2023b) Outcome of the first global stocktake. Draft decision -/CMA.5. Proposal by the President. Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (CMA). https://unfccc.int/documents/636608

Wang, Z., Yen-Ku, K., Li, Z., An, N. B., & Abdul-Samad, Z. (2022). The transition of renewable energy and ecological sustainability through environmental policy stringency: Estimations from advance panel estimators. *Renewable Energy*, 188, 70–80. https://doi.org/10.1016/j.renene.2022.01.075