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Energy Efficiency and Institutional Quality. The Role of Renewable Energies

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Abstract

Energy efficiency and renewable energy systems have been a major concern of energy policy mainly due to resource scarcity and climate change issues. However, the successful deployment of energy efficiency and renewable energy systems can be compromised by institutions and governance performance. While the influence of institutions on these issues is well-documented in the literature, the absence of an index of energy efficiency governance has prevented testing the relationship between energy governance and the improvements of energy efficiency and renewable energy.

This work contributes to fill this gap and proposes the construction of an index that captures the institutional, economic and political environment underpinning energy efficiency governance across three different areas: enabling frameworks, institutional arrangements and co-ordination mechanisms. The index assesses 32 OECD countries and represents the period between 2000 and 2015. The existence of this index enables both the establishment of a country ranking about energy efficiency governance and the characterization of the sample of countries in three groups. While countries such as Denmark, Germany or Spain compound the top group, others such as Mexico, Slovenia or, surprisingly, Switzerland are included within the bottom group. On average, the ranking is shown to be positively correlated with economic development and general governance. Finally, this work illustrates the positive correlation between energy efficiency governance and both the long-run energy intensity growth and changes in the share of renewable energy.

Acronyms and abbreviations

EE	Energy Efficiency
EEGI	Energy Efficiency Governance Index
EI	Energy Intensity
EU	European Union
GDP	Gross Domestic Product
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
MPES	Minimum Performance Efficiency Standards
OECD	Organization for Economic Co-operation and Development
PCA	Principal Components Analysis
REN21	Renewable Energy Policy Network for the 21st Century
RES	Renewable Energy Systems
TPES	Total Primary Energy Supply
TPRES	Total Primary Renewable Energy Share
USD	United States Dollars
WEC	World Energy Council
WGI	World Governance Indicator

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1. Introduction

Improvements in Energy Efficiency (EE) emerge as the main alternative to cope with climate change mitigation and energy security in many countries [1]. Furthermore, in nations faced with low economic growth and high unemployment, EE is considered as the best strategy to improve the competitiveness of industry, by reducing energy cost and stimulating economic growth and job creation through the investment generated [2].

Nevertheless, implementing EE successfully is a complex task compromised by features such as regulation failures, lack of co-ordination and corruption, among others. In general, these aspects are closely related to the role of institutions and governance in implementing EE policies. Institutions and governance are similar concepts but with different implications: the former is referred to rules that support social interactions, while the latter is more related to the capability of generating rules to achieve a particular objective.

Since a wide set of indicators about democracy, corruption or governmental effectiveness is available, the impact of general institutions and overall governance in the economy are widely studied in the literature [3] [4] [5] [6]. However, the relationship between EE performance, RES deployment and institutions have been assessed in a reduced number of papers [7] [8] [9]. Moreover, the specific concept of EE governance is a recent concern described for the first time by the International Energy Agency (IEA) in [10]. In this report, three main EE governance areas have been identified: enabling frameworks, institutional arrangements and co-ordination mechanisms. Despite the existence of descriptive studies based on EE governance [2] [10], there is no available –to the best of our knowledge– any indicator reflecting EE governance performance.

In addition, further research has revealed that the contribution of Renewable Energy Systems (RES) to the improvements in EE has been broadly unnoticed in a remarkable number of studies. Nevertheless, according to the literature, there are synergies between EE and RES targets [11] [12] [13] [14]. Thus, seeking some coordination between the respective targets and instruments for EE improvements and RES deployment, taking into account their interaction, is essential for energy policy development. Otherwise, the joint implementation of EE and RES can imply a conflictive interaction which hinders the achievement of both kind of targets [15].

This work is the first to construct a composite index that captures the performance of EE governance between 2000 and 2015 for 32 OECD countries across the three different areas identified by IEA: enabling frameworks, institutional arrangements and co-ordination mechanisms. The Energy Efficiency Governance Index (EEGI) breaks new ground, since indices about EE governance are not available and can be used to assess the influence of institutions and governance on EE outcomes. Secondly, EEGI is correlated with EE and RES to examine the role of EE governance in the deployment of both issues. In this work, the final

Energy Intensity (EI) is the proxy used to assess the EE performance, while the primary share of renewable energies is used as a proxy to measure the level of deployment of RES. [1]

Countries such as Denmark, Germany, France or Spain account the highest EEGI scores due mainly to a profusely developed enabling frameworks area. The case of Denmark deserves a special mention, since this country has reduced notably its EI, it accounts the highest increase in RES and the highest EEGI score, and also one of the highest scores in general governance. Conversely, Estonia, Slovenia, Mexico or Switzerland have obtained the worst EEGI scores. Moreover, on average, the ranking is shown to be positively correlated with economic development and general governance. In addition, EE performance and RES deployment are also positively correlated with EEGI.

The remainder of the work proceeds as follows. The theoretical framework that supports the concept of EE governance and the construction of EEGI is described in Section 2. Then, in Section 3, the procedure for the construction of the composite index is detailed. Section 4 presents the EEGI scores for the sample of countries and the statistical relationship of these results with other common indicators (such as economic development and general governance quality), which can explain EEGI scores. The Section 4 also describes the robustness assessment for the EEGI. In Section 5, EEGI is correlated with EE and RES. Finally, Section 6 draws main conclusions and presents potential future research.

[1] The final EI is the ratio between the final energy consumption in the industry, transport, residential, services and agriculture sectors and the Gross Domestic Product (GDP) of a country. This indicator is widely used in the literature to estimate the EE outcomes by means of a set of variables, among which can be included several issues related to institutional and general governance. However, the effectiveness of this indicator is limited and subjected to discussion, since changes in energy intensity can be caused by factors other than EE, such as structural changes in the economy. Despite this fact, it is used due to both the lack of an internationally agreed-upon indicator for measuring EE and because changes in EE are reflected, obviously, in the resulting EI [14].

2. Theoretical framework

Energy efficiency forms an essential part of climate policies and is a smart way of reducing the depletion of natural resources. However, the efficient use of energy is a task seriously compromised by the presence of numerous failures which affect both demand and supply sides energy markets [3] [4]. Thus, the correct improvement in EE requires a combination of government policies, which evidences the importance of governance and institutions [9].

Governance and institutions are independent concepts but they are closely related to each other. Institutions can be defined as "systems of stablished and prevalent social rules that structure social interactions" [16]. Language, money, law and systems of measures are examples of institutions. On the other hand, governance is the ability of an administration to generate rules and enforce them in order to achieve particular objectives [17]. The connection between institutions and governance is a two-way causality, since institutions can damage the objectives of policies and, thus, the objectives of governance; and policies (governance) can modify the structure of institutions [9].

A broad number of studies have focused their attention on institutions and general governance and their influence on a wide range of political and economic issues [18] [19] [20] [21]. In [22], the achievement of policy objectives and well-functioning of institutions is assessed. A revision of the main potential market failures and policies to cope with them can be found in [3] and [4]. The influence of institutions on general governance is described in [5] and [6]. As mentioned in Section 1, the wide literature on this issue has enabled the development of a set of indicators reflecting general institutional and governance features. These indicators are available from distinct statistical sources: the World Governance Index, from the Forum for a new World Governance; the World Governance Indicators from the World Bank; and the Polity IV Project, from the Center for Systemic Peace, among others.

In the vein of energy, there is a certain number of papers in which the relationship between institutions and both EE performance and RES deployment is assessed, although in a more reduced number than in the case of political and economic issues. A proper institutional framework for EE implementation is described in [7] and [8]. In [23], the linkage between institutions and RES is stablished through the influence of rent-seeking and corruption on the creation of markets for clean technologies. Finally, [9] represents a first step to characterize empirically the influence of institutional issues on EE performance using the final EI as a proxy for this purpose.

The remainder of this section proceeds as follows. First, the EE governance concept and its main components are described according to the report published by IEA and mentioned in the preceding section [10]. This document provides the theoretical framework for the EEGI constructed in this work. Second, the role of RES in implementing and improving EE is also studied.

2.1. Energy Efficiency Governance

Unlike institutions and general governance, EE governance is a youthful concern and the literature on this issue is rather scarce. IEA states that EE governance is "the combination of the institutional and co-ordination arrangements needed to scale-up EE, added to the legislative frameworks and funding mechanisms, which works to support the implementation of EE strategies, policies and programmes". EE governance is a complex and critical part of the EE delivery system. In fact, actions to improve EE have failed to deliver their full potential, in part, because of limited attention to EE governance arrangements [10].

In [10] IEA identifies three main EE governance areas: enabling frameworks, institutional arrangements and co-ordination mechanisms. Likewise, each of these areas are composed of several indicators (see Figure 1***)***. Despite the existence of this extensive theoretical framework, indicators that reflect EE governance are lacked by researchers in the field of energy economics, due to both the youthfulness of this concern and the difficulty to construct an index that reflects the context of each country homogeneously. The index proposed in this work draws on the information collected in [10] to construct a comprehensive EEGI that complements institutional and general governance indicators in their role of assessing EE performance.

Enabling frameworks. This is the basic building block of EE governance. It literally enables EE policies and programs to be implemented by providing a basis in law, an overarching strategy linked to national development objectives and the resources needed for governmental action [10]. This area is composed of three indicators:

- Laws and decrees. They state the overall objectives for EE, as well as policies for achieving these objectives. It includes building codes, Minimum Performance Efficiency Standards (MPES) and the establishment of funding mechanisms, among others.
- Strategies and action plans. They can help guide and encourage EE policy development and implementation. They should prioritize resource allocation, capture synergies between policies and ensure strategies reflect country context and sectorial issues.
- Funding mechanisms. They should consist on a steady and reliable source of funding, since they are a critical aspect for good EE governance.

Institutional arrangements: They provide the practical instruments by which EE policy is formulated and implemented. They include both the political economy of EE governance as well as the creation of practical instruments, e.g., implementing agencies for EE deployment [10]. Six indicators compound this area:

- EE agencies. They have proliferated for years despite the fact that they require an administrative structure capable of conducting tasks such as economic and policy analysis, planning, management and evaluation. A proper statutory basis confers, according to IEA, advantage for an EE agency. A wide variety of organisational models can be found.
- Resourcing requirements. They are attempts to estimate and compare EE financial and human resources.

- The role of energy providers. They have some distinct advantages as EE implementers, since they have ready access to capital, market data and existing relationships with end users.
- Stakeholder engagement. It is considered as the main promoter for political consensus.
- Public-private sector co-operation. This is indispensable in order to ensure that policies take full advantage of the resources and commercial acumen of the private sector.
- International development assistance. That plays an important role in assuring good EE governance practices, since enables the establishment of frameworks, institutional arrangements and co-ordination mechanisms.

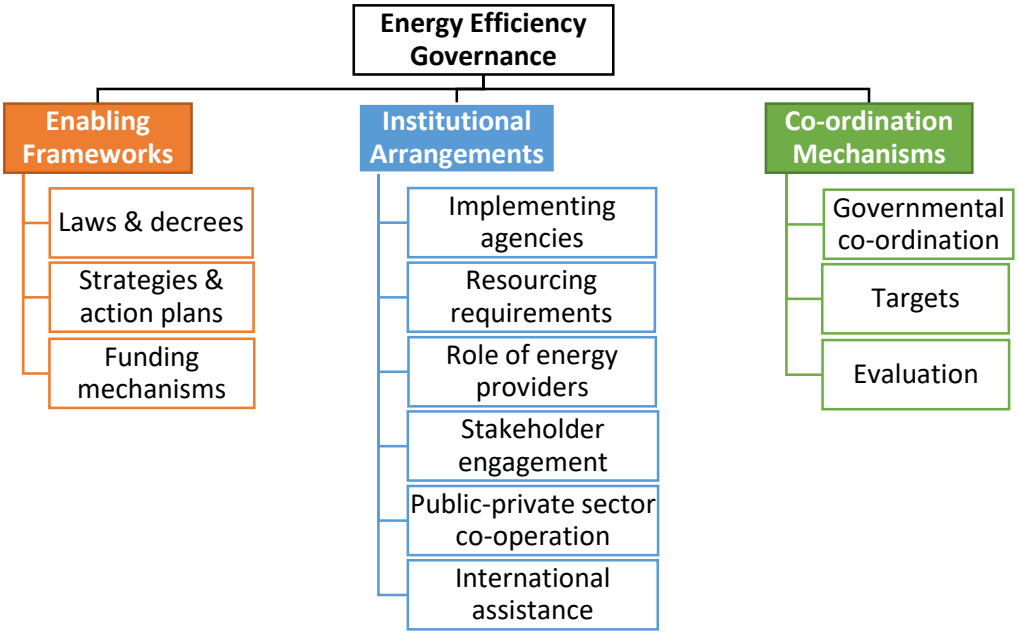

Figure 1. Key areas for EE governance.

Co-ordinations mechanisms: The final aspect of EE governance addresses the need to co-ordinate policy and programme implementation and to monitor results. This area is composed of three indicators:

- Governmental co-ordination. That is referred to the effective co-ordination across levels of government. In general, two levels of co-ordination are identified: intra-governmental (or horizontal) and inter-governmental (or vertical).
- Targets. They are specific policy or programme objectives that can be expressed quantitatively.

- Evaluation. This is considered the assessment of the outcomes of a policy or measure and of the inputs required to generate such outcomes.

Furthermore, the World Energy Council (WEC) has also published a similar report [2] in which EE implementation is studied. The aim of this report is to examine EE trends and policies at global level, rather than establishing a theoretical framework that support the EE governance concept. However, this report also provides some key issues for good EE governance practices.

In summary, the reports from IEA and WEC conclude that it is not possible to define unequivocally valid mechanisms and strategies which define good EE governance practices to any country. It means that EE governance should be adapted to the context of each country, including features such as economic development, energy dependence, and even institutions structure. This idea reinforce the previous two-way relationship stablished in this work between institutions and governance. For instance, funding mechanisms cannot achieve their objective if institutions are impregnated with corruption and bad practices. At the same time, the presence of abundant funding mechanisms can modify the structure of institutions.

2.2. Role of renewable energy systems

The reports and papers mentioned previously are focused on the extent to which EE performance can be affected by institutions and governance, but the role of RES in implementing and improving EE has been broadly overlooked. According to the International Renewable Energy Agency (IRENA) [11], scarce is the research that addresses aspects of the synergies between EE and RES.

In its Green Paper issued in March 2013, the European Commission declared that higher levels of EE could help to attain the European Union's (EU) renewable energy targets. Indeed, in [13] IRENA states that EE solutions together with RES can boost the global share for renewable to 30% by 2030 in the Total Primary Energy Supply (TPES), while without this combination the share would rise just to 21% by the same year. The main reason is that, unlike fossil-fuel generation, high thermal losses are not present in RES, enabling decreases in the primary energy demand (i.e., the EI is reduced and thus, the EE increases). A profuse discussion about the synergies between RES and EE in different dimensions (such as time, economic and geographic) is presented in [12]. This kind of synergies could also enable improvements to other technologies and sectors such as electric vehicles, heat pumps, buildings or industry, among others. In all cases the efficiency obtained is much higher when RES and EE are implemented together, enabling additional EI reductions [11] [14].

On the other hand, [15] states the urgent need of co-ordinating EE and RES policies. Otherwise, the joint implementation of EE and RES can imply a conflictive interaction which hinders the achievement of both kind of targets. For instance, improvements in EE reduce the overall energy demand and, thus, the demand for new RES capacity as well, limiting the increase in the share of RES in total final energy consumption.

To finish, the foremost common conclusion of these studies is that the set of synergies mentioned above can build political consensus and reinforce the authority to implement EE policies, since they can alleviate regional differences across countries. Therefore, the role of RES is crucial to develop good EE governance practices. In this work, the role of the RES is taken into account through the Total Primary Renewable Energy Share (TPRES), which is calculated as the ratio between the primary renewable energy supply and TPES, both measured in the same units. TPRES enables the assessment of the influence of RES penetration on implementing and improving EE.

3. Experimental: Energy Efficiency Governance Index (EEGI)

Composite indices have proved to be a useful tool in policy analysis. They provide valuable information of complex aspects and enable straightforward comparisons of countries and issues in wide-ranging fields: economy, society and development [24]. The construction of a composite index involves assumptions which have to be assessed carefully to avoid a lack of rigour in the results. The importance of establishing and developing a theoretical framework, the correct variable selection, a proper weighting and aggregation and, finally, the necessity of a robustness analysis are stated in [24]. Based on these recommendations, the composition of an index which assesses the public investment efficiency across four indicators can be found in [25]. In this work, the EEGI construction procedure is based on [24] and [25], and supported by the theoretical framework and the variable selection established by IEA in [10] and commented in the previous section. The baseline aggregation and weighting method is described below, while a robustness assessment of these aspects is carried out in Sub-section 4.4.

3.1. Primary data

The construction of the index relies upon an extensive data collection effort. Data were compiled from a large number of sources, including IEA, WEC, REN21, IRENA and Ecofys. The EE policy and measures databases from IEA has provided the most important information about EE policies, laws, strategies, institutional arrangements and targets across the set of countries between 2000 and 2015. The information obtained from IEA has been tested and complemented with information about policies for the same period of time from WEC, IRENA and REN21. This information is qualitative in nature.

Regarding the funding mechanisms indicator, [10] states the complexity in determining the spending on EE, since it is difficult to separate out this expenditure from other spending and also few attempts have been made to estimate EE investment. Fortunately, Ecofys provides reliable and homogeneous economic figures for EE spending, but only for a sample of 18 European countries.

3.2. Construction of the index

Under the three areas described in Section 2 –enabling frameworks, institutional arrangements and co-ordination mechanisms, EEGI should capture the meaningful information provided by all the individual indicators for each country in the sample. The corresponding indicators are aggregated into three sub-indices, one for each EE governance area, which are then aggregated into an overall EEGI.

Due to the qualitative nature of the information, questions are used for each indicator with the aim of scoring in a scale between 0 and 4 [25], with a higher score reflecting better EE

governance. In answering the questions, which are described and collected in Appendix I, it is inevitable that some degree of judgment is exercised. To minimize the degree of discretion, a set of coding rules is used, which is also described in Appendix I. Depending on the nature of the available information (quantity, deepness, availability and reliability), the score is re-scaled to maintain the range 0–4 [25].

Despite the fact that IEA describes 12 individual indicators, all of them are not considered. On the one hand, a basic EEGI assesses 32 OECD members (Israel and Iceland have been excluded due to the lack of information) and takes into account 8 indicators. On the other hand, an extended EEGI assesses 18 European countries across 9 indicators (see Table 1 and Figure 2***)***. The extended EEGI includes the funding mechanisms indicator –belonging to the enabling frameworks area– using the economic figures provided by Ecofys. Unfortunately, this information is not available for the complete set of countries assessed by the basic EEGI.

Some aspects of the score method are described below. For further information, see Appendix I. Regarding the **enabling frameworks** area, EEGI assesses this dimension by means of its three individual indicators:

- EE laws and decrees. EEGI analyses whether broad regulation is available. The minimum score is assigned if any regulation has been found, while the maximum score is assigned whether the regulation is extremely abundant –according to the rest of countries– and dedicated to several important sectors (transport and buildings, among others). [2]
- EE strategies and action plans. The existence of abundant strategies and action plans is examined, focusing specifically on the quantification of the targets and the estimation of the costs. The maximum score is for those countries that account with abundant strategies and plans –according to the number of plans and strategies in the rest of countries– with costs estimated and targets defined. [3]
- EE Funding mechanisms. Due to the lack of homogeneous information, this criterion has been assessed only for a reduced set of countries, constructing the extended EEGI. For those countries, the index assesses the ratio between EE spending and GDP, assigning the maximum score to the countries with the highest ratio and the minimum score to those countries with null spending on EE. Using this ratio and not the total EE spending enables both the evaluation of EE spending and the prevention of excessive quantitative differences inherent to GDP variations across countries.

Only four indicators of the **Institutional arrangements** area are assessed:

- Implementing agencies. EEGI assesses both if energy agencies take part actively into EE policies deployment and whether EE agencies are supported by a proper legal basis. The number of plans and programs promoted by the EE agency is used as a proxy for the

[2] For instance, in the case of Italy, the score of the laws and decrees indicator is 4, since more than 80 legal references that take into account EE issues have been found covering all the main sectors (residential, industry, buildings, transport, lighting, energy utilities, commercial/industrial equipment). Conversely, in the case of Mexico, the score for the same indicator is 0.8, since only two legal reference dedicated to EE have been found.

[3] Germany, Denmark and The United Kingdom are examples of countries with the maximum score for the strategies and action plans indicator. For instance, The United Kingdom account with 19 strategies and action plans and 15 of them have targets set and/or costs estimated.

activity of the agency, while the number of legal references which support the EE agency activity is used to examine the legal basis. Then, the higher activity and the more developed legal basis, the higher resulting score. There are other interesting issues, e.g. the organisational model for the EE agency (government agency, independent statutory authority and independent corporation, among others). However, each organisational type has advantages and drawbacks and there is no evidence that any one is always preferable, since the choice of organisational types should reflect historical development, country context, EE objectives and many other factors [8]. Hence, EEGI just considers the existence of a proper legal basis and the extent to which the EE agency promotes plans and programmes.

- Role of energy providers in implementing EE. EEGI assesses whether the energy providers play a null, discreet, or conversely, significant role implementing policies and programmes based on EE. Thus, the maximum score is for those countries in which the number of EE plans and programmes promoted directly by energy providers is the highest, while the minimum score if for countries in which there is no actions or programmes promoted by energy providers. [4]
- Stakeholder engagement. EEGI analyses if there are plans or programmes that instigate the engagement of the stakeholders and also if these programs enable a close co-operation between the counterparts by means of councils, committees or organs intended for that purpose. Thus, the highest score is for those countries that account with the highest number of plans and programmes involving stakeholders through well-established committees, councils or working groups.
- Public-private sector co-operation. The existence of plans or programmes that promotes public-private sector co-operation is assessed. Moreover, it is also considered whether the effort is focused on voluntary agreements, public-private partnerships, energy service companies and regulating end-use equipment. Therefore, a higher number of plans promoting public-private sector co-operation in a wide variety of aspects implies a higher resulting score. [5]

Regarding resourcing requirements, as IEA states, few attempts have been made to estimate EE resourcing requirements and the attempts carried out do not yet provide the level of detail or comparability needed to serve such purposes. Thus, this indicator is not examined by the EEGI.

On the other hand, taking into consideration the international development assistance implies to consider any donor and national or international organization that promotes EE investment. According to the available information, overall in those countries with medium or low incomes in which EE awareness is a recent issue, it would not be possible to define and homogeneous scale to assess the sample due to the lack of data. In addition, even in countries in which data are properly collected and organised, it would not be an easy task to

[4] Canada is the only country that accounts the maximum score in the role of energy providers indicator. Up to 58 programmes that involve energy providers have been found, and more than 10 are directly promoted by the energy providers.
[5] The United States has obtained the highest score in the public-private sector co-operation indicator, since more than 51 plans promoting this co-operation have been found.

identify completely all the organizations that provide EE assistance, since some of them do not appear in the available database and others belong to different countries, hindering the search and location of the data. Consequently, this indicator is not taken into consideration during the construction of EEGI.

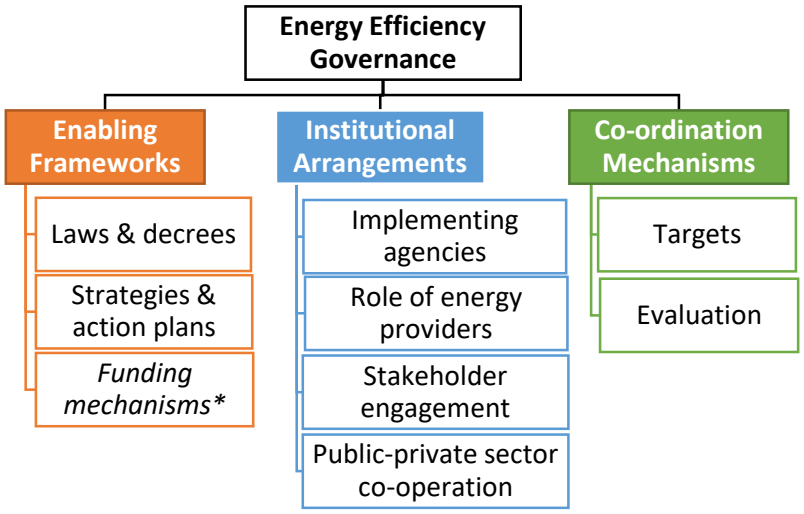

Figure 2. Key indicators assessed by EEGI. * *Only in the extended EEGI*

To finish, EEGI examines two indicators of the **co-ordination mechanisms** area:

- Targets. Since EEGI takes into account whether goals are set and quantified when strategies and action plans are assessed, it makes no sense that the index analyses again if targets are quantified. To avoid this redundancy, EEGI examines the period in which targets have to be achieved: the score is worse as the period of time is longer. This is based on the assumption that the longer period of time to achieve a target, the easier to explain a slow improvement at the beginning [10]. However, EEGI also assesses whether long-term targets have foreseen intermediate evaluation in order not to underestimate their potential. On the other hand, targets require a strong analytic basis to be set realistically or they could be abused, giving a false impression of government action. Nevertheless, according to the available information, there are no methods to estimate the depth of this analytical basis so this aspect is not considered by the index.
- Evaluation. EEGI assesses the number of evaluation or monitoring protocols according to the amount of plans and strategies found. Then, the maximum score is for those countries that account with evaluation mechanisms in the most of plans, while the minimum score is for countries in which evaluation mechanisms have not been found.

IEA also includes government co-ordination mechanisms as the third indicator of the area co-ordination mechanisms. These co-ordination types cannot be identified according to the available information, since that not include regional and provincial regulation. It would require to survey different experts in the subject, and it goes beyond the scope of this work.

Basic EEGI	Extended EEGI
Australia	-
Austria	Austria
Belgium	Belgium
Canada	-
Chile	-
Czech Republic	Czech Republic
Denmark	-
Estonia	-
Finland	Finland
France	France
Germany	Germany
Greece	Greece
Hungary	Hungary
Ireland	Ireland
Italy	Italy
Japan	-
Korea	-
Luxembourg	-
Mexico	-
Netherlands	Netherlands
New Zealand	-
Norway	-
Poland	Poland
Portugal	Portugal
Slovakia	Slovakia
Slovenia	Slovenia
Spain	Spain
Sweden	-
Switzerland	-
Turkey	Turkey
United Kingdom	United Kingdom
United States of America	-

Table 1. Countries assessed under each release of EEGI**.** ***Basic EEGI****: Takes into consideration eight indicators, excluding from the assessment: funding mechanisms, resourcing requirements, international development assistance and government co-ordination.* ***Extended EEGI****: It is constructed taking into account the same indicators considered under the basic EEGI, but adding the funding mechanisms indicator to the assessment for a limited sample of countries.*

3.3. Weighting and aggregation

Appropriate weighting of indicators into sub-indices, and subsequently into an aggregate index, is a crucial issue in the composite index construction. Most composite indicators rely on equal weighting, which implies that all variables are given the same weight [24]. This rule

is followed in the baseline index construction. Thus, the three sub-indices are constructed using a simple arithmetic mean. For instance, the enabling frameworks sub-index for the extended EEGI is the average of its three indicators terms (laws and decrees, strategies and action plans and funding mechanisms). In the case of the basic EEGI, that is the average of two indicators (laws and decrees and strategies and action plans). Then, the EEGI overall index is derived as an average of the three sub-index. According to [24] and [25], the advantage of arithmetic averaging is that it is straightforward and transparent. In addition, the absence of strong priors over the weights of indicators in each of the sub-indices makes simple averaging the natural benchmark candidate in the literature [26].

The robustness of EEGI and its aggregation method is assessed in Sub-section 4.4. As discussed below, the rank correlations between different approach are high and significant, suggesting that the additive aggregation procedure used for the construction of the overall index is robust.

To conclude this section, due to the lack of information to assess some indicators, the compilation of the index should be seen as a first attempt to amass comparative information of interest on EE governance. As such, it should be viewed as a helpful starting point for identifying broad trends and providing an approximation of EE governance rather than a substitute for in-depth policy analysis and diagnostics [25].

4. EEGI scores and country rankings

In this section, the EEGI score of each country is presented. The description provided below is focused on the overall index and the three sub-indices. Furthermore, this section describes the relationship between EEGI and other variables that enable the understanding of EEGI scores, such as economic development and general governance quality. Finally, the robustness assessment for the index construction procedure is also carried out in the present section.

4.1. Overall scores and ranking

The advantage of reporting scores is that they provide a metric for assessing country performances and the requirements to report a ranking.

Figure 3 illustrates the overall scores and the contribution of the three sub-indices to the basic EEGI, while Figure 4 presents those results for the extended EEGI. The introduction of the funding mechanisms indicator into the extended EEGI changes country scores slightly. Moreover, the relative position between the countries that are assessed in both samples is almost identical, with a Spearman rank correlation of 0.97. [6] Thus, in this work only the results relative to the basic EEGI are analysed, since the information provided is equivalent to that provided by the extended EEGI, while the set of countries is notoriously wider.

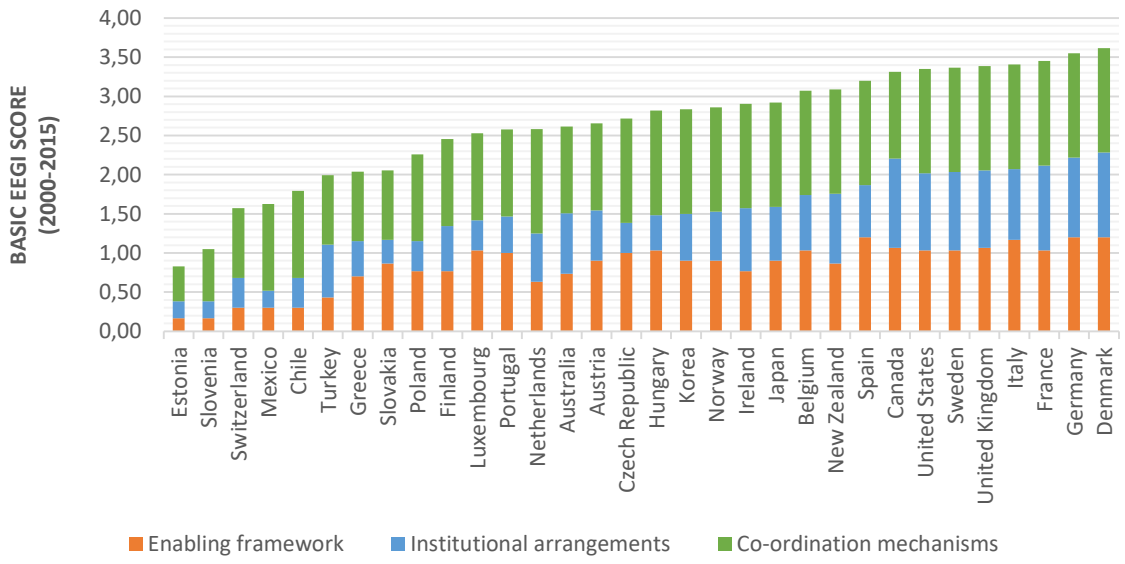

Figure 3. Overall basic EEGI and decomposition by sub-index.

[6] The Spearman rank correlation is a measure of statistical dependence between the ranking of two variables. It assesses how well the relationship between two variables can be described using a monotonic function. The Spearman rank coefficient ranges from a correlation of -1 for fully opposed rankings to +1 for identical rankings.

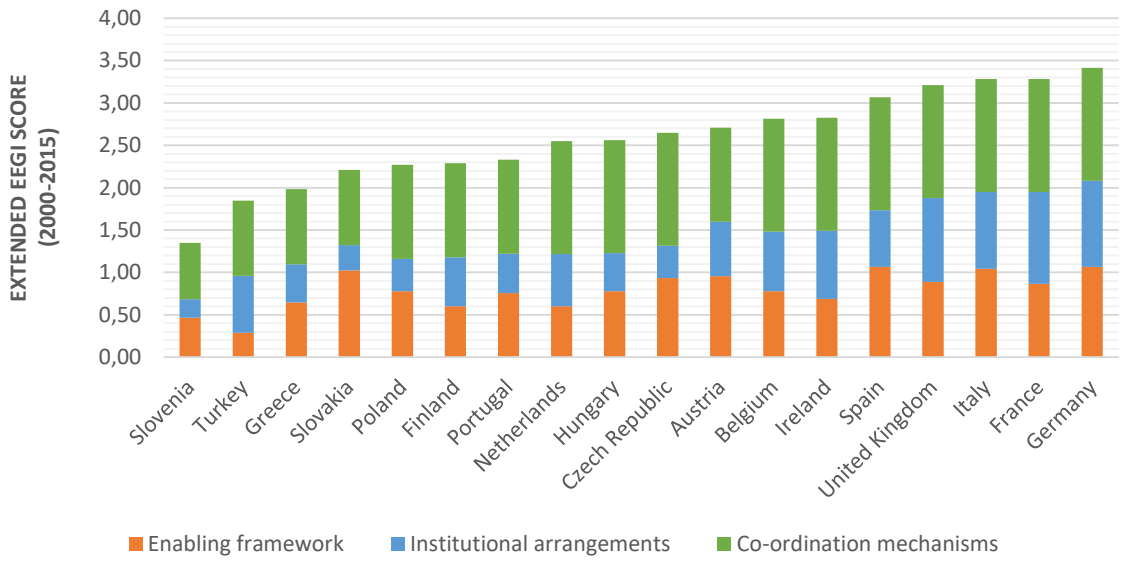

Figure 4. Overall extended EEGI and decomposition by sub-index.

Table 2 reports scores and rankings for both set of countries. As mention above, there is a high degree of correlation between the ranks for the basic and the extended EEGI. In these results, the mean overall index score for this sample is 2.64, while the standard deviation is 0.72, highlighting a large variation in the index score across countries. The country sample has been divided in three groups. The top group collects countries with EEGI scores higher than 3.0, while the bottom group accounts with EEGI scores very close to 2.0 and lower than this. The intermediate group collects the rest of countries, whose scores range from very close to 2.5 up to 3.0. Except from some particular cases which are commented in Sub-section 4.3, these EEGI scores enable the establishment of a certain relationship between EE governance performance and both the economic development and the general governance quality.

4.2. Energy efficiency governance, economic development and general governance

Economic development and general governance quality enable the partially understanding of the EEGI scores obtained above. The economic development is assessed through the real GDP per capita. Economic figures have been provided by IEA in USD of the year 2000. To confer consistency along the time to the proposed EEGI, the GDP per capita has been calculated as an average from 1995 to 2005 (expressed in a logarithmic scale). [7]

[7] The most proper period of time to calculate the average real GDP per capita is that which matches with the period of time assessed by EEGI (2000-2015). However, the influence of the economic crisis on years after 2005 could distort the results. In addition, the fact that EEGI is focused on years after 2000 is not relevant since, according to [25], most institutional processes are time-invariant. Due to these reasons, the average real GDP per capita is calculated between 1995 and 2005.

Group	Country	Code	Basic overall EEGI		Extended overall EEGI	
			Score	Rank	Score	Rank
Top group	Denmark	DNK	3,62	1		
	Germany	DEU	3,55	2	3,42	1
	France	FRA	3,45	3	3,28	2
	Italy	ITA	3,41	4	3,28	2
	United Kingdom	GBR	3,39	5	3,21	3
	Sweden	SWE	3,37	6		
	United States	USA	3,35	7		
	Canada	CAN	3,32	8		
	Spain	ESP	3,20	9	3,07	4
	New Zealand	NZL	3,09	10		
	Belgium	BEL	3,07	11	2,82	6
Medium group	Japan	JPN	2,92	12		
	Ireland	IRL	2,91	13	2,83	5
	Norway	NOR	2,86	14		
	Korea	KOR	2,83	15		
	Hungary	HUN	2,82	16	2,56	9
	Czech Republic	CZE	2,72	17	2,65	8
	Austria	AUT	2,65	18	2,71	7
	Australia	AUS	2,62	19		
	Netherlands	NLD	2,58	20	2,55	10
	Portugal	PRT	2,58	20	2,33	11
	Luxembourg	LUX	2,53	21		
	Finland	FIN	2,45	22	2,29	12
Bottom group	Poland	POL	2,26	23	2,27	13
	Slovakia	SVK	2,06	24	2,21	14
	Greece	GRC	2,04	25	1,98	15
	Turkey	TUR	1,99	26	1,85	16
	Chile	CHL	1,79	27		
	Mexico	MEX	1,63	28		
	Switzerland	CHE	1,57	29		
	Slovenia	SVN	1,05	30	1,35	17
	Estonia	EST	0,83	31		

Table 2. Country scores and rankings for the basic and the extended EEGI**.** *The basic EEGI and the extended EEGI are constructed under the same procedure, but the extended EEGI considers an additional indicator, the funding mechanisms indicator.*

Figure 5 illustrates a clear positive correlation between EEGI score (i.e., EE governance performance) and the average real GDP per capita (i.e., economic development). However, more information is clearly needed to explain the EEGI scores beyond this variable, since R^2

takes a relatively low value. [8] Despite this fact, it validates the assumption that countries with high economic development account, on average, with a high EEGI score, and vice versa.

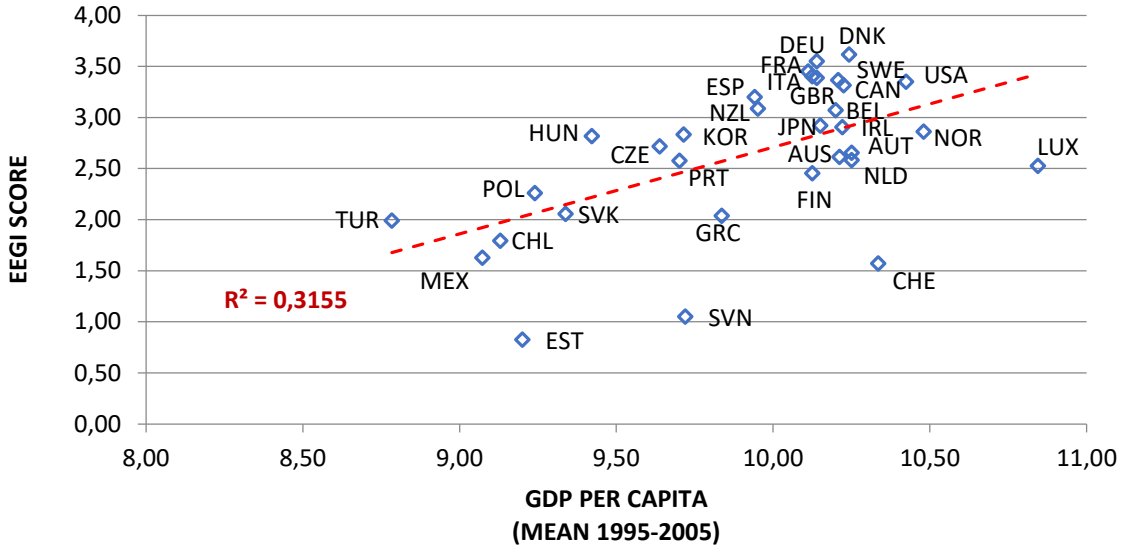

Figure 5. EEGI versus economic development.

According to their economic development, countries such as Belgium, Canada, United States, Sweden or Denmark occupy an expected place in the top group. Others such as Finland, Portugal, Czech Republic, Hungary, Korea and Japan are placed in expected positions within the medium group. For instance, Japan is the closest country to the top group, while Portugal is close to the bottom of the medium group. Lastly, Estonia, Slovenia, Mexico, Chile and Slovakia are countries expected to be placed in the bottom group.

However, it is worth mentioning that countries such as Luxembourg, Switzerland, Netherlands, Australia, Austria and Norway should be placed in a higher position within the top group according to their economic development (i.e., their EEGI score is lower than expected), while France, Germany, Italy or Spain are countries expected to be close to the top group but in a lower position, within the medium group (i.e., their EEGI score is higher than expected). The possible source for this exceptions is commented in the next sub-section.

According to the EEGI scores, it is also possible that the EE governance performance is related to the general governance quality. This comparison has been performed through the six World Governance Indicators, from the World Bank, which have been aggregated through an arithmetic mean to construct an overall World Governance Indicator (WGI). It is used as a proxy that reflects the features of general governance from 2000 to 2014 –the last

[8] R^2 indicates the proportion of the variance in the dependent variable (i.e., EEGI) that is predictable from the independent variable (i.e., economic development). R^2 ranges from 0 to 1, with 1 indicating that the regression line perfectly fits the data.

year with available information, in order to be consistent with period of time assessed by the EEGI.

Figure 6 presents the relationship between WGI (i.e., general governance quality) and EEGI score (i.e., EE governance performance). Matching with the preceding case, there is a positive correlation between EEGI and general governance which implies that the higher general governance quality, the higher EEGI score. However, further research is needed in order to understand the correlation and the resulting R^2, since this parameter is lower than in the preceding case and its value does not improve although the components of the WGI are taken individually (these latter results are available upon request).

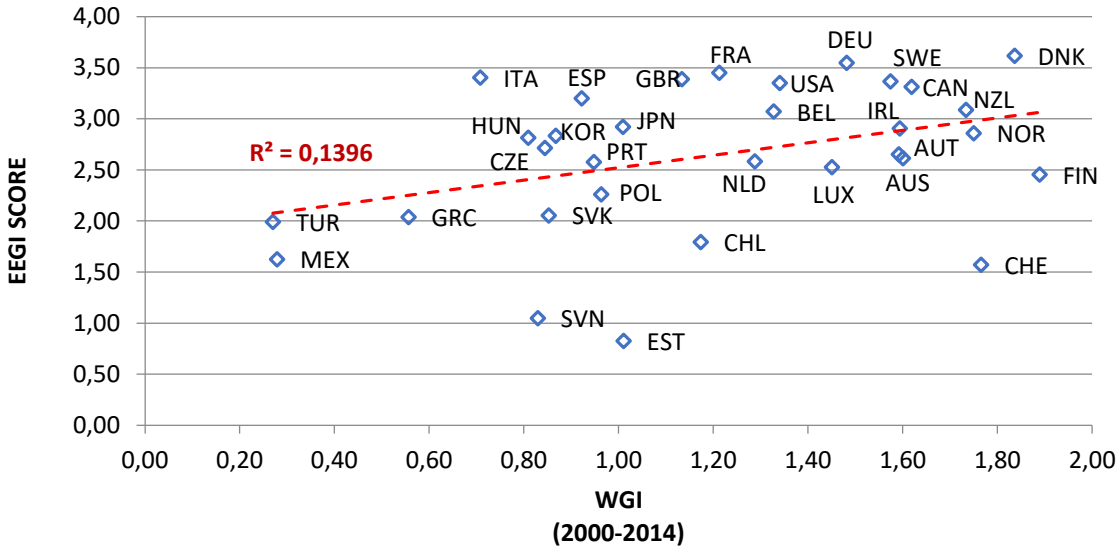

Figure 6. EEGI versus WGI.

There are some interesting matches with the previous assessment. For instance, Switzerland and Luxembourg occupy a significantly worse place than the expected according to their level of general governance quality. In the same vein, the EEGI scores for Estonia and Slovenia are lower than the predictable for countries with a similar general governance quality. On the contrary, consistently with the assessment between EEGI and economic development, countries such as Spain, France, Germany or Italy account higher EEGI scores than the average tendency. As mention above, these exceptions are commented in the next sub-section but it can be anticipated that the legal basis stablished in each country for EE plays a crucial role.

Despite the scope of this work is limited to the construction of EEGI and data availability, the positive correlation between EEGI (i.e., EE governance performance), economic development and general governance quality, and overall, the matches between countries in

both assessments, suggests that these variables are intrinsically related, although further research is needed in order to stablish a model that explains properly these relationships.

4.3. Scores and ranking based on the sub-indices

Unlike the overall EEGI, there is no notable variation within each sub-index. This suggest that the observed differences in EE governance performance across countries do not stem from the cross-country heterogeneity across the three sub-indices, but from the heterogeneity across the indicators.

The score and ranking for the basic EEGI by sub-index is reported in Table 3.The foremost feature is that the co-ordination mechanisms sub-index takes the same result in a wide range of countries. From a descriptive perspective, it suggests that most countries of the sample have taken into account the importance of setting reasonable targets and stablishing evaluation mechanisms, since 26 countries compete for the first and second positions. This fact indicates the necessity of modifying the third sub-index structure including more indicators or of disposing information regarding the governmental co-ordination indicator.

On the other hand, the enabling framework sub-index is highly correlated with the overall EEGI. In fact, the Spearman rank correlation is higher than 0.87. Following the discussion presented in the preceding section, due to their economic development and general governance quality, countries such as Netherlands, Australia, Austria and Norway, which are included in the medium group, should belong to the top group. One possible reason is that all of them account with a less developed legal framework than in countries of the top group, since the indicator laws and decrees has lower score while the strategies and action plans indicator is closely similar. Luxembourg is included in the medium group not due to a low score in the enabling frameworks sub-index, but that accounts almost the worst score in the institutional arrangements sub-index. On the contrary, countries such as Italy, France, New Zealand, Germany and United Kingdom should be included in the medium group instead of the top group. However, all of them account the highest scores in the enabling frameworks sub-index. In addition, on average, they are countries with also the highest scores in the implementing agencies indicator of the second sub-index. Thus, this is a first hint which indicates that the laws and decrees indicator is crucial to achieve a good EE governance performance.

Spain is included in those countries that belong to the top group due to a well-developed legal framework, although it was expected to be included within the medium group. Spain accounts one of the highest scores in the enabling frameworks sub-index and, similarly to the rest of countries of the top group, the maximum score in the co-ordination mechanisms sub-index. However, the score of the institutional arrangements sub-index is more proper of a country within the medium group. The constant activity of the energy agency (IDAE) and the legal basis which supports this compensate a null stakeholder engagement, the lack of public-private sector cooperation and the scarcity of programmes promoted by energy providers.

Switzerland, Estonia and Slovenia deserves also a special mention. Switzerland should be included in the top group (according to its economic development and general governance quality), rather than the bottom group. However, the EE governance in this country seems to remain in a primary state according to the IEA database, since the score is considerably low across the three sub-indices. Estonia is included in the expected group, although the EEGI score is low due to a scarce EE governance development. Finally, the score for Slovenia must be interpreted carefully, since the information available for this country is noticeably scarce.

Country	Code	Sub-indices					
		Enabling frameworks		Institutional arrangements		Co-ordination mechanisms	
		Score	Rank	Score	Rank	Score	Rank
Denmark	DNK	3,60	1	3,25	2	4,00	1
Germany	DEU	3,60	1	3,05	3	4,00	1
Spain	ESP	3,60	1	2,00	14	4,00	1
Italy	ITA	3,50	2	2,72	7	4,00	1
United Kingdom	GBR	3,20	3	2,97	5	4,00	1
Canada	CAN	3,20	3	3,42	1	3,33	2
France	FRA	3,10	4	3,25	2	4,00	1
Sweden	SWE	3,10	4	3,00	4	4,00	1
United States	USA	3,10	4	2,95	6	4,00	1
Belgium	BEL	3,10	4	2,12	11	4,00	1
Hungary	HUN	3,10	4	1,35	21	4,00	1
Luxembourg	LUX	3,10	4	1,15	22	3,33	2
Czech Republic	CZE	3,00	5	1,15	22	4,00	1
Portugal	PRT	3,00	5	1,40	20	3,33	2
Japan	JPN	2,70	6	2,07	12	4,00	1
Norway	NOR	2,70	6	1,88	16	4,00	1
Korea	KOR	2,70	6	1,80	18	4,00	1
Austria	AUT	2,70	6	1,93	15	3,33	2
New Zealand	NZL	2,60	7	2,67	8	4,00	1
Slovakia	SLK	2,60	7	0,90	23	2,67	3
Ireland	IRL	2,30	8	2,42	9	4,00	1
Finland	FIN	2,30	8	1,73	19	3,33	2
Poland	POL	2,30	8	1,15	22	3,33	2
Australia	AUS	2,20	9	2,32	10	3,33	2
Greece	GRC	2,10	10	1,35	21	2,67	3
Netherlands	NLD	1,90	11	1,85	17	4,00	1
Turkey	TUR	1,30	12	2,02	13	2,66	4
Chile	CHL	0,90	13	1,15	22	3,33	2
Mexico	MEX	0,90	13	0,65	24	3,33	2
Switzerland	CHE	0,90	13	1,15	22	2,67	3
Slovenia	SVN	0,50	14	0,65	24	2,00	5
Estonia	EST	0,50	14	0,65	24	1,33	6

Table 3. Country scores and ranking by sub-index for the basic EEGI.

Therefore, to develop an adequate legal basis is crucial, since countries with high score in the enabling framework sub-index and, concretely, in the laws and decrees indicator, are placed in a position higher than the expected according to their economic development and general governance.

4.4. Robustness

In this sub-section, the correlations among indicators and sub-indices are examined to assess whether indicators are properly classified into different sub-indices. Furthermore, sensitivity analysis is carried out to check the robustness of the index proposed in this work to alternative aggregating and weighting schemes. As mentioned above, the score obtained under the extended EEGI does not provide any substantial result in comparison with the basic EEGI score. Thus, in the robustness assessment only the basic EEGI is analysed, since very similar results can be expected for the extended EEGI.

The second column in Table 4 presents the average Spearman rank correlation coefficient among indicators in each sub-index and in the basic overall EEGI, accompanied by the Spearman correlation coefficient between the proposed basic overall EEGI and the basic-8 overall EEGI, an alternative index where each of the 8 indicators are weighted equally and not aggregated into sub-indices. The third and fourth columns specifies the number of indicators in each sub-index and the Cronbach's alpha test. [9]

	Average inter-item correlation	No. of items	Cronbach's alpha
Sub-indices			
Enabling frameworks	0.34	2	0.64
Institutional arrangements	0.37	4	0.70
Co-ordination mechanisms	0.11	2	0.19
Basic overall EEGI (average of 3 sub-indices)	0.65	3	0.85
Basic-8 overall EEGI (average of 8 indicators)	0.34	8	0.83

Table 4. Spearman rank correlations among indicators, sub-indices, basic overall EEGI and basic-8 overall EEGI.

The average inter-item Spearman rank correlation within the enabling framework sub-index is 0.34 and the Cronbach's alpha is 0.64, close similar to those values obtained under the institutional arrangements sub-index. Nevertheless, the Spearman rank correlation and

[9] The Cronbach's alpha is a 0-1 normalized statistic widely used in social sciences, business and other disciplines to measure how reliable and consistent the aggregation of a particular index is. [29]. This coefficient is function of the number of items (indicators) in a test, the average covariance between item-pairs and the variance of the total score. Most tests found in the literature falls in the range 0.7 to 0.83, which is considered good internal consistency. A higher alpha value provides higher internal consistency.

the Cronbach's alpha are fairly low in the co-ordination mechanisms sub-index, 0.11 and 0.19 respectively. This confirms the previous conclusion in Sub-section 4.2, indicating that further research is needed to adapt the structure that IEA provides for the third area in [10], achieving higher consistency and reliability in the co-ordination mechanisms sub-index. Additionally, this correlation may be improved whether there were available information regarding the governmental co-ordination mechanisms indicator to be assessed by the third EEGI sub-index. However, further research is also needed to confirm this statement.

Despite this fact, the Cronbach's alpha of the basic overall EEGI is reasonably high, with a reliability of 0.85. The Cronbach's alpha for the basic-8 overall EEGI is also high enough, but lower than in the previous case. These figures justify the structure of the overall EEGI and they provide indication that the set of sub-indices is reasonably constructed [25].

Regarding alternative weighting schemes, in addition to the basic-8 overall EEGI, in which the 8 indicators are equally weighted, the Principal Components Analysis (PCA) is used to obtain an alternative EEGI-PCA. [10] Table 5 reports the results in terms of rank and score for the three weighting schemes. The alternative weighting schemes affect country scores and rankings, but the resultant changes are not substantial and the main results are unaltered. For instance, the top 10 EE governance performers are the same under all three versions of EEGI, and the same is true for the bottom 6 countries. The average Spearman rank correlation between the three different approaches is higher than 0.9896 and significant in 0.01, suggesting that the baseline aggregation procedure described above is robust to alternative specifications [25].

Country	Code	Overall index		Alternative index			
		EEGI		Basic-8 EEGI		EEGI-PCA	
		Score	Rank	Score	Rank	Score	Rank
Denmark	DNK	3,62	1	3,53	1	1,31704	1
Germany	DEU	3,55	2	3,43	2	1,23065	2
France	FRA	3,45	3	3,40	3	1,10679	3
Italy	ITA	3,41	4	3,23	7	1,04388	4
United Kingdom	GBR	3,39	5	3,28	5	1,02572	5
Sweden	SWE	3,37	6	3,28	5	0,99879	6
United States	USA	3,35	7	3,25	6	0,97719	7
Canada	CAN	3,32	8	3,34	4	0,84499	8
Spain	ESP	3,20	9	2,90	9	0,77706	9
New Zealand	NZL	3,09	10	2,98	8	0,64382	10
Belgium	BEL	3,07	11	2,83	10	0,61649	11
Japan	JPN	2,92	12	2,71	12	0,42668	12

Table 5. Country scores ad rankings with different weights.

[10] The aim of PCA is to explain the variance of the observed data through a few combinations (principal components) of the original data that preserve high amount of the cumulative variance [24]. In this paper, it is calculated an only principal component (i.e., the EEGI) in order to stablish a ranking for the countries according to the PCA score. For each country, this score is calculated as the product between the standardised value on each indicator and the loading factor of that indicator for the principal component and then, summing these products.

Country	Code	Overall index		Alternative index			
		EEGI		Basic-8 EEGI		EEGI-PCA	
		Score	Rank	Score	Rank	Score	Rank
Ireland	IRL	2,91	13	2,78	11	0,40967	13
Norway	NOR	2,86	14	2,62	13	0,34785	14
Korea	KOR	2,83	15	2,58	14	0,31221	15
Hungary	HUN	2,82	16	2,45	17	0,28602	16
Czech Republic	CZE	2,72	17	2,33	19	0,15757	17
Austria	AUT	2,65	18	2,47	16	-0,00568	19
Australia	AUS	2,62	19	2,54	15	-0,0507	20
Netherlands	NLD	2,58	20	2,40	18	-0,0026	18
Portugal	PRT	2,58	20	2,28	20	-0,10956	21
Luxembourg	LUX	2,53	21	2,18	22	-0,1755	22
Finland	FIN	2,45	22	2,27	21	-0,26028	23
Poland	POL	2,26	23	1,98	24	-0,51191	24
Slovakia	SVK	2,06	24	1,77	26	-0,86608	25
Greece	GRC	2,04	25	1,87	25	-0,88194	26
Turkey	TUR	1,99	26	2,00	23	-0,93388	27
Chile	CHL	1,79	27	1,63	27	-1,10063	28
Mexico	MEX	1,63	28	1,38	29	-1,31662	29
Switzerland	CHE	1,57	29	1,47	28	-1,47295	30
Slovenia	SVN	1,05	30	0,95	30	-2,22948	31
Estonia	EST	0,83	31	0,78	31	-2,6046	32

Table 5. Continued

5. Applications: Energy intensity and share of renewable energy

EEGI can be used to study a wide range of questions in the literature regarding EE performance and RES deployment. Likewise, EEGI can also play an important role in the development of models which explain the features of EE performance taking into account general governance and economic development, as demonstrated in the previous section.

The assessment of EE performance using Energy Intensity (EI) as a proxy is widely used in the literature. The EI enables the estimation of EE outcomes by means of a set of variables, including issues related to institutional and general governance. For instance, in [9] EI is characterised through a dynamic model which takes into account general institutional variables (democracy, human capital and the structure of the economy) in order to assess the variations in the EE outcomes. The lack of EE governance indicators to complement this assessment is evidenced by the authors. On the other hand, IRENA has stated that the role of RES in implementing and improving EE has been broadly overlooked. To avoid this deficiency, the level of deployment of RES is represented in this work by the TPRES, the share of renewable energy into the total primary energy supply.

Therefore, to answer the issues raised by the EEGI related to both EI and synergies between RES and EE, the relationship between EEGI and these issues is examined in the present section. Data have been acquired from IEA for the period 1975 to 2005 (a larger period of time than that used in the assessment presented in Sub-section 4.2) to examine whether countries that have improved notably their EI or TPRES in this period also account with a higher EEGI score. The most proper period of time should include years after 2005, although they are not considered to avoid the interferences caused by the economic crisis in the calculation of EI. This is feasible due to the time-invariant character of EEGI [25].

Figure 7 illustrates the relationship between EEGI and the average annual EI growth from 1975 to 2005. There is a significant negative correlation between EEGI and EI growth, since the higher EEGI score, the lower annual increase (or higher annual reduction) of EI along the period. Like in previous assessments, Switzerland, Chile, Turkey and Mexico are the worst countries in terms of EI growth, which is coherent with their EEGI scores. On the other hand, countries with high EEGI score, such as Denmark, Germany, France, Sweden, United Kingdom or United States top the list in EI reduction. However, it is worth mentioning some concrete cases: Luxembourg, Poland and Slovenia presents EI reductions higher than expected, while Spain and New Zealand, that account high EEGI scores, have incremented their EI growth. At this point, it is necessary to keep in mind that EI is a complex variable influenced by a set of issues with different nature (institutional, governmental and economic, among others). The exercise presented in this work is not intended to develop a detailed model and its scope is limited to illustrates the negative correlation between EEGI (i.e., EE governance performance) and EI growth. Thus, further research is needed in order to define a model that takes into account EEGI and other additional variables that explain the behaviour of EI.

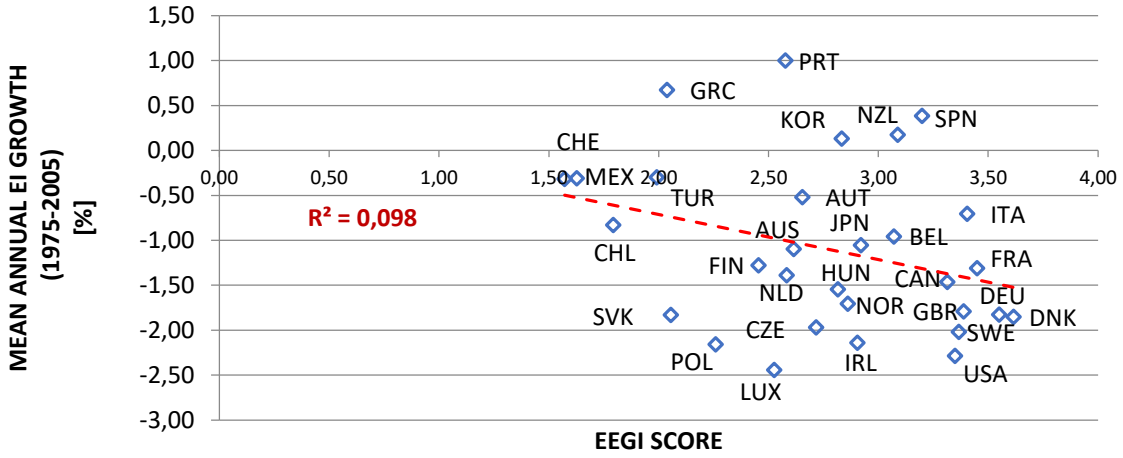

Figure 7. Mean annual EI growth versus EEGI.

In addition, Figure 8 illustrates the correlation between EEGI and RES, through the average annual TPRES change (in percentage points) from 1975 to 2005. This is a positive correlation, indicating that higher EEGI scores contribute favourably to the deployment of RES. This relation is more consistent than the preceding, since the R^2 is higher. Interesting cases have been detected again. Countries such as Denmark, Sweden and Austria are considerably over the average tendency. Norway and France have reached lower deployment of RES than expected. It could be due to the broad availability of fossil energy resources in Norway or to the high penetration of nuclear energy in France, for instance. Finally, while Turkey and Mexico remains in the bottom of the list, Switzerland has improved its RES deployment over expected.

Further research should be focused conscientiously on the case of Denmark, since this country has reduced notably its EI, it accounts the highest increase in RES and represents one of the highest scores in general and EE governance. In addition, although the economic development is high, it is not the highest registered in the data. That means that the Danish policy framework is efficiently adapted to the context of the country and is able to capture the prevailing needs in terms of economics, general and EE governance, and energy (EE and RES). Thus, the direction of Danish policies should be taken into consideration by other countries and adapted to their particular context and needs. On the contrary, Switzerland also deserves an individual assessment, since is one of the most economic developed countries and, however, this fact is not reflected in energy policies that reduce remarkably the EI or improve the RES deployment as expected.

Delving deeper in this analysis, the explanation of the EI growth seems to be closely related to the second and the third sub-indices –institutional arrangements and co-ordination mechanisms. Figure 9A illustrates the negative correlation between the institutional

arrangements sub-index and EI growth: the more developed the institutional framework, the lower EI growth (or higher EI reduction). Likewise, Figure 9B presents the negative correlation between the co-ordination mechanisms sub-index and EI growth: several targets to achieve in an adequate period of time accompanied by proper evaluation mechanisms for targets and strategies reduce the EI growth (or facilitates its reduction). This straightforward exercise is intended to illustrate that part of the EI behaviour is closely related to the development of a proper institutional framework but, even more important, to the imposition of targets to culminate the legal basis accompanied by the pertinent evaluation mechanisms for the achievement of these targets.

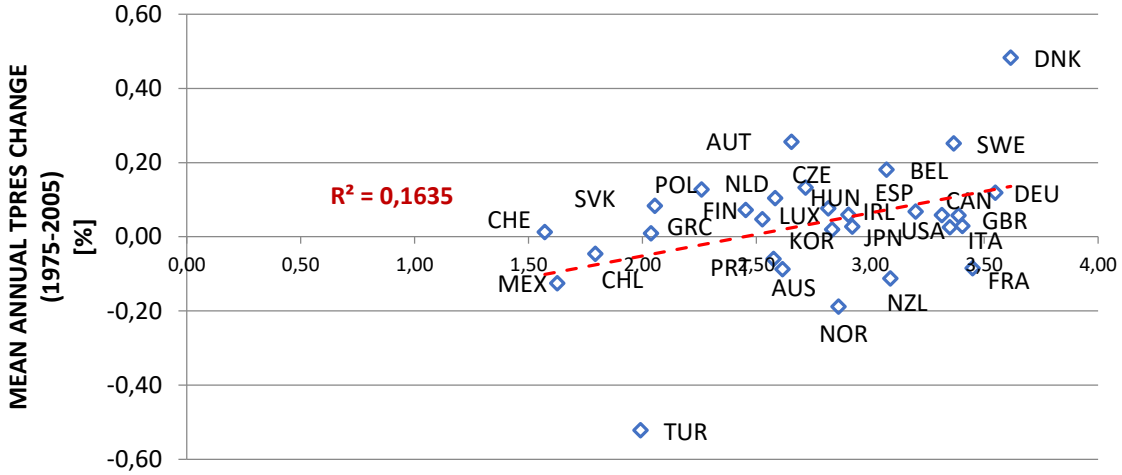

Figure 8. Average annual TPRES change versus EEGI.

The close relationship between EI and both institutional arrangements and co-ordination mechanisms areas have been documented in [8] and [27]. Although these reports are focused on EE issues and not directly on EI, variations on EE performance are reflected in EI and thus, those aspects that can affect directly the EE outcome are able to affect also the resulting EI. In [27], IEA states that energy and economic measurable objectives (targets) accompanied by evaluation mechanisms to measure the accomplishment of these targets are foremost issues to provide a solid foundation for supporting EE improvements and thus, EI enhancements. In addition, IEA also recognises that institutional arrangements are much important than enabling frameworks for improving EE performance, pointing to the special role of energy agencies in implementing and monitoring programs and plans.

Unlike EI growth, RES deployment seems to be more related to the enabling framework sub-index, while institutional arrangements and co-ordination mechanisms sub-indices are much less correlated. Figure 10A illustrates that the higher score of the enabling framework sub-index, the higher RES deployment. In this case, the R^2 is slightly higher than 0.24, which means that this model is more precise than the preceding ones. Figure 10B presents the

positive correlation between RES deployment and the co-ordination mechanisms sub-index, although this is less significant than the previous one.

This relationship between RES deployment and the enabling frameworks area has been widely documented in works such as [27], [13] and [28], among others. In this regard, IEA states that "policy frameworks play a crucial role since they should provide an adequate degree of stability for investment and project development, and yet also be capable of adapting as the market evolves". Therefore, policy plays a key role for RES because that establish the level of confidence in the market and the associated risk perception, determining also the extent to which non-economic barriers (difficulties to obtain permits or lack of market access) inhibit or push up the cost of deployment, facilitating the integration of this kind of systems.

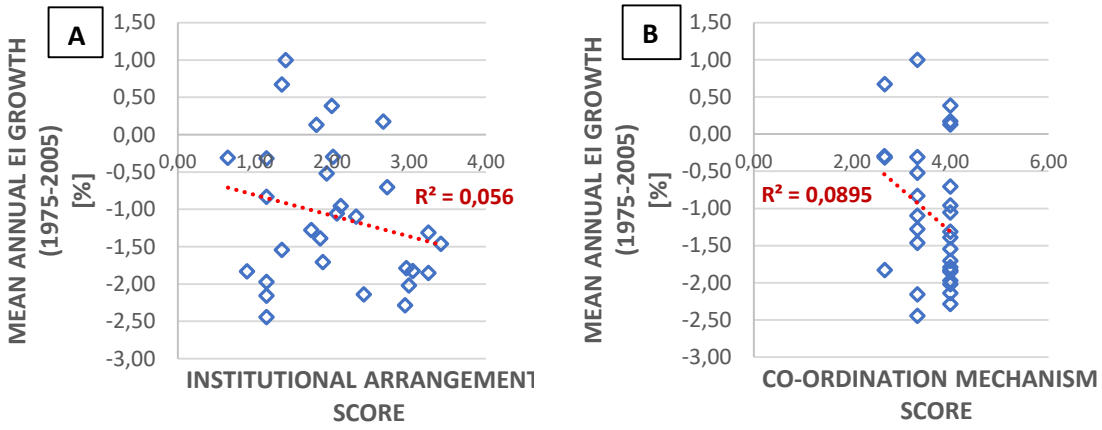

Figure 9. A) Mean annual EI growth versus enabling frameworks sub-index. **B)** Mean annual EI growth versus co-ordination mechanisms sub-index.

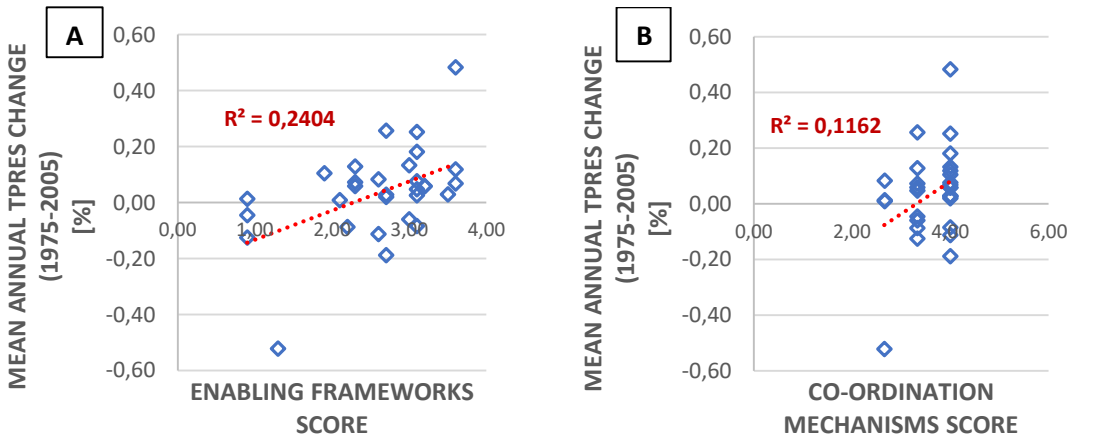

Figure 10. A) Mean annual TPRES change versus enabling frameworks sub-index. **B)** Mean annual TPRES change versus co-ordination mechanisms sub-index.

To summarise, this section of the work has provided empirical evidence that EEGI captures issues needed to complement the assessment of EE performance through institutional variables, as this maintains a proper correlation with EI and RES deployment (which can affect EE outcomes) and also with institutional variables such as economic development and general governance. In addition, it has been also provided empirical support to the theoretical framework established by IEA and other sources through a brief statistical assessment that confirms the close relationship between EI and both co-ordination mechanisms and institutional arrangements areas, and also between RES deployment and the enabling frameworks area.

6. Concluding remarks and further research

This work constructs, for the first time, a multi-dimensional index of the quality of EE governance in a set of 32 OECD countries. The composite index draws on multiple sources to assemble the most comprehensive set of information to date and is based on three individual features described by IEA in [10] (enabling frameworks, institutional arrangements and co-ordination mechanisms), which capture the requirements for a good EE governance. This index breaks new ground, since indices about EE governance are not available yet and it complements the available institutional indices in the assessment of the influence of institutions on EE performance. By exploring sub-indices, researchers can investigate different dimensions of EE governance in their role of implementing EE, as well as the kind of policies for RES that should be implemented together EE measures in order to harness their common synergies.

The EEGI seems to maintain a positive correlation with economic development and general governance quality. Thus, the higher economic development and general governance quality, the higher EE governance quality. Further research should be focused on the case of Denmark as the country with the highest score in EE governance despite not being the more economic developed country or the country with the highest general governance quality. However, it can be anticipated that the enabling frameworks area and more concretely, the laws and decrees indicator, seems to be the most determining factor for a good EE governance. On the other hand, the funding mechanisms indicator –also belonging to the first EE governance area– does not provide any substantial information.

Unlike the enabling frameworks area, the co-ordination mechanisms area requires further research to include additional indicators that improve the internal correlation of this sub-index. Likewise, the availability of information regarding the governmental co-ordination indicator could also overcome this barrier. Despite this fact, the robustness analysis has revealed a high internal consistency for the proposed index: the correlation among sub-indices and indicators is adequate and the Cronbach's alpha coefficient is notably high. Furthermore, the aggregation procedure is also robust to alternative specifications such as PCA and basic-8 overall EEGI.

The proposed overall index can be used as an EE governance indicator in that studies which assess the influence of institutions on EE performance through the EI proxy and institutional variables, since they have broadly overlooked EE governance issues. In this vein, although this work has evidenced the adequate correlation between EEGI (i.e., EE governance performance) and both EI improvement and RES deployment, further research is needed yet in order to stablish a proper model that explains more profusely the features of EI and thus, EE, through EEGI.

The EEGI also provides empirical evidence for IEA statements, in which the deployment of RES is plentifully related to the establishment of a proper legal and economic framework (enabling frameworks area), while the EE performance is much more related to the

imposition of measurable targets and their respective evaluation methods (co-ordination mechanisms area), accompanied by a widely developed institutional arrangements area in which energy agencies play a crucial role.

To conclude, despite the high consistency of the results provided by this work, the compilation of the index should be seen as a first attempt to amass comparative information of interest on EE governance. As such, it should be viewed as a helpful starting point for identifying broad trends and providing an approximation of EE governance performance rather than a substitute for in-depth policy analysis and diagnostics.

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