A multicriteria classification approach of energy efficiency governance in the European Union

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Abstract

Energy efficiency was brought into the world's policy agenda due to its significant effects toward attaining a sustainable energy future along. Since the European Union wants to lead the clean energy transition, it has been presenting ambitious targets for energy efficiency improvement. In 2014, the established target for 2020 on energy efficiency was 20%. However, it is likely that this goal will not be achieved. For this reason, it is necessary to rethink the current strategy to a more effective implementation plan. This dissertation intends to build and develop a Multi-Criteria Decision Aiding Method (MCDA) to assess the current governance capacities on energy efficiency of the 28 members states of the European Union. The literature review chapter explores what has been developed on energy efficiency governance and introduces the MCDA methodology, in particular the ELECTRE TRI-nC method. After gathering all data, the evaluation criteria are defined, and a set of parameters are chosen in order to execute the ELECTRE TRI-nC method. In the end, each country is classified according to its current governance efforts on energy efficiency into a set of pre-defined categories, which will be sustained by a sensitivity analysis.

Keywords: Energy Efficiency, Governance, European Union, Multi-Criteria Decision Aiding Methodology (MCDA), ELECTRE TRI-nC

1. Introduction

There is not a commonly-accepted definition of energy efficiency (EE). The European Commission (EC) defines EE, in the Energy Efficiency Directive (EED), as the ratio of output of performance, service, goods or energy, to input of energy (EC, 2017a). The main driver for EE improvement is technological change since it allows the decrease of energy consumption (considering constant demand). However, EE can also be improved through better organization, better management resources or even by better economic conditions in the sector (non-technical factors) (Makridou, 2016). The improvement of EE might lead to the attainment of many goals, such as the reduction of energy costs, the increase of competitiveness, the support of innovation and the promotion of welfare. Therefore, it continues to gain attention as a key resource for economic and social development across all economies (IEA, 2014a). EE is also a great cost-effective and readily available way to address many energy-related issues as it contributes to the sustainability of economic, environmental and social aspects (IEA, 2014a). The objective of this thesis is to develop a MCDA model that will assess

the EE governance capacities of the 28 countries of the European Union (EU).

The EC aimed to reach a 20% of improvement on EE until 2020, but recent projections predict that it will be improbable to achieve it (Euractive, 2014). This said, it is important to understand how to develop a better strategy in order to ensure that targets will be accomplished.

2. Problem Definition

2.1. Market Trends

The global energy landscape is changing and the energy markets are growing at a high rate. The world economy is expected to double over the next 20 years and the global population will reach nearly 8.8 billion people by 2035 (BP, 2017). At the same time, fossil fuels, the most consumed energy resources, are getting scarce. In this context, the energy sector aims to achieve three seemingly conflicting objectives (Planete Energies, 2015): (1) Energy security: the reliability of the energy supply ensuring to meet the current and future demand; (2) Energy equity: the accessibility of energy around the world at an affordable cost; and Environmental Sustainability: since it is crucial to improve the efficiency of energy systems and to develop renewable and low GHG energy sources. To conclude, EE is one of the main tools to create a new *status quo* in the energy market.

2.2. Energy Efficiency Issues

There are three main issues that usually come along with the improvement of EE – the barriers, the rebound effect and the EE gap. The EE barriers are the mechanisms that inhibit a decision or behaviour that appears both energetically and economically efficient (Makridou, 2016). The rebound effect occurs when EE is used to obtain more energy services rather than achieving energy demand reduction (IEA, 2014a). The EE gap consists in the difference between the technical feasible and economically viable improvements and the actual level of investment on those. This gap results in the potential efficiency improvement that is not accomplished due to barriers in the energy market (Pereira, 2014).

2.3. Energy Efficiency in the EU

Initially, in 2012 the EED established a set of binding measures to help the EU reach its 20% EE target by 2020. All EU countries are under this Directive and are required to use energy more efficiently at all stages of the energy chain, from production to final consumption (EC, 2017a). Then, in October 2014, the European Council presented the 2030 Framework for climate and energy. This framework includes EU-wide targets and policy objectives until 2030. The established targets are (EC, 2018b): (1) a 40% cut in GHG emissions compared to 1990 levels; (2) at least a 27% share of renewable energy consumptions; (3) at least 27% of EE improvement at EU level compared to projections; and, (4) support the completion of the internal energy market by achieving the existing electricity interconnection target of 10% by 2020 (EC, 2018b). These targets were based on an economic analysis with the focus on the achievement of decarbonization by 2050 in a cost-effective way. They were also meant to help the EU achieve a more competitive, secure and sustainable energy system (EC, 2018b).

In this context, EC released the package of measures ‘Clean Energy for all Europeans’ on the 30th of November 2016 with the goal of creating a stable legislative framework to facilitate the clean energy transition. The EC wants the EU to lead the clean energy transition, and not only to adapt to it (EC, 2016a). The ‘Clean Energy for All Europeans’ package aims to enable EU delivering its Paris Agreement commitments and to help the EU energy sector become stable, competitive and sustainable. The three main goals of the package are (EC, 2018a): (1) Putting energy efficiency first; (2) Achieving global leadership in renewable energies; and, (3) Providing a fair deal for consumers. A clear signal of the EC commitment on the first issue is the rising of the binding EU-wide target of 30% for EE by 2030 (EC, 2017a) (which was previously set as 27% in 2014 (EC, 2018)). The established target of 20% of EE improvement by 2020 will likely not be achieved, being the expected improvement only around the 18% or 19% (Euractive, 2014).

3. Literature Review

3.1. EE Governance

There is a great lack of scholarly attention on energy governance, even though its extraordinary importance in current international affairs (Florini and Sovacool, 2009). Jollands and Ellis (2009) defined EE governance as "the use of political authority, institutions and resources by decision-makers and implementers to achieve improved EE". Meyer-Ohlendorf et al. (2015) state that due to the lack of a formal definition of governance, the term remains vague and ambiguous, leaving ample room for interpretation. However, effectiveness, compliance, reporting and planning are considered central as governance issues.

According to Turner (2015) an adequate governance framework for EE shall be in line with the principles of good governance, which are: effectiveness, transparency, accountability, legitimacy, policy coherence and flexibility. Today, policy makers tend to focus on micro-level issues, since energy saving resources are widely spread amongst many individual actors in society and the existent barriers are very specific to particular sectors of the economy. Indeed, this micro-level EE policies have been quite successful on their sphere of influence, but there are still many gaps in policy coverage. This approach might be one strong reason why levels of EE typically do not improve rapidly as expected (Jolland and Ellis, 2009).

Jollands and Ellis (2009) proposed a broader and more holistic framework for EE assessment. Based on their combined experiences in EE policies, they identify a range of relevant issues covered by the governance concept:

- **Foundations for governance**, or in other words, the resources and structures required to establish a governance system are: (1) Institutional structure; (2) Resources (people and finance); (3) Human capacity and training; and, (4) Political mandate.
- **Governance activities**, that refers to the actions that governance systems undertake: (1) EE strategies; (2) Policy development; (3) Mechanisms to fund EE; (4) Monitoring EE programmes; (5) Compliance and enforcement; and, (6) Research and innovation. Considering all these dimensions, Figure 1 shows a schematic outlining the span of EE governance.

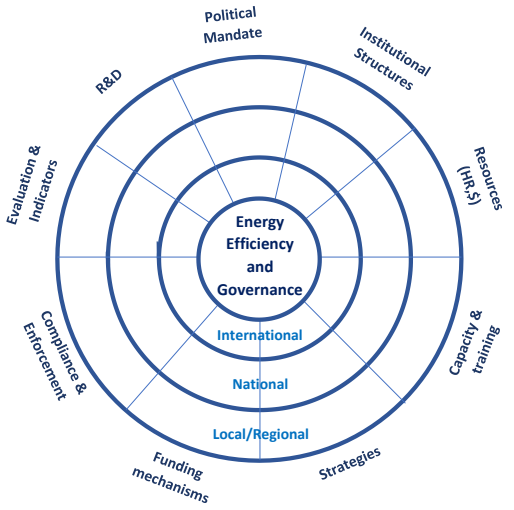

Figure 1: Schematic of governance dimensions (adapted from Jollands and Ellis, 2009)

Other studies with smaller scope were considered. Delina (2012) defends that must exist coherence between the current transformation of the energy systems and the governance of EE institutions. This paper presents a framework that builds on concepts encompassing three principal identifiers of coherence institutional governance: (1) Motivation: (2) Capacity and (3) Interventions. Schlomann et al. (2014) explores the lack of clear definitions and common rules for the measuring of EE. The presented approach analyses the typical baseline formulations and the used accounting methods. Pereira and Silva (2017) developed a research to understand EE governance by analysing a set of indicators covering aspects related to institutional, human, financial and political dimensions. This approach enables an analysis on the existing governance capacities.

3.2. MCDA Methodology

MCDA approaches may help to consider various levels of information, quantitative and qualitative and to take into account the subjective preferences of the decision maker (Figueiredo and Oliveira, 2009). The meaning of "classification" in MCDA scope refers to the assignment of a set of alternatives described over a set of attributes (criteria) into predefined homogenous classes (Doumpos and Zopounidis, 2004).

The developed model in this thesis is an example of classification through a MCDA method, namely the ELECTRE Tri-nC.

In MCDA, ELECTRE methods are based on outranking relations (Costa et al, 2016). The ELECTRE Tri-nC method is designed to associate a set of actions $A = \{a_1, \dots, a_i, \dots\}$ to ordered classes. Let $C = \{C_1, \dots, C_h, \dots, C_q\}$ a set of q ordered categories in order of preference in which it is assumed C_1 is the worst and C_q is the best. This method allocates each action a_q from A to a certain C_q categories. This classification is a comparison between a_q and reference action corresponding to the upper and lower bounds of the class represented by $B = \{B_1, \dots, B_h, \dots, B_q\}$. The evaluation considers a set of criteria $F = (g_1, g_2, \dots, g_j)$ and define a set of performances $\{g_j(b_0, \dots, g_j(b_n)\}, \forall\, j = 1, \dots, n$ (Almeida-Dias et al, 2010). When constructing an outranking relation, there are three main concepts to consider: concordance, nondiscordance and credibility index. Concordance refers to the strength of the coalition of criteria being in favour of the outranking relation aS_ja'. Nondiscordance happens when there are no criteria that are in opposition to the assertion aS_ja'. The credibility of the assertion "a outranks a'" (aSa') is defined by the credibility index $\sigma(a, a')$ (Costa et al, 2016). Let λ denote a credibility level as the minimum degree of credibility, which is considered or judged necessary by the decision maker for validating or not an outranking statement considering all criteria from F. The minimum credibility level takes a value within the range [0.5,1]. The ELECTRE TRI-nC assignment procedure is composed of two joint rules: (1) The descending rule states: choose a credibility level, $\lambda\left(\frac{1}{2} \leq \lambda \leq 1\right)$; decrease h from $(q+1)$ until the first value, t, such that $\sigma(\{a\}, B_t) \geq \lambda$; (2) The ascending rule states: choose a credibility level, $\lambda\left(\frac{1}{2} \leq \lambda \leq 1\right)$; decrease h from zero until the first value, k, such that $\sigma(B_k, \{a\}) \geq \lambda$ (Costa et al, 2016).

4. Formal Model

4.1. Framework and EED

The process of comparing different countries is quite complex due to the number of variables (economic, social, political and environmental) that influence the governance efforts that each country chooses to take. Having this said, it is important to establish a 'common ground', where all countries have comparable responsibilities and duties. The presented solution to establish this "common ground" between all MS, and to be used as the basis of the criteria construction, is EED. This choice is justified by three main reasons: (1) All MS must harmonize their national laws and governance measures with the Articles of the EED; (2) EED establishes targets that are based on national socio-economic indicators, which make the targets calibrated to each MS's situation; (3) All measures triggered by EED compliance actions must be reported to the EC and are publicly available. In 2014 and 2017, all MS had to elaborate an extensive report, the National Energy Efficiency Action Plans (NEEAP), on all current measures and how they are complying with EED demands.

It was possible to identify overlaps between EED requirements and the EE governance framework that Jollands and Ellis had proposed, as it is shown in Figure 2.

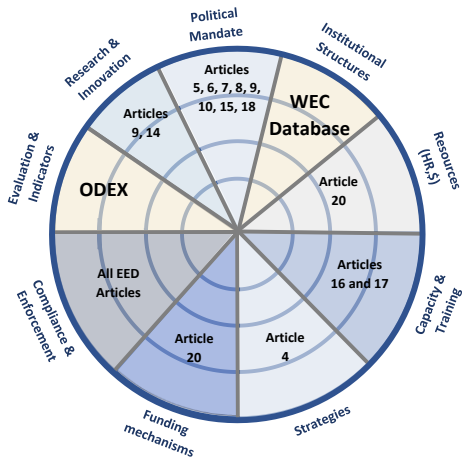

Figure 2: EE governance framework covered in all dimensions, and respective sources.

Considering that there is still two dimensions of the EE governance framework that are not covered by any EED article, it will be added two extra sources of information to develop

criteria on these topics. The source of information to approach the Evaluation and Indicators dimension is the Odyssee database (ODYSSEE-MURE, 2018). The Institutional Structure dimension will be represented by a criterion based on information by the World Energy Council – Energy Efficiency Policy and Measures database (WEC, 2018). Note that the decision maker is hypothetical in this dissertation.

4.2. Construction of the Criteria Tree

The assessment of EE governance capacities is supported by the Areas of Concern (AC) which represent a wide scope of concerns of different actors on the problem. These areas may be disaggregated into specific areas by the Fundamental Points of View (FPV), and these into even smaller issues by the Elementary Points of View (EPV). EPV are defined as effects or attributes that are recognized as consequences and present certain characteristics. These aspects are operationalized by the criteria (Roy, 1996).

There were defined eight FPV: FPV_1 considers the Political Mandate measures; FPV_2 translates the impact of the Institutional Structures; FPV_3 states the availability and accessibility of capacity programmes; FPV_4 analyses information availability; FPV_5 considers Funding Mechanisms; FPV_6 focuses on Strategies on End-Uses; FPV_7 considers the efficiency improvement in supply and FPV_8 translates the technical performance by EE indicators. The following criteria were considered:

g1: EE performance on the Public Sector: reflects the exemplary role of public bodies' buildings om EE and the EE performance of public purchases (referred in EED articles 5 and 6). Table 1 shows the scale to characterize criterion g1.

Impact Level	Classification
L1	Very good compliance.
L2	Good compliance.
L3	Moderate compliance.
L4	Average compliance.
L5	Weak compliance.
L6	Very weak compliance.
L7	No compliance.

Table 1: Levels of impact of g1.

g2: Availability of Energy Management Systems: evaluates the level of availability on energy management systems (referred in EE article 8). The scale of this criterion is S_2={Very good compliance (L1); Good compliance (L2); Moderate compliance (L3); Weak compliance (L4)}.

g3: Metering and Billing Reliability: assesses the quality of metering and billing systems free of charge for end-users (stated in EED articles 9 and 10). The scale of this criterion is equal as the one shown in Table 1 for criterion g1.

g4: Accessibility of Energy Services for SME: evaluates the level of accessibility for SMEs, stated in EED Article 18. The scale of this criterion is S_4={Good compliance (L1); Moderate (L2); Weak compliance (L3)}.

g5: EE Promotion by Institutional Structures: analyses the impact by Institutions on the EE improvement (WEC database). The scale for this criterion is shown in Table 2.

Level	Description
L1	National Agency dedicated to EE promotion, with more than 50 staff members, and more than 10 local points.
L2	National Agency dedicated to EE promotion, with less than 50 staff members, and some local points.
L3	National Agency dedicated to EE promotion, with less than 50 staff members, and no local points.
L4	No valuable information.

Table 2: Scale of criterion g5.

g6: Effectiveness of Qualification, Accreditation and Certification Schemes: quantifies the amount and quality of measures on qualification, accreditation and certification (referred in EED Article 16). The scale of this criterion is S_6={Good compliance (L1); Moderate (L2); Weak compliance (L3)}.

g7: Information and Training Availability: quantifies the amount and quality of measures on information and training (stated in EED Article 17). The scale of this criterion is S_7={Good compliance (L1); Moderate (L2); Weak compliance (L3)}.

g8: Availability of EE Funding Mechanisms: analysis the existence of funding mechanisms dedicated to EE (based on info reported on EED Article 20 and WEC database). The scale for this criterion is shown in Table 3.

Level	Description
L1	National EE dedicated Fund. The ratio National EE Fund/GDP per capita is greater or equal than 20000.
L2	National EE dedicated Fund. The ratio National EE Fund/GDP per capita is smaller than 20000
L3	National EE dedicated Fund but there are no concrete values reported.
L4	No valuable information.

Table 3: Scale of criterion g8.

g9: Scope of the National Building Renovation Strategy: assesses the scope and current efforts on the strategy for national building renovation stated in EED Article 4. The scale of this criterion is S_9={Good compliance (L1); Moderate (L2); Weak compliance (L3)}.

g10: Efficiency in Energy Supply: analyses the promotion of efficiency on heating and cooling and the EE performance on transformation, transmission and distribution (stated on EED articles 14 and 15). The scale for this criterion is shown in Table 4.

Impact Level	Classification
L1	Very good compliance.
L2	Good compliance.
L3	Moderate compliance.
L4	Weak compliance.
L5	Very Weak compliance.

Table 4: Scale of criterion g10.

g11: Effectiveness of the EE Obligation Schemes: evaluates the success of the implemented EE obligation schemes (stated in EED Article 7). The scale of this criterion is S_{11}={Very good compliance (L1); Good compliance (L2); Moderate compliance (L3); Weak compliance (L4)}.

g12: ODEX: considers the ODEX indicator, from the Odyssee database, of the whole economy of the country on the year in the analysis. ODEX is given by a numerical scale where a value of 90 means a 10% EE gain. This index is a better proxy for assessing EE trends at aggregate level than the traditional energy intensities, as they are cleaned from structural changes and from other factors not related to EE (ODYSSEE-MURE, 2018).

The performance tables are shown in Tables 5 and 6.

		g1	g2	g3	g4	g5	g6	g7	g8	g9	g10	g11	g12
Austria	AT	2	1	1	1	1	1	1	1	2	2	1	82
Belgium	BE	2	3	4	1	4	3	1	3	3	5	4	75
Bulgaria	BG	3	2	1	1	4	1	1	4	1	1	3	66
Croatia	HR	4	2	3	1	2	1	1	3	2	1	2	84
Cyprus	CY	3	3	5	2	4	1	1	2	2	4	2	78
Czech Republic	CZ	3	2	1	1	3	1	2	1	2	2	2	79
Denmark	DK	3	1	1	1	2	1	1	1	2	1	2	84
Estonia	EE	5	2	3	1	2	1	1	3	3	4	2	75
Finland	FI	2	2	3	1	1	1	1	4	1	1	2	92
France	FR	3	2	5	3	1	2	1	4	2	3	3	85
Germany	DE	2	2	7	1	1	2	3	3	1	4	3	82
Greece	EL	2	2	3	1	4	2	1	3	1	1	2	70
Hungary	HU	2	2	3	1	4	1	1	4	1	2	2	78
Ireland	IE	2	2	3	1	3	1	1	3	2	2	2	73
Italy	IT	1	2	4	1	1	1	1	2	1	1	2	87
Latvia	LV	3	2	4	3	3	1	3	3	1	2	2	70
Lithuania	LT	5	2	3	2	2	2	3	3	3	2	4	73
Luxembourg	LU	2	2	3	1	4	1	1	4	1	2	1	83
Malta	MT	2	2	2	2	2	1	1	1	1	2	3	82
Netherlands	NL	2	2	4	2	1	2	1	4	1	1	2	76
Poland	PL	4	2	5	2	2	1	1	2	1	3	2	73
Portugal	PT	7	4	7	2	1	3	3	1	3	5	3	73
Romania	RO	2	2	5	2	3	1	1	1	1	2	3	66
Slovakia	SK	7	4	7	3	1	3	1	1	3	5	4	63
Slovenia	SI	4	2	3	1	3	1	1	1	2	1	2	78
Spain	ES	1	2	3	1	1	1	1	1	1	1	2	82
Sweden	SE	1	2	3	1	1	2	1	4	1	2	1	75
United Kingdom	UK	3	2	3	1	3	1	1	3	1	1	1	76

Table 5: Performances for 2013.

		g1	g2	g3	g4	g5	g6	g7	g8	g9	g10	g11	g12
Austria	AT	2	1	1	1	1	1	1	1	2	3	1	80
Belgium	BE	3	2	7	1	4	3	1	3	3	5	4	75
Bulgaria	BG	4	3	1	1	4	1	1	4	1	1	2	65
Croatia	HR	4	1	2	1	2	1	1	3	2	1	2	81
Cyprus	CY	4	2	5	2	4	1	1	2	2	2	1	77
Czech Republic	CZ	4	2	1	3	3	1	2	1	2	1	2	77
Denmark	DK	4	1	1	1	2	1	1	1	2	1	2	83
Estonia	EE	5	3	1	1	2	1	1	3	3	3	1	72
Finland	FI	2	2	1	1	1	1	1	4	1	1	2	91
France	FR	2	3	3	3	1	2	1	4	2	3	3	83
Germany	DE	2	2	4	1	1	2	3	3	1	2	3	80
Greece	EL	3	2	3	1	4	2	1	3	1	1	1	67
Hungary	HU	4	2	3	1	4	1	1	4	1	4	2	76
Ireland	IE	2	2	3	1	3	1	1	3	2	2	2	71
Italy	IT	1	2	3	1	1	1	1	2	1	1	2	86
Latvia	LV	2	2	4	2	3	1	3	3	1	2	2	68
Lithuania	LT	7	4	7	3	2	3	3	3	3	2	4	70
Luxembourg	LU	1	3	3	1	4	1	1	4	1	2	1	81
Malta	MT	3	1	2	2	2	1	1	1	1	2	1	80
Netherlands	NL	1	2	3	1	1	2	1	4	1	1	2	75
Poland	PL	4	2	6	1	2	1	1	2	1	3	2	71
Portugal	PT	7	3	4	1	1	1	1	1	3	1	1	72
Romania	RO	4	4	5	3	3	1	3	1	3	5	4	64
Slovakia	SK	3	3	7	1	1	2	1	1	2	1	2	60
Slovenia	SI	4	2	3	1	3	1	1	1	2	1	2	77
Spain	ES	1	2	3	1	1	1	1	1	1	1	2	80
Sweden	SE	1	3	3	1	1	2	1	4	1	2	1	74
United Kingdom	UK	4	2	4	1	3	1	3	3	1	2	2	74

Table 6: Performances for 2016.

5. Model Execution

5.1. Criteria Weighting

The ponderation of the weights was executed by the revised Simos' procedure (Figueira and Roy, 2002). It presents two phases: the first one consists in gathering data with the decision maker (which in the present problem is a hypothetic decision maker); and, the second part consists in the

calculation in order to get the weights of each criterion. In the first part it is defined a set of cards, being one card correspondent to one of the criteria previously defined. It is also defined a set of white cards. Then, the cards of the criteria are ordered by importance in a hierarchy. The card on the top presents the greatest weight (the most important) while the card on the bottom presents the smallest weight (the least important). In the case that decision maker considers that there are criteria with the same importance, the cards of these criteria are in the hierarchy. After this, the white cards are added. The more white cards there is between two criteria, the bigger is the difference of importance between the two. If there are not white cards in the hierarchy, it is considered that the difference of two sequential levels of the hierarchy corresponds to one unit. If there is a white card between two levels then the difference of importance is considered two units, and so on. The proposed hierarchy is shown in Table 7.

Rank	Cards	Normalized Weight
1	g12	19.6
2	White Card	-
3	g10, g11	13.7
4	g8, g9	10.8
5	g2, g3	7.8
6	g1, g4	4.9
7	g5, g6, g7	2

Table 7: Hierarchy of Criteria – Hypothesis 1

It is considered also a hypothesis 2 which defined all criteria with the same weight. This hypothesis aims to be used as a control version and to help take more conclusions on the results since there is no formal decision maker.

5.2. Definition of Model Elements

Categories	Performance	Reference actions	Criteria											
			g1	g2	g3	g4	g5	g6	g7	g8	g9	g10	g11	g12
C_1	Very Good	b_1^1	1	1	1	1	1	1	1	1	1	1	1	60
		b_1^2	1	1	2	1	1	1	1	1	1	1	1	80
C_2	Good	b_2^1	2	2	2	1	1	1	1	1	1	1	2	80
		b_2^2	3	2	3	1	2	1	1	2	2	2	3	85
C_3	Moderate	b_3^1	3	3	3	2	3	2	2	3	2	3	3	85
		b_3^2	5	3	4	3	3	3	3	3	3	4	3	90
C_4	Weak	b_4^1	7	4	7	3	4	3	3	4	3	5	4	90

Table 8: Performances of the reference actions of each category.

In this problem, the actions to be classified in the pre-defined categories are the current 28 MS of the EU. There were defined four categories, ordered by performance, to describe the performance of EE Governance of the MS: (1) C_1 – Very Good performance; (2) C_2 – Good performance; (3) C_3 – Moderate performance; and, (4) C_4 – Weak performance. All categories were defined with two reference actions, except C_4, which corresponds to the lowest performance (Table 8).

Thresholds	g1	g2	g3	g4	g5	g6	g7	g8	g9	g10	g11	g12
q	-	-	-	-	-	-	-	-	-	-	-	3
p	-	-	-	-	-	-	-	-	-	-	-	5

Table 9: Preference and Indifference thresholds of each criterion.

The method ELECTRE TRI-nC uses thresholds of preference and indifference to model the imperfect character of the data, as well as the arbitrariness that affects the definition of the criteria. These thresholds were defined as shown in Table 9. Note that there were no thresholds defined for the criteria that is described by qualitative scales of levels, since due to their nature these thresholds are not applicable. This happens because the attribution of a level in a criterion for a certain action is exclusive (it is not possible for an action to be defined by two different levels of a qualitative scale). Note that would be possible to add veto thresholds as well. In this case, it was not considered any veto threshold. However, this attribution may vary with the preferences of different decision makers.

5.3. Execution of the Model

Statistics :

<min,max>	#	%
<1,1>	1	3,5714%
<2,2>	3	10,7143%
<2,3>	2	7,1429%
<3,3>	18	64,2857%
<3,4>	4	14,2857%

ACTION	Minimum	Maximum
AT	C_3 Good	C_4 Very Good
BE	C_2 Moderate	C_2 Moderate
BG	C_3 Good	C_4 Very Good
HR	C_3 Good	C_3 Good
CY	C_3 Good	C_3 Good
CZ	C_3 Good	C_3 Good
DK	C_3 Good	C_3 Good
EE	C_3 Good	C_3 Good
FI	C_3 Good	C_3 Good
FR	C_2 Moderate	C_3 Good
DE	C_2 Moderate	C_3 Good
EL	C_3 Good	C_3 Good
HU	C_3 Good	C_3 Good
IE	C_3 Good	C_3 Good
IT	C_3 Good	C_3 Good
LV	C_3 Good	C_3 Good
LT	C_2 Moderate	C_2 Moderate
LU	C_3 Good	C_3 Good
MT	C_3 Good	C_3 Good
NL	C_3 Good	C_3 Good
PL	C_3 Good	C_3 Good
PT	C_2 Moderate	C_2 Moderate
RO	C_3 Good	C_3 Good
SK	C_4 Weak	C_4 Weak
SI	C_3 Good	C_3 Good
ES	C_3 Good	C_4 Very Good
SE	C_3 Good	C_3 Good
UK	C_3 Good	C_4 Very Good

Statistics :

<min,max>	#	%
<2,2>	3	10,7143%
<2,3>	1	3,5714%
<3,3>	17	60,7143%
<3,4>	7	25,0000%

ACTION	Minimum	Maximum
AT	C_3 Good	C_4 Very Good
BE	C_2 Moderate	C_2 Moderate
BG	C_3 Good	C_4 Very Good
HR	C_3 Good	C_3 Good
CY	C_3 Good	C_3 Good
CZ	C_3 Good	C_3 Good
DK	C_3 Good	C_4 Very Good
EE	C_3 Good	C_3 Good
FI	C_3 Good	C_3 Good
FR	C_2 Moderate	C_3 Good
DE	C_3 Good	C_3 Good
EL	C_3 Good	C_4 Very Good
HU	C_3 Good	C_3 Good
IE	C_3 Good	C_3 Good
IT	C_3 Good	C_3 Good
LV	C_3 Good	C_3 Good
LT	C_2 Moderate	C_2 Moderate
LU	C_3 Good	C_3 Good
MT	C_3 Good	C_4 Very Good
NL	C_3 Good	C_3 Good
PL	C_3 Good	C_3 Good
PT	C_3 Good	C_4 Very Good
RO	C_2 Moderate	C_2 Moderate
SK	C_3 Good	C_3 Good
SI	C_3 Good	C_3 Good
ES	C_3 Good	C_4 Very Good
SE	C_3 Good	C_3 Good
UK	C_3 Good	C_3 Good

Figure 3: Results for 2013 (left) and 2016 (right) for the set of weights defined in Hypothesis 1.

Once all information inserted on the MCDA ULaval software, the results were obtained for a level of credibility of $\lambda = 0.6$. The results of the first executed model can be seen in Figure 3 for both years. Note that, in some cases, there is a non-agreement between the maximum and minimum categories. This is justified due to the lack of enough data to attribute an action to only one category. These situations are usually solved with the input of a formal decision maker in order to attribute the action to the most adequate category.

In a general look, most countries maintained their category, 5 improved and 2 got worse. The two countries that presented worse results in 2016 are Romania and the United Kingdom. The situation of Romania is justified by lack of data since its NEEAP of 2017 was not available in the EC website and the document used as source of information was the Annual Report of 2017 – which is quite limited in comparison with the NEEAP. In the end, there was significant lack of information to justify the measures. Regarding United Kingdom, the drop is caused by the lack of quality in the information from NEEAP 2017, since many measures were not described with a good level of detail, and for that reason there was lack of evidence on implementation of several measures. The United Kingdom's ODEX also dropped slightly in comparison to 2013. Portugal and Slovakia presented the best evolutions in the results, but both are justified with the lack of data available in 2014 NEEAPs. The Portuguese NEEAP of 2014 was a document of very poor quality regarding its purpose. Indeed, it described many actions for the EE improvement, but it did not respond to the matters exposed in EED. For this reason, the specific and needed information was not reported and so it was not possible to understand the real efforts for the year of 2013. In 2017, Portugal presented a proper NEEAP with the expected information and therefore was evaluated accordingly. A similar situation happened regarding Slovakia, since the NEEAP of 2014 was not available, and the source of information used for the 2013 model was its Annual Report of 2014, which is quite incomplete in comparison with the NEEAP. The other three countries that improved their categories in this period were Germany, Greece and Malta. Their improvements were supported by the better quality of evidence of their implemented measures reported in NEEAP of 2017.

The Balkan region presented good performances overall, especially Bulgaria and Greece. Both present very good evaluations in the most important criteria (g12) the ODEX, which sustains their good global performances. At the same time, it is interesting that France and Germany did not present solid performances. Indeed, for both cases, the quality of the reported information in the NEEAPs was not generally detailed and based on evidence. Belgium was another example of a central European country with a performance that falls short. In both years, Belgium was only able to achieve the categories C2 – Moderate.

5.4. Sensitivity Analysis

a) Credibility level variation λ: the model was tested with $\lambda = 0.7$. In 2013, the differences are that Bulgaria and the United Kingdom drop to C_3, France and Germany drop to C_2 and Slovakia improves to a minimum of C_1 and a maximum of C_2. In 2016, the differences are that Bulgaria, Denmark and Greece drop to C_3 and Slovakia improves to a minimum of C_1 and a maximum of C_2.

b) Parameter Z variation: the model was tested for Z = 9 and Z = 11, for both credibility levels $\lambda = 0.6$ and $\lambda = 0.7$. The results coincided with the results of the models for Z = 10.

6. Conclusion

The method ELECTRE TRI-nC was shown to have potential for sorting problems as the one presented. The results appeared quite consistent, even after the sensitivity analysis. The countries that showed better overall performances were Austria and Spain. The country that presented the worst performance in both years was Latvia, even though Slovakia presented worst results in 2013 (justified by the lack of reporting quality of the 2013 NEEAP). Belgium, France and Germany had performances below the average in almost all model executions. In the end, most of the countries were attributed to C_2 – Good category, which

indicates that mandatory measures by the EU present a good global level of compliance.

Indeed, there are some considerations that must not be forgotten. First, note that this thesis is a first approach on the evaluation of EE governance capacities and there is a general lack of data to support all defined criteria. In this case, since most of the criteria was based on information reported in the NEEAPs, the information of these reports played the major role on the final performances of each country. Indeed, the information reported on these documents does not ensure total reliability and transparency. A possible solution is to create a qualified entity, aware of a factual and transparent framework of evaluation, that execute the evaluation for all 28 MS. However, this would need more investment of capital, human resources and time. Generally, it was also identified a lack of evidence to support the results that are communicated in the reports. This creates some fuzziness and subjectivity on the final evaluation. A small point of improvement that might contribute to soften this situation is the creation of a fixed template for the NEEAPs. This way, each country would know exactly what type of information must be reported and it would also facilitate the comparisons between different countries. Another structural limitation was the strong presence of only one Directive on the whole framework. Even though, the EED covers most of the dimensions of the EE governance framework, it did not cover everything in each dimension. This thesis focused on the evaluation of the areas that already are covered by European legislation, but others might be added. Another more point to consider in future studies is to identify and quantify relations between criteria. In the limit, it would be interesting to develop a study on EE governance capacities by sector, in order to understand what type of measures to have a greater impact in the energy savings of a country.

In a general way, it is possible to understand that the European mandatory measures present a moderate level of compliance, and that the general commitment of reporting to EC by MS has improved since 2014 until 2017. Having this said, it would be beneficial to have a more rigid and exigent European legal framework on EE in the medium and long term. There is still room for improvement, even in countries with high competitiveness in their market as Germany and France.

This thesis presented a new approach of assessment on EE governance capacities supported in a MCDA method. In the end, it is clear that, as much as EE and energy sustainability are important for our society, there is a lack of studies and efforts that aim to contribute to this the solution of this problem.

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