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Decision making in the Investment in Renewal Energy according to each EU Region

Sérgio Miguel Couto Neto

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Sérgio Miguel Couto Neto

under orientation of
Dr Ozren Despic

and co-orientation of
Dr Gonçalo Faria

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Abstract

The European Commission is increasingly pressuring its members to become carbon neutral. Wherefore, it is pertinent to develop a decision support tool for investing in renewable energy projects customised for each member of the European Union. To accomplish this objective, the use of Data envelopment analysis (DEA) was considered appropriate, either through CRS models or VRS, when possible, as the valuation method for the various existing investment options. Therefore, based on the primary renewable sources described by IRENA, geothermal energy, hydropower, solar energy (photovoltaic and thermal) and wind energy (onshore and offshore), it was possible to build 62 portfolios through their combinations. In this way, each investment option is mirrored as DMUs that will be evaluated on four different thematic: economic, technology, environmental and social, thus resulting in what will be defined as sustainable efficiency.

With the objective of exploring different alternatives for the inclusion of themes in the models, four hypotheses were developed, considering the use of weight restriction, the equal distribution of the weight of energies in the portfolios and alternatives for the representation of the technological thematic in the model. The inclusion of more comprehensive variables from the four previously mentioned groups allows the reduction of the gap in the evaluation of renewable energy investment projects, considering the most studied factors in the academic environment over the years, and, thus, allowing a more sustainable vision.

The support tool was personalised in this Business Project, considering the German context. In this sense, it was intended to collect the German figures of the representative variables and to perceive the usefulness of the developed models' results. After the elaboration of the models, it was possible to perceive that several suffered from difficulties in discriminating the DMUs; however, their results showed significant similarities in terms of the average evaluation of efficiency and the number of efficient DMUs between the VRS models and between the models CRS, with exceptions.

In total, 19 different DMUs were considered efficient, of which 12 were shared by three or more models of the different hypotheses. Taking into account their compositions, it was perceived the substantial importance of wind energy, particularly onshore and solar energy, especially photovoltaic, thus corresponding to the energy sources highlighted as fundamental for the conversion of the economy into a greener one by the German Federal Ministry for Economic Affairs and Climate Protection. Despite the presence of several limitations, such as the lack of data related to the German context, or the impossibility of implementing restrictions to create a lower limit on the weight of the variables, it is possible to observe the inherent value of DEA as a tool that enhances opportunities and allows a possible resolution of problems in complex contexts. Regardless this project insights, further studies are recommended, considering additional renewable energies, such as Bioenergy and the use of DEA models that better consider the complexity of the renewable energy environment, such as the geometric efficiency model. Additionally, inserting new comprehensive variables representing the four thematic would be advantageous for perceiving the capacity and the relative differences in the evaluation of DMUs through this method. Nevertheless, DEA seems to prove to be a valuable and transparent tool in analysing investment possibilities, thus serving as an essential support to decision-makers.

Keywords: Data Envelopment Analysis, German Renewable Energy Efficiency Evaluation; Sustainable Efficiency; Renewable Energy Portfolios Evaluation; Weight Restrictions; European Union Renewable Energy sector

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Abreviations

CRS – Constant Returns to Scale

CSP – Concentrated Solar Power or Solar Thermal

DEA – Data Envelopment Analysis

DMUs – Decision-Making Units

EU – European Union

IRENA – International Renewable Energy Agency

LCOE – Levelised Cost of Electricity

MCDM – Multi-Criteria Decision-Making

PV – Photovoltaic Energy

UN – United Nations

VRS – Variable Returns to Scale

Introduction

Nowadays, we can find "a force so dreadful it must be repelled, all former enmities aside"[1]. It is the case of one of the global issues published by the United Nations (2022): Climate Change. It is easy to understand that the problem of global warming is, as the name implies, global, which affects everything and everyone who lives on the Blue Planet. In this case, European greenhouse emissions may not only affect the region itself but also Maldives, Peru, etc. (Akram, 2022). Therefore, it is evident that Climate Change is not a fight between the UK and France or Nigeria and India, but of us against all of us, where the result can only be a victory for all or none. In recent years, we have seen an increase in storms and forest fires in the United States of America (Kenward et al., 2016) and in Europe (Turco et al., 2016); we see the rapid rise of the sea(Church & White, 2011), threatening millions of coastal cities and the extinction of countless species that regulate the planet's ecosystem(Lassalle et al., 2010). In this sense, various organisations, countries, and communities have joined forces to win this battle, as is the case of the European Union (EU).

On December 11, 2019, the Green Deal was presented, a plan that leads the EU member states to guarantee a fair and inclusive energy transition, meeting the climate and environmental challenges, thus creating a more sustainable European economy. This vision of the Commission is in line with the agreement concluded at the Paris climate conference (COP21), which shows the commitment of almost 190 parties to combat climate change. Jimmy Carter, the 39th President of the United States, once said, "Unless both sides win, no agreement can be permanent". The European Commission decided to go further

[1] Quote from the character Adrian Veidt from the book Watchmen written by Alan Moore and Dave Gibbons. (Moore & Gibbons, 2020)

and implement the European Climate Law that institutionalises the European Green Deal goal of achieving climate neutrality for Europe's economy and society by 2050 (and reducing net greenhouse gas emissions by at least 55% by 2030). Thus, the Member States of the EU have to focus on decarbonising the sector that contributes more than 75% of the EU's greenhouse gas emissions: the energy sector (European Commission, 2022b). To this extent, the management of EU countries regarding the energy transition must take into account three fundamental principles, as agreed in the Green Deal (European Commission, 2022b):

1. "ensuring a secure and affordable EU energy supply";
2. "developing a fully integrated, interconnected and digitised EU energy market";
3. "prioritising energy efficiency, improving the energy performance of our buildings and developing a power sector based largely on renewable sources".

Therefore, in the next 30 years, there should be a substantial public and private investment in changing energy sources and the respective infrastructures (EU, 2020). Consequently, a question arises with more importance than ever: "Which energy sources should we invest in to ensure that the EU's environmental objectives are met?"

This question and all the associated paradigms serve as the foundation for the present business project. Bearing in mind the value of the words "sustainability" and "efficiency" today and in the future, it is essential to direct them toward the development of the European energy sector. Hence, this work aims to present one valid path to analysing different renewable energy investments from the point of view of efficiency and sustainability. Regarding the latter, it was intended to define it through four distinct factors: technological, economic, environmental, and social. Then, using the data analysis development method, the efficiency of the respective renewable energy sources[2] will be evaluated, considering the four aforementioned factors. Ultimately, this business project aims to develop a personalised tool to support the investment decision for the governments and European institutions/organisations through constructing a quantitative model. Through this model, a country, for example, considering its characteristics and the data of existing energy production infrastructures, will be able to classify which investments guarantee more significant efficiency. Thus, in this paper, the member state under analysis is Germany; however, it is intended that the model can be extrapolated to other countries using their respective data. It should also be noted that the evaluation and analysis developed only considers the investment in energy production, not its distribution. Therefore, in this business project, one can expect a description of the context of the EU energy sector, specifically the available mechanisms to alter this sector and the transformations itself. Additionally, attention will be paid to investments in renewable energy sources through the methodologies and factors used to evaluate them. After this comprehension, it will follow an explanation of the framework used, the DEA, and its characteristics. Furthermore, several models are going to be explored, considering different factors included in their formulations. Finally, the results will be shown, and the differences and similarities between them will be comprehended, culminating in the final insights of this business project.

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[2] Appendix 1 contains a concise overview of the renewable energy employed in the creation of this business project.

Literature Review

For developing this Business Project, it is vital to be aware of related topics such as the context of the EU's energy sector, its evolutions and the policies that support them. Additionally, it is crucial to go into detail on research methods for decision-making on the respective transformations of the sector and to understand which variables impact the success of an energy investment project. In light of this background, it will become clearer to understand the actions taken throughout the project.

1. European Energy Policy

As mentioned in the previous point, there is a great determination on behalf of the EU to fight climate change through the carbon neutralisation of all activities carried out in the community. This intention translates into the conclusion of agreements between the Member Countries and the consequent development of roadmaps, guidelines and supervision to ensure compliance with the objectives.

Concerning the energy sector, Member States, in order to comply with the obligations imposed by the European Climate Law and consequently the Green Deal, must develop "national energy and climate plans" based on five different dimensions of the Energy Union (European Commission, 2022c): decarbonisation (greenhouse gas reduction and renewables); energy security; energy efficiency; internal energy market and research, innovation and competitiveness.

The last submission was made in 2019 regarding the plans from 2021 to 2030. However, despite of this time span focus, these plans must be in accordance with the long-term national strategies developed by the Member States. Therefore, considering these obligations, it is noticeable that in the national energy and climate plans, we can find measures that allow at least a 55% reduction of net emissions of greenhouse gases as compared to 1990 and a sustainable path towards achieving climate neutrality by 2050. In other words, the absence of investment in renewable energies within countries is inconceivable, both short/medium term and long term. As an example, in the plan submitted by Germany, it can be found that "the purposeful, efficient, grid-synchronous and increasingly market-oriented expansion of the use of renewable sources of energy is a crucial component in the achievement of the national climate goals in the energy industry". Similar statement is advocated in the Latvian Member State plan, "At the same time, in order to ensure Latvia's energy security and to provide society with cheap and competitive energy, Latvia should ensure an increase in the share of RES, which should obviously be provided using the most cost-efficient technologies". Therefore, investment in renewable energy is always considered indispensable, whatever the country's objective.

The results observed in **Figure *1*** were highly positive regarding the progress of the European community in the area of renewable energies and concerning the goals outlined for the share of renewable energy in energy consumption by the EU for 2020. All Member States reached their targets, except France, which presented a result lower than intended by 3.9 percentage points.

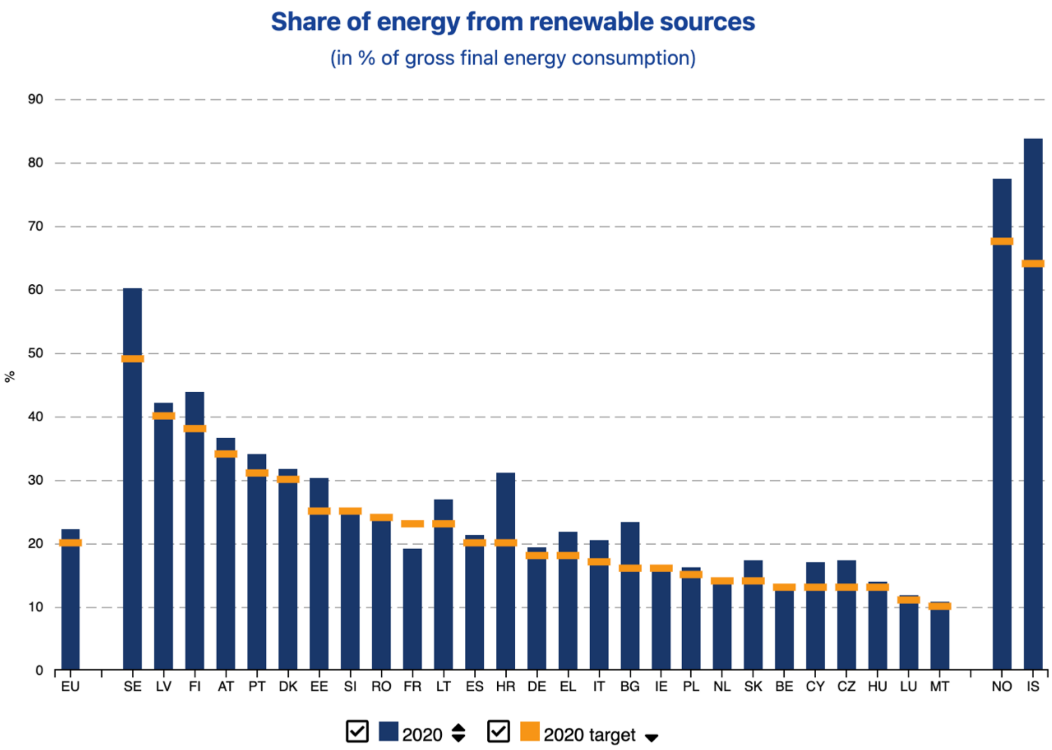

Figure 1 - Share of energy from renewable sources
Source: (EUROSTAT, 2022b)

However, these results can lead to erroneous interpretations about the efficiency of countries in meeting environmental goals, since due to the actions to combat and mitigate the Covid-19 pandemic the consumption of fossil fuels was impacted, leading to its reduction and of the total energy consumed in the respective year. Consequently, the share of renewable energies increases, even maintaining the amount of energy produced in the "energy sources pie"(EEA (European Environment Agency), 2022).

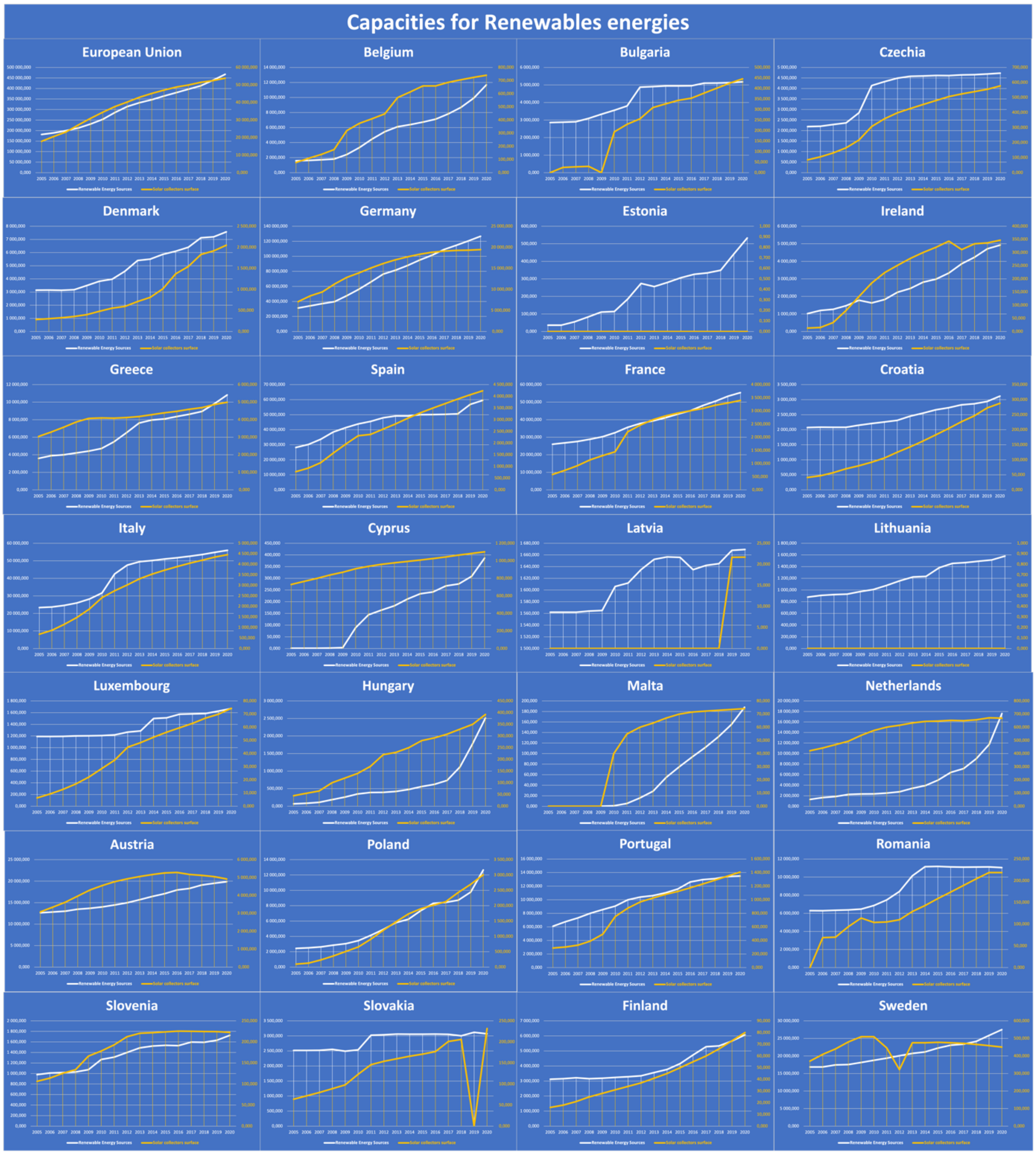

Figure 2 - Renewable Energies Capacities
Source:(EUROSTAT, 2022c)

A good way of perceiving the investment in the generation of renewable energy is by analysing the evolution of its electricity production capacity (IEA, 2021a). Thus, based on the data provided in **Figure 2**, it is evident that all member states have followed an upward path in terms of their energy production capacity. However, even though in recent years it was witnessed an increase in investment in renewable energy in all countries, it should be noted that it will still be necessary to profoundly transform the energy system to reach the current 32% renewable energy target set by 2030(EEA (European Environment Agency), 2022). Moreover, a more prominent warning could be given if the European Commission's proposal to redefine the target set for 2030 to 40% is approved.

1.1 Incentive Mechanisms of EU Governments

The motivations behind the evolution of the energy sector in the EU are easily understood and can be visualized numerically in an equally clear way. Nonetheless, the central puzzle is not related to the energy sector supervision but the development of incentives for its transformation. In this way, numerous questions may arise regarding the state's role in this domain. First, it is essential to mention that the European Parliament and the Council of Ministers did not provide strong and concrete guidelines for the liberalization of the energy production market in European nations until 1997 (Heddenhausen, 2007).

Currently, we can see examples of public and private companies operating in this sector. Due to the market's growing competition and liberalization, all sectoral transformational mechanisms will need to take these two different ownership origins into account. Therefore, what mechanisms does the state have to promote the energy sector in its respective country? What are its efficiencies?

Governments implement a set of policy types when defining an incentive mechanism for the energy sector. In this case, since we are focusing on the role of the state, the **Table *1*** will only mention the policies that have a regulatory character according to the different characteristics presented (Haas et al., 2011):

		DIRECT		***INDIRECT***
		Price-driven	*Quantity-driven*	
Regulatory	*Investment focused*	Investment incentives Tax credits Low interest/soft loans	Tendering system for investment grant	Environmental taxes Simplification of authorisation procedures Connexion charges, balancing costs
	Generation based	(Fixed) Feed-in tariffs Fixed premium system	Tendering system for long term contracts Tradable green certificate system	
Voluntary	*Investment focused*	Shareholder programs Contribution programs		Voluntary agreements
	Generation based	Green tariffs		

Table 1 - Incentive Mechanisms
Source: (Haas et al., 2011)

Therefore, and since our geographical field of study is the EU region, the **Table 2** will only focus on and describe the most common policy support used by the respective governments(Kitzing et al., 2012):

MAJOR SUPPORT INSTRUMENTS	*DESCRIPTION*	*SUPPLEMENTARY SUPPORT INSTRUMENTS*	*DESCRIPTION*
Feed-In Tariffs (Fit)	A program in which the government agrees on a price per unit of electricity that a third party must pay to the RES producers. There are different types of FIT schemes like fixed feed-in tariff, time-dependent feed-in tariff, etc. ((EEA) European Environment Agency, 2022)	*Fiscal measures (TAX)*	As the name implies, it mainly embraces direct fiscal support. For example, Income tax reliefs, Electricity tax reliefs, Reduced value added tax (VAT), etc.
Feed-In Premiums (Fip)	RES producers gain a premium on top of the market price for their electricity production under this system. The FIP might be fixed or sliding. Fixed FIP are easier to design, but there is a risk of overcompensation in high market prices and undercompensation in low market prices.(Energypedia, 2022)	*Financing support (FIN)*	This scheme involves a variety of financial instruments such as loans with low interest rates, investments in the investor's equity, etc. that the national government assumes in order to help investors to gain more capital for the development of their projects.
Tenders (Tnd)	Calls for tenders for projects with specified capacity are launched by the responsible authority. Interested investors develop a bid taking into account the required support level and several other specifications. After the evaluation, the investor with the most interesting proposal wins the tender and becomes responsible for developing the respective project. Tenders for fixed Feed-in tariffs and Tenders for target-price Feed-in tariffs are the two different implementations of tender processes in the EU.(Kitzing et al., 2012)	*Investment grants (INV)*	Investment grants are non-reimbursable payments made by governmental (and European) agencies to investors in renewable energy projects during the construction phase of the project. However, payments are frequently contingent on the achievement of certain predetermined milestones.
Quota Obligations With Tradeable Green Certificates (Tgc)	Governments put quota obligations on consumers, suppliers, or producers to source a particular percentage of their electricity from renewable sources. This requirement is typically facilitated via tradable green certificates (TGC), which renewable producers can sell to the interested parties, therefore earn on top of selling electricity on the market. In contrast to FIT and FIP, where policymakers manage price levels, TGC is referred to be a 'quantity'-control tool.(Commission of The European Communities, 2008)		

Table 2 *- Description of Most Common Incentive Mechanisms*
Source: (Kitzing et al., 2012)

After understanding the mechanisms available and used by the members of the EU, it becomes easier to understand their strong influence when using one or a set of policies to boost and transform the energy sector. According to an OECD study(Geraldine Ang et al., 2017), these instruments effectively impact investment and research and innovation (R&I) in renewable energies, especially FITs in the EU. The combination of instruments and factors can leverage R&I in Both developed and emerging economies. Nevertheless, governments should also consider the factors that make up the existing environment in each country. According to the same study, the ease of doing business and the number of existing universities promote innovation in this area, and the explicit carbon price encourages investment within the EU.

Furthermore, on the one hand, considering the analysis based on developed economies, the introduction of tenders in an environment with a strong presence of state-owned companies tends to reduce their impact in terms of investment. On the other hand, greater degrees of direct state control over firms throughout the economy were found to have a favourable effect on renewables investment across OECD and G20 countries (even though that can be explained by the direct influence of green political agendas). Yet, one does not imply the other when it comes to investment and innovation. As an example, while tenders encourage investment, it implies that investors who struggle to win the respective tender will not have enough budget to spend on R&I, unlike Feed-in tariffs or other forms of support that may leave profit margins. It is thus evident that governments must not only consider the set of policies suited to their reality but also how to best position their economies and respective environments to attract investors.

1.2 Energy Investment Analysis Methods

After analysing the influence of the state in creating a captivating market for investors, it was identified a gap in the investment evaluation process or, in other words, the decision analysis of RES investments. Throughout history, several decision-supporting methods in the energy sector were developed, such as future energy demand forecast models (Bhatia, 1987) or the identification of lower cost options(Meier & Mubayi, 1983). New criteria have been included, such as environmental and social, thus making decision analysis a vital tool for strategic decisions and policy development. Currently, the three most common analysis models are Life cycle assessment (LCA), cost-benefit analysis (CBA) and multi-criteria decision-making (MCDM) (Strantzali & Aravossis, 2016).

1.2.1 LCA

LCA is a technique used to identify and analyse the environmental impacts through the quantification and comparison of the entire spectrum of environmental implications of materials and processes (inputs and outputs) used in the whole life cycle of a product, process or activity (Azapagic, 1999; S. Kim et al., 2012). Through this data collection and quantification of relevant inputs and outputs, it is also possible to identify opportunities to achieve environmental improvements. Over the years, this methodology has been used in different ways when it comes to analysing the energy sector, for example: to assess the environmental performance and the respective factors of renewable energies, to develop comparative analyses between different energy sources, to compute scenarios analysis, etc. (Lund & Biswas, 2008).

1.2.2 CBA

The CBA method is reflected in measuring the net present monetary value of processes or products by comparing overall benefits to the total costs of the entire procedure (Yeo et al., 2022). This method can be translated into the monetary quantification of all impacts (either internal, such as market prices, or external, which only indirectly influence the market mechanism) (Strantzali & Aravossis, 2016).

Thus, the positive impacts are seen as benefits and the negative ones as costs. In this way, the evaluation between projects can translate into the project with the greatest net present value or the lowest social cost, for example. Moreover, the advantages of this approach correspond to the easy understanding of the results since it translates the utility of the projects in monetary terms (Wegner & Pascual, 2011)and the production of outcomes on a scale that is compatible with the market mechanism.

However, the disadvantages are evident, such as the difficulty of converting non-traded goods into monetary terms, which directs this methodology to a more quantifiable field, such as operation and maintenance costs (Strantzali & Aravossis, 2016).

1.2.2 MCDM

Finally, MCDM is a technique that involves defining a solution that best satisfies several conflicting objectives through trade-offs or compromises (Cheng et al., 2006). Different methods outline the best path to obtain the most efficient solution (Strantzali & Aravossis, 2016), such as weighted averages, priority setting, outranking, fuzzy principles, and several method combinations (Wang et al., 2009).[3]

[3] For the comprehension of MCDA methods through a specific example, see Annex 1.

1.2.2.1 DEA

Several studies and analyses have been carried out on the characterization of this method as an MCDM (Doyle & Green, 1993; Mousavi-Nasab & Sotoudeh-Anvari, 2017; Opricovic & Tzeng, 2003; Sarkis, 2000), even though there is no apparent consensus among all academics. In fact, there are several papers addressing issues related to the measurement of renewable energy efficiency through DEA. Concretely, one can access analyses where "conventional" DEA and modified DEA were used (Davoudabadi et al., 2021). However, if looking into detail, it is possible to find research based on economic and technologic efficiency (Boubaker, 2012; Davoudabadi et al., 2021; K. T. Kim et al., 2015; Liu et al., 2021), in which variables such as "Debt/equity ratio", "Total production of renewable energy"and "Investiment for Renewable energy Development" are considered as inputs, and "Total relative savings", "Energy Security", among others, as outputs. Additionally, it is still possible to find other papers which includes an environmental dimension, such are the cases, where the "CO_2 Emissions" or "CO_2 Emissions Avoid" is inserted in the model (San Cristóbal, 2011; Zha et al., 2016). Nevertheless, there are analyses (Davoudabadi et al., 2021; Menegaki, 2013) that considered aspects of four different areas: economic, technologic, environmental, and social. However, especially considering the last two areas, their representation is not comprehensive as it could be. That is, considering the environmental factor, there are more environmental impacts, as mentioned later, than greenhouse emissions. In terms of the social aspect, even though "Job Creation" and the "Contribution to Regional Development" impact public acceptance, it is not *per si* sufficient to portray the acceptance of the population since, as discussed later, the residents must be aware of such benefits and considerate it compensatory.

In short, there is a lack of assessments of renewable energy investments considering in a comprehensively way all the factors previously stated. In other words, there is the need to evaluate these investments through DEA, considering what will be afterwards explained as sustainable efficiency.

2. Energy Production - European Context

The energy available from the members of the EU comes from the members themselves and from third parties, which makes it essential to consider domestic production and imports when analysing the mix of sources used. Regarding the weight that the latter hold, in 2020, 58% of the energy used came from third countries, a reduction of two percentage points compared to the previous year (also explained by the impacts of the covid-19 pandemic). Concerning the mix of energy sources used in the EU, it is composed of 5 different sources: petroleum products (including crude oil) (35%), natural gas (24%), renewable energy (17%), nuclear energy (13%) and solid fossil fuels (12%). However, it is vital to mention that the distribution and weight of energy sources differ significantly amongst nations, as seen in the **Figure 3** (EUROSTAT, 2022b):

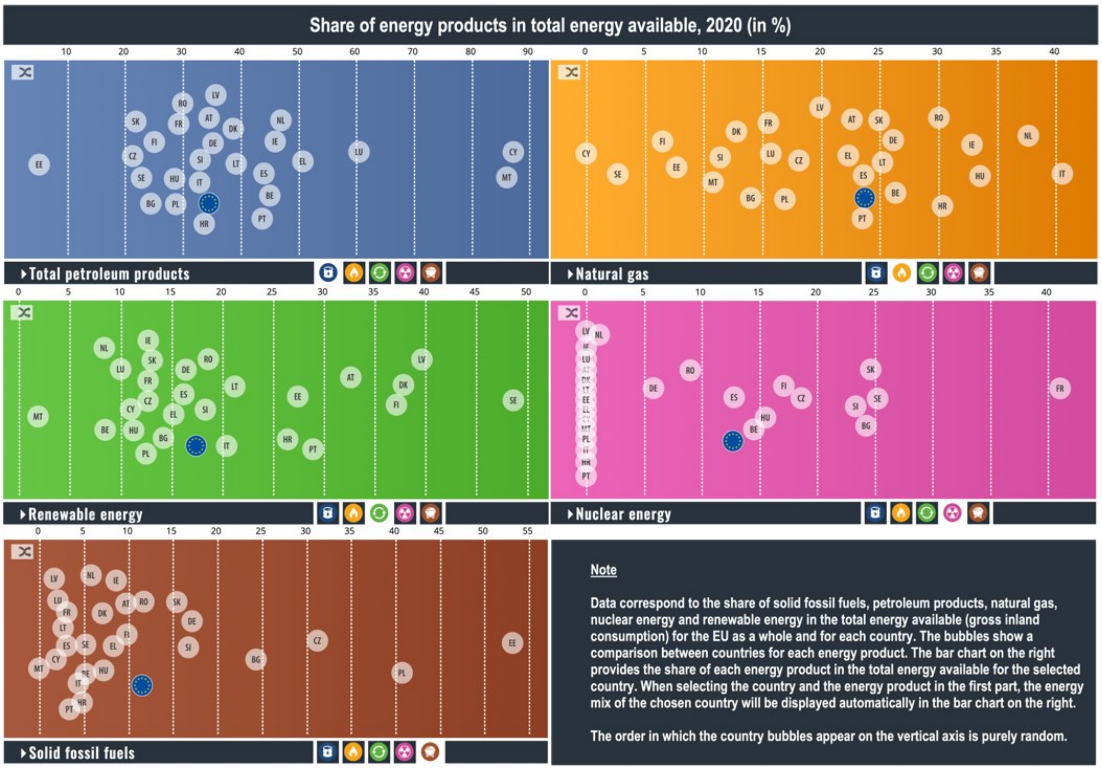

Figure 3 - *Share of energy products in total energy available, 2020 (in %)*
Source: (EUROSTAT, 2022b)

In terms of primary energy production, renewable energy accounts for 41% of the total energy produced in the EU in 2020, followed by nuclear energy (31%), solid fuels (18%), natural gas (7%), and crude oil (4%). As before, this distribution differs from country to country, as it is stated in **Figure 4**, (EUROSTAT, 2022b).

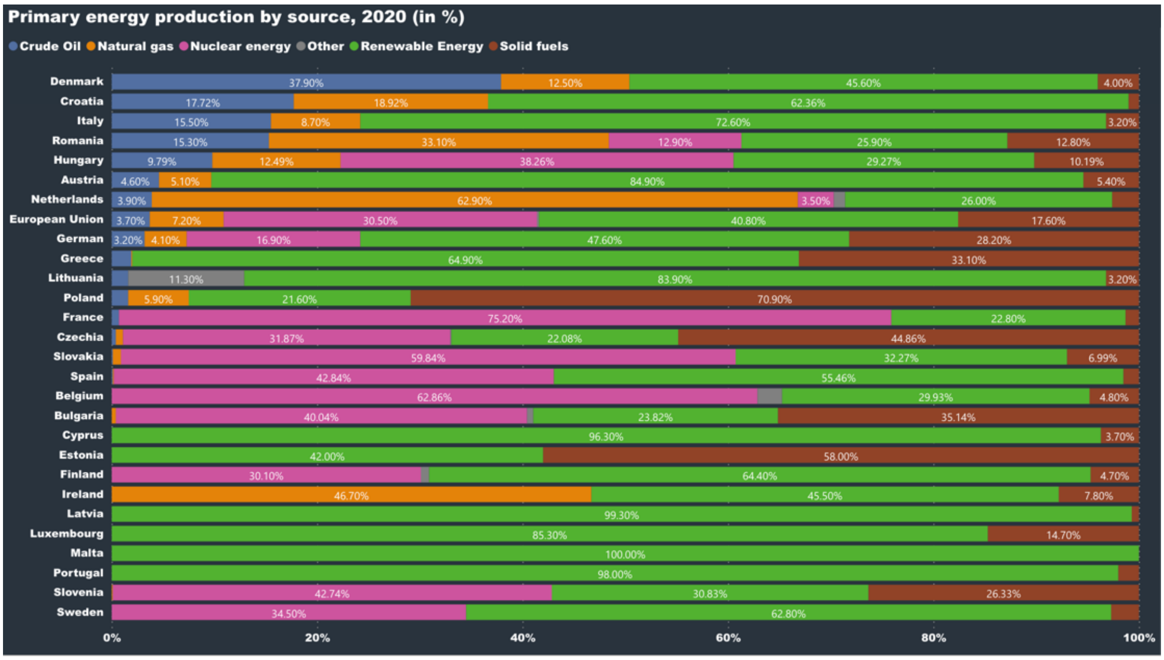

Figure 4 - *Primary energy by source, 2020 (in %)*
Source: (EUROSTAT, 2022b)

Through flow diagrams, we can examine the energy products of a country and perceive the entire amount of energy extracted from the environment, exchanged, converted, and utilized by end-users in the EU.

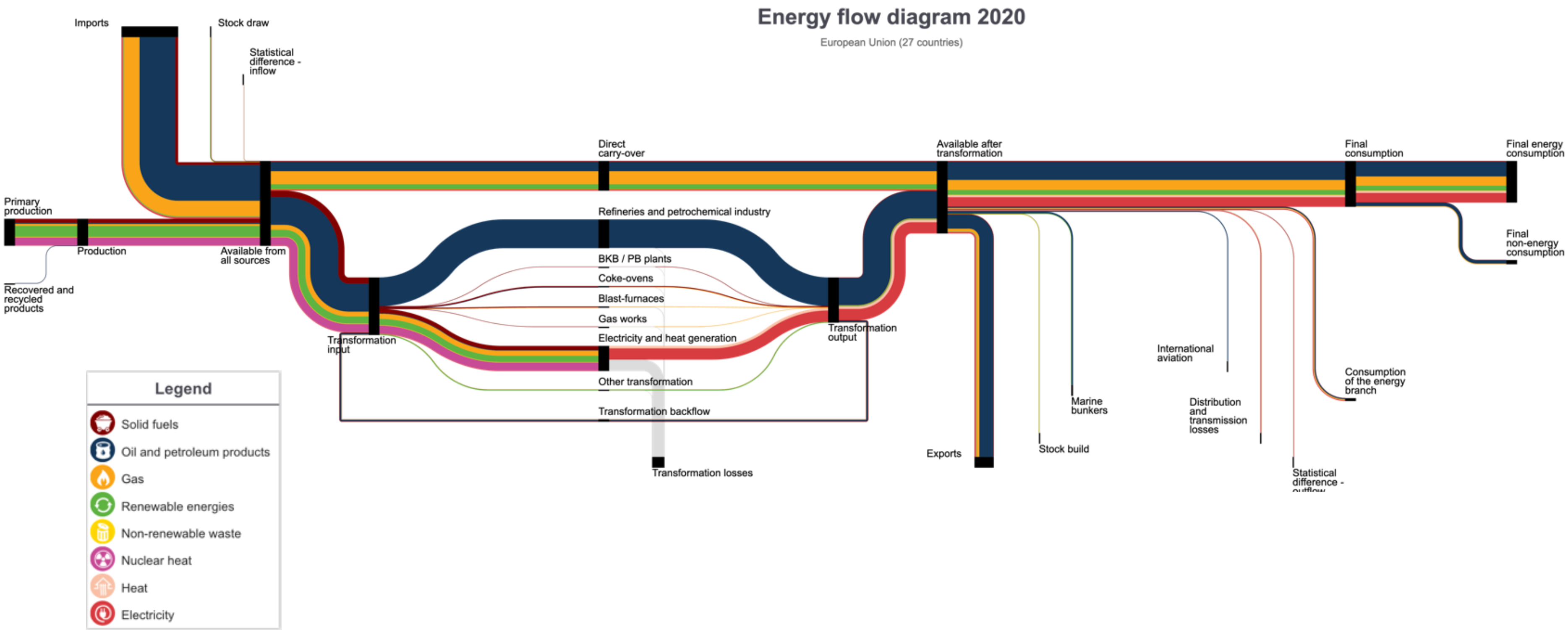

Figure 5 *- Energy Flow Diagram - All Energy Sources*

Source: (EUROSTAT, 2022b)

When visualising the flow of energy available in the EU, presented in **Figure 5**, one can quickly notice that it exhibits a high energy-dependent rate, precisely 57.5%(EUROSTAT, 2022b). It should be noted that the main imported products are Oil and petroleum products and gas. After obtaining the energy, either by its internal production or by importing, part of it is directed to the transformation process, in which, for example, wind, gas or nuclear energy is used to produce electricity and heat. Moreover, it is also in this process that crude oil and other intermediate materials are transformed into refined petroleum products (like gasoline, diesel oil, fuel oil, lubricants, etc.), along with other types of minor transformations[4]. However, another energy portion does not go through any transformation process as it can be used in its original form, which is the case of the heat produced by pump heat and natural gas. Part of the energy available after these two phases is exported (26.6% in 2020); the rest is mostly directed to final consumption (63.3% in 2020), specifically for the sectors of industry, transport, and households, among others.

[4] For a better understanding of the processes see Annex 2.

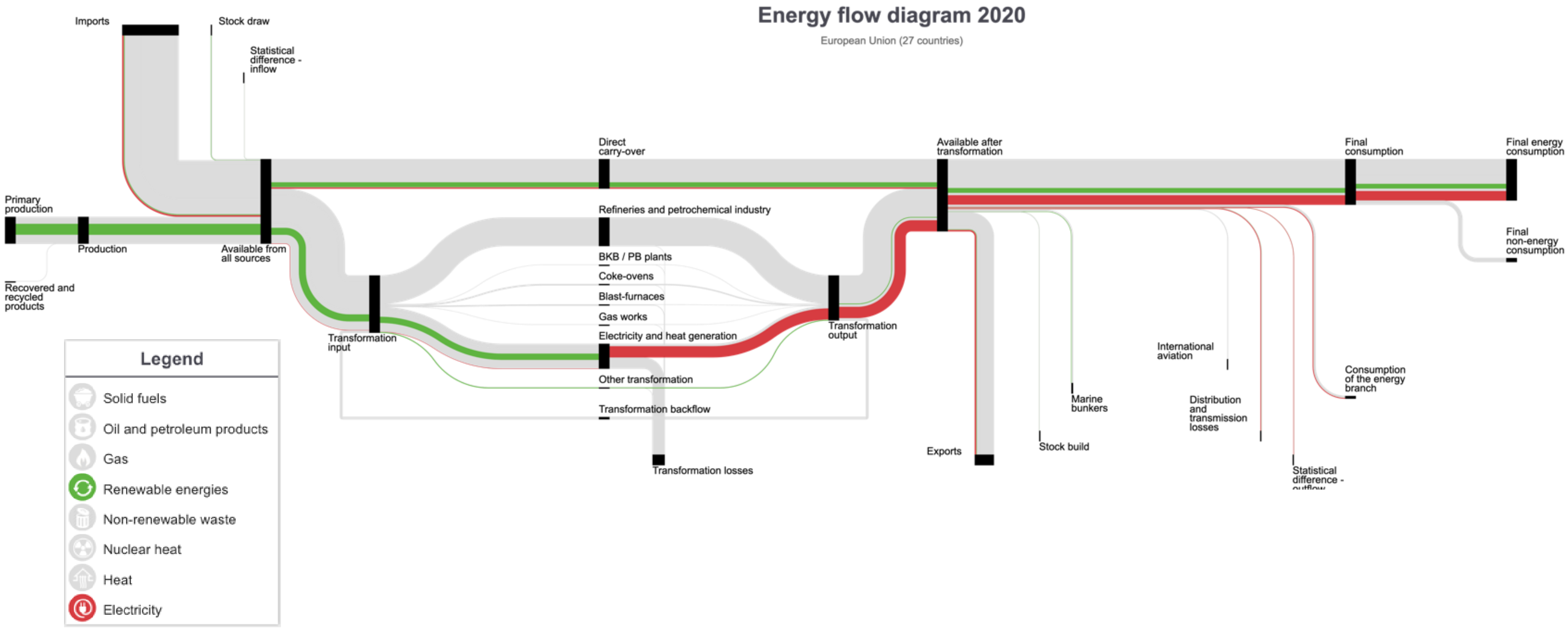

Figure 6 - *Energy Flow Diagram 2020 - Renewable Energies and Electricity*
Source (EUROSTAT, 2022b)

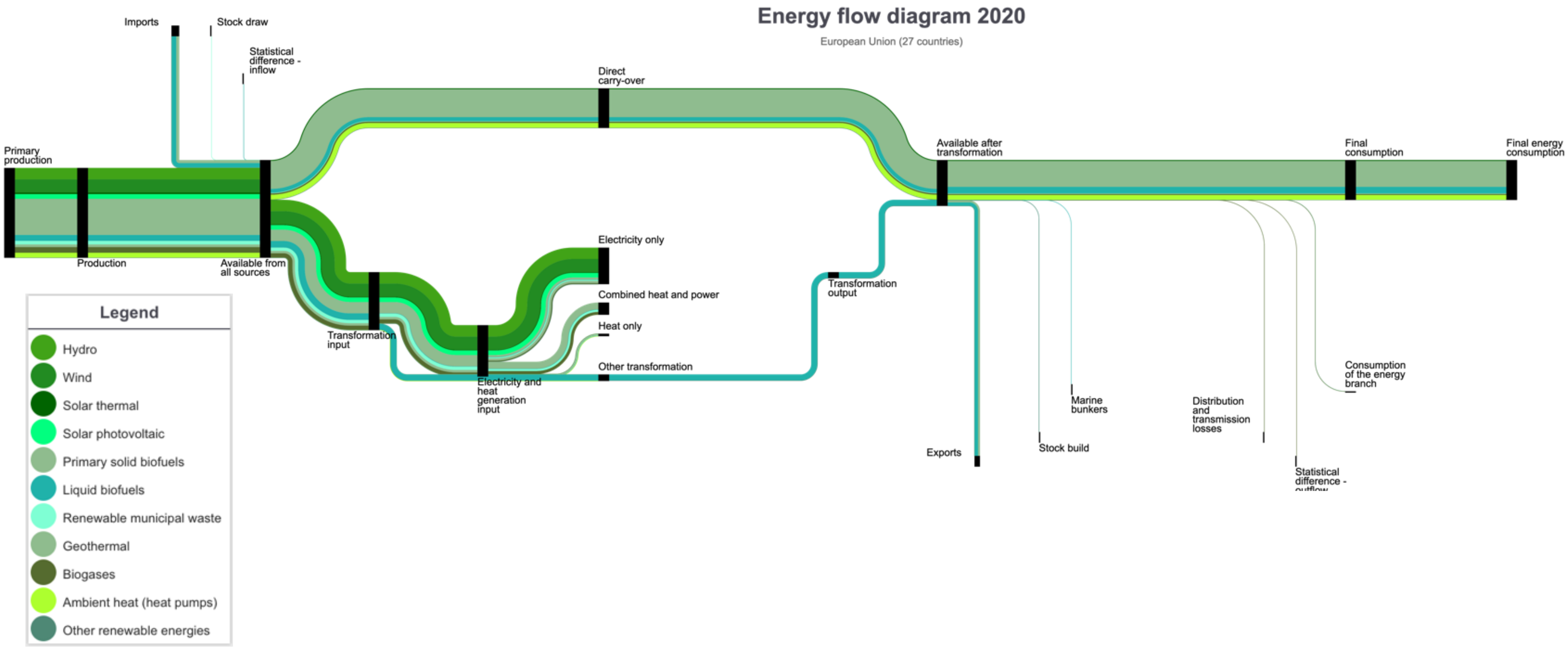

Figure 7 *- Energy Flow Diagram 2020 - Renewable Energies*
Source: (EUROSTAT, 2022b)

Nevertheless, considering the energy analysed in this project (renewable energies), it is essential to carry out an identical energy flow analysis, by looking at **Figure 6** and **Figure 7**. Within this energy source, the main imports refer to biofuels (Liquid and Primary Biofuels). When it comes to the transformation process, we can perceive the exclusivity that hydro, solar photovoltaic and wind sources have in producing electricity. In contrast, thermal and geothermal are more dispersed between their direct use and their transformation into electricity and heat. In addition, we see that the energy from heat pumps and biofuels is involved in a process mostly without transformation. After the transformation, the primary sector using renewable energy, either through electricity or through its direct use, are households (38.7% in 2020) and the industrial sectors (30.3% in 2020), and services (19.1% in 2020).

2.1 Public Acceptance

From this point, we have an idea of the current scenario of renewable energy production in the EU. Its benefits are immense, such as greater energy security, using inexhaustible resources[5], and reducing greenhouse gas emissions, among others (Olz, 2007). However, regarding environmental impacts, much concern is raised regarding the respective negative externalities of these renewable sources. This concern is of high importance since the social acceptance of renewable energies is one of the essential factors in the investment and development of renewable energy infrastructure (Segreto et al., 2020). In this sense, numerous factors influence public opinion, the most impacting being (Segreto et al., 2020):

[5] Except bioenergy which is dependent on biomass and other resources. For example, it can suffer the risk of not having sufficient material to produce energy.

SOCIAL ACCEPTANCE DRIVERS	*DESCRIPTION*
Trust in Governance and Procedural Justice	It has to do with the fact that the community must perceive the process of transformation of the energy sector in a clear and transparent way, and the dissemination of information and the incentive for community participation are extremely fundamental for this gain of trust. The lack of accessible and truthful communication regarding the benefits and costs of these projects, creates a negative perception of REP for the community.
Distributional justice	More in terms of local acceptance, a determining factor is the equal distribution of the benefits gained by residents, since they have to bear part of the costs (visual pollution, for example). This perception of costs and benefits is fundamental when it comes to the support that the community offers to projects, in particular the understanding of possible financial incentives, for example, lower energy rates, opportunities for employment, or tax returns.
Siting issues	It was evident that siting would be the main factor in terms of social acceptance, due to the respective physical characteristics necessary for the production of renewable energy. Thus, communities fear that there may be harmful effects on human health and the environment. Additionally, there is also a concern about the impacts that these infrastructures may have on the quality of life of citizens, such as the disturbance of the aesthetic quality of the landscape and the reduction in the value of properties surrounding the energy production plants.
Socio-demographic factors	Despite recent studies demonstrating that general demographics do not reach a moderate weight as a factor of social acceptance, there are strong positive correlations between high levels of acceptance with a higher level of education and a younger age. However, it is worth noting that the participation in discussion sessions and knowledge sharing for citizens at the other extreme of these demographic factors, mitigates this evidence.

Table 3 *- Social Acceptance Drivers*
Source: (Segreto et al., 2020)

On the other hand, there are ways to mitigate these drivers, as some were mentioned in **Table 3**. In particular, one can verify that the community's involvement in an embryonic phase of the project's development, through discussion panels and informative sessions, allows developers to create a connection of trust among the community. Additionally, it can destroy prejudices and develop an agreement that mitigates the main concerns of the population and reward their losses.

Additionally, through this explanation of costs and clarification (or addition) of benefits, and for example, through the creation of a local supporters' network, which publicly supports the renewable energy projects (Segreto et al., 2020), investors will be able to transform in advance a project threat, into a community strength. Finally, it is critical to identify strategies to mitigate the impacts of infrastructure on communities, which will be examined in further depth later.

In addition, in previous lines, it was presented two concepts, local acceptance and social acceptance. Although the former is part of the latter, in this report, the term "social acceptance" has a more global or national character since we are talking about investments across borders. In contrast, local acceptance, as the name implies, refers to an issue more individual to the citizen since his locality may be involved. However, it is important to understand that the same person can have a level of local acceptance that is entirely different from the level of social acceptance. For example, a citizen can vote for a significant investment in renewable energy in his country, but as long as it is not in his region or close to the main points of his daily life (Not in My Back Yard phenomenon). A research conducted in 2015 in Germany evaluating the acceptance of a wind farm 500 meters from a home, onshore, and offshore wind farms in the nation provides evidence of this variation in a more quantitative panorama. The results showed that the acceptance rate for the first case is 35% versus 52% and 66%, respectively (Sonnberger & Ruddat, 2017).

When we focus on a European context, we realize that the EU citizens have a strong conviction regarding the development of energy through renewable energies (Spandagos et al., 2022). According to data from the Special Eurobarometer 513: Climate Change surveys, shown in **Figure 8**, the EU population strongly believes in the transition from the current economy to a greener one. Through the topics presented in figure 8, we can observe a generalized concern about climate change. It is worth noting the great dissatisfaction of citizens regarding the actions of their respective governments, except Finland, which was the only country with less than 50% of the population agreeing with this statement (35%). Additionally, we perceive that the main tool to tackle climate change is the transformation of the different sectors existing in the EU, especially the energy sector. All related topics brought by **Figure 8** have the support of more than half of the population, particularly the definition of more ambitious goals for the EU and the strong investment in these energy sources.

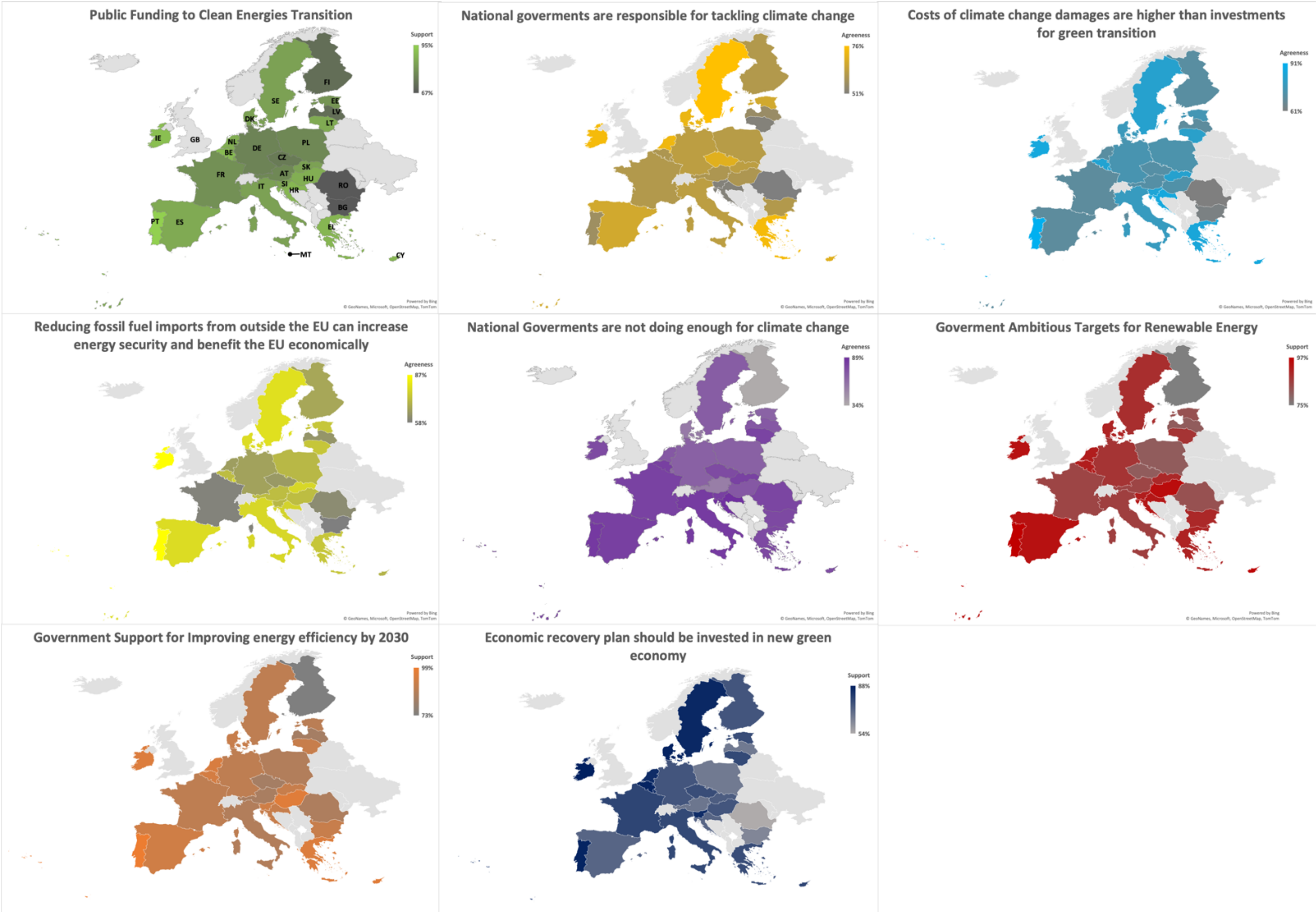

Figure 8 *- the Special Eurobarometer 513: Climate Change surveys*

Source: (Directorate-General for Communication, 2021)

There are still two points to mention, the remaining benefits of renewable energies perceived by the European population and the need to improve energy efficiency. Concerning the first, the results show that, on average, in the EU, 70% of the population believes that reducing imports of fossil fuels will help to grow the European Union and make it economically stronger. This belief sends a powerful signal to European countries' rulers. Regarding the last point, the intention to improve energy efficiency is an important sign as it can open the door to an increase in investment in renewable energies, since investment in efficiency and renewable energy when thought in parallel, can bring great advantages for the future (Gielen et al., 2015).

2.2 Environmental Impacts

2.2.1 Life Cycle Emissions

Even though the European population has a strong yearning for sustainable development, as previously mentioned, certain factors affect the acceptance of new actions, such as investment and construction of renewable energy production plants. In particular, it is important to focus on the siting issues.

Considering a life cycle assessment, it would be misleading to say that renewable energy production does not constitute any environmental pollution. Let us think about the infrastructure's construction. We understand that this implies using materials and energy whose production involves using fossil fuels or deforestation; for example, mining aluminium and steel operation processes regarding the construction of photovoltaic solar energy plants (Silva & Raadal, n.d.).

However, it is not just solar photovoltaics which the principal global warming potential (GWP) pollution moment is construction. As it is shown in **Figure 9**, it is also the case for wind energy (both offshore and onshore), concentrated solar power, and hydropower. On the other hand, there are some renewable sources whose main moment of pollution of GWP of the life cycle is found in production, as is the case of geothermal and renewable waste (Bouman, 2020).

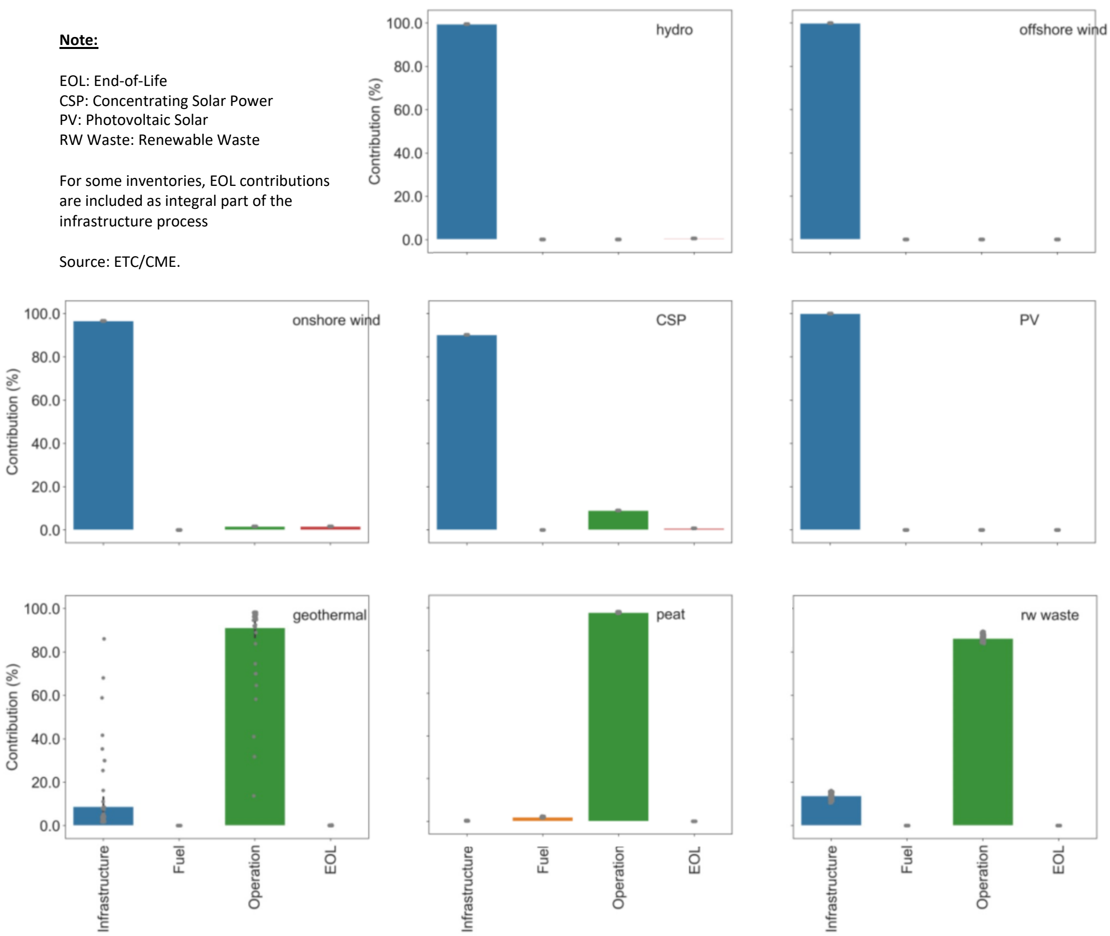

Figure 9 - *Life Cycle Emissions of Energy Sources*
Source: (Bouman, 2020)

Regarding environmental impacts, we can list six critical categories, as it is show in **Table 4**:

CATEGORY	*DESCRIPTION*
Climate Change (Global Warming Potential)	The term "global warming potential" refers to the capability of a unit of emissions released in the present to retain heat in the atmosphere over a given time period, as measured in comparison to a reference gas, CO_2, which has a GWP value of 1 (EPA, 2014).
Freshwater Eutrophication	Freshwater eutrophication is the result of nutrient runoff into soil or freshwater bodies, followed by an increase in nutrient levels (namely, of phosphorus and nitrogen). There are several environmental impacts related to freshwater eutrophication, for example an increased intake of nutrients in freshwater increases the amount of nutrients taken up by organisms such as cyanobacteria and algae and hence there are potential losses to biodiversity (Verones et al., 2020).
Particulate Matter Formation	Particulate matter (PM) is mixture of solid and liquid particles present in the air, some of which some can only be detected using an electron microscope, for example particules with diameters that are 10 micrometers and smaller (PM_{10}). Because these particules are so tiny, they can be ingested and cause major health concerns. For example, the previously mentioned particule type, PM10, can penetrate deep into the lungs, and some may even enter the bloodstream. The particules that represent the greatest risk to health are the particles with less than 2,5 micrometres in diameter ($PM_{2,5}$) (EPA, 2022).
Terrestrial Acidification	Terrestrial acidification is defined by changes in soil chemical characteristics due to the deposition of acidifying nutrients (mostly nitrogen and sulfur). Increased concentrations of acidifying nutrients in the soil reduce soil fertility, jeopardizing plant development (such as seed germination failure or a reduction in new root formation) and, in extreme situations, plant diversity (Verones et al., 2020).
Freshwater Ecotoxicity	Freshwater ecotoxicity is defined by the number of toxic elements (contaminants) present in an environment, such as in water and sediments, that affect the normal development of the existing biodiversity(WA Goverment, 2022).
Land Occupation	The occupation, settlement, or proprietorship of solid areas of the earth's land (EEA (European Environment Agency), 2017).

Table 4 *- Environmental Impacts Description*
Source: (EEA (European Environment Agency), 2021)

After understanding and obtaining the aforementioned categories, it is easier for us to compare the environmental impact of each energy source in an identical way, considering its annual life cycle. Therefore, **Figure 10** shows us this same comparison and its evolution between 2005 and 2018 in the 27 EU countries (EEA (European Environment Agency), 2021).

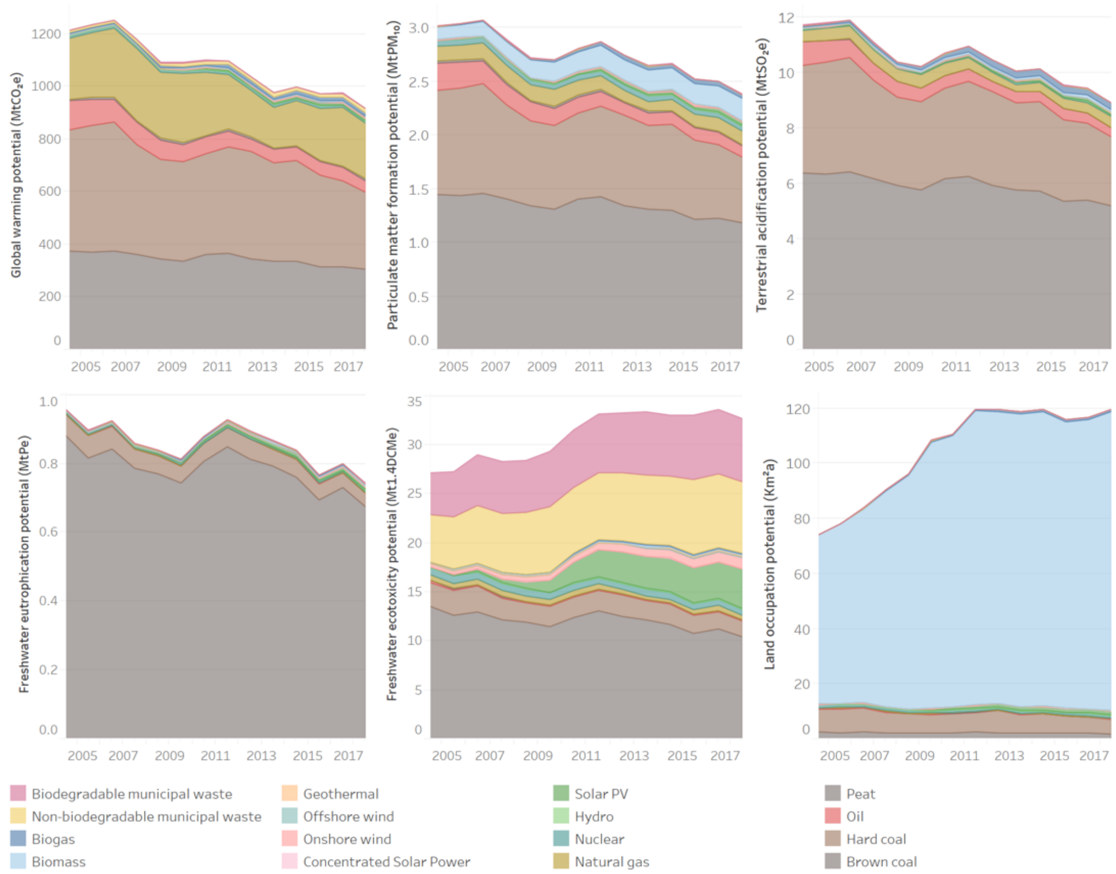

Figure 10 - *Environmental Impacts [2015-2018]*
Source: (EEA (European Environment Agency), 2021).

As we can see, the energy sources with the most significant environmental impacts on energy production are non-renewable, specifically, coal combustion, followed by the emissions from natural gas and oil burning. Regarding the individual analysis of the categories, the investment in renewable energies resulted in the reduction of the emission of GWP, the formation of Particle matter, terrestrial acidification and freshwater eutrophication in 2018 compared to 2005.

However, the same cannot be said for the freshwater ecotoxicity and land occupation impacts, where the weight distribution of all categories is distributed equally, except for the impacts that bioenergy from Biomass have on land occupation. Thus, we can say that concerning these last two categories of environmental impacts, the introduction of renewable energies in the energy sector led to their increase in 2018 compared to 2005 (EEA (European Environment Agency), 2021). It is also important to note that Biomass also shows an upward trend in terms of particle formation.

On the other hand, although renewable energies imply an environmental impact, this does not indicate that their investment will increase the damage caused to planet earth. Clear examples include the introduction of measures, strategies and even the perception of the manufacturing requirements for plants construction. For example, regarding photovoltaic solar energy, end-of-life material recovery enables emissions reduction. Moreover, the increasing weight of renewable energies in the electricity sector indicates a larger use of electricity and heating from clean energy in the manufacture of materials required for energy production, implying a reduction in pollution throughout the life cycle. Additionally, there is still room for the development of more efficient technologies that allow, for example, the use of less space to produce energy from biomass fuels.

2.2.1 Social and Ecosystem Impacts

Nevertheless, other types of environmental impacts are crucial for the success of a clean energy project since, as mentioned above, they are the main concerns of citizens, such as visual and sound impacts (Devine-Wright, 2005; Stigka et al., 2014). In this way, it is crucial to go into detail about the misperceptions and ways to mitigate the negative externalities feared by citizens. Therefore, we will address the main measures regarding wind, hydro, geothermal and solar (Rabaia et al., 2021; Sayed et al., 2021), as these are the energies that will come under the most scrutiny in this report.

In this sense, when it comes to wind energy, its location is essential to address numerous concerns of the population. Firstly, regarding noise pollution, the distance from the residential area reduces sound disturbance and prevents electromagnetic interference, which can distort television and radio broadcasts. Secondly, in terms of visual pollution, the location avoids impacts such as the shadow flickering, the Disco Effect (periodic flashes of light) and a marked degradation of the visual of the surrounding ecosystem. Thirdly, concerning animal impact, choosing a suitable location can reduce the death of numerous species, such as birds, bats and dolphins (considering offshore wind turbines). However, although there are some relationships between the death of species and these infrastructures, it is interesting to notice the following statistic provided by **Figure 11**, which shows us how sometimes our perceptions may not be adequately positioned in real-world contexts:

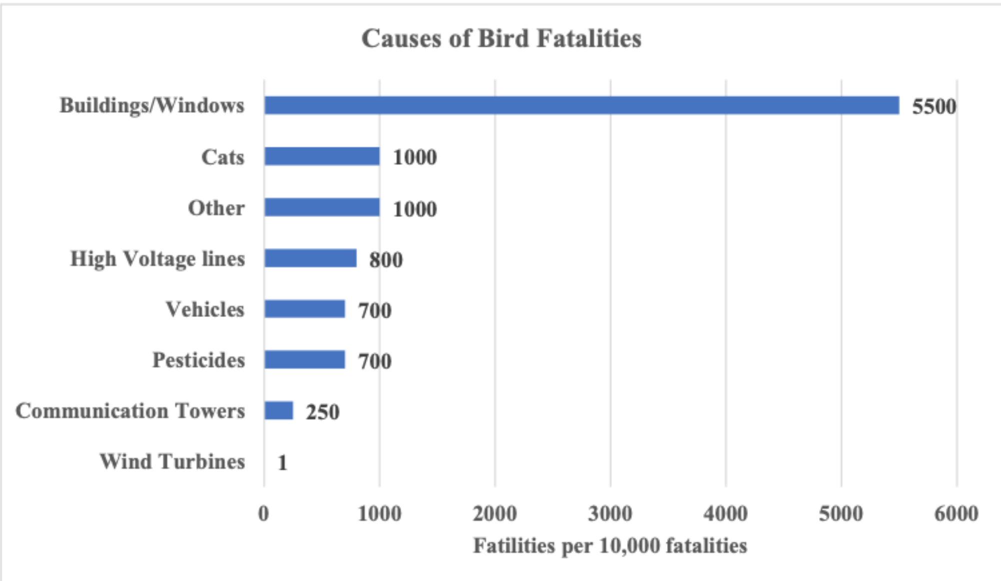

Figure 11 *- Wind Energy Impacts - Causes of Bird Fatalities*
Source: (Sayed et al., 2021)

It is also important to mention some additional measures, such as appropriate and more meticulous overall blade design and proper acoustic insulation for the inside of the turbine housing that attenuates noise pollution. For addressing visual pollution, the turbine's pixels can be mixed with the background or surrounding pixels at the turbine's edges.

As for hydropower, some environmental impacts are difficult to assess and address. For example, through the change in water flow, a greater erosion effect caused by the turbines produces a more significant transport of sediments and consequently their sedimentation in new places, causing changes in ecosystems. On the one hand, it can create artificial reefs and increase the availability of nutrients, thus boosting the existing ecosystem; however, it can also create the perfect environment for non-native predators. Additionally, there is also the possibility that these infrastructures may cause possible aquatic life threats through collisions and underwater noises. Nevertheless, mitigation measures already exist for certain impacts, for example, the use of noise-cancelling materials and techniques or coating materials that prevent radiation and contamination. Finally, and most importantly, as for wind energy, a studied and carefully considered infrastructure construction site choice can alleviate numerous dangers to the existing ecosystem.

Regarding Geothermal energy, several environmental impacts are associated with the respective energy extraction process. For example, land subsidence, induced landslides and seismic activities due to the flow of hot water/steam, soil contamination through leakages or even the discharge of used water (which contains pernicious materials and salts), noise pollution, offensive odour, etc. These impacts can be dangerous for humans, especially workers in these facilities, and the ecosystem itself. However, as other energies, there are measures to mitigate environmental impacts. Once again, the location and adaptation of the infrastructure construction to the surroundings are fundamental for mitigation and may even create synergies, resulting in the preservation of the environment with improvements in the plant's performance. Furthermore, it is crucial to develop good waste management or control systems, such as hydrogen sulfide abatement system (Shortall et al., 2015). Additionally, there is another mechanism that translates into crossing geothermal energy with other renewable energy systems to reduce the land-use footprint, for example, the use of solar thermal energy to provide heat to the reservoirs.

Concerning solar energy, as mentioned above, the main polluting moment is the production of materials necessary for constructing the respective infrastructures; however, there are environmental impacts also associated with its installation and operation. Therefore, once again, the location of the installation is crucial for the mitigation of visual pollution, impacts on biodiversity and soil degradation; for example, the choice of a place uninhabited by species or that is not part of the path of migratory waves, the choice of already degraded lands, etc. (Hernandez et al., 2014). Regarding the use of water for panel washing and dust suppression, this is very low in terms of PV plants (0.02 m3/ MW h). The same cannot be said for CSP plants, which depends on the chosen cooling system: wet cooling (3.07 m3/MW h), dry cooling, or a combination of the two. As the name implies, the choice of dry cooling reduces water consumption by 90% to 95% (Hernandez et al., 2014). Another point worth mentioning is the decommissioning phase, which allows the toxic materials used in the construction of the panels not to pollute the environment and threaten human health and to be reused (Hernandez et al., 2014; Rabaia et al., 2021). Finally, other new measures must also be considered to reduce the environmental impact: the colocation of solar panels with agriculture, hybrid power systems, and the redefinition and innovation of technologies and plant design, among others (Hernandez et al., 2014).

As the name implies, the exposure of mitigation measures is of reduction and not elimination. Currently, in investing in renewable energies, there will always be environmental impacts, even if these are minor disturbances in the ecosystem. However, it is up to the construction project developer to consider all impacts and seek to mitigate them as much as possible with existing measures and capacities. Despite these impacts, the benefits associated with the reduction of energy production through fossil fuels are remarkable, which makes the option of renewable energies an undeniable way to protect the blue planet.

Methodology

1. Framework: DEA

This project is designed as one of the possible paths regarding decision support in renewable energy investments in the respective countries, which implies an evaluation of the respective alternatives. Thus, as mentioned in the literature review in chapter 1.2, different methods could be used to achieve the objective of this paper: LCA, BCA or MCDM. This report will perform the analysis using the DEA method.

There is no doubt that DEA is valuable as a decision support tool since it manages to define the efficiency of several alternatives or Decision-Making Units (DMUs) comparable according to several categories without a priori ranking. DEA also demonstrates the necessary changes in each category to increase each DMU's efficiency, among other advantages (Kotsemir, 2013; Zhou et al., 2008). It is precisely for the aforementioned advantages that the DEA method was selected, considering that the analysis environment is complex since it involves financial, technological, social and environmental parameters (Strantzali & Aravossis, 2016). Moreover, this choice was also motivated by the flexibility provided to the user when defining the category weights in the evaluation of DMUs, as it will be explained later. Thus, DEA is a nonparametric performance measurement technique developed by Charnes, Cooper and Rhodes to evaluate the comparative efficiency of homogenous operational units through the resources and environmental factors used by DMU's transformation process. It can also be used to select the ideal alternative among competing multi-attribute options (Thanassoulis, 2001). Therefore, the factors and resources used are then considered as inputs (which it is wanted to be minimized or maintained constant) and outputs (which it is wanted to be maximized or maintained constant) according to the transformation process. The DMUs with the best practice are going to be considered as (100%) efficient (pure technical efficient) and will form an efficient frontier as it is shown in **Figure 12**[6].

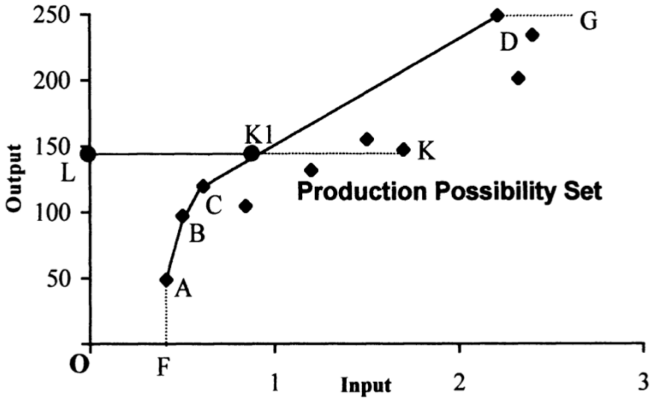

Figure 12 *- DEA Graphic Representation*
Source: (Thanassoulis, 2001)

Moreover, the method allows for the measurement of the non-frontier unit efficiency and the identification of necessary improvements in each factor for (inefficient) units to be technical efficient through benchmarks of the pure technical efficient ones (Cook & Seiford, 2009). It is also important to mention that the conventional DEA[7] can have four different models concerning the returns to scale conditions, constant or variable estimates overall efficiency, and the model orientation, input or output oriented (Fried et al., 2008; Thanassoulis, 2001).

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[6] Note that the graphic representation is not possible for DMUs with more than two inputs/outputs.
[7] There are other options that users may use, like the additive model, slacks-based measures, the Russell measure Network DEA, etc. (Cook & Seiford, 2009), but in this project, only the four mentioned models are going to be considered.

1.1 CRS Input and Output Oriented

Considering the constant return to scale, it estimates overall efficiency (i.e., pure technical efficiency and scale efficiency). Additionally, the fact that the orientation is different will not change how efficiency is calculated. However, the results will be regarded as the minimization of inputs of the inefficient unit, while its output proportions are held constant if we use input orientation. In the case of the output orientation, the model user will get findings that explain that for the unit to be efficient, for its current inputs, it has to increase the output in specific amounts. Mathematically, the general case of the input-oriented constant returns to the scale model can be translated as the following:

Considering n DMUs with m inputs and s outputs.

$$DMU_j, \sim (X_j, Y_j), \qquad j = 1, \dots, n$$

$$X_j=(x_{1j}, x_{2j}, \dots, x_{mj}), \qquad Y_j=(y_{1j}, y_{2j}, \dots, y_{sj})$$

The input-oriented envelopment form of the CRS Model for evaluating DMU_w is:

$$\boldsymbol{Min\ \theta}$$

$$\begin{aligned} \boldsymbol{s.t.}\ & \boldsymbol{\lambda_1 x_{i1} + \lambda_2 x_{i2} + \cdots + \lambda_n x_{in} \le \theta x_{iw}}, \quad \boldsymbol{i = 1, \dots, m}, \\ & \boldsymbol{\lambda_1 y_{r1} + \lambda_2 y_{r2} + \cdots + \lambda_n y_{rn} \ge y_{rw}}, \ \boldsymbol{r = 1, \dots, s}, \\ & \boldsymbol{\lambda_1,\ \lambda_2\ , \dots,\ \lambda_n \ge 0.} \end{aligned} \qquad \text{Model (Aa)}$$

In other words, we minimize theta ($\boldsymbol{Min\ \theta}$) according to three constrains:

- The input constrain, in which $\boldsymbol{\lambda_1 x_{i1} + \lambda_2 x_{i2} + \cdots + \lambda_n x_{in}}$, is less than or equal to theta times the respective input variable value;
- The output constrain, in which $\boldsymbol{\lambda_1 y_{r1} + \lambda_2 y_{r2} + \cdots + \lambda_n y_{rn}}$ is greater than or equal to respective output variable value;
- And finally according to the non-negativity constrain for the variables' lambdas.

At the end, we are going to get the following: $(\boldsymbol{\theta^*, \lambda_1^*, \dots, \lambda_n^*})$, which is the optimal solution of model. Specifically, we get or Efficiency score $\boldsymbol{\theta^*}$, which if equals to 1 it means that the respective DMU is technically efficient, otherwise, it translates that a decrease of the inputs is needed without reducing the number of outputs to achieve 100% efficiency. Regarding the efficient peers, the alternatives who the DMU can benchmark for improvement, they have positive value of $\boldsymbol{\lambda_j^*}$ at optimality.

It is also important to mention that there is the possibility of slacks existence or, in other words, even though a DMU can be in the frontier isoquant and be considered efficient, it can still make some additional improvement, like an increase in outputs or decrease in inputs to be as pure efficient as other units. In that case, the input-oriented envelopment form of the CRS Model is written like the following:

$$\begin{aligned} &\boldsymbol{Min\ \ \theta} \\ &\boldsymbol{s.t.}\quad \boldsymbol{\lambda_1 x_{i1} + \lambda_2 x_{i2} + \cdots + \lambda_n x_{in} + s_i^- = \theta x_{ip},\quad i = 1, \ldots, m,} \\ &\qquad\ \ \boldsymbol{\lambda_1 y_{r1} + \lambda_2 y_{r2} + \cdots + \lambda_n y_{rn} - s_r^+ = y_{rp},\ r = 1, \ldots, s,} \\ &\qquad\ \ \boldsymbol{\lambda_1,\ \lambda_2\ , \ldots,\ \lambda_n \geq 0.} \\ &\qquad\ \ \boldsymbol{s_i^-, s_r^+\ \geq 0,\quad i = 1, \ldots, m, r = 1, \ldots, s.} \end{aligned} \qquad \text{Model (Aa1)}$$

Regarding the Mathematical form of the general case of the output-oriented constant returns to scale model, it uses the same logic as the previous, but obviously with some differences like the maximization of the function, the interpretation of the final Fi (the equivalent of the input theta), for example. The output-oriented envelopment form of the CRS Model for evaluating DMU_w can be written as follows:

$$\begin{aligned} &\boldsymbol{Max\ \varphi} \\ &\boldsymbol{s.t.}\ \ \boldsymbol{\lambda_1 x_{i1} + \lambda_2 x_{i2} + \cdots + \lambda_n x_{in} \leq x_{iw},\quad i = 1, \ldots, m,} \\ &\qquad \boldsymbol{\lambda_1 y_{r1} + \lambda_2 y_{r2} + \cdots + \lambda_n y_{rn} \geq \varphi y_{rw},\ r = 1, \ldots, s,} \\ &\qquad \boldsymbol{\lambda_1,\ \lambda_2\ , \ldots,\ \lambda_n \geq 0.} \end{aligned} \qquad \text{Model (Ab)}$$

In this case, we maximize Fi ($\boldsymbol{Max}\ (\boldsymbol{\varphi}^{*}, \boldsymbol{\lambda}_{1}^{*}, \ldots, \boldsymbol{\lambda}_{n}^{*})$) according to these three constrains:

- The input constrain, in which $\boldsymbol{\lambda_1 x_{i1} + \lambda_2 x_{i2} + \cdots + \lambda_n x_{in}}$, is less than or equal to the respective input variable value;
- The output constrain, in which $\boldsymbol{\lambda_1 y_{r1} + \lambda_2 y_{r2} + \cdots + \lambda_n y_{rn}}$ is greater than or equal to Fi times the respective output variable value;
- And finally, the non-negativity constrain for the variables lambdas.

Like in the previous model, this optimization results into:

- $\boldsymbol{1/\varphi^{*}}$, which is the efficiency score of the unit DMUP.
- ($\boldsymbol{\lambda_1^{*}}$, ..., $\boldsymbol{\lambda_n^{*}}$), which represents what efficient peers the respective unit must reach to become fully efficient.

1.2 VRS Input and Output Oriented

In what matters the variable return to scale, this model decomposes overall efficiency into technical and scale efficiency, which pure technical efficiency has the effect of scale removed. Additionally, the only difference between VRS and CRS in the linear programming formulation is the insertion of a convexity constrain (underlined in Model Ba), which helps the model consider the different sizes of the DMUs when accessing them. It is also important to mention that, contrarily to the CRS model, the efficiency scores change if we swap the orientation of our model (input vs output). Additionally, in VRS, it is also possible to identify the returns to scale of each DMU: Increasing Returns to Scale, Constant Returns to Scale, and Decreasing Returns to Scale. One can write the linear programming problem of the input-oriented VRS model (with slacks) as follows:

$$\begin{aligned} &\boldsymbol{Min\ \theta} \\ &\boldsymbol{s.t.}\ \ \boldsymbol{\lambda_1 x_{i1} + \lambda_2 x_{i2} + \cdots \lambda_n x_{in}} + s_i^{-} = \boldsymbol{\theta x_{ip}},\quad \boldsymbol{i = 1, \ldots, m}, \\ &\qquad \boldsymbol{\lambda_1 y_{r1} + \lambda_2 x_{r2} + \cdots \lambda_n x_{rn}} - s_r^{+} = \boldsymbol{y_{rp}},\ \boldsymbol{r = 1, \ldots, s}, \\ &\qquad \underline{\boldsymbol{\lambda_1 + \lambda_2\ + \cdots +\ \lambda_n = 1}} \end{aligned}$$

Model (Ba)

$$\boldsymbol{\lambda_1,\ \lambda_2\ ,\dots,\ \lambda_n \geq 0.}$$

$$\boldsymbol{s_i^-,\ s_r^+\ \geq 0,\quad i = 1,\dots,m,\ r = 1,\dots,s.}$$

Regarding the linear programming problem of the output oriented VRS model we can represent it like the following:

$$\begin{aligned}
&\boldsymbol{Max\ \varphi}\\
&\quad \boldsymbol{s.t.}\ \ \boldsymbol{\lambda_1 x_{i1} + \lambda_2 x_{i2} + \cdots + \lambda_n x_{in} \leq x_{ip},\quad i = 1,\dots,m,}\\
&\qquad\quad \boldsymbol{\lambda_1 y_{r1} + \lambda_2 y_{r2} + \cdots + \lambda_n y_{rn} \geq \varphi y_{rp},\ r = 1,\dots,s,}\\
&\qquad\quad \boldsymbol{\lambda_1 + \lambda_2\ + \cdots +\ \lambda_n = 1,} \qquad\qquad \text{Model (Ba)}\\
&\qquad\quad \boldsymbol{\lambda_1,\ \lambda_2\ ,\dots,\ \lambda_n \geq 0.}
\end{aligned}$$

The interpretation of the results is the same as that done with the input/output CRS models. There is also a figure that the DEA users can obtain when resolving the previous optimizations, which is the Fully Efficient Target Point. In other words, the Fully Efficient Target Points are the level of inputs/outputs which the DMUs must reach to be fully efficient. In all those models presented, this can be obtained by multiplying the DMU input/output value by the respective lambda values: $\sum_{j=1}^{n} \boldsymbol{\lambda_j^*\ X_j}$, $\sum_{j=1}^{n} \boldsymbol{\lambda_j^*\ Y_j}$.

1.3 Weight Restriction

Additionally, as mentioned, one of the advantages of DEA is the dispensability of priorities or knowledge of the weight of the various inputs/outputs that each DMU uses/produces. The possibility for the model to define the relative importance for each DMU in a weights system makes this efficiency evaluation extremely flexible. This flexibility is important since, at the time of model implementation, users assume that all inputs/outputs are important, without knowing their respective weight, due to the complexity of the environment in which they are inserted. Thus, the model chooses the weights that portray each unit in the best possible way (Pedraja-chaparro et al., 1997). However, what if a decision-maker know that one input is at least two times more important than another? Can one not take advantage of this information (Golany, 1988)? Does the DEA become obsolete? It is in order to answer these questions that it is possible to restrict the DEA's flexibility in defining the weight of each variable. Weight restrictions are a helpful tool for using imperfect information from a complex environment that is difficult to characterize. However, it is crucial to be aware that one should not completely restrict the flexibility of the software since we would end up making the DEA irrelevant, developing only a ratio analysis (Pedraja-chaparro et al., 1997). In this way, new restrictions are inserted in the linear program formulation of the models, which in turn may reduce the efficiency of the DMUs. This reduction happens since the model may be limited to assigning a greater weight to the input than the DMU is more efficient, for example, through restrictions that make it impossible for the inefficient inputs of a specific DMU to receive a weight equal to zero (lower bound restriction). Evidently, with the introduction of restrictions, the efficiency of DMUs either remains or decreases. There are several approaches [8] to implement weight

[8] The red nomenclatures of the following equations are the values defined by the user in order to establish the respective restriction.

restriction in DEA. For example, the implementation of an absolute constraint on individual weights through numerical limits on each weight (Dyson & Thanassoulis, 1988).

$$Q2_r \leq V_r \leq Q1_r$$
$$P2_r \leq U_r \leq P1_r$$

Another option is the formulation of a relative constraint using the weight of an input/output as a standard for defining the weights of the remaining inputs/outputs so that the relationships between the various weights are established, according to the user's view. This method is based on the concept of "assurance region" (AR) (Thompson et al., 1990).

$$k_r U_1 \leq U_r \leq l_r U_1$$
$$p_r V_1 \leq V_i \leq q_r V_1$$

Additionally, one could also consider the importance of input measure i to DMUj ($\frac{V_i X_{ij}}{\sum V_i X_{ij}}$) and develop a constraint based on the use of proportions. Thus, by defining an upper and a lower bound, [a_i, b_i], the user is able to define the limits that he considers logical to the importance of input measure i to DMUj. The same applies in the case of outputs. (Wong & Beasley, 1990).

$$a_i \leq \frac{V_i X_{ij}}{\sum_{i=1}^{m} V_i X_{ij}} \leq b_i$$

Finally, the last-mentioned option, the Contingent weight restriction, has to do with the use of the AR principle and the use of the previously explained propositions. As an example, this method translates into the fact that the outcomes of the transformation process of DMUs assigned to an output cannot exceed the outcomes of another output by more than a certain multiple, for all i >1 (Pedraja-chaparro et al., 1997).

$$c_i V_1 X_{1j} \leq V_i X_{ij} \leq d_i V_1 X_{1j}$$

In this paper, the Performance Improvement Management (PIM) DEA software (PIM-DEA), developed by Doctor Ali Emrouznejad and Professor Emmanuel Thanassoulis (Emrouznejad & Thanassoulis, 2010) will be used in order to employ weight restriction and to obtain the results of the DEA method.

2. Aproach

The development of this project and, consequently, of the model considers the analysis of the investment of renewable energies of a single country belonging to the EU, although it is not impossible to extrapolate to a higher scope. In this way, the selected member state was the German country for the sake of greater availability and accessibility of data and academic studies related to it. Thus, the composition of the investment analysis will consider several different portfolios of renewable energies for two reasons. First, several studies relate the diversity of energy sources with the increase of energy security in the region and the enhancement of its efficiency (Gökgöz & Güvercin, 2018; Grubb et al., 2006; IRENA & C2E2, 2015; Lo, 2011; Sinsel et al., 2019; Zhu et al., 2020) which reminds us of the importance of the famous saying, "Don't put all your eggs in one basket". Second, empirically, investment in renewable energy over the years is not focused on a single energy source but on several, as we can see in **Figure 13**.

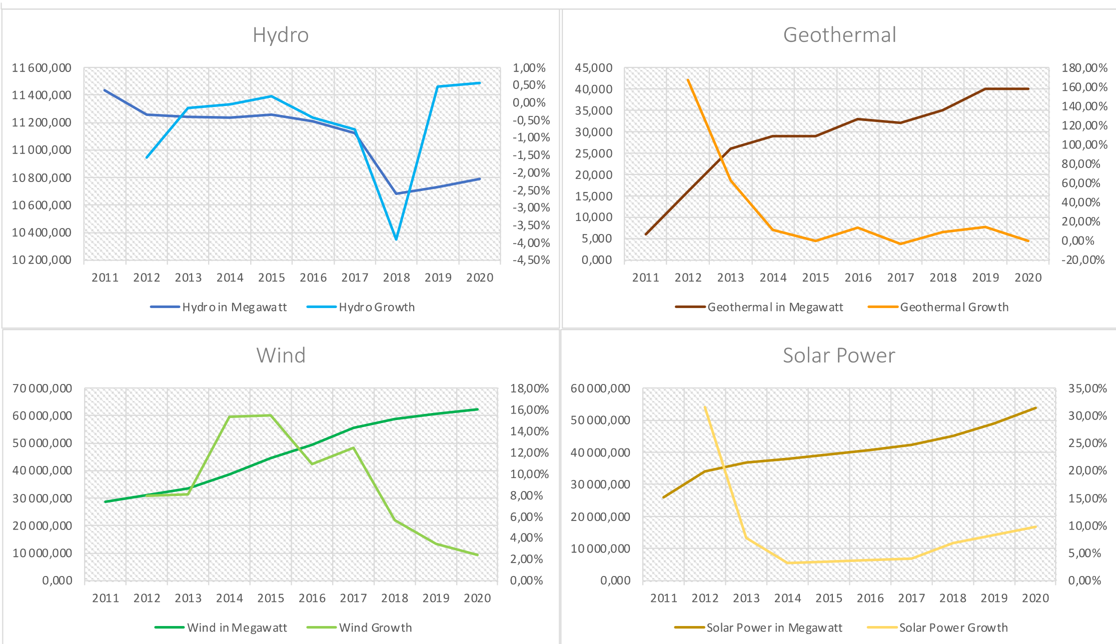

Figure 13 *- Germany Net Maximum Electrical Capacity*
Source: (EUROSTAT, 2022c)

Therefore, according to the International Renewable Energy Agency (IRENA), the primary renewable energy sources are Bioenergy, Geothermal, Hydropower, Ocean, Solar and Wind. In this sense, in the development of this project, we are going to focus on building different portfolios considering all the following sources, except for two of them: Bioenergy and Ocean. This exception comes from different reasons. Regarding ocean energy, according to IRENA, most of its technologies are still in the Research and Development phase and hence are not commercially available (IRENA, 2020), which makes it unreasonable to compare to other energies already vigorously employed and in a more mature state. Concerning Bioenergy sources, even though it will be crucial for reducing our carbon footprint, especially in the aviation and ship industry (Gates, 2021), the transformation process of this energy is not as homogeneous as the remaining energies themselves. For example, the production of some varieties like biomass (traditional bioenergy), which requires wood, or liquid biofuels (modern bioenergy) that use natural resources such as bagasse and oil crops. These requirements can imply the employment of farms or deforestation for the running of the respective operations and, therefore, the creation of an unsustainable ecosystem involving habitat destruction and more significant amounts of CO_2 released than ever imagined (Bourgeon & Ollivier, 2012; Chum et al., 2011). Even though it is known that the inputs used can be based on recycled material, there are no guarantees that the development of this type of project is going to be solely using reused material. Therefore, there are no guarantees that the development of this type of project will have the good direct and indirect impact as the rest of renewable energy sources have on the environment. Finally, there is great belief in bioenergy, and it is definitely a key player in a future sustainable world, but such must be under suitable supervision and a sustainable management plan (IEA, 2021b).

In this sense, the creation of the portfolio will be composed of the different combinations of Geothermal, Hydropower, Solar, which is divided between Solar PV and Solar thermal (CSP) and Wind, which is diversified by Wind onshore and Wind offshore. The previous distinction within Solar and wind energy source concerns the information available and displayed in IRENA datasets. There was additional research, for example, on EUROSTAT, yet the display of the values only respects the following criteria as it is shown in **Table 5**:

RA000	*Renewables and biofuels*
RA100	Hydro
RA200	Geothermal
RA300	Wind
RA410	Solar thermal
RA420	Solar photovoltaic
RA500	Tide, wave, ocean

Table 5 *- Renewables Categorization*
Source: (EUROSTAT, 2022c)

Additionally, one main reason for following the criteria of the values provided by IRENA instead of the ones provided by EUROSTAT was the personal belief that this distinction in the Wind energy could provide some value to the analysis. Therefore, we end up with six different energy sources:

- Geothermal
- Hydropower
- Solar PV
- CSP
- Wind onshore
- Wind offshore

Thus, calculating the combinations, in which order does not matter, between those mentioned above, it is possible to obtain the following 62 portfolio options (up to five different types of energy invested in each portfolio), shown in **Table 6**:

DMU	*ENERGY TYPE 1.*	*ENERGY TYPE 2.*	*ENERGY TYPE 3.*	*ENERGY TYPE 4.*	*ENERGY TYPE 5.*
DMUH	Hydro				
DMUG	Geothermal				
DMUWN	Wind Onshore				
DMUWF	Wind Offshore				
DMUST	Solar Thermal				
DMUSP	Solar Photovoltaic				
DMUHG	Hydro	Geothermal			
DMUHWN	Hydro	Wind Onshore			
DMUHWF	Hydro	Wind Offshore			
DMUHST	Hydro	Solar Thermal			
DMUHSP	Hydro	Solar Photovoltaic			
DMUGWN	Geothermal	Wind Onshore			
DMUGWF	Geothermal	Wind Offshore			
DMUGST	Geothermal	Solar Thermal			
DMUGSP	Geothermal	Solar Photovoltaic			
DMUWNWF	Wind Onshore	Wind Offshore			
DMUWNST	Wind Onshore	Solar Thermal			
DMUWNSP	Wind Onshore	Solar Photovoltaic			
DMUWFST	Wind Offshore	Solar Thermal			
DMUWFSP	Wind Offshore	Solar Photovoltaic			
DMUSTSP	Solar Thermal	Solar Photovoltaic			
DMUHGWN	Hydro	Geothermal	Wind Onshore		
DMUHGWF	Hydro	Geothermal	Wind Offshore		
DMUHGST	Hydro	Geothermal	Solar Thermal		
DMUHGSP	Hydro	Geothermal	Solar Photovoltaic		
DMUHWNWF	Hydro	Wind Onshore	Wind Offshore		
DMUHWNST	Hydro	Wind Onshore	Solar Thermal		
DMUHWNSP	Hydro	Wind Onshore	Solar Photovoltaic		
DMUHWFST	Hydro	Wind Offshore	Solar Thermal		
DMUHWFSP	Hydro	Wind Offshore	Solar Photovoltaic		
DMUHSTSP	Hydro	Solar Thermal	Solar Photovoltaic		
DMUGWNWF	Geothermal	Wind Onshore	Wind Offshore		
DMUGWNST	Geothermal	Wind Onshore	Solar Thermal		
DMUGWNSP	Geothermal	Wind Onshore	Solar Photovoltaic		
DMUGWFST	Geothermal	Wind Offshore	Solar Thermal		
DMUGWFSP	Geothermal	Wind Offshore	Solar Photovoltaic		
DMUGSTSP	Geothermal	Solar Thermal	Solar Photovoltaic		
DMUWNWFST	Wind Onshore	Wind Offshore	Solar Thermal		
DMUWNWFSP	Wind Onshore	Wind Offshore	Solar Photovoltaic		
DMUWNSTSP	Wind Onshore	Solar Thermal	Solar Photovoltaic		
DMUWFSTSP	Wind Offshore	Solar Thermal	Solar Photovoltaic		
DMUHGWNWF	Hydro	Geothermal	Wind Onshore	Wind Offshore	
DMUHGWNST	Hydro	Geothermal	Wind Onshore	Solar Thermal	
DMUHGWNSP	Hydro	Geothermal	Wind Onshore	Solar Photovoltaic	

DMUHGWFST	Hydro	Geothermal	Wind Offshore	Solar Thermal	
DMUHGWFSP	Hydro	Geothermal	Wind Offshore	Solar Photovoltaic	
DMUHGSTSP	Hydro	Geothermal	Solar Thermal	Solar Photovoltaic	
DMUHWNWFST	Hydro	Wind Onshore	Wind Offshore	Solar Thermal	
DMUHWNWFSP	Hydro	Wind Onshore	Wind Offshore	Solar Photovoltaic	
DMUHWNSTSP	Hydro	Wind Onshore	Solar Thermal	Solar Photovoltaic	
DMUHWFSTSP	Hydro	Wind Offshore	Solar Thermal	Solar Photovoltaic	
DMUGWNWFST	Geothermal	Wind Onshore	Wind Offshore	Solar Thermal	
DMUGWNWFSP	Geothermal	Wind Onshore	Wind Offshore	Solar Photovoltaic	
DMUGWNSTSP	Geothermal	Wind Onshore	Solar Thermal	Solar Photovoltaic	
DMUGWFSTSP	Geothermal	Wind Offshore	Solar Thermal	Solar Photovoltaic	
DMUWNWFSTSP	Wind Onshore	Wind Offshore	Solar Thermal	Solar Photovoltaic	
DMUHGWNWFST	Hydro	Geothermal	Wind Onshore	Wind Offshore	Solar Thermal
DMUHGWNWFSP	Hydro	Geothermal	Wind Onshore	Wind Offshore	Solar Photovoltaic
DMUHGWNSTSP	Hydro	Geothermal	Wind Onshore	Solar Thermal	Solar Photovoltaic
DMUHGWFSTSP	Hydro	Geothermal	Wind Offshore	Solar Thermal	Solar Photovoltaic
DMUHWNWFSTSP	Hydro	Wind Onshore	Wind Offshore	Solar Thermal	Solar Photovoltaic
DMUGWNWFSTSP	Geothermal	Wind Onshore	Wind Offshore	Solar Thermal	Solar Photovoltaic

Table 6 *- Portfolio Options Energy Source Composition*

After defining the respective portfolios, it is essential to define which parameters these DMUs will be evaluated. Let us start by remembering that in DEA development, the key word is efficiency, considering x inputs and y outputs. After reading and studying several approaches and crucial points regarding evaluating an investment in renewable energy projects, it became easier to start defining what kind of efficiency and parameters will be used in this project. Therefore, with the existing literature on this investment topic, one can define the evaluation criteria in four different types: Technical, Economic, Environmental and Social (Strantzali & Aravossis, 2016). The categories representatives of each type and their frequency is displayed in **Figure 14**:

Classification of criteria.

Technical criteria	%
Efficiency	31%
Reliability	20%
Resource availability	18%
Nominal power/Installed capacity (kW)	17%
Maturity	16%
Safety	10%
Energy production	9%
Demand	9%
Primary Energy Ratio (PER)	8%
Lifespan	8%
Continuity	5%
Stability	3%
Economic criteria	**%**
Investment Cost	52%
Operation and Maintenance Cost	34%
Energy cost	23%
Payback period	16%
Internal Rate of Return (IRR)	9%
Life Cycle Cost (LCC)	6%
Net Present Value (NPV)	5%
Service life	5%
Equivalent Annual Cost (EAC)	2%
Environmental criteria	**%**
CO2 emissions	52%
Land use	33%
Impacts on ecosystems	31%
NOx emissions	22%
SO2 emissions	17%
Emissions (generally)	17%
Noise	14%
Particles emissions	2%
Social criteria	**%**
Job creation	46%
Social acceptability	28%
Social benefits	15%
Visual impact	14%
Local development	13%
Impacts on health	10%
Income from jobs	8%

Figure 14 *- Most Common Energy Investment Criteria*
Source: (Strantzali & Aravossis, 2016)

In this way, the development of a project evaluation involving the four main characteristics studied and used over the years would become highly advantageous since it allows us to develop and evaluate a unique type of efficiency: sustainable efficiency[9]. Consider this nomenclature to be the type of efficiency that recognizes the social impact parameters and the technological (technical) factors, which we seek to maximize their relative impact, as well as the economic parameters and the environmental impacts, with the goal of minimizing their impact. Thus, in this paper, "sustainable efficiency" is a term that defines the most efficient alternative in protecting and responding to the challenges of the current and future ecosystem. Therefore, variables representing each characteristic were chosen, which will allow us to evaluate investment options based on their sustainable efficiency:

- **Energy Group:** Energy Production (Primary Energy) in Gigawatt-hour or Capacity Factor in percentage (of each Renewable energy source)
- **Economic Group:** Levelised Cost of Energy (LCOE) in USD/kWh
- **Environmental Group:** Global Warning Potential ($MtCO_2e$); Freshwater Eutrophication (MtPe); Particulate Matter Formation ($MtPM_{10}$); Terrestrial Acidification ($MtSO_2e$); Freshwater Ecotoxicity (Mt1.4DCMe); Land Occupation (Km^2a).
- **Social Group:** Public Acceptance in percentage (of each Renewable energy source)

As far as the Energy Group is concerned, the energy production in gigawatts per hour of each renewable energy was chosen because it is an element that best reflects the actual generation of energy, since it takes into account the technology used in the country and the conditions which it has to bear. For example, in the case of solar energy, even though the installed energy capacity is 1.5 Megawatts, this does not ensure that 3 Megawatt-hours of energy will be produced in two hours in cases where the weather conditions are a highly clouded sky. Thus, this variable translates into the measure of the output of German electricity power

[9] It should be noted that this nomenclature is nothing like interpretations such as the "more durable/self-sustaining efficiency" or a measure that indicates alternatives that do not have any impact on the ecosystem.

stations (EUROSTAT, 2013). On the other hand, the variable “Capacity Factor” was also thought since it precisely measures this difference between energy capacity and actual energy production. In other words, it is a ratio between the true output versus the potential output (Badgett et al., 2022; Neill & Hashemi, 2018).

Regarding the Economic Group, the choice of LCOE was preferred since it is a measure that considers the total installation costs, lifetime capacity factor, operation and maintenance costs, project economic lifespan, and capital cost (IRENA, 2022a). In this way, this single variable encompasses the main economic decision factors studied over the years, making it crucial for evaluating the efficiency of renewable energies.

Concerning the Environmental Group, the main environmental impacts of the renewable energy life cycle are covered, as already mentioned and explored in previous chapters. These variables are fundamental as they reflect the still existing impacts of self-considered "clean" energies.

Finally, as previously mentioned, the public acceptance of investment projects in renewable energies is of greater importance due to its impact on its success. Therefore, it was crucial to include it in the analysis of the efficiency of this type of energy. Moreover, since the definition of public acceptance encompasses benefits such as job creation, local development, and sustainable management of the respective environmental and social impacts, its inclusion in the model is more than enough.

Therefore, of all the characteristics studied academically over the years and previously mentioned, we managed to create our model and, through the chosen variables, include the following presented in **Table 7**:

ACADEMIC STUDIED VARIABLES	TYPE OF REPRESENTATION	REPRESENTATION GROUP
ENERGY PRODUCTION	Direct	Energy Group
INSTALLED CAPACITY	Indirect	Energy Group
LIFESPAN	Indirect	Economic Group
INVESTMENT COST	Indirect	Economic Group
OPERATION AND MAINTENANCE COST	Indirect	Economic Group
ENERGY COST	Direct	Economic Group
LIFE CYCLE COST (LCC)	Indirect	Economic Group
CO2 EMISSIONS	Direct	Environmental Group
EMISSIONS (GENERALLY)	Direct	Environmental Group
SO2 EMISSIONS	Indirect	Environmental Group
NOX EMISSIONS	Indirect	Environmental Group
IMPACTS ON ECOSYSTEMS	Direct	Environmental Group
LAND USE	Direct	Environmental Group
PARTICLES EMISSIONS	Direct	Environmental Group
JOB CREATION	Indirect	Social Group
SOCIAL ACCEPTABILITY	Direct	Social Group
SOCIAL BENEFITS	Indirect	Social Group
VISUAL IMPACT	Indirect	Social Group
LOCAL DEVELOPMENT	Indirect	Social Group
IMPACTS ON HEALTH	Indirect	Social Group
INCOME FROM JOBS	Indirect	Social Group

Table 7 *- Academic Studied Variaables implicit in Models Formulation*

Hence, each renewable energy can be represented as follows in **Table 8**:

DMU	*ENERGY TYPE*	*ENERGY PRODUCTION*	*CAPACITY FACTOR*	*LCOE*	*ACIDIFICATION*	*ECOTOXICITY*	*EUTROPHICATI ON*	*GWP*	*LAND OCCUPATION*	*PM*	*SOCIAL ACCEPTANCE*
DMUH	Hydro	17693	0,3790	0,1520	0,0127	0,0829	0,0004	3,6413	0,3654	0,0095	0,6404
DMUG	Geothermal	3509,722	0,5806	0,0722	0,0021	0,0886	0,0000	0,6900	0,0006	0,0004	0,2848
DMUWN	Wind Onshore	19467	0,1974	0,0720	0,0235	0,1481	0,0004	0,4925	0,0227	0,0023	0,6373
DMUWF	Wind Offshore	90484	0,3476	0,1200	0,0046	1,0628	0,0030	3,4041	0,1913	0,0140	0,8087
DMUST	Solar thermal	8875	0,2418	0,1860	0,0009	0,0101	0,0001	0,1623	0,1135	0,0005	0,8727
DMUSP	Solar photovoltaic	43459	0,1173	0,1120	0,0792	4,0760	0,0087	9,2183	1,3523	0,0287	0,8727

Table 8 *- Representation of Variables Used in Model Formulation*

Regarding the collection of the respective data, data were collected from open access and proprietary sources, as shown in **Table 9**, **Table 10**, **Table 11**, **Table 12**, **Table 13** and **Table 14**.

ENERGY TYPE	VARIABLE	YEAR	GEOGRAPHIC SCOPE	SOURCE	SOURCE TYPE
HYDRO	Energy Production	2018	Germany	(EUROSTAT, 2022c)	Open Access
	Capacity Factor	2018	Germany	(IRENA, 2019, 2021, 2022)	Open Access
	LCOE	2018	Europe	(IRENA, 2019, 2021, 2022)	Open Access
	Acidification	2018	Europe	(EEA (European Environment Agency), 2021)	Open Access
	Ecotoxicity	2018	Europe	(EEA (European Environment Agency), 2021)	Open Access
	Eutrophication	2018	Europe	(EEA (European Environment Agency), 2021)	Open Access
	GWP	2018	Europe	(EEA (European Environment Agency), 2021)	Open Access
	Land Occupation	2018	Europe	(EEA (European Environment Agency), 2021)	Open Access
	PM	2018	Europe	(EEA (European Environment Agency), 2021)	Open Access
	Social Acceptance	2016	Germany	(Schumacher et al., 2019)	Proprietary

Table 9 *- Hydro Variables Description*

ENERGY TYPE	VARIABLE	YEAR	GEOGRAPHIC SCOPE	SOURCE	SOURCE TYPE
GEOTHERMAL	*Energy Production*	*2018*	*Germany*	(EUROSTAT, 2022c)	*Open Access*
	Capacity Factor	2018	Germany	(IRENA, 2019, 2021, 2022)	Open Access
	LCOE	*2018*	*World*	(IRENA, 2019, 2021, 2022)	*Open Access*
	Acidification	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Ecotoxicity	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Eutrophication	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	GWP	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Land Occupation	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	PM	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Social Acceptance	*2016*	*Germany*	(Schumacher et al., 2019)	*Proprietary*

Table 10 *- Geothermal Variables Description*

ENERGY TYPE	VARIABLE	YEAR	GEOGRAPHIC SCOPE	SOURCE	SOURCE TYPE
WIND ONSHORE	*Energy Production*	*2018*	*Germany*	(IRENA, 2019, 2021, 2022)	*Open Access*
	Capacity Factor	2018	Germany	(IRENA, 2019, 2021, 2022)	Open Access
	LCOE	*2018*	*Germany*	(IRENA, 2019, 2021, 2022)	*Open Access*
	Acidification	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Ecotoxicity	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Eutrophication	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	GWP	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Land Occupation	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	PM	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Social Acceptance	2016	*Germany*	*(Schumacher et al., 2019; Sonnberger & Ruddat, 2017)*	*Proprietary*

Table 11 *- Wind Onshore Variables Description*

ENERGY TYPE	***VARIABLE***	***YEAR***	***GEOGRAPHIC SCOPE***	***SOURCE***	***SOURCE TYPE***
WIND OFFSHORE	Energy Production	2018	Germany	(IRENA, 2019, 2021, 2022)	Open Access
	Capacity Factor	2018	Germany	(IRENA, 2019, 2021, 2022)	Open Access
	LCOE	2019	Germany	(IRENA, 2019, 2021, 2022)	Open Access
	Acidification	2018	Europe	(EEA (European Environment Agency), 2021)	Open Access
	Ecotoxicity	2018	Europe	(EEA (European Environment Agency), 2021)	Open Access
	Eutrophication	2018	Europe	(EEA (European Environment Agency), 2021)	Open Access
	GWP	2018	Europe	(EEA (European Environment Agency), 2021)	Open Access
	Land Occupation	2018	Europe	(EEA (European Environment Agency), 2021)	Open Access
	PM	2018	Europe	(EEA (European Environment Agency), 2021)	Open Access
	Social Acceptance	2016	Germany	(Schumacher et al., 2019; Sonnberger & Ruddat, 2017)	Proprietary

Table 12 *- Wind Offshore Variables Description*

ENERGY TYPE	***VARIABLE***	***YEAR***	***GEOGRAPHIC SCOPE***	***SOURCE***	***SOURCE TYPE***
SOLAR THERMAL	*Energy Production*	*2018*	*Germany*	(EUROSTAT, 2022c)	*Open Access*
	Capacity Factor	2018	Germany	(IRENA, 2019, 2021, 2022)	Open Access
	LCOE	*2018*	*World*	(IRENA, 2019, 2021, 2022)	*Open Access*
	Acidification	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Ecotoxicity	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Eutrophication	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	GWP	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Land Occupation	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	PM	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Social Acceptance	*2016*	*Germany*	(Schumacher et al., 2019)	*Proprietary*

Table 13 *- Solar Thermal Variables Description*

ENERGY TYPE	VARIABLE	YEAR	GEOGRAPHIC SCOPE	SOURCE	SOURCE TYPE
SOLAR PHOTOVOLTAIC	*Energy Production*	*2018*	*Germany*	(EUROSTAT, 2022c)	*Open Access*
	Capacity Factor	2018	Germany	(IRENA, 2019, 2021, 2022)	Open Access
	LCOE	*2018*	*Germany*	(IRENA, 2019, 2021, 2022)	*Open Access*
	Acidification	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Ecotoxicity	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Eutrophication	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	GWP	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Land Occupation	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	PM	*2018*	*Europe*	(EEA (European Environment Agency), 2021)	*Open Access*
	Social Acceptance	*2016*	*Germany*	(Schumacher et al., 2019)	*Proprietary*

Table 14 *- Solar Photovoltaic Variables Description*

Therefore, there are several points (limitations) that should be mentioned when it comes to collecting data on the respective variables. Firstly, regarding the year, the main period under analysis is 2018. This choice is related to data availability in databases and articles, especially concerning environmental impacts, which the only information available on all these energy sources was from 2005 to 2018. The same lack of data apllies to the social acceptance variable, whose data only showed the German perceptions of solar (as a whole), wind (as a whole), geothermal and hydro energies. Thus, it was necessary to use other articles available to distinguish between solar photovoltaic and solar thermal and between wind offshore and wind onshore. Therefore, the distinction of wind energy subcategories was possible through another scientific article, which categorized its social acceptance levels in 2015. In this way, the following calculations were made in order to use the available data from 2015 and 2016 displayed in **Table 15**:

YEAR	**2015** (SONNBERGER & RUDDAT, 2017)	**2016** (SCHUMACHER ET AL., 2019)
WIND (WHOLE)	N.A.	72,3%
WIND OFFSHORE	66%	N.A.
WIND ONSHORE	52%	N.A.
PERCENTUAL DIFFERENCE	26,9%	N.A.

Table 15 *- Wind Energy Public Acceptance Yearly Differences*

Thus, assuming that the preference differential between Wind offshore and Wind Onshore remains and considering the general evolution of the acceptance of energies as a whole. The final value was calculated considering that the 2016 value is the average between the value of acceptance referring to Wind Offshore and Onshore, maintaining its percentage difference of 27%. This assumption can be solved using the following mathematical system, where x is the general acceptance value of 2016; y, the acceptance value referring to Wind Offshore; and z, the value of acceptance referring to Wind Onshore:

$$\begin{cases} x = 0{,}723 \\ x = \dfrac{(y+z)}{2} \\ \dfrac{y}{z} - 1 = 0{,}269 \end{cases} \Leftrightarrow \begin{cases} x = 0{,}723 \\ y = 0{,}8087 \\ z = 0{,}6373 \end{cases}$$

Concerning solar energy, since no documents and data were found regarding its distinction by German citizens, it was assumed that both have the same social acceptance. It is also important to mention that when it comes to "Wind Offshore" energy, the only LCOE data available refers to 2019. Regarding the Geographic scope, unfortunately, data on German performance from all clean sources were not available. In this way, when possible, the respective European data were obtained and those relating to world performance in the case of the total absence of data. It should also be mentioned that the only geographical scope found for the environmental variables closest to the German reality was the European scope. Finally, the data with a "Proprietary" nature were obtained directly with the academic professor responsible for the respective elaboration.

Models Development

1. Approach

In previous chapters, it was explained how the DEA methodology works, emphasizing its ability to display the efficiency of DMUs by valuing their best attributes (either inputs or outputs) and minimizing the effect of the worst ones by attributing them either a null or reduced weight. Thus, this system implies that all factors entered into the system are "equally"[10] meaningful, giving the DEA flexibility to define the factor weights in evaluating each DMU. Thanks to this feature, we must employ weight restrictions in our DEA models to avoid the following situation:

1. We set the variables "Energy Production", "LCOE", "Acidification", "Ecotoxicity", "Eutrophication", "GWP", "Land Occupation", "PM", and "Social Acceptance" without any restriction.
2. We get the results and look to weights used to compute the DMUs efficiencies. We notice that for some efficiencies, the program considered that the LCOE and GWP weights should be 0. Whereas the weight of "Acidification" is always higher than 0.
3. We get perplexed since this computation does not make sense. How can a single environmental attribute be so vital that it makes the Economic attribute redundant?

In this problem, with the absence of weight restrictions, we indicate to the model that the "LCOE" is "equally" important as the "Acidification" or the Land Occupation is "equally" important as "Social Acceptance". The misstep behind

[10] The term "equally" must be carefully interpreted. In this case, the equality of importance does not refer to each factor's equal contribution to transforming the DMUs. Instead, it means that those factors are all essential to be included in the model, but whose complexity of the real context does not allow us to go beyond this conception.

this assumption is that we tell the model that a single variable of a group composed of six (in this case, the environmental group) must be considered in the same way as the only representatives of their respective groups, which is the case of the remaining non-environmental variables. Ultimately, this would imply that the model overestimates the environmental group compared to the other groups.

Therefore, it is crucial to apply some transformations. But which ones? In this paper, two different ways will be approached and compared. The first is through weight restrictions in the model to overcome the overvaluation of the environmental group. The second is to develop a final score by aggregating the environmental variables into one.

Before exploring the model, it is crucial to mention the way of computing portfolio options previously mentioned in previous chapters. It was explained that by combining the different energy sources in portfolios composed of one, two, three, four and five different energy sources, it can be obtained 62 options. However, how do we measure the values of the variables we consider in the model? What is its ratio? These questions imply an assumption. That is, the value of the variables is calculated through the proportion of green fonts in the portfolio. For example, a portfolio composed of two energy sources, Geothermal and Hydro, whose proportion is equally distributed, will imply an LCOE equal to the average of the LCOEs of these energy sources.

However, it is clear that preferences within portfolios do not need to be equally distributed in investment processes. In this sense, it would also be interesting to include these different portfolios and perceive the differences in their efficiencies compared to portfolios with equal distributions. In order to demonstrate the DEA's contribution and capabilities as a decision support tool for governments, one must consider different distributions of the weight of renewable energies in investment portfolios (Equal/Diverse Portfolio Weights of

Energy Sources) and mitigation forms in the distribution of factor weights by DEA (Weight Restriction/Environment Score). The flexibility offered by these options allows decision-makers to adapt DE models to the actual circumstances of each context. In this way, four different model hypotheses will be explored in detail, considering their respective singularities:

- Energy Production vs Capacity Factor
- Equal Portfolio Weights vs Diverse Portfolio Weights
- Weight Restriction vs Environmental Aggregated Score

That is, it is going to be developed the following hypotheses shown in **Table 16**:

Hypothesis Nº and Name	**Techinical Group Represent**	**Portfolio Weights Distribution**	**Enviromental Variables Handling Type**
1 - EEW	Energy Production	Equal Portfolio Weights	Weight Restriction
2 - EDW	Energy Production	Diverse Portfolio Weights	Weight Restriction
3 - EEE	Energy Production	Equal Portfolio Weights	Environmental Aggregated Score
5 - CEW	Capacity Factor	Equal Portfolio Weights	Weight Restriction

***Table 16** - Hypothesis Description*

Evidently, if it was considered all the possible combinations of developing models considering these singularities, it could have been created much more than four models. However, unfortunately, time and space constraints prevent us from thoroughly examining this diversity.

Nevertheless, before going into the hypotheses and their models in detail, it is necessary to explain the implications and assumptions regarding weight restriction and the Environmental Aggregated Score.

Concerning weight restrictions, as mentioned above, it is essential to restrict the DEA's flexibility in imposing weights between DMUs, in order to overcome the problem of overvaluing the environmental group and safeguarding the importance of each group. In this sense, the following objectives were taken into account:

a) Develop a constraint that reflects the importance of the various environmental variables to the same extent as the rest.
b) Ensure that all variables are considered.

Thus, in relation to objective a), the following restriction was included in the system, with *V* being the weight of the respective variable:

- $V_{Energy\ Production} - V_{Acidification} - V_{\mathrm{Ecotoxicity}} - V_{\mathrm{Eutrophication}} - V_{\mathrm{GWP}} - V_{\mathrm{Land\ Occupation}} - V_{\mathrm{PM}} \geq 0$

- $V_{LCOE} - V_{Acidification} - V_{\mathrm{Ecotoxicity}} - V_{\mathrm{Eutrophication}} - V_{\mathrm{GWP}} - V_{\mathrm{Land\ Occupation}} - V_{\mathrm{PM}} \geq 0$

- $V_{Social\ Acceptance} - V_{Acidification} - V_{\mathrm{Ecotoxicity}} - V_{\mathrm{Eutrophication}} - V_{\mathrm{GWP}} - V_{\mathrm{Land\ Occupation}} - V_{\mathrm{PM}} \geq 0$

These restrictions imply that the weight of the variables representing the entire respective group is the same or greater than the sum of the weight of the variables of the environmental group.

Regarding objective b), the following restriction was considered in the system, where *V* is the weight of the respective variable:

- $V_{Energy\ Production} \geq 0{,}0000000001$

- $V_{LCOE} \geq 0{,}0000000001$

- $V_{Social\ Acceptance} \geq 0{,}0000000001$

- $V_{Acidification} + V_{\mathrm{Ecotoxicity}} + V_{\mathrm{Eutrophication}} + V_{\mathrm{GWP}} + V_{\mathrm{Land\ Occupation}} + V_{\mathrm{PM}} \geq 0{,}0000000001$

Including a minimal number, instead of using an operation of type ">0", is necessary since the program only supports the following-mentioned operations:

"≥", "≤" or "=". However, during the construction of the models, it was found that using the objectives a) and b) constraints rendered infeasible computations. As a result, only the restrictions of objective a) were preserved, and the "border" limits were eliminated.

Regarding the development of the Environmental Score, several steps and assumptions were necessary for its implementation. Firstly, its computation is based on each variable's equal importance (contribution); that is, since there are six variables, each one represents a weight of ~16.667% of the total environmental group. However, it would be imprudent to add the respective values and divide them by six to obtain the final result since each variable has a different scale. In this sense, a normalization process was carried out to place each variable between 1 and 2, considering the values of each renewable energy. Finally, the final result was the average of the normalized value of each environmental variable in the respective portfolio. Therefore, we are left with four variables: Energy Production, LCOE, Environmental Score and Social Acceptance.

1.1 Hypothesis 1: EEW Models

1.1.1 Model Description

As mentioned, DEA assumes several models, and it is essential to outline which ones will be used in this paper. In this business project, one can categorized the 62 alternatives as different-sized portfolios. In other words, creating incentives for hydropower implies a rise in hydropower production, which is different from the impact of creating incentives for hydro, solar photovoltaic, and geothermal energy, that implies a rise in the production of three energy sources that will undoubtedly be greater than the first. In this sense, the choice of a model that distinguishes the variation of returns of scale seems more appropriate since it allows lesser discrimination between the evaluated alternatives (DMUs), thus considering the different dimensions and the respective impact that they can have in determining the efficiency of DMUs (Thanassoulis, 2001). However, a model that only considers constant returns to scale will also be evaluated in case of excessive discrimination.

Regarding the model's orientation, the two possible orientations will be computed, exposing the alternatives that decision-makers can choose. This decision is based on two facts. First, both the inputs used and the outputs generated can undergo alterations, making it possible to modify them. For example, through the development of technology, it is possible to reduce the installation cost and, thus, the LCOE of the energy source, or it is possible to increase the productivity of energy production per square meter of the plant of the respective clean source. Second, it demonstrates the flexibility decision-makers have in obtaining knowledge in the face of the current context. That is, depending on the perspective, the decision maker can assess, for that level of environmental impact, which level of public acceptance would be ideal (or acceptable), or conversely, for energy production of x, what is the ideal cost to make the respective energy source more efficient. Therefore, **Table 17** shows the three models that will be developed:

MODEL NAME	*RETURNS TO SCALE*	*MODEL ORIENTATION*	*ENVIRONMENTAL VARIABLES HANDLING*	*PORTFOLIO WEIGHTS OF ENERGY SOURCES*
EEW-VRS-I	Variable Returns to Scale	Input Oriented	Weight Restrictions	Equal Portfolio Weights
EEW-VRS-O	Variable Returns to Scale	Output Oriented	Weight Restrictions	Equal Portfolio Weights
EEW-CRS-I	Constant Returns to Scale	Input Oriented	Weight Restrictions	Equal Portfolio Weights

Table 17 *- Hypothesis 1 – Models*

Moreover, one must consider how these factors fit into the various models:

VARIABLES	*CHARACTHERISTIC*	*TYPE*	*COMBINATION CALCULATION METHOD*
ENERGY PRODUCTION	Output	Nominal	Sum
LCOE	Cost	Nominal	Average
ACIDIFICATION	Input	Nominal	Average
ECOTOXICITY	Input	Nominal	Average
EUTROPHICATION	Input	Nominal	Average
GWP	Input	Nominal	Average
LAND OCCUPATION	Input	Nominal	Average
PM	Input	Nominal	Average
SOCIAL ACCEPTANCE	Output	Interval	Average

Table 18 *- Hypothesis 1 - Variables Characteristics*

It is noticeable that some strangeness and dubiousness may arise when analysing **Table 18** since the environmental impacts, which clearly result from the transformation process, are considered as inputs in the formulation of the model. Obviously, it is absurd to consider that the emission of gases into the atmosphere is a necessary process to produce energy. However, as stated, in our DEA, the only viable movements for outputs/inputs are maintenance/minimization (input-oriented model) or maximization/maintenance (output-oriented model), respectively. Given the intention to measure efficiency, considering the maintenance or minimization of environmental impact values, one must consider them as "inputs" in the respective models.

It is also worth mentioning why the LCOE variable is considered as a cost and not directly as input. That is due to the fact that the cost of a process is not implicitly an input but rather an input times its respective price. Nevertheless, the LCOE variable will also be considered as an input in the models. In terms of outputs, not surprisingly, energy production will be one of them, but also social acceptance since one would never want to choose the portfolio with the lowest social acceptance value but the opposite. Furthermore, although social acceptance can be considered as a valuable input for the investment decision, it is undoubtedly also a result of the existing transformation processes of energy sources.

The Combination Calculation Method indicates how the values of the respective variables in the combinations will be calculated. So, concerning energy production, its sum will be used since it is an absolute value concerning the annual production. So, for example, if a portfolio corresponds to Hydro energy and Solar Thermal energy, the final result corresponds to the production of the first energy plus the production of the energy of the second when it comes to the Equal Portfolio Weights models. Still, regarding this model, the calculations of the remaining variables, since they are values related to the amount of energy produced, will be through the computation of an average. For instance, using the last example, the Social Acceptance value is the average between the respective Hydro energy value and Solar Thermal energy.

It is crucial now to move to a detailed analysis of the variable's behaviour and the respective models' datasets.

1.1.2 Variables Summary Statistics

Variable	*Obs*	*Mean*	*Std. Dev.*	*CV*	*Min*	*Max*
Energy Production	62	91744	50718	0,55	3510	179978
LCOE	62	0,11904	0,02204	0,19	0,07200	0,18600
Acidification	62	0,02049	0,01476	0,72	0,00085	0,07920
Ecotoxicity	62	0,91143	0,78753	0,86	0,01007	4,07596
Eutrophication	62	0,00210	0,00168	0,80	0,00001	0,00869
GWP	62	2,93475	1,68952	0,58	0,16230	9,21826
Land Occupation	62	0,34098	0,25243	0,74	0,00064	1,35229
PM	62	0,00922	0,00541	0,59	0,00038	0,02870
Social Acceptance	62	0,68612	0,11012	0,16	0,28485	0,87273

Table 19 *- Hypothesis 1 - Variables Summary Statistics*

As it is show in **Table 19**, the variables used in this model do not present a very dispersed distribution, which can be proven by computing the coefficient of variation[11] since it is always lower than 1.

[11] [11] The coefficient of variation (CV) is the ratio of the standard deviation to the mean and displays the level of variability in comparison to the population mean. The larger the dispersion, the bigger the CV. (European Commission, 2022a)

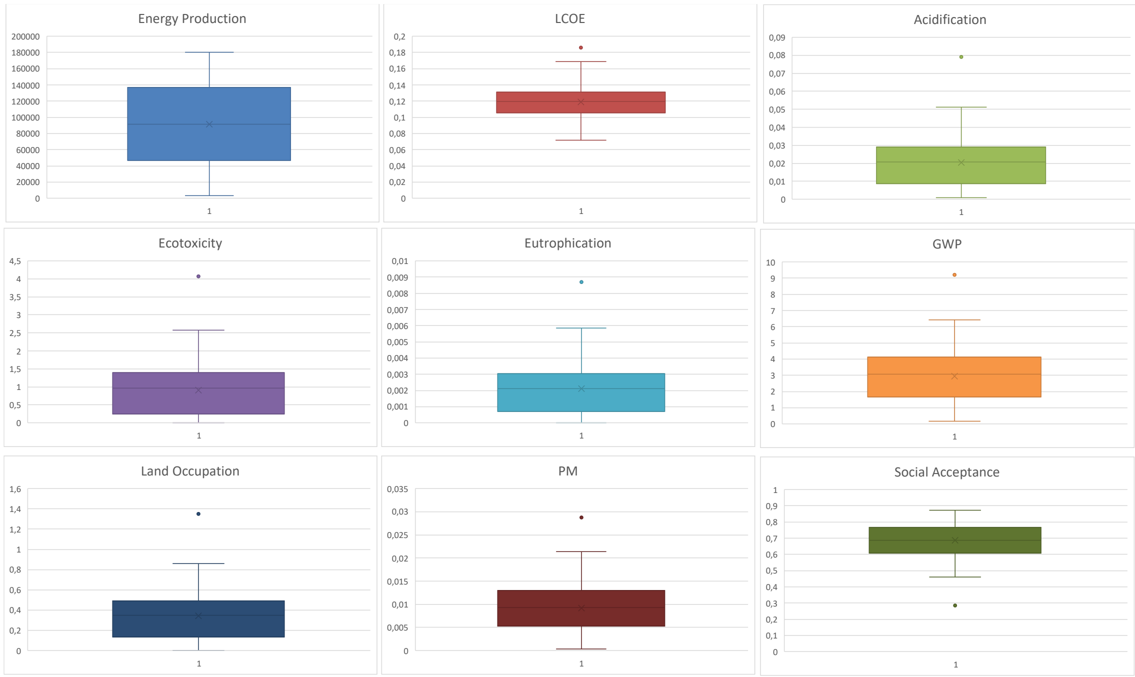

Figure 15 *- Hypothesis 1 - Variables Boxplot*

In order to have this perception visually, one must observe the results offered by the boxplots displayed in **Figure 15**. As a result, it is possible to determine that the median for each variable is roughly in the middle of the representative border of the 25th percentile of observations and the representative border of the 75th percentile of observations. That confirms the little dispersion in our distribution analysis, leading us to believe that these variables are normally and symmetrically distributed.

However, the presence of outliers in all variables, except for the energy production variable, is worth noting. These outliers correspond precisely to the respective values of each energy source, thus highlighting the disadvantages of each one. In other words, the outlier of the "LCOE" variable is the LCOE value of the thermal solar energy; the outlier of the variable "Acidification", “Ecotoxicity”, “Eutrophication”, “GWP”, “Land Occupation” and “PM” is the respective values of the Solar Photovoltaic. Finally, the outlier of the variable "Social Acceptance" is the respective value of the geothermal energy. That variable distribution was already expected since the calculations of the portfolios' composition resulted in values between the maximum and the minimum of the different renewable energies' respective values. In this way, since it was perceivde a low dispersion, it will be considered the constant returns to scale models, as previously mentioned.

	Energy Production	*LCOE*	*Acidification*	*Ecotoxicity*	*Eutrophication*	*GWP*	*Land Occupation*	*PM*	*Social Acceptance*
Energy Production	100%								
LCOE	-32%	100%							
Acidification	29%	-19%	100%						
Ecotoxicity	12%	-10%	92%	100%					
Eutrophication	11%	-8%	89%	100%	100%				
GWP	5%	2%	86%	93%	94%	100%			
Land Occupation	8%	8%	93%	95%	93%	96%	100%		
PM	8%	1%	84%	94%	96%	98%	93%	100%	
Social Acceptance	10%	62%	39%	47%	51%	44%	49%	53%	100%

Table 20 *- Hypothesis 1 - Variables Correlation*

Regarding the levels of correlation, in **Table 20**, one can observe the presence of several relationships. First, it is vital to highlight the respective moderate positive relationship between the environmental impact variables and the Social Acceptance variable, which may imply that, effectively, our Public opinion is more related to direct impacts on our daily lives (visual and noise pollution, for example) than those harder to identify on the ecosystems. Secondly, one can also perceive a relationship that can raise some perplexity between the LCOE and Social Acceptance, emphasising, once again, that acceptance is a very complex variable. Furthermore, it can be pointed out a weak relationship between the variables of the environmental group and those of the economic and technological group. Finally, the negative relationship between the variable

“Energy Production” and “LCOE” should be highlighted, which does justice to the mathematics implicit in calculating the economic variable. Finally, it can be observed a tremendously positive relationship between the environmental variables.

1.1.2 Results

After computing the models, one can perceive the models' differences, quality and results, by looking at **Table 21**. In this sense, the first point observed is that although the VRS models allow for greater discrimination, the truth is that compared to the EEW-CRS-I model, the average efficiency increased only ~6% and ~15%, from the models EEW-VRS-I and EEW-VRS-O, respectively, which implies that there was no high level of discrimination.

	EEW-VRS-I	*EEW-VRS-O*	*EEW-CRS-I*
Model Orientation	Input-oriented	Output-oriented	Input-oriented
Input 1	LCOE	LCOE	LCOE
Input 2	Acidification	Acidification	Acidification
Input 3	Ecotoxicity	Ecotoxicity	Ecotoxicity
Input 4	Eutrophication	Eutrophication	Eutrophication
Input 5	GWP	GWP	GWP
Input 6	Land Occupation	Land Occupation	Land Occupation
Input 7	PM	PM	PM
Output 1	Energy Production	Energy Production	Energy Production
Output 2	Social Acceptance	Social Acceptance	Social Acceptance
Average	77,57	86,67	71,77
St. Dev	15,31	12,34	14,87
Min	47,72	44,6	44,55
Max	100	100	100
Fully Eff	12	13	3
Fully Eff %	19%	21%	5%
Correlation EEW-VRS-I	100%		
Correlation EEW-VRS-O	55%	100%	
Correlation EEW-CRS-I	84%	70%	100%

Table 21 *- Hypothesis 1 - Models Result*

Nevertheless, it can also be focused on the fact that in the VRS models, it was found a large number of efficient DMUs, totaling 19% and 21% for the EEW-VRS-I and EEW-VRS-O models, respectively. That can be worrying since it can signify that the model cannot discriminate enough. Adding to this possible concern, **Table 22** identify the presence of efficient DMUs that present themselves as peers for two or fewer DMUs, which alerts us that the model results and their interpretation may not be as clear and assertive as they may seem at first glance. Respectively to the EEW-CRS-I model, it was already identified only three efficient DMUs (5% of the total), each one being a Peer of a large number of DMUs. Interestingly, this model presents a greater correlation with the VRS models than the VRS models themselves. However, it is essential to note that when evaluating models, their quality always depends on each context, as is the case with the number of efficient DMUs. In this sense, even though 5% of the portfolios present themselves as efficient, which seems acceptable to us (compared to the 20%, on average, of the other VRS models), it is necessary to exercise the same caution and understand if the CRS model does not present a degree of severe discrimination. Since the average efficiency difference between the models is not much, it seems that it is not.

	EEW-VRS-I		*EEW-VRS-O*		EEW-CRS-I	
	DMUs Efficient	Peers	DMUs Efficient	Peers	DMUs Efficient	Peers
DMUGWN	Efficient	6	Efficient	1		
DMUGWNSP	Efficient	8	Efficient	1		
DMUGWNWFSP	Efficient	11	Efficient	4	Efficient	23
DMUHGWNWFSP	Efficient	4	Efficient	6		
DMUHWNWFSP	Efficient	2	Efficient	4		
DMUHWNWFSTSP	Efficient	1	Efficient	7		
DMUSP	Efficient	14	Efficient	31		
DMUST			Efficient	5		
DMUSTSP	Efficient	1	Efficient	28		
DMUWN	Efficient	32	Efficient	3	Efficient	38
DMUWNSP	Efficient	30	Efficient	7	Efficient	25
DMUWNWFSP	Efficient	7	Efficient	15		
DMUWNWFSTSP	Efficient	4	Efficient	28		

Table 22 *- Hypothesis 1 - Peers Results*

Finally, it is also worth mentioning that the efficiencies attributed to the three models denote a strong influence of the weights of the LCOE and Social

Acceptance variables. Contrarily, the variables "Energy Production" and the environmental ones registered several weights equal to zero. Additionally, when the weight of the environmental group was different from 0, within the group itself, only one variable was highlighted and denoted of influence in the computation of efficiency[12].

[12] To visualize the results of the weights of models EEW-VRS-I, EEW-VRS-O and EEW-CRS-I, see Annex 4, 5 and 6, respectively.

1.2 Hypothesis 2: EDW Models

1.2.1 Model Description

Hypothesis 2 involves the same parameters that the previous model had, except for how the portfolios are computed, meaning that, it is intended to exist differences in the weight of each renewable energy that composes the portfolio. Therefore, it was maintained the same philosophy regarding the preference for the VRS models and the inclusion of the CRS model for security.

Additionally, it will be considered the two possible directions of orientation in the computation of the models, except for the CRS model, since the efficiency values are the same for both input-oriented and output-oriented (although the weights and targets are different for both types).

Thus, as in the previous hypothesis, **Table 23** displays the three models that will be developed:

MODEL NAME	***RETURNS TO SCALE***	***MODEL ORIENTATION***	***ENVIRONMENTAL VARIABLES HANDLING***	***PORTFOLIO WEIGHTS OF ENERGY SOURCES***
EDW-VRS-I	Variable Returns to Scale	Input Oriented	Weight Restrictions	Diverse Portfolio Weights
EDW-VRS-O	Variable Returns to Scale	Output Oriented	Weight Restrictions	Diverse Portfolio Weights
EDW-CRS-I	Constant Returns to Scale	Input Oriented	Weight Restrictions	Diverse Portfolio Weights

Table 23 *- Hypothesis 2 - Models*

Regarding the variables used and defined for the development of the models, it is perceived in **Table 24** that their characteristics remain unchanged, so it is crucial to explain the logic behind the Combination Calculation Method.

VARIABLES	*CHARACTHERISTIC*	*TYPE*	*COMBINATION CALCULATION METHOD*
ENERGY PRODUCTION	Output	Nominal	Sum
LCOE	Cost	Nominal	Weight
ACIDIFICATION	Input	Nominal	Weight
ECOTOXICITY	Input	Nominal	Weight
EUTROPHICATION	Input	Nominal	Weight
GWP	Input	Nominal	Weight
LAND OCCUPATION	Input	Nominal	Weight
PM	Input	Nominal	Weight
SOCIAL ACCEPTANCE	Output	Interval	Weight

Table 24 *-Hypothesis 2 - Variables Characteristics*

Regarding the Diverse Portfolio Weights models displayed in the above table, the sum of the variable "Energy Production" will consider each energy source's investment weight. For example, suppose a portfolio corresponds to the investment of 20% in geothermal energy and 80% in solar photovoltaic energy. In that case, the sum will reach 40% of the production value of the first energy plus 160% of the value of the production of the second energy. These values result from the assumption that the number of renewable energies in each portfolio reflects the respective increase in energy production. That is, the choice of a portfolio with a single energy source represents a 100% increase in the annual production of the respective energy source; a portfolio with only two energy sources represents an increase of 200% in the yearly production of the aggregation of the individual energy sources, and so on.

The reason behind this assumption is related to the fact that the respective data are related to large structures of energy production. Therefore, the calculation of the production of 20% of the energy produced annually, for example, taking into account the costs of large areas that benefit from economies of scale, would bias the model and distance it further from the real context (Farrell, 2019). Thus, this assumption was a way of approaching the issue of diversifying the weight of alternatives within the portfolios without departing from the feasibility of reducing energy production and its respective production cost. Additionally, since there are numerous possible combinations, a specific type of combination was assumed. However, it is variable according to the size of the portfolio. The combination process translates into the first energy source in the portfolio always holding 20% of the portfolio's total weight; the rest obtains the remaining weight equally. As an example, it can be observed the logic behind the following portfolios, where *E*, is the value of energy produced and *N*, is the number of energy sources that make up the portfolio:

- DMUHG: $0{,}2 \times E_{Hydro} \times N_{DMUHG} + \frac{(1-0{,}2)}{N_{DMUHG}-1} \times E_{Geothermal} \times N_{DMUHG}$
- DMUGWNSP: $0{,}2 \times E_{Geothermal} \times N_{DMUGWNSP} + \frac{(1-0{,}2)}{N_{DMUGWNSP}-1} \times E_{Wind\ Onshore} \times N_{DMUGWNSP} + \frac{(1-0{,}2)}{N_{DMUGWNSP}-1} \times E_{Solar\ Photovoltaic} \times N_{DMUGWNSP}$

Since the remaining factors are values related to the amount of energy produced, a computation of the value of the variable times the weight of the energy source in the portfolio will be performed.

1.2.2 Variables Summary Statistics

Variable	*Obs*	*Mean*	*Std. Dev.*	*CV*	*Min*	*Max*
Energy Production	62	94409	52679	0,56	3510	179978
LCOE	62	0,12015	0,02431	0,20	0,07200	0,18600
Acidification	62	0,02278	0,01902	0,83	0,00085	0,07920
Ecotoxicity	62	1,07414	1,00315	0,93	0,01007	4,07596
Eutrophication	62	0,00245	0,00213	0,87	0,00001	0,00869
GWP	62	3,12356	2,14410	0,69	0,16230	9,21826
Land Occupation	62	0,37821	0,32408	0,86	0,00064	1,35229
PM	62	0,01000	0,00680	0,68	0,00038	0,02870
Social Acceptance	62	0,71269	0,11585	0,16	0,28485	0,87273

Table 25 *- Hypothesis 2 - Variables Summary Statistics*

As expected, in **Table 25**, the variables present a greater dispersion than in hypothesis 1. In particular, in **Figure 16**, it can be seen that the highest concentration of data closer to the 75th percentile, in some variables, such as Acidification, Ecotoxicity, Eutrophication and Land Occupation. However, the standard deviation is still below the mean in all variables, which indicates that there is still some possibility and utility in computing a model that only considers constant returns to scale.

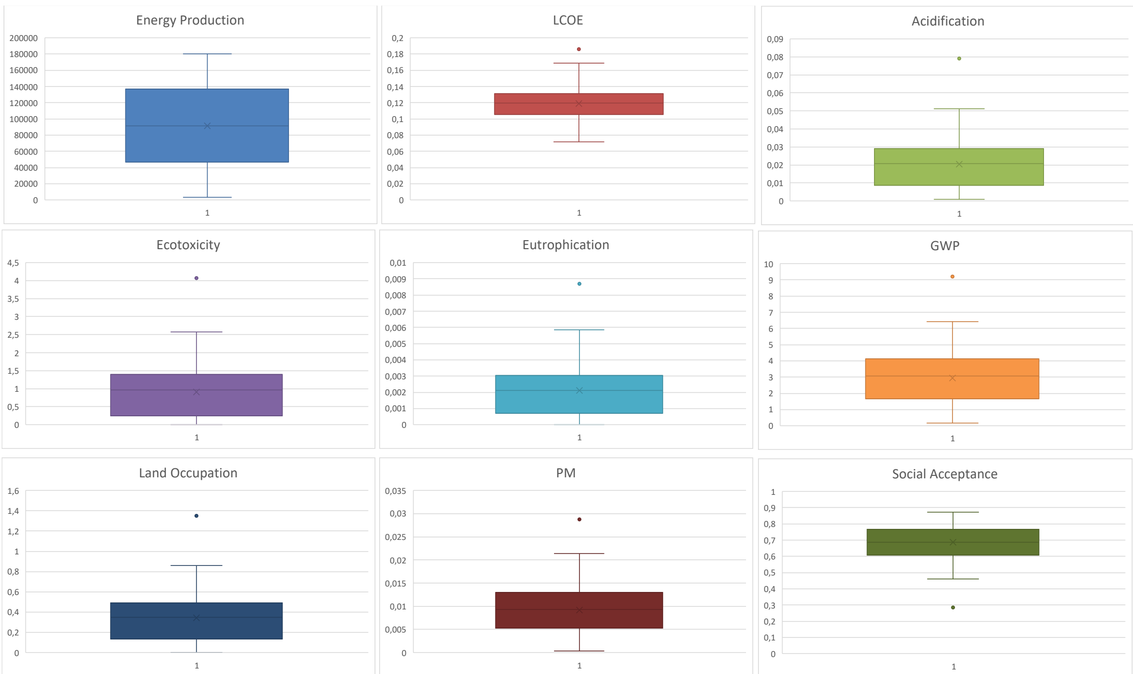

Figure 16 *- Hypothesis 2 - Variables Boxplot*

Regarding the outliers, their interpretation is identical to the previous hypothesis; that is, they correspond precisely to the respective maximum or minimum values of each energy source or the portfolios composed of only one energy source, thus highlighting the sources with the worst performance on each variable. Concerning the levels of correlation shown in **Table 26**, compared to the previous hypothesis, it was perceived a reduction in the positive correlations and an aggravation of the negative ones between Energy Production and the other variables. It should be noted that based on the computations made, the relationship between Social Acceptance and Energy Production became negative. The same must be said regarding the relationship between LCOE and environmental variables.

	Energy Production	*LCOE*	*Acidification*	*Ecotoxicity*	*Eutrophication*	*GWP*	*Land Occupation*	*PM*	*Social Acceptance*
Energy Production	100%								
LCOE	-42%	100%							
Acidification	25%	-25%	100%						
Ecotoxicity	8%	-14%	94%	100%					
Eutrophication	8%	-14%	92%	100%	100%				
GWP	6%	-13%	91%	97%	98%	100%			
Land Occupation	6%	-3%	95%	97%	96%	97%	100%		
PM	7%	-13%	87%	97%	98%	99%	94%	100%	
Social Acceptance	-5%	62%	38%	48%	51%	43%	49%	50%	100%

Table 26 *- Hypothesis 2 - Variables Correlation*

Even though, it was possible to identify, in general, a higher level of correlation, the degree of the correlation remains the same in most cases; relationships previously considered high or moderate remain high and moderate, and relationships that were reflected as weak stay at the same intensity.

1.2.2 Results

In the case of the models developed under hypothesis 2, by looking at **Table 27**, one can see more significant discrimination between the different orientations, the most striking being between the EDW-VRS-O model and the EDW-CRS-I model (~18 percentage points). However, at a general level, the evaluation DMUs' efficiency does not seem to have a significant discrepancy between the discrimination performed by the different models. On the other hand, it can be identified at which point this discrepancy is sensed, that is, in the definition of the efficient portfolios, since in the VRS models, it was identified 11 efficient DMUs. In contrast, in the CRS model, only two were considered as such. In this hypothesis, concerning the technical efficiency definition, there is a greater disparity, which can be a warning, both for the VRS model and for the CRS model, for opposite reasons.

	EDW-VRS-I	*EDW-VRS-O*	*EDW-CRS-I*
Model Orientation	Input-oriented	Output-oriented	Input-oriented
Input 1	LCOE	LCOE	LCOE
Input 2	Acidification	Acidification	Acidification
Input 3	Ecotoxicity	Ecotoxicity	Ecotoxicity
Input 4	Eutrophication	Eutrophication	Eutrophication
Input 5	GWP	GWP	GWP
Input 6	Land Occupation	Land Occupation	Land Occupation
Input 7	PM	PM	PM
Output 1	Energy Production	Energy Production	Energy Production
Output 2	Social Acceptance	Social Acceptance	Social Acceptance
Average	79,46	88,25	70,83
St. Dev	14,92	11,83	13,09
Min	47,72	44,60	44,55
Max	100	100	100
Fully Eff	11	11	2
Fully Eff %	18%	18%	3%
Correlation EDW-VRS-I	100%		
Correlation EDW-VRS-O	51%	100%	
Correlation EDW-CRS-I	80%	74%	100%

Table 27 *- Hypothesis 2 - Models Result*

Regarding the correlations, it was perceived a more significant discrepancy in the DMUS efficiency evaluation regarding the model's orientation than under the consideration of variable returns to scale. Therefore, it is possible again to confirm the value and relevance that the CRS model holds in evaluating the different portfolios. Furthermore, it should be noted that with the insertion of different weights of energy sources within each portfolio, it was obtained, in general, a smaller number of efficient DMUs and lower relationship between the models.

In the same perspective as the previous hypothesis's interpretation, one must analyse the number of DMUs that have the respective efficient DMUs as peers. Therefore, under this hypothesis, **Table 28** shows models with higher quality, since only 1 DMU in both VRS models having two or lower numbers of Peers.

	EDW-VRS-I		*EDW-VRS-O*		*EDW-CRS-I*	
	DMUs Efficient	Peers	DMUs Efficient	Peers	DMUs Efficient	Peers
DMUGWN	Efficient	8	Efficient	1	Efficient	25
DMUGWNSP	Efficient	16	Efficient	7		
DMUHGWNWFSP	Efficient	3	Efficient	4		
DMUHWNSP	Efficient	4	Efficient	3		
DMUHWNWFSP	Efficient	5	Efficient	11		
DMUHWNWFSTSP	Efficient	1	Efficient	6		
DMUSP	Efficient	8	Efficient	22		
DMUWFSP	Efficient	3	Efficient	18		
DMUWN	Efficient	35	Efficient	5	Efficient	59
DMUWNSP	Efficient	36	Efficient	29		
DMUWNWFSTSP	Efficient	4	Efficient	13		

Table 28 *- Hypothesis 2 - Peers Results*

Finally, although it was opted for a model that considers different weights of the energy sources in portfolios, there were no relevant changes in the weights assigned by the DEA. Once again, there was a strong presence of the LCOE and

Social Acceptance variables, and a reduced one, registering up to several “0’s” in the assigned weights, of the environmental variables and Energy Production.[13]

[13] To visualize the results of the weights of models EDW-VRS-I, EDW-VRS-O and EDW-CRS-I, see Annex 7, 8 and 9, respectively.

1.3 Hypothesis 3: EEE Models

1.3.1 Model Description

Regarding hypothesis 3, only the model that assumes constant returns to scale will be explored since replacing the six environmental variables with one (aggregation process) impacted the ability to differentiate the various investment options. This reduced discrimination ability eliminated VRS models' usefulness since more than 70% of DMUs were considered efficient. In this sense, it is necessary to develop a more rigid model in the differentiation between DMUs, that is, the CRS model:

MODEL NAME	*RETURNS TO SCALE*	*MODEL ORIENTATION*	*ENVIRONMENTAL VARIABLES HANDLING*	*PORTFOLIO WEIGHTS OF ENERGY SOURCES*
EEE-CRS-I	Constant Returns to Scale	Input Oriented	Weight Restrictions	Environmental Aggregated Score

Table 29 *- Hypothesis 3 - Models*

Regarding the characteristics of the variables used, by looking at **Table 30**, one must highlight the environmental score variable's status as an interval variable, since it ranges from 1 to 2. The remaining characteristics have already been mentioned previously.

VARIABLES	*CHARACTHERISTIC*	*TYPE*	*COMBINATION CALCULATION METHOD*
ENERGY PRODUCTION	Output	Nominal	Sum
LCOE	Cost	Nominal	Average
ENVIRONMENTAL SCORE	Input	Interval	Average
SOCIAL ACCEPTANCE	Output	Interval	Average

Table 30 *- Hypothesis 3 - Variables Characteristics*

1.3.2 Variables Summary Statistics

Variable	*Obs*	*Mean*	*Std. Dev.*	*CV*	*Min*	*Max*
Energy Production	62	91744	50718	0,55	3510	179978
LCOE	62	0,11904	0,02204	0,19	0,07200	0,18600
Environment Score	62	1,26397	0,18455	0,15	1,01560	2,00000
Social Acceptance	62	0,68612	0,11012	0,16	0,28485	0,87273

Table 31 *- Hypothesis 3 - Variables Summary Statistics*

Using the Environment Score resulted in a significant reduction of the average dispersion of the variables, as it is shown in **Table 31**, which confirms the model's difficulty distinguishing the different DMUs. In this sense, the CRS model will be central to developing hypothesis 3. Once again, looking at the box plots created in **Figure 17**, one confirm the already explained presence of outliers and the normal distribution followed by model variables.

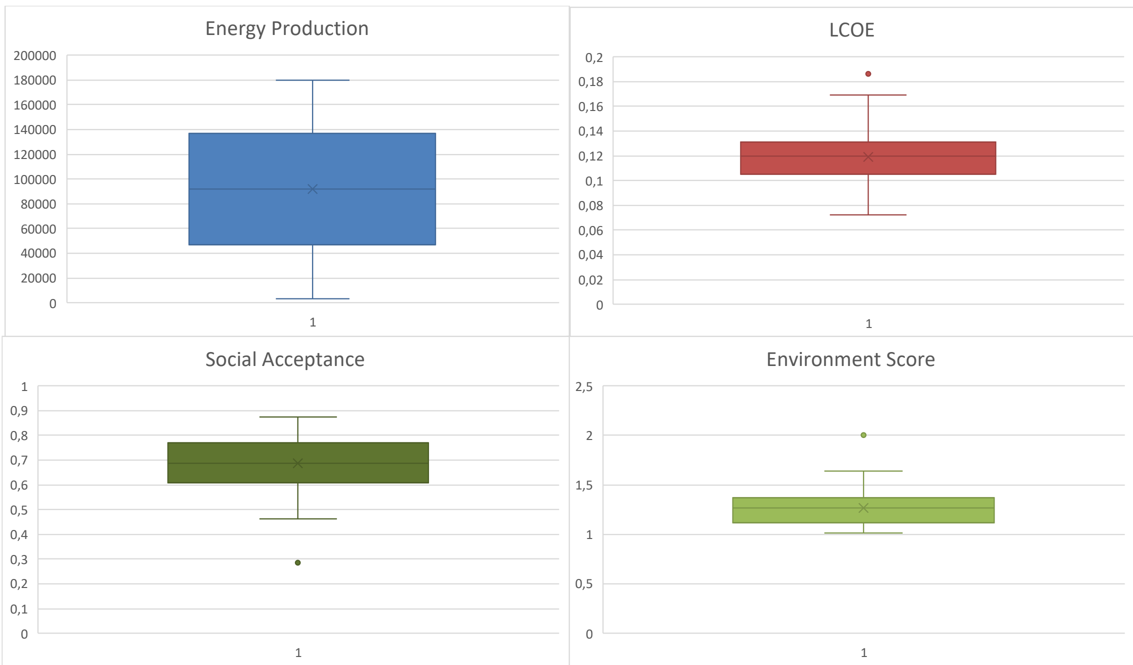

Figure 17 *- Hypothesis 3 - Variables Boxplot*

	Energy Production	LCOE	Environment Score	Social Acceptance
Energy Production	100%			
LCOE	-32%	100%		
Environment Score	12%	64%	100%	
Social Acceptance	10%	62%	48%	100%

Table 32 *- Hypothesis 3 - Variables Correlation*

Regarding the levels of correlation, it was perceived in **Table 32** that the use of an environment score made the environmental variables more relational with the LCOE and Social Acceptance variables, thus registering a moderate correlation. However, the low correlation between Energy Production and environmental impact variables remained similar. Concerning the remaining correlations, their values have already been explained in the interpretation of the variables of hypothesis 1.

1.3.2 Results

The results of the EEE-CRS-I model, shown in **Table 34**, are not surprising since previously, it was raised the concern of the possible inability of the model to differentiate the characteristics of the DMUs. In this sense, it is natural that the CRS model of hypothesis 3 differs from the previous models developed. However, this does not indicate that it is still a good model for supporting government investment. In this case, 18% of the DMUs being efficient, under the assumption of constant returns to scale, is a lavish alert for a possible biased model with unclear results.

	EEE-CRS-I
Model Orientation	Input-oriented
Input 1	LCOE
Input 2	Enviromental Score
Output 1	Energy Production
Output 2	Social Acceptance
Average	87,92
St. Dev	11,04
Min	46,76
Max	100
Fully Eff	11
Fully Eff %	18%

Table 34 *- Hypothesis 3 - Models Result*

EEE-CRS-I	
DMUs Efficient	Peers
DMUWN	33
DMUST	7
DMUWNST	29
DMUWNSP	3
DMUWNWFST	9
DMUWNWFSP	10
DMUHWNWFST	4
DMUGWNWFSP	4
DMUWNWFSTSP	8
DMUHGWNWFSP	6
DMUHWNWFSTSP	14

Table 33 *- Hypothesis 3 - Peers Results*

On the other hand, by analysing **Table 33**, one could see that, unlike the models that identified 11 or more efficient models, the EEE-CRS-I model presents efficient DMUs that are Peers of more than two different DMUs, which is a possible positive sign. Additionally, regarding the allocation of weights to define the efficiency of the DMUs, it was identified an equal impact of the variables, except for the variable Energy Production, whose model assigns 0 to approximately half of the DMUs.[14] In this sense, it is worth considering a different variable from Energy Production that represents the technological group in

[14] To visualize the results of the weights of models EEE-CRS-I, see Annex 10.

evaluating the efficiency of the portfolios. In the following case, it will be used the respective alternative: “Capacity Factor”.

1.4 Hypothesis 4: CEW Models

1.4.1 Model Description

In developing hypothesis 4, it was considered the change of the variable "Energy Production" by the variable "Capacity Factor" as an alternative in the representation of the technological group. This variable, as already mentioned, is a ratio between maximum energy production capacity and current energy production. Thus, since it reduces the model's ability to perceive the different dimensions that DMUs can hold, only the constant returns to scale model will be considered to guarantee that the model discriminates enough to a reasonable resolution of the efficiency of the different DMUs[15].

MODEL NAME	*RETURNS TO SCALE*	*MODEL ORIENTATION*	*ENVIRONMENTAL VARIABLES HANDLING*	*PORTFOLIO WEIGHTS OF ENERGY SOURCES*
CEW-CRS-I	Constant Returns to Scale	Input Oriented	Weight Restrictions	Equal Portfolio Weights

Table 35 *- Hypothesis 4 - Models*

Concerning the characteristics of the CEW-CRS-I model, shown in **Table 36** these are equal to those of the EEW-CRS-I model developed under hypothesis 1. However, the only difference in terms of the characteristics of the variables used is because unlike "Energy Production", "Capacity Factor" is an interval variable and will be calculated in the same way as "Social Acceptance".

[15] Subsequently, this model was produced on the assumption of variable returns to scale, which resulted in the classification of most DMUs as technical efficient, which confirmed our suspicion of lack of discrimination capacity on the part of these models.

VARIABLES	*CHARACTHERISTIC*	*TYPE*	*COMBINATION CALCULATION METHOD*
CAPACITY FACTOR	Output	Interval	Average
LCOE	Cost	Nominal	Average
ACIDIFICATION	Input	Nominal	Average
ECOTOXICITY	Input	Nominal	Average
EUTROPHICATION	Input	Nominal	Average
GWP	Input	Nominal	Average
LAND OCCUPATION	Input	Nominal	Average
PM	Input	Nominal	Average
SOCIAL ACCEPTANCE	Output	Interval	Average

Table 36 *- Hypothesis 4 - Variables Characteristics*

1.4.2 Variables Summary Statistics

Variable	*Obs*	*Mean*	*Std. Dev.*	*CV*	*Min*	*Max*
Capacity Factor	62	0,31061	0,08054	0,26	0,11731	0,58056
LCOE	62	0,11904	0,02204	0,19	0,07200	0,18600
Acidification	62	0,02049	0,01476	0,72	0,00085	0,07920
Ecotoxicity	62	0,91143	0,78753	0,86	0,01007	4,07596
Eutrophication	62	0,00210	0,00168	0,80	0,00001	0,00869
GWP	62	2,93475	1,68952	0,58	0,16230	9,21826
Land Occupation	62	0,34098	0,25243	0,74	0,00064	1,35229
PM	62	0,00922	0,00541	0,59	0,00038	0,02870
Social Acceptance	62	0,68612	0,11012	0,16	0,28485	0,87273

Table 37 *- Hypothesis 4 - Variables Summary Statistics*

As suspected and displayed in **Table 37**, the variable "Capacity Factor" reduces the general dispersion of the data used in this model, which proves the relevance of using the CRS model and the possible dangers associated with computing a VRS model.

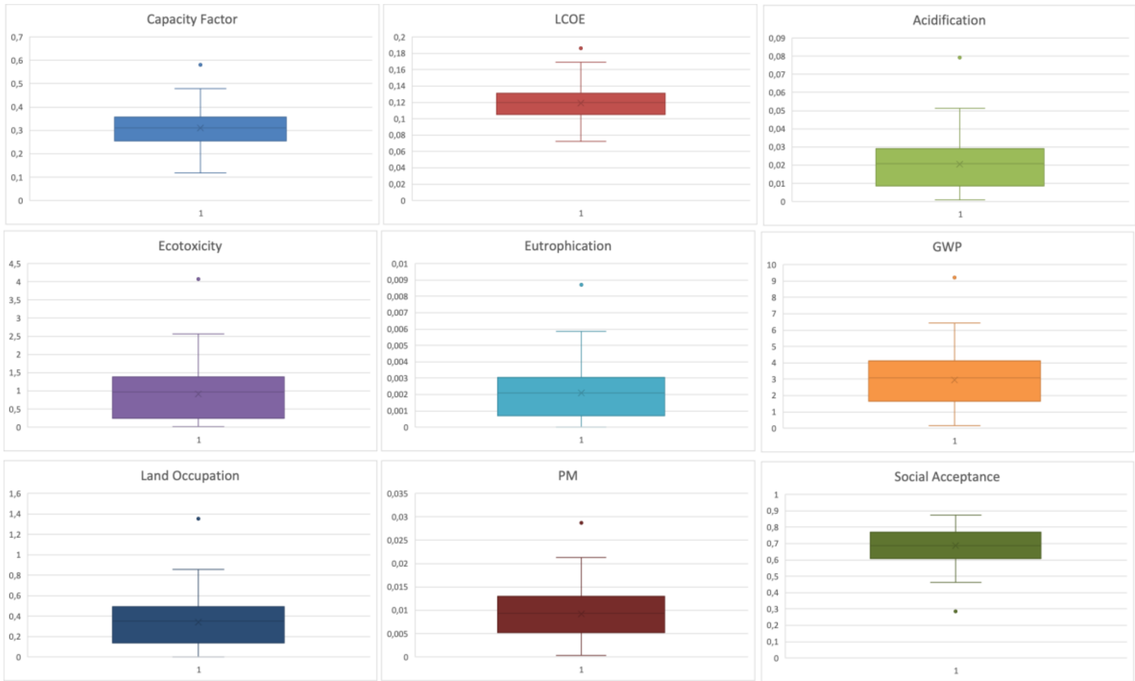

Figure 18 *- Hypothesis 4 - Variables Boxplot*

As mentioned in hypothesis 1, **Figure 18** shows that the outliers remain, and the respective outlier of the variable "Capacity Factor" corresponds to the value of the "Geothermal" energy source, which has a value 20 percentage points higher than the second largest in the dataset, the value of the "Hydro" energy source.

	Capacity Factor	*LCOE*	*Acidification*	*Ecotoxicity*	*Eutrophication*	*GWP*	*Land Occupation*	*PM*	*Social Acceptance*
Capacity Factor	100%								
LCOE	-23%	100%							
Acidification	-67%	-19%	100%						
Ecotoxicity	-56%	-10%	92%	100%					
Eutrophication	-57%	-8%	89%	100%	100%				
GWP	-46%	2%	86%	93%	94%	100%			
Land Occupation	-57%	8%	93%	95%	93%	96%	100%		
PM	-51%	1%	84%	94%	96%	98%	93%	100%	
Social Acceptance	-82%	62%	39%	47%	51%	44%	49%	53%	100%

Table 38 *- Hypothesis 4 - Variables Correlation*

Regarding the correlations in the CEW-CRS-I model shown in **Table 38**, it is essential to mention the differences recorded when replacing "Energy Production" with "Capacity Factor". In this sense, the former has a much stronger relationship with all other variables, except for LCOE, whose correlation has decreased. Regarding the relationship between the technological variable and the environmental and social variables, it was identified a moderate negative relationship with the former and an equally negative relationship, but with a strong nature, with Social Acceptance, mainly caused by Geothermal energy sources and the variants of solar energy.

1.4.2 Results

As exhibited in **Table 40**, the CEW-CRS-I model presents acceptable results regarding the definition of efficient DMUs, that is, 5 DMUs, totalling 8% of the total DMUs, with an average efficiency of 78%, approximately, which is around the values obtained in the past hypotheses. However, a big alert is triggered when analysing in **Table 39** the peers of each efficient DMU, since three of the five are either two times peer in the definition of DMU efficiency or not even in the definition of one. Respectively, the DMUG and DMUWN are peers of the DMUGWN portfolio option and the DMUWN and DMUST of the DMUWNST option. Without a doubt, this is the worst result in the analysis of this component.

	CEW-CRS-I
Model Orientation	Input-oriented
Input 1	LCOE
Input 2	Acidification
Input 3	Ecotoxicity
Input 4	Eutrophication
Input 5	GWP
Input 6	Land Occupation
Input 7	PM
Output 1	Capacity Factor
Output 2	Social Acceptance
Average	77,61
St. Dev	11,18
Min	60,45
Max	100
Fully Eff	5
Fully Eff %	8%

Table 40 *- Hypothesis 4 - Models Result*

CEW-CRS-I	
DMUs Efficient	Peers
DMUG	51
DMUWN	60
DMUST	2
DMUGWN	0
DMUWNST	0

Table 39 *- Hypothesis 4 - Peers Results*

Regarding the assignment of weights in the contribution of each variable to define efficiency, it is essential to note that in this model, it was found a greater weight of all variables, highlighting that only 8 out of 62 DMUs obtained a weight equal to 0 in the "Capacity Factor" variable. However, despite the environmental group registering a more frequent assignment of a non-zero weight, its regularity remains low.[16]

[16] To visualize the results of the weights of models CEW-CRS-I, see Annex 11.

2. Overall Results

It is equally imperative to address the differences and similarities of the models under the various hypotheses. In this sense, in the first instance, it was verified in **Table 41** that the models produced very similar results concerning average efficiency, with values between 70% and 88%, approximately. The main difference relates to the number of DMUs classified as efficient, and the VRS models always obtained a number greater than ten efficient DMUs. In comparison, the CRS models presented fewer than 5 DMUs, except for the EEE-CRS-I, which also featured more than 10 DMUs with the maximum efficiency level. Moreover, it was not found major differences between the models under hypothesis 1 and their coequals under hypothesis 2, and they always recorded a correlation greater than 87% in the attribution of efficiencies. In addition, regarding the definition of efficient DMUs, of the 12 defined by the EEW-VRS-I model, nine were identified by the EDW-VRS-I model. The EDW-VRS-0 model found nine of the 13 described by the EEW-VRS-O model; however, of the three defined by the EEW-CRS-I model, only one was recognised by the EDW-CRS-I model.

Furthermore, the EEE-CRS-I and CEW-CRS-I models were clearly the most differentiated among the models, which can be seen in the correlation value between these and the other models. In the first one, it was found a much larger definition of efficient DMUs than the other CRS models, similar to the VRS models. As an example, of the 11 DMUS classified as efficient in this model, eight were also classified as efficient in the EEW-VRS-O model. These two models present a correlation of 82%. Regarding the CEW-CRS-I, it is difficult to compare since it evaluates the investment options through different factors; however, even so, in the five efficient DMUs, the remaining models also identified four.

Concerning the definition of Peers show in **Table 42**, the EEE-CRS-I model, despite the added difficulty of discrimination presented, was the model that presented "healthier" results together with the EEW-CRS-I model, in contrast with the last model presented, which generated great alerts. However, despite inserting several changes between the different hypotheses and varying the assumptions between the models, in a sample of 19 efficient DMUs, approximately 63% were identified by three or more models. Whereas EEE-CRS-I and CEW-CRS-I were the ones that contributed the most to the reduction of this number since approximately 27% and 40% of DMUs considered efficient had less than three presences between the models, respectively. However, these two models demonstrated a more equal degree of utilisation of the variables to describe the DMUs' performance.

Finally, by looking in detail at the use of different energy sources among all DMUs considered efficient (**Table 43**), one can see the great importance that onshore wind energy and photovoltaic solar energy have in classifying investment options since they obtained a presence in 74 % and 63% of efficient DMUs, respectively. Interestingly, if one excludes the presence of Bioenergies, wind energy and solar energy were the two primary energies used in Germany in 2018 and are the energies highlighted to drive forward the country's energy transition (BMWK, 2022).

	EEW-VRS-I	*EEW-VRS-O*	*EEW-CRS-I*	*EDW-VRS-I*	*EDW-VRS-O*	EDW-CRS-I	*EEE-CRS-I*	*CEW-CRS-I*
Model Orientation	Input-oriented	Output-oriented	Input-oriented	Input-oriented	Output-oriented	Input-oriented	Input-oriented	Input-oriented
Input 1	LCOE	LCOE	LCOE	LCOE	LCOE	LCOE	LCOE	LCOE
Input 2	Acidification	Acidification	Acidification	Acidification	Acidification	Acidification	Enviromental Score	Acidification
Input 3	Ecotoxicity	Ecotoxicity	Ecotoxicity	Ecotoxicity	Ecotoxicity	Ecotoxicity		Ecotoxicity
Input 4	Eutrophication	Eutrophication	Eutrophication	Eutrophication	Eutrophication	Eutrophication		Eutrophication
Input 5	GWP	GWP	GWP	GWP	GWP	GWP		GWP
Input 6	Land Occupation	Land Occupation	Land Occupation	Land Occupation	Land Occupation	Land Occupation		Land Occupation
Input 7	PM	PM	PM	PM	PM	PM		PM
Output 1	Energy Production	Energy Production	Energy Production	Energy Production	Energy Production	Energy Production	Energy Production	Capacity Factor
Output 2	Social Acceptance	Social Acceptance	Social Acceptance	Social Acceptance	Social Acceptance	Social Acceptance	Social Acceptance	Social Acceptance
Average	77,57	86,67	71,77	79,46	88,25	70,83	87,92	77,61
St. Dev	15,31	12,34	14,87	14,92	11,83	13,09	11,04	11,18
Min	47,72	44,60	44,55	47,72	44,60	44,55	46,76	60,45
Max	100	100	100	100	100	100	100	100
Fully Eff	12	13	3	11	11	2	11	5
Fully Eff %	19%	21%	5%	18%	18%	3%	18%	8%
Correlation|EEW-VRS-I	100%							
Correlation|EEW-VRS-O	55%	100%						
Correlation|EEW-CRS-I	84%	50%	100%					
Correlation|EDW-VRS-I	92%	45%	76%	100%				
Correlation|EDW-VRS-O	53%	93%	72%	51%	100%			
Correlation|EDW-CRS-I	75%	62%	87%	80%	74%	100%		
Correlation|EEE-CRS-I	41%	82%	67%	26%	77%	46%	100%	
Correlation|CEW-VRS-O	41%	-4%	32%	34%	3%	34%	5%	100%

Table 41 *- Overall Models Results*

	EEW-VRS-I		*EEW-VRS-O*		EEW-CRS-I		*EDW-VRS-I*		*EDW-VRS-O*		EDW-CRS-I		*EEE-CRS-I*		*CEW-CRS-I*	
	Efficiency	Peers	Efficiency	Peers	Efficiency	Peers	Efficiency	Peers	Efficiency	Peers	Efficiency	Peers	Efficiency	Peers	Efficiency	Peers
DMUG															Efficient	51
DMUGWN	Efficient	6	Efficient	1			Efficient	8	Efficient	1	Efficient	25			Efficient	0
DMUGWNSP	Efficient	8	Efficient	1			Efficient	16	Efficient	7						
DMUGWNWFSP	Efficient	11	Efficient	4	Efficient	23							Efficient	4		
DMUHGWNWFSP	Efficient	4	Efficient	6			Efficient	3	Efficient	4			Efficient	6		
DMUHWNWFSP	Efficient	2	Efficient	4			Efficient	5	Efficient	11						
DMUHWNWFST													Efficient	4		
DMUHWNWFSTSP	Efficient	1	Efficient	7			Efficient	1	Efficient	6			Efficient	14		
DMUSP	Efficient	14	Efficient	31			Efficient	8	Efficient	22						
DMUST			Efficient	5									Efficient	7	Efficient	2
DMUSTSP	Efficient	1	Efficient	28												
DMUWN	Efficient	32	Efficient	3	Efficient	38	Efficient	35	Efficient	5	Efficient	59	Efficient	33	Efficient	60
DMUWNSP	Efficient	30	Efficient	7	Efficient	25	Efficient	36	Efficient	29			Efficient	3		
DMUWNST													Efficient	29	Efficient	0
DMUWNWFSP	Efficient	7	Efficient	15									Efficient	10		
DMUWNWFST													Efficient	9		
DMUWNWFSTSP	Efficient	4	Efficient	28			Efficient	4	Efficient	13			Efficient	8		
DMUWFSP							Efficient	3	Efficient	18						
DMUHWNSP							Efficient	4	Efficient	3						

Table 42 *- Overall Peers Results*

	Hydro	Geothermal	Wind Onshore	Wind Ofshore	Solar Thermal	Solar Photovoltaic
DMUG		Present				
DMUGWN		Present	Present			
DMUGWNSP		Present	Present			Present
DMUGWNWFSP		Present	Present	Present		Present
DMUHGWNWFSP	Present	Present	Present	Present		Present
DMUHWNWFSP	Present		Present	Present		Present
DMUHWNWFST	Present		Present	Present	Present	
DMUHWNWFSTSP	Present		Present	Present	Present	Present
DMUSP						Present
DMUST					Present	
DMUSTSP					Present	Present
DMUWN			Present			
DMUWNSP			Present			Present
DMUWNST			Present		Present	
DMUWNWFSP			Present	Present		Present
DMUWNWFST			Present	Present	Present	
DMUWNWFSTSP			Present	Present	Present	Present
DMUWFSP				Present		Present
DMUHWNSP	Present		Present			Present
Total	5	5	14	9	7	12
Total %	26%	26%	74%	47%	37%	63%

Table 43 *- Energy Sources Presence in Efficient DMUs*

Limitations and Potentials

1. Challenges and Prospects

Throughout the project development, several limitations stood out, both in the available data, the formulation of the problem, and the results obtained. Therefore, it is vital to mention each of them in each section.

1.1 Data

First, and already mentioned several times, to obtain a clearer picture of the DEA's role as a tool to help decision-makers, it would be necessary to develop many more models and explore even more variants, which will be discussed later. However, the first limitation, time and space, made it impossible to achieve this same objective, allowing only the exploration of one side of the coin. Regarding the variables used, one can identify several limitations. First of all, several data used do not precisely correspond to the current reality of the German country. For example, the year used is 2018, and it would be interesting to perceive this same analysis in the new decade of the 2020s.

Additionally, several pertinent data were unavailable, and the only feasible solution was to use values corresponding to other years or geographic areas, thus biasing our model. Moreover, several assumptions were necessary due to a lack of data, which is the case of the Public Acceptance of the variants of wind and solar energy, which distances our models from the concrete German reality. In addition, it would be precious to include other types of renewable energies, particularly modern Bioenergy, to comprehensively assess the potential of renewable energies. For this, of course, it was necessary to ensure that the data used only came from energy production from sustainable and adequately supervised processes.

1.2 Problem Formulation

Regarding the formulation of the problem, the first mentioned corresponds to the use of traditional DEA, which makes it impossible, for example, to position environmental impacts as outputs that it was intended to minimise. It would be interesting to use, for example, the geometric efficiency model, which allows to distinguish negative outputs (which are aimed to be reduced) from positive outputs (which are aimed to be maximised) in different groups, thus making the evaluation of DMUs more flexible and closer to the real context (Despić, 2013). Additionally, in the formulation of the weight restriction, it was assumed that the environmental group could never have a higher weight than the other groups individually, which perhaps conditions the model in valuing environmental variables. Despite restricting the group as a whole, this condition still allows the model to select the weight of environmental variables within the group itself. However, it would be advantageous to look for other types of constraints that provide the model with a different kind of flexibility and compare them. For example, suppose that the goal was not to restrict the variables as a whole but individually. In that case, one could have used the same logic for each environmental variable, despite restricting the choice of weights among the same variables. That is, with V being the weight of each variable and O, the different non-environmental variables:

- $V_O - 6V_{Acidification} \geq 0$
- $V_O - 6V_{\text{Ecotoxicity}} \geq 0$
- $V_O - 6V_{\text{Eutrophication}} \geq 0$

- $V_O - 6V_{\text{GWP}} \geq 0$
- $V_O - 6V_{\text{Land Occupation}} \geq 0$
- $V_O - 6V_{\text{PM}} \geq 0$

These restrictions[17] would be based on the fact that the environmental group is composed of 6 variables, so the weight of each variable compared to the other groups would have to be $\frac{1}{6}$. Furthermore, one couldn't implement restrictions that create a lower limit on the weight of the variables, thus ensuring that each variable is used in defining the efficiency of the portfolios. Additionally, there are three more limitations worth mentioning. Firstly, the definition of portfolios under the condition "Diverse Portfolio Weights" is very conditioned since it only changes the weight of the first option, keeping the weight of the others equal to each other. Therefore, it would be essential to create a much more diversified portfolio, including a sample with many more investment options, to visualise more concretely the differentials that this assumption can make in the definition of efficiency. Second, the model developed under the "Environment Score" condition was constrained by equalising the weight of each environmental impact. Thus, it would be interesting if it is possible to obtain more information and adapt the weights of each impact to the German context. However, this limitation is of little concern since it was visible that the model under this condition had an increased difficulty in discriminating the DMUs, which leads us to the third hurdle. It would be crucial to investigate and test in greater detail the variables that best reflect the different groups mentioned in this project: technological, economic, environmental and social. In particular, a different path was tested regarding the technological representation, which on the one hand, proved to be more relevant since it was used with greater regularity, and

[17] Experimental result through this restriction available in Annex 12.

therefore the technological group was taken into more consideration given our impossibility of implementing lower limit restrictions. On the other hand, using the Capacity Factor variable reduced the model's ability to discriminate the DMUS, having even classified two efficient DMUS that alerted the model's quality.

1.3 Results

Finally, the results and final interpretations are consequently impacted due to all these limitations. Although, in the end, it was obtained results that mirror the intentions of the German government regarding the energy transition, it is evident that the interpretations are very conditioned, giving only a brief light on the potential that the DEA has to promote more conscious and supported decisions. In addition, of course, there are still other aspects that influence the decision. For example, despite considering the LCOE, the short-term investment capacity of decision-makers is also taken into question; the same is related to political influences or beliefs in the technological evolution of one factor. Therefore, in the end, it cannot be said that the results of the models are a law that must be followed, but results that highlight paths and possibilities in the eyes of decision-makers, thus allowing promising prospects to emerge from the shadows and be appropriately evaluated.

Conclusion

1. Final Insights

The choices developed throughout this Business Project always focused on a single objective, the development of a decision support tool that would help decision-makers, in this case, governments, to select the best renewable energy investment options based on their efficiency and sustainability. In this sense, the most used renewable energy sources worldwide were highlighted and combined, resulting on the creation of 62 portfolios. Based on the literature review on investments in renewable energies, the variables to be considered were identified to evaluate investment options under the concept explored here, sustainable efficiency. Among the various possible ways of assessing efficiency, the DEA method was chosen, which evaluates the performance of different portfolios (DMUs) according to the inputs used and the outputs generated. Thus, based on the groups used and the respective variables, that is, the technological group (Energy Production or Capacity Factor), economic group (LCOE), environmental group (Acidification, Ecotoxicity, Eutrophication, GWP, Land Occupation and PM) and social group (Social Acceptance), four different hypotheses were developed to explore the capabilities of the DEA in achieving our objective. First, models with weight restrictions were considered to equalize the importance between the environmental group and the remaining groups. Additionally, to address the same issue, an aggregator variable for all environmental variables was developed. Next, the models were explored through portfolios composed of diversified weights of energy sources. And finally, in order to perceive other insights based on alternatives in the representation of the aforementioned groups, it was decided to develop a model that included the annual energy production in relation to its maximum productive capacity, thus eliminating the use of the "Energy Production" variable.

After setting these four hypotheses through input and output-oriented models that assume constant returns to scale, and, when possible, variable returns to scale, it was obtained and presented the results and the respective interpretation. It was evaluated their performance in assessing each DMU's degree of efficiency, the number of DMUs considered technically efficient and their ability to be peers for the efficient DMUs. Intra-hypotheses and inter-hypotheses comparisons were also made based on the correlations of the DMUs evaluation of each model and the previously mentioned points.

The findings revealed that the watchword of Data Envelopment Analysis is "Flexibility", doing justice to all academics who support this method based on this attribute. It was realized that, effectively, there is a lot of capacity and agility to manage how one want our units to be evaluated. However, it can guide us to the frustrating fact that there is no ideal and perfect way to assess efficiency. In contrast, the DEA can give us several signals that reflect the health and quality of our models, such as the ability to discriminate portfolio options or the assignment of Peers. In this direction, our results were guided, and it was realized that even though one could not pinpoint which models were the best, it was possible to determine the most insightful findings of each model compared to the others. Their development was always computed by considering a general overview. Thus, the more information about the context, for example, from the respective variable data, the more assertive the models became. It was also highlighted, through hypothesis 4, that the way that model formulation is perceived can greatly impact the results obtained. However, by solving several models and increasing the scope of the analysis a little, it was possible to see a picture along the different hypotheses: In 2018, the energy sources that were most included in the efficient portfolios were Wind Onshore and Solar photovoltaic. These results were noteworthy since, according to an article by the Federal Ministry for Economic Affairs and Climate Protection (2022), the two of the three most critical renewable energies for developing a greener economy and society are energy, wind, and solar sources. Even with all the flexibility promoted by the DEA method and despite the different hypotheses existing under various limitations, the models were able to indicate a path that goes along with the factual context, in this case, with the German context. That shows us that the DEA model can be a helpful decision support tool and that whatever its formulation, as long as it remains sane, there is always truth in the results. Despite not being able to demonstrate universal truth or empirically undeniable results, DEA presents us with lucidity and discernment into the options that decision-makers have at hand. In this way, there is undoubtedly usefulness in using this model to help decision-makers in each member state of the EU, and who knows for extrapolation to another type of scope, whether intranational or international. Thus, based on this business Project, one can say that the DEA is capable of illuminating an agile and conscientious path in evaluating investment options and, together with other existing methods, being the support that fills the limited rationality of the Human Being.

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Appendices

Appendix 1 – Renewable Energy Description

Renewable Energy Source	***Description***
Geothermal	Geothermal energy is heat obtained from the earth's subsurface. Geothermal energy is transported to the Earth's surface via water and/or steam, and depending on the characteristics of the plant, it can produce clean electricity or be used for heating and cooling. However, to produce this type of energy, the plants should be localized in tectonic areas since the recourses used to produce energy have a high or medium temperature. In this sense, this source is highlighted for its independence of weather conditions and its high-capacity factor.
Hydropower	Hydropower is one of the most cost-effective ways of generating power and is frequently the favored technique when it is available. It creates energy by flowing water to drive turbines. Hydropower plants are classified into two types: those with dams and reservoirs and those without. Large reservoir hydropower dams have the capacity to store water for short- or long-term periods to satisfy peak demand. Without dams and reservoirs, hydropower is generated on a smaller scale, generally from a plant built into a river without obstructing its flow.
Solar Photovoltaic	Solar energy is the energy generated from the sun. It can be used to produce electricity or heat and desalinate water. Solar photovoltaics (PV) are capable to produce electricity using sunlight, thanks to its solar cells and other electronic devices. This source can often be the cheapest type of energy, especially thanks to the reduction in the cost of

	manufacturing the necessary equipment over the years. PV have a lifespan of around 30 years and is now one of the renewable energy technologies with the quickest rate of growth, and it is poised to play a significant part in the mix of the world's future power supply.
Solar Thermal	Solar thermal or Concentrated solar power (CSP), uses mirrors to concentrate solar radiation, which heats the fluid inside the equipment, and consequently producing steam that powers a turbine and produces energy. This source is generally used to produce large scale energy. It can have different dispositions, which the most common one is a field of mirrors that reflect light toward a tower. Comparing to PV, one of the advantages is thanks to the composition of its equipment, it allows to produce energy after the sunset.
Wind	Concerning Wind power, the energy is created in a first moment through the creation of kinect energy by the rotation of the wind blades and consequently the turn of turbine connected to them creates rotational energy. At the end electricity is produced through electromagnetism in the generator. Evidently, that the production of electrical energy is dependent on size of the turbine and the length of its blades and the speed of wind. Because of the need of strong wind speeds, the wind onshore plants present themselves as the most promising infrastructures considering wind power. Additionally, this source is one of the most rapidly expanding renewable energy sources in part due to the decreasing of its prices.

Table 44 - *Renewable Energy Source Description*
Source: (IRENA, 2022b, 2022c, 2022d, 2022e)

Appendix 2 – MCDA Example

An example of how a MCDA method works can be reach through the Analytical Hierarchy Process. In this case, criteria and alternatives that constitute the problem are identified. Then, the criteria are compared to each other to express their relative weight regarding the overall goal, yielding in a final result (priorities weight). Next, alternatives are compared through the criteria, resulting in final values for each alternative concerning each criterion. Finally, the results of the alternatives in each criterion are multiplied by the priorities weight of the respective criterion, which will generate a final value for each alternative, that is, a ranking among the alternatives (Huang et al., 1995; Ramanathan, 2004). It is essential to mention that there is no "the right method". The choice of method is related to the interpretation of each decision maker(s) in the adequacy of the different methods to the respective context. This methodology is usually applied in technology choice, electric power planning, and environmental impact analysis, among others (Strantzali & Aravossis, 2016).

Appendix 3 – Flow Diagram Processes Description

Concept	***Description***
Primary production	The extraction of energy products from natural sources to a usable form. It occurs within the territory under consideration
Recovered and recycled products	Regroup several categories, like supply of renewable energy commodities produced in other fuel balances or certain petroleum products which are reprocessed and recycled.
Production	The sum of primary production and recovered and recycled products
Imports	Cover the amount of energy produced outside and brought into the considered territory for consumption
Stock draw	The energy taken from storage facilities (e.a. gas storage vessels). It represents a positive variation of stock changes
Statistical difference - inflow	The negative statistical difference, that is the negative difference between the energy available for final consumption and final consumption.
Available from all sources	The addition of production, Imports, stock draw and inflow of statistical difference
Transformation input	The sum of energy Inpus to al to all transformation processes (for example, crude oil for refineries to produce derived products or natural gas for power plants to produce electricity
Direct carry-over	The energy quantities that do not go through any transformation process (i.e. energy commodities which are used in their original form)
Refineries and petrochemical industry	The transformation of crude oil and other intermediary products into refined petroleum products (like gasoline, diesel oil, fuel oil, lubricants, etc.) in refineries or the

	transformation of energy carriers during the production of petrochemicals (chemical products derived from petroleum) in the petrochemical industry.
BKB/ PB plants	Plants used to produce brown coal briquettes and peat briquettes. which are bricks composed of shredded peat or brown coal, compressed to form a slow-burning, easily stored and transported fuel
Coke-ovens	The transformation of coal into coke-oven-coke, which is the most important raw material for blast furnaces and some other by-products such as coke oven gas.
Blast-fumaces	The transtormation of coke-oven-coke intc blast turnace gas, a by-product of coal consumed in blast furnaces in the reoucion orocess orron ores
Gas works	The transformation of fuels into gas works gas. which is a flammable gas.
Electricity and heat generation	Electricity and heat generation includes the production or electricity) and/or heat, including renewable energies, like hydro power, wind power and solar photovoltaic. which are transformed into electricity, or the energy transformed in nuclear or thermal power plants (e.g. burning of oil. Coal, gas and biofuels) to produce electricity and/or heat, or District heating plants, which are central locations used to produce district heat that is distributed through a network and may be used for process or space heating purposes.
Other Transformation	Includes, among other, the following categories: patent fuel plants, coal liquefaction plants, for blended natural gas. charcoal oroduction plants (transtormation). aas-to-liquids (GIL) plants (transtormation), non- specified transtormation input.

Transformation backflow	Transformation backflow includes all energy commodities that are obtained as outputs from transtormation processes but are used as an input to other transformation processes, for examole fuels returned from the petrochemica centor to refineries for futher processing/blending.
Transformation losses	Transformation losses represent energy not accounted (lost) during the transformation processes. It is calcuated as the differences between total input and total output of each transformation flow
Transformation output	Transformation output is the sum of energy obtained as a result or all transformation processes (for example, refined petroleum products from a refinery or electricity from a power plant)
Available after transformation	The addition of direct carry-over and net transformation output (i.e. transformation output minus the blackflow) an thus represents energy quantities that are available for use
Exports	Energy quantities produced or transformed in the considered territory which are sent abroad
Stock build	Energy stored in storage facilities (e.g. gas storage vessels). It represents a negative variation of stock changes.
Marine Bunkers	Internalonal marine bunkers represent fuel consumption of ships during international navigation
International aviation	International aviation covers quantities of aviation fuels delivered to aircraft for international aviation (ea. jet kerosene consumption during international flights).
Distribution and transmission losses	Include, for instance, energy losses due to transport or distribution of electricity, heat, gas, as well as pipeline losses
Statistical difference - outflow	The positive statistical difference, that is the positive difference between the energy available for final consumption and final consumption.

Consumption of the energy branch	The energy consumed to operate installations for energy production and transformation.
Final consumption	The addition of final non-energy consumption and final energy consumption.
Final energy consumption	Final energy consumption covers all fuels used for energy purposes in the industry (e.g. steam used to support industrial plant activities), transport (e.g. motor gasoline used in vehicles), residential (eg. electricity used at home). commercial/services (e.g. natural gas used for heating a public school, agriculture (e.g. diesel oil used in tractors). fishing (ea. fuels used by coastal fishing boats) and other sectors (e.g. military energy use)
Final non-energy consumption	Final non-energy consumption covers certain fuels used to non-energy purposes, for instance oil used as timber preservative.

Table 45 - *Flow Diagram Processes Description*
Source: (EUROSTAT, 2022a)

Appendix 4 – Weight Results of EEW-VRS-I

Name	Energy Production	LCOE	Acidification	Ecotoxicity	Eutrophication	GWP	Land Occupation	PM	Social Acceptance
DMUH	0,00	6,58	0,00	0,00	0,00	0,00	0,00	0,00	1,12
DMUG	0,00	13,84	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUWN	0,00	13,89	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUWF	0,00	8,33	0,00	0,00	0,00	0,00	0,00	0,00	1,42
DMUST	0,00	5,38	0,00	0,00	0,00	0,00	0,00	0,00	0,91
DMUSP	0,00	8,93	0,00	0,00	0,00	0,00	0,00	0,00	1,52
DMUHG	0,00	8,92	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUHWN	2,88E-06	8,93	0,00	2,88E-06	0,00	0,00	0,00	0,00	0,40
DMUHWF	0,00	7,35	0,00	0,00	0,00	0,00	0,00	0,00	1,25
DMUHST	0,00	5,92	0,00	0,00	0,00	0,00	0,00	0,00	1,01
DMUHSP	0,00	7,58	0,00	0,00	0,00	0,00	0,00	0,00	1,29
DMUGWN	4,60E-07	13,87	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUGWF	0,00	10,40	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUGST	0,00	7,74	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUGSP	0,00	10,86	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUWNWF	0,00	10,42	0,00	0,00	0,00	0,00	0,00	0,00	1,77
DMUWNST	0,00	7,75	0,00	0,00	0,00	0,00	0,00	0,00	1,32
DMUWNSP	0,00	10,87	0,00	0,00	0,00	0,00	0,00	0,00	1,85
DMUWFST	0,00	6,54	0,00	0,00	0,00	0,00	0,00	0,00	1,11
DMUWFSP	0,00	8,62	0,00	0,00	0,00	0,00	0,00	0,00	1,46
DMUSTSP	2,80E-05	6,71	0,00	0,00	0,00	2,80E-05	0,00	0,00	43,44
DMUHGWN	2,93E-06	10,13	0,00	2,93E-06	0,00	0,00	0,00	0,00	0,05
DMUHGWF	0,00	8,71	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUHGST	0,00	7,31	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUHGSP	0,00	8,92	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUHWNWF	2,80E-06	8,72	0,00	0,00	0,00	2,80E-06	0,00	0,00	0,45
DMUHWNST	0,00	7,32	0,00	0,00	0,00	0,00	0,00	0,00	1,24
DMUHWNSP	3,69E-06	8,93	0,00	3,69E-06	0,00	0,00	0,00	0,00	0,64
DMUHWFST	0,00	6,55	0,00	0,00	0,00	0,00	0,00	0,00	1,11
DMUHWFSP	0,00	7,81	0,00	0,00	0,00	0,00	0,00	0,00	1,33
DMUHSTSP	0,00	6,67	0,00	0,00	0,00	0,00	0,00	0,00	1,13
DMUGWNWF	3,29E-06	11,35	0,00	0,00	0,00	3,29E-06	0,00	0,00	0,06
DMUGWNST	2,63E-06	9,08	0,00	0,00	0,00	2,63E-06	0,00	0,00	0,05
DMUGWNSP	5,20E-06	11,71	0,00	0,00	0,00	5,20E-06	0,00	0,00	0,00
DMUGWFST	0,00	7,93	0,00	0,00	0,00	0,00	0,00	0,00	1,35

DMUGWFSP	0,00	9,86	0,00	0,00	0,00	0,00	0,00	0,00	1,68
DMUGSTSP	0,00	8,10	0,00	0,00	0,00	0,00	0,00	0,00	1,38
DMUWNWFST	0,00	7,94	0,00	0,00	0,00	0,00	0,00	0,00	1,35
DMUWNWFSP	4,08E-06	9,87	0,00	0,00	0,00	4,08E-06	0,00	0,00	0,71
DMUWNSTSP	4,12E-06	8,11	0,00	0,00	0,00	4,12E-06	0,00	0,00	5,41
DMUWFSTSP	3,65E-06	7,18	0,00	0,00	0,00	3,65E-06	0,00	0,00	4,79
DMUHGWNWF	2,78E-06	9,61	0,00	0,00	0,00	2,78E-06	0,00	0,00	0,05
DMUHGWNST	2,40E-06	8,29	0,00	0,00	0,00	2,40E-06	0,00	0,00	0,04
DMUHGWNSP	4,35E-06	9,80	0,00	4,35E-06	0,00	0,00	0,00	0,00	4,35E-06
DMUHGWFST	0,00	7,54	0,00	0,00	0,00	0,00	0,00	0,00	1,28
DMUHGWFSP	0,00	8,77	0,00	0,00	0,00	0,00	0,00	0,00	1,49
DMUHGSTSP	0,00	7,66	0,00	0,00	0,00	0,00	0,00	0,00	1,30
DMUHWNWFST	2,43E-06	7,55	0,00	0,00	0,00	2,43E-06	0,00	0,00	0,39
DMUHWNWFSP	8,39E-06	8,77	0,00	0,00	0,00	8,39E-06	0,00	0,00	1,13
DMUHWNSTSP	7,33E-06	7,66	0,00	0,00	0,00	7,33E-06	0,00	0,00	0,99
DMUHWFSTSP	0,00	7,02	0,00	0,00	0,00	0,00	0,00	0,00	1,19
DMUGWNWFST	2,86E-06	8,88	0,00	0,00	0,00	2,86E-06	0,00	0,00	0,45
DMUGWNWFSP	4,72E-06	10,63	0,00	0,00	0,00	4,72E-06	0,00	0,00	4,72E-06
DMUGWNSTSP	2,91E-06	9,04	0,00	0,00	0,00	2,91E-06	0,00	0,00	0,46
DMUGWFSTSP	0,00	8,16	0,00	0,00	0,00	0,00	0,00	0,00	1,39
DMUWNWFSTSP	4,15E-06	8,16	0,00	0,00	0,00	4,15E-06	0,00	0,00	5,45
DMUHGWNWFST	2,67E-06	8,30	0,00	0,00	0,00	2,67E-06	0,00	0,00	0,43
DMUHGWNWFSP	6,20E-06	9,47	0,00	0,00	0,00	6,20E-06	0,00	0,00	6,20E-06
DMUHGWNSTSP	5,59E-06	8,41	0,00	0,00	0,00	5,59E-06	0,00	0,00	0,66
DMUHGWFSTSP	0,00	7,79	0,00	0,00	0,00	0,00	0,00	0,00	1,32
DMUHWNWFSTSP	9,41E-06	7,79	0,00	0,00	0,00	9,41E-06	0,00	0,00	1,08
DMUGWNWFSTSP	5,91E-06	8,89	0,00	0,00	0,00	5,91E-06	0,00	0,00	0,70

Table 46 *- Weight Results of EEW-VRS-I*

Appendix 5 – Weight Results of EEW-VRS-O

Name	Energy Production	LCOE	Acidification	Ecotoxicity	Eutrophication	GWP	Land Occupation	PM	Social Acceptance
DMUH	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,56
DMUG	0,00	20,66	0,00	0,00	0,00	0,00	0,00	0,00	3,51
DMUWN	0,00	9,24	0,00	0,00	0,00	0,00	0,00	0,00	1,57
DMUWF	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,24
DMUST	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,15
DMUSP	0,00	6,74	0,00	0,00	0,00	0,00	0,00	0,00	1,15
DMUHG	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	2,16
DMUHWN	1,06E-06	2,08	0,00	0,00	0,00	1,06E-06	0,00	0,00	1,39
DMUHWF	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,38
DMUHST	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,32
DMUHSP	8,10E-07	0,19	0,00	8,10E-07	0,00	0,00	0,00	0,00	1,26
DMUGWN	1,06E-05	34,78	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUGWF	0,00	10,76	0,00	0,00	0,00	0,00	0,00	0,00	1,83
DMUGST	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,73
DMUGSP	0,00	10,17	0,00	0,00	0,00	0,00	0,00	0,00	1,73
DMUWNWF	7,60E-07	4,02	0,00	0,00	0,00	7,60E-07	0,00	0,00	1,27
DMUWNST	7,90E-07	0,19	0,00	0,00	0,00	7,90E-07	0,00	0,00	1,22
DMUWNSP	0,00	7,80	0,00	0,00	0,00	0,00	0,00	0,00	1,32
DMUWFST	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,19
DMUWFSP	7,30E-07	0,18	0,00	0,00	0,00	7,30E-07	0,00	0,00	1,13
DMUSTSP	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,15
DMUHGWN	5,77E-06	8,68	0,00	0,00	0,00	5,77E-06	0,00	0,00	0,68
DMUHGWF	1,07E-06	0,26	0,00	0,00	0,00	1,07E-06	0,00	0,00	1,66
DMUHGST	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,67
DMUHGSP	1,18E-06	2,31	0,00	0,00	0,00	1,18E-06	0,00	0,00	1,54
DMUHWNWF	9,60E-07	1,89	0,00	0,00	0,00	9,60E-07	0,00	0,00	1,26
DMUHWNST	8,50E-07	8,50E-07	0,00	0,00	0,00	8,50E-07	0,00	0,00	1,26
DMUHWNSP	2,30E-06	2,03	0,00	2,30E-06	0,00	0,00	0,00	0,00	0,91
DMUHWFST	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,29
DMUHWFSP	7,80E-07	0,19	0,00	7,80E-07	0,00	0,00	0,00	0,00	1,21
DMUHSTSP	8,10E-07	8,10E-07	0,00	8,10E-07	0,00	0,00	0,00	0,00	1,19
DMUGWNWF	4,87E-06	15,15	0,00	0,00	0,00	4,87E-06	0,00	0,00	0,78
DMUGWNST	1,13E-06	2,21	0,00	0,00	0,00	1,13E-06	0,00	0,00	1,48
DMUGWNSP	7,28E-06	23,78	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUGWFST	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	1,53

DMUGWFSP	0,00	8,98	0,00	0,00	0,00	0,00	0,00	0,00	1,53
DMUGSTSP	9,00E-07	0,22	0,00	0,00	0,00	9,00E-07	0,00	0,00	1,40
DMUWNWFST	7,60E-07	0,18	0,00	0,00	0,00	7,60E-07	0,00	0,00	1,18
DMUWNWFSP	8,60E-07	1,68	0,00	0,00	0,00	8,60E-07	0,00	0,00	1,12
DMUWNSTSP	7,30E-07	0,17	0,00	0,00	0,00	7,30E-07	0,00	0,00	1,13
DMUWFSTSP	7,20E-07	0,17	0,00	0,00	0,00	7,20E-07	0,00	0,00	1,11
DMUHGWNWF	4,74E-06	4,96	0,00	0,00	0,00	4,74E-06	0,00	0,00	0,64
DMUHGWNST	1,09E-06	2,14	0,00	0,00	0,00	1,09E-06	0,00	0,00	1,43
DMUHGWNSP	4,40E-06	6,62	0,00	4,40E-06	0,00	0,00	0,00	0,00	0,52
DMUHGWFST	9,40E-07	0,23	0,00	0,00	0,00	9,40E-07	0,00	0,00	1,46
DMUHGWFSP	1,07E-06	2,09	0,00	0,00	0,00	1,07E-06	0,00	0,00	1,40
DMUHGSTSP	9,00E-07	0,22	0,00	0,00	0,00	9,00E-07	0,00	0,00	1,40
DMUHWNWFST	8,20E-07	0,00	0,00	0,00	0,00	8,20E-07	0,00	0,00	1,20
DMUHWNWFSP	3,91E-06	3,24	0,00	0,00	0,00	0,00	0,00	0,00	0,45
DMUHWNSTSP	1,71E-06	1,71E-06	0,00	1,71E-06	0,00	0,00	0,00	0,00	0,96
DMUHWFSTSP	7,90E-07	7,90E-07	0,00	7,90E-07	0,00	0,00	0,00	0,00	1,16
DMUGWNWFST	1,02E-06	2,01	0,00	0,00	0,00	1,02E-06	0,00	0,00	1,34
DMUGWNWFSP	6,37E-06	14,35	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUGWNSTSP	3,80E-06	3,57	0,00	0,00	0,00	3,80E-06	0,00	0,00	0,67
DMUGWFSTSP	8,50E-07	0,20	0,00	0,00	0,00	8,50E-07	0,00	0,00	1,32
DMUWNWFSTSP	7,10E-07	0,17	0,00	7,10E-07	0,00	0,00	0,00	0,00	1,11
DMUHGWNWFST	2,52E-06	2,23	0,00	0,00	0,00	2,52E-06	0,00	0,00	1,00
DMUHGWNWFSP	5,73E-06	8,74	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUHGWNSTSP	6,10E-06	1,44	0,00	0,00	0,00	6,10E-06	0,00	0,00	6,10E-06
DMUHGWFSTSP	8,50E-07	0,20	0,00	0,00	0,00	8,50E-07	0,00	0,00	1,32
DMUHWNWFSTSP	1,64E-06	1,64E-06	0,00	1,64E-06	0,00	0,00	0,00	0,00	0,92
DMUGWNWFSTSP	4,07E-06	3,37	0,00	0,00	0,00	4,07E-06	0,00	0,00	0,47

Table 47 *- Weight Results of EEW-VRS-O*

Appendix 6 – Weight Results of EEW-CRS-I

Name	Energy Production	LCOE	Acidification	Ecotoxicity	Eutrophication	GWP	Land Occupation	PM	Social Acceptance
DMUH	0,00	6,58	0,00	0,00	0,00	0,00	0,00	0,00	0,74
DMUG	0,00	13,84	0,00	0,00	0,00	0,00	0,00	0,00	1,56
DMUWN	0,00	13,89	0,00	0,00	0,00	0,00	0,00	0,00	1,57
DMUWF	0,00	8,33	0,00	0,00	0,00	0,00	0,00	0,00	0,94
DMUST	0,00	5,38	0,00	0,00	0,00	0,00	0,00	0,00	0,61
DMUSP	0,00	8,93	0,00	0,00	0,00	0,00	0,00	0,00	1,01
DMUHG	0,00	8,92	0,00	0,00	0,00	0,00	0,00	0,00	1,01
DMUHWN	2,24E-06	8,93	0,00	0,00	0,00	2,24E-06	0,00	0,00	0,69
DMUHWF	0,00	7,35	0,00	0,00	0,00	0,00	0,00	0,00	0,83
DMUHST	0,00	5,92	0,00	0,00	0,00	0,00	0,00	0,00	0,67
DMUHSP	0,00	7,58	0,00	0,00	0,00	0,00	0,00	0,00	0,86
DMUGWN	4,93E-06	13,87	0,00	0,00	0,00	4,93E-06	0,00	0,00	0,81
DMUGWF	0,00	10,40	0,00	0,00	0,00	0,00	0,00	0,00	1,18
DMUGST	0,00	7,74	0,00	0,00	0,00	0,00	0,00	0,00	0,87
DMUGSP	0,00	10,86	0,00	0,00	0,00	0,00	0,00	0,00	1,23
DMUWNWF	2,61E-06	10,42	0,00	2,61E-06	0,00	0,00	0,00	0,00	0,81
DMUWNST	0,00	7,75	0,00	0,00	0,00	0,00	0,00	0,00	0,88
DMUWNSP	2,72E-06	10,87	0,00	0,00	0,00	2,72E-06	0,00	0,00	0,84
DMUWFST	0,00	6,54	0,00	0,00	0,00	0,00	0,00	0,00	0,74
DMUWFSP	0,00	8,62	0,00	0,00	0,00	0,00	0,00	0,00	0,97
DMUSTSP	0,00	6,71	0,00	0,00	0,00	0,00	0,00	0,00	0,76
DMUHGWN	3,60E-06	10,13	0,00	0,00	0,00	3,60E-06	0,00	0,00	0,59
DMUHGWF	0,00	8,71	0,00	0,00	0,00	0,00	0,00	0,00	0,98
DMUHGST	0,00	7,31	0,00	0,00	0,00	0,00	0,00	0,00	0,83
DMUHGSP	0,00	8,92	0,00	0,00	0,00	0,00	0,00	0,00	1,01
DMUHWNWF	3,10E-06	8,72	0,00	0,00	0,00	3,10E-06	0,00	0,00	0,51
DMUHWNST	1,83E-06	7,32	0,00	0,00	0,00	1,83E-06	0,00	0,00	0,57
DMUHWNSP	3,18E-06	8,93	0,00	3,18E-06	0,00	0,00	0,00	0,00	0,52
DMUHWFST	0,00	6,55	0,00	0,00	0,00	0,00	0,00	0,00	0,74
DMUHWFSP	0,00	7,81	0,00	0,00	0,00	0,00	0,00	0,00	0,88
DMUHSTSP	0,00	6,67	0,00	0,00	0,00	0,00	0,00	0,00	0,75
DMUGWNWF	4,04E-06	11,35	0,00	0,00	0,00	4,04E-06	0,00	0,00	0,67
DMUGWNST	2,28E-06	9,08	0,00	0,00	0,00	2,28E-06	0,00	0,00	0,70
DMUGWNSP	4,17E-06	11,71	0,00	0,00	0,00	0,00	0,00	4,17E-06	0,69
DMUGWFST	0,00	7,93	0,00	0,00	0,00	0,00	0,00	0,00	0,90

DMUGWFSP	0,00	9,86	0,00	0,00	0,00	0,00	0,00	0,00	1,11
DMUGSTSP	0,00	8,10	0,00	0,00	0,00	0,00	0,00	0,00	0,92
DMUWNWFST	1,99E-06	7,94	0,00	0,00	0,00	1,99E-06	0,00	0,00	0,61
DMUWNWFSP	3,51E-06	9,87	0,00	0,00	0,00	3,51E-06	0,00	0,00	0,58
DMUWNSTSP	2,88E-06	8,11	0,00	0,00	0,00	2,88E-06	0,00	0,00	0,48
DMUWFSTSP	0,00	7,18	0,00	0,00	0,00	0,00	0,00	0,00	0,81
DMUHGWNWF	3,42E-06	9,61	0,00	0,00	0,00	3,42E-06	0,00	0,00	0,56
DMUHGWNST	2,95E-06	8,29	0,00	0,00	0,00	2,95E-06	0,00	0,00	0,49
DMUHGWNSP	5,87E-06	9,80	0,00	5,87E-06	0,00	0,00	0,00	0,00	5,87E-06
DMUHGWFST	0,00	7,54	0,00	0,00	0,00	0,00	0,00	0,00	0,85
DMUHGWFSP	0,00	8,77	0,00	0,00	0,00	0,00	0,00	0,00	0,99
DMUHGSTSP	0,00	7,66	0,00	0,00	0,00	0,00	0,00	0,00	0,87
DMUHWNWFST	2,68E-06	7,55	0,00	0,00	0,00	2,68E-06	0,00	0,00	0,44
DMUHWNWFSP	3,12E-06	8,77	0,00	3,12E-06	0,00	0,00	0,00	0,00	0,52
DMUHWNSTSP	2,73E-06	7,66	0,00	0,00	0,00	2,73E-06	0,00	0,00	0,45
DMUHWFSTSP	0,00	7,02	0,00	0,00	0,00	0,00	0,00	0,00	0,79
DMUGWNWFST	3,16E-06	8,88	0,00	0,00	0,00	3,16E-06	0,00	0,00	0,52
DMUGWNWFSP	3,78E-06	10,63	0,00	0,00	0,00	3,78E-06	0,00	0,00	0,62
DMUGWNSTSP	3,22E-06	9,04	0,00	0,00	0,00	3,22E-06	0,00	0,00	0,53
DMUGWFSTSP	0,00	8,16	0,00	0,00	0,00	0,00	0,00	0,00	0,92
DMUWNWFSTSP	2,90E-06	8,16	0,00	0,00	0,00	2,90E-06	0,00	0,00	0,48
DMUHGWNWFST	2,95E-06	8,30	0,00	0,00	0,00	2,95E-06	0,00	0,00	0,49
DMUHGWNWFSP	5,67E-06	9,47	0,00	5,67E-06	0,00	0,00	0,00	0,00	5,67E-06
DMUHGWNSTSP	5,04E-06	8,41	0,00	0,00	0,00	5,04E-06	0,00	0,00	5,04E-06
DMUHGWFSTSP	0,00	7,79	0,00	0,00	0,00	0,00	0,00	0,00	0,88
DMUHWNWFSTSP	2,77E-06	7,79	0,00	0,00	0,00	2,77E-06	0,00	0,00	0,46
DMUGWNWFSTSP	3,16E-06	8,89	0,00	0,00	0,00	3,16E-06	0,00	0,00	0,52

***Table 48** - Weight Results of EEW-CRS-I*

Appendix 7 – Weight Results of EDW-VRS-I

Name	Energy Production	LCOE	Acidification	Ecotoxicity	Eutrophication	GWP	Land Occupation	PM	Social Acceptance
DMUH	0,00	6,58	0,00	0,00	0,00	0,00	0,00	0,00	1,12
DMUG	0,00	13,84	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUWN	0,00	13,89	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUWF	0,00	8,33	0,00	0,00	0,00	0,00	0,00	0,00	1,42
DMUST	0,00	5,38	0,00	0,00	0,00	0,00	0,00	0,00	0,91
DMUSP	0,00	8,93	0,00	0,00	0,00	0,00	0,00	0,00	1,52
DMUHG	0,00	11,34	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUHWN	2,00E-06	11,36	0,00	0,00	0,00	2,00E-06	0,00	0,00	1,58
DMUHWF	0,00	7,91	0,00	0,00	0,00	0,00	0,00	0,00	1,34
DMUHST	0,00	5,58	0,00	0,00	0,00	0,00	0,00	0,00	0,95
DMUHSP	0,00	8,33	0,00	0,00	0,00	0,00	0,00	0,00	1,42
DMUGWN	1,00E-08	13,88	0,00	0,00	0,00	1,00E-08	0,00	0,00	1,00E-08
DMUGWF	0,00	9,05	0,00	0,00	0,00	0,00	0,00	0,00	1,54
DMUGST	0,00	6,13	0,00	0,00	0,00	0,00	0,00	0,00	1,04
DMUGSP	0,00	9,61	0,00	0,00	0,00	0,00	0,00	0,00	1,63
DMUWNWF	0,00	9,06	0,00	0,00	0,00	0,00	0,00	0,00	1,54
DMUWNST	0,00	6,13	0,00	0,00	0,00	0,00	0,00	0,00	1,04
DMUWNSP	0,00	9,62	0,00	0,00	0,00	0,00	0,00	0,00	1,63
DMUWFST	0,00	5,79	0,00	0,00	0,00	0,00	0,00	0,00	0,98
DMUWFSP	1,96E-06	8,80	0,00	0,00	0,00	1,96E-06	0,00	0,00	4,09
DMUSTSP	3,35E-06	7,89	0,00	0,00	0,00	3,35E-06	0,00	0,00	7,89
DMUHGWN	1,00E-08	11,35	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUHGWF	0,00	9,32	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUHGST	0,00	7,48	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUHGSP	0,00	9,61	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUHWNWF	1,59E-06	9,33	0,00	0,00	0,00	1,59E-06	0,00	0,00	1,46
DMUHWNST	1,28E-06	7,49	0,00	0,00	0,00	1,28E-06	0,00	0,00	1,17
DMUHWNSP	2,63E-06	9,62	0,00	0,00	0,00	2,63E-06	0,00	0,00	1,84
DMUHWFST	0,00	6,54	0,00	0,00	0,00	0,00	0,00	0,00	1,11
DMUHWFSP	0,00	8,12	0,00	0,00	0,00	0,00	0,00	0,00	1,38
DMUHSTSP	0,00	6,68	0,00	0,00	0,00	0,00	0,00	0,00	1,14
DMUGWNWF	1,93E-06	10,96	0,00	0,00	0,00	1,93E-06	0,00	0,00	1,52
DMUGWNST	1,45E-06	8,50	0,00	0,00	0,00	1,45E-06	0,00	0,00	1,33
DMUGWNSP	3,10E-06	11,36	0,00	0,00	0,00	3,10E-06	0,00	0,00	2,18
DMUGWFST	0,00	7,31	0,00	0,00	0,00	0,00	0,00	0,00	1,24

DMUGWFSP	0,00	9,32	0,00	0,00	0,00	0,00	0,00	0,00	1,58
DMUGSTSP	0,00	7,48	0,00	0,00	0,00	0,00	0,00	0,00	1,27
DMUWNWFST	0,00	7,31	0,00	0,00	0,00	0,00	0,00	0,00	1,24
DMUWNWFSP	6,82E-06	9,33	0,00	0,00	0,00	6,82E-06	0,00	0,00	5,32
DMUWNSTSP	6,74E-06	7,48	0,00	0,00	0,00	6,74E-06	0,00	0,00	7,48
DMUWFSTSP	1,56E-06	6,98	0,00	0,00	0,00	1,56E-06	0,00	0,00	3,25
DMUHGWNWF	1,75E-06	9,91	1,75E-06	0,00	0,00	0,00	0,00	0,00	1,38
DMUHGWNST	1,49E-06	8,44	0,00	1,49E-06	0,00	0,00	0,00	0,00	1,17
DMUHGWNSP	9,73E-06	10,13	0,00	0,00	0,00	9,73E-06	0,00	0,00	9,73E-06
DMUHGWFST	0,00	7,62	0,00	0,00	0,00	0,00	0,00	0,00	1,29
DMUHGWFSP	0,00	8,97	0,00	0,00	0,00	0,00	0,00	0,00	1,52
DMUHGSTSP	0,00	7,74	0,00	0,00	0,00	0,00	0,00	0,00	1,32
DMUHWNWFST	2,08E-06	7,62	0,00	0,00	0,00	2,08E-06	0,00	0,00	1,46
DMUHWNWFSP	4,06E-06	8,97	0,00	0,00	0,00	4,06E-06	0,00	0,00	2,85
DMUHWNSTSP	5,66E-06	7,75	0,00	0,00	0,00	5,66E-06	0,00	0,00	4,42
DMUHWFSTSP	0,00	7,05	0,00	0,00	0,00	0,00	0,00	0,00	1,20
DMUGWNWFST	1,48E-06	8,68	0,00	0,00	0,00	1,48E-06	0,00	0,00	1,35
DMUGWNWFSP	1,58E-05	10,47	0,00	0,00	0,00	1,58E-05	0,00	0,00	0,11
DMUGWNSTSP	2,42E-06	8,84	0,00	0,00	0,00	2,42E-06	0,00	0,00	1,69
DMUGWFSTSP	0,00	7,94	0,00	0,00	0,00	0,00	0,00	0,00	1,35
DMUWNWFSTSP	5,81E-06	7,94	0,00	0,00	0,00	5,81E-06	0,00	0,00	4,53
DMUHGWNWFST	1,46E-06	8,30	0,00	0,00	0,00	1,46E-06	0,00	0,00	1,15
DMUHGWNWFSP	1,43E-05	9,47	0,00	0,00	0,00	1,43E-05	0,00	0,00	0,10
DMUHGWNSTSP	1,27E-05	8,41	0,00	0,00	0,00	1,27E-05	0,00	0,00	0,09
DMUHGWFSTSP	0,00	7,79	0,00	0,00	0,00	0,00	0,00	0,00	1,32
DMUHWNWFSTSP	8,38E-06	7,79	0,00	0,00	0,00	8,38E-06	0,00	0,00	5,69
DMUGWNWFSTSP	2,43E-06	8,89	0,00	0,00	0,00	2,43E-06	0,00	0,00	1,70

Table 49 *- Weight Results of EDW-VRS-I*

Appendix 8 – Weight Results of EDW-VRS-O

Name	Energy Production	LCOE	Acidification	Ecotoxicity	Eutrophication	GWP	Land Occupation	PM	Social Acceptance
DMUH	0,00	1,56	0,00	0,00	0,00	0,00	0,00	0,00	1,56
DMUG	0,00	20,66	0,00	0,00	0,00	0,00	0,00	0,00	3,51
DMUWN	0,00	9,24	0,00	0,00	0,00	0,00	0,00	0,00	1,57
DMUWF	0,00	1,24	0,00	0,00	0,00	0,00	0,00	0,00	1,24
DMUST	0,00	1,15	0,00	0,00	0,00	0,00	0,00	0,00	1,15
DMUSP	0,00	6,74	0,00	0,00	0,00	0,00	0,00	0,00	1,15
DMUHG	0,00	16,53	0,00	0,00	0,00	0,00	0,00	0,00	2,81
DMUHWN	1,36E-06	7,97	0,00	0,00	0,00	1,36E-06	0,00	0,00	1,24
DMUHWF	5,40E-07	1,26	0,00	0,00	0,00	5,40E-07	0,00	0,00	1,26
DMUHST	0,00	1,21	0,00	0,00	0,00	0,00	0,00	0,00	1,21
DMUHSP	9,70E-07	1,12	0,00	9,70E-07	0,00	0,00	0,00	0,00	1,12
DMUGWN	6,84E-06	7,12	0,00	0,00	0,00	6,84E-06	0,00	0,00	0,00
DMUGWF	0,00	8,36	0,00	0,00	0,00	0,00	0,00	0,00	1,42
DMUGST	0,00	1,32	0,00	0,00	0,00	0,00	0,00	0,00	1,32
DMUGSP	0,00	7,79	0,00	0,00	0,00	0,00	0,00	0,00	1,32
DMUWNWF	5,90E-07	2,67	0,00	0,00	0,00	5,90E-07	0,00	0,00	1,24
DMUWNST	5,00E-07	1,18	0,00	0,00	0,00	5,00E-07	0,00	0,00	1,18
DMUWNSP	1,16E-06	6,81	0,00	0,00	0,00	1,16E-06	0,00	0,00	1,06
DMUWFST	0,00	1,16	0,00	0,00	0,00	0,00	0,00	0,00	1,16
DMUWFSP	9,40E-07	1,08	0,00	0,00	0,00	0,00	9,40E-07	0,00	1,08
DMUSTSP	4,70E-07	1,11	0,00	0,00	0,00	4,70E-07	0,00	0,00	1,11
DMUHGWN	8,10E-06	5,42	0,00	0,00	0,00	8,10E-06	0,00	0,00	8,10E-06
DMUHGWF	0,00	10,41	0,00	0,00	0,00	0,00	0,00	0,00	1,77
DMUHGST	0,00	1,69	0,00	0,00	0,00	0,00	0,00	0,00	1,69
DMUHGSP	0,00	9,96	0,00	0,00	0,00	0,00	0,00	0,00	1,69
DMUHWNWF	1,57E-06	3,46	0,00	0,00	0,00	1,57E-06	0,00	0,00	1,10
DMUHWNST	1,06E-06	1,18	0,00	0,00	0,00	1,06E-06	0,00	0,00	1,18
DMUHWNSP	1,46E-06	3,22	0,00	1,46E-06	0,00	0,00	0,00	0,00	1,02
DMUHWFST	5,20E-07	1,22	0,00	0,00	0,00	5,20E-07	0,00	0,00	1,22
DMUHWFSP	9,90E-07	1,14	0,00	0,00	0,00	9,90E-07	0,00	0,00	1,14
DMUHSTSP	9,80E-07	1,12	0,00	0,00	0,00	9,80E-07	0,00	0,00	1,12
DMUGWNWF	1,40E-06	8,19	0,00	0,00	0,00	1,40E-06	0,00	0,00	1,28
DMUGWNST	1,57E-06	2,15	0,00	0,00	0,00	1,57E-06	0,00	0,00	1,22
DMUGWNSP	6,14E-06	4,11	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUGWFST	5,70E-07	1,34	0,00	0,00	0,00	5,70E-07	0,00	0,00	1,34

DMUGWFSP	6,30E-07	2,81	0,00	0,00	0,00	6,30E-07	0,00	0,00	1,30
DMUGSTSP	5,40E-07	1,28	0,00	0,00	0,00	5,40E-07	0,00	0,00	1,28
DMUWNWFST	9,90E-07	1,14	0,00	0,00	0,00	9,90E-07	0,00	0,00	1,14
DMUWNWFSP	1,33E-06	1,81	0,00	0,00	0,00	1,33E-06	0,00	0,00	1,03
DMUWNSTSP	9,70E-07	1,07	0,00	0,00	0,00	9,70E-07	0,00	0,00	1,07
DMUWFSTSP	4,80E-07	1,12	0,00	0,00	0,00	4,80E-07	0,00	0,00	1,12
DMUHGWNWF	1,82E-06	6,67	0,00	0,00	0,00	1,82E-06	0,00	0,00	1,28
DMUHGWNST	1,67E-06	2,29	0,00	0,00	0,00	1,67E-06	0,00	0,00	1,31
DMUHGWNSP	6,22E-06	4,16	0,00	0,00	0,00	6,22E-06	0,00	0,00	0,00
DMUHGWFST	6,30E-07	1,49	0,00	0,00	0,00	6,30E-07	0,00	0,00	1,49
DMUHGWFSP	1,24E-06	1,37	0,00	0,00	0,00	1,24E-06	0,00	0,00	1,37
DMUHGSTSP	1,18E-06	1,36	0,00	0,00	0,00	1,18E-06	0,00	0,00	1,36
DMUHWNWFST	1,52E-06	1,05	0,00	0,00	0,00	1,52E-06	0,00	0,00	1,05
DMUHWNWFSP	1,46E-06	1,36	1,46E-06	0,00	0,00	0,00	0,00	0,00	0,99
DMUHWNSTSP	1,44E-06	1,00	0,00	0,00	0,00	1,44E-06	0,00	0,00	1,00
DMUHWFSTSP	9,80E-07	1,13	0,00	0,00	0,00	9,80E-07	0,00	0,00	1,13
DMUGWNWFST	1,52E-06	2,08	0,00	0,00	0,00	1,52E-06	0,00	0,00	1,19
DMUGWNWFSP	5,84E-06	3,88	0,00	0,00	0,00	5,84E-06	0,00	0,00	0,04
DMUGWNSTSP	1,44E-06	1,97	0,00	0,00	0,00	1,44E-06	0,00	0,00	1,12
DMUGWFSTSP	1,08E-06	1,24	0,00	0,00	0,00	1,08E-06	0,00	0,00	1,24
DMUWNWFSTSP	9,60E-07	1,06	0,00	0,00	0,00	9,60E-07	0,00	0,00	1,06
DMUHGWNWFST	1,72E-06	1,60	0,00	0,00	0,00	1,72E-06	0,00	0,00	1,17
DMUHGWNWFSP	5,73E-06	3,83	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUHGWNSTSP	6,10E-06	0,79	0,00	0,00	0,00	6,10E-06	0,00	0,00	6,10E-06
DMUHGWFSTSP	1,15E-06	1,28	0,00	0,00	0,00	1,15E-06	0,00	0,00	1,28
DMUHWNWFSTSP	5,56E-06	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUGWNWFSTSP	6,03E-06	0,78	0,00	0,00	0,00	6,03E-06	0,00	0,00	6,03E-06

Table 50 *- Weight Results of EDW-VRS-0*

Appendix 9 – Weight Results of EDW-CRS-I

Name	Energy Production	LCOE	Acidification	Ecotoxicity	Eutrophication	GWP	Land Occupation	PM	Social Acceptance
DMUH	0,00	6,58	0,00	0,00	0,00	0,00	0,00	0,00	0,74
DMUG	0,00	13,84	0,00	0,00	0,00	0,00	0,00	0,00	1,56
DMUWN	0,00	13,89	0,00	0,00	0,00	0,00	0,00	0,00	1,57
DMUWF	0,00	8,33	0,00	0,00	0,00	0,00	0,00	0,00	0,94
DMUST	0,00	5,38	0,00	0,00	0,00	0,00	0,00	0,00	0,61
DMUSP	0,00	8,93	0,00	0,00	0,00	0,00	0,00	0,00	1,01
DMUHG	0,00	11,34	0,00	0,00	0,00	0,00	0,00	0,00	1,28
DMUHWN	1,39E-06	11,36	0,00	1,39E-06	0,00	0,00	0,00	0,00	1,09
DMUHWF	0,00	7,91	0,00	0,00	0,00	0,00	0,00	0,00	0,89
DMUHST	0,00	5,58	0,00	0,00	0,00	0,00	0,00	0,00	0,63
DMUHSP	0,00	8,33	0,00	0,00	0,00	0,00	0,00	0,00	0,94
DMUGWN	1,69E-06	13,88	0,00	0,00	0,00	1,69E-06	0,00	0,00	1,33
DMUGWF	0,00	9,05	0,00	0,00	0,00	0,00	0,00	0,00	1,02
DMUGST	0,00	6,13	0,00	0,00	0,00	0,00	0,00	0,00	0,69
DMUGSP	0,00	9,61	0,00	0,00	0,00	0,00	0,00	0,00	1,09
DMUWNWF	0,00	9,06	0,00	0,00	0,00	0,00	0,00	0,00	1,02
DMUWNST	0,00	6,13	0,00	0,00	0,00	0,00	0,00	0,00	0,69
DMUWNSP	0,00	9,62	0,00	0,00	0,00	0,00	0,00	0,00	1,09
DMUWFST	0,00	5,79	0,00	0,00	0,00	0,00	0,00	0,00	0,65
DMUWFSP	0,00	8,80	0,00	0,00	0,00	0,00	0,00	0,00	0,99
DMUSTSP	0,00	7,89	0,00	0,00	0,00	0,00	0,00	0,00	0,89
DMUHGWN	1,38E-06	11,35	0,00	1,38E-06	0,00	0,00	0,00	0,00	1,09
DMUHGWF	0,00	9,32	0,00	0,00	0,00	0,00	0,00	0,00	1,05
DMUHGST	0,00	7,48	0,00	0,00	0,00	0,00	0,00	0,00	0,85
DMUHGSP	0,00	9,61	0,00	0,00	0,00	0,00	0,00	0,00	1,09
DMUHWNWF	1,14E-06	9,33	1,14E-06	0,00	0,00	0,00	0,00	0,00	0,89
DMUHWNST	9,10E-07	7,49	0,00	9,10E-07	0,00	0,00	0,00	0,00	0,72
DMUHWNSP	1,17E-06	9,62	0,00	0,00	0,00	0,00	0,00	0,00	0,92
DMUHWFST	0,00	6,54	0,00	0,00	0,00	0,00	0,00	0,00	0,74
DMUHWFSP	0,00	8,12	0,00	0,00	0,00	0,00	0,00	0,00	0,92
DMUHSTSP	0,00	6,68	0,00	0,00	0,00	0,00	0,00	0,00	0,76
DMUGWNWF	1,34E-06	10,96	1,34E-06	0,00	0,00	0,00	0,00	0,00	1,05
DMUGWNST	1,04E-06	8,50	0,00	0,00	0,00	1,04E-06	0,00	0,00	0,81
DMUGWNSP	1,38E-06	11,36	0,00	0,00	0,00	0,00	0,00	0,00	1,09
DMUGWFST	0,00	7,31	0,00	0,00	0,00	0,00	0,00	0,00	0,83

DMUGWFSP	0,00	9,32	0,00	0,00	0,00	0,00	0,00	0,00	1,05
DMUGSTSP	0,00	7,48	0,00	0,00	0,00	0,00	0,00	0,00	0,85
DMUWNWFST	0,00	7,31	0,00	0,00	0,00	0,00	0,00	0,00	0,83
DMUWNWFSP	1,14E-06	9,33	0,00	0,00	0,00	0,00	0,00	0,00	0,89
DMUWNSTSP	0,00	7,49	0,00	0,00	0,00	0,00	0,00	0,00	0,85
DMUWFSTSP	0,00	6,98	0,00	0,00	0,00	0,00	0,00	0,00	0,79
DMUHGWNWF	1,21E-06	9,91	1,21E-06	0,00	0,00	0,00	0,00	0,00	0,95
DMUHGWNST	1,03E-06	8,44	0,00	1,03E-06	0,00	0,00	0,00	0,00	0,81
DMUHGWNSP	4,99E-06	10,13	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUHGWFST	0,00	7,62	0,00	0,00	0,00	0,00	0,00	0,00	0,86
DMUHGWFSP	0,00	8,97	0,00	0,00	0,00	0,00	0,00	0,00	1,01
DMUHGSTSP	0,00	7,74	0,00	0,00	0,00	0,00	0,00	0,00	0,87
DMUHWNWFST	9,30E-07	7,62	9,30E-07	0,00	0,00	0,00	0,00	0,00	0,73
DMUHWNWFSP	1,09E-06	8,97	0,00	0,00	0,00	0,00	0,00	0,00	0,86
DMUHWNSTSP	9,40E-07	7,75	9,40E-07	0,00	0,00	0,00	0,00	0,00	0,74
DMUHWFSTSP	0,00	7,05	0,00	0,00	0,00	0,00	0,00	0,00	0,80
DMUGWNWFST	1,06E-06	8,68	1,06E-06	0,00	0,00	0,00	0,00	0,00	0,83
DMUGWNWFSP	1,28E-06	10,47	0,00	0,00	0,00	0,00	0,00	0,00	1,00
DMUGWNSTSP	1,08E-06	8,84	1,08E-06	0,00	0,00	0,00	0,00	0,00	0,85
DMUGWFSTSP	0,00	7,94	0,00	0,00	0,00	0,00	0,00	0,00	0,90
DMUWNWFSTSP	9,70E-07	7,94	9,70E-07	0,00	0,00	0,00	0,00	0,00	0,76
DMUHGWNWFST	1,01E-06	8,30	1,01E-06	0,00	0,00	0,00	0,00	0,00	0,79
DMUHGWNWFSP	4,67E-06	9,47	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUHGWNSTSP	1,03E-06	8,41	1,03E-06	0,00	0,00	0,00	0,00	0,00	0,80
DMUHGWFSTSP	0,00	7,79	0,00	0,00	0,00	0,00	0,00	0,00	0,88
DMUHWNWFSTSP	9,50E-07	7,79	9,50E-07	0,00	0,00	0,00	0,00	0,00	0,75
DMUGWNWFSTSP	1,08E-06	8,89	1,08E-06	0,00	0,00	0,00	0,00	0,00	0,85

Table 51 *- Weight Results of EDW-CRS-I*

Appendix 10 – Weight Results of EEE-CRS-I

Name	Energy Production	LCOE	Social Acceptance	Environmental Score
DMUH	0,00	2,65	1,14	0,50
DMUG	0,00	3,80	1,64	0,71
DMUWN	7,50E-07	3,54	1,46	0,69
DMUWF	0,00	2,79	1,20	0,52
DMUST	0,00	2,65	1,15	0,50
DMUSP	0,00	8,93	1,01	0,00
DMUHG	0,00	3,12	1,35	0,59
DMUHWN	1,98E-06	3,21	1,03	0,56
DMUHWF	0,00	2,72	1,17	0,51
DMUHST	0,00	2,65	1,15	0,50
DMUHSP	0,00	2,31	1,00	0,43
DMUGWN	4,33E-06	12,06	0,95	0,12
DMUGWF	0,00	3,22	1,39	0,60
DMUGST	0,00	3,13	1,35	0,59
DMUGSP	0,00	10,86	1,23	0,00
DMUWNWF	2,05E-06	3,31	1,07	0,58
DMUWNST	6,40E-07	3,00	1,24	0,58
DMUWNSP	3,27E-06	9,20	0,74	0,10
DMUWFST	0,00	2,72	1,17	0,51
DMUWFSP	0,00	2,36	1,02	0,44
DMUSTSP	0,00	2,31	1,00	0,43
DMUHGWN	3,08E-06	5,10	0,91	0,45
DMUHGWF	0,00	3,00	1,30	0,56
DMUHGST	0,00	2,95	1,27	0,55
DMUHGSP	0,00	2,66	1,15	0,50
DMUHWNWF	1,92E-06	3,10	1,00	0,54
DMUHWNST	2,68E-06	0,00	0,91	0,91
DMUHWNSP	2,69E-06	4,31	0,71	0,36
DMUHWFST	0,00	2,70	1,16	0,51
DMUHWFSP	0,00	2,45	1,06	0,46
DMUHSTSP	0,00	2,42	1,04	0,45
DMUGWNWF	3,22E-06	5,33	0,95	0,47
DMUGWNST	2,13E-06	3,41	1,10	0,60
DMUGWNSP	4,17E-06	11,71	0,69	0,00
DMUGWFST	0,00	3,00	1,30	0,56
DMUGWFSP	0,00	2,70	1,17	0,51
DMUGSTSP	0,00	2,66	1,15	0,50
DMUWNWFST	6,10E-07	2,90	1,20	0,57
DMUWNWFSP	3,09E-06	8,60	0,68	0,09

DMUWNSTSP	1,71E-06	2,76	0,89	0,48
DMUWFSTSP	0,00	2,45	1,06	0,46
DMUHGWNWF	2,94E-06	4,87	0,87	0,43
DMUHGWNST	3,14E-06	0,00	0,85	0,93
DMUHGWNSP	3,17E-06	5,52	0,71	0,33
DMUHGWFST	0,00	2,91	1,26	0,55
DMUHGWFSP	0,00	2,69	1,16	0,51
DMUHGSTSP	0,00	2,66	1,15	0,50
DMUHWNWFST	2,58E-06	0,00	0,88	0,88
DMUHWNWFSP	2,71E-06	4,34	0,72	0,36
DMUHWNSTSP	1,71E-06	2,75	0,89	0,48
DMUHWFSTSP	0,00	2,50	1,08	0,47
DMUGWNWFST	2,04E-06	3,27	1,06	0,58
DMUGWNWFSP	3,33E-06	9,27	0,73	0,10
DMUGWNSTSP	2,70E-06	4,47	0,79	0,40
DMUGWFSTSP	0,00	2,69	1,16	0,51
DMUWNWFSTSP	1,75E-06	2,82	0,90	0,49
DMUHGWNWFST	3,03E-06	0,00	0,82	0,90
DMUHGWNWFSP	3,11E-06	5,43	0,70	0,32
DMUHGWNSTSP	5,82E-06	1,37	0,00	0,66
DMUHGWFSTSP	0,00	2,68	1,16	0,50
DMUHWNWFSTSP	2,61E-06	4,19	0,69	0,35
DMUGWNWFSTSP	2,84E-06	4,55	0,75	0,38

Table 52 *- Weight Results of EEE-CRS-I*

Appendix 11 – Weight Results of CEW-CRS-I

Name	Capacity Factor	LCOE	Acidification	Ecotoxicity	Eutrophication	GWP	Land Occupation	PM	Social Acceptance
DMUH	0,54	6,29	0,00	0,54	0,00	0,00	0,00	0,00	0,67
DMUG	1,72	13,84	0,00	0,00	0,00	0,00	0,00	0,00	0,00
DMUWN	1,20	9,45	0,00	0,79	0,00	0,41	0,00	0,00	1,20
DMUWF	0,66	8,31	0,66	0,00	0,00	0,00	0,00	0,00	0,76
DMUST	0,90	4,66	0,00	0,08	0,00	0,81	0,00	0,00	0,90
DMUSP	0,00	8,93	0,00	0,00	0,00	0,00	0,00	0,00	1,01
DMUHG	0,71	8,37	0,00	0,71	0,00	0,00	0,00	0,00	0,89
DMUHWN	0,70	8,21	0,00	0,70	0,00	0,00	0,00	0,00	0,87
DMUHWF	0,59	7,32	0,59	0,00	0,00	0,00	0,00	0,00	0,67
DMUHST	0,49	5,78	0,00	0,49	0,00	0,00	0,00	0,00	0,62
DMUHSP	0,62	7,58	0,00	0,00	0,00	0,00	0,00	0,00	0,66
DMUGWN	1,41	5,83	0,00	0,00	0,00	0,98	0,00	0,00	0,98
DMUGWF	0,83	10,38	0,83	0,00	0,00	0,00	0,00	0,00	0,95
DMUGST	1,20	4,98	0,00	0,00	0,00	0,84	0,00	0,00	0,84
DMUGSP	0,88	10,86	0,00	0,00	0,00	0,00	0,00	0,00	0,95
DMUWNWF	0,82	10,30	0,82	0,00	0,00	0,00	0,00	0,00	0,94
DMUWNST	1,03	5,33	0,00	0,10	0,00	0,93	0,00	0,00	1,03
DMUWNSP	0,00	10,87	0,00	0,00	0,00	0,00	0,00	0,00	1,23
DMUWFST	0,52	6,53	0,52	0,00	0,00	0,00	0,00	0,00	0,59
DMUWFSP	0,00	8,62	0,00	0,00	0,00	0,00	0,00	0,00	0,97
DMUSTSP	0,00	6,71	0,00	0,00	0,00	0,00	0,00	0,00	0,76
DMUHGWN	0,79	9,27	0,00	0,79	0,00	0,00	0,00	0,00	0,99
DMUHGWF	0,69	8,68	0,69	0,00	0,00	0,00	0,00	0,00	0,79
DMUHGST	0,60	7,05	0,00	0,60	0,00	0,00	0,00	0,00	0,75
DMUHGSP	0,73	8,92	0,00	0,00	0,00	0,00	0,00	0,00	0,78
DMUHWNWF	0,69	8,64	0,69	0,00	0,00	0,00	0,00	0,00	0,79
DMUHWNST	0,59	6,97	0,00	0,59	0,00	0,00	0,00	0,00	0,74
DMUHWNSP	0,73	8,93	0,00	0,00	0,00	0,00	0,00	0,00	0,78
DMUHWFST	0,52	6,53	0,52	0,00	0,00	0,00	0,00	0,00	0,60
DMUHWFSP	0,61	7,66	0,61	0,00	0,00	0,00	0,00	0,00	0,70
DMUHSTSP	0,52	6,56	0,52	0,00	0,00	0,00	0,00	0,00	0,60
DMUGWNWF	0,90	11,25	0,90	0,00	0,00	0,00	0,00	0,00	1,03
DMUGWNST	1,30	5,40	0,00	0,00	0,00	0,91	0,00	0,00	0,91
DMUGWNSP	0,95	11,71	0,00	0,00	0,00	0,00	0,00	0,00	1,03
DMUGWFST	0,63	7,92	0,63	0,00	0,00	0,00	0,00	0,00	0,72

DMUGWFSP	0,80	9,86	0,00	0,00	0,00	0,00	0,00	0,00	0,87
DMUGSTSP	0,64	7,96	0,64	0,00	0,00	0,00	0,00	0,00	0,73
DMUWNWFST	0,63	7,89	0,63	0,00	0,00	0,00	0,00	0,00	0,72
DMUWNWFSP	0,00	9,87	0,00	0,00	0,00	0,00	0,00	0,00	1,11
DMUWNSTSP	0,00	8,11	0,00	0,00	0,00	0,00	0,00	0,00	0,92
DMUWFSTSP	0,00	7,18	0,00	0,00	0,00	0,00	0,00	0,00	0,81
DMUHGWNWF	0,76	9,53	0,76	0,00	0,00	0,00	0,00	0,00	0,87
DMUHGWNST	0,67	7,84	0,00	0,67	0,00	0,00	0,00	0,00	0,83
DMUHGWNSP	0,80	9,80	0,00	0,00	0,00	0,00	0,00	0,00	0,86
DMUHGWFST	0,60	7,52	0,60	0,00	0,00	0,00	0,00	0,00	0,69
DMUHGWFSP	0,69	8,62	0,69	0,00	0,00	0,00	0,00	0,00	0,79
DMUHGSTSP	0,60	7,55	0,60	0,00	0,00	0,00	0,00	0,00	0,69
DMUHWNWFST	0,60	7,50	0,60	0,00	0,00	0,00	0,00	0,00	0,68
DMUHWNWFSP	0,69	8,59	0,69	0,00	0,00	0,00	0,00	0,00	0,78
DMUHWNSTSP	0,60	7,53	0,60	0,00	0,00	0,00	0,00	0,00	0,69
DMUHWFSTSP	0,55	6,92	0,55	0,00	0,00	0,00	0,00	0,00	0,63
DMUGWNWFST	0,71	8,84	0,71	0,00	0,00	0,00	0,00	0,00	0,81
DMUGWNWFSP	0,86	10,63	0,00	0,00	0,00	0,00	0,00	0,00	0,93
DMUGWNSTSP	0,71	8,88	0,71	0,00	0,00	0,00	0,00	0,00	0,81
DMUGWFSTSP	0,64	8,05	0,64	0,00	0,00	0,00	0,00	0,00	0,73
DMUWNWFSTSP	0,00	8,16	0,00	0,00	0,00	0,00	0,00	0,00	0,92
DMUHGWNWFST	0,66	8,25	0,66	0,00	0,00	0,00	0,00	0,00	0,75
DMUHGWNWFSP	0,74	9,29	0,74	0,00	0,00	0,00	0,00	0,00	0,85
DMUHGWNSTSP	0,66	8,28	0,66	0,00	0,00	0,00	0,00	0,00	0,75
DMUHGWFSTSP	0,62	7,69	0,62	0,00	0,00	0,00	0,00	0,00	0,70
DMUHWNWFSTSP	0,61	7,67	0,61	0,00	0,00	0,00	0,00	0,00	0,70
DMUGWNWFSTSP	0,70	8,76	0,70	0,00	0,00	0,00	0,00	0,00	0,80

Table 53 *- Weight Results of CEW-CRS-I*

Appendix 12 – Results from Model with Weight Restriction Alternative

Summary of crs-i | Efficiencies of crs-i | Lambdas of crs-i | Weights of crs-i

Period: Data Crossover 5 Selection: <All> Categorical: <Al

Name	Efficiency	
DMUG	100	100%
DMUWN	100	100%
DMUGWN	100	100%
DMUWNSP	92.72	93%
DMUGWNWF	92.29	92%
DMUGWNSP	89.91	90%
DMUGWF	89.39	89%
DMUWNWF	89.39	89%
DMUSP	88.03	88%
DMUGWNWFSP	87.62	88%
DMUWNWFSP	86.17	86%
DMUGSP	85.97	86%
DMUGWFSP	84.69	85%
DMUWF	83	83%
DMUWFSP	81.88	82%
DMUHGWNWF	79.54	80%
DMUHGWNWFSP	78.92	79%
DMUHGWN	78.8	79%
DMUGWNST	78.07	78%
DMUHGWNSP	77.76	78%
DMUGWNWFST...	75.85	76%
DMUGWNWFST	75.66	76%
DMUHGWFSP	75.59	76%
DMUHWNWFSP	75.59	76%
DMUHGWF	75.25	75%
DMUHWNWF	75.25	75%
DMUGWNSTSP	73.91	74%
DMUWNWFSTSP	73.58	74%
DMUHGSP	72.99	73%
DMUHWNSP	72.98	73%
DMUWNSTSP	72.76	73%

Summary of crs-i | Efficiencies of crs-i | Lambdas of crs-i | Weights of crs-i

Period: Data Crossover 5 Selection: <All> Categorical: <Al

Name	Efficiency	
DMUHWN	71.96	72%
DMUHG	71.85	72%
DMUGST	71.43	71%
DMUWNST	71.21	71%
DMUHGWNWFST	71.04	71%
DMUHWFSP	71.01	71%
DMUWNWFST	71.01	71%
DMUGWFST	71	71%
DMUHGWNSTSP	69.69	70%
DMUHGWNST	69.11	69%
DMUWFSTSP	69.03	69%
DMUGSTSP	68.83	69%
DMUHGWFSTSP	68.77	69%
DMUHWNWFST...	68.77	69%
DMUHWF	68.68	69%
DMUHGWFST	67.1	67%
DMUHWNWFST	67.1	67%
DMUSTSP	66.17	66%
DMUHSP	65.61	66%
DMUHWNSTSP	65.51	66%
DMUHGSTSP	65.5	66%
DMUHWFSTSP	64.82	65%
DMUWFST	64.16	64%
DMUHWNST	63.63	64%
DMUHGST	63.55	64%
DMUHWFST	61.91	62%
DMUHSTSP	59.98	60%
DMUST	58.59	59%
DMUH	58.36	58%
DMUHST	55.66	56%

Figure 19 *- Efficiency Result of Weight Restriction Alternative Model*

Summary of crs-i | Efficiencies of crs-i | **Lambdas of crs-i** | Weights of crs-i

Period: Data Crossover 5 Selection: <All> Categor

Name	DMUG	DMUWN	DMUGWN
DMUH	0.40842187	0.82232181	0
DMUG	1	0	0
DMUWN	0	1	0
DMUWF	0.20551722	1.17708886	0
DMUST	0.25911821	1.25359774	0
DMUSP	0	1.36941358	0
DMUHG	0.70635329	0.41020336	0
DMUHWN	0.21019667	0.90848551	0
DMUHWF	0.28833726	1.00803325	0
DMUHST	0.21457992	1.09123316	0
DMUHSP	0.0280804	1.17459124	0
DMUGWN	0.5	0.5	0
DMUGWF	0.60274712	0.58854957	0
DMUGST	0.67019624	0.60863564	0
DMUGSP	0.34461169	0.75415936	0
DMUWNWF	0.10313081	1.08837807	0
DMUWNST	0.16396436	1.11142105	0
DMUWNSP	0	1.18470679	0
DMUWFST	0.07936404	1.28370769	0
DMUWFSP	0	1.31918035	0
DMUSTSP	0	1.36941358	0
DMUHGWN	0.47356643	0.60561143	0
DMUHGWF	0.52548933	0.67205294	0
DMUHGST	0.47918018	0.72624015	0
DMUHGSP	0.3520536	0.78306083	0
DMUHWNWF	0.19275244	1.00511968	0
DMUHWNST	0.14918281	1.05808244	0
DMUHWNSP	0.01872026	1.11639416	0
DMUHWFST	0.17666531	1.13544787	0
DMUHWFSP	0.08617906	1.17589172	0
DMUHSTSP	0.00306267	1.24653036	0
DMUGWNST	0.45798001	0.73409228	0
DMUGWNSP	0.22974113	0.83610624	0
DMUGWFST	0.38626967	0.85579307	0
DMUGWFSP	0.2955001	0.89636356	0
DMUGSTSP	0.21190281	0.96721714	0
DMUWNWFST	0.05363523	1.18881402	0
DMUWNWFSP	0	1.2127869	0
DMUWNSTSP	0	1.24627572	0
DMUWFSTSP	0	1.33592476	0
DMUHGWNWF	0.39445305	0.7538895	0
DMUHGWNST	0.36296946	0.79307806	0
DMUHGWNSP	0.2640402	0.83729562	0
DMUHGWFST	0.38247819	0.85159519	0
DMUHGWFSP	0.31430499	0.88206598	0
DMUHGSTSP	0.25192598	0.9350636	0
DMUHWNWFST	0.13307296	1.10132935	0
DMUHWNWFSP	0.0647461	1.13186882	0
DMUHWNSTSP	0.00254929	1.18478501	0
DMUHWFSTSP	0.05336778	1.22930788	0
DMUGWNWFST	0.29015611	0.89164195	0
DMUGWNWFSP	0.22162507	0.92227267	0
DMUGWNSTSP	0.15909286	0.97533877	0
DMUGWFSTSP	0.21010768	1.0197739	0
DMUWNWFSTSP	0	1.25194357	0
DMUHGWNWFST	0.30638869	0.88109462	0
DMUHGWNWFSP	0.25155719	0.90560219	0
DMUHGWNSTSP	0.20175416	0.94795551	0
DMUHGWFSTSP	0.24247912	0.98354245	0
DMUHWNWFST...	0.04293064	1.18334064	0
DMUGWNWFST...	0.16826171	1.01574065	0

Figure 20 *- Lambdas Results of Weight Restriction Alternative Model*

Summary of crs-i | Efficiencies of crs-i | Lambdas of crs-i | **Weights of crs-i**

Period: Data Crossover 5 Selection: <All> Categorical: <All> Precision: 8

Name	Capacity Factor	LCOE	Acidification	Ecotoxicity	Eutrophication	GWP	Land Occupation	PM	Social Acceptance
DMUH	0.53315265	6.52282893	0.08885877	0.08885877	0.08885877	0	0	0	0.59578388
DMUG	1.15552236	11.75952154	0.19258706	0.19258706	0.19258706	0.19258706	0.19258706	0.19258706	1.15552236
DMUWN	1.17447466	12.07587062	0.19574578	0.19574578	0.19574578	0.19574578	0	0.19574578	1.20534436
DMUWF	0.67567156	8.32905178	0.11261193	0	0	0	0	0	0.73586695
DMUST	0.51509139	5.29613548	0.08584856	0.08584856	0.08584856	0.08584856	0	0.08584856	0.52862996
DMUSP	0	8.92857143	0	0	0	0	0	0	1.00871982
DMUHG	0.72084878	8.8191877	0.12014146	0.12014146	0.12014146	0	0	0	0.80552931
DMUHWN	0.71808257	8.78534463	0.11968043	0.11968043	0.11968043	0	0	0	0.80243814
DMUHWF	0.59597644	7.34664428	0.09932941	0	0	0	0	0	0.64907181
DMUHST	0.48157091	5.89175477	0.08026182	0.08026182	0.08026182	0	0	0	0.53814266
DMUHSP	0.61631264	7.57575758	0	0	0	0	0	0	0.66499018
DMUGWN	1.15986346	11.92563923	0.19331058	0.19331058	0.19331058	0.19331058	0	0.19331058	1.19034912
DMUGWF	0.84359867	10.3991014	0.14059978	0	0	0	0	0	0.91875465
DMUGST	0.71065643	7.30692227	0.11844274	0.11844274	0.11844274	0.11844274	0	0.11844274	0.7293352
DMUGSP	0.88315073	10.8557498	0	0	0	0	0	0	0.95290364
DMUWNWF	0.8433553	10.39610135	0.14055922	0	0	0	0	0	0.9184896
DMUWNST	0.71611498	7.36304679	0.1193525	0.1193525	0.1193525	0.1193525	0	0.1193525	0.73493723
DMUWNSP	0	10.86956522	0	0	0	0	0	0	1.22800674
DMUWFST	0.53008409	6.53438462	0.08834735	0	0	0	0	0	0.57730914
DMUWFSP	0	8.62068966	0	0	0	0	0	0	0.97393638
DMUSTSP	0	6.7114094	0	0	0	0	0	0	0.75823235
DMUHGWN	0.81431752	9.96272629	0.13571959	0.13571959	0.13571959	0	0	0	0.90997814
DMUHGWF	0.70644353	8.70838009	0.11774059	0	0	0	0	0	0.76938039
DMUHGST	0.59383053	7.26518941	0.09897176	0.09897176	0.09897176	0	0	0	0.6635898
DMUHGSP	0.7258626	8.92235327	0	0	0	0	0	0	0.7831926
DMUHWNWF	0.70632974	8.70697735	0.11772162	0	0	0	0	0	0.76925646
DMUHWNST	0.59257686	7.24985147	0.09876281	0.09876281	0.09876281	0	0	0	0.66218886
DMUHWNSP	0.72636847	8.92857143	0	0	0	0	0	0	0.78373842
DMUHWFST	0.53108487	6.54672132	0.08851415	0	0	0	0	0	0.57839908
DMUGWNSP	0.95248737	11.70804057	0	0	0	0	0	0	1.02771662
DMUGWFST	0.64325603	7.92946325	0.10720934	0	0	0	0	0	0.70056353
DMUGWFSP	0.80221038	9.86082546	0	0	0	0	0	0	0.86557047
DMUGSTSP	0.65536578	8.07874104	0.10922763	0	0	0	0	0	0.71375214
DMUWNWFST	0.64316168	7.92830021	0.10719361	0	0	0	0	0	0.70046078
DMUWNWFSP	0	9.86842105	0	0	0	0	0	0	1.11490086
DMUWNSTSP	0	8.10810811	0	0	0	0	0	0	0.91602665
DMUWFSTSP	0	7.17703349	0	0	0	0	0	0	0.81083699
DMUHGWNWF	0.7784987	9.59660936	0.12974978	0	0	0	0	0	0.84785494
DMUHGWNST	0.6709714	8.20896544	0.11182857	0.11182857	0.11182857	0	0	0	0.74979267
DMUHGWNSP	0.79712357	9.79829799	0	0	0	0	0	0	0.86008189
DMUHGWFST	0.61165809	7.53995321	0.10194302	0	0	0	0	0	0.66615054
DMUHGWFSP	0.70916247	8.74189661	0.11819374	0	0	0	0	0	0.77234155
DMUHGSTSP	0.61982594	7.6406388	0.10330432	0	0	0	0	0	0.67504606
DMUHWNWFST	0.61159411	7.53916449	0.10193235	0	0	0	0	0	0.66608086
DMUHWNWFSP	0.70907646	8.7408364	0.11817941	0	0	0	0	0	0.77224789
DMUHWNSTSP	0.61976023	7.63982887	0.10329337	0	0	0	0	0	0.6749745
DMUHWFSTSP	0.56796825	7.00138541	0.09466138	0	0	0	0	0	0.61856839
DMUGWNWFST	0.72004044	8.87599018	0.12000674	0	0	0	0	0	0.78418865
DMUGWNWFSP	0.86492165	10.63167668	0	0	0	0	0	0	0.93323479
DMUGWNSTSP	0.73138617	9.01584984	0.1218977	0	0	0	0	0	0.79654517
DMUGWFSTSP	0.66032694	8.13989758	0.11005449	0	0	0	0	0	0.71915529
DMUWNWFSTSP	0	8.16326531	0	0	0	0	0	0	0.92225812
DMUHGWNWFST	0.67285044	8.29427567	0.11214174	0	0	0	0	0	0.7327945
DMUHGWNWFSP	0.76547088	9.43601443	0.12757848	0	0	0	0	0	0.83366647
DMUHGWNSTSP	0.68074489	8.39159111	0.11345748	0	0	0	0	0	0.74139226
DMUHGWFSTSP	0.63024413	7.76906458	0.10504069	0	0	0	0	0	0.6863924
DMUHWNWFST...	0.63018978	7.76839466	0.10503163	0	0	0	0	0	0.68633322
DMUGWNWFST...	0.71952012	8.8695761	0.11992002	0	0	0	0	0	0.78362196

Figure 21 *- Weights Results of Weight Restriction Alternative Model*