Economic and environmental impacts of the energy sector in Portugal

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This thesis is especially dedicated to my parents, because they were always there for me and worked really hard so that I could embrace a successful education.

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Resumo

Análise input-output tem sido utilizada para determinar vários tipos de impactos em diversas áreas de estudo. Neste trabalho um modelo input-output hibrido é construído (unidades monetárias e energéticas) para calcular os impactos ambientais, económicos e sociais tanto para o sector energético como para o resto da economia. Apesar de haver alguns estudos que abordem problemas similares, este trabalho especifica pretende desagregar o sector energético em tecnologias e vetores energéticos para calcular os tipos de impactos mencionados na realidade Portuguesa desde 2000 a 2010. São estudados 3 tipos diferentes de efeitos: operacionais, investimento no sector energético e subsídios aos produtores de eletricidade associado ao défice tarifário. Estes efeitos são isolados e analisados relativamente aos diferentes tipos de impactos. Posteriormente é também apresentada uma desagregação por tecnologia e atividade evidenciando os impactos resultantes de cada efeito. Enquanto o efeito do desenvolvimento do mix energético tecnológico revela impactos que dependem do ano, os efeitos de capital mostram impactos positivos. Por sua vez, os impactos dos subsídios associados ao défice tarifário revelam-se negativos.

Os impactos da política energética Portuguesa são obtidos combinando estes três efeitos. O resultado genérico demonstra que esta política foi positiva no que toca ao crescimento económico, emprego e emissões de gases de efeito de estufa. No entanto, em 2010 os impactos começam a revelar-se negativos a nível de emprego e valor acrescentado bruto, podendo indicar um impacto negativo crescente nos anos que se seguiram.

Palavras-chave: Input-output, modelo híbrido, emprego ”verde”, sector energético, subsídios.

Abstract

Input-output analysis has been used to assess numerous types of impacts associated with a diversity of areas. In this work an hybrid input-output model is built (monetary and energy units) and the environment, economic and social impacts are calculated for the energy sector and the rest of the economy.

Although some studies have provided answers towards similar problems, this specific work intends to disaggregate the energy sector into technologies and carriers to assess the mentioned impacts to the Portuguese reality from 2000 to 2010. Three different effects are studied: operational, capital investment towards capacity power installation and subsidies to technologies/tariff deficit. These effects are isolated and analyzed regarding the several types of impact. A disaggregation is also further presented by activities and technologies on the impacts arising from each effect. While the energy technology mix development shows different results depending on the year, the capital investment reveals positive impacts. The subsidies associated with the tariff deficit show negative impacts.

The Portuguese energy policy impacts are obtained combining these different effects. The overall result shows a positive impact towards economic growth, employment and Green House Gases (GHG) emissions reduction. However, in 2010 the energy policy begins to have a negative impact on employment and on Gross Value Added (GVA), possibly forecasting an increasing negative impact on the following years.

Keywords: Input-output, hybrid model, green jobs, energy sector, subsidies.

Contents

List of Tables

List of Figures

List of Abbreviations

AT	*Alta Tensão*.
BT	*Baixa Tensão*.
BTE	*Baixa Tensão Especial*.
BTN	*Baixa Tensão Normal*.
CCGT	Combined Cycle Gas-Turbine.
CCOT	Combined Cycle Oil-Turbine.
CGE	Computable General Equilibrium.
CHP	Combined Heat and Power.
CMEC	*Custos de Manutenção de Equilíbrio Contratual*.
DGEG	Direcção Geral de Energia e Geologia.
E3	Environment, Energy and Economy.
EC	European Commission.
ENE 2020	National Energy Strategy 2020.
EREC	European Renewable Energy Council.
EU ETS	European Union Emission Trading Scheme.
FIT	Feed-in Tariff.
FTE	Full Time Employment.
GCF	Gross Capital Formation.
GDP	Gross Domestic Product.
GHG	Green House Gases.
GVA	Gross Value Added.
GWP	Global Warming Potential.
INE	National Statistics Institute.
IO	Input-Output.
MAT	*Muito Alta Tensão*.
MT	*Media Tensão*.
NACE	Statistical Classification of Economic Activities in the European Community.
NPISH	Non-Profit Institutions Serving Households.

NRES-E	Non-Renewable Energy Source Electricity.
O&M	Operation and Maintenance.
OR	Ordinary Regime.
PCC	Pulverized Coal Combustion.
PPA	Power Purchase Agreements.
PV	Solar Photovoltaics.
RES	Renewable Energy Source.
RES-E	Renewable Energy Source Electricity.
RNBC	*Roteiro Nacional do Baixo Carbono*.
ROE	Rest of the Economy.
ROW	Rest of the World.
SCA	System of Environmental Accounts.
SR	Special Regime.
SUT	Supply-Use Table.

Chapter 1

Introduction

1.1 Context

Energy produced from renewable sources is becoming a significant fraction of the energy mix in many countries, as the result of policies that aim to reduce the emission of GHG and mitigate climate change. International policies applied, as Kyoto protocol, and also at the European Union (EU) level, renewable energy and carbon mitigation policies have been guided by the European Renewable Energy Council (EREC) and the European Commission (EC), among other directives and road maps. At the national level, Portuguese policies on these matters have been guided by *Roteiro Nacional do Baixo Carbono* (RNBC), for example. In the Portuguese case, the electricity generation promotion from the renewable sources, Renewable Energy Source Electricity (RES-E), has been a priority not only due to the environmental concerns but also to increase energy security and diversify our energy supply. Of course, social and economical considerations play a fundamental role in energy policy (Philbert 2011).

In the last decade Portugal witnessed a substantial increase in the penetration rate of renewable energies, fueled by high Feed-in Tariff (FIT). As a result, over a short period of time Portugal became a leader in renewable energy use (IEA 2009). Feed-in tariffs are a part of an energy policy which includes other financial incentives (National Renewable Energy Action Plan from 2009) and ambitious targets for the development of hydro power, wind and solar and other technologies. According to the National Energy Strategy 2020 (ENE 2020), in 2020 Portugal should reduce the energy dependency on imports to 74%, the RES-E production share should increase to 60%, and the final energy consumption should decrease by 20%, among others goals such as the creation of 100,000 new green jobs.

The main policy instrument applied in Portugal for the promotion of electricity produced from renewable energy sources are the so called FIT. In a FIT scheme, a fixed amount of money per unit of renewable electricity is paid to the renewable energy producer, irrespective of the market value. This tariff is an incentive to compensate the higher costs of the RES-E technologies compared to conventional energy production. The value of the FIT is calculated by taking into account the technology, environmental aspects and the inflation rate. This tariff is fixed for a long time (usually 15-20 years) to create long term stability for the electricity producers. When considering the electricity sector, one must consider both production regimes, the so-called special and ordinary regime. In the Special Regime (SR), it is included not only the renewable sources (except large hydro power plants) but also micro production, waste and co-generation, Combined Heat and Power (CHP) both from renewable and other non-renewable sources. In fact, since 1988 that special incentives and guaranteed purchase prices have been granted to generators in SR (**?**) to support the expenses of these emerging technologies. If the electricity is produced from conventional non-renewable thermal sources (mainly as fuel, coal, natural gas) and large hydroelectric plants, Ordinary Regime (OR), there are also subsidies to compensate the high investment costs and support a portion of the financial expenses. They are commonly referred in the literature as Power Purchase Agreements (PPA) and later in 2004 exchanged by a financial equivalent fee called *Custos de Manutenção de Equilíbrio Contratual* (CMEC), designed to guarantee a pre-establish return on investment over the economic lifetime of the plant. The Portuguese Renewable Energy Source (RES) policy uses other mechanisms, such as fiscal deductions for heating and cooling where 30% of the RES equipment costs were deductible; a mandatory biofuels quota in fossil fuels; total or partial tax exemption regarding the transport sector as the tax on petroleum and energy products (see EREC Portugal policy review 2009).

The energy sector has developed, and it will continue to grow towards a future where efficiency, environmental and economical targets meet each other. In fact, according to the National Action Plan for Energy Efficiency from 2008, Portugal intends to implement energy efficiency measures equivalent to 9.8% of total final energy consumption by 2015. Therefore, the rest of the economy sectors also change and develop over the years. Hence, the interaction between energy and economy is fundamental to understand and evaluate impacts such as the ones related to employment and gas emissions. It is within this present context, that Input-Output (IO) analysis arises and thus the usefulness of this technique to evaluate economy-wide impacts.

1.2 Motivation

A major limitation in current IO studies of renewable energy is the lack of detailed source data, in particular for countries like Portugal where some European and even worldwide studies seem to provide few information. Hence, a major expected contribution of the present study is an improved characterization of the production recipe of the energy sector. Furthermore, the energy sector characterization will contain a larger portion dedicated to existing and emerging technologies for electricity production within this 10 year time period. This will be accomplished searching for several data sources such as Direcção Geral de Energia e Geologia (DGEG) and National Statistics Institute (INE) databases and documents such as the Energy Sources Production Costs and Performance of Technologies for Power Generation, Heating and Transport (European Commission 2008) although this will be presented in more detail further on chapter 4. This work will be mostly turned to a more technological component of the analysis proposed. In other words, this technological component could be understood as investment, operation and maintenance costs for each renewable energy source as well as efficiencies, power generation and capacities, among other factors as capital and labor associated to this sector. Overall, with this improved characterization it is intended to establish in a more detailed way the social, environmental and economic RES impacts on the economy as a whole through our implemented IO model. Therefore, the possibility to provide an answer to several questions such as the ones announced before, and also analyze them in an historical context is definitely a motivation boost. Ultimately, disaggregating the energy sector from the rest of the economy and characterize it with more technologies will allow a enhanced study on the interaction between energy and economy.

Several issues like the ”green” employment creation, as discussed earlier, are still controversial. Another issue that is not widely accepted and has been a reason to criticize the government policies regarding the renewables is the case that the monetary value of these subsidies is not properly determined (Amorim et al. 2010), and its benefits are not clear to the several axis of interaction, Environment, Energy and Economy (E3) an social. In order to be able to provide an answer and justify my position on these issues this study will take place and hopefully will end up being a positive contribute to the Portuguese economy energy sector characterization.

1.3 Problem Formulation

Although a number of challenges still remain, the renewable energy technologies development has been undisputed. This is also because in a country with natural conditions such as Portugal, rainfall (for hydro power) and wind play a main role. As a result, if measured by penetration rate of several renewables sources, the contemporary Portuguese energy policy has been a great success. But at what cost?

The cost of our renewable energy policy contains both direct and indirect impacts. Direct impacts are the tax burden required to subsidize the feed-in tariffs and other policy mechanisms, as well as the increased energy prices supported by consumers and the variation of the energy mix, with a reduced consumption of fossil fuels. However, there are also indirect impacts, because the purchase structure of the renewable and conventional energy sectors are different, which means that the impacts in the rest of the economy will be different. Hence, besides environmental impacts such as the reduction in carbon emissions, the Portuguese RES policy has also had social impacts such as the creation or destruction of employment and the increase or decrease in Gross Domestic Product (GDP). Although it is often claimed that the promotion of renewable energy increases energy security, mitigates climate change and promotes job creation, the latter result is still disputed (Lamberti & Silva 2012).

The goal of this thesis is to build a hybrid Input-Output model (which will be discussed further) of the Portuguese economy which integrates a disaggregated energy sector in an existing model of the full economy and use it to assess a number of impacts. After the necessary data is gathered and the hybrid model is built it will be used to calculate impacts of the Portuguese energy sector in terms of employment, added value and greenhouse gas emissions. The costs and benefits of the PortugueseRES policy will be assessed by comparing the historical impacts of the period 2000-2010 with counter-factual scenarios in which the observed energy policy had not taken place.

1.4 Thesis outline

The remainder of this thesis is organized as follows. In chapter 2 it is explained the theoretical foundations about input-output. In the same chapter it is presented the literature review on Portuguese studies as well as Rest of the World (ROW) case studies. Later, in chapter 3 the Leontief and the the hybrid units IO model built will be presented. Chapter 2 will be used to discuss the fundamental information and assumptions steps on gathering and manipulating the data. Then, chapter 5 will handle the results and the conclusions are provided in chapter 6.

Chapter 2

Literature Review

2.1 Theory

In order to assess the impact of the renewable energies in the Portuguese context, this study will use Input-Output (IO) techniques. It is an analytical framework, often known as interindustry analysis, since its fundamental purpose is to analyze the interdependence of industries in an economy represented as a whole.

The first attempt to describe the way economy works in an analytical way was performed by François Quesnay, a French economist known for developing a first approach of this technique which he published in 1758 as *Tableau Économique* (economic table). In addition Léon Walras, a French mathematical economist presented *Elements of Pure Economics* where he explained the general equilibrium theory in 1874. This theoretical model, in a brief description, seeks to explain the behavior of supply, demand, and prices in a whole economy linear system with several interacting markets, considering that the long term prices will tend to be in equilibrium. The problem was that, despite their valuable work, no one could employ their findings to the solution of problems. Wassily Leontief was influenced by these previous works that could be seen as a forerunner to Leontief's own concept. Due to his work (Leontief 1936, 1941) he was later credited with the development of this framework which granted him the Nobel Prize in Economics in 1973. His major contribution was to simplify Léon Walras's formulation in order to make the computation feasible and due to his work on input-output tables and its development as a model the Input Output technique is often known as Leontief's own model.

The Leontief demand-driven quantity input-output model allows the quantification of the final demand stimulus in primary production factors (Miller & Blair 2009). This model allows to identify the impacts that arise from changes in the intermediary flows between industries (and products) as a result to a variation in the final demand. It is a widely used model for its numerous applications and input-output may be used recurring to units other than monetary. In fact, Leontief continued to explore his framework regarding physical units (Leontief 1989), and many researchers such as Duchin (1992) and Cleveland (1999) have extended the original framework in the direction of areas such as industrial ecology and economics ecologic. In addition, environmental concerns can also be addressed as, for example, pollution that should be related in a measurable way to a particular consumption or production process (Leontief 1970). With the contribution of several researchers and the continuous work being developed, the utility about input-output to numerous disciplines is unanimously recognized. Hence, energy input-output analysis is no exception.

Energy was and still is a crucial factor on production for many industries over the world. The focus on the role of energy in the economy became a priority, specially during fossil fuel crisis and climate change in recent years (Miller & Blair 2009, pag. 400-401). The early developments were achieved by several authors and their work such as Strout (1967), Cumberland (1966), Bullard & Herendeen (1975), among others. Also, the concern and technology changes worldwide has boosted several works. Although it seems to be only a recent issue, it is not. Such studies have been guided also in the past years by authors such as Just (1974), Gowdy & Miller (1968) and Herendeen & Plant (1981). In this work, it is proposed to built and hybrid units model (both monetary and energy units). The so-called 'hybrid units" approach was first introduced by Bullard & Herendeen (1975) to address the limitations about the simplest approaches.

The development and growth of new energy technologies has encouraged several studies. As a result, numerous studies have been conducted either for Portugal or other countries and regions regarding the use of IO for the evaluation of the impact of renewable resources use in the economy. In the next sub chapters some of them will be briefly presented and discussed first for many countries or regions around the world and then the focus will be on Portugal case studies in the literature.

2.2 Rest of the world case studies

Input-output analysis and similar techniques have been providing some interesting results on the impacts caused by the renewable energy sources sectors. Social impacts are related to employment or sometimes referred as clean jobs creation. One of these studies was published in 2013 by the National Council of Applied Economic Research (NCAER 2013). In this, they estimated the number of jobs created in the wind sector for Gujarat State, India. This study was motivated due to the increasing importance of the wind technology energy production (80% of RES-E share just by wind in 2010). In addition, the importance on understanding the growth on the RES sector and its impacts on all other sectors of the economy fueled this study. It was necessary to construct their Gajurat state IO table and with that purpose they created a 7 sector (Agriculture, Mining, Manufacturing, Construction, Electricity, Other Services and Public Sector) transaction matrix based on the All-India-Input-Output table from 2006-2007 (most recent data available) and disaggregated the wind energy sector from the electricity sector, making it an 8 sector table. To obtain the data required for wind sector, surveys were taken in consideration and questionnaires were done to workers and wind entities (which were concluded in 2012). The state table was adapted for 2009-2010 due to the available data. Wind energy plants require heavy expenditure in construction, manufacturing, infrastructure, etc. Therefore, this fact is easily observed in the employment results, as an unit increase of the wind energy output generates a total employment of 0.334 man-year as compared to 0.268 man-year for conventional electricity. Even though the assumptions made to gather the data necessary to build the state table and the usage of older information could cause a significant deviation in the results, the study proved to be an interesting way to provide an insight about the wind sector impacts on the state level regarding the job creation.

Another highly controversial issue is the government subsidies and other incentives that are applied to the renewables sources with the energy sector. This following case study considers Spain which had clearly defined goals to enhance the RES sector by 2010, such as to reach 12% penetration by these sources in the energy market and 20% of electric production. Àlvarez (2013) provided an answer to the question of what is the price to pay while making efforts to promote large numbers of green jobs. In fact, the European current policy and strategy for supporting the so-called ”green jobs” or renewable energy dates back to 1997, and has become one of the principal justifications for U.S. ”green jobs” proposals. The study calculates that since 2000 Spain spent 571,138 € to create each green job, including subsidies of more than 1 million € per wind industry job. Moreover, creating those jobs also resulted in the destruction of nearly 110,500 jobs elsewhere in the economy, or 2.2 jobs destroyed for every job created by the renewables. In other type of analysis, they estimated that each ”green” megawatt installed destroys essentially 8.99 jobs by photovoltaics, 4.27 by wind energy and 5.05 by mini-hydro in the rest of the economy. It is interesting to note that the prices for renewables to generate electricity is far above market prices, resulting in a vast amount of capital that could have been otherwise allocated in other sectors in the economy. However, these costs do not appear to be unique to Spain's approach but seem instead inherent in schemes used to promote renewable energy sources in other countries.

The whole idea of ”green jobs” and they meaning is vastly discussed in the paper published by Winter and Moore (Winter & Moore 2013). It is proposed a better way to measure very clearly and reliably whether we are harming the environment or not. It is based on measuring the energy use intensity and emissions intensity, even though it is not as political appealing as promising ”green employment”, which is considered an illusion and an arbitrary concept. This study was conducted taking in consideration the Canadian context on 20 sectors describing the economy and it was found that the majority of Canadian industries improved their emissions intensity between 1990 and 2008.

Investments on the energy sector is also an important effect to consider. Markaki et al. (2013) provides in his work a specific study about the impact of clean energy investments on the Greek economy between 2010 and 2020. These impacts are evaluated using the IO analysis on 20 industrial sectors of the economy. the required data was gathered from the Eurostat's domestic input-output table from 2010. Furthermore, in their IO model both direct, indirect and induced effects are considered. Of course that Greece, as a part of EU, also has its ambitious goals regarding environmental and energy objectives to be achieved by 2020. Therefore, it was proposed first to calculate the amount of capital investments in the renewable energies, by industrial sector, that the country would need in order to satisfy a number of energy and environmental targets adopted in the context of the European Commission's energy and climate change package. Afterwards, the macro-economic impacts of these ”green” investments in the whole Greek economy would be calculated. In their results, the required investments would reach the amount of 47,9 billion € over the 10 year range period. Simultaneously these investments would not only increase the nation production by 9,4 billion € as it would also create 108,000 Full Time Employment (FTE) for the same period. And from these results obtained for Greece, one can identify that large scale exploitation of clean energy technologies to achieve the European Commission goals would create a large volume of output and employment.

When completing a study about energy and employment several factors should be considered, such as labor intensity of renewables, cost increases and availability of investments, counting job losses, job quality and skills, model assumptions and sources of information Lamberti & Silva (2012). In this, R. J. Lambert and P. P. Silva discuss these factors that affect job estimates as well as how should job creation be measured. It is important to take in consideration that not only each technology has its own job ratio (e.g. per MW installed) but also that ratio changes from country to country, meaning that one should be cautious when using those data informations. As an example, consider Denmark because it has a large wind turbine manufacturing sector (high job rate). however most of the components are exported and this falsely inflates the job per MW installed ratio. Furthermore, when obtaining results, renewable energy should not be encouraged solely because of a perceived benefit to employment, nor should it be rejected without considering other potential benefits (E3 interactions plus social).

In the literature there is also some studies to measure the impact of policies strategies in the labor market due to the high level of unemployment. One example is the work conducted by Lehr et al. (2007). In this paper it is developed an IO vector for the renewable energy sector based on the results of an questionnaire (more than 1000 interviews). The process is based on the calculation of gross and net effects of two difference policy scenarios for Germany until 2030. The IO tables of the German Federal Statistical Office consist of 59 production sectors and the difference from earlier studies resides in the modeling, which accounts explicitly of exports and foreign trade effects.

One thing that is also fundamental when applying these IO models are the units used and their influence on the desired analysis. An analysis in monetary units can be done, or instead in physical units, but also a mix of both, i.e. hybrid units. Therefore, energy sectors or commodities of hybrid IO tables for energy are in physical units which are usually reported in joule, while non-energy sectors or commodities are in monetary units. These differences and limitations are discussed by Liang et al. (2010) and it is proposed an hybrid physical input-output model for energy analysis to study energy metabolism taking Suzhou in China as a case of application. This improved model calculates energy resources in both energetic and mass units and air pollutants in mass units simultaneously from the perspective of energy and mass balance, which is said to be beyond the reach of current IO tables for energy. The model can be used both as an accounting tool (it provides a measure on the environmental impacts) or as a forecasting tool (e.g. for Suzhou in 2020). Regarding the data used, for example the energy consumption and domestic extraction data of each 25 sectors used came from the 2006 Suzhou Statistical Yearbook (SBS). Among other results, it is referred that the energy consumption of Suzhou (where manufacturing dominates the energy consumption) relies mostly on energy imports and it will keep relying in the future years.

Sometimes a sensitivity analysis should be taken in consideration in order to identify the potential of one or various coefficients to change the desired output significantly. These sensitivity analysis can be combined with IO methodology to study several impacts, as for example environmental related ones, as CO_2 emissions (Tarancon & Río 2007). In their work, it was suggested that emissions are connected to the IO productive relationship within an economy; to the CO_2 emissions intensity of sectors and to the structure of final demand on the different sectors. This methodology was applied to the Spanish case and for that, data based on the Spanish IO table was used. This table was built from the National Statistical Office for 1995 and the 1995 CO_2 emissions vector (disaggregated by activity branch), also published by INE as part of the System of Environmental Accounts (SCA). The study ended up with 44 production sectors and the sensitivity analysis revealed that emissions in the energy, residential and transport sectors should be tackled if total emissions are to be significantly reduced.

In conclusion, there are a relative large amount of studies which are based on the IO method to study energy. Some of them with a more financial and economical analysis, others oriented towards social and environmental analysis and so on. The wide range of uses of this IO technique and models implemented from this one is well reproduced in the literature as we have seen in the selected studies discussed above. The results are not entirely global and some case studies seem to present different conclusions, depending for example on the country/region, policies applied and model implementation.

2.3 Portugal case studies

In the beginning of the review it was said that these impacts by the renewable energy sources were also studied in the Portugal case, although there are not that many studies under this conditions. Nevertheless, social effects, such as employment, seem to be an recurring subject worth studying. Consequently, Silva et al. (2012) claimed that employment effects and green energy policies call for more concrete applied research. Therefore, the aim of this work was to contribute the renewables discussion using the IO modeling approach. Considering that, Portuguese data used was based on the symmetric tables produced by the Department of Foresight and Planing for the year 2008 (Dias & Domingos 2012). For this study this data was adapted to 64 production sectors. For Portugal and most countries the employment data on FTE is not directly available, and so for this study several sources were taken in consideration to gather the job ratios per RES technology. Continuing the implementation, new IO vectors have been constructed for each RES source with their respective intermediary input structure allocation and then the direct and indirect employment were estimated. Afterwards, two case scenarios were considered: the RES basic equipment is domestically produced and that same equipment is imported. These different scenarios allowed to conclude that the production of a significant part of the manufacturing activities domestically is an ideal prerequisite for maximizing the positive socio-economic effects of the RES development in the Portuguese economy. In fact, this same conclusion is also achieved by Oliveira et al. (2013) using a optimization multi-objective model to optimize the economic growth (gross domestic product); level of employment and RES production creating different scenarios. Considering the 105 thousand "green" employment expected for Portugal by the NES 2020, this goal would only be achieved if induced effects were considered in the analysis.

In chapter 1, it was stated the main policy to promote the renewable energy sources are the feed-in tariffs. This system has been in place in Portugal since 1988 and since then several changes have occurred. One example, occurred in 2001 where the tariffs began to be differentiated by type of renewable technology. Proença & Aubyn (2013) intended to provide an empirical assessment of the economic and environmental effects of the Portuguese FIT policy to promote RES-E generation according to the national target of 45 % RES-E in 2010. The methodology used in their quantitative analysis is a hybrid top-down/bottom-up Computable General Equilibrium (CGE) model, once it contains both technological foundation of bottom-up models and the economic richness of top-down general equilibrium models. These characteristics would allow to study the E3 interactions in an integrated and consistent way. In addition, this approach had never been applied to assess the FIT scheme effects in the Portuguese economy. This model approach is explained in detail by Proença & Aubyn (2009). The model framework dimensions consists of: 18 production sectors/commodities (14 non-energy and 4 energy); final demand drivers; 7 representative electricity generation technologies; primary factors (labor, capital and natural resources) and national and ROW regions. The results show that these tariffs lead to a diversification of the energy mix with a large deployment of renewable energy source illustrating also the shift from high-carbon fossil fuel technologies towards carbon-free sources. Furthermore, not only the FIT policy modifies the national production structure of the national electricity sector as described before but it also makes it less dependent on energy imports. Of course, it also makes it more costly for household and other activities as they support the part of subsidies (and not for the producers of RES-E).

It is also interesting to understand how the population reacts to the emerging of theses renewable technologies in the economy, because the subsidies to special and ordinary regime are supported by consumers (households and activities). In other words, the level of acceptance for each technology is a substantial social factor that proves itself to be relevant in the deployment of renewable energy sources. In general, Portuguese residents are quite aware of the RES, and even though some do not understand that these sources increase the electricity bill due to the tariffs, in the ones who do realize it there is a tendency to still be favorable to the projects implementation which boosts the social acceptance regarding these technologies. These results, among others, were obtained by Ribeiro et al. (2013) in a survey conducted in for Portugal on this subject.

In fact, the studies for Portugal are not that many and there is still a substantial margin to improve and keep the development of further studies. For the study proposed it is intended to build a hybrid Input-Output model of the Portuguese economy which integrates a disaggregated energy sector in an existing model of the full economy. Therefore, the results will hopefully be more accurate and conclusive as the energy sector will be more detailed. In addiction, as mentioned in chapter 1, the model will be used to calculate employment, gross value added and greenhouse gas emissions impacts of the Portuguese energy sector and compare them with the counter-factual scenario in which the observed energy policy had not occurred the way it did.

Chapter 3

Method

3.1 Fundamental concepts

Within this section, the fundamental basic concepts are presented and discussed. It begins with a introduction to explain the Leontief model and its inherent formal objects. Then, the advantages and limitations are provided to enhance the knowledge about the use of input output analysis on problems such as the ones proposed for this work. Consequently, the use of multipliers, they meaning and relevance is discussed. In the same subsection, the relation between multipliers and the impacts to be assessed is revealed (recurring to expressions to be used ahead on calculations).

The standard notation used further on this thesis is based on uppercase bold letters to denote matrix objects, while bold lowercase letters refer to vector objects in column format (transposed objects are followed by ').

3.1.1 Leontief model

In order to understand the Input-Output model approach to the problem proposed it is necessary to explain and go through a couple of fundamental introductory concepts. Note that this model consists of a system of linear equations, each one of which describes the distribution of an industry's product throughout the economy. In fact, Leontief was the first to use matrix representation. An interindustry transaction table is considered in which all the IO model information is contained. Basically it concerns the flow of products or goods from the producers to other sectors, considered consumers. It allows to see how dependent each sector is on every other sector. Therefore in this table, the rows describe the distribution of a producer's output throughout the economy and the columns describe the composition of inputs required by a particular industry to produce its own output (Miller & Blair 2009). In a simple way, the IO table can be represented in quadrants as seen in Figure 3.1.

Adding the several values in the rows across quadrant 1 and 2 (adding its sales of goods or services for intermediate use by other industry and for final use) it is possible to obtain the total output for an industry. This same output can also be found by adding its own use of goods and services (its intermediate inputs) and primary inputs of labor and capital to production (that is, down quadrants 1 and 3).

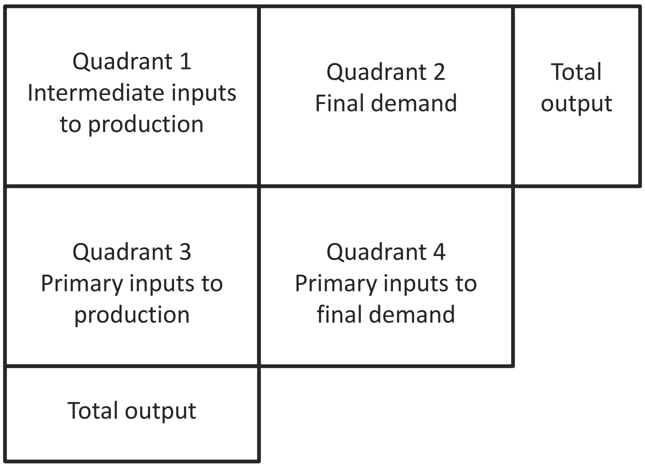


Figure 3.1: Input Output table structure represensation. Based on figure from Gretton (2013).

For this reason, the row and column sum of these tables have to match as a validation process step. The center-piece of the system is the the industry by industry intermediate inputs matrix **Z** (in quadrant 1). Additionally it is important to mention clearly what final demand means because it will be a very important definition to take in account when applying this type of analysis (as seen in chapter 2, final demand is the exogenous stimulus to our system). Therefore, consider that final demand is referred as the demand of external units, which tends to be much more to goods to be used than to be applied as input to an industrial production process.

There is another term that is relevant to mention, as it was already described above without acknowledging it, and that is usually known as the interindustry inputs or intermediate inputs, z_{ij} (which fills the intermediate inputs matrix, quadrant 1). These are the designation for the monetary values of the transaction between sectors i to each other sector j. Hence, the total output production x_i can be obtained the following way:

$$x_i = \sum_{j=1}^{n} z_{ij} + y_i \tag{3.1}$$

Introducing the technical coefficient matrix:

$$\mathbf{A} = \mathbf{Z}\mathbf{x}^{-1} \tag{3.2}$$

Each element of A, $a_{ij} = z_{ij}/x_j$, is the technical coefficient ratio. This is viewed as a relationship between a sector's output and it's input, meaning how much of good or services from sector i are required to produce one unit of output in sector j. When using this expression, equation 3.1 simply becomes:

$$x_i = \sum_{j=1}^{n} a_{ij} x_j + y_i \tag{3.3}$$

These are mathematical relations that arise from a logical point of view, but the model itself appears assuming that these technical coefficients are fixed in time. In other words, input proportions between different economic sectors are fixed and do not change significantly in the short-term.

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} = \mathbf{L}\mathbf{y} \tag{3.4}$$

In this, $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$ is known as the Leontief inverse or total requirements matrix, in which each matrix component l_{ij} represents the total amount directly and indirectly needed of good or service i to deliver one unit of final demand of good or service j. These assumption allows us to establish a way to compute the output of each sector, as for example, the economy response to changes in the final demand stimulus $\mathbf{y}$. Therefore, this model provides the possibility to assess impacts on primary factors such as employment, GHG emissions, value added, among others.

Advantages and Limitations

Now that we have seen a brief description of the IO model, it is necessary to present the reasons why this type of analysis should be appropriate to the problem considered on measuring the impact of the energy sector in Portugal. In order to construct an IO table it is required a lot of data, which is not easy to gather, and so, these methods are usually used on a national scope rather than on a local or regional level. Hence, it is possible to identify some advantages regarding these tables:

- The data is usually comprehensive and consistent. These IO tables encompass all the formal market place activity that occurs in the economy, allowing its representation as a whole regarding the flows of goods and services industries trade with one another. The several data sources that are needed to build these tables and to ensure their completeness and internal consistency makes them probably the single most comprehensive and complete source for economic data for most countries. As a consequence, IO tables frequently play a fundamental role in the construction of the national accounts, which are the implementation of several accounting techniques to measure the economic activity of a nation.

- The nature of IO analysis makes it possible to analyze the economy as an interconnected system of industries that directly and indirectly affect one another, tracing structural changes back through industrial interconnections. This is especially important as production processes become more complex, requiring the interaction of different sectors in these processes. As a result, this model is appropriate in a way that changes occurring in domestic demand will not only affect the industry providing that good or product but also the suppliers to that industry, for instance it is possible to measure the loss in one determined sector due to the growth of another. In other words, IO techniques trace these linkages from the raw material stage to the sale of the product as a final, finished good. Therefore this model also has the very important ability to capture not only the direct effects, but also the indirect and even induced effects.

- The design of input-output tables allows a decomposition of structural change which identifies the sources of change as well as the direction and magnitude of change. This means that the model enables changes in output to be linked with underlying changes in factors such as exports, imports, domestic final demand as well as technology. This permits a consistent estimation of the relative importance of these factors in generating output and, for example, employment growth on the several sectors.

Nowadays, this type of impact analysis has become important to all the highly-industrialized countries in economic planning and decision making due to several characteristics mentioned before. However, one must also consider the associated limitations included on the usage of input-output.

- Technical coefficients are assumed to constant over time meaning that the amount of each input necessary to produce one unit of each output is constant. The amount of input purchased by a sector is determined solely on the level of output. No consideration is made to price effects, changing technology or economies of scale. Therefore, the model assumes that the same relative mix of inputs will be used by an industry to create output regardless of quantity.
- Each industry is assumed to produce only one type of product. For example, the automobile industry produces only cars. The distribution and sale of this product is fixed.
- Each product within the industry is assumed to be the same. Also, there is no substitution between inputs. The output of each sector is produced with a unique set of inputs.
- It is assumed that there are no constraints on resources, meaning that supply is considered infinite and perfectly elastic.
- It is assumed that all local resources are efficiently employed. There is no underemployment of resources.
- Timeliness of input-output data. Due to the several sources needed to construct these tables, there is a long time lag between the collection of data and the availability of the tables.

In conclusion, IO models have commonly been applied to evaluate targeted economic policies and to estimate short and medium term employment impacts. Actually, it is a widely used as a very useful method capable of simulating almost any conceivable economic impact.

3.1.2 Multipliers and impacts

There are some ratios, also known as multipliers, which are used to estimate the effects of exogenous changes on: output of sectors in the economy; income earned by households in each sector due to the new output; social effects (employment) and value added generated across sectors (Miller & Blair 2009, pag. 243-244). These are some of the most frequently used types of multipliers. Another type is related to environmental concerns, such as GHG emissions which will be evaluated in this work. Before explaining how do these multipliers will be obtained and their meaning, it is proposed to first take a look at the concepts behind direct, indirect and induced effects. To begin with, consider there is a change in the final demand. As a result, there will be changes in the output of the producers to meet this final demand increase, which are known as direct effects. As these producers increase their output, there will also be an increase in demand on their suppliers and so on up the supply chain and these changes are known as indirect effects. Then, as a result of the direct and indirect effects mentioned before, the level of household income throughout the economy will increase as a result of increased employment, for example, and a proportion of this increased income will be re-spent on final goods and services describing what is known as induced effects. It is important to mention the work of Miyazawa (1976) on endongenizing the households in an input-output model to reproduce these induced effects and generate various multipliers matrices.

In the Leontief model, the impact of one euro worth of final demand of product j on the use of a primary factor (as employment for instance) of sector i is given the multiplier M_{ij}:

$$\mathbf{M} = \mathrm{diag}(\mathbf{r})\mathbf{L}, \tag{3.5}$$

where ”diag” is a diagonal matrix and **r** is the direct primary factor coefficients. The **r** coefficients vector is obtained dividing each element of the vector for the corresponding element in the original output vector **x**. Then r_i represents the amount of primary factor used per unity of output of industry i. Moreover, the total impact of final demand j on production factor i can be obtained by the product $r_i L_{ij} y_j$. From 3.5, in algebra standard notation, the total impact mentioned before can be simply obtained by the following product: **My**. However, for further impacts discussion it is important to keep in mind the simple expression 3.4 (**x**=**Ly**). The reason for this reminder is that this model responds to an exogenous stimulus, thus **x** is the variable that will determine the impact $\mathbf{b} = \mathrm{diag}(\mathbf{r})\mathbf{x}$.

It is intended to present more than one scenario for the historical analysis, hence every year from 2000 to 2010 will have an alternative scenario in addition to the reference one (the so-called ”real case scenario”). The operational, capital investment and subsidies related to the tariff deficit effects (electricity cost/price difference) on the economic, social and environment impacts are obtained from alternative scenarios. Furthermore, each effect has different methods of obtaining the appropriate alternative scenario. The net values comparing reference to alternative scenario are obtained from the following expression:

$$\Delta\mathbf{x} = \mathbf{x}^R - \mathbf{x}^A \tag{3.6}$$

The way that $\mathbf{x}^A$ is obtained depends on the effect desired. These methods are explained further for each case in the subsection 3.2.3. Obtaining $\Delta\mathbf{x}$ from expression 3.6, the difference between reference and alternative scenario impacts are calculated as follows:

$$\Delta\mathbf{b} = \mathrm{diag}(\mathbf{r})\Delta\mathbf{x} \tag{3.7}$$

In this case, calculating $\Delta\mathbf{b}$ allows a relative interpretation about impact **r** on both reference and alternative scenario (as a comparison result). Given the possibility that if the absolute values may not correspond exactly to the reality, using differences enhances the process of understanding the behavior of the full model in response to certain desired stimulus and/or effect.

3.2 Structure of the model

In this subsection it is explained the whole model construction process. First it is presented a description about the structure of the isolated energy and economy models. Secondly, the first integrated hybrid model and the following extensions are explained as well as their composing blocks. Therefore, the modifications required to calculate the desired impacts from the selected effects are still discussed.

3.2.1 Economic model

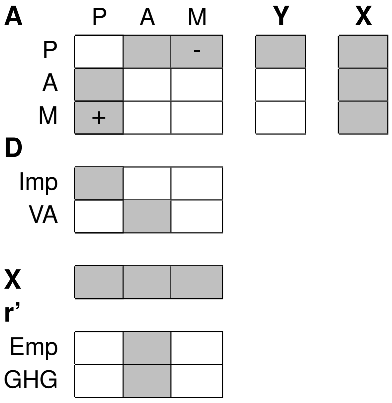
In spite of presenting and explain only the final hybrid model, it is rather appealing to introduce first the economic and energy isolated models. Hence, lets consider first the economic system. This model has 49 products and 49 activities sectors. In order to better understand the following steps it is helpful to note that an IO system is a network of causal links. This means that the whole system is represented by a set of nodes (e.g., as industries or products) and a set of arcs that connect these nodes to each other (e.g., intermediary flows referring to activities using products and also producing them). In particular, this model main quadrant (**Z**, intermediary matrix) is built with a Supply-Use Table (SUT) framework. The *use* matrix has information regarding the uses of products by the industries. On the other hand the *supply* matrix refers to products made by the activities. This being said, in table 3.1 the description of symbols used further can be observed and in table 3.2 it is possible see the schematic representation of this whole economic model. The $\mathbf{A}^{PA}$ block is the *use* matrix and the $\mathbf{A}^{AP}$ is the *make* matrix.

Symbol	Description
P	Economic products
A	Economic activities or industries
M	Trade margins
C	Energy carriers
T	Energy technologies
K	Capital investment
H	Households
S	Subsidies
Dom	Domestic production
L	Net Losses on conversion
Imp	Imports
VA	Value added
Emp	Employment
GHG	Green house gas emissions

Table 3.1: Description of symbols used in economy and energy model

The shaded areas contain the matrices where information is located. The units here in the main blocks **Z**, **D**, **Y** and **X** are simply monetary. It is important to know if the monetary flows, i.e, prices, are in purchase or basic terms. Purchaser prices include the trade margins and the reason they are included in the **Z** block full matrix is only a compatibility issue. Therefore, the equality between sum in rows and columns still has to remain valid. The block **r'** has information relatively to employment (obviously with no units) and GHG emissions in physical units (Mton).

The detail in the total final demand **y** is accomplished with 5 different categories. As a result the



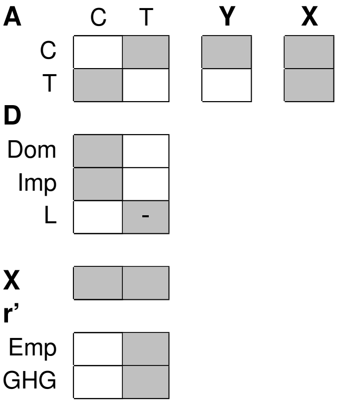
A	P	A	M	**Y**	**X**
P		▨	▨ -	▨	▨
A	▨				▨
M	▨ +				▨
D					
Imp	▨				
VA		▨			
X	▨	▨	▨		
r’					
Emp		▨			
GHG		▨			

Table 3.2: Structure of the economic model. **A**= technical coefficients matrix; **y**=final demand; **D** and **r’** are primary inputs vectors; **x**= total output.

initial total exogenous stimulus is composed by households expenditures; Non-Profit Institutions Serving Households (NPISH); government; Gross Capital Formation (GCF) and exports. In the hope that there is nothing wrong with this built system, after checking the row and column sums, one can perform another test. That is, compute the technical coefficient matrix using equation 3.2, **A** and then the Leontief’s inverse, **L**, from equation 3.4. Afterwards, the Leontief model equation is applied and as a result it is expected that with the final demand data, **y**, the output vector obtained matches with the one used to calculate the **A** matrix. In the final analysis it is possible to be sure that there these two validation criteria mentioned above are fulfilled (calibration process).

3.2.2 Energy model

The hybrid units model, as it has been mentioned is composed by information in different units. With this in mind, the energy model hereby presented is in units of energy, tonnes of oil equivalent (toe) for instance. Table 3.3 shows the overview of the isolated energy model structure. It is possible to identify some similarity with the previous economic structure. This means that several blocks have the same meaning such as, final demand **y**, total output **x**, and primary factors input vectors **r’**.



A	C	T	**Y**	**X**
C		▨	▨	▨
T	▨			▨
D				
Dom	▨			
Imp	▨			
L		▨ -		
X	▨	▨		
r’				
Emp		▨		
GHG		▨		

Table 3.3: Structure of the energy model. **A**= technical coefficients matrix; **y**=final demand; **D** and **r’** are primary inputs vectors; **x**= total output.

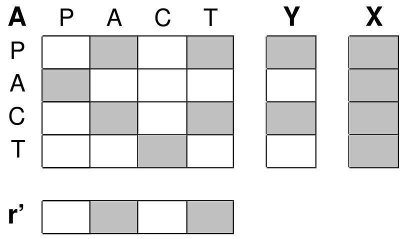
The description of these new symbols can be found in Table 3.1. If the previous model was well understood, and hopefully nicely explained, this energy one would be another simple step towards our final stage. Consider the full technical coefficient matrix presented above, **A**. This matrix is built with two blocks, *use* and *make* (supply's transpose) matrices. The first , **A**^{CT} has information on how the energy technologies use the different energy carriers (in energy units), and logically the *make* matrix block, **A**^{TC}, connects technologies to carriers concerning their production and supply (just like activities make products, technologies make carriers). All the other blocks left uncolored are filled with 0's. It is important to have the clear definition of energy carriers and not mistake them with primary energy sources. From now on, note that when carriers are mention it is referring to the energy form produced by the energy sector using primary energy sources.

The energy model itself is made with 42 carriers and 18 technologies. In the **D** matrix, it can be found the domestic production, imports and the net losses through the transformation process (e.g, electricity production). The final demand vector is composed by a merge of data accounting the exports, stock variation, corrections and final consumption by households as well other activities (i.e. 5 different categories). All things considered, the same two validation tests as before (Leontief's model test and matching row and columns sums) were performed resulting in a functioning energy model. Note that the matching of row and column sums has to be analyzed and checked in this phase because when hybrid units are involved and the full model is developed this is no longer valid (different units in columns).

3.2.3 Hybrid model

Operational (O&M) effects

It is provided in Table 3.4 the first extension of the hybrid model do assess these operational effects. Two extra blocks are inserted where interaction between energy and economy is provided. The block **A**^{CA} contains the use of energy carriers by all of the 49 economy activities considered. The block **A**^{PT} reefers to the use of economy products by each of the 18 technologies. The first block mentioned is in energy units (toe) while the second is in monetary units (M€).



A	P	A	C	T	**Y**	**X**
P		▨		▨	▨	▨
A	▨					▨
C		▨		▨	▨	▨
T			▨			▨
r'		▨		▨		

Table 3.4: Energy and economy interaction hybrid model.

In this, to calculate the impacts including only the basic energy and economy blocks with O&M costs, the technical coefficient matrix A is divided in two blocks: **A**$^{R}_{ROE}$ and **A**$^{R}_{E}$.

To assess the operational effects, O&M, each alternative scenario considers that the energy sector remains constant from the previous year to the present one, i.e., there is no technology evolution (technical coefficient matrix $\mathbf{A}_E$ does not change). As a result, the output variables for the reference scenario "R" and alternative "A" are given by:

$$\mathbf{x}^R = \mathbf{L}\mathbf{y}^R \tag{3.8}$$

$$\mathbf{x}^A = \mathbf{L}^*\mathbf{y}^R \tag{3.9}$$

In which $\mathbf{L}^* = (\mathbf{I} - \mathbf{A}^*)^{-1}$ and $\mathbf{A}^* = [\mathbf{A}^R_{ROE}|\mathbf{A}^A_E]$. This technical coefficient matrix is therefore built with both the reference year t economy block, $\mathbf{A}^R_{ROE}$, and the $t-1$ energy block, $\mathbf{A}^A_E$ (as an alternative). Naturally, from this, the $\mathbf{A}^R_{ROE}$ block includes the products and industry/activities columns and $\mathbf{A}^R_E$ the carriers and technologies respective columns. It may be useful to analyze the results as differences:

$$\Delta\mathbf{x} = \mathbf{x}^R - \mathbf{x}^A = (\mathbf{L} - \mathbf{L}^*)\mathbf{y}^R \tag{3.10}$$

The resulting $\Delta\mathbf{x}$ can be used in the expression 3.7 to obtain the economic, social and environmental impacts due to the energy technology mix development over the years.

Electricity cost and price difference effects

The following extension includes the households endogenous and the energy subsidies spent on electricity producing technologies. As a result, a couple of selected modifications were processed to obtain the extended hybrid model shown in Table 3.5.

A	P	A	C	T	H	S	**y**	**x**
P		▨		▨	▨		▨	▨
A	▨					▨		▨
C		▨		▨	▨		▨	▨
T			▨					▨
H						▨		▨
S				-				▨
r'		▨		▨				

Table 3.5: Hybrid model extension with subsidies and endogenous households

The $\mathbf{A}^{ST}$ block considers the subsidies received by the energy technologies (electricity producers). The tables composing these blocks for each year are obtained from processed and manipulated data explained with detail in chapter 4. The $\mathbf{A}^{AS}$ and $\mathbf{A}^{HS}$ blocks are the amount that is paid for subsidies either by ROE activities, A, or by households, H. Note that these 2 group of blocks must have different signs in the technological matrix to represent the different flow direction either by receiving or paying processes. Hence, to simplify, the $\mathbf{A}^{ST}$ is negative as the $\mathbf{A}^{AS}$ and $\mathbf{A}^{HS}$ remain positive elements of the full **A** matrix.

The blocks $\mathbf{A}^{PH}$ and $\mathbf{A}^{CH}$ describe the use of products and carriers by the households. To explain, consider that endogenous households column in the intermediary flow matrix is denoted as $\mathbf{Z}_H$:

$$\mathbf{Z}_H = \frac{s}{W_{tot}}\mathbf{y}^*, \tag{3.11}$$

where s is the amount of subsidies paid by households and W_{tot} is their total wages received. Also, $\mathbf{y}^*$ represents the total final demand vector before the endogenizing process. It is important to note that the total households final consumption is a sum of endogenous and endogenous vectors:

$$\mathbf{H}_{tot} = \mathbf{H}_{endo} + \mathbf{H}_{exo} \tag{3.12}$$

The endogenous component is already calculated from 3.11 ($\mathbf{H}_{endo} = \mathbf{Z}_H$), thus the real exogenous final demand vector will be $\mathbf{y} = \mathbf{y}^* - \mathbf{H}_{endo}$. The process of obtaining the impacts in this case is similar, with the same alternative scenario method.

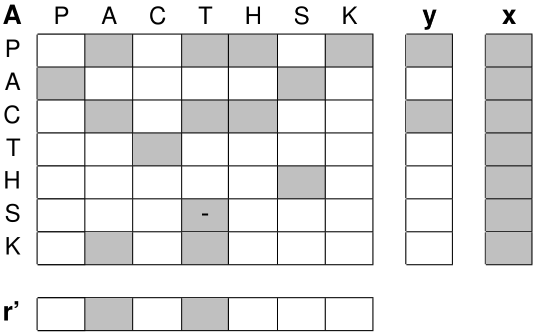
To assess the effects on subsidies and the tariff deficit the alternative scenario considers endogenous modifications. The main question here is: what would happen if the subsidies were fully reproduced in the electricity bill and no tariff deficit would occur? In other words, the cost/price difference of electricity producing is considered zero in alternative scenario. Therefore, these effects are captured on the resulting impacts.

Therefore, with the presented hybrid model, this question can be answered by stating that alternative scenario considers the blocks $\mathbf{A}^{AS}$ and $\mathbf{A}^{HS}$ to be consistent with the block $\mathbf{A}^{ST}$ (every subsidy received is really supported by consumers). Naturally $\mathbf{A}^{PH}$ and $\mathbf{A}^{CH}$ are recalculated for the alternative scenario.

To summarize, the $\Delta\mathbf{x}$ is obtained just as for the operational effects. The difference is in the alternative scenario considerations.

Capital investments effects

The following procedure considers the capital investments in the hybrid model with the block structure presented in Table 3.6. The implemented blocks are $\mathbf{A}^{PK}$, $\mathbf{A}^{KA}$ and $\mathbf{A}^{KT}$.



A	P	A	C	T	H	S	K	**y**	**x**
P		▨		▨	▨		▨	▨	▨
A	▨					▨			▨
C		▨		▨	▨			▨	▨
T			▨						▨
H						▨			▨
S				-					▨
K		▨		▨					▨
r’		▨		▨					

Table 3.6: Full integrated hybrid model.

First of all the investment, K, has 5 different categories: construction, transport equipment, other machinery and equipment, cultivated assets and intangible fixed assets. Their meaning and a brief discussion is presented further on the next chapter, 4.4.3. Hence the block $\mathbf{A}^{PK}$ is a 49×5 matrix obtained from the gross fixed capital formation (included in the final demand as exogenous). Those values had to become endogenous according to a conversion key to disaggregate the 49 goods in those 5 categories. Obviously, just as the previous case with the endogenous households, the gross fixed capital formation is removed from the final the demand as it is already considered inside the **A** matrix. The $\mathbf{A}^{KA}$ block is simply the consumption of fixed capital distributed across the 49 activities (without counting the energy sectors: electricity and oil refining). However, the $\mathbf{A}^{KT}$ block is more subtle. It has to consider the investment expenditures related to the maintenance according to the consumption of fixed capital. The investment portion related to the installation of new capacity power has to be exogenous in order to contribute to the alternative scenario. The data manipulation to obtain this blocks in detail is explained in the following chapter.

To sum, the reference scenario is obtained simply by $\mathbf{x}^R = \mathbf{L}^R\mathbf{y}^R$ while the alternative scenario includes a different approach:

$$\mathbf{x}^A = \mathbf{L}^R\mathbf{y}^A \tag{3.13}$$

In this case the alternative scenario does not use the reference year final demand but a different exogenous stimulus instead, $\mathbf{y}^A$. This alternative final demand vector does not include the investment estimated to contribute to the installation of new capacity power (as it is considered only in the reference final demand). Therefore, this analysis is possible for all of the 10 years, once the variable in this alternative scenario is related to the exogenous stimulus and no previous year data is necessary. The investment effects are thus isolated from every other effects.

Chapter 4

Data and Assumptions

4.1 Overview and aggregation/disaggregation

The data gathering process is usually an intense and demanding step, because obviously it is intended to find the most detailed and accurate data available. This is true for any study and/or research. In the present work, this is no exception. The historical analysis requires a lot of different data sources to interpret, cross information, evaluate compatibilities and apply some assumptions. To summarize, the transition from raw to processed data (in the finished state) can be quite detailed and full of assumptions that may need to be explained. This chapter 4 is dedicated to this mentioned process.

Detailed information has already been provided in the previous chapter, however, the fundamental characteristics that should be retained before continuing are presented in the Table 4.1.

Model characteristics	
Products	49
Activities	49
Technologies	18
Carriers	42
Final demand	5

Table 4.1: The model overview characteristics.

The model has 49 products and activities, 18 technologies (12 for generating electricity) and 42 carriers. The final demand has 5 components either for energy and economy. For economy it contains: households; NPISH; government; GCF and exports. For energy the final demand includes: residential; intermediate consumption (Rest of the Economy); stock variation; corrections and exports.

Sometimes the information required is available for n sectors or products while the goal should be having it according to a classification of m sectors. The aggregation and disaggregation manipulating methods provide the possibility to do the conversion of the desired information from n to m. If $n > m$, an aggregation is what is required, thus the direction is towards a lower level of detail. However, if $n < m$ a disaggregation process has to be applied. Both these methods were used numerous times, hence it is useful to briefly explain them in this introductory subsection for further reference.

To start with, lets consider an aggregation. The first step is to establish the relation between the n and m elements and build a bridge matrix (conversion matrix with 1's and 0's) that contains the identified relation. For further use, lets call it the **P** matrix. Therefore, to aggregate is only necessary to multiply the initial object by **P**. As an example, suppose $\mathbf{M}^{10\times65}$ and it is intended to achieve a 10 rows and 49 columns matrix, $\mathbf{M}^{10\times49}$. Here our $n = 65$ and $m = 49$. The aggregation would simply be:

$$\mathbf{M}^{10\times49} = \mathbf{M}^{10\times65}\mathbf{P}^{65\times49} \tag{4.1}$$

Disaggregation is more subtle, because it is about a conversion towards more detail. One can choose do allocate the information equally (if one sector with data x is disaggregated into 3 other, each one of them would have $x/3$). Regardless, this option is not very accurate and it can be misleading. What is indeed required is called a proxy vector, **v**, to estimate a more accurate proportion. This vector has to have the number of elements equal to m and it can be the output of those sectors, employment, capital or whatever seems suitable. Consider $\mathbf{P}^*$ to be the new bridge matrix with the new proportions and tot_j the column j sum of the matrix resulting from $\mathrm{diag}(\mathbf{v})\mathbf{P}$. Each entry of the new proportional bridge matrix is obtained as follows:

$$P^*_{ij} = \frac{v_j P_{ij}}{tot_j} \tag{4.2}$$

Afterwards the process is similar to the aggregation method. The multiplication of the new proportions matrix, $\mathbf{P}^*$, by the object intended to be converted results in the desired dimension object.

4.2 Rest of the economy

The economy data gather is the most accessible part of the whole process. This is because there is data in SUT format available for Portugal on the Eurostat database, for instance. Consequently, and considering our 2000 to 2010 year period, there was a change in the sectoral scheme from the years following 2006. In this case, from 1995 to 2006 the data was presented according to the Statistical Classification of Economic Activities in the European Community (NACE), version 1.1 (59 sectors) and the following years under the NACE 2 (65 sectors) conditions. The economic data was therefore arranged according to this criteria and it was processed and modified to be a set of supply and use tables with 49 products and activities [1]. However, the GHG emissions were not included in the tables, although Eurostat also contained this type of data by country and activities (following the same classification of NACE 1.1 and NACE 2). For environmental concerns the emissions considered cover GHG such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). This data was further adapted to the 49 products and sectors format using an appropriate conversion matrix. In this case both processes (59 and 65 to 49 sectors) were aggregations. Hence, the resulting vector containing the emissions was obtained according to the aggregation method described above in which **P** is a 49×59 or 49×65 depending on the

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[1] This processed version was given to me, and as mention in the acknowledgments, i have to thank Zeus Guevara and João Rodrigues for this data.

conversion process to be before or after 2006. This operation is thus repeated for each one of the 10 years from 2000 to 2010.

Employment data was found on tables supplied by INE (available online). Although the information was organized for 38 activity sectors, a equivalence key had to be constructed to disaggregate the data into the 49 sectors. This was accomplished with proportional allocation (using Eurostat employment proportions available from 2002 to 2010). The proportions from 2002 were assumed to be the same for 2001 and 2000 due to the lack of other accurate options. The disaggregation process was performed according to the explanation provided in the previous section 4.1 where $\mathbf{v}_t$ is the proxy used (employment from eurostat relative to year t). In the end, the employment data for the 49 economic activities from 2000 to 2010 was processed and ready to be used. In addition, data for the fixed capital formation (investment) was required. This type of data is available from INE, (Statistics Portugal, National Accounts) for 38 economy sectors. Therefore the equivalence key from 38 to 49 sectors was used and an identical process as the one described above was conducted for each year (using economic output as proxy, $\mathbf{v}$).

4.3 Characterization of the energy sector

It is within this sub chapter that the most important and significant part of the data gathering and assumptions are made. This results from the disaggregation goal where more detail and information are required. It is known that nowadays the energy sector plays a crucial role in society and in economy. Considering this, and Portugal being a country mostly dependent on fossil fuel imports to meet the energy demands, there has been an overall recognition that renewable have a significant developing potential (NREAP 2010). As a result, the importance associated with this green sources is clearly known mainly regarding electricity production.

4.3.1 Installed capacity and technology

To begin with, it was necessary to investigate the main technologies that would be responsible for the electricity produced not only in Portugal mainland but also in the islands. The main division would be to separate what is renewable and what are the conventional technologies. Sources as wind, solar, hydro, biomass, waste and geothermal were first considered. In the following research steps fossil fuel technologies, mostly thermoelectric were noted. Provided that, in Table 4.2 it is possible to see the main electricity producing technologies considered for further analysis.

To explain these choices, a brief overview will be presented. Biomass dedicated includes power plants that use wood and vegetal as well as animal waste. Those are facilities designed to produce electricity by burning biomass residues. On the other hand, some plants may allow combined cycle biomass (CHP), and that represents increased efficiencies in the whole process due to the re-use of the released heat in the combustion cycle. Although the fuel is the same in principle, several differences were identified, and the cost structure was no exception, as it will be discussed later on. Some documents present also this separation, as for instance yearly reports on DGEG database (DGEG 2013).

Energy Technologies	
Biomass	Dedicated CHP
MUW	Incineration
Biogas	
Wind	On-shore
Hydro	Small Large
Geothermal	Binary Cycle
Solar	Photovoltaic
Thermoelectric	Fuel Oil (CCOT) Coal (PCC) Natural Gas (CCGT)

Table 4.2: Electricity generation technologies. Combined Heat and Power (CHP) allows heat supply as well.

Similarly, municipal solid waste based on mostly the incineration of industrial residues also contributes to electricity production in Portugal, even though as a smaller fraction. The use of biogas, is an emerging technology since there are still goals that need to be achieved in our established road maps. In fact, the main application of biogas is for electricity production (Miguel Ferreira & Malico 2012).

The potential in wind power is widely accepted and its continuous growth has been notorious over the years (INEGI 2010). Additionally hydro power can be divided in two different categories: small scale and large scale. This distinction is widely accepted in the 10MW capacity mark, i.e. small scale refers to facilities with power capacity below 10MW and large scale is for the remaining plants with more than that. This separate technology consideration within hydro power is important because i) the investment and Operation and Maintenance (O&M) costs are not the same and they change significantly; ii) electricity is produced under two different regimes, in which small scale hydro is a part of the SR and large scale is considered as OR resulting in different policies, incentives and subsidies (discussed in more detailed further).

Usually one of the greatest differences about consider just Portugal mainland or decide to include the islands is connected with geothermal power. The possibility of producing electricity from this renewable source depends on the region, due to geological properties. In particular, Azores is the only Portuguese region where this is possible and, in fact, in S. Miguel this source meets about 40% of the population's electricity requirements (Alison Holm & Gawell 2010). For this reason Geothermal was included in the characterization using a binary cycle conversion to produce electricity due to the working conditions of these power plants (Ribeira Grande and Pico Vermelho). Another technology considered, and the last renewable source is Solar Photovoltaics (PV). Portugal once had the biggest photovoltaic power plant in the world (Moura, Amareleja power station) and the electricity produced from solar sources has been growing in the recent years, making this inclusion in the characterization one mandatory choice. To finish the electricity (and heat) producing technologies, the thermoelectric sector was added. It is important to note that cogeneration (non-renewable CHP in this case) is included as a part of fuel oil and natural gas technologies. In the description Table 4.2, Combined Cycle Oil-Turbine (CCOT) and Combined Cycle Gas-Turbine (CCGT) exposes the assumption that was made. To put it in another way, after some research on these fossil fuel plants, it was observed that most thermoelectric systems do work according to this cycles and assuming the costs (O&M and investment) associated with this type of power stations is an accurate assumption. As for coal, Pulverized Coal Combustion (PCC) is the most common cycle implemented in these coal power plants. To illustrate the evolution of each one of the described technologies in Portugal, the Figures 4.1 and 4.2 are displayed in MW.

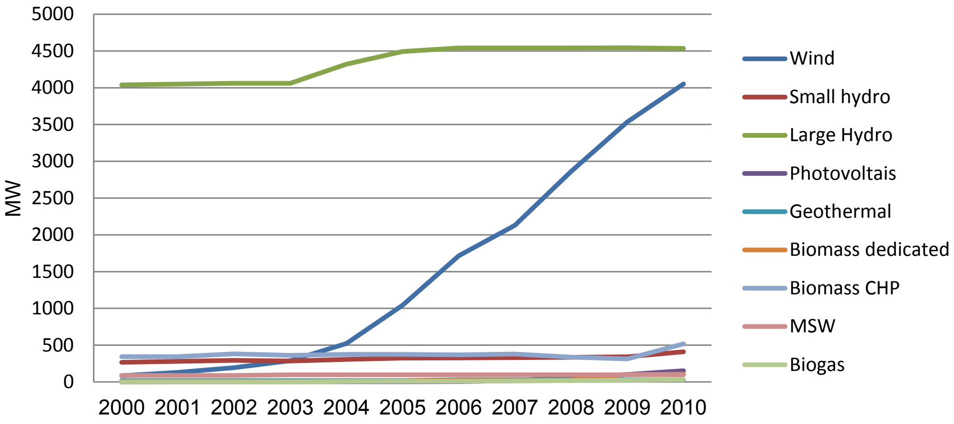

Figure 4.1: Evolution of the accumulated power capacities for each renewable energy technology considered.

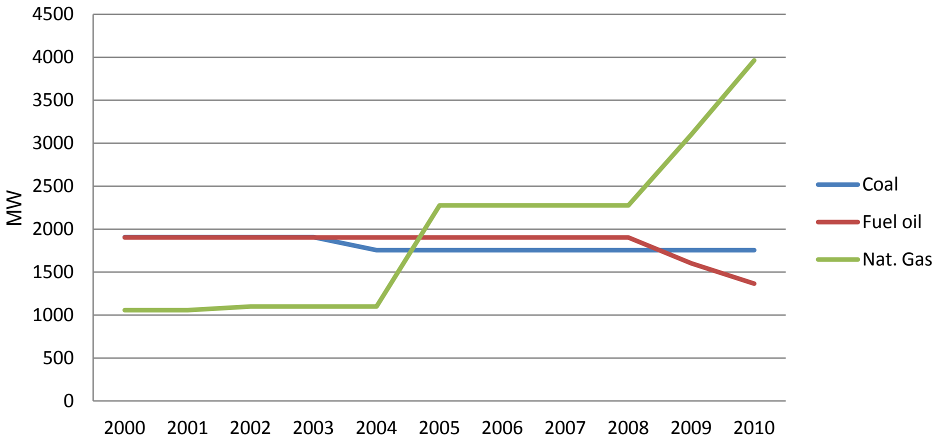

Figure 4.2: Evolution of the accumulated power capacities for each conventional fossil fuel technologies considered.

Over the 10 years period from 2000 to 2010 several power plants were built, some were improved with new groups (more capacity) installation, others became non operational. The challenge is to discover the facilities profile, in the most accessible way possible, and create a database with information such as the accumulated capacity installed and electricity produced over the years for each technology described above. To obtain these values several sources were consulted, although the main database was DGEG with yearly reports and tables available online. At the same time, some information was relative only to Portugal mainland, thus it was necessary to compare different documents (including Madeira and Azores) to extract the desired information. After obtaining it, the evolution share was calculated summing the renewable electricity produced from all RES technologies *versus* the fossil fuel thermoelectric contribution. The result is illustrated in Figure 4.3. The RES-E significant growth over the years becomes clear, reaching over 50% in 2010.

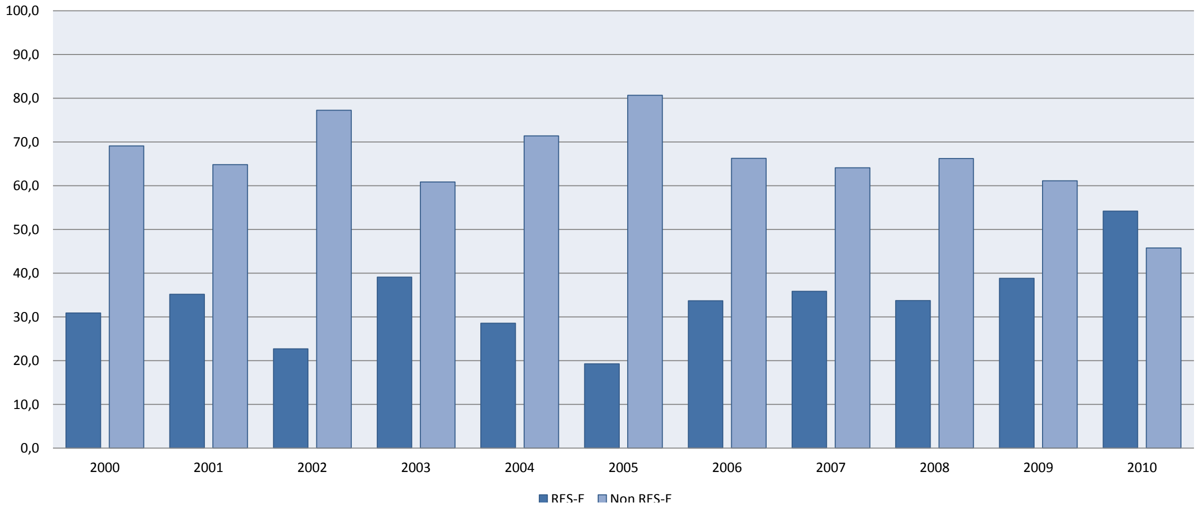

Figure 4.3: Evolution of the electricity production share percentage by renewable sources vs. non renewable (fossil fuel).

4.3.2 Investment and O&M costs

Additionally, information on investment, operation and maintenance costs were also required. In order to accomplish these costs and obtain a reference value for the selected technologies, the main sources were EU (2008), Kaplan (2008), EIA (2013), NREL (2012), IEA & NEA (2010), among others. The costs presented in each document seem to slightly change because they are very dependent on region, type of plant, location, and several other characteristics of the project. Despite that, the values presented in the Table 4.3 are reference costs chosen considering several documentation such as the citations above.

The asymmetric tolerance ranges for investment costs are also presented. These were accomplished by consulting several documents that had different values for investment (and different ranges). For both O&M values no fixed range was obtained due to the nature of these costs (extremely dependent), although the margins must be in average around the order of 10 to 20%. However, the reference values were used and no statistical error analysis was conducted during this procedure (a further step adjusts the absolute values to match the national accounts numbers on capital formation).

These values were prepared and had to converted in the same monetary unit (same reference year). The investment costs are considered to be overnight costs, i.e. the power plant/station would require that amount of money per capacity installed if it would be built overnight. Fixed O&M costs are expenses fixed, hence do not change (at least significantly) from power plant to power plant. On the other hand, the variable costs do, and they are dependent on the amount of electricity produced. It is important to mention that both these operational and maintenance costs do not include fuel expenses (which is of great importance for the thermoelectric technologies). However, this is actually not problematic,

Technology	**Investment [€$_{2005}$/kW]**	**Fixed O&M [€$_{2005}$/kW-yr]**	**Variable O&M [€$_{2005}$/MWh]**
Biomass Dedicated	2400^{+770}_{-430}	67	10
Biomass CHP	5900^{+885}_{-885}	226	11
MUW	6200^{+930}_{-930}	250	5
Biogas	3140^{+2650}_{-180}	245*	
Wind on-shore	1140^{+230}_{-140}	19	-
Small Hydro	3500^{+1300}_{-1000}	17	-
Large Hydro	1800^{+1300}_{-450}	8	-
Solar PV	4700^{+2200}_{-600}	13	-
Geothermal	3500^{+1500}_{-1500}	56	7
Fuel oil	900^{+200}_{-350}	45*	
Coal	1265^{+175}_{-265}	60*	
Natural Gas	635^{+95}_{-155}	25*	

Table 4.3: Costs structure considered for each technology. The marked numbers (*) consider both variable and fixed O&M due to their different sources.

because the use of carriers by technologies is represented in energy units and therefore no double counting occurs.

In order to asses the investment costs, the accumulated capacities were consulted (from the database created with the available data) and from the installed capacities it would be assumed that for each kW increase from one year to another the investment would be the price presented in Table 4.3. If there was no capacity installation it is assumed that no investment occurred. Altogether, this assumption is acceptable due to the constant power plants installation in technologies such as wind energy. From the period 2000 to 2010 the conventional thermo power plants were considered individually because Natural Gas was the only technology growing with several stations becoming operational over these years (see Table 4.4). Therefore, it can be seen the reason why it was considered no investment took place from 2000 to 2010 in technologies as coal and fuel oil power plants. Furthermore, it is possible to compute tables with information referring to year by year monetary expenditures on investment (Gross fixed capital formation) and by operating and maintaining every power station of each technology.

4.3.3 GHG emissions and employment

In general there are three ways for estimating the green house gas emissions: i) fuel-specific emission factor coefficients; ii) direct measurement; iii) mass or carbon balance approach (Herold 2003). For estimating the emissions of CO_2, CH_4 and N_2O by each one of the technologies considered the first method is selected. The data was gathered from IPCC 2006 Guidelines (Gómez et al. 2006) and the coefficients are presented in Table 4.5. Note that the coefficients in the category ”Solid Biomass” were also used for the combined cycle technology (assumed to be similar). As a result, knowing already the electricity produced from each source and considering the efficiency in converting fuel (input) to

Power Plant	Cap.[MW]	Year
Gas Natural		
Tapada do Outeiro II	990	1999 - Present
SOPORGEN	67	2000 - Present
ENERGIN	43	2002 - Present
Ribatejo	1176	2004 - Present
Lares	826	2009 - Present
Pego II	837	2010 - Present
FISIGEN	25	2010 - Present
Fuel Oil		
Carregado	708	1969 - 2009,2010,2011*
Tunes	165	1973-2010 - Present
Setúbal	946	1979 - 2012
Barreiro	64,5	1979 - 2009
Central Termoeléctrica de Porto Santo	19	1992 - Present
Coal		
Sines	1180	1985-Present
Tapada do Outeiro I	150	1959-2004
Pego I	576	1993 - Present

Table 4.4: Thermoelectric power plants in Portugal and their capacities. The symbol (*) is intended to note that in each year a facility group of 236 MW was closed.

electricity the GHG emissions in physical units (Tonnes) were calculated for the energy sector.

Technology/Fuel	CO_2			CH_4			N_2O		
	Min	Ref	Max	Min	Ref	Max	Min	Ref	Max
Hard coal	95.00	100.00	105	0.30	1.00	3.00	0.50	1.50	5.00
Crude oil	71.10	73.33	75.5	1.00	3.00	10.00	0.20	0.60	2.00
Natural gas	54.30	56.10	58.3	0.30	1.00	3.00	0.03	0.10	0.30
Solid biomass	66.00	80.70	100	10.00	30.00	100.00	1.50	4.00	15.00
Biogas	46.20	54.60	66	0.30	1.00	3.00	0.03	0.10	0.30
MSW	73.30	91.70	121	10.00	30.00	100.00	1.50	4.00	15.00

Table 4.5: GHG emission factors used per fuel-type/technology in tonnes per TJ of input (Gómez et al. 2006).

Due to several policies and protocols already mention in early chapters, such as Kyoto, there has been an obligation referring to CO_2 emissions. Usually this results in another cost for the electricity producers, which is the carbon emission tax price (€/Ton). In 2005 European Union Emission Trading Scheme (EU ETS) was implemented targeting the reduction of GHG emissions. These values are presented in Table 4.6 in current prices. Consequently, these emission costs can also be considered in the further analysis as they were not included in the previous O&M expenditures mentioned. Therefore, avoiding several amounts of carbon dioxide emissions can also be seen as avoiding money expenditures on CO_2 allowances. This could encourage the efforts to reduce the carbon emissions by electricity producers in addition to the proclaimed environmental concerns.

In order to simplify the results display in the following chapter 5, the methane and nitrous oxide emissions can be presented in carbon equivalent emissions. To accomplish this, Global Warming Potential (GWP) is a relative measure that can be used. It measures the amount of heat a certain GHG traps in

CO_2 price	2005	2006	2007	2008	2009	2010
€/ton	21	17	1	18	13	14

Table 4.6: Carbon emission prices in current €/ton. From Reinaud (2007).

the atmosphere in comparison to the amount trapped by a similar mass of carbon dioxide. Hence, the GWP for methane over 100 years is 25 and for nitrous oxide 298. In other words, it means that emissions of 1 million metric tonnes of methane and nitrous oxide respectively is equivalent to emissions of 25 and 298 million metric tonnes of carbon dioxide (Forster et al. 2007).

Another key point is green jobs. They are still controversial, because although jobs can be created by the renewable they could be destroyed elsewhere. Hence, one of the most important question is about employment. So, in a similar way, data had to be found for each of these technologies that were chosen. Direct jobs are related with the primary industry sector and include jobs in fuel production, manufacturing, construction and O&M (Rutovitz & Harris 2012). For this model purpose the data required is just for fuel handling (fossil fuel technologies) and O&M and it is described with detail in Rutovitz & Harris (2012). This is because construction and manufacturing jobs will be described on the rest of the economy and therefore associated with each technology by the hybrid model built presented in the previous chapter. The extracted data is presented in the Table 4.7.

Technology	O&M [Jobs/MW]	Fuel [jobs/PJ]
Dedicated Biomass	1.5	32.0
Biomass CC	2.3	32.0
MSW	1.5	32.0
Biogas	1.5	32.0
Wind	0.2	0.0
Small hydro	2.4	0.0
Large Hydro	0.3	0.0
PV	0.3	0.0
Geothermal	0.4	0.0
Oil	0.1	22.0
Coal	0.1	40.0
Natural Gas	0.1	22.0

Table 4.7: Job creation data for each technology. From Rutovitz & Harris (2012).

4.3.4 Electricity subsidies, tarriffs and the tariff deficit

The special regime production, which includes cogeneration and renewable sources other than large hydro plants, supplies power to REN under special ”Feed-in” tariffs decided by the government (Amorim et al. 2013). In Table 4.8 these prices guaranteed to the special regime producers are presented and in Figure 4.4 the graphical representation is displayed. No geothermal data was found, meaning that no substantial subsidy is associated with this technology (assumption). ”Feed-in” tariffs have already been discussed in previous chapters but now it is possible to have an idea of their values really received by the producers per MWh of electricity generated.

Technology	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
RES CHP	44.00	47.75	55.50	80.00	81.00	79.00	82.00	86.00	91.00	90.00	90.50
Other CHP	48.00	56.50	67.00	77.00	79.75	92.00	103.00	100.00	122.00	99.00	104.50
Wind on	60.25	62.00	80.00	84.50	88.00	89.50	92.25	95.00	95.00	94.50	92.00
Small hydro	54.50	65.50	75.75	78.75	80.00	82.00	84.75	89.00	89.00	88.00	89.00
MSW	56.00	66.00	69.00	71.00	73.00	75.00	77.50	79.00	81.00	80.00	80.00
Biomass	60.00	64.50	67.00	69.50	72.75	102.50	111.50	110.50	112.00	110.00	109.00
Biogas	54.00	55.25	45.00	53.00	69.75	95.75	106.50	105.00	109.50	106.50	108.00
Solar PV	0.00	0.00	0.00	520.00	522.50	520.00	380.00	330.00	337.50	302.50	305.00

Table 4.8: SR subsidies. "Feed-in" tarrifs values in current prices [€/MWh] from 2000 to 2010 (Amorim et al. 2013).

The graphic representation of Table 4.8 is shown in Figure 4.4. The secondary axis, in the right hand-side, is related to photovoltaic technologies (much higher than the ones for other technologies).

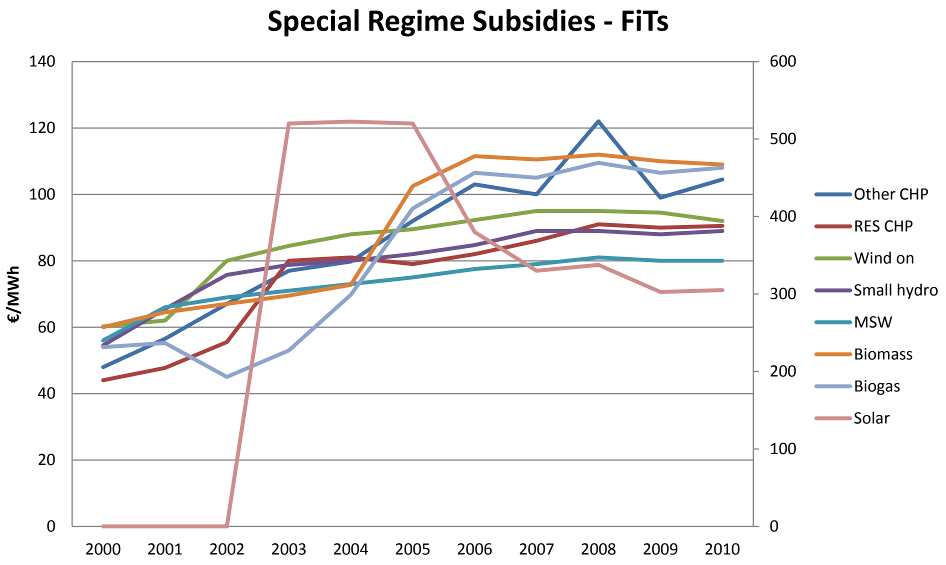

Figure 4.4: Special Regime. "Feed-in" tarrifs values in current prices [€/MWh] from 2000 to 2010. Data from Amorim et al. (2013).

As it was mentioned before, the ordinary regime production, benefits from their own incentives, usually known as CMEC/PPA. They exist to support the investment costs of conventional thermo plants and large hydro power power plants, and their average value per year is displayed in Table 4.9. The subsidized OR production plants ratio was also applied to total MWh per technology to obtain the absolute amount spent per year.

OR	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
PPA/CMEC	48.4	48.0	52.2	46.0	55.9	67.7	59.1	67.8	97.9	73.7	62.1

Table 4.9: Ordinary Regime. Power Purchase Agreements (PPA) / CMEC values in current prices from 2000 to 2010 (Amorim et al. 2013).

When observing the electricity bill, the price mentioned is not only due to the energy price acquired. To explain, it contains three main components: the energy itself; grid connection tariffs and *Custos de Interesse Economico Geral* (CIEG) (ERSE 2013). These shares are not constant over the several types of consumer. In fact, these CIEG contain other sub-divisions such as SR and OR production subsidies expenses (at least part of them), other rents, among other components that differ from high voltage consumer to a low voltage consumer (Abreu 2012). In Portugal, the responsible entities mention these consumers in the literature as follows: *Baixa Tensão* (BT), *Media Tensão* (MT), *Alta Tensão* (AT) and *Muito Alta Tensão* (MAT). See Table 4.10 for the detailed share values used. The BT is usually divided into more detailed categories, and as a result the average of *Baixa Tensão Normal* (BTN) and *Baixa Tensão Especial* (BTE) is expressed as BT to simplify the calculations.

Electricity bill components	BT	AT	MT	MAT
Energy	0.47	0.67	0.60	0.73
Grid	0.28	0.15	0.23	0.08
CIEG				
Municipal Rents	0.06	0.00	0.00	0.00
Costs SR	0.05	0.07	0.06	0.07
Costs Autonomous Regions	0.04	0.02	0.03	0.00
Costs OR (CMECS/PPA)	0.08	0.06	0.06	0.08
Other	0.02	0.03	0.02	0.03

Table 4.10: Electricity costs decomposition [%]. Data from ERSE (2013).

These type of data (structural decomposition of the bill components) is very detailed and, was found for 2 years. Therefore, it was assumed they remained constant from 2000 to 2010. According to the type of customer it was estimated what was paid from each of the economic sectors including households. From DGEG, it can be extracted, for this year range, data about the electricity consumed per activity sector and depending on whether it is a low or high voltage consumer. The proportions were estimated from this raw data tables. Hence, this proportions were applied to the historical use of electricity (in GWh) per type of voltage customer. Moreover, the electricity prices over the years are displayed in Table 4.11.

€/MWh	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
MAT	42.30	43.08	41.60	42.10	44.30	48.73	50.13	53.28	55.00	57.70	58.60
AT	46.34	47.20	43.59	44.20	45.80	50.92	52.74	56.57	58.80	62.30	64.40
MT	64.52	65.54	64.41	65.60	67.50	73.36	77.67	81.43	84.10	89.40	92.25
BT	114.05	115.50	108.59	111.60	113.90	116.64	120.22	131.76	137.45	144.30	148.90

Table 4.11: Electricity prices evolution per type of consumer. Data source from DGEG.

The total amount paid by each activity sector was thus estimated. Then, using the costs share decomposition in Table 4.10 the amount of subsidies paid for the SR production was simply obtained. Note that the unprocessed activity sectors were 28 until 2007, 78 in 2008, 88 in 2009 and 85 in 2010. As a result, several conversion matrices, **P**, had to be constructed from specific aggregation keys. The resulting data can be consulted in the appendix section.

Within this time period from 2000 to 2010, several things have changed in the energy sector, specially in the electricity area such as the transition to the ”free market” and the inclusion of several renewable sources. Since 2006 and especially in 2008 with the substantial increase of fossil fuel prices the average costs of electricity followed that behavior (BPI 2011). Despite that, the Portuguese Government wanted to keep electricity and energy in general at a rather low price (comparable to the real costs). The producers costs were paid the full amount of these subsidies (because only a part of it was really paid by the consumers) by EDP *Serviço Universal* and REN. These entities supported these costs, while the ordinary customer was charged less than it should be (ERSE had the prices regulated so that producers could not charge more than the established price). Under those circumstances, the debt started to increase, and is commonly known as tariff deficit in the energy sector. To summarize, this debt will be paid in the following years, with interests, once the charged prices did not follow the real production, transportation and distribution costs. It is a rather controversial issue, and some argue that this deficit should be eliminated as fast as possible recurring to a loan with low interest rate (GEOTA 2013).

4.4 Energy and ROE interaction

The present section is dedicated to the explanation of the data gathering process and assumptions connected to both energy and economy. The main goals here were to build the use of economic products by technologies and the use of energy carriers by activities in the economy.

4.4.1 Use of products by technologies

To start with, let's consider first the use of products by energy technologies. Although several documents were consulted, not many information seemed to be available with the expected detail. Usually this type of information could be gathered with more detail using specific surveys on a sample of power plant facilities for each technology proposed. As this was very unlikely to succeed (not public information), similarly data was found from Oliveira et al. (2013) and rearranged, thus obtaining the O&M costs share presented in Table 4.12.

O&M costs share [%]	Hydro	Biomass	Wind	PV	Geothermal	Non RES-E
Real estate services	16.2	1.5	9.8	8.6	1.7	15.2
Financial servies	6.5	0.5	6.1	23.0	16.7	12.9
Telecommunications services	1.3	13.4	2.0	0.6	0.0	7.0
Accommodation and food services	0.0	15.1	2.5	0.0	0.0	2.3
Transport services	1.3	15.1	2.0	0.6	0.0	1.2
Trade services	3.2	13.4	2.0	2.9	0.0	2.9
Constructions	26.0	0.8	6.1	9.2	8.3	11.1
Waste collection	0.0	16.8	0.0	0.0	0.0	0.0
Water treatment	3.2	13.4	2.0	2.9	8.3	0.0
Machinery and equipment	12.3	2.3	8.2	11.5	15.0	10.5
Electrical equipment	12.3	2.3	8.2	10.9	16.7	10.5
Fabricated metal products	11.7	2.8	8.2	11.5	16.7	8.8
Basic metals	2.6	1.7	9.8	15.5	16.7	14.6
Rubber and plastics products	3.2	0.8	32.8	2.9	0.0	2.9

Table 4.12: Use of economic products by the energy technologies. From Oliveira et al. (2013).

First of all, the technology description does not match the one discussed before. With this in mind, some data had to be used for more than one technology. To explain, for example, hydro products use share is considered the same for small and large scale plants, biomass data is used not only for biomass dedicated and CHP but also for biogas and waste. Moreover, NRES-E data is equally applied to fossil fuel plants. The next step is based on the calculation of the absolute values of O&M per year for each technology and allocate them according to this data. After establishing a key relating these products to the 49 of Eurostat, the tables were computed and adjusted to match the national accounts on the economic model. To explain, the normalized conversion matrix 49×14 , $\mathbf{P}^*$, was calculated according to disaggregation method described in section 4.1. The vector $\mathbf{v}_t$ (year t) is the use of the 49 products by the "Electricity and gas" sector and it is used as a proxy to perform proportional allocation. Under these circumstances, the matrix $\mathbf{M}_t$ is obtained using the following expression:

$$\mathbf{M}_t = \mathbf{P}^* \mathbf{T} \operatorname{diag}(\mathbf{c}_t) \tag{4.3}$$

These process is similar to the one described earlier for employment and it is has numerous applications throughout the whole data manipulation required for this work. The **T** matrix contains the O&M share values presented in Table 4.12, while $\mathbf{c}_t$ is the absolute O&M values in year t (calculated from the costs gathered and installed capacities in Portugal). In order to have these resulting matrix, $\mathbf{M}_t$, matching with the economy values for the electricity sector, this matrix was adjusted. In addiction, the remaining portion of these costs were allocated to another sector "other". Then, these remaining costs in "other" were disaggregated using proportional allocation (considering energy output as proxy) to the technologies: natural gas distributed and electric grid. On the other hand, the "Manufacture of coke, refined petroleum products and nuclear fuels" ("Oil Refining" in short: see appendix A.4 for the classification list) use of products was identically distributed proportionally to the following technologies: oil refinery, coal refinery, biodiesel and petrochemical. To ensure that this distribution criteria is valid INE (2007) was consulted. To summarize, the final matrix, is a 49×18 in monetary units containing the use of products for each one of the 12 electricity generation technologies plus these 6 other technologies to close the energy sector.

The total expenditure by energy technologies on economic products, in constant prices of 2002, is shown in Figure 4.5.

These values do not include the use of energy products in monetary units (products number 10 and 22: see Table A.3 in the appendix section). The growth of the total use reaches the maximum value of 5193 M€$_{2002}$ in 2007. Since that year, these values get reduced revealing themselves as, perhaps, an indicator for the crisis period.

4.4.2 Use of carriers by activities

The economic activities also use energy carriers. Therefore, this information also has to be included so that the economy, energy and their interaction is described in the most accurate way possible. There were 2 different reliable sources where this information could be found, one from INE and the other from DGEG. The first only had 14 carriers for the 50 sectors required (49 activities plus households after aggregation) and DGEG data had the 42 carriers required but for 24 activities. Although the raw data

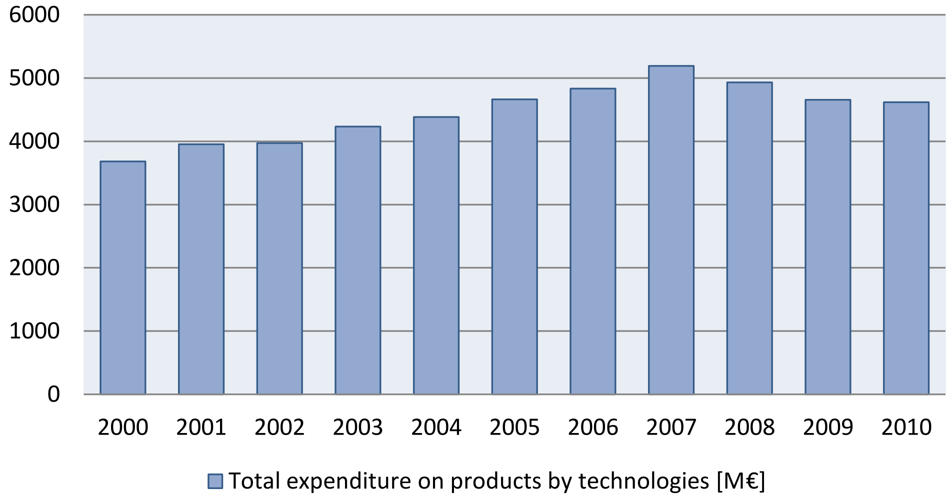

Figure 4.5: Use of economy products by technologies (except energy related) in M€$_{2002}$ by year.

seemed to be available, the need for manipulation (e.g. establishing aggregation and disaggregation keys with proportional allocation) was obvious. That is to say, maintain the dimensions required, i.e. 49 activities and 42 carriers. The DGEG source was compatible with the energy SUT used. Therefore, one of the restraints was the row sum (use of carriers) and the other restrain was column sum (total sector use of carriers).

Hence, an initial matrix, **Mi**, had to be transformed into another matrix, **Mn**, according to the desired row and column sum vectors, **un** and **vn** (Okuyama et al. 2002). This is the original RAS procedure or bi proportional technique. In the end, after evaluating the resulting matrix, it respected the constraints (although it is an iterative method and the the result is defined with a tolerance) but the original table obtained with proportional allocation (42×49) from DGEG was more reliable to use than this manipulated RAS one. Consequently the final matrix used was indeed the one obtained from DGEG after a proportional desegregation process (total use of carriers per sector as a proxy vector from INE data).

4.4.3 Breakdown of investment costs

Investment costs were estimated according to the procedure mentioned earlier on the present chapter (installed capacities times the costs in Table 4.3). However the absolute values are not enough. To put it differently, these costs have to be assessed to economy activities, i.e. cost breakdown per activity. This process can be divided in two steps: first, gather the data shares with the raw categories and secondly, manipulate them so that they match our economic sectors division. To find these data several technical reports from several institutions were consulted such as Krohn et al. (2012) for wind energy technology, IRENA (2012) and EIA (2010*b*) for hydro power plants. In addition, geothermal power plant investment information comes from document sources such as EIA (2010*a*) and Henneberger (2013). The remaining technologies breakdown is provided with some detail in NREL (2012). All of these gathered data (in an intermediary step of manipulation) is provided in Table 4.13.

In order to evaluate the investment for the 12 electricity technologies some shares were considered

Investment share allocation [%]	Biomass	Wind	Hydro	PV	Geothermal	Coal	Nat. Gas
Construction	0.26	0.13	0.40	0.07	0.79	0.61	0.58
Transport equipment	0.02	0.04	0.02	0.04	0.01	0.01	0.01
Other machinery and equipment	0.38	0.74	0.29	0.82	0.10	0.13	0.18
Cultivated assets	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Intangible fixed assets	0.15	0.04	0.07	0.02	0.11	0.08	0.06
Owners cost	0.19	0.05	0.23	0.05	0.00	0.17	0.17

Table 4.13: Most significant fractions of the investment costs breakdown structure per energy technology.

the same. To explain, biomass share was considered the same for biomass dedicated, biomass CHP, MSW and biogas; hydro power share was equally used for large and small power plants; and fuel oil has the same share as natural gas technology (literature assumption). Considering that **T** is the technology investment share matrix (fixed over time) created from sources described above while the vector **c** is the absolute values of investment for each technology in year t, the new investment matrix for the 12 electricity technologies is

$$\mathbf{M}_t = \mathbf{PT}\,\mathrm{diag}(\mathbf{c}_t) \tag{4.4}$$

The **P** matrix is used to aggregate 12 assets (NACE A10 plus transportation and owner's costs) into 6, and the matrix resulting from **PT** is displayed in Table 4.13. To summarize, the data was first manipulated to match the 10 sector NACE division, A10, and further aggregated according to the described process. Afterwards the resulting matrx was adjusted to match the values from the gross fixed capital formation Tables ("Electricity, gas, steam and hot watter supply" sector) provided by the Statistics Portugal, National Accounts (INE). In the end, the whole process is repeated for each year.

Although some categories are self explanatory it is preferred to briefly discuss them. To start with, construction activities have the most share for geothermal technology. The injection wells and systems for the pipelines and the construction of power plant itself justify this superior share of 79%. Transportation material was assumed to be 5% of the allocated shares for "Industry, energy, water supply and sewerage" in the A10 classification. The following sector, "other machinery and equipment", also contains specialized equipments such as boilers, turbines, steam engines, and so on. Hence, solar photovoltaics and wind energy have the two highest shares on this sector due to the turbines, basic metals and the high capital requirement for solar panels (the modules and the structure). Cultivated assets are not a significant portion of the capital investment, and therefore have no percentage share for each one of the technologies. In fact this asset is only applied to agriculture, forestry and fishing. The" intangible fixed assets" activity sector concern the financial and insurance activities, real estate activities, administrative and support service activities among others. However, owner's cost definition may differ in the literature. One of the possible definition states that these costs are related to the development, preliminary feasibility and engineering studies, environmental studies and permitting, legal fees, insurance, property taxes during construction, and the electrical interconnection (including transmission system) (EIA 2013). Despite that, this category of costs is not considered in the further analysis.

To summarize, it was explained how the total investment by technology, category and year were estimated. Now, the detailed process on data manipulation to estimate the maintenance and capacity power installation investment is presented. Recall the previous chapter where the investment costs are added in the model, 3.2.3. Technology x has one specific vector $\mathbf{K}_i^x$ containing the average proportions for each investment category i:

$$\mathbf{K}_i^x = \frac{\sum_{t=2000}^{2010} k_{it}}{\sum_{i=1}^{5} \sum_{t=2000}^{2010} k_{it}} \tag{4.5}$$

From each one of these vectors a proportions matrix (each column sum is 1) is obtained (technology as columns and categories of investment as row).

Thus, to estimate the investment related to the maintenance, the proportions matrix is applied to the consumption of fixed capital for each year. The resulting matrix is used as the endogenous block for investment in technologies. Afterwards, the total investment matrix is subtracted from the investment related to maintenance. The resulting matrix is assumed to be the investment expenditure by category and technology directly related to the installation of new capacity power. This is the exogenous investment considered discussed previously in the method description.

The installed power on renewable energies and on other power plants (mainly natural gas) is more significant on recent years. This fact is confirmed, as expected, in the historical evolution of both portions of the investments. The total investment expenditure related to maintenance and associated to the installed power is displayed in the Figure 4.6.

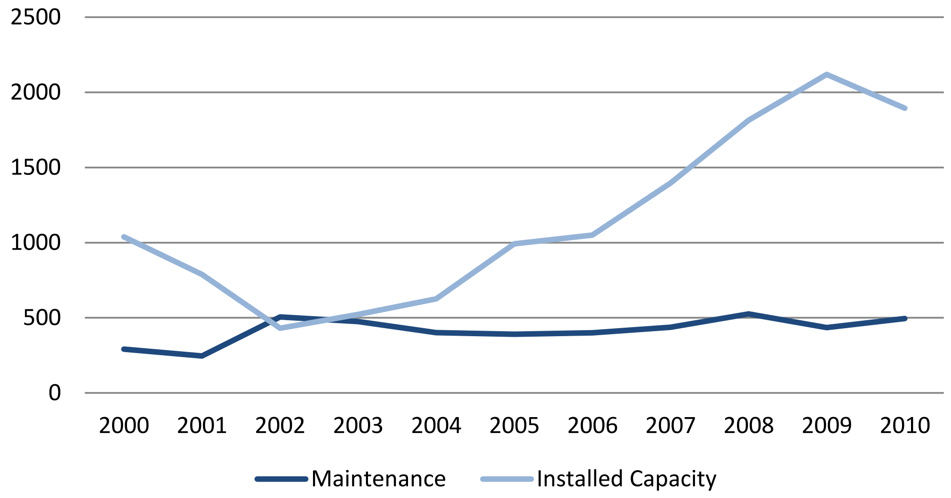

Figure 4.6: Total investment expenditure in the energy sector related to the maintenance and the installed capacity in M€$_{2002}$ by year.

The endogenous investment related to the maintenance is smaller and piratically constant over the years which is understandable. The investment in constructing new power plants, wind farms, hydro damns, etc as well as installing more capacity power is rather large, reaching its peak in 2009 with more than 2000 M€$_{2002}$ spent on the improvements of the energy sector.

Chapter 5

Results

5.1 Scenarios and structure

Portugal, as many other worldwide countries, has been facing numerous modifications in the energy sector over the years. In addition to the technologies mix development, subsidies to electricity producers and capital investment also contribute to the overall structure as seen in chapter 3 . These modifications are applied to what is understood as an integrated system of different axis interacting with each other E3.

Therefore, it is considered three different effects. First the effect related to the energy sector development year by year (technologies). Secondly, the effect resulting from the capital investment (towards capacity installation) in the energy sector. The third one is related to the subsidies and tariff deficit, i.e., what would happen if the subsidies paid to the electricity producers were supported consumers (no debt scenario where electricity costs are represented in its price). These three different effects combined provide an answer to the Portuguese energy policy applied during this 10 years time line.

The economic, social and environmental impacts are calculated recurring to alternative scenarios. These scenarios are built considering the different effects mentioned above. The first alternative scenario considers that the energy sector remained constant from the previous year until the year studied (same technology description). The second alternative scenario provides an alternative view to what would have happened if no capital investment in the energy sector would occur. Thirdly, the alternative scenario considers that no debt (tariff deficit) would occur once the subsidies are completely paid by consumers in the same year.

This chapter structure is organized to be followed with increasingly more detail, i.e., results keep getting more disaggregated. Hence, this chapter will start with general results and impacts of the Portuguese energy policy (effect combination) in section 5.2. After, within this subsection, the net impacts are presented for the energy sector and the rest of economy (ROE) considering different types of impacts. The final section 5.3 intends to disaggregate the results by type of effect, and within each subsection (each for effect), the results are displayed for every economic activity and each energy technology.

The economy model consists in 49 activities and products. Hence, to ensure an easily understandable display of results those activities were converted to a system of 10 (A10 classification). After the ”raw” results were obtained the aggregation process was applied and the results can be presented according to the description provided in the appendix section, Table A.5.The results for the energy sector are shown for 14 technologies. Besides the 12 electricity producing technologies (Table 4.2), there is oil refining as number 13 and the residual one is called as ”other”. This final category is an aggregation of the remaining 5 technologies (coal refining, natural gas distributed, electric grid, biodiesel and petrochemical - see A.1) due to their relevance assumed in this work.

5.2 Total impacts

In this section the total impacts are presented. First, the overall results are displayed for each type of impact. Afterwards, the total separated impacts disaggregated only by effect, i.e, operational, capital investment and subsidies/tariff deficit are shown. The Table 5.1 shows the observed absolute impacts in the reference scenario. The purpose of this table is to provide an insight about the Portuguese reality regarding both energy and economy between 2000 and 2010.

	GVA [M€$_{2002}$]		**Employment** $[10^3]$		**CO$_{2eq}$** [Mton]	
Year	Energy	ROE	Energy	ROE	Energy	ROE
2000	2383	65475	18	5559	22	54
2001	2504	114423	17	5620	22	53
2002	2606	115141	15	5658	26	54
2003	2807	114382	15	5631	21	53
2004	2884	116241	14	5623	23	54
2005	2759	117148	13	5619	26	54
2006	3018	118649	13	5622	23	52
2007	3117	126920	13	5692	21	50
2008	3423	127144	12	5707	20	49
2009	3002	144086	12	5561	20	44
2010	3456	147049	11	5464	15	44

Table 5.1: Reference scenario impacts for each year and impact type.

5.2.1 Overall

The most general and fundamental question that motivated this thesis work is related the evaluation of the impacts of Portuguese energy policy. Combining the considered effects, the results (in the most aggregated way possible) that provide an answer to this formulated question are presented in Table 5.2.

The economic impacts studied are related to the GVA which is proportional to the GDP and this is a key indicator of the country whole economy condition. From observing the table, the national energy policy generated economic output until 2009. Afterwards, these policies costed 278.02 M€$_{2002}$. However note that comparing to the absolute values in Table 5.1, these impacts represent less than 1%. The social impacts follow the same behavior, generating employment mainly due to investments associated

Year	**GVA**[M€$_{2002}$]	**Employment** [10^3]	**CO$_{2eq}$** [Mton]
2000	125.45	12.76	0.18
2001	579.04	26.06	-0.36
2002	81.80	2.37	1.85
2003	123.08	10.00	-2.76
2004	223.66	10.37	1.05
2005	395.77	19.31	0.77
2006	320.36	22.62	-1.63
2007	973.96	42.90	-1.26
2008	599.33	28.52	-0.07
2009	39.15	13.35	0.12
2010	-278.02	-0.82	-4.60

Table 5.2: Total impacts of the Portuguese energy policy.

with capacity installations (as it will be clarified in the following subsections). In 2010 the total result accounts for the loss of 820 jobs. Although in 2010 the impacts start to be negative for economy and employment, the environmental impacts show that the future seems to be ”greener’. In fact 6 out of 10 analyzed years show a cleaner environment, culminating in 4.60 Mton of GHG avoided emissions into the atmosphere.

The following subsections will disaggregate the Table 5.2 by effect for economic, social and environmental impacts.

5.2.2 Economic impacts

In Table 5.3 the net contribution of each effect regarding the economic impacts is shown. Note that in the operational analysis (model with O&M costs) there are no results for the year 2000. This is because naturally the alternative scenario requires data from the year preceding the year to be analyzed. Therefore, 1999 data for the energy sector would be necessary, and the timeline of this study ranges from 2000 to 2010, thus truncating the results for 2010 in this case.

	Operational		**Capital**		**Cost/Price dif.**	
Year	Energy	ROE	Energy	ROE	Energy	ROE
2000	-	-	10.7	400.9	-19.8	-266.3
2001	16.9	59.5	14.9	963.8	-20.3	-455.8
2002	25.9	1.8	8.3	549.6	-21.6	-482.2
2003	-64.9	67.0	9.6	564.0	-21.1	-431.5
2004	73.7	7.2	11.6	649.4	-24.0	-494.3
2005	59.9	51.9	15.1	902.1	-28.7	-604.6
2006	-56.7	31.5	16.0	877.1	-27.7	-519.9
2007	4.2	375.0	21.1	1176.7	-27.6	-575.4
2008	108.0	-128.1	27.2	1291.4	-34.1	-665.0
2009	72.8	-59.6	17.2	938.5	-30.9	-898.8
2010	20.0	-149.4	15.4	807.0	-35.9	-935.0

Table 5.3: Total economic impacts, GVA, by type of effect. Monetary units in M€$_{2002}$.

Observing the Table, operational results have positive or negative values depending on the energy sector technology mix development. On the other hand, capital investment impacts are, as expected, always positive, adding up the GVA. However, the fact that the subsidies payed to the electricity (and heat) producers are not fully supported by activities and households generate debt that have a negative impact on GVA.

5.2.3 Social impacts

In Table 5.4 the net contribution of each effect regarding the social impacts is shown. Just as the previous subsection, operational net impacts for 2000 are not available.

	Operational		**Capital**		**Cost/Price dif.**	
Year	Energy	ROE	Energy	ROE	Energy	ROE
2000	-	-	0.07	34.79	-0.12	-21.98
2001	-0.20	2.26	0.09	45.66	-0.14	-21.61
2002	-0.40	-0.11	0.04	25.83	-0.13	-22.87
2003	-0.43	2.43	0.05	28.35	-0.11	-20.28
2004	-0.85	1.87	0.05	32.31	-0.12	-22.89
2005	-1.51	2.57	0.06	46.12	-0.14	-27.80
2006	0.51	0.65	0.06	45.41	-0.12	-23.88
2007	-1.42	14.44	0.08	54.63	-0.11	-24.72
2008	-0.60	-4.87	0.09	60.73	-0.12	-26.70
2009	0.66	-1.50	0.06	42.60	-0.12	-28.35
2010	-2.11	-6.05	0.05	36.04	-0.12	-28.63

Table 5.4: Total employment impacts (10^3 jobs) by type of effect

The positive or negative contributions is maintained by the same type of effects. In other words, capital investment towards capacity installation tends to generate more jobs in the ROE activities (which is comprehensive, e.g., construction, manufacture, etc). In addition, the impacts captured by the electricity cost/price difference effects are negative. As a result there is job destruction, growing year by year representing the higher difference in what is received by the producers (subsidies) and what is really paid by the consumers.

5.2.4 Environment impacts

In Table 5.5 the net contribution of each effect regarding the environmental impacts is shown.

For CO_{2eq} emissions, the behavior of these effects is similar as in the previous impacts discussed. For example, the operational effect shows that the energy sector has developed towards a cleaner sector and from 2008 further the reductions are even visible on the ROE. Capital investment obviously contributes to additional emissions while subsidies/tariff deficit avoids emissions (much smaller contribution).

Note that the row sum (for each year) for economic, social and environmental impacts in Tables 5.3, 5.4 and 5.5 respectively produce the total impacts in Table 5.2.

	Operational		**Capital**		**Cost/Price dif.**	
Year	Energy	ROE	Energy	ROE	Energy	ROE
2000	-	-	0.08	0.35	-0.18	-0.08
2001	-0.73	0.05	0.11	0.48	-0.18	-0.09
2002	1.81	0.01	0.07	0.26	-0.21	-0.10
2003	-2.87	0.01	0.06	0.30	-0.16	-0.09
2004	0.89	0.03	0.08	0.35	-0.19	-0.11
2005	0.48	0.00	0.12	0.52	-0.27	-0.09
2006	-1.94	0.02	0.10	0.48	-0.22	-0.07
2007	-1.84	0.18	0.12	0.54	-0.18	-0.07
2008	-0.47	-0.04	0.14	0.57	-0.20	-0.07
2009	-0.01	-0.03	0.10	0.37	-0.21	-0.10
2010	-4.69	-0.05	0.06	0.33	-0.16	-0.09

Table 5.5: Total environmental impacts. Emissions of CO_{2eq} in Mton by type of effect.

5.3 Effect disaggregation

The level of detail continues to increase while the disaggregation level follows. The following subsections display the impacts for each technology in the energy sector and each activity considered. Besides that, these results are divided by type of effect allowing the displaying of results with much more detail.

5.3.1 Operational

Economic impacts

The differences between reference and alternative scenarios in the energy sector are presented in Table 5.6 using constant prices of 2002, M€$_{2002}$. Once the operational effects are hereby addressed the 2000 year is not available for the reasons presented in section 5.2.

	Technologies	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
1	Dedicated Biomass	0.0	3.2	0.7	1.2	0.3	0.9	6.3	0.4	11.8	22.4
2	Biomass CC	-0.4	-1.5	7.1	-1.9	-3.3	6.1	2.9	-2.3	4.6	13.0
3	MSW	-1.2	0.4	0.4	-0.5	2.1	-0.2	-0.2	0.0	0.3	-0.5
4	Biogas	0.0	0.0	0.0	0.2	1.8	-5.8	16.1	12.5	2.6	6.7
5	Wind	1.9	1.5	2.2	5.7	13.9	19.0	20.3	35.5	29.2	22.0
6	Small hydro	1.3	-1.6	3.1	-6.0	-3.6	7.8	-5.8	0.2	3.2	5.3
7	Large Hydro	40.6	-115.4	139.8	-106.9	-86.5	101.0	-13.6	-55.7	23.6	119.7
8	PV	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.3	2.1	1.0
9	Geothermal	0.0	0.0	0.0	0.0	1.2	0.2	2.1	-0.1	-0.2	0.1
10	Oil	9.9	30.7	-139.2	0.0	15.7	-97.7	-17.6	-32.1	-28.9	-14.6
11	Coal	-19.0	18.3	-29.3	6.4	-4.7	-16.8	-43.2	-9.8	13.4	-102.4
12	Natural Gas	-6.0	32.7	3.1	55.8	47.5	1.2	18.9	58.8	-21.8	-24.0
13	Oil Refining	-1.6	0.0	-0.4	0.5	-0.7	0.1	-0.3	-7.3	-3.1	8.4
14	Other	-8.6	57.4	-52.5	119.3	76.3	-72.6	17.9	107.7	36.1	-37.5
	Net	18.5	23.8	-73.1	74.7	59.1	-57.7	-20.9	97.4	53.5	-21.9

Table 5.6: Disaggregated net impacts for the technologies regarding the GVA in M€$_{2002}$.

Note that the negative values, just as the analysis processed before, indicate loss while positive numbers indicate positive contribution (economic growth). Considering this, it is expected that technologies that had a significant growth in these years have positive values (e.g. wind energy, photovoltaics, biomass dedicated and even natural gas). As explained previously in 3.1.2, the alternative scenario uses the energy technology coefficients matrix of the previous year, thus indicating what would have happened if the energy sector characterization remained the same.

The consequently less importance of the fossil fuel plants (such as oil and coal) is also notorious when observing the overall structure of these results. The net results displayed in table 5.6 provide an interesting proof that the diversification of technologies may not always end up in economic growth of the energy sector. As an example, see 2008, 2009 and 2010. In 2008 and 2009 the positive net value indicates that the transition 2007-2008 and 2008-2009 was positive in economic terms and it enabled 97.4 and 53.5 M€$_{2002}$ more of GVA. However, in 2010, the positive value states that the transition 2009-2010 revealed to be a potential loss of 21.9 M€$_{2002}$ worth of value added in the energy sector. This is justified due to the different importance of the technologies. If in one year the use of coal technologies decrease to allow the production of energy from wind, biomass or hydro, the total value added may reflect this exact importance of conventional energy sources.

The same type of results are also obtained for the rest of the activities in the economy and they are shown in Table 5.7. The list with the description of these 10 activities can be revisited in the appendix section, A.5.

	Activities	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
1	Agriculture	0.2	-0.2	0.4	0.2	0.2	0.0	0.5	-0.7	0.0	-0.9
2	Industry	20.3	-1.0	4.9	-21.1	-1.8	-2.9	80.9	-26.0	-17.3	-32.5
3	Construction	2.7	-0.6	4.4	1.8	-0.6	0.1	57.3	-12.9	-12.7	-28.3
4	Trade	17.7	3.3	10.3	17.1	14.9	12.8	102.7	-10.8	-8.8	-29.6
5	Communication	0.5	0.2	2.5	0.0	0.6	0.6	13.8	-1.1	1.0	-3.4
6	Financial	8.0	5.9	17.5	3.7	2.4	20.9	58.0	-34.4	-28.9	-17.4
7	Real Estate	2.3	-0.4	2.4	-0.5	0.4	0.6	8.5	-2.7	-3.3	-9.9
8	Services	6.4	-4.0	18.9	4.4	28.8	-0.7	46.3	-33.1	9.2	-30.1
9	Government	1.0	-1.3	4.8	1.3	5.7	0.0	3.8	-5.6	0.9	4.0
10	Arts	0.3	-0.1	0.9	0.3	1.2	0.0	3.1	-1.0	0.3	-1.4
	Net	59.5	1.8	67.0	7.2	51.9	31.5	375.0	-128.1	-59.6	-149.4

Table 5.7: Disaggregated net impacts for activities regarding the GVA in M€$_{2002}$.

The activities in which the impacts are more frequently notorious are: industry (2), construction (3), transportation (4) and professional and technical activities (8). Financial and insurance activities (6) also become significantly more important in the recent years which is expected due to the many new energy related projects planned.

The net values (total year sum) can be analyzed identically to the energy results. Until 2007, every yearly transition in the energy sector revealed to be advantageous against the counter scenario in which these modifications have not occurred. However, from 2008 until 2010, the total value added in the economy seems to be higher in the scenario which the energy sector had stayed the same. This effect could be related to the growth of renewable technologies.

Social impacts

The following results are related to the social impacts, i.e. employment creation or destruction. These impacts are displayed for each energy technology in number of jobs in Table 5.8.

	Technologies	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Dedicated Biomass	0	35	8	12	2	10	54	3	125	198
2	Biomass CC	-21	-69	239	-63	-107	144	67	-45	79	262
3	MSW	-15	4	5	-5	19	-29	-27	0	20	-29
4	Biogas	0	0	0	9	17	-3	14	14	4	13
5	Wind	10	8	14	39	85	112	111	162	130	99
6	Small hydro	85	-97	152	-448	-385	368	-456	17	175	255
7	Large Hydro	264	-1145	717	-846	-1270	651	-97	-516	186	538
8	PV	0	0	0	0	1	0	4	7	19	11
9	Geothermal	0	0	0	0	6	1	6	0	-1	0
10	Oil	63	183	-663	0	83	-361	-69	-127	-116	-56
11	Coal	-624	507	-900	174	-113	-404	-1105	-219	324	-3402
12	Natural Gas	-35	173	13	245	199	4	68	199	-81	-91
13	Oil Refining	90	1	-18	26	-45	7	-8	-91	-225	78
14	Other	-13	-2	1	2	0	10	16	-8	17	16
	Net	-197	-399	-432	-855	-1509	510	-1420	-605	657	-2108

Table 5.8: Disaggregated employment net impacts (number of jobs) for the technologies.

When considering the positive or negative signs, the interpretation remains similar as in the previous cases. Positive numbers indicate job creation while negative terms reveal a certain number of jobs destroyed. The growth of wind power in the electricity producers mix is quite visible in the direct employment creation. As an example, the energy sector development from 2000 to 2001 created 10 direct jobs in wind power. Eventually, in 2009, these growth represented 130 more jobs. This is a clear indicator that from year to year renewables such as wind have been growing in our energy mix (while 2008 had 2862 MW installed, in 2009 it grew up to 3535 MW).

For example, natural gas to produce electricity and/or heat from combined cycles grew with the construction of Ribatejo, Lares and Pego II power plants in 2005, 2009 and 2010 (Table 4.4), respectively. These facilities contributed to the creation of jobs in natural gas, among other not mentioned smaller plants. The energy development from 2004 to 2005 allowed 199 more jobs in this technology. In fact, natural gas is an exception to the fossil fuel technologies production mix decrease over the years. See for example coal, due to job creation in other technologies (mainly renewable) the job destruction is clearly identified. To illustrate, consider 2010 and the 3402 jobs lost in coal thermoelectric plants. This high number of job destruction in coal in 2010 contributed largely to the total net value of job destruction in that same year (destruction of fossil fuel plants jobs).

All things considered, the net values are always negative (except 2006 and 2009) meaning that the insertion and growth of new technologies would cost more jobs relatively to conventional technologies. The 2006 exception occurred because the growth in employment of hydro power, either large and small was big enough to compensate the coal and oil employment destruction. The significant growth of photovoltaics occurs in the transition 2008 to 2009 (120 MW installed). This difference is also observed when observing that 19 direct jobs are thus created in photovoltaics. In the same transition, biomass dedicated and biogas also had their highest impact on job creation due to their real development. Despite the trend of hydro power, small and large plants, is to become more and more significant over time, when assessing employment the results seem to change yearly. This is a result of the several dams that were decommissioned and others that were upgraded. These oscillations obviously have their impact on employment as it can be seen in Table 5.8.

One interesting aspect about the creation and destruction of employment in the energy sector is that there are also repercussions in the Rest of the Economy (ROE) activities. The impacts on employment, that result from the described energy changes as an alternative scenario, are shown in Table 5.9.

	Activities	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
1	Agriculture	20	0	70	30	60	0	150	-90	20	-90
2	Industry	840	-50	180	670	-80	-130	2940	-960	-670	-1120
3	Construction	170	-40	320	130	-40	0	3630	-830	-840	-1920
4	Trade	720	160	410	660	630	550	4020	-370	-340	-1100
5	Communication	10	10	60	0	20	20	320	-30	30	-80
6	Financial	80	80	120	90	50	250	830	-440	-290	-120
7	Real Estate	10	0	10	-10	0	0	40	-10	0	-10
8	Services	360	-230	1050	250	1680	-50	1910	-1900	550	-1580
9	Government	30	-50	160	40	180	10	110	-190	30	110
10	Arts	20	10	50	10	70	0	490	-50	10	-140
	Net	2260	-110	2430	1870	2570	650	14440	-4870	-1500	-6050

Table 5.9: Comparison between reference and alternative scenarios for employment in activities due to operational effects. See A.5 for activities description.

Due to the energy sector, the activities in which the social impacts are higher are the industry (2), construction (3), wholesale, retail, transportation and accommodation and food services (4) and professional and scientific technical activities (8). One thing that is important to mention is that it is normal that in the year $t + 1$ the total energy production is higher than in the year t. Energy requirements such as the electricity production grew from about 44 TWh in 2000 to 54 TWh in 2010. Therefore the total output from one year to the other also influences the results on the several impacts. The energy demand gets higher, but the mix also becomes diversified. This diversification of technologies is what is studied when observing these results. The net jobs values are higher in absolute terms and they keep growing in this time period, which might reveal the increasing significance of the energy sector in the full economy.

Environment impacts

The second type of impacts studied are related to the environment. The GHG emissions policies have became continuously more demanding concerning their requirements. Table 5.10 shows the differences, in Kton of CO_{2eq} (accounts for carbon dioxide, methane and nitrous oxide), between the reference and the alternative scenarios.

The total directs emissions presented as "Net" in Table 5.10 reveals the Portuguese reality towards a greener future. Note that, if the demand requirements are higher, naturally the electricity production has to meet those demands. Therefore, more emissions would occur in the conversion process. As

	Technologies	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Dedicated Biomass	0.0	38.9	6.7	10.3	2.8	9.6	60.5	3.3	123.8	197.6
2	Biomass CC	-20.4	-82.5	249.4	-81.1	-194.9	252.0	112.8	-93.1	207.2	409.8
3	MSW	-12.1	4.3	3.7	-4.0	20.0	-31.5	-25.1	-0.1	18.0	-21.2
4	Biogas	-0.1	0.2	0.2	4.3	11.1	-1.9	8.3	7.7	1.8	4.9
5	Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	Small hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	Large Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	PV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	Oil	149.6	526.0	-1778.7	-0.5	281.8	-1391.6	-237.6	-428.3	-436.0	-177.7
11	Coal	-886.7	883.2	-1355.4	291.3	-243.0	-814.0	-1984.9	-412.8	645.3	-5040.0
12	Natural Gas	-71.6	443.3	31.7	624.7	673.0	13.7	201.1	616.8	-259.6	-230.9
13	Oil Refining	126.1	2.2	-26.8	43.1	-67.5	10.2	-12.5	-152.2	-344.3	135.1
14	Other	-18.4	-3.0	0.8	2.5	-0.5	14.9	26.9	-13.3	26.5	27.8
	Net	-734	1813	-2868	891	483	-1939	-1851	-472	-17	-4695

Table 5.10: Comparison between reference and alternative scenarios for direct CO_{2eq} emissions (Kton) due to operational effects.

already mentioned before, in 2010, the demands were about more 10 TWh than in 2000. Despite that, since 2006 the results show that the emissions have been reduced. For instance, in 2006, the energy sector development avoided 1.9 Mton of CO_{2eq} of direct emissions. The same interpretation is valid for the following years.

The extra emissions would not only have represented environment contamination/pollution but would also express themselves as potential taxes around 29 M€$_{2002}$ in 2006, 1.6 in 2007, 7.1, 0.2 and 54.6 M€$_{2002}$ in the following years (carbon prices from Table 4.6). These costs could have been smaller in reality because of the emission caps for each power plant. However, these expenditures were estimated considering that each avoided ton would be priced as settled in the EU ETS scheme.

In the following Table, 5.11, the activities CO_{2eq} emissions impacts is displayed in tonnes.

	Activities	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Agriculture	376	23	898	399	860	57	2216	-1423	294	-1259
2	Industry	28070	5221	19	20290	-4372	-733	66344	-16726	-21389	-35546
3	Construction	935	-200	1655	665	-202	18	12376	-2528	-2722	-6554
4	Trade	17232	3423	2259	7127	3027	17031	91948	-13011	-9859	-8203
5	Communication	24	6	94	-1	22	21	588	-42	39	-120
6	Financial	56	41	109	161	95	164	887	-521	-337	-108
7	Real Estate	15	-2	13	-3	2	3	50	-13	-5	-15
8	Services	326	-167	947	233	1464	-21	2594	-1511	392	-1316
9	Government	95	-41	317	88	431	-5	521	-364	54	300
10	Arts	20	-6	52	15	70	2	260	-65	19	-101
	Net	47150	8299	6361	28975	1398	16537	177784	-36203	-33513	-52921

Table 5.11: Comparison between reference and alternative scenarios for indirect CO_{2eq} emissions (ton) due to operational effects

Most of the entries in Table 5.11 are positive, which turn up to be indicators of the indirect emissions resulting from the technological growth year by year. Activities related to industry, trade (which includes transportation) and construction are the most influenced by energy development.

The energy sector became indisputably cleaner from 2008 further, and the reductions are clearly observed in Table 5.10. It is important to note, however, that the differences in the energy sector are higher (kton) and considering both direct and indirect impacts, Portugal became clearly a successful country towards GHG emission reduction (just as it was stated in 5.2).

5.3.2 Capital investment

Economic impacts

The effect to be addressed and presented with more detail in this subsection is the capital investment. These effects are related to the investment towards capacity installation (e.g. wind farms, power plants and other facilities). Therefore, if no investment had occurred, there would be associated impacts. The order of results display remains the same as in the previous case, thus hereby presenting the economic impacts. In Table 5.12 the impacts disaggregated by technology are presented, consistently in M€$_{2002}$.

	Technologies	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Dedicated Biomass	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2
2	Biomass CC	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.2
3	MSW	0.0	0.2	0.1	0.1	0.2	0.2	0.0	0.0	0.0	0.0	0.0
4	Biogas	0.1	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.3	0.2	0.2
5	Wind	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.9	0.7	0.7
6	Small hydro	0.1	0.1	0.0	0.1	0.0	0.0	0.1	0.1	0.1	0.1	0.1
7	Large Hydro	0.8	1.3	0.4	0.9	0.7	0.4	0.9	1.1	1.0	0.8	1.2
8	PV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	Oil	1.2	1.6	0.9	0.7	0.8	1.2	0.8	1.0	1.0	0.5	0.4
11	Coal	0.9	1.1	0.6	0.7	0.8	1.0	1.1	1.1	1.3	0.9	0.3
12	Natural Gas	1.0	1.2	0.7	0.9	1.2	1.8	1.9	2.6	3.6	2.2	1.8
13	Oil Refining	-0.1	-0.2	0.1	0.1	0.1	0.2	0.2	0.4	0.9	0.1	0.7
14	Other	6.6	9.4	5.2	6.0	7.6	10.1	10.5	13.8	17.6	11.3	9.5
	Net	10.7	14.9	8.3	9.6	11.6	15.1	16.1	21.1	27.2	17.2	15.4

Table 5.12: Disaggregated economic impacts per technology due to capital investment effects. GVA in M€$_{2002}$.

The effect of capital investment in the energy sector contributes to additional economic output, in this case GVA is presented. It is relevant to see the significant growth in wind and other technologies, although geothermal and PV show no variation. Natural gas reaches its maximum value in 2008 which is understandable to the investment in new CCGT plants. In the ”other” technology this higher value is due mostly to the electric grid and the natural distribution grid.

In Table 5.13 the impacts disaggregated by activities are presented, same monetary units, M€$_{2002}$.

The effect of investment is the one related to the installation of new power capacity. From the above table, it can be seen that the impacts are higher, naturally, in the construction related activities. Industry and trade also show a relatively high economic impact due to investment effects. The net behavior of these impacts follows the investment expenditure, however note that although the maximum investment occurred in 2009 (see figure 4.6) the highest impact economic impact is seen the year before, in 2008.

	Activities	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Agriculture	0.7	8.0	4.4	4.5	5.1	7.3	7.5	8.2	9.4	7.7	6.1
2	Industry	87.0	184.6	98.7	103.8	120.6	173.8	177.0	244.3	324.1	239.1	207.7
3	Construction	159.2	355.3	184.7	210.4	238.3	361.6	354.6	488.6	489.3	308.1	270.7
4	Trade	72.3	159.6	87.0	85.5	102.2	137.4	138.9	192.3	253.2	199.8	169.5
5	Communication	12.1	26.5	22.7	19.8	24.6	25.9	22.4	18.9	11.9	8.3	6.7
6	Financial	15.3	47.4	31.2	33.1	38.3	50.5	50.3	64.4	63.4	44.3	41.3
7	Real Estate	2.5	81.1	57.0	45.9	51.1	56.7	44.8	69.6	49.0	65.0	48.8
8	Services	27.1	63.4	41.0	38.8	44.5	57.1	51.6	61.9	63.3	48.4	40.2
9	Government	18.4	26.7	15.0	15.2	16.2	22.9	22.4	21.2	21.6	13.7	12.8
10	Arts	6.3	11.2	7.9	6.9	8.5	9.0	7.7	7.3	6.2	4.2	3.4
	Net	400.9	963.8	549.7	564.0	649.4	902.1	877.1	1176.7	1291.4	938.5	807.0

Table 5.13: Disaggregated economic impacts per activity due to capital investment effects. GVA in M€$_{2002}$.

Social impacts

The impact on job creation or destruction is once again addressed, but now in response to capital investment. In Table 5.14 the number of jobs created on the disaggregated technologies is shown.

	Technologies	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Dedicated Biomass	0	0	0	0	0	0	0	1	1	1	2
2	Biomass CC	4	4	2	2	3	3	3	4	4	2	4
3	MSW	2	3	1	1	2	2	2	2	3	2	2
4	Biogas	0	0	0	0	0	0	0	0	0	0	0
5	Wind	0	0	0	0	0	1	2	3	4	3	3
6	Small hydro	4	5	2	3	3	3	4	5	6	4	4
7	Large Hydro	7	9	4	5	5	6	6	8	10	6	5
8	PV	0	0	0	0	0	0	0	0	0	0	0
9	Geothermal	0	0	0	0	0	0	0	0	0	0	0
10	Oil	7	10	6	3	3	6	3	4	4	2	1
11	Coal	33	37	18	21	23	25	25	28	30	23	11
12	Natural Gas	6	7	4	4	5	7	7	9	12	8	7
13	Oil Refining	9	12	6	6	7	11	9	11	12	9	6
14	Other	1	0	0	0	0	0	0	0	0	0	0
	Net	72	87	43	45	52	64	60	75	85	62	46

Table 5.14: Disaggregated social impacts (number of jobs) per technology due to capital investment effects.

The energy sector comparing to the ROE has a small fraction of employment. The investments only represent effects of a couple dozens of direct jobs. Note that although most of the investment is directed toward technologies other than fossil fuels, the job rate in those are higher, therefore the impacts on jobs in technologies such as coal for are higher.

In Table 5.15 the number of jobs created on the disaggregated activities due to investment in the energy sector is shown.

Recall the E3 interaction and more precisely, keep in mind the energy-economy. Building a new power plant, or even other non-energy project requires activities or other services. Investing to increase the installed capacity power by building new plants, or even upgrade existing ones create jobs. This table shows exactly this effect, the job creation in ROE (one may call them indirect jobs). Construction related activities clearly reveal the highest impacts towards employment.

	Activities	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Agriculture	0.55	0.71	0.39	0.41	0.45	0.61	0.58	0.71	0.82	0.63	0.43
2	Industry	6.15	7.94	4.20	4.42	5.02	7.15	7.07	9.15	12.08	9.22	7.22
3	Construction	17.04	23.06	12.86	15.39	17.27	25.94	25.74	30.96	31.69	20.52	18.32
4	Trade	5.55	7.29	3.95	4.01	4.76	6.48	6.63	7.73	10.27	7.95	6.53
5	Communication	0.55	0.65	0.57	0.51	0.64	0.68	0.58	0.44	0.29	0.21	0.18
6	Financial	0.62	0.77	0.46	0.44	0.49	0.63	0.61	0.70	0.65	0.47	0.39
7	Real Estate	0.34	0.37	0.25	0.20	0.22	0.25	0.20	0.32	0.23	0.10	0.07
8	Services	2.81	3.46	2.28	2.16	2.51	3.16	2.85	3.33	3.38	2.63	2.12
9	Government	0.74	0.91	0.52	0.50	0.56	0.78	0.77	0.77	0.79	0.51	0.48
10	Arts	0.44	0.50	0.35	0.31	0.39	0.44	0.38	0.52	0.53	0.36	0.30
	Net	34.79	45.66	25.83	28.35	32.31	46.12	45.41	54.63	60.73	42.60	36.04

Table 5.15: Disaggregated social impacts (10^3 jobs) per activity due to capital investment effects.

Environment impacts

The environmental impacts are now considered when associated with capital investment effects. In Table 5.16 these impacts, CO_{2eq} emissions, are presented disaggregated for the technologies.

	Technology	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Dedicated Biomass	0.00	0.00	0.11	0.12	0.18	0.27	0.35	0.81	0.98	1.45	1.89
2	Biomass CC	3.23	4.34	2.69	2.54	3.49	5.36	4.98	6.72	7.85	6.46	5.54
3	MSW	1.60	2.08	1.13	1.21	1.32	1.94	1.98	2.22	2.45	1.76	1.16
4	Biogas	0.00	0.00	0.00	0.00	0.02	0.06	0.06	0.12	0.19	0.15	0.12
5	Wind	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	Small hydro	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	Large Hydro	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	PV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	Geothermal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	Oil	16.71	23.97	16.08	8.86	11.95	20.76	11.56	13.01	13.14	7.46	4.56
11	Coal	41.67	52.26	31.29	31.37	37.94	53.52	51.04	50.67	56.24	45.49	16.82
12	Natural Gas	10.67	14.54	10.08	8.65	13.68	25.35	21.45	27.64	37.88	26.35	17.59
13	Oil Refining	10.40	16.74	9.25	9.58	11.80	15.94	13.36	17.31	19.77	13.90	11.14
14	Other	0.65	0.23	0.01	0.01	0.03	0.03	0.09	0.27	0.25	0.32	0.34
	Net	84.94	114.15	70.64	62.34	80.40	123.25	104.88	118.77	138.75	103.32	59.15

Table 5.16: Disaggregated environmental impacts (CO_{2eq} in Kton) per technology due to capital investment effects.

The results displayed follow a structure that it is obviously expected. The technologies with higher emission factors show the most differences. However, biomass technologies do have an higher emission factor of methane and nitrous oxide, therefore the equivalent carbon emissions are also significant (although much less than conventional energy sources).

Building a new wind farm, or a new power plant requires activities that generate their own emissions. Therefore, even though wind energy does not contribute directly to the carbon emissions, the related activities do. This is true for every power plant, every project (energy related or not). In this case, the energy sector developed quite fast in Portugal, and during this time period. The positive entries in the tables exposes this fact. Just as in the previous employment analysis, construction is one of the activities with highest impacts on environmental concerns. However, the emission factor of industry related activities (e.g. manufacturing) is considerably higher making it the activity with highest impacts over the years, between approximately 60% to 70% of net impacts.

	Activities	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Agriculture	7.39	8.98	5.27	5.06	5.59	7.60	7.30	9.58	10.94	8.17	6.07
2	Industry	224.91	297.14	163.07	178.98	210.14	325.24	310.89	380.62	408.26	255.21	234.84
3	Construction	81.30	124.13	66.40	79.37	90.55	133.52	117.23	105.51	96.10	66.15	62.64
4	Trade	34.85	45.66	25.25	27.77	33.75	47.01	42.32	41.08	48.83	34.12	24.00
5	Communication	0.93	1.27	0.79	0.76	0.89	0.94	0.74	0.80	0.48	0.32	0.24
6	Financial	0.24	0.32	0.21	0.22	0.35	0.47	0.49	0.65	0.67	0.48	0.42
7	Real Estate	0.42	0.55	0.32	0.26	0.26	0.31	0.24	0.41	0.24	0.10	0.07
8	Services	2.57	3.43	1.95	2.09	2.39	3.04	2.50	3.00	2.94	2.26	1.75
9	Government	1.81	2.21	1.17	1.11	1.17	1.67	1.53	1.51	1.38	0.86	0.76
10	Arts	0.50	0.62	0.41	0.38	0.46	0.49	0.40	0.53	0.45	0.33	0.25
	Net	354.92	484.30	264.85	296.01	345.56	520.27	483.64	543.69	570.28	368.02	331.05

Table 5.17: Disaggregated environmental impacts (CO_{2eq} in Kton) per activity due to capital investment effects.

5.3.3 Electricity cost/price difference

Economic impacts

The effect to be addressed and presented with more detail in this subsection is the subsidies paid to the electricity producers and the tariff deficit. In this effect the alternative scenario considers that all there would be no tariff deficit, meaning that the consumers would be paying the real price of electricity (the subsidies would be fully supported by consumers). The disaggregated economic impacts per technology and activity is provided in Tables 5.18 and 5.19, respectively.

	Technologies	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Dedicated Biomass	0.00	0.00	-0.03	-0.03	-0.04	-0.05	-0.06	-0.12	-0.14	-0.25	-0.51
2	Biomass CC	-0.19	-0.18	-0.17	-0.22	-0.23	-0.24	-0.29	-0.31	-0.34	-0.35	-0.54
3	MSW	0.00	-0.30	-0.31	-0.31	-0.34	-0.42	-0.02	-0.03	-0.05	-0.05	-0.07
4	Biogas	-0.31	0.00	0.00	0.00	0.00	-0.02	-0.38	-0.36	-0.41	-0.41	-0.41
5	Wind	-0.04	-0.05	-0.07	-0.08	-0.14	-0.31	-0.48	-0.66	-1.11	-1.34	-1.68
6	Small hydro	-0.11	-0.12	-0.10	-0.13	-0.09	-0.07	-0.14	-0.09	-0.10	-0.13	-0.19
7	Large Hydro	-1.68	-2.03	-1.11	-2.15	-1.48	-0.82	-1.73	-1.62	-1.31	-1.47	-2.83
8	PV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	-0.03	-0.04
9	Geothermal	0.00	0.00	0.00	0.00	0.00	-0.01	-0.01	-0.03	-0.04	-0.03	-0.04
10	Oil	-2.66	-2.70	-2.98	-1.93	-2.13	-2.67	-1.73	-1.57	-1.50	-1.06	-1.05
11	Coal	-1.83	-1.70	-1.88	-1.65	-1.87	-2.12	-1.93	-1.56	-1.69	-1.73	-0.80
12	Natural Gas	-2.15	-2.07	-2.36	-2.38	-3.10	-4.14	-4.07	-4.22	-5.48	-4.73	-5.12
13	Oil Refining	0.28	0.31	-0.36	-0.32	-0.30	-0.36	-0.41	-0.61	-1.62	-0.29	-2.04
14	Other	-11.15	-11.45	-12.26	-11.88	-14.28	-17.49	-16.34	-16.43	-20.30	-19.05	-20.63
	Net	-19.83	-20.29	-21.64	-21.09	-24.01	-28.72	-27.59	-27.59	-34.08	-30.90	-35.94

Table 5.18: Disaggregated economic impacts per technology due to electricity cost/price difference alternative scenario effects. GVA in M€$_{2002}$.

The same proportions between energy and rest of the economy is maintained. In other words, the impacts on the energy sector are significantly smaller than the ones in the activities. In the energy sector, the electric grid and natural gas distribution grid (a part of ”other”) have the highest economic impact due to these Cost/Price dif. scenario. The natural gas technology receives both subsidies from SR and OR (PPA) depending whether it is co-generation (CHP) or thermoelectric.

The activities where the impacts are more notorious are trade related, real estate and government. The total net impacts on the ROE activities tends to increase. This fact can be explained, due to the increasing difference between electricity costs and the price to the consumers (increasing of the tariff

	Activities	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Agriculture	-2.8	-14.2	-14.8	-12.7	-14.7	-15.4	-15.5	-13.2	-16.4	-18.5	-19.4
2	Industry	-20.1	-28.6	-30.8	-28.8	-32.1	-24.7	-18.4	-30.4	-29.8	-34.5	-41.7
3	Construction	-42.3	-65.9	-64.5	-53.0	-58.9	-72.1	-60.0	-70.0	-49.0	-43.9	-41.9
4	Trade	-49.9	-81.6	-91.1	-79.2	-96.2	-120.7	-102.1	-138.6	-118.4	-124.5	-133.3
5	Communication	-2.5	-4.3	-5.0	-4.5	-5.3	-6.8	-6.2	-7.3	-14.3	-15.4	-16.0
6	Financial	-18.0	-41.4	-45.3	-44.5	-51.3	-65.8	-62.6	-67.1	-86.3	-91.6	-101.6
7	Real Estate	-1.9	-53.0	-53.4	-48.3	-52.7	-67.4	-58.3	-62.3	-72.2	-277.6	-281.3
8	Services	-16.1	-32.4	-33.8	-30.4	-35.3	-45.6	-39.1	-39.2	-79.5	-81.7	-84.6
9	Government	-100.9	-119	-127.0	-114.5	-130.1	-164.2	-139.1	-130.0	-176.8	-187.2	-192.5
10	Arts	-11.7	-15.5	-16.6	-15.5	-17.7	-21.9	-18.6	-17.3	-22.5	-23.9	-22.8
	Net	-266.3	-455.8	-482.2	-431.5	-494.3	-604.6	-519.9	-575.4	-665.0	-898.8	-935.0

Table 5.19: Disaggregated economic impacts per activity due to electricity cost/price difference alternative scenario effects. GVA in M€$_{2002}$.

deficit).

Social impacts

The social impacts that arise from the subsidies/tariff deficit are now addressed. In Tables 5.20 and 5.21 the jobs destruction disaggregated by technology and activity in the economy is presented, respectively.

	Technologies	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Dedicated Biomass	0	0	0	0	0	0	-1	-1	-1	-3	-4
2	Biomass CC	-11	-8	-8	-11	-8	-8	-7	-7	-7	-6	-11
3	MSW	-1	-4	-3	-1	-4	-4	-3	-3	-3	-3	-4
4	Biogas	2	0	0	2	0	0	0	0	0	-1	-1
5	Wind	4	0	0	4	-1	-2	-3	-4	-5	-6	-8
6	Small hydro	-4	-7	-6	-4	-7	-7	-6	-7	-7	-7	-9
7	Large Hydro	-10	-13	-11	-10	-12	-12	-11	-12	-12	-12	-13
8	PV	0	0	0	0	0	0	0	0	0	0	0
9	Geothermal	0	0	0	0	0	0	0	0	0	0	0
10	Oil	-11	-17	-18	-11	-8	-14	-6	-6	-6	-4	-4
11	Coal	-67	-56	-52	-67	-50	-51	-46	-40	-38	-42	-27
12	Natural Gas	-13	-12	-12	-13	-14	-17	-14	-15	-19	-17	-19
13	Oil Refining	-16	-17	-17	-16	-16	-22	-19	-18	-20	-20	-19
14	Other	3	0	0	3	0	0	0	0	0	0	-1
	Net	-124	-136	-129	-124	-119	-138	-118	-113	-119	-122	-120

Table 5.20: Disaggregated social impacts (number of jobs) per activity due to Cost/Price dif. alternative scenario effects.

The effects of these alternative scenario related to the subsidies are negative, and this effect associated with employment impacts result in job destruction. This jobs are destructed in the future, once in reality the debt related to the energy, and more precisely the electricity sub sector, accumulates and it is payed in the form of rents with interest rate. So the fact that this tariff deficit is accumulating and it is not really supported by households and activities , results in negative impacts (employment is no exception).

Despite the fact that in 2010 the activities with more job losses are trade, services and government, there is not one main activity where the job destruction can be mentioned as evident during these 10 years.

	Activities	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Agriculture	-3.2	-3.0	-3.0	-2.7	-2.8	-3.1	-2.9	-2.6	-2.0	-2.5	-2.4
2	Industry	-2.0	-2.0	-2.1	-1.8	-2.1	-2.3	-1.9	-2.1	-2.1	-2.3	-2.3
3	Construction	-4.5	-4.3	-4.5	-3.9	-4.3	-5.2	-4.4	-4.4	-3.2	-2.9	-2.8
4	Trade	-3.2	-3.2	-3.6	-3.2	-3.8	-4.7	-3.9	-4.9	-3.7	-4.0	-4.4
5	Communication	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.4	-0.4	-0.4
6	Financial	-0.7	-0.7	-0.7	-0.6	-0.6	-0.9	-0.8	-0.8	-0.9	-0.9	-0.9
7	Real Estate	-0.3	-0.2	-0.2	-0.2	-0.2	-0.3	-0.3	-0.3	-0.3	-0.4	-0.4
8	Services	-1.6	-1.7	-1.8	-1.6	-1.9	-2.4	-2.1	-2.1	-4.2	-4.4	-4.5
9	Government	-4.8	-4.8	-5.2	-4.7	-5.3	-6.6	-5.6	-5.4	-7.4	-7.9	-8.2
10	Arts	-1.6	-1.6	-1.7	-1.6	-1.8	-2.3	-2.0	-2.0	-2.4	-2.6	-2.3
	Net	-22.0	-21.6	-22.9	-20.3	-22.9	-27.8	-23.9	-24.7	-26.7	-28.4	-28.6

Table 5.21: Disaggregated social impacts (10^3 jobs) per activity due to electricity cost/price difference alternative scenario effects.

Environment impacts

The environmental impacts associated with the alternative scenario analysis in which the subsidies/tariff deficit is considered are now discussed. The Tables 5.22 and 5.23 show the CO_{2eq} emissions avoided (negative values) in the energy technologies and economy activities, respectively.

	Technologies	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
1	Dedicated Biomass	0.0	0.0	-0.3	-0.3	-0.4	-0.6	-0.6	-1.1	-1.2	-2.6	-4.4
2	Biomass CC	-7.9	-8.1	-9.3	-7.7	-9.8	-13.8	-11.9	-12.1	-13.9	-15.7	-17.1
3	MSW	-3.2	-3.1	-3.3	-2.9	-2.9	-4.0	-3.6	-3.1	-3.1	-3.2	-2.7
4	Biogas	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.3	-0.3	-0.3
5	Wind	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
6	Small hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
7	Large Hydro	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8	PV	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9	Geothermal	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10	Oil	-37.7	-40.7	-51.1	-24.7	-30.3	-48.0	-24.7	-21.1	-19.9	-15.9	-12.7
11	Coal	-84.3	-79.1	-90.8	-76.1	-84.4	-110.6	-93.5	-71.5	-71.3	-83.0	-39.5
12	Natural Gas	-24.1	-24.7	-32.0	-24.1	-34.7	-58.6	-45.8	-44.9	-57.5	-56.3	-49.2
13	Oil Refining	-22.2	-24.1	-25.6	-23.6	-26.7	-33.1	-29.0	-29.3	-33.6	-31.3	-33.0
14	Other	-0.7	-0.2	0.0	0.0	-0.1	-0.1	-0.2	-0.5	-0.5	-0.7	-0.9
	Net	-180.2	-180.1	-212.4	-159.4	-189.4	-269.0	-209.4	-183.8	-201.3	-209.1	-159.9

Table 5.22: Disaggregated environmental impacts (CO_{2eq} in Kton) per activity due to electricity cost/price difference alternative scenario effects.

As seen in numerous tables presented before the impacts on the energy sector are much smaller that the ones in the economy. This is explained because it is a reduced portion of the full economy (see Table 5.1 and compare). However, when GHG emissions are considered this difference is not observed. In fact the energy sector, as described in this thesis, accounts for percentages varying in this timeline from approximately 35% to 48% of the ROE emissions. Environmental impacts due to this effect is most evident on agriculture, industry, construction and trade activities. As for technologies the same facts as the ones observed in the previous environmental analysis are once again confirmed. This means that fossil fuel plants (conventional energy sources) and oil refining avoided the most emissions contributing to the biggest share on this environmental impacts.

Note that if the 'Net" rows from all the disaggregated tables presented in this section are collected

	Activities	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
1	Agriculture	-46.2	-43.2	-43.9	-35.7	-39.8	-42.5	-41.5	-37.7	-28.6	-35.6	-36.3
2	Industry	46.0	36.7	31.8	19.7	25.9	64.4	63.7	47.9	44.3	13.0	12.4
3	Construction	-21.6	-23.0	-23.2	-20.0	-22.4	-26.6	-19.8	-15.1	-9.6	-9.4	-9.7
4	Trade	-47.8	-46.0	-48.7	-46.0	-55.8	-72.6	-61.5	-51.9	-54.3	-44.9	-41.1
5	Communication	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.3	-0.6	-0.6	-0.6
6	Financial	-0.3	-0.3	-0.3	-0.3	-0.5	-0.6	-0.6	-0.8	-1.0	-1.0	-1.0
7	Real Estate	-0.3	-0.4	-0.3	-0.3	-0.3	-0.4	-0.3	-0.4	-0.4	-0.4	-0.4
8	Services	-1.7	-1.8	-1.7	-1.7	-2.0	-2.5	-2.0	-1.9	-3.7	-3.9	-3.7
9	Government	-8.0	-8.6	-9.1	-8.1	-9.4	-11.3	-8.5	-8.3	-10.4	-11.1	-10.3
10	Arts	-0.9	-0.9	-0.8	-0.8	-0.9	-1.1	-0.9	-1.0	-0.9	-1.0	-0.9
	Net	-81.0	-87.7	-96.3	-93.2	-105.3	-93.5	-71.7	-69.4	-65.1	-95.0	-91.6

Table 5.23: Disaggregated environmental impacts (CO_{2eq} in Kton) per technology due to electricity cost/price difference alternative scenario effects.

and transposed, the Tables in 5.2.2, and are obtained. To sum, the level of detail is thus concluded with a disaggregated insight on technologies and activities impacts due to the three different effects that compose the Portuguese energy policy interpretation.

Chapter 6

Conclusions

6.1 Achievements

The disaggregation of the energy sector and thus the characterization of the several technologies was one of the main milestones of the work. Achieving the technological description regarding issues such as subsidies and tariffs to electricity producers, both O&M and investment costs as well their decomposition, gases emission factors and to try to able to replicate the Portuguese energy reality between 2000 and 2010 was indeed a major portion of this work (although with a lot of assumptions). Therefore, the data manipulating step associated with the gathering process revealed to be quite extensive and it is clearly worth mentioning.

Although the results obtained, as seen in the previous chapter, can provide a significant level of detail the main question is related to the general impacts of the Portuguese energy policy. Hence, the major result provides information on how this policy and the several modifications and implementations that occurred during these 10 years affected the whole economy (energy sector included). The environmental impacts are without a doubt positive, meaning that the energy policy allowed the development towards a greener future (GHG emissions are indeed reduced, specially observed in 2010). Economic and social impacts have also been positive, until 2009. From that year further, the impacts switch signs, thus having negative impacts both on employment (job destruction) and economic growth (GVA). However, note that these overall net impacts originated by the energy sector are not even on the 1% of the whole economy.

The national energy policy was conceived considering three different type of effects: operational, capital investment and subsidies related to the tariff deficit. The increasingly negative impacts related to the tariff deficit seem to explain the impacts sign switch in 2010, possibly forecasting a future with total negative impacts regarding employment and economic growth.

Isolating these effects also provide important information on how technologies or activities behave towards selected type of impacts. Operational (O&M) effects show that the increasing mix of renewable sources in the energy sector is not always positive regarding social and economic concerns. In fact, renewable energies do create jobs, however other jobs are destructed elsewhere (mainly fossil fuel - conventional source plants). From 2008 to 2010, the net results show job destruction on technologies and on ROE activities. However, when comparing the reference to the alternative scenario where the available technology mix in the system (technology characterization in the energy sector, O&M effects) is considered the same from one year to the following, it is necessary to take in consideration the importance of several factors, such as the natural sources availability. Therefore, factors as rain Hydroelectric Index (which translates into the Productibility HydroelectricIndex, PHI) may distort the results obtained for these technologies (small and large hydro).

Isolating the capital investment effects, the impacts are positive. This means that, investing towards the installation of new power capacity (building or upgrading plants) creates employment, enhances economic growth and generates additional CO_{2eq} emissions. The activities related to construction reveals the highest impact on job creation. Industry and trade activities however show the highest impacts towards environmental concerns. When the electricity cost/price difference effects are isolated, these show clearly negative impacts on the whole economy, i.e., the fact that debt is being generated prevents economic growth and destructs jobs. Government and real estate related activities are the ones that reveal the most notorious negative economic impacts.

The several initially proposed goals were achieved, meaning that the economic, social and environmental impacts were obtained for isolated effects that compose the Portuguese energy policy.

6.2 Future Work

This thesis had a lot of assumptions necessary to obtain the data in the required conditions. Studies based on Input-Output do need a lot of information, and when disaggregating an entire sector such as the energy one, accuracy and detail is rather important. In addition this is an historical work, thus requiring continuous information for the whole time period between 2000 and 2010. To enhance the validity of the results obtained, more detailed/accurate data would be fundamental. However, as discussed for many countries such as Portugal these informations may be not available. Surveys or similar processes could be performed in order to estimate with much more accuracy the use of economic products by energy power plants associated technologies.

Despite of this limitations, for future work it is intended to publish a scientific paper presenting the main steps and results of this thesis.

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Appendix A

List of classifications used

Energy technologies			
1	Dedicated biomass	10	Fuel oil
2	Biomass CC	11	Coal
3	MSW	12	Natural gas
4	Biogas	13	Oil refining
5	Wind	14	Coal refining
6	Small hydro	15	Natural gas distribution
7	Large hydro	16	Electric grid
8	PV	17	Biodiesel
9	Geothermal	18	Petrochemical

Table A.1: List of the 18 energy technologies considered.

Energy carriers			
1	Coal and anthracite	22	Gas coke
2	Anthracite	23	Blast furnace gas
3	Coke	24	Tar
4	Crude	25	Petrochemicals gases
5	Waste and intermediates	26	Hydrogen
6	Liquefied petroleum gas	27	Electricity
7	Motor gasoline	28	Electricity distributed
8	Oil	29	Heat
9	Jets	30	Industrial waste
10	Diesel oils	31	Solar thermal
11	Fuel oil	32	Firewood and vegetable waste
12	Naphtha	33	MUW
13	Petroleum coke	34	Sulfite liquors and related
14	Lubricants NE	35	Other renewables
15	Asphalts NE	36	Biogas
16	Paraffins NE	37	Biodiesel
17	Solvents NE	38	Biodiesel distributed
18	Propylene NE	39	Hydro power
19	Natural gas	40	Wind power
20	Natural gas distributed	41	Solar power
21	City gas	42	Geothermal

Table A.2: List of the 42 energy carriers considered.

	Products
1	Products of agriculture, hunting and related services
2	Products of forestry, logging and related services
3	Fish and other fishing products; services incidental of fishing
4	Mining and quarrying
5	Food products, beverages and tobacco products
6	Textiles, wearing apparel and leather products
7	Wood and products of wood and cork (except furniture)
8	Pulp, paper and paper products
9	Printed matter and recorded media
10	Coke, refined petroleum products and nuclear fuels
11	Chemicals, chemical products and man-made fibres
12	Rubber and plastic products
13	Other non-metallic mineral products
14	Basic metals
15	Fabricated metal products, except machinery and equipment
16	Machinery and equipment n.e.c.
17	Computer, electronic and optical products
18	Electrical machinery and apparatus n.e.c.
19	Motor vehicles, trailers and semi-trailers
20	Other transport equipment
21	Furniture; other manufactured goods n.e.c.
22	Electrical energy, gas, steam and hot water
23	Collected and purified water, distribution services of water
24	Construction work
25	Trade, maintenance, retail sale and repair of motor vehicles
26	Wholesale trade and commission trade, except of motor vehicles and motorcycles
27	Retail trade, except of motor vehicles; repair services of personal and household goods
28	Hotel and restaurant services
29	Land transport; transport via pipeline services
30	Water transport services
31	Air transport services
32	Supporting and auxiliary transport services; travel agency services
33	Post and telecommunication services
34	Financial intermediation services, except insurance and pension funding services
35	Insurance and pension funding services, except compulsory social security services
36	Services auxiliary to financial intermediation
37	Real estate services
38	Renting services of machinery and equipment without operator and of personal and household goods
39	Computer and related services
40	Research and development services
41	Other business services
42	Public administration and defense services; compulsory social security services
43	Education services
44	Health and social work services
45	Sewerage; waste collection and management, treatment and disposal; materials recovery
46	Membership organization services n.e.c.
47	Recreational, cultural and sporting services
48	Other services
49	Private households with employed persons

Table A.3: List of the 49 economy products considered.

	Activities/Industries
1	Agriculture, hunting and related service activities
2	Forestry, logging and related service activities
3	Fishing, operating of fish hatcheries and fish farms; service activities incidental to fishing
4	Mining and quarrying
5	Manufacture of food products, beverages and tobacco products
6	Manufacture of textiles, wearing apparel and leather products
7	Manufacture of wood and of products of wood and cork, except furniture;
8	Manufacture of pulp, paper and paper products
9	Publishing, printing and reproduction of recorded media
10	Manufacture of coke, refined petroleum products and nuclear fuels
11	Manufacture of chemicals and chemical products
12	Manufacture of rubber and plastic products
13	Manufacture of other non-metallic mineral products
14	Manufacture of basic metals
15	Manufacture of fabricated metal products, except machinery and equipment
16	Manufacture of machinery and equipment n.e.c.
17	Manufacture of computer, electronic and optical products
18	Manufacture of electrical machinery and apparatus n.e.c.
19	Manufacture of motor vehicles, trailers and semi-trailers
20	Manufacture of other transport equipment
21	Manufacture of furniture; manufacturing n.e.c.
22	Electricity, gas, steam and hot water supply
23	Collection, purification and distribution of water
24	Construction
25	Sale, maintenance and repair of motor vehicles and motorcycles; retail sale services of automotive fuel
26	Wholesale trade and commission trade, except of motor vehicles and motorcycles
27	Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods
28	Hotels and restaurants
29	Land transport; transport via pipelines
30	Water transport
31	Air transport
32	Supporting and auxiliary transport activities; activities of travel agencies
33	Post and telecommunications
34	Financial intermediation, except insurance and pension funding
35	Insurance and pension funding, except compulsory social security
36	Activities auxiliary to financial intermediation
37	Real estate activities
38	Renting of machinery and equipment without operator and of personal and household goods
39	Computer and related activities
40	Research and development
41	Other business activities
42	Public administration and defense; compulsory social security
43	Education
44	Health and social work
45	Sewerage; waste collection and management, treatment and disposal; materials recovery
46	Activities of membership organization n.e.c.
47	Recreational, cultural and sporting activities
48	Other service activities
49	Private households with employed persons

Table A.4: List of the 49 economy activities considered.

A10 Classification			
1	Agriculture, forestry and fishing	6	Financial and insurance
2	Industry, water supply and sewerage	7	Real estate
3	Construction	8	Professional, scientific and technical activities; administrative and support service
4	Wholesale and retail trade, repair of motor vehicles and motorcycles; transportation and storage; accommodation and food service	9	Public administration and defense; compulsory social security; education; human health and social work
5	Information and communication	10	Arts; entertainment; repair of household goods and other services

Table A.5: A10 classification of activities description.