



Universiteit
Leiden
The Netherlands

Untangling the web : integrating energy and environmental policy instruments by assessing their interactions along power systems

Simões, S.

Citation

Simões, S. (2013, September 4). *Untangling the web : integrating energy and environmental policy instruments by assessing their interactions along power systems*. Retrieved from <https://hdl.handle.net/1887/21628>

Version: Not Applicable (or Unknown)

License: [Licence agreement concerning inclusion of doctoral thesis in the Institutional Repository of the University of Leiden](#)

Downloaded from: <https://hdl.handle.net/1887/21628>

Note: To cite this publication please use the final published version (if applicable).

Cover Page



Universiteit Leiden



The handle <http://hdl.handle.net/1887/21628> holds various files of this Leiden University dissertation.

Author: Simões, Sofia

Title: Untangling the web : integrating energy and environmental policy instruments by assessing their interactions along power systems

Issue Date: 2013-09-04

1 General Introduction

“There are currently more than 100 pieces of legislation in place covering the entire spectrum of environmental problems. Of these, only 12% require Member-States to provide evaluative information on the effects of the implemented policy measures”

European Environment Agency, 2001. Reporting on environmental measures: Are we being effective? Environmental Issue Report No. 25. Copenhagen, European Environment Agency

“A patchwork of policies, burdens and new regulations keeps building up without sufficient coherence, balance, or properly thought-out economic assessment”

Secretary General of EURELECTRIC - Union of the Electricity Industry, Closing the circle of competitiveness: the need to reorient European electricity policy, EURELECTRIC, June 2005, Lyon, France.

These two quotations played a major role motivating the research work undertaken in this dissertation. When defining the objectives of my PhD I found extremely relevant that two different key stakeholders in the energy and environment policy arena, with intrinsically different perspectives (EEA as a public government organisation and EURELECTRIC as an association of mostly private companies), seemed to agree that there was not enough assessment on the policy instruments in place. I have found later that this view was shared by many other stakeholders, including researchers. Another quotation that has caught my attention was made by Sorrel and Sijm (2003), as follows:

“(...). The net result may be a mix of overlapping, interacting, and conflicting instruments which lack any overall coherence. In short, a policy mix may easily become a policy mess.”

The issue has become increasingly relevant as the expanding climate change policy area has been bringing together environment and energy policy

making. In fact, it is not always easy to clearly separate what are energy and what are environment policies. Therefore, being an over-optimistic PhD student, I decided to try to contribute in finding a way out of what I considered "the tangled web" of environment and energy policy instruments in place along power systems. In my quest for "untangling the web" I believe that only by providing quantitative estimates on the costs caused by counteracting policy instruments could researchers hope to communicate the relevance of the matter to policy makers, and hopefully, provide guidance on which policy interactions to tackle first. In a nutshell, the main topic of this dissertation is to assess how interactions between energy and environment policy instruments can be quantified.

1.1 The need for environment and energy policy integration

Energy is one of the fundamental factors for economic development. Abundant, cheap energy is considered as a pre-requisite for a prosperous economy, and energy consumption per capita is still used as a key indicator for development. However, the base of most energy systems are still limited resources, such as coal, uranium, oil and gas, which will continue to be essential to produce sufficient energy to satisfy the demand until 2050 (IEA, 2011, IEA, 2012). The subsequent negative environmental impacts (e.g. climate change, air pollution problems, depletion of natural resources) limit even further the availability of these resources deemed necessary for economic development and decrease the well being of the society as a whole. The non-sustainability of the energy systems shows from negative effects on areas as public health, economic development and quality of the environment (Johansson and Goldemberg, 2002; EEA, 2003; DG TREN, 2003.a).

Of all end-use carriers of energy, electricity is probably one of the most important, since it precludes most industrial and service activities. Factors affecting power systems are determinant for economies and for the well-being of populations. Simultaneously, the production and consumption of electricity might also allow for significant effects along the supply chain, as mentioned before. These might be aggravated by the expected growth in electricity consumption. According to the International Energy Agency (IEA)

world electricity consumption will grow from 20 000 TWh in 2009 to 40 000 to 49 000 TWh in 2050 (IEA, 2012).

Nonetheless, there is ample room to reduce the consumption of electricity by improving electricity efficiency (Box 2). There is abundant technology already in the marketplace that allows for more efficient production and consumption of electricity. This not only reduces the magnitude of negative impacts associated to electricity systems, but also increases economic competitiveness, since electricity is an important production factor. However, although such technologies already exist and it is widely known that improving energy efficiency will bring economic, environmental and social benefits, its implementation is a slow, gradual process that needs to overcome a series of barriers, largely discussed in literature (e.g. Vine *et al.*, 2003; Worrell and Price, 2003; Wuppertal, *et al.*, 2000; Bergmash *et al.*, 2000; Turkenburg, 2002). It is necessary to develop and effectively implement policies to enhance this change in production and consumption systems (Fuchs and Arentsen, 2002; Wuppertal, *et al.*, 2000; Johansson and Goldemberg, 2002).

The European Union (EU) has developed and continues to develop a number of policy initiatives concerning energy and in particular electricity, such as the ones mentioned in Box 1.

Box 1 - Some EU Policy initiatives concerning electricity

Communication from the Commission to the European Parliament, the Council, the European Economics and Social Committee and the Committee of the Regions – Renewable energy: a major player in the European energy market, COM(2012) 271

Communication from the Commission to the European Parliament, the Council, the European Economics and Social Committee and the Committee of the Regions – Energy Roadmap 2050, COM(2011) 0885 final

Proposal for a Directive of the European Parliament and of the Council on energy efficiency and repealing Directives 2004/8/EC and 2006/32/EC. COM(2011)0370 final

A Roadmap for moving to a competitive low carbon economy in 2050, Communication from the Commission to European Parliament, the Council, the European Economic and Social Committee of the Regions, COM(2011) 112 final.

Energy 2020, a strategy for competitive, sustainable and secure energy, Communication from the Commission to the European Parliament, the Council, the European Economics and Social Committee and the Committee of the Regions, COM(2010) 0639 final

Communication from the Commission to the European Parliament, the Council, the European Economics and Social Committee and the Committee of the Regions – On security of energy supply and international cooperation – The EU energy policy: Engaging with partners beyond our borders, COM(2011) 0539 final

Directive 2010/31 of the European Parliament and of the Council of 17 May 2010 on the energy performance of buildings

Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources.

Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity

Directive 2006/32 of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services

Directive 2004/8/EC of the European Parliament and of the Council of 11 February 2004 on the promotion of cogeneration

Directive 1996/92/EC of the European Parliament and of the Council of 19 December 1996 concerning common rules for the internal market in electricity

EU Commission Proposal COM(95)369 final. Proposal for a Council Directive to introduce rational planning techniques in the electricity and the gas distribution sectors

Of these, the Council and European Parliament Directive 96/92/EC of 19 December 1996 concerning common rules for the internal market in electricity is probably the policy initiative that most fundamentally changes the structure of the existing electricity markets (Box 2). This is a major change in the power system of which policy makers and policy researchers should be aware of.

Box 2 - Main features of the liberalisation of electricity markets

According to the EU Directive 96/92/EC, the formal restructuring process of electricity markets has started in February 1999 for the entire EU, even if some countries had already started it before. The major alterations are the requirement for separation of the transmission and distribution activities from the other activities developed by electricity companies and to separate distribution from retail supply of electricity. The electricity companies prior to liberalisation, were typically vertically integrated companies, i.e. companies performing two or more of the functions of generation, transmission and distribution of electricity, and with the restructuring of the electric market there is a tendency for their separation in horizontally integrated companies (companies performing at least one of the functions of generation for sale, or transmission or distribution of electricity, and another non-electricity activity).

Source: Simoes, 2001; Wuppertal et al., 2000

It is difficult to distinguish up to what extent the mentioned Directives, to be implemented in national policy instruments solely have energy policy objectives, such as the need to secure supply reducing consumption and diversifying production, or are also influenced by environment policy objectives, such as the commitment to reduce the emissions of Greenhouse Gases (GHG). The frontier separating what is environment and what is energy policy instruments is not a clear one. For example, energy labelling of appliances might induce a reduction in consumption and thus on the environmental impacts associated with supply of electricity, but this reduction in consumption may also allow for guarantying the adequate

dimension of the existing electricity supply infrastructures, and avoiding the necessity to build new ones (Rabl and Gellings, 1988).

This distinction matters since in many cases energy and environment policy objectives are not the same and the implementation of the policy measures mentioned above has to consider a multiplicity of requirements established by other environment policy instruments, such as environmental impact assessment.

Governments worldwide face policy challenges in order to meet the concerns with the threat of environmental damage caused by energy production and use and the design and implementation of policies to tackle these challenges is a very complex task. Moreover, environmental impacts are only one of many concerns for decision makers, along with security of energy supply and affordability. Although there are efforts to integrate environment into energy policies, following the Cardiff initiative¹, according to the World Energy Outlook already in 2002, the security of energy supply “has moved to the top of the energy policy agenda” (IEA, 2002). The EU Commission (DG Energy and Transport) acknowledges that there is still room for improvement in this integration of environment in energy policies, namely by “enhancing energy efficiency, with a strong focus on demand-side management” (EU Commission SEC(2001)502, 2001).

On the other hand, although environment policies do not interfere directly with such objectives, most of the environment policy instruments (see Box 3) somehow condition energy supply and/or demand by imposing restrictions to the use of natural resources (e.g. establishing land use restrictions or emission limit values) or by providing incentives to change the supply and demand profiles (e.g. creating a EU market for the emissions of CO₂ and thus an incentive for shifting to low-carbon fuels or promoting energy efficiency; establishing environment taxes on electricity or subsidising

¹ The 1998 European Council in Cardiff formulated an initiative to aiming to more effectively integrate environmental aspects into sectoral policy making, following the articles 2 and 6 of the Treaty of the European Union. In 2001 the Council adopted environmental integration strategies in the energy area, among other (EU Commission SEC (2001)502, 2001).

electricity produced from renewable sources). Regarding the nomenclature of policy instruments it should be noted that there are many different classifications. However, in this dissertation the intention is not to discuss or clarify them. Instead this research simply aims to assess interactions between a portfolio of instruments, regardless of their classification.

Due to its size, the amount of emissions produced and its visibility, the electricity generators have tended to be a central area in environment policy making (Midttun and Koefod, 2003). Therefore, electricity generators are also a central point for the conflicting effects of opposite energy and environment policy objectives to be felt upon.

Box 3 - Nomenclature of policy instruments

Policy instruments, and specifically environment (or energy) policy instruments, are instruments that are utilised to enforce and implement environment/energy policies. According to Hanks and Sillén (1999), policy instruments can be divided in: directive based regulation (“traditional use of government regulations whereby a public authority sets standards, monitors and enforces compliance to these standards, and punished transgressions”); economic instruments (“efforts to encourage beneficial behaviour by altering the prices of resources and of goods and services”); voluntary initiatives (this category includes a very broad range of instruments, from negotiated environmental agreements, self-auditing and voluntary disclosure, voluntary programmes, eco-labelling and other measures to enhance awareness on environment/energy issues) (Hanks and Sillén, 1999).

Once again, to distinguish energy from environment policy instruments and the reverse it is not immediate. Nonetheless, it seems clear that some environment policy instruments may act as constraints to energy supply and thus, clearly interfere with the main objectives of traditional energy policies (Figure

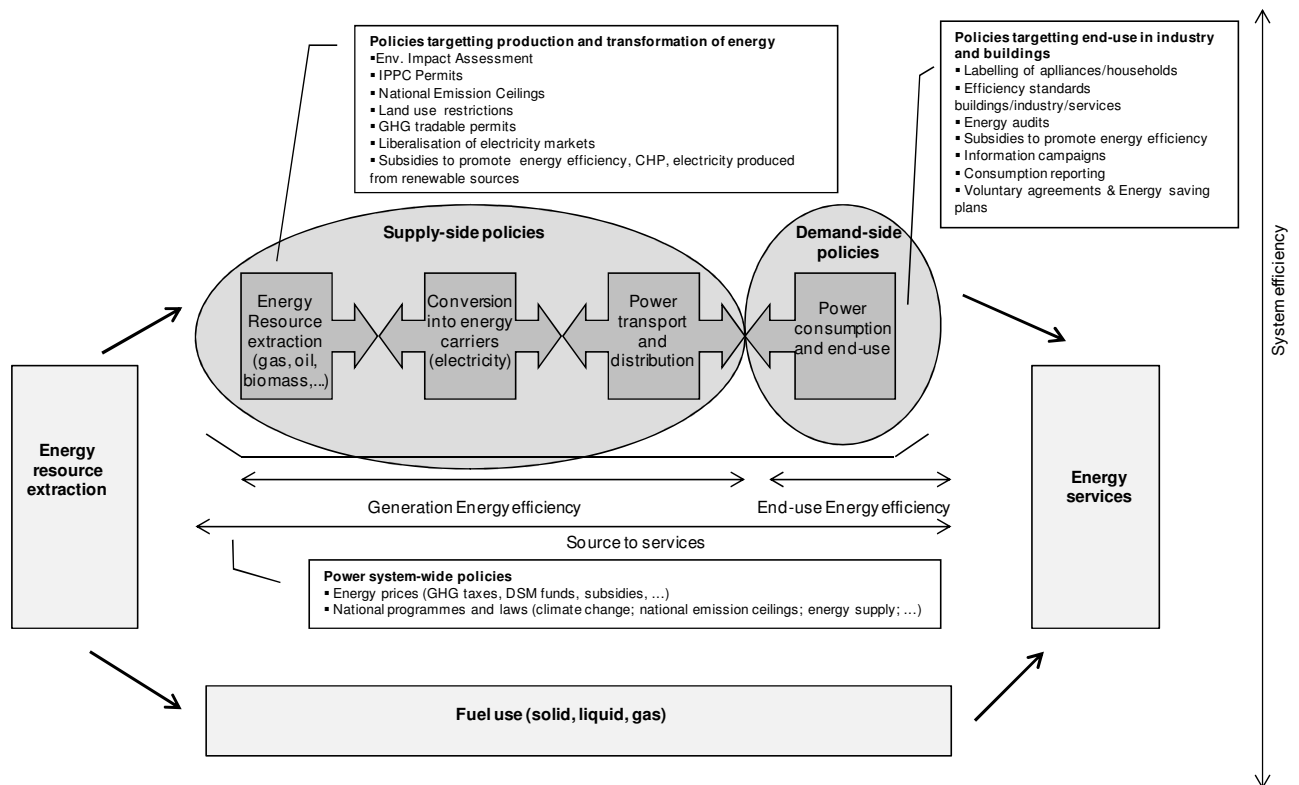


Figure 1 – Power system and some energy and environment policy instruments in place, illustrating potential for fragmentation and inconsistencies

The inverse situation also occurs; that is, energy policies might also negatively affect environment purposes. Biofuels deployment as on-going in the EU might have severe negative environment impacts (Pimentel, 2003; Kim and Dale, 2005; Phalan, 2009).

The conflict in objectives of policy instruments and measures, mostly targeting the same stakeholders along the electricity system, is likely to hamper the effectiveness of each of them.

1.2 Striving for energy and environment policy integration

As mentioned before, it is acknowledged that the disarticulation of energy and environment policy instruments generates costs and inefficiencies that stretch already limited government budgets and hamper the efficiency and

effectiveness of all policy instruments in place (Briassoulis, 2004; Greening and Bernow, 2004; RIVM et al., 2001; EU Commission COM(2004) 394 final). For example, CO₂ charges for emissions reduction are counteracted by on-budget aids to subsidising oil and coal infrastructures, or subsidies to renewable electricity generation are counteracted by restrictions of hydropower for water conservation purposes.

Accordingly, policy makers have been taking efforts to integrate environment and energy policy goals, as in the 1998 European Council in Cardiff and in the 2001 Council's environment integration strategy in the energy area (EU Commission SEC (2001)502, 2001). This was reinforced by the European Council of March 2007 which has decided to "develop a sustainable integrated European climate and energy policy".

Despite these well-intentioned efforts, little policy integration has actually been achieved (Coffey & Dom, 2004; EEB, 2003; Constantinescu and Janssen, 2003; EU Commission SEC (2001)502, 2001). This is due to four main flaws: 1) the intrinsic limitations of the policy making process; 2) the vertical approach used for integration focusing on the broad policy goals and not on the policy instruments, 3) the historical lack of systematic policy evaluation efforts as an integral part of the policy development process, and 4) the subsequent lack of systematic identification of priority areas for policy integration.

Regarding the limitations of the policy making process, human capabilities and the existing evaluation methods do not allow for the apprehension of all the dimensions of complex problems. Therefore, it is not realistic to expect that policies can develop perfectly coordinated instruments capable of simultaneously addressing all social, economic and environmental problems. Instead, policy making is incremental, i.e. the result of continual step-by-step readjustments that aim for slight modifications of existing policy goals, handling one issue at a time (Lindblom, 1959). Moreover, policies result from the aggregation of "many politically self-contained programs and activities" (Schulman, 1975), which have to be negotiated by differently empowered lobbies (Dahl and Lindblom, 1953). Thus, according to public policy analysis literature, policy integration is hampered from the start, also the integration of energy and environment policy. However, although optimal policy integration is unattainable, it is still possible to achieve some piecemeal improvement of optimality. The ultimate objective of this

dissertation is to contribute for the best possible policy integration, highlighting the most relevant counteracting policy instruments, as an essential first step to improvement.

To do so it is necessary to change the current approach for policy integration starting from the policy goals. Most of the policy integration efforts developed so far seems to be nothing more than vague statements on the integration of equally vague broad policy goals. These attempts merely result in the addition of environmental goals to sector policies (e.g. energy or transport policy shall be environmental sustainable), without actual integration of the instruments and procedures (Briassoulis, 2004). This fundamentally hampers the cost-effectiveness of policy integration, since despite beautifully formulated policy goals the effects of any policy are dependent on its instruments design and implementation. Although the rationale behind this approach starting at policy goals is that eventually integration will trickle down to the level of the policy instruments, this did not happen yet. Meanwhile, there are a number of policy instruments in place that potentially counteract each other. These are more than is minimally required in empirically overlapping domains.

This brings up the third flaw of the current policy integration approach – systematic policy evaluation efforts as an integral part of the policy development process. Although detailed analysis of different energy policies have been done (e.g. industry energy efficiency by Worrell and Price (2003); household appliances by Menanteau (2003), Uytterlinde and Jeeninga, (1999) and even on all energy efficiency policies by the World Energy Council (2003), and although the majority of authors acknowledges the importance of performing integrated evaluations of outcomes of policy instruments, this is a very complex task.

Furthermore, policy evaluation is a relatively new field and came rather late to the energy/environment field compared to other policy issues (e.g. health, education). The problem has been stressed because of the seriousness of environmental degradation and impacts of energy systems on global human/natural systems. Not only this is a new research field, but also it is fragmented in concepts, theories and views as its development is exponential. The lack of policy evaluation is a common feature of both energy and environment policy fields. For environment policy EU policies have developed so fast that, according to a study of the European Environment

Agency, there are currently more than 100 pieces of legislation in place covering the entire spectrum of environmental problems. Of these, only 12% require Member-States to provide evaluative information on the effects of the implemented policy measures (EEA, 2001). No newer references seem to be available.

The lack of systematic policy evaluation is probably the cause for the fourth flaw of the policy of the current policy integration approach - the lack of systematic identification of priority areas for integration. The policy integration efforts made so far seem to be based on subjective qualitative assessments, such as “energy contributes to greenhouse gas emissions, thus energy and environment policy should be integrated”. However, a more robust approach is necessary to deal with the myriad of energy and environment policy instruments in place. Which of these interact with other instruments? Which interactions are antagonistic or synergetic? And, more importantly: Which of the interactions are significant regarding the overall policy success? Which counteractions might be avoided? Such questions have to be answered in order to improve optimality.

1.3 Methods for policy evaluation and assessment of interactions between instruments

Acknowledging the beforehand mentioned questions, a new interest starts to rise on the study of collateral effects of policy measures, such as the effects of the policies deigned for reducing acidifying emissions on the GHG emissions and the opposite (Brink, 2002) or different energy policies aiming for energy efficiency, such as voluntary agreements and efficiency standards (Menanteau, 2003). The 6th Environmental Action Programme for the European Union (Article 10) explicitly called for improvements in the policy decision-making through ex-ante and ex-post evaluations. This also addressed energy (efficiency) policies tackling climate change (Article 5). As a result of this initiative, the Commission launched the system of *Integrated Impact Assessment* to address significant environmental, economic and social impacts arising from major EU policy (proposals) in 2002. However, it has been argued that the quality of the evaluation studies is low and that the actual effects of the studies on the policy decision-making are unknown, even in cases in which comprehensive analyses have been performed (Jordan and Lenschow, 2010).

The scientific literature on interaction between policies and policy instruments is divided in three main fields: policy evaluation (e.g. Mickwitz, 2003; Mickwitz, 2009 and Jordan and Lenschow, 2010); applied policy analysis (e.g. Oikonomou, 2010; IEA, 2011; and Böhringer *et al.* 2009), and more theoretical economic policy analysis (stemming from Tinbergen, 1956 and followed up by many authors as Hoel, 2012).

Economy-energy-environment models, such as MARKAL, TIMES, PRIMES, RAINS or GEM-E3, have been widely used for the analysis of policy effects and to support decision-making (van Harmelen *et al.*, 2002; Greening, 2004; Capros *et al.*, 2008; DGEC, 2011; ENEA, 2012; AEA, 2011). However, these models have been sparsely used to assess how different policy instruments interact with each other. Here I try to bring such models use one step further by illustrating how they can be useful in energy and environment policy integration.

A quantitative approach that estimates the losses or gains on effectiveness and cost-effectiveness of interacting policy instruments is most useful to support successful policy integration. Such methodology allows assessing the relevance of counteracting effects between policy instruments, to set priorities for their integration, and to test more integrated policy designs. For this I use a bottom-up TIMES technology model, which is widely used. It has been implemented for Portugal as a country example in the TIMES_PT model. Bottom-up models adopt a partial equilibrium representation of the energy system, describing it with high technological detail. On the other hand, top-down models, also known as Computable General Equilibrium models, describe the interaction between the energy system and the economy as a whole representing the energy sector in an aggregated form by production functions (Böhringer, 1998).

The bottom-up modeling approach complements not only top-down modeling analysis, but also other analytical approaches. Optimization models can only capture part of the overall picture as they do entail numerous limitations (e.g. unrealistic portrayal of decision-making rules used by energy agents – e.g. households; representation of market imperfections, etc.). Given the nature, functioning and context in which policy instruments are introduced, it is highly unlikely that one single policy evaluation method will provide a comprehensive assessment. Therefore, several evaluation methods are needed to fully capture the empirical and

normative aspects of policy instruments and provide useful comparative evaluations. In this dissertation the emphasis was placed on using a bottom-up optimization model. Nonetheless, a top-down model has been used for comparison with the bottom-up TIMES model, assessing how outcomes differ based on choice of model. This modeling is one key step in developing a methodological basis for improving policy performance.

1.4 The Portuguese case-study

Environmental policy making in Portugal is relatively recent (the Law that established the framework for environmental legislation dates from 1987 – Law 11/87 of 11 April) and is strongly dependent on the European Union's directives. As a result of this, many of the implemented policy instruments seem not adapted to adequately fit to the Portuguese reality and thus, seem not effective (Almeida, Lopes, Carvalho, 2000; Santos *et al.*, 1999; OECD, 2011). Additionally, there is room for improvement regarding the enforcement of both energy and environment policies (IEA, 2009; OECD, 2011).

Portuguese Energy Policy was for the first time formally defined and adopted in April 2003². The promotion of sustainable development is acknowledged as one of the key objectives to be met, together with securing the supply and promoting the competitiveness of Portuguese economy. The question on how to meet its objectives in practice is crucial. This is especially relevant since:

- There is a significant potential for energy saving in Portugal (see Box 3 for electricity savings);
- About 90% of the Portuguese primary energy is imported, severely burdening the national trade balance;
- Between 1990 and 2005 the country was still increasing the energy intensity of its GDP and until 2009 its electricity consumption per

² The most recent Portuguese energy policy is named ENE2020 and is dated from 2010, but the same approach to sustainable development applies.

capita. The country has a rapidly growing electricity consumption although it has decreased in 2008 for the first time since 1990 ³;

- Portugal has to make a strong effort to meet its commitment to increase its non-EU-ETS GHG emissions only 1% of the 2005 levels, established within the EU 20-20-20 energy climate policy package (EU Decision COM(2008) 17, EU Commission COM(2008) 30).

It seems that all conditions point to a favourable setting to promote energy efficiency, both for environmental and economical purposes. However, many of these were also present in the past and the actual improvements have been slow (EU Commission COM(2010) 639 final, Wuppertal, *et. al.*, 2000, Simoes, 2001). Up to what point can the integration of energy and environment policies objectives in Portugal enhance this improvement? And how can this integration be executed?

³ On average since 1990 to 2009 3% per year, with episodes of 8.1% average annual rates being reached within the residential and services sector during the 90's.

Box 3 – Potential for electricity saving in Portugal

A study promoted under the EU SAVE programme in 1992-1994 has identified the technical potential for savings by replacing some of the existing equipment, with other more efficient ones. The study is essentially based on the substitution of the existent equipments for more efficient ones available in the market in 1992 (the time frame for the study was 1992 to 2000). It did not consider the utilisation patterns and the difficulties with the implementation of these new equipment. The results point to saving potentials ranging from 27% saving per year (4236.3 GWh/yr) in the industry sector to 40% saving per year (4508.6 GWh/yr) in the services sector.

These values simply represent the technical potential for the reduction of electricity and it is important to refer that they are probably outdated, since the study used the year of 1992 as a baseline and since then many alterations took place, such as the introduction of natural gas.

The National Energy Efficiency Action Plan (NEEAP) (RCM 80/2008) sets an overall target of 10% minimum energy savings by 2015 compared to a baseline scenario, but does not set specific targets for electricity savings. The NEEAP defines specific targets and incentives for stimulating energy efficiency in buildings through increase of insulation, double glazed windows, solar thermal, heat pumps, efficient biomass heating equipment, and A+ and A++ appliances.

Source: Simões, 2001; Júlio, Cabral, Costa and Almeida, 1997; Baía, Cabral and Almeida, (n.d.); RCM 80/2008.

1.5 Research questions and Thesis Outline

The objective of this dissertation is to contribute to the understanding of how energy and environment policies can be further integrated in order to improve its cost-effectiveness, considering the currently on-going debate on the transition to more sustainable energy systems. The dissertation aims to assess the necessity and benefits of developing integrated policy approaches to the energy systems in general, and electricity in particular, regarding not only the integration of energy and environment policy objectives, but also the integration of different policy instruments along the electricity system.

In order to do this, the following main research questions are raised:

- A) What divergences exist between the objectives of energy and environment policies and how relevant are these?

This question is addressed in Chapter 2 (Tangled web) where a qualitative framework to systematically assess the divergences between such policy instruments is presented. The reasons for these divergences are also discussed in this chapter. Chapters 3 (Cost of energy and environmental policy) and 4 (Savings of energy savings) also deal with this question by quantifying divergences between current environment and energy policies, as a proxy for the policy instruments themselves.

- B) How well can we assess the interactions between energy and environment policies and instruments? In particular, how can they be quantified?

This methodology is presented in Chapters 2, 3, 5 and 6. In Chapter 2 (Tangled web) is presented a conceptual methodological framework for the assessment. In Chapter 3 (Cost of energy and environmental policy) is presented a methodology for quantitative assessment using the TIMES energy system model to quantify interactions between energy and environment policies and measures. In Chapter 5 (Effects of exogenous assumptions) is performed an assessment of the methodology's limitations by studying how the TIMES model responds to systematic variations in exogenous inputs. In Chapter 6 (Top-down and bottom-up modelling to support low carbon scenarios) is presented a comparison between differences in outputs of the bottom-up TIMES model outputs and the alternative model paradigm the top-down GEM-E3 model.

- C) How do the different energy and environment policies instruments & measures along the power energy system interact with each other and how does that interaction affect their effectiveness and cost-effectiveness?

This is addressed in Chapter 2 (Tangled web) in a qualitative manner and quantified in Chapters 3 and 4. In Chapter 3 (Costs of energy and environmental policy) interactions of broad energy and environment policy options are quantified as a ban on nuclear or no carbon capture and storage in fossil power plants. In Chapter 4 (Savings of energy savings) the

quantification of interactions focus on more specific policy options either targeted on the supply side of the power system or on the demand side.

- D) How can energy and environment policy instruments be better integrated in order to improve their overall effectiveness and cost-effectiveness?

Suggestions are made in Chapter 2 (Tangled web) namely on structuring trade offs and on Chapter 4 (Savings of energy savings) particularly on energy efficiency and permits to large fossil power plants.

These main questions are interconnected and encompass a number of more specific questions, which are addressed in detail from Chapters 2 to 6, as shown in Table 1.1.

Table 1.1 - Overview of the research questions addressed in each chapter of the thesis

Chapter	Main Research questions			
	A What divergences	B How well can we assess interactions	C Extent of the interactions	D How can instruments be better integrated
2 A Tangled Web	●	● (qualitative assessment of interactions)	● (qualitative assessment of interactions)	●
3 Cost of energy and environmental policy	● (quantitative assessment of interactions)	● (quantitative assessment of interactions)	● (quantitative assessment of interactions)	
4 Savings of energy savings	● (quantitative assessment of interactions)		● (quantitative assessment of interactions)	●
5 Quantifying the contribution of different exogenous assumptions		● (limitations)		
6 Top-down and bottom-up modelling		● (limitations)		

1.6 References

AEA, 2011. Pathways to 2050 – Detailed Analysis - MARKAL Model Review and Scenarios for DECC's 4th Carbon Budget Evidence Base Final Report. May 2011, London, United

Kingdom. Available at: [<http://www.decc.gov.uk/assets/decc/11/cutting-emissions/carbon-budgets/2270-pathways-to-2050-detailed-analyses.pdf>]

Almeida, A. T., Lopes, Ana, C., Carvalho, Anabela. (2000). Energy services in Portugal. In J. H. Chesshire From Electricity Supply to Energy Services: Prospects for Active Energy Services in the EU – Report prepared for the Union of the Electricity Industry – Eurelectric and European Commission – Directorate General for Energy and Transport (169-204). Union of the Electricity Industry – Eurelectric and European Commission – Directorate General for Energy and Transport.

Baía, M., Cabral, P., and Almeida, A. (n.d.). An approach for feasible DSM implementation in Portugal. Unpublished. Coimbra: Portugal.

Bergmash, M., Lewald, A., Nilsson, L., Strid, M. (2000). The Role of Energy Efficiency in the Deregulated Swedish Electricity Market. In 2000 ACEEE Summer Study on Energy Efficiency in Buildings – Efficiency & Sustainability – Panel 5 Deregulation of the utility industry and role of energy services companies. 2000, p. 5.15-5.26. Washington D.C.: American Council for an Energy-Efficient Economy

Böhringer, C., 1998. The synthesis of bottom-up and top-down in energy policy modelling. *Energy Economics* 20(3), 233-248

Bohringer, C., Loschel, A., Moslener, U., Rutherford. T. (2009). EU climate policy up to 2020: An economic impact assessment. *Energy Economics*, 31 (2): S295-S305.

Briassoulis, H. (2004). Policy Integration for Complex Policy Problems: What, Why and How. In: 2004 Berlin Conference on Human Dimensions of Global Environmental Change: Greening of Policies-Interlinkages and Policy Integration, Berlin, Environmental Policy Research Centre (FFU), Freie Universität Berlin, 3-4 December 2004. Available: www.fu-berlin.de/ffu/akumwelt/bc2004

Brink, C.; Ierland, E.C. van; Hordijk, L.; Kroeze, C. (2002). Cost-effective abatement of nitrous oxide and methane from European agriculture considering interrelations with ammonia abatement. In: Non-CO₂ greenhouse gases: scientific understanding, control options and policy aspects : Third International symposium, Maastricht, 2002 / Van Ham, J., A.P.M. Baede, R. Guicherit, J. Williams-Jacobse (Eds.). - Rotterdam :Millpress, 2002. - p. 651-656

Capros, P., Mantzos, L., Papandreou, V., Tasios, N., 2008. Model-based Analysis of the 2008 EU Policy Package on Climate Change and Renewables. Report to DG ENV of the

European Commission. June 2008. Available at:
[http://ec.europa.eu/clima/policies/package/docs/analysis_en.pdf]

Coffey, C., Dom, A. (2004). Environmental Policy Integration in Europe: looking back, thinking ahead. In: 2004 Berlin Conference on Human Dimensions of Global Environmental Change: Greening of Policies-Interlinkages and Policy Integration, Berlin, Environmental Policy Research Centre (FFU), Freie Universität Berlin, 3-4 December 2004. Available: www.fu-berlin.de/ffu/akumwelt/bc2004

Commission Proposal COM(2000) 247 final – Action Plan to Improve Energy Efficiency in the European Community. Available: http://europa.eu.int/eur-lex/en/com/cnc/2000/com2000_0247en01.pdf [2003, April 15]

Commission Working Document COM(2004) 394 final – Integrating environmental Considerations into other policy areas – a stocktaking of the Cardiff process. Available: http://europa.eu.int/comm/environment/integration/com2004394_en.pdf

Constantinescu, T.; Janssen, R. (2003). Energy efficiency – an integrated concept in an integrated Europe. In ECEEE 2003 Summer Study. 2-7 June 2003.

Council and European Parliament Directive 96/92/EC of 19 December 1996 concerning common rules for the internal market in electricity. OJ L 027 30.01.1997 p. 0020 – 0029

Dahl, R., Lindblom, C. (1953). Politics, Economics and Welfare. New York: Harper and Brothers.

DG TREN. (2003.a). Environment – Environment in Energy and Transport. Available: http://europa.eu.int/comm/energy_transport/en/envir_en.html [2003, April 22]

DG TREN. (2003.b). Scadplus – The Energy Dimension of Climate Change. Available: <http://www.europa.eu.int/scadplus/leg/en/lvb/l27022.htm> [2003, April 22]

DGEC, 2011. Scénarios prospectifs Energie – Climat – Air à horizon 2030. [Prospective Scenarios Energy – Climate – Air for the 2030 horizon]. General Directorate Energy and Climate, Ministry of Ecology, Sustainable Development and Energy. July 2011, France. Available at: [http://www.developpement-durable.gouv.fr/IMG/pdf/11-0362_5A_ET_note_synthese_sc_pros_v3.pdf]

Directive 2001/77/EC of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market. O.J. L283, 33-40.

EEA – European Environment Agency. (2003). Energy. Available: http://themes.eea.eu.int/Sectors_and_activities/energy [April 20]

EEA. (2001) Reporting on environmental measures: Are we being effective? Environmental Issue Report No. 25. Copenhagen: European Environment Agency. Available http://themes.eea.eu.int/Actions_for_improvement/policy/reports [2003, April 15]

EEB. (2003). Environmental policy integration: theory and practice in the unece region. Brussels. May 2003. European Environmental Bureau. Available :<http://www.eeb.org>

ENEA, 2012. Il Compendio del Rapporto Energia e Ambiente 2009-2010. [The Summary Report of Energy and Environment 2009-2010]. Italian National Energy Agency. April 2012, Rome, Italy. Available at: [<http://www.enea.it/it/produzione-scientifica/pdf-volumi/v2012compendiorea2009-2010.pdf>]

Environment DG. (2004). Europa - Environment DG – Water Quality in the EU - Water Framework Directive (Online). Available: <http://europa.eu.int/comm/environment/water/water-framework/overview.html>

EU COM(2008) 17. EU Decision of the European Parliament and of the Council COM(2008) 17 on the effort of Member States to reduce their greenhouse gas emissions to meet the Community's greenhouse gas emission reduction commitments up to 2020.

EU Commission (2010) 0639 final. Energy 2020, a strategy for competitive, sustainable and secure energy, Communication from the Commission to the European Parliament, the Council, the European Economics and Social Committee and the Committee of the Regions, COM(2010) 0639 final

EU Commission COM(2008) 30. 2008. 2020 by 2020—Europe's climate change opportunity, Communication from the European Commission to European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2008) 30.

EU Commission Proposal COM(2001) 580 final Communication from the Commission on the implementation of the first phase of the European Climate Change Programme. Available: http://europa.eu.int/eur-lex/en/com/pdf/2001/com2001_0580en01.pdf [2003, April 20]

EU Commission Proposal COM(2001) 68 final – Green Paper on Integrated Product Policy. Available: http://europa.eu.int/eur-lex/en/com/gpr/2001/com2001_0068en01.pdf [2003, April 20]

EU Commission Proposal COM(2002) 321 final – Final Report on the Green Paper “Towards a European strategy for the security of energy supply”. Available: http://europa.eu.int/comm/energy_transport/livrevert/final/report_en.pdf [2003, April 20]

EU Commission Proposal COM(2002)415 final. Proposal for a European Parliament and Council Directive on the promotion of cogeneration based on a useful heat demand in the internal energy market.

EU Commission Proposal COM(95)369 final. Proposal for a Council Directive to introduce rational planning techniques in the electricity and the gas distribution sectors.

EU Commission Staff Working Paper SEC(2001) 502. Integrating Environment and Sustainable Development into Energy and Transport Policies: Review Report 2001 and Implementation of the Strategies. Available: http://europa.eu.int/comm/energy_transport/en/envir_integr_en.html [2003, April 19]

EU Commission Staff Working Paper SEC(2003) 448. Second benchmarking report on the implementation of the internal electricity and gas market. Available: http://europa.eu.int/comm/energy/en/gas_single_market/2benchmarking/sec_2003_448_en.pdf [2003, April 26]

EU Commission. (2001). European Climate Change Programme. June 2001. Available: <http://europa.eu.int/comm/environment/climat/eccp.htm> [September 01]

EU Commission. (2003). Second ECCP Progress Report – Can we meet our Kyoto targets?. April 2003. Available: http://europa.eu.int/comm/environment/climat/pdf/second_eccp_report.pdf

Fuchs, D., Arentsen, M. (2002). Green Electricity in the market place: the policy challenge. *Energy Policy*, 30, 525-538.

Greening, L., Bernow, S. (2004). Design of coordinated energy and environmental policies: use of multi-criteria decision-making. *Energy policy*, 32 (6): 721-735.

Hanks, J., Sillén, M. (1999). Introducing voluntary Environmental Agreements for Industrial Energy in Sweden. International Institute for Industrial Environmental Economics at Lund University, Sweden.

Hoel, M. Second best climate policy. (2012). Memorandum no. 04/2012. Department of Economics, University of Oslo. Available: <http://www.sv.uio.no/econ/forskning/memorandum/pdf-filer/2012/Memo-04-2012.pdf>. Accessed 3rd February 2012.

IEA – International Energy Agency. (2003). [Online]. Energy Efficiency Update – Energy Efficiency policies 2003. Available <http://www.iea.org/pubs/newslett/eneeff/table.htm> [2003, March 20]

IEA - International Energy Agency. (2011). Interactions of Policies for Renewable Energy and Climate. Working Paper. OECD/IEA. Paris Hilton, France.

IEA - International Energy Agency. (2011). World Energy Outlook: 2011. Available: <http://www.worldenergyoutlook.org/publications/weo-2011/>. November 2011.

Johansson, T., Goldemberg, J. (2002). The Role of Energy in Sustainable Development: Basic Facts and Issues. In Energy for Sustainable Development. 2002, p. 25-40. New York: United Nations Development Programme

Jordan, A., Lenschow, A. (2010). Environmental policy integration: A state of the art review. *Environmental Policy and Governance*, 20(3): 147-158.

Júlio, S., Cabral, P., Costa, R., Almeida, T. (1997). Characterisation of the potential for electricity conservation in Portugal. In ECEEE 1997 Summer Study. July 1997, Berlin: Germany.

Kim, S., Dale, B. 2005. Life cycle assessment of various cropping systems utilized for producing biofuels: Bioethanol and biodiesel. *Biomass and Bioenergy* 29:426-439.

Kleijn, R., van der Voet, E. (2002). Co-benefits & Co-damages of environmental policies: using the principles of Industrial Ecology in Environmental Policy making with the case of PVC. In: Proceedings of The Fifth International Conference on EcoBalance - Practical tools and thoughtful principles for sustainability. 6-8 November 2002, Tsukuba, Japan. The Society of Non-Traditional Technology. Available: http://www.leidenuniv.nl/cml/ssp/publications/2002_010.pdf

Law 11/87 of 7 April regarding the Framework for Environmental Policy. *Diário da República* 81 07.04.1987 p. 1386 – 1397.

Lindblom, C. (1959). The science of “muddling through”. *Public Administration Review*, 19, no. 2: 79-88.

Mickwitz, P. A. (2003) Framework for Evaluating Environmental Policy Instruments: Context and Key Concepts. *Evaluation*, 9(4):415-436.

Mickwitz, P., Birnbaum, M. (2009). Key insights for the design of environmental evaluations. In: Birnbaum M., Mickwitz, P., editors. *Environmental program and policy evaluation: Addressing methodological challenges, New directions for Evaluation*, 122: 105-112.

Midttun, A., Koefoed, A. (2003). Greening of electricity in Europe: challenges and developments. *Energy Policy*, 31, 677-687.

OECD. (2011). *Environmental Performance Reviews-Portugal*. OECD:Paris. 2011.

Oikonomou, V., Flamos, A., Grafakos, S. (2010). Is blending of energy and climate policy instruments always desirable? *Energy Policy*, 38(1): 4186-4195.

Phalan, B. 2009. The social and environmental impacts of biofuels in Asia: An overview, *Applied Energy* 86(1): S21-S29.

Pimentel, D. 2003. Ethanol fuels: energy balance, economics, and environmental impacts are negative. *Natural Resources Research* 12(2): 127-134.

Rabl, V., Gellings, C. (1988). The concept of Demand-side management. In A. T. de Almeida and A. H. Rosenfeld, *Demand-Side Management and Electricity End-Use Efficiency* (99-112). NATO ASI Series –Vol. 149.

RCM 63/2003, April 28th. Resolução do Conselhos de Ministros aprovando as orientacoes da Politica Energetica Portuguesa. [Resolution of Council of Ministers 80/2008 approving the orientations of the Portuguese Energy Policy]. DR 1st series, no 98. (in Portuguese)

RCM 80/2008, May 20th. Resolução do Conselhos de Ministros 80/2008 relativa ao Plano Nacional de Acção para a Eficiência Energética [Resolution of Council of Ministers 80/2008 regarding the National Action Plan for Energy Efficiency]. DR 1st series, no. 97. (in Portuguese)

RIVM, EFTEC, NTUA and IIASA, (2001). European environmental priorities: an integrated economic and environmental assessment. RIVM, Report 481505010/2001. The Netherlands. Available: <http://www.rivm.nl/bibliotheek/rapporten/481505010.pdf>

Santos, R., Antunes, P., Martinho, S., (1999). Environmental Implications of Market-Based Instruments in Portugal - Discussion and Examples. In T. Sterner, (ed.), *The Market and the Environment*, Ch. 22,.Edward Elgar, Cheltenham.

Simoës, S. (2001). Incentives for demand-side management initiatives promoted by electricity companies: case study of EDP -- Electricidade de Portugal. IIIIEE Master's Thesis 2001:24. IIIIEE, Lund University, Sweden

Sorrel, S., Sijm. 2003. Carbon Trading in the Policy Mix. *Oxford Review of Economic Policy*.19 (3): 420-437. doi: 10.1093/oxrep/19.3.420

Tinbergen, J. (1956). On the Theory of Income Distribution,. *Weltwirtschaftliches Archiv* 1956, 77(1): 156-175.

Turkenburg, W. (2002). The Innovation Chain: Policies to Promote Energy Innovations. In *Energy for Sustainable Development*. 2002, p. 137-172. New York: United Nations Development Programme

Uyterlinde, M.; Jeeninga, H. (1999). [Online]. Evaluation of energy efficiency policy instruments in households in five European countries. In *ECEEE 1999 Summer Study*. June 1999. Available: http://www.eceee.org/library_links/proceedings/1999/pdf99/Panel1/1-20.pdf [2003, April 25]

Vine, E., et al. (2003). Public policy analysis of energy efficiency and loan management in changing electricity businesses. *Energy Policy*, 31, 405-430.

World Energy Council. (2001). *Energy Efficiency Policies and Indicators*. Available: <http://www.worldenergy.org/wec-geis/publications/reports/eeipi/foreword/foreword.asp>. 2001. [2003, April 25]

Worrell, E., Price, Linn. (2003). Policy scenarios for energy efficiency improvement in industry. *Energy Policy*, 29, 1223-1241.

Wuppertal Institute for Climate Environment Energy et al. (2000). [Online]. Completing the Market for Least-Cost Energy Services – Strengthening Energy Efficiency in the Changing European Electricity and Gas Markets-Project Final Report – A Study under the

SAVE Programme. September 2000. Available:
<http://www.wupperinst.org/energie/produkte/dsm/eng/index.html> [2001, May 30]