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*Project Finance and MCDM financial models:
An application in renewable energy projects*

Project Finance y modelos financieros
multicriterio: Una aplicación para proyectos de
energías renovables

TESIS DOCTORAL

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Abstract

Academics, managerial and policy making community reinforce that renewable energy investments are one of the most effective instruments to attain CO_2 emission reduction targets set by the Kyoto Protocol and by the recent Paris Agreement signed at the Paris climate conference (COP21) in December 2015 in which 195 countries adopted the first-ever universal, legally binding global climate deal.

The problem of financing Renewable Energy (RE) projects has become a crucial issue for private and public decision makers worldwide. Budget constraints from governments and limited bank lending capacities have led to a reconsideration of the traditional financial instruments in the RE sector. The lack of credit makes impossible for commercial banks to fund RE projects with traditional loans. Research on new financing techniques for RE projects, such as Project Finance (PF) has gained interest in recent years. PF is a recent technique applied in large investments projects. During the last decades of the 20th century new public private partnership schemes enabled large infrastructure, energy and environmental projects. In these sectors PF has been used to reduce cost agency conflicts and better risk management.

There is a wide number of contributions underlying the relevance of RE, however there is a lack of research on the financial aspects of RE projects. This research aims to make several contributions. First, to provide a better understanding of the PF technique and its use in the RE sector. Second, to fill the gap of research on financial aspects of RE in the literature by reviewing contributions of MCDM to RE project evaluation from the investor's perspective. Third, we propose a MPDM *Moderate Pessimism Decision Making* model, which adds to the rational financial evaluation of investment opportunities a set of non-financial factors that affects the investor's decisions. Finally, within the illustrative example, we apply this multi-criteria decision making process to help banks to decide if they must join a project or not.

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Resumen

Investigadores, comunidad empresarial y clase política destacan que la inversión en energías renovables es uno de los instrumentos más efectivos para alcanzar los objetivos de reducción de CO_2 establecidos por el reciente acuerdo firmado en la conferencia de Paris (COP21) en diciembre de 2015, en el cual, 195 países adoptaron el primer acuerdo universal y jurídicamente vinculante de la historia.

El problema de la financiación de los proyectos de energía renovable (RE) es un tema crucial para cualquier decisor público o privado. Las limitaciones presupuestarias de los gobiernos y la falta de crédito han provocado que se reconsideren los instrumentos de financiación en el sector de las RE, por lo tanto, la investigación en nuevas técnicas de financiamiento para los proyectos de RE, como Project Finance (PF) ha ganado interés en los últimos años. PF es una técnica que se aplica en grandes proyectos de inversión. A finales del Siglo XX, los nuevos esquemas de colaboración público-privadas han permitido llevar a cabo grandes proyectos de infraestructuras y de RE. En estos sectores, el PF se ha utilizado para reducir costes, conflictos y mitigar riesgos.

Numerosas contribuciones científicas subrayan la importancia de la RE, sin embargo hay un vacío en la investigación sobre los aspectos financieros de los proyectos de RE. Esta tesis tiene como objetivo aportar varias contribuciones. En primer lugar, proporcionar una mejor comprensión de la técnica del PF y su uso en el sector de las RE. En segundo lugar, cubrir el vacío existente en la literatura sobre la investigación de los aspectos financieros de las RE mediante la revisión de las contribuciones sobre MCDM para la evaluación de los proyectos de RE desde el punto de vista del inversor. En tercer lugar, se propone un modelo MPDM *Moderate Pessimism Decision Making*, el cual añade a la evaluación financiera racional de oportunidades de inversión, un conjunto de factores no financieros que afectan a las decisiones de los inversores. Finalmente, se aplica este modelo multicriterio de toma de decisiones para ayudar a decidir a los bancos si deben unirse al proyecto.

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Resum

Investigadors, comunitat empresarial i classe política, destaquen que la inversió en energies renovables és un dels instruments més efectius per assolir els objectius de reducció de les emissions de CO_2 establerts pel recent acord signat a la conferència de Paris (COP21) al desembre de 2015, mitjançant el qual, 195 països van adoptar el primer acord universal i jurídicament vinculant de la història.

El problema del finançament dels projectes d'energia renovable (RE) s'ha convertit en un tema crucial per a qualsevol decisor públics i privats. Les limitacions pressupostàries dels governs i La falta de crèdit han provocat que es reconsiderin els instruments de finançament en el sector de les RE, per tant, la investigació en noves tècniques de finançament per als projectes de RE, com el Project Finance (PF) ha guanyat interès en els últims anys. PF és una tècnica que s'aplica en grans projectes d'inversió. Durant les últimes dècades del Segle XX, els nous esquemes de coŀlaboració publico-privades han permès portar a terme grans projectes d'infraestructures i de RE. En aquests sectors, el PF s'ha utilitzat per reduir costos, conflictes i gestionar millor els riscos.

Existeixen nombroses contribucions científiques que subratllen la importància de la RE, però hi ha un buit en la investigació pel que fa als aspectes financers dels projectes de RE. Aquesta tesis té com a objectiu aportar diverses contribucions. En primer lloc, proporcionar una millor comprensió de la tècnica del PF i el seu ús en el sector de les RE. En segon lloc, cobrir el buit existent en la literatura sobre la investigació dels aspectes financers de les RE mitjançant la revisió de les contribucions sobre MCDM per a l'avaluació dels projectes de RE des del punt de vista de l'inversor. En tercer lloc, es proposa un model MPDM *Moderate Pessimism Decision Making*, que afegeix a l'avaluació financera racional d'oportunitats d'inversió, un conjunt de factors no financers que afecten les decisions dels inversors. Finalment, mitjançant un exemple iŀlustratiu, s'aplica aquest model multicriteri de presa de decisions per ajudar a decidir als bancs si han de unir-se al projecte.

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Contents

Chapter 1

Introduction

In this first chapter, we present the background of this doctoral thesis and the objetives that have motivated us to conduct this work during all these years of investigation in the areas of Project Finance, renewable energies and multicriteria decision making methods. Also, the structure of the different chapters developed along the document is described.

1.1 Background and motivation

At the very beginning, this research was focused on finding new applications for Project Finance and how this methodology can help innovative industries to grow and to improve their benefits. So, during the first months of our investigation, it aimed at: a) gaining insight into the status of Project Finance at both theoretical and practical levels and b) analyzing deeply the new technology-based firms (NTBF).

As a result of the investigation in these two fields, a first paper, "Project Finance: a new approach for financing new technology-based firms", was presented in the GIKA 2013 international congress, which took place at the University of Valencia, Spain in June 2013 (see Figure 1.1). Also, our contribution with Chapter 6 (pages 367 to 375) to the book "Creación de empresas y emprendimiento: de Estudiante a Empresario", with ISBN 978841552291, was published in 2014 by Pearson Educacion SA.

At that stage of the research and due to the characteristics of Project Finance and the peculiarities of New Technology-Based Firms (NTBFs), its compatibility

Figure 1.1: Contribution at 2013 GIKA Conference

is very limited. Generally speaking, Project Finance works perfectly when it is applied to large-scale projects, but NTBF are usually small and risky by definition.

Therefore, we decided to extend our research in two ways, firstly by considering the implementation of Project Finance in renewable energy projects and secondly by using the techniques of multi-criteria decison making (MCDM) with the objetive of developing a practical approach.

Looking for new fields to develop this thesis, we have found that there is a consensus on the need of promoting renewable energy (RE) investments as the most effective way to curb greenhouse gas emissions. The problem of financing Renewable Energy (RE) projects has become a crucial issue for private and public decision makers worldwide. Budget constraints from governments and limited bank lending capacities have led to a reconsideration of the traditional financial instruments in the RE sector. Investments in the RE sector are characterized by combining capital intensity with new technologies, which implies high returns but also high risks. Based on the European experience, the lack of credit makes it impossible for commercial banks to fund RE projects with traditional loans. Research on new financing techniques for RE projects, such as Project Finance has gained interest in recent years due to the rising awareness of environmental issues. There is a wide number of reports, like European-Commission (2014), Deloitte (2011) or the adoption of the Paris agreement, underlying the relevance of RE and the benefits provided for society.

Regarding financing, Project Finance has emerged as a leading way to finance long term and large scale infrastructure projects around the world over the last 40 years. Nowadays, especially in Europe, Project Finance principles have been applied to other types of public infrastructure under public-private partnerships (PPP) schemes. PPP is a specific form of Project Finance where a public service is funded and operated through a partnership of government and the private sector using a long term concession arrangement. According to EPEC (European PPP Expertise Center), the value of PPP transactions that reached financial close in the European market totalled EUR 15.6 billion in 2015, a 17% decrease from 2014 (EUR 18.7 billion) (EPEC 2015). However, also in 2015, the global Project Finance loan market saw volumes reach new highs, up 6.8% at US$277.7bn from last year, when volumes hit US$260bn. In 2014, the PF loans market grew by 23.2% from the 2013 figure of US$204bn.

There is no consensus on Project Finance superiority over other forms of traditional finance. The main advantage of project financing is that it is a non-recourse financing, which allows high levels of leverage for the firms and permits an off-balance sheet treatment of the debt. The wide set of agreements allow risk sharing and provides efficient returns in comparison to conventional financing techniques. The shortcomings of project financing are related to the complexity of the process due to the increase in the number of parties. Project finance involves higher

transaction costs and, as to project debt, it is more expensive than traditional finance due to the non-recourse nature of the former. Moreover, in Project Finance bank requirements imply broad financial, technical and risk analyses.

According to Gatti (2012), despite the increasing use of Project Finance and its significant share of the global syndicated debt market, attention of academics and researchers to this field of finance is still very limited from both theoretical and empirical perspectives. A large part of the existing literature agrees that there are not too many publications focusing on the field of Project Finance methodology.

As highlighted by Zopounidis and Doumpos (2013), since the 1970s the field of finance has evolved rapidly involving new financial products and services such as Project Finance. Multi-criteria decision making (MCDM) models provide a wide set of methodologies to handle theoretical and applied decision problems in finance. MCDM techniques add important practical contributions supporting financial decision makers in modeling, analyzing and evaluating multiple ways of action under several decision criteria. It is well-known that modern theory of finance has developed around the tradeoff between return and risk. When considering return, its estimation and prediction could imply multiple explanatory factors. For example, in assessing corporate profitability, managers and investors are beginning to consider new aspects of long term profitability including, among others, principles of corporate social resposibility, sustainability, and socially responsible investments Ballestero et al. (2012). Regarding the concept of risk it is easy to understand the multidimensional aspects of risk assessment and management. This research has rapidly grown since late 1990s improving the traditional mean-variance framework introduced by Markowitz (1952b). These new approaches consider multiple risk measures and factors and different perceptions of risk and risk attitudes Balzer (1994), Ballestero (1997).

One of the main concerns is that the more the uncertainty increases in the global environment, the more difficult it is to make financial decisions. In this framework, multicriteria decision systems fit perfectly because financial decision makers like investors, managers, policy makers or institutions need to present a broad analysis of multiple pertinent quantitative and qualitative aspects to apply the best decisions to solve specific problems, so MCDM has a relevant role to play.

MCDM models have been mainly used in portfolio selection and corporate performance evaluation. In portfolio selection, Markowitz (1959) sets the basis of modern portfolio theory through the mean-variance (MV) model. The MV model was presented as a normative model in which the mean is used to estimate the expected outcome of the portfolio and the variance is the measure of risk. Markowitz formulates a bi-objective modeling approach as a quadratic optimization problem involving the minimization of risk subject to a constraint of the decided level of return. The assessment of corporate financial performance is one of the main fi-

nancial applications of MCDM models, which include capital budgeting decisions, investment decisions, mergers and acquisitions and corporate financing.

In most of the multicriteria decision making methods, the aggregation weights are obtained from particular preferences of the decision maker. From our point of view, this creates two problems, especially when many criteria and more than one decision maker are involved: a) the effectiveness of the methods is reduced as the number of criteria is increased and b) Project Finance always involves many decision makers.

The Moderate Pessimism Decision Making (MPDM) method (Ballestero 2002) proposed in this dissertation allows us to rank a set of RE projects to be funded using Project Finance from an objective perspective since weights are obtained from the method. Therefore, MPDM is able to rank a set of alternatives in an objective way.

1.2 Objectives

The main objective is to enhance the research in recent Multiple Criteria Decision Making Methods (MCDM) in order to select Renewable Energy (RE) projects to be funded using Project Finance methodology.

Additionally, this research provides a Project Finance literature review since it has emerged as a leading way to finance long-term large-scale projects, including Renewable Energy projects. Moreover, current features of Project Finance worldwide are described.

In order to reach this target, it is also necessary to evaluate trends in renewable energies in the world and to assess main difficulties when they need to be funded. As budget constraints from the public administration remain since the beginning of the world financial crisis, RE project financing must appeal to the private sector. However, the role of private finance has been marginal in the RE sector.

Multiple factors affect the success of RE financing decisions; thus, RE Project Finance selection can be viewed as a MCDM problem. We review the main MCDM methodologies, and the Moderate Pesimissm Decision Making method is proposed to obtain a complete ranking of RE projects. To illustrate the method a case study based on real RE projects is developed in detail.

1.3   Structure

This dissertation is structured in six chapters.

The first chapter introduces the background and motivation, the objectives and the structure.

The second chapter corresponds to the paper, "Project Finance recent applications and future trends: The state of the art", published in The International Journal of Business and Economics (2015, Vol 14; No 2, pages 159-178), which is indexed by EconLit EBSCO, ProQuest, and Cabell's, (see Figure 1.2). This paper provides a review of the state of the art of Project Finance methodology. The growing body of literature on this field serves to emphasize the increasing use and new areas of application of Project Finance techniques. This research attempts to describe the main features of Project Finance and to explain the role of the participants and the main contractual arrangements. Reviewing the state of the art of Project Finance provides a special opportunity to draw attention to the main challenges of this technique and to identify new trends.

The third chapter reviews MCDM methods applied to finance and RE projects.This chapter provides an analysis of MCDM methodologies from two points of view: financial and environmental. The nature of these two fields has become more complicated and important when talking about the decision making process. As it is shown, financial criteria are not the only ones to be taken into account by the decision makers because other factors related to social and environmental issues must also be considered.

The fourth chapter highlights the most important features of RE in different countries and regions. This chapter gives a general and updated overview of the status of renewable energies in the world. Key relevant issues such as countries commited to environmental protection, major indicators, financing techniques, as well as general concerns about the importance of renewable energies for society in the short and long term are discussed.

The fifth chapter develops the application of MPDM to RE Project Finance through a case study. The proposed method has been presented in the 27th European Conference on Operational Research, which took place at the University of Strathclyde in Glasgow from 12th to 15th July, 2015. (see Figure 1.3 and Figure 1.4). In addition, the application has been published as the paper, "A MCDM approach for Project Finance selection: An application in the renewable energy sector" in Vol 16(2015), pages 13 to 26 of the Revista Electrónica de Comunicaciones y Trabajos de ASEPUMA. Rect@ with ISSN: 1575-605X and it is indexed by DOAJ (Directory of Open Access Journals), (see Figure 1.5)

Project Finance Recent Applications and Future Trends: The State of the Art

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Abstract

This paper provides a review of the state of the art of project finance methodology. The growing body of literature in this field serves to emphasize the increasing use and new areas of application of project finance techniques. The paper attempts to describe the main features of project finance, to explain the role of the participants, and the main contractual arrangements. Reviewing the state of the art of project finance provides a special opportunity to draw attention to the main challenges of this technique and to identify new trends.

Key words: developing countries; economic growth; financial development; financial risks; project finance; public-private partnerships

JEL classification: D53; F30; G15; G30

1. Introduction

This article will present and discuss selected research in fields related to project finance. In this work, the term "project finance" is used according to Finnerty (2007), who defines it as "the raisings on a limited-recourse or nonrecourse basis to finance an economically separable capital investment project in which the providers of the funds look primarily to the cash flow from the project as the source of funds to service their loans and provide the return of and a return on their equity invested in the project."

Project finance has emerged as a leading way to finance long-term and large-scale infrastructure projects around the world over the last 40 years. Nowadays,

Figure 1.2: Paper published at IJBE, 2015

Finally , all the conclusions obtained throughout the development of this thesis and future lines of research are discussed in the sixth chapter.

Figure 1.3: Contribution at 2015 Euro Conference

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DTU

Dear Dr. Ana Garcia-Bernabeu, Mr. Fernando Mayor Vitoria, Prof. Dr. Francisco Mas-Verdú,

On behalf of the Scientific Program Committee, I am pleased to inform you that your abstract:

A multicriteria approach to evaluating project finance in renewable energy projects

has been accepted for oral presentation at the 27th European Conference on Operational Research to be held in Glasgow, UK, 12-15 July 2015. For further information about the Conference, please visit the conference webpage: `http://www.euro2015.org`.

We thank you for your contribution and look forward to your participation.

Sincerely,

David Pisinger
Program Committee Chair
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July 20, 2015

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Figure 1.4: Letter of acceptance at 2015 Euro Conference

A MCDM APPROACH FOR PROJECT FINANCE SELECTION: AN APPLICATION IN THE RENEWABLE ENERGY SECTOR

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ABSTRACT:

Renewable energy (RE) is emerging as a solution in order to replace fossil fuels and become the primary source of energy consumption. Investments in the RE sector involve huge amounts of capital but also many risks. Public sector plays an important role in promoting RE projects but due to the need for reducing public expenditure the private sector becomes essential in financing this type of projects. Project Finance is widely used in RE projects and is especially attractive to the private sector because it can fund major projects off balance sheet. The objective of this paper is to present a decision making tool for helping the private sector on the selection process of RE projects to be funded. The problem could be considered as a multiple criteria decision-making problem where both, financial and non-financial criteria have to be taken into account. Objective aggregation weights for those criteria are obtained using the Moderate Pessimism Decision Making approach and a final ranking of the projects is obtained.

Keywords : Project Finance, Renewable Energy Projects, Multi-Criteria Decision Making and Preference Weights.

RESUMEN:

Las Energías Renovables se están convirtiendo en una alternativa cada vez mas importante para reemplazar a los combustibles fósiles como fuente de energía. Los proyectos en el sector de las energías renovables implican grandes inversiones y también muchos riesgos. El sector público desempeña un importante papel para promover los proyectos de energías renovables pero debido a la necesidad de reducir el gasto público ha de recurrir al sector privado. Project Finance es un método de financiación ampliamente utilizado en este tipo de proyectos y resulta especialmente atractivo al sector privado porque permite financiar proyectos fuera de balance. El objetivo de este artículo es proponer un modelo de decisión multicriterio para ayudar el sector privado en el proceso de selección de proyectos de energías renovables que han de ser financiados con Project Finance. El método conocido como *Moderate Pessimism Decision Making* (MPDM) permite clasificar fácilmente alternativas desde varios criterios tanto financieros como no financieros de una manera objetiva .

Palabras clave: Project Finance, Proyectos de Energías Renovables. Teoría de la decisión multicriterio, Pesos preferenciales.

Figure 1.5: Paper published at Rect@, 2015

Chapter 2

Project Finance recent applications and future trend: the state of the art

This paper provides a review of the state of the art of Project Finance methodology. The growing body of literature on this field serves to emphasize the increasing use and new areas of application of Project Finance techniques. This research attempts to describe the main features of Project Finance, to explain the role of the participants and the main contractual arrangements. Reviewing the state of the art of Project Finance provides a special opportunity to draw attention to main challenges of this technique and to identify new trends.

2.1   Introduction

Project finance has emerged as a leading way to finance long term and large scale infrastructure projects around the world over the last 40 years. Nowadays, specially in Europe, Project Finance principles have been applied to other types of public infrastructure under public-private partnerships (PPP) schemes. PPP is a specific form of Project Finance where a public service is funded and operated through a partnership of government and the private sector using a long term concession arrangement. According to EPEC (European PPP Expertise Center), the value of PPP transactions in the European market totalled EUR 11.7 billion in 2012. This is the lowest volume and number of transactions in a decade (EPEC 2013). However, Project Finance has been a growing financial technique in the

last four decades, ranging form 100 to 150 loans annually in the 1980s, the Project Finance loans reached USD 213.5 millions in 2012.

There is no consensus on Project Finance superiority over other forms of traditional finance. The main advantage of project financing is that it is a non-recourse financing, which allows high levels of leverage for the firms and permits an off-balance sheet treatment of the debt. The wide set of agreements allows risk sharing and provides efficient returns in comparison to conventional financing techniques. The shortcomings of project financing are related to the complexity of the process due to the increase in the number of parties. Project finance involves higher transaction costs and as to project debt it is more expensive due to its non-recourse nature than traditional finance. The bank requirements imply broad financial, technical and risk analyse.

According to Gatti (2012), despite the increasing use of Project Finance and its significant share of the global syndicated debt market, attention of academics and researchers in these field of finance is still very limited from both theoretical and empirical perspectives. A large part of the existing literature agree that there are not too many publications focusing on the field of Project Finance methodology.

A recent in-depth review of the literature in this area should be of interest to corporate financial managers, bankers, large private investors, regulators and host governments, sponsors, and financial researchers.

The purpose of the present paper is: (a) to describe the main features, participants and contracts of the Project Finance technique; (b) to review the state of the art in the theory and practice of Project Finance; and (c) to identify main recent applications and trends for Project Finance methodology.

This paper is organized as follows. An overview of Project Finance is developed in Section 2 including main features, participants and contracts. In Section 3 some representative examples of main applications are described. An updated review of the literature for Project Finance is shown in Section 4 identifying main applications and future trends. From the information obtained in the previous section we identify future applications to Project Finance in Section 5. The paper closes with concluding remarks.

2.2   Project Finance overview

There is no single agreed definition of Project Finance. Ballestero (2000a) describes Project Finance as a sound technique which involves performing a set of security arrangements to reduce risk in large infrastructure investments or capital intensive projects such as roads and highways, railways, pipelines, dams, electric power generating facilities, large scale fiberoptic networks, mineral processing facilities,

and many others in industrial areas and developing countries. These arrangements are made between the project sponsors and the clients or their agencies, a host government, a supplier, a constructor, an operator, a bank or lenders. According to Nevitt and Fabozzi (2000) Project finance can be defined as "financing of a particular economic unit in which a lender is satisfied to look initially to the cash flow and earnings of that economic unit as the source of funds from which a loan will be repaid and to the assets of the economic unit as collateral for the loan". Esty (2004) defines Project finance as "the creation of a legally independent project company financed with equity from one or more sponsoring firms and non-recourse debt for the purpose of investing in a capital asset". In conclusion, there is not a single definition of Project Finance, but on the other hand, it is common to describe Project Finance through some distinguishing features, as follows:

1. The sponsors create a legally independent company, the so called, Special Purpose Vehicle (SPV) or project company, with a finite life whose only business is the project.

2. There is a high ratio of debt to equity, up to 90% in some cases. The SPV borrows funds from the lenders and these look to the future cash flows and the assets as collateral to repay all loans.

3. The future cash flows of the project must be sufficient to fund operating costs and the debt service, since they are the basic guarantee for raising funds. Usually, Project Finance assets involve either an strategic asset with high barriers to entry, or monopolistic position, or the certainty of demand and price that comes with a long-term off-take contract or revenue agreement. As a result, the cash flows are sufficient, stable and predictable .

4. Project risks are allocated among all the participants involved in the project. Through a wide range of commercial and legal issues, the SPV is linked to the numerous participants, as for example, the constructor, the operator, the clients or the suppliers in order to assure the corresponding cost or the future revenue.

5. The lenders have either no recourse or limited recourse to the SPV, namely, the lender has only a limited claim if the collateral is not sufficient to repay the debt.

An essential target of Project Finance is to mitigate risk for sponsors and lenders. There are several types of risk, such as random sales and supplies (off-take and shortage risk), construction and completion risk, operating risk, political, legal and current risk. These risks should be allocated to the different participants of the project (Beenhakker 1997).

2.3 Participants

The parties are the concession authority (either a central/regional government or municipality), the purchasers, the suppliers, the contractors and the operators along with lenders and sponsors. The main participant is the project company, also called SPV, which enters into risk allocation agreements with the other parties. In this contractual framework, the risk of random sales is allocated either to a buyer or to a host government (for example, a municipality) interested in the project. These parties act as guarantors or off-takers through the off-take agreement. The robustness of Project Finance is based on these agreements, which assures the return of the project (Ballestero 2000b). The rationale of such an agreement relies on the fact that the guarantor is the best at managing sales risks. The "off-take agreement" between the project company and the client plays a central role in most Project Finance structures . In this agreement the client assures a minimum level of sales paying for the balance if the amount of sales remains below this minimum level. Another significant agreement is the Engineering, Procurement and Construction (EPC) Contract, in which the project will be designed and built for a fixed price on a fixed date. In a "Put-or-pay" contract the supplier is committed to purchasing a minimum amount of inputs at a fixed price for a specific period, or to pay for the shortfall. A project is generally covered by several types of insurances. The coverage of these insurance policies is related to several kind of risks as for example, force majeure events, employer's liability, contractor insolvency and delays in obtaining permits. Other arrangements with the supplier (supply or pay agreement), the operator (Operating & Maintenance agreement, O&M), or the government enhance the project (Ballestero et al. 2004a).

In Figure 2.1 the basic structure of Project Finance, with some participants and the corresponding agreements is represented.
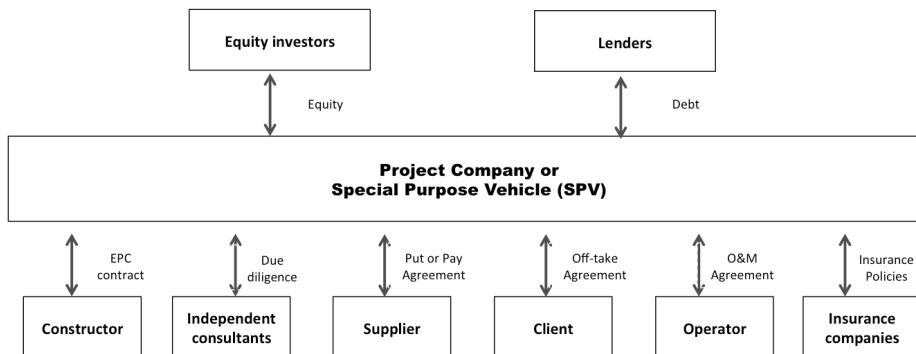

Figure 2.1: Basic structure for a Project Finance: participants and agreements

2.4 Project finance market: applications and sectors

In this section, we review the historical evolution of Project Finance particularly in the last three decades of the 20th century and the first decade of the current century. This previous perspective provides us with a basis for a better understanding the current main applications of this financial technique.

Several authors agree that modern Project Finance dates back to the U.S. power market following the 1978 Public Utility Regulatory Policy Act (PURPA)(Finnerty 2007). During these years, the main applications were related to low risk technological projects such as industrial plants, mining, oil&gas and power generation. At the beginning of the 1970, Project Finance spread to Europe in the petroleum sector using long term contracts with buyers (off-takers). Over the next ten years in Europe, Project Finance has been used to the above cited low technological risk level projects (Gatti 2012). In the 1980s and 1990s Project Finance evolved towards a new era in which two trends can be identified: (i) First, Project Finance was introduced in developing countries as a way to transfer a significant share of the financing burden to the private sector (Yescombe 2002). This implied that this financial technique was exported by developers in the industrialized countries to less developed countries to construct basic infrastructure. (ii) Second, Project Finance began to be used in new sectors as a new off-balance sheet financial technique. As a significant fact, in 1992 the United Kingdom government implemented the Private Finance Initiative (PFI) as a way to involve private sector in the provision of public services. These new applications were for example, schools, military, roads, hospitals,street lighting and prisons.

The Project Finance market has traditionally focused on the EMEA region (Europe, Middle East and Africa) and North America. This is due to the increase use of PPP schemes as a method of funding infrastructure. The Asia Pacific Project Finance market has been reduced by half as a consequence of the Global Financial Crisis.Sector wise assessment for Project Finance applications is shown in Figure 2.2. In 2011, the majority of transactions occurring in the infrastructure and energy sector, and only a minor percentage is devoted to other applications such as metal and mining (6%) and finally only 7% in industry and TIC.

As shown in Figure 2.3 Western Europe and North America are strongly active in both PPP and Project Finance followed by Latin America and Southeast Asia. The emerging market countries that received the most Project Finance dollars were Asia Pacific, India and Middle Est and Africa (24%, 20% and 12% respectively).
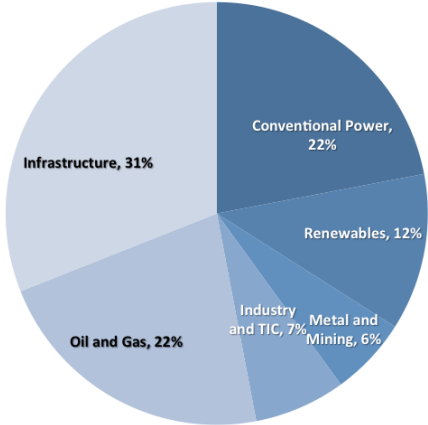
Figure 2.2: Project Finance market by sector (2011): Source: Dealogic
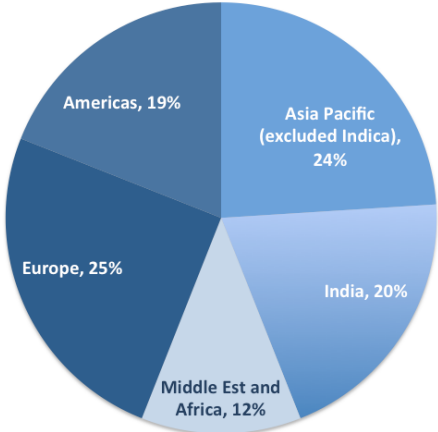
Figure 2.3: Project Finance market by region (2011): Source: Dealogic

2.5   Literature review

We have conducted a basic bibliometric study of Project Finance using the ISI database, which is updated weekly. Regarding Project Finance, ISI database covers over 148 papers. We report basic statistics regarding how the field of Project Finance has developed during the period $1969 - 2013$. According to this database, the results of the search using "Project Finance" keyword are organized in the following subtopical areas: business economics, computer science, engineering, energy fuels and environmental sciences (ecology).

In Figure 2.4 the number of publications over the 1969–2013 period is shown. Growth in the number of publications and in the number of citations has been rapid since 2003. Regarding published items, there is a peak in the year 2009, but it slows down from then to 2013.
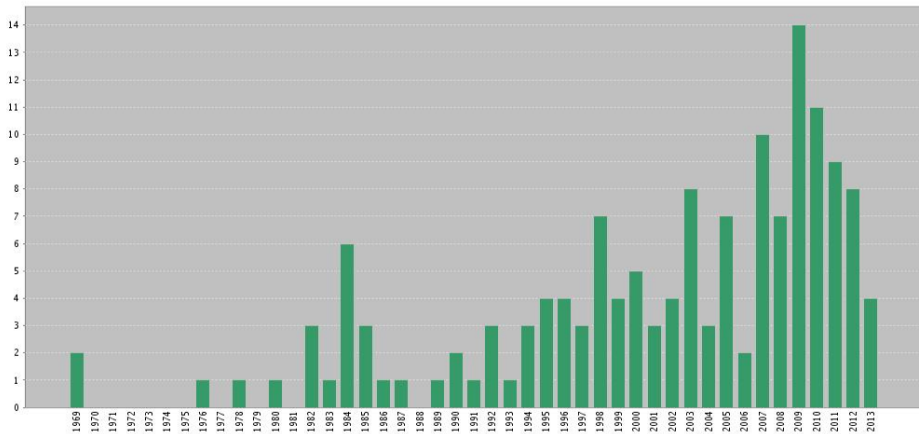
Figure 2.4: Published items in the period 1969 –2013: Source: ISI Web of Knowledge

Information about publications by country of residence of the first author and subtopical areas within the Project Finance fields is provided in Table 2.1 and Table 2.2. Although authors from the United States and England have been most prolific (43.9% of the total), the other 56.1% have come from all over the world highlighting the international nature of Project Finance research. Among the subtopical areas within Project Finance, business economics is listed first reflecting its potential applications. Also, engineering and energy fuels are important, reflecting the broad, interdisciplinary nature of our field. We also compared ISI publications for years 1992-2007 and 2008-2013 by subtopical are and we found

that business economics, engineering and energy fuels have been in both periods the most popular.

Table 2.1: Number of publications by country. Data: May, 2013.

	Number	Percentage
United States	37	25.0%
England	28	18.9%
China	18	12.2%
Australia	10	6.8%
Italy	8	5.4%
Spain	3	2.0%
Others	44	29.7%

Source: ISI Web of Knwoledge database

Table 2.2: Number of publications by subtopical areas. Data: May, 2013.

	Number	Percentage
Business economics	63	42.6%
Engineering	36	24.3%
Energy fuels	24	16.2%
Environmental sciences ecology	16	10.8%
Computer science	9	6.1%

Source: ISI Web of Knowledge database

We classified the 148 items found under the heading "Project Finance" according to our own classification, which is divided in two main areas: 1) Theoretical approaches and 2) Case studies. The first one is also divided in four subgroups, as follows: a) General overviews, b) Financial analysis, c) Risk management and d) Operational research. The area "case studies" is divided in two areas: a) Regional studies and b) Sectorial applications.Among the 148 papers found at ISI database under the topic "Project Finance", 87 of them can be considered theoretical approaches, which represents 58.7% of the total number of studies. The other 42.1% are considered empirical cases, so we have named them case studies. Among the 87 theoretical studies, 34.48% of them are related to risk management which indicates that it is a very important issue inside the Project Finance technique. In

Table 2.3: Top 30 citations

Number	Area	Times cited	Author
1	Risk management	56	Esty and Megginson (2003)
2	Financial analysis	20	Leland (2007)
3	Regional study	18	Bakatjan et al. (2003)
4	Operational research	17	Raskovich (2003)
5	Risk management	15	Doh and Ramamurti (2003)
6	Financial analysis	11	Dailami and Leipziger (1998)
7	Regional study	10	Beaverstock and Doel (2001)
8	Financial analysis	10	Huang and Xu (1998)
9	Sectorial applications	9	Kahn (1996)
10	Regional study	8	Wibowo and Kochendörfer (2005a)
11	Operational research	8	Schweik et al. (2005)
12	Operational research	7	Park (2007)
13	Regional study	6	Marino et al. (2011)
14	Regional study	6	Kann (2009)
15	Financial analysis	6	Kaivanto and Stoneman (2007)
16	Sectorial applications	5	Scholtens and Dam (2007a)
17	Risk management	5	Gatti et al. (2007)
18	Sectorial applications	5	Michaelson et al. (2001)
19	Operational research	5	Bjerre (1999)
20	General Overview	5	Pollio (1998)
21	Risk management	5	Hoffman (1989)
22	Regional study	4	Haack et al. (2012)
23	Financial analysis	4	Jun 2010
24	Risk management	4	Kong (2008)
25	Sectorial applications	4	McGovern and Hicks (2004)
26	General Overview	4	Merna and Smith (1999)
27	Sectorial applications	4	Keller and Plath (1999)
28	Sectorial applications	4	Barnett (1992)
29	Risk management	4	Beidleman and D Fletcher (1990)
30	Operational research	3	Ballestero (2000a)

Source: ISI Web of Knowledge database

fact, one basic principle of Project finance is that it has been used for high-risk infrastructure schemes. The second one is general overviews, which represents 24.1%, while operational research is in the third position with 22.98% of the theoretical approaches. Lastly, financial analysis has 18.39% of the theoretical studies only. Regarding the 61 case studies, 57.37% are considered sectorial applications and only 42.63% regional studies.

The top 30 cited papers are shown in Table 2.3. A big difference between the first and last one is noticeable. The most cited paper is Esty and Megginson (2003), in which the authors examine the relation between legal risk and debt ownership structure. There is also a significant difference compared to the second paper, Leland (2007), in which the author considers activities with no synergistic operational cash flows, and examines the purely financial benefits of separation versus merger. The results are interesting because they provide a rationale for structured finance techniques such as asset securitization and Project Finance.

Among the five top rated articles by citation, only one of them, the third one, is considered non-theoretical. We are talking about Bakatjan et al. (2003). The objective of this paper is to present a simplified model to determine the optimum equity level for decision makers at the evaluation stage of a Build/Operate/Transfer (BOT) power plant in Turkey.

The most recent published papers are Gatti et al. (2013) included in operational research, Nelson and Simshauser (2012), which belongs to sectorial applicancations, Vecchi and Hellowell (2013) and Donkor and Duffey (2013) both of them being inside financial analysis.

In the case of Spain, the most cited author is Ballestero (2000a), with the paper titled "A multicriteria approach to arbitration for Project Finance" and published in Journal of the Operational Research Society.

By year of publication, 35.81% of the papers were published between 2008 and 2013. During this period, 30 of them were theoretical approaches, the remaining 23 being to empirical approaches. The main limitation of this study is the number of papers provided by ISI database, since the total amount has been only 148 items. Entering other keywords such as "public private partnership", we can get a total of 1302 results and using "Project Financing" the amount obtained is 297 results.

A further analysis taking into account our own classification and considering other publications not included in the ISI data base can highlight the main contributions in these fields. This analysis is as developed in the following subsections.

2.5.1 Theoretical approaches

(a) General overviews: There are several works providing a complete description of Project Finance, such as Nevitt and Fabozzi (2000), Finnerty (2007), Yescombe (2002), Gatti (2012). Theoretical microeconomic approaches, related to principal-agency problems or moral hazard are undertaken in: Farrell (2003), Shah and Thakor (1987), Sorge (2011), Hainz and Kleimeier (2011) and Leland (2007).

Other authors analyse the fact that Project Finance appears in developing countries as a way to transfer a significant share of the financing burden to the private sector (Yescombe 2002). For example, Kleimeier and Megginson (1998)), Wang et al. (2004), Griffith-Jones and Lima (2004), Hainz and Kleimeier (2004), and Vaaler et al. (2008) discuss a great deal of Project Finance in Asia and Latin America, and therefore, emphasise the ability of Project Finance to mitigate the corresponding political risk.

(b) Financial analysis: The financial analysis of the project is of interest for lenders and investors. Therefore, there is a huge body of literature on financial issues related to Project Finance. Although previous general overviews include several chapters on financial problems, we here add other specifics works. Chen et al. (1989). A cumbersome problem is to determine the optimal leverage of a firm.(John and John 1991), particularly, the literatures that mostly focuses on Project Finance in relation to other issues, such as financial synergies (Leland 2007).

(c) Risk management: As Project Finance deals with large-scale and risk projects, risk management is a key area of research. The essence of Project Finance arrangements is to allocate risks to the parties who are best able to manage them . A a result of this allocation, Project Finance creates value to the project by improving project risk management Sorge (2011), Kong (2008). In a recent paper, Byoun et al. (2011) find that "project companies use less leverage and instead rely more on off-take agreements when the control benefits of cash flow from the project are high, suggesting that leverage and contract structures in the project company are important hedging mechanisms´´.

Many researchers stress that one of the key comparative advantages of Project Finance is that it allocates the specific project risks, such as completion and operating risk, revenue and price risk, and the risk of political interference or expropriation, to the parties who are best able to manage them (Kleimeier and Megginson, 2000, p.4; Sorge, 2004, p.94)Sorge (2011). Ballestero (2000a) comments that the agree-

ments made under Project Finance make a project less risky and less expensive to perform, by allocating the risks to the different participants with specific risks. Projects in developing countries usually face greater country risk, political risk, currency risk, and business risk. Esty (2004) states that, despite the importance of mitigating completion and operating risks, the function of Project Finance in mitigating sovereign risks cannot be replicated under conventional corporate financing schemes.

(d) Operational research. As far as we know, there are hardly operational research (OR) models aimed at the computation of critical variables (e.g., limited recourse interest rate) and OR models to help make quantitative decisions concerning Project Finance arrangements. A compromise programming approach is Ballestero (2000a). Other contributions in the field of OR are: Raskovich (2003), Schweik et al. (2005), Ballestero (2000b), and Ballestero et al. (2004a) in which the authors introduce a binomial probability distribution model to determine the guaranteed minimum amount of revenues in order to bargain the off-take agreement.

Main contributions in each area are displayed in Table 2.4 and Table 2.5.

2.5.2 Case studies

There are many works involving Project Finance empirical cases like Esty (2004), where it is possible to find carefully selected cases which reflect actual use of Project Finance over the last years in terms of geographic location and industrial sectors. Others publications, like Davis (1996) and Fabozzi and Nevitt (2000), consider the wider world of Project Finance by showing several practitioner case studies to present many complex and real issues.

(a) Regional studies: The project Finance technique has been used traditionally in the EMEA area (Europe, the Middle East and Africa), therefore large amount of publications focus on these regions, like Marino et al. (2011), Akbiyikli et al. (2011), Lüdeke-Freund and Loock (2011) or Makajić Nikolić et al. (2011)), but there are also numerous studies which Project Finance is applied dealing with different regions across the world such as Wibowo and Kochendörfer (2005b) with their financial risk analysis of Project Finance in Indonesian toll roads. Others, like Kann (2009), talk about the overcoming barriers to wind Project Finance in Australia and Mathavan (2008) about the power sector in one of the most important emerging countries such as India. Risk and Capital structure is one of the major aspects when Project Finance must be applied and this is discussed in Asia region by Vaaler et al. (2008). Regarding Latin America, Project finance issues are mainly related to gas-fired power development in Brazil were studied by Hirst (2001).

Table 2.4: Main theoretical contributions on Project Finance literature

Area	Times cited	Author	Comments
Risk management	56	Esty and Megginson (2003)	An evidence from the Global Syndicated Loan Market where using a sample of 495 project finance loans (worth 151 billion) to borrowers in 61 different countries, they examine the relation between legal risk and debt ownership structure.
Risk management	15	Doh and Ramamurti (2003)	This article reviews data and surveys recent cases that highlight the emergent threats faced by companies seeking to develop and manage infrastructure projects. It proposes strategies for investors to assess and mitigate these continuing risks. Its recommendations include leveraging international agreements and drawing on multilateral Project Finance.
Financial analysis	20	Leland (2007)	The author considers activities with no synergistic operational cash flows, and examines the purely financial benefits of separation versus merger. The results are interesting because they provide a rationale for structured finance techniques such as asset securitization and Project Finance.
Financial analysis	11	Dailami and Leipziger (1998)	This paper emphasizes the role of private infrastructure investment as a vehicle for attracting foreign capital to developing countries in the 1990s. The paper provides tentative quantitative evidence of the importance of macroeconomic and project-specific attributes of project risk. The key finding is that the market seems to impose a high risk premium on loans to countries with high inflation.

Source: ISI Web of Knwoledge database

Table 2.5: Main theoretical contributions on Project Finance literature (cont)

Area	Times cited	Author	Comments
Operational research	17	Raskovich (2003)	If other buyers' payments fall short of costs, a pivotal buyer must cover the shortfall or forfeit consumption. This affords leverage that the supplier lacks when bargaining with non-pivotal buyers. The analysis illuminates contracting in markets with high fixed costs.
Operational research	8	Schweik et al. (2005)	This paper describe OS and OC licensing and relate these structures to traditional scientific process. The authors outline how these techniques can be applied in collaborative research areas and include the Project Finance methodology as a key issue to be considered.
General overview	5	Pollio (1998)	This paper explores the preference for Project Finance, as a favoured vehicle for funding energy development. The main focus is on the interests of project sponsors, commercial banks and host governments. Besides, risk management, long recognized as one of the primary reasons for choosing Project Finance over rival debt structures, is affirmed as a key explanatory factor.
General overview	2	Sawant (2009)	In this paper, a theoretical framework is developed to explain why multinational enterprises invest in infrastructure through the mode of Project Finance instead of using corporate finance. Corporate finance-based foreign direct investment cannot fully mitigate these threats. However, PF-based FDI through strategic use of capital structure improves the bargaining position of firms in ex post recontracting negotiations.

Source: ISI Web of Knwoledge database

(b) Sectorial applications: Project Finance methodology has been analyzed and used in many different applications such as: electricity supply, McGovern and Hicks (2004) and Jechoutek and Lamech (1995); renewable and alternative energy, Mills and Taylor (1994) and Richter (2009); mining industry, Braun (2009); high-speed railway financing, Xie (2010); hospitals, Contarino et al. (2009); wind power, Wei (2011); biotechnology projects; Keller and Plath (1999); desalination projects, Wolfs and Woodroffe (2002) and Wenner (1996); oil and gas; Khatib (1997) and even for financing software projects, Michaelson et al. (2001) and Uzal et al. (2009).

Regarding case studies (regional and sectorial), some relevant papers are commented in Table 2.6.

Table 2.6: Main practical contributions (case studies) on Project Finance literature.

Area	Times cited	Author	Comments
Regional study	18	Bakatjan et al. (2003)	The objective of this paper is to present a simplified model to determine the optimum equity level for decision makers at the evaluation stage of a Build/Operate/Transfer (BOT) power plant in Turkey.
Regional study	10	Beaverstock and Doel (2001)	Numerous European and North American banks began to restructure their organizational capabilities in capital markets, foreign exchange, securities, and Project Finance, as they became exposed to bad debts and reductions in the volume of trading. Unfortunately, the plight of the Asian banks was far worse than their non-Asian counterparts.
Sectorial application	9	Kann (2009)	This paper argues that the impact of the wind turbine production tax credit will be minimal. The argument depends entirely on the nature of the Project Finance structure used by the private power industry for wind turbine development. We show that tax credits can only be absorbed by equity investors if there is a large fraction of equity in the project capital structure.
Sectorial application	5	Scholtens and Dam (2007b)	They analyze the performance of banks that adopted the Equator Principles. The "Equator Principles´´ are designed to assure sustainable development in Project Finance. The social, ethical, and environmental policies of the adopters differ significantly from those banks that did not adopt them.

Source: ISI Web of Knwoledge database

2.6   Areas for future research

Considering the previous analysis we can observe that at the beginning Project Finance has been used in low technological risk level projects involving high investments. Later, Project Finance was exported to less developed countries to construct basic infrastructure. At the same time, in the industrialized countries, Project Finance principles have been applied to other types of projects, such as public infrastructures (PPP) in which there is an increasing use of public funds. In the last 2/3 decades, Project Finance played a key role in telecom projects and in the field of renewable energies.

Based on the European experience where limited bank lending capacities and high public debts make the governments unable to fund large projects with public capital, Project Finance arises in the near future as an innovative financial instrument. According to the European Commission, by 2020 the investment needs will focus on the following sectors: information and communication technology (ICT), infrastructures, transport and energy (Scannella 2012). Moreover, volumes in project and infrastructure debt reached around 350 billion US$ in 2011 and in the next 20 years, OECD countries will require over 50 trillion US$ in capital investment for roads, water, energy airports and telecommunications, so the need for project financing will continue to grow (OECD 2011).

ICT sector and and New Technology Based Firms (NTBFs) are going to be the future of the industrialized countries. Due to the budget constraint in the public administration new and innovative ways to fund this type of projects are needed. As an example of the future relevance of private and public instruments the European Union is conducting a new program since 2010, the so called "The Future Internet Public-Private Partnership", short: FI-PPP. The program has two clear objectives: a) to increase the effectiveness of Business Processes and infrastructures supporting applications in areas like transport, health, and energy. b) To derive innovative business models that strengthen the competitive position of European industry: such as telecommunication, mobile devices, software and services, and content provision and media.

Then, we have identified Project Finance trends taking into account the future investment needs in large and risky projects. In Europe and OECD countries Project Finance could be an interesting tool for high technological companies if additional support is given by the financial authorities to promote the development of a project bond market and encourage private sector investments. As an example of this support we can refer to the initiative of the European Investment Bank and the European Union creating the European project bond market.

2.7   Concluding remarks

In this study we have reviewed recent evolution of the Project Finance technique as an innovative financial tool applied in large investments projects. During the last decades of the 20th century new public private partnership schemes enabled large infrastructure, energy and environmental projects. In these sectors Project Finance has been used to reduce cost agency conflicts and better risk management. Therefore, Project Finance has been introduced when costs and risks are relevant issues to manage and has been chosen by project developers to reduce lender's recourse to the sponsors, permit and off-balance sheet of the debt and specially to reduce all type of project risks.

The current financial crisis and the governments difficulties in raising funds for new projects has led to an increase of private capital demand in both developed and developing markets. In this sense, Project Finance will play an important role in financing future large investment projects.

Through the literature review we have identified the main interest areas for Project Finance researchers from both theoretical and practical points of views and we can conclude that Project Finance became a rapidly growing field of finance as showed in Figure 2.4. Financial analysis and risk management are the most relevant areas in theoretical papers. Regarding applications, infrastructures and energy have been the main topics in the last years. Also, we observe that as new funding needs are identified in future strategic sectors, such as NTBF's (Michaelson et al. 2001; Uzal et al. 2009) and biotechnology projects (Keller and Plath 1999), Project Finance could be a new instrument to be considered.

Chapter 3

Multi-Criteria Decision Making Approaches to Finance and RE Projects

Investment decisions in RE projects involves not only financial criteria but also environmental, social and political-legal issues, so RE financial decision making can be considered as a MCDM problem. In this chapter a brief overview of main MCDM methologoies are included to introduce these methodologies in RE and Financial problems.

3.1   Reviewing main MCDM methodologies

MCDM is a branch of Operations Research models that started to emerge in the 1950s. However, it has not been an active area of research until the 1970s with important contributions from Contini and Zionts (1968) and Zionts and Wallenius (1976). Saaty (1977) introduced the Analytic Hierarchy Process (AHP), a multi-criteria method that relies on pairwise comparison of criteria/assets to be evaluated from the decision maker's preferences. Keeney and Raiffa (1976) established the multiattribute value theory (including utility theory) as a standard reference for decision analysis and MCDM. In the late 1970s MCDM research focused on multiple objective mathematical programming problems, especially related to linear and discrete problems Korhonen et al. (1984). In 1972, Zeleny (1982) and Yu (1985)organized the First International Conference on MCDM at the University of Southern California. This conference was a turning point in MCDM.

MCDM has experienced a growing development from the 1990s until now and many sub-fields have emerged with a wide number of contributors. In 1992 Simon French edited the Journal of MultiCriteria Decision Analysis aimed to be the repository of choice for papers covering all aspects of MCDA/MCDM. A significant contribution to MCDM was Ballestero and Romero (1998) with their book "Multiple Criteria Decision Making and its Applications to Economic Problems". Relevant developments in the field of goal programming are due to Romero (1991), Ignizio (1985), Ignizio (1976), and Lee (1972a). A review of the early history of MCDM is made in Köksalan et al. (2013).

According to those authors, MCDM is divided into multi-objective decision making (MODM) and multiattribute decision making (MADM). While MODM is related to problems in which the decision space is continuous, MADM is devoted to problems with discrete decision spaces. Continuous methods seek to identify an optimal quantity, which can vary infinitely in a decision problem. Linear programming (LP), goal programming (GP) and aspiration-based models are considered continuous. Discrete methods include weighting and ranking methods as for example, Multi-attribute value theory (MAVT), multi-attribute utility theory (MAUT), Analytic Hierarchy Process (AHP), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), Elimination and Choice Expressing Reality (ELECTRE), and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). A comparative analysis of MCDM methods VIKOR, TOPSIS, ELECTRE and PROMETHEE is presented in Opricovic and Tzeng (2007).

As an example of MODM methods we develope main features of Goal Programming (GP), Weighted Goal Programming (WGP) and Compromise Programming. Methods such as AHP or VIKOR are explained in the MADM framework among other methodologies that are briefly introduced.

3.2 Multiobjective decision making methods (MODM)

In MODM the problem is characterized by the existence of multiple objectives that should be optimized against a set of feasible constraints. In the following subsections main features of Goal Programming and Compromise Programming are developed.

3.2.1   Goal Programming

Goal Programming (GP) is considered as a subfield of the MCDM techniques that stems from the Simonian paradigm in which the decision makers are viewed as seekers of satisfying solutions rather than optimal solutions in a framework of Simonian bounded rationality and multiple objectives (Steuer 1986). In GP the decision maker establishes the objective function trying to conciliate the achievement of a set of goals rather than actually attempting to optimize each goal. Before Charnes and Cooper, some other author searched for a broader view of GP (Ijiri 1965; Lee 1972a; Ignizio 1976). As a multiple criteria approach to decision making, GP advises a "satisfying" trade-off between the goals. Thus, GP solutions are an alternative representation that often is more effective in capturing the nature of real world problems.

The most usual GP approaches are deterministic Weighted Goal Programming (WGP), lexicographic GP Lee (1972a), minmax GP, and multigoal programming. Since 1970s, a wide number of theoretical and practical developments has been developed.

To formulate a GP model, a first step consists of defining the relevant criteria and target values for the decisional problem under consideration. Previously, some basic definitions are needed.

- **Criteria**. A criterion is a single measure by which the goodness of any solution to a decision problem can be measured.

- **Objective**. An objective is referred to as a criterion with the additional information of the direction (maximise or minimise) in which the decision maker(s) prefer on the criterion scale.

- **Goal**. A goal refers to a criterion and a numerical level, known as a target level which the decision maker(s) desire to achieve on that criterion.

- **Constraint**. A constraint is a restriction upon the decision variables that must be satisfied in order for the solution to be implementable in practice.

Suppose the decision maker has j goals and m decision variables x. Each goal has an achieved value, $f_j(x)$, on its underlying criterion. This is a function of the decision variables. The decision makers sets a numeric target level for each goal which is denoted b_j. Then, each goal is formulated as follows:

$$f_j(x) + d_j^- - d_j^+ = b_j \tag{3.1}$$

where, d_j^- is the negative deviational variable of the jth goal. It represents the level by which the target level is under-achieved. d_j^+ is the positive deviational variable of the jth goal. It represents the level by which the target level is over-achieved.

Once the goals established, the decision maker must then decide which deviational variables are unwanted and for this reason should be penalised in the achievement function. There are three basic types of penalisation. (i) If the goal involves costs, then, any positive d_j^+ deviation above the goal level should be penalised.(ii) If the goal involves profit, then, any negative d_j^- deviation below the goal level would be penalised. (iii) If the goal involves involve a workforce-level target, then any negative d_j^- or positive d_j^+ deviation from the target level would be penalised.

Sometimes the set of goals are viewed as constraints and if the targets are not accomplished, then, it does not imply that the solution is infeasible (soft constraints). In addition, a set of linear constraints (hard constraints) could be considered whose violation will make the solution infeasible.

$$x \in F \tag{3.2}$$

where F is the feasible region that satisfy all the constraints.

The generic form of a GP model consist in minimize an achievement function ensuring that the solution is as close as possible to the set of desired goals, that is:

$$\min a = h(d^-, d^+) \tag{3.3}$$

subject to the following goal constraints:

$$
\begin{aligned}
f_j(x_i) + d_j^- - d_j^+ &= b_j \\
x_i &\in F \\
d_j^-, d_j^+ &\geq 0
\end{aligned}
\tag{3.4}
$$

Major GP variants are lexicographic, weighted, and Chebyshev goal programming. Lexicographic GP has been the first variant of GP and its main feature is that introduces a number of priority levels that includes a set of unwanted deviation to be minimized. However, one of the most used GP variant is weighted goal programming (WGP) that is used when the decision maker is able to provide relative preferences weights between goals.

WGP is stated as follows:

$$\min D = \sum_{j=1}^{n} \frac{w_j(w_j^+ d_j^+ + w_j^- d_j^-)}{b_j}$$

$$b_j \neq 0 \quad w_j^+ + w_j^- = 1 \quad \forall j; \quad \sum_{j=1}^{n} w_j = 1 \tag{3.5}$$

subject to the following goal constraints:

$$\sum_{i=1}^{m} a_{ij} x_i = b_j + d_j^+ - d_j^-; \quad j = 1, 2, ..., n \tag{3.6}$$

together with $x_i \geq 0, \quad \forall i$, where,

x_i is the ith output (decision variable)

a_{ij} is the per unit cost of the ith output for the jth goal

b_j is the target or aspiration level for the jth goal

and d_j^+ are the jth positive and negative deviations, respectively, from the jth target

w_j, w_j^+ and w_j^- are preference weights attached to the jth deviation

In objective function (3.5), each deviation is normalized by the respective b_j target.

A slightly modified version of model (3.5)-(3.6) is as follows. Make $W_j^+ = w_j w_j^+$ and $W_j^- = w_j w_j^-$. Then, the model becomes:

$$\min D = \sum_{j=1}^{n} \frac{W_j^+ d_j^+ + W_j^- d_j^-}{b_j}$$

where the sum of weights are equal to 1, subject to goal constraints (5.2) and the non-negativity conditions, where:

$$\sum_{j=1}^{n} (W_j^+ + W_j^-) = \sum_{j=1}^{n} w_j(w_j^+ + w_j^-) = 1$$

WGP is used when the decision maker wishes to examine trade-offs between goals via different weight sets. In this case he achievement function consists of a weighted, normalised sum of unwanted deviations.

A significant contribution to the field of GP is Romero (1991). One of the most recent developments in GP is Extended Lexicographic Goal Programming (ELGP). Romero (2001) and Romero (2004). Practical applications are included in Jones and Tamiz (2010), Schniederjans (2012), Tanino et al. (2013), and Aouni et al. (2014).

3.2.2 Compromise Programming

Compromise Programming (CP) is a widely used subfield of MCDM, that assumes that the decision maker looks for a compromise between objectives of different character, financial, ethical or others. As described by CP, the decision maker looks for an ideal point, which is a set containing the best feasible level of each objective. This ideal is a utopian infeasible basket of reference because all the best objectives cannot be simultaneously reached. The CP satisfying solution is to choose the basket closer to the ideal and is obtained by minimizing the distance between a frontier basket and the ideal. Distances are not necessarily measured by the Euclidean quadratic metric but by a conventional metric between 1 and infinity. Moreover, the distance in CP is not a purely geometric notion but a composite measure in which the geometric components are multiplied by the decision maker's preference weights for each objective (Zeleny 1982; Yu 1985).

The main features of CP are as follows:

(i) CP requires specifying the efficient frontier defined as an allocation set in which no variable can be made better off without making some other variable worse off.

(ii) CP considers the ideal as an analytic reference for optimization.

(iii) The CP ideal is a vector whose components are the best values (anchor values) of criteria representing an infeasible point derived from the efficient frontier.

(iv) The CP ideal is not a target established by the DM from his own views and judgments (unlike Goal Programming).

(v) The CP solution is derived by minimizing the weighted distance from each efficient point on the frontier set to the infeasible ideal.

(vi) The CP model, searches for an optimal solution rather than for a "satisfactory" solution in the most literal sense of this word.

A large amount of CP papers have been published in the academic literature. Currently, more than 18 000 articles can be found in ScienceDirect, which is one of the world's leading full-text scientific database, from which more than 1300 are

applications in finance and, in particular, more than 300 papers include applications of CP-based models to the portfolio selection problem. One of the pioneering applications of CP for portfolio selection are due to Ballestero and Romero (1996) and since then several interesting works can be found in the literature. Some recently published applications are: Bilbao-Terol et al. (2006a) and Bilbao-Terol et al. (2006b), Amiri et al. (2011), Abdelaziz et al. (2007), Ballestero and Plà-Santamaría (2003) and Ballestero and Pla-Santamaria (2004), Ballestero et al. (2007) and Perez Gladish et al. (2007).

The structure of a CP problem under Zeleny's axiom can be summarized as follows:

$$\min L_p = [w_1^p(x_1 - x_1^*)^p + w_2^p(x2 - x_2^*)^p]^{1/p}$$
$$\text{subject to } T(x_1, x_2) = k \tag{3.7}$$
$$0 \le x_1 \le x_1^*, \quad 0 \le x_2 \le x_2^*$$

where (x_1^*, x_2^*) is the ideal point which is usually derived from $T(x_1^*, 0) = k$ and $T(0, x_2^*) = k$; (w_1, w_2) is the vector of weights attached to both magnitudes; and p is a parameter defining the family of distance functions $1 \le p \le \infty$.

In CP, weights w_1 and w_2 can play two different roles: (i) shadow prices for normalizing both x_1 and x_2 magnitudes in order to make their aggregation possible; (ii) preferential indexes, when utility functions are not considered in the analysis. In this paper weights will only be used for normalizing purposes, since utility functions involve the preferential scheme.

For several values of the parameter p different baskets which are closest to the ideal point are obtained . Yu (1973) demonstrated that for the bi-criteria case the distance function L_∞, is monotone nondecreasing for $1 \le p \le \infty$. Thus, L_1 and L_∞ metrics define a subset of the attainable frontier , known as the compromise set.

The other best-compromise solutions fall between those corresponding to L_1 and L_∞ metrics, i.e., $L_p \in [L_1, L_\infty]$. Baskets on the compromise set enjoy some useful economic properties, such as feasibility, Paretian efficiency, independence of irrelevant alternatives, etc. (Yu 1985, Ch.4)

It is worth pointing out that equation (8.3) is a particular case of equation (8.4) when $p = \infty$ and weights are inversely proportional to the values (i.e. $w_1/w_2 = x_2^*/x_1^*$) as can easily be proved. See Ballestero and Romero (1991).

3.3 Multiattribute decision making methods

MADM methods require to define a decision matrix with four parts: (a) alterntives, (b) atributes, (c) weight or relative importance of each atribute, and (d) measures of performance of the alternatives with rspect to the atributes. Given this decision matrix, the DM has to find the best alterntive or to rank the entire set of the alternatives. There are many MADM methods, but in this section we develope the main features of the popular methods, such as, AHP, ELECTRE, PROMETHEE, VIKOR and TOPSIS. Additionally, we introduce the MPDM as a recent method to rank the alternatives from an objective way

3.3.1 Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a MADM method that was originally developed by Saaty (1980). In AHP, the problem is constructed as a hierarchy breaking down the decision top to bottom. The goal is at the top level, criteria and sub-criteria are in middle levels, and the alternatives are at the bottom level of the hierarchy.
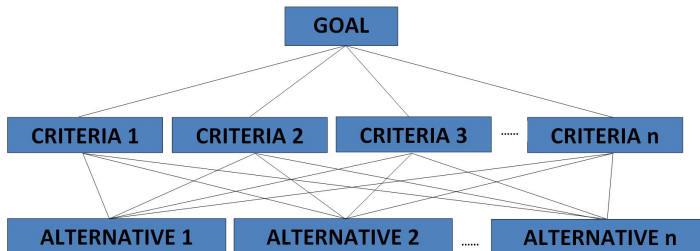
Figure 3.1: AHP structure (Source: Own elaboration)

In AHP, input of experts and decision makers (DM) is considered as paired comparisons. Based on the DM's judgements, the analyst establishes the relative importance of the criteria through "pairwise comparisons", thus obtaining a set of preference weights. AHP can be structured in the following steps:

- To develop the hierarchy structure from the top level (goal of the decision problem), the intermediate level (criteria) and the low level (alternatives).

- To determine the relative importance of the selection criteria to the goal. In this stage, The comparisons are made using a scale of absolute judgements that represents, how much more, one element dominates another with respect to a given attribute. For this purpose, the analyst uses an scale ranging from 1 to 9 using the Saaty rating scale (table 3.1) in order to cover the entire spectrum of the comparison.

Table 3.1: The Saaty Rating Scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgement slightly favour one over the other
5	Much more important	Experience and judgement very strongly favour one over the other
7	Veru much more important	Experience and judgement very strongly favour one over the other. Its importance is demonstrated in practice
9	Absolutely more important	The evidence favouring one over the other is of the highest possible validity
2,4,6,8	Intermediate values	When compromise is needed

Source: Own elaboration based in Saaty (1980)

Although AHP has been subjected to some criticism, it is one of the most widely used multiple criteria decision-making tools in many fields and applications

Recently, the Analytic Network Process (ANP), also introduced by Saaty is used as a general form of the AHP methodology. Although AHP is easy to use and apply, its unidirectional relationship characteristic cannot handle the complexity of many problems. ANP, however, deals with the Brans (1982) as a network of complex relationships between alternatives and criteria where all the elements can be connected. In Cheng and Li (2007) an empirical example to illustrate use of ANP is developed.

In order to test a decision making technique, a proposed problem is given to different methods and the resuts are evalutated in order to check if the output rank shows logical contradictions.

As an example, suppose that three managers (A, B and C) are evaluated for the same possition. Imagin that a decision making method has returned that the first in the ranking is A, followed by B, who is followed by C. (A > B > C). Then, suppose that candidate B is replaced for a worse candidate (D). In this case, we have B>D. But candidates A and C remain in the ranking with the same characteristics.

Now, rank reversal appears if candidates, A, D and C, are ranked again (with the same weights given to the same critera as before), but the results say that candidate A is not the best option anymore.

The first type of rank reversal in the above context was observed by Belton (1999), they first considered a simple decision problem comprised by 3 alternatives and

2 criteria. Next a copy of a non-optimal alternative was introduced. When the 4 alternatives (i.e., the previous 3 plus the copy) were evaluated, and under the assumption that the criteria weights are exactly the same as before, it was observed that now the indication of the best alternative can change (rank reversal)

Rank reversal is not something unique in AHP but it has attracted the attention of many researchers that considered AHP controversial in the field of decision making. See, for example, Leskinen and Kangas (2005), Ishizaka and Lusti (2006) and Zahir (2009).

3.3.2 Preference Ranking Organization Method for Enrichment Evaluation

PROMETHEE's methodology was developed by Brans (1982) and further extended by Brans and Vincke (1985) and Mareschal, Brans, et al. (1994). It is characterized by easy of use and decreased complexity. As an outranking method, it ranks the different alternatives and performs a comparison of them in order to sort the alternatives with respect to a number of criteria.

PROMETHEE's methodology has the following two steps:

1. **Assigning a preference function**. The starting point is the evaluation matrix, which presents the performance of each alternative in relation to each criterion. Using the data contained in the evaluation matrix, the alternatives are pairwise compared with respect to every single criterion. The results are expressed by the preference functions, which are calculated for each pair of options and can range from 0 to 1. Whereas 0 means that there is no difference between the pair of options, 1 indicates a big difference.

2. **Estimating the outranking degree of the options**. By multiplying the preferences by the criterias, weights and adding the single values, a matrix of global preferences is calculated. In this matrix, the sum of the row expresses the strength of an alternative (dominance). The sum of the column expresses how much an alternative is dominated by the other ones (subdominance). A linear ranking is obtained by subtracting the subdominance value from the dominance value.

The family of PROMETHEE methodologies have included PROMETHEE I & II:

1. **PROMETHEE I**. It provides a partial preorder of alternatives, which, in some cases, may be incomplete. This means that some alternatives cannot be compared and, therefore, cannot be included in complete ranking. This occurs when the one alternative obtains high scores on particular criteria for which another alternative obtains low scores and the opposite occurs between the same alternatives for other criteria. The use of PROMETHEE

I then suggests that the DM should engage in additional evaluation efforts (Macharis et al. 2004; Macharis 2004). The advantage of the partial preorder is that some bad performing alternatives can be excluded from the further evaluation exercises, with the consequence that the data requirement is reduced.

2. **PROMETHEE II**. Within this method a complete ranking of alternatives from the best to the worst one is provided. It is useful to supply to the DM information on how the final ranking changes when different decisions on weights, criteria and aggregation procedures are taken.

There is a software to make operating the PROMETHEE methods. It si called Visual PROMETHEE and it was developed in 2010 based on the old PROMCALC. To analyse the potential of this tool, there are some examples like Mareschal and De Smet (2009) or Barberis et al. (2013) where it is applied to a real case that aims to optimize the Spanish participation in peacekeeping operations.

3.3.3 Elimination and Choice Translating Reality

In the mid-1960s, the ELECTRE (Elimination and Choice Translating Reality) method was initiated in France by Roy et al. (1966) when they were working in how firms can decide on new activities. Since then, important efforts have been made by scholars to improve this method and publishing their different proposals involving theories and applications, such as Mousseau and Slowinski (1998), Beccali et al. (2003) or Rogers et al. (2013).

This method is capable of handling discrete criteria of both quantitative and qualitative nature and provides a complete ordering of the alternatives. The analysis is focused on the dominance relations between alternatives. It is based on the outranking relations hips and exploitation notions of concordance. The outranking method uses pair-wise comparison between alternatives.

Different versions of the ELECTRE method are proposed and the family of ELECTRE includes ELECTRE I, ELECTRE II, ELECTRE III, ELECTRE IV, and ELECTRE TRI. The implementation of the ELECTRE methods differ from one version to another according to the degree of complexity, quality of information or according to the nature of the decision problem.

Many times, ELECTRE is used in combination of other MCDA method in order to save time by discarding the unacceptable alternatives of the problem.

There are two parts on a ELECTRE application, first the construction of the outranking relations and secondly, the execution of the procedure that creates on the recommendations got on the first phase.

3.3.4 Technique for Order Preference by Similarity to Ideal Solutions

The Technique for Order Preference by Similarity to Ideal Solutions (TOPSIS) was proposed by Yoon and Hwang (1981) and extended by Lai et al. (1994). It is known as an ideal point MCDA method. The principle behind the method is that the optimal alternative should have the shortest distance from the positive ideal solution and the furthest distance from the negative ideal solution. The positive and negative ideal solutions are artificial alternatives which are hypothesised by the decision-maker, based on the ideal solution for all criteria and the worst solution which possesses the most inferior decision variables. Assuming every criterion has an increasing or decreasing scale, TOPSIS calculates the results by comparing Euclidean distances between the actual alternatives and the hypothesised ones.

3.3.5 Multi-attribute Utility Theory

The multi-attribute utility theory (MAUT) is an extension of the classical utility theory. Its aim is to represent/model the decision maker's preferences through a utility function aggregating all the evaluation criteria In general, it is possible to decompose a multicriteria utility function in real functions concerning the independence of criteria.

On the basis of the utilities of the alternatives that are determined through the developed utility function, the decision maker can rank them from the best alternatives (alternatives with the higher utility) to the worst ones (alternatives with the lower utility), classify them into appropriate classes through the definition of appropriate utility thresholds, or select the alternative with the higher utility as the best one.

This is one of the most popular MCDM methods. As an example, Amador et al. (1998) proposes a methodological approach for large farms in Spain. This research provides farmers a utility function with three attributes: working capital, risk and level of relative profitability.

A closely related theory to MAUT is MAVT (Multiple attribute value theory). It is a compensatory technique. This means that the method does allow compensation of weak performance of one criteria by a good performance of another criteria. MAVT aggregates the options' performance across all the criteria to form an overall assessment.

3.3.6 VIKOR

The VIKOR method is able to determine a multicriteria ranking of alternatives $(a_1, a_2, \ldots, a_j)$ in the presence of conflicting criteria. The method assumes that each alternative is evaluated according to a criterion function and the compromise ranking could be performed by comparing the measure of closeness to the ideal solution F^*. The multicriteria measure for the compromise ranking is derived from the compromise programming L_p-metric (Zeleny 1982; Yu 1985).

$$L_{pj} = \left\{ \sum_{i=1}^{n} \left[w_i \frac{f_i^* - f_{ij}}{f_i^* - f_i^-} \right]^p \right\}^{1/p} \tag{3.8}$$

$$1 \leq p \leq \infty, \; j = 1, 2, \ldots, J$$

where:

f_{ij} is the value of the *ith* criterion function for alternative a_j

$f_i^* = \max\limits_{j} f_{ij}$ when the criteria function is a benefit and $f_i^* = \min\limits_{j} f_{ij}$ when the criteria function is a cost.

$f_i^- = \min\limits_{j} f_{ij}$ when the criteria function is a benefit and $[f_i^- = \max\limits_{j} f_{ij}]$ when the criteria function is a cost.

w_i is the preference weight for the *ith* criterion.

p is the compromise metric.

When the p metric is equal to 1, namely, L_1 metric allows to obtain the S_j value as follows:

3.3.7 MPDM

Moderately Pessimism Decision Making (MPDM) is a method created by Ballestero (2002), in which it is proved that the existence of a consistent weight system to rank the actions by assuming that the DM is neither an incurable optimist (maximax follower) nor an extreme pessimist (maximin follower), but a moderate pessimist who does not expect the best from the action taken. This method proposes a decision rule to rank actions under strict uncertainty, the available information being limited to the states of nature, the set of alternative rows, and the consequence of choosing every row if a given state occurs. This rule is suitable to moderately pessimistic individuals and social groups, these agents being neither

maximax nor maximin DM but people who assume that the best outcome from the action will not occur.

The concept of "uncertainty" does not suggest complete inability to make a decision. It means, the decision maker (DM) is plagued by doubts as to what to do. Under strict uncertainty, nevertheless, the individual decides to choose one and only one of the possible actions. For these DM's the method shows the existence of a consistent weight system in which one and only one weight is attached to each state of the world under plausible conditions of domination.

This model is a departure from Laplace (1825) rule, which provides a consistent weight system in which one and only one well-defined weight corresponds to each state of the world but it relies on a very strong controversial by assumuming that knowing nothing about the true state of the world is equivalent to all states having equal weight. Only in the special case of equal column dispersion do both Laplace's rule and the proposed weights in MPDM lead to the same solution.

To be able to use the the proposed model, the decision problem under strict uncertainty needs to exhibit the following characteristics:

1. It should have logical fundation, so a consistent weight system can be provided

2. It should incorporate the idea of security associated with attitudes of moderate, as opposed to extreme, pessimism as are commonly observed in a sizeable number of decision makers.

3. It should use all the available information in the decision table.

4. It should be easy to apply to both individual and group decisions.

And it is based in these two theorems:

- Theorem 1: the existence of a consistent weight system to rank the actions by assuming that the DM is neither an incurable optimist (maximax follower) nor an extreme pessimist (maximin follower), but a moderate pessimist who does not expect the best from the action taken.

- Theorem 2 (A key property): It is demonstrated that Laplace's rule, if applied to the normalized table but not to the original table, yields the same solution as the proposed criterion. This result appears significant as showing the importance of using information on column dispersion and disappointment. Numerical examples are as convincing as the mathematical reasoning on these respects.

3.4 MCDM in finance

The more uncertainty increases in the global environment, more involved become financial decisions. Moreover, restrictions and regulations are tighter and need to be adapted to all new impositions which have appeared during the past decade. In this framework, multicriteria decision systems fit together because financial decision makers like investors, managers, policy makers or institutions need to present a broad analysis of multiple pertinent quantitative and qualitative aspects to apply the best decisions to solve specific problems.

The overview of this section shows how MCDM brings approaches for decision modeling and focus on the situations that a financial decision maker has to deal with, in order to emphasize how relevant multicriteria approaches can be to support and improve other existing techniques from the field of finance. Multicriteria decision systems add important practical contributions in this sense, supporting financial decision makers in modeling, analyzing, and evaluating several ways of actions.

3.4.1 The multicriteria issues of financial decisions

Return and risk are considered the central pillars over the modern theory of finance are build around. This section studies the varied sides of concepts like profitability, wealth, return and risk in order to underscore how important are the contributions that MCDM provide to the financial decision making process. The key point is to discuss about the multiple aspects of financial decisions in a constructive way.

The first one, return, is easy to understand from the point of view of the concept. However, the hardest matter here is to predict it, thus, giving a precise estimation is a very demanding task. Over the years, researches have dedicated many efforts to prognosticate future returns and classify factors that can guide investors in the selection of the correct and profitable investment. The evolution has resulted in much more complex models; for example, Sharpe (1964) published the capital asset pricing model (CAPM), where return is described as a function of systematic risk.

In evaluating the profitability of a corporate, managers, analysts and investors consider criteria like a) return on equity (shareholders' return), b) return on assets (the way that corporate assets are used in a profitable way), c) cash flows (the ability of the company to keep a stream of strong future cash flows) and d) profit margins (the cost structure of the firm. Moreover, latest developments include new complexities, involving socially responsible investment, sustainability and concepts related to the social responsibility of the corporation. Steuer and Na (2003).

Secondly, risk, which is the other central point in the finance theory, is quite complicated to define, but also to manage and measure. Thus, in Basel II (The capital adequacy regulatory framework) it was recognized several kinds of risks, such as a) credit risk, b) market risk, c) operational risk and d) liquidity risk (this was added in Basel III). Although Basel II framework refers to the risk management practices for financial institutions, it must be enhanced that very similar financial risks also concern to non-financial firms too. So, it is possible to define that risk assessment and management approaches are multidimensional.

In this sense, since the end of the 1990s, this area of research has increased and strengthened considerably making more evident the multi-facet nature of risk. Talking about literature, it is important to highlight to Markowitz (1959) who introduced the mean-variance model on which new literature Artzner (1999) has established new perspective to the financial risk management and has introduced new concepts like the value of the risk Jorion (2007).

Nevertheless, decision makers (DM) attitude against risk is fundamental subjective and it use to be united to the considered alternatives Coleman (2007). The consequence is that generally the specific financial problems must be attend by operational techniques that can provide exclusive decision support, but also taking into account the posture of the particular DM.

All the above mentioned, emphasize that these two concepts, that have such an important role in the financial decisions, are quite complex. So the accent must be put on developing models to fully inform DM when they face a financial decision and not just literature in a descriptive context. The analyst should move one step beyond by identifying the features which could involve specific regulatory, policy constraints and conditions or qualitative expert judgements describing special issues of the problem. These are difficult dimensions to quantify but relevant for the decision context.

MCDM covers all the important concepts such as risk and return, but also the multiple factors involved and the framework in which financial decisions are implemented by structuring the problem, modelling the process and evaluating of the alternatives and solutions.

By launching a prescriptive and constructive perspective, MCDM modelling extends descriptive models developed in the context of the finance theory. In Bouyssou et al. (2006), the prescriptive approach is defined as the one that can give to the DM a suitable model for a concert decision context based on the systems of values of the DM. Furthermore, due to the progressive learning process it is possible to build a constructive approach of the model, which seeks to intensify the DMs understanding of the problem. The combination of the results from the constructive and the prescriptive sides, allows the creation of a realistic approach to financial decisions making that takes under consideration the specific features

of the particular instance where the financial decision is taken and not only the available general knowledge on the area of the problem under consideration.

3.4.2   Modelling financial decisions

Two types of financial decisions, called portfolio selection and corporate performance evaluation, are analysed in this section.

Portfolio selection

The idea of establishing the Paretian Efficient frontiers to portfolio selection was conceived by Markowitz (1952a) in the framework of mean-variance (MV) optimization. Mean-variance is considered as an initial step in portfolio selection. Markowitz was the pioneer in setting up the basis of the modern portfolio theory (MPT) that attempts to maximize portfolio expected return for a given amount of portfolio risk. This is equivalent to minimize risk for a given level of expected return, by choosing the proportions of various assets. MPT is a bi-objective modelling approach and it started new directions in the way that asset allocation decisions are modeled and taken.

Markowitz mean-variance (MV) analysis is a component of MPT, which assumes investors make rational decisions and that for increased risk they expect a higher return. There are two major factors in mean variance analysis: variance and expected return. Variance represents how spreads out data set numbers are, such as the variability in daily returns. Return is expected as a subjective probability assessment on the return of the stock. In case that two investments have the same expected return, but one has a lower variance, the one with lower variance is the better choice.

The mean-variance model was presented as a normative/descriptive model relying on plausible assumptions, namely, (i) risk i s the investor's main concern, (ii) risk is associated with volatility, and (iii) the investor tries to minimize risk under the constraint of achieving a desired level of expected return (profitability constraint). This is the essence of mean-variance model, an approach widely discussed by Tobin (1957), Feldstein (1969), Levy (1974), Hanock and Levy (1969).

Markowitz MV model, in which matrices and vectors are written in bold, is stated as follows:

$$\min V = \mathbf{X}\mathbf{V}\mathbf{X}' \tag{3.9}$$

subject to

$$\bar{E} = \mathbf{E}\mathbf{X}' \geq e_0 \tag{3.10}$$

$$\sum_{i=1}^{m} x_i = 1 \tag{3.11}$$

where

X is the vector of portfolio weights $(x_1, x_2, \ldots .x_i, \ldots \ x_m)$.

V is the mxm covariance matrix of returns on the assets.

$\mathbf{X}'$ is the transposed vector of **X**.

E is the $1xm$ row vector of expected returns from the assets.

e_0 is the investor's target for E. To determine the efficient frontier, target e_0 is viewed as a parameter which takes feasible values.

The main criticisms of the MV approach has focused its reliance on the assumption that returns are multivariate normally distributed and the use of variance as a measure of risk, which imply that the preferences of the investor are described by a quadratic function of these two statistical measures. Many are the critics to MPT as an ideal investment tool, because its model of financial markets does not match the real world in many ways. In fact, risk, return and correlation measures used by MPT are based on expected values, which mean that they are mathematical statements about the future. In practice, investors must substitute predictions based on historical measurements of asset return and volatility for these values in the equations, so often such expected values fail to take account of new circumstances that does not exist when the historical data was generated.

Markovitz already introduced some extensions to the MV approach such as semi-variance, mean absolute deviation and expected loss. All these concepts were developed and become new portfolio selection criteria and optimization models.

Portfolio selection demands the consideration of extra issues which related to the results of the investment and the portfolio management process such as transaction costs Yu and Lee (2011), liquidity Şakar and Köksalan (2013), dividends, constraints involving other goals to guarantee the diversification of the investment. (Steuer et al. 2007; Steuer et al. 2008).

Corporate Performance evaluation

The problem of asset selection appears when an investor has the opportunity to chose among several options to invest. Portfolio analyst and traders examine multiple assets, usually from a set of alternatives to select. Fundamental analysis includes a) data taken from the financial statements of the firms (solvency, profitability or leverage), b) stock market ratios (dividends, price to earnings or book to market value) and c) information on the general economic.

In a multicriteria framework, Hurson and Zopounidis (1997) were the first ones to introduce the use of outranking and disaggregation techniques in the modelling of the stock selection. Roy and Bouyssou (1993) and Siskos and Yannacopoulos (1985) where first authors that implement outranking techniques to select a limited set of stocks on the basis of financial and stock market criteria. Nowadays, recent studies include implementations in decision support systems and empirical results, such as Samaras et al. (2008), (Xidonas et al. 2011; Xidonas et al. 2012) and Zopounidis (1999).

During the recent years new approaches try to articulate Socially Responsible Investments (SRI) into modern corporate evaluation techniques as a new deal defended by institutional investors and banks. Under this perspective financial criteria must be complemented with ethical criteria due to the importance of social and environmental issues in our modern society. The Forum for Sustainable and Responsible Investment (SIF) defines SRI as an investment process that integrates environmental, social, and governance (ESG) considerations into investment decision making. According to SIF, SRI in USA is situated at 3.74 trillion USD, so it covers about the 10 per cent of USA investment marketplace. MCDM techniques also seem very interesting in this field as SRI involves multiple points of view and most of the stakeholders take part in the decision process Ballestero et al. (2012) and Ballestero et al. (2014).

3.4.3   Evaluation of financial performance

Evaluating the financial performance of firms and organizations is a key topic in finance with several points of view, such as a) capital budgeting decisions, b) investment decisions, c) mergers and acquisitions and d) corporate financing. In this section, the multiple measures used to evaluate corporate performance are discussed, mainly refered to, credit scoring and bank evaluation.

In financial performance, the financial criteria such as profitability, solvency, liquidity, and performance ratios prevail.

Financial analysis of firms need to be complemented with extra information on the current risk and value creation factors, including qualitative factors linked to

the quality of the management, the organizational structure, its market position and its advantages compared to its rivals.

New perspectives have been added on the evaluation of firms financial performance, due to the rise of new business principles based on social responsibility and corporate governance (CG). Issues like management style, business ethics, ownership status, transparency, eco-efficiency, environmental policies, social activities, etc. have been emphasized and literature enhance the connectivity between these factors and company financial performance Ducassy (2013). The finance literature about these matters is usually descriptive and it is focused on the evaluation of the impact of CG and SRI on different indicators of the financial performance like, profitability and stock market results.

MCDM systems are used to formulate a synthetic indicator that can be used to estimate the general financial performance of the corporations in a comprehensive way. The identification of existing strengths and weaknesses, the monitoring of the results as long as the conducts of benchmark comparisons among firms in the same sector is enabled thanks to such aggregated index of financial performance. ELECTRE methods proposed by Iazzolino et al. (2012) provide an illustration of the MCDM process in a comprehensive framework for assessing the financial performance.

The analysis of banking performance has attracted much interest during the past few years, in part due to the recent crisis and the quantity of bank defaults.Banks performance indexes are used on the basis of expert peer review procedures according to criteria linked to the competence of their capital, the quality of their assets, their management reputation, earnings generating ability, liquidity position and tolerance to market risks. These dimensions are known as CAMELS (Capital, Assets, Management, Earnings, Liquidity, and Sensitivity to market risks). A comprehensive overview on the application of CAMELS from the point of view of supervisory risk assessment of banking institutions was presented by Sahajwala and Bergh (2000).

Doumpos and Zopounidis (2010) also presented a multiciteria decision support system developed on the premises of CAMELS framework for supervisory risk analysis of banks in Greece. The system contributes to help analysts with flexibility on the evaluation criteria and provides additional control using the PROMETHEE method a part from additional sensitivity analysis results. The fact is that the diverse nature of the evaluation qualitative and quantitative criteria and the importance of adding the contributions of expert banking analysts make MCDM a very suitable approach for creating bank evaluation models.

Another related point is credit scoring. Credit scoring models are used to analyse risk credit applications by financial institutions due to they are closely related to financial performance evaluation. Usually, credit scoring systems are based on

the combinations of financial and non-financial data describing the probability of default for a firm or an individual (an applicant). Usually, the output of these models is a recommendation on the risk rating, which is linked with the grade to default. Some reviews about this matter are Papageorgiou and Sircar (2008) and Abdou and Pointon (2011).

As the decisions models are built based on historical default data, credit scoring is considered a statistical model of problem classification from the methodological point of view. Therefore, some characteristics required by scoring models (Krahen and Weber, 2011) and which make MCDM emerge in this context are: a) Monotonicity (In business, it means that when the input information for a given applicant increase, the probability of default decrease. b) Ordinal risk grades (by definition) c) Transparency (it makes easier for credit analyst to calibrate them in based to their experience knowledge).

Some examples of MCDM used in credit scoring area and bankruptcy prediction are Costa et al. (2002) with tools for building transparent and accurate credit scoring systems. Vukovic et al. (2012): combination with other modelling techniques, including fuzzy models and Doumpos and Zopounidis (2011) as alternatives to popular statistical and machine learning approached providing more accurate rating results.

3.5   MCDM in RE Projects

Investments in the RE sector are characterized by combining capital intensity with new technologies, which implies high returns but also high risks. Based on the European experience, limited bank lending capacities make the commercial banks unable to fund large projects with traditional loans. Project finance is a key element when transferring risk from the public to the private sector when there are high levels of public debt.

Selecting the right source of energy to invest in is an issue which involves many factors, policies and situations, so renewable energy decision-making can be considered as a multiple criteria decision-making (MCDM) problem with many risks, criteria, variables and alternatives which increase the complexity of decision-making processes.

Research on new financing techniques for RE projects has gained interest in recent years due to the rising awareness of environmental issues. There is a wide number of contributions underlying the relevance of RE as, for example, D'Alessandro et al. (2010) and Dovì et al. (2009). However, there is a lack of research on the financial aspects of RE projects (Lüdeke-Freund and Loock 2011). Moreover, the energy policy literature has seldom incorporated the investor's perspective. For these reasons, given the relevance of considering a wide set of criteria to better

understand the investor's preferences in the decision making process to evalualte Project Finance alternatives, we address the following question: What kind of RE project configuration do lenders prefer to finance? To answer this question, MCDM methods are proposed as a flexible tool to handle a wide range of variables. This is because traditional single criteria decision-making approaches cannot manage the complex analysis that a multi-dimensional space of different indicators and objectives involves Zeleny (1982), Yu (1985). In RE projects, MCDM have been widely used in areas such as wind farm projects, geothermal projects, hydro-site selection and the main applications have been related to planning, RE evaluation, project selection, allocation and environmental issues are analysed in Ballestero (2000a), Yazdani-Chamzini et al. (2013), Taha and Daim (2013).

This research intends to fill this gap in the literature by reviewing contributions of MCDM to RE project evaluation from the investor's perspective. The proposed model adds to the rational financial evaluation of investment opportunities a set of non-financial factors that affects the investor's decisions. For this purpose we apply the Moderate Pessimism Decision Making (MPDM) model to rank several real RE projects by analyzing the most important variables which can make a project succeed or fail Ballestero (2002). Within a case study, we apply this multi-criteria decision making method to help banks to decide if they must join a project or not.

MCDM draws upon knowledge in many fields including: Mathematics, Behavioral decision theory, Economics, Engineering and Information systems. In RE projects, MCDM has been widely used in areas such as wind farm projects, geothermal projects, and hydro-site selection. A review of multi-criteria applications in renewable energy analysis is made in Taha and Daim (2013).

Recently many authors have been interested in comparing and analyzing different MCDM methods when applied to real world problems (see, for example, Chu et al. (2007), Hobbs and Meier (1994), Opricovic and Tzeng (2004)). Applications to renewable energy that compare several MCDM methods can be found in Theodorou et al. (2010), Theodorou et al. (2010), Sánchez-Lozano et al. (2014a).

3.5.1   Assessing non-financial factors in RE investments

The aim of this section is to expose that apart from analytical evaluation of the investment opportunities in terms of capital investment, a huge quantity of non-financial criteria affect to the investor's decisions. Non-financial criteria come from very distinct sources depending on investors' personal knowledge, experience and background, so they are very different to the usual criteria considered in financial decisions. Moreover, the social and political environment, the grade of uncertainty about technological matters they are willing to adopt and their awareness about performance issues related to RE, are fundamental for the decision making process.

All the variables related to the mentioned issues are directly linked to decisions and their impact is essential to the development of the procedure by which investors allocate their resources to RE technologies although they do not have a purely economic sense. This section aims to provide many contributions. Not only to understand better the decision making process, but also to be a guide for policy makers to map out effective tools to support the market of RE technologies and to present a wide set of agents which do not use to appear in these kinds of reports.

Depending on the roll of non-financial factors and revising the literature, it is said that technical and economic constraints including: a) high capital and maintenance cost, b) limited experience with energy technology and c) under-valuing the long-term benefits of environmental investments, are the best parameters to select among uncertain options and in those are focus the attention of the scholars. Bradshaw and Borchers (2000). On the other hand, other researchers notice that it is not enough with a technical and economic analysis and to have a wider vision they propose to incorporate social and behavioural issues when evaluating RE, for example, West et al. (2010).

Diversification

Another gap in the literature is related to diversification. This concept is basic to avoid further unforeseen situations and renewable energies case is not an exception. Besides, recent scholars manifest that the fact of involving RE technologies into a portfolio of several generating resources makes cost and risk decrease Awerbuch (2000). However, this has not been widely studied in the literature about RE, so it becomes an interesting gap to cover.

In fact, this point of view has been used to check the results of RE in energy portfolios which include both renewable and non renewable resources. We clarify that it is important to consider diversification within a portfolio of RE technologies too, due to two main reasons:

1. First of all, by increasing the number of technologies in a portfolio, investors are less vulnerable when facing sudden changes including external factors that can influence in the viability of a specific RE technology, like regulatory frameworks, raw material costs or customers decisions.

2. Second assertion is related to the relation between investigation and operation. In environments marked where there is performance uncertainty, technological heterogeneity and the curve of experience affects, any policy selection that highlight the exploitation of the best current alternative in terms of the operational expenses, may cause the early finish of options that have the potential to be more worthy in the long term. Lee et al. (2003) and IEA (2009).

Chapter 4

Overview of renewable energies in the world

Renewable energies are defined as any naturally occurring source of energy which is not derived from fossil or nuclear fuel and they are theoretically inexhaustible on a human timescale. These sources include biomass, solar, wind, geothermal, tidal, wave, and hydroelectric power. While concerns about environmental should be taken into account in the same way by any country worldwide, each government has different ways of approaching problems and achieving goals. This chapter pretends to give an overview of renewable energies global situation and therefore, relevant issues such as financing techniques, countries committed to environmental protection, major indicators and most popular technologies are discussed from the information of UNEP (2014) and the European Commission.

4.1 Types of renewable energies

In one or the other way, most of the renewable energies derive from the Sun. Solar energy can be utilized for heating homes, lighting up buildings, to generate electricity, to produce hot water, cooling and a wide variety of industrial and commercial uses.

Heat from the Sun also boost winds and the energy generated by them is captured by turbines. Moreover, winds and Sun's heat make water to evaporate and when the vapor is transformed into snow or rain, it flows down to the rivers. Then, this energy can be collected by using hydro power.

Sunlight, together with rain and snow, helps plants to grow. The organic material which conforms those plants is the biomass. When biomass is used to generate electricity, chemicals or fuels, it is known as bioenergy.

Hydrogen which is usually found in several organic compounds (for example in water), it is the most bountiful element and it can be used as a fuel after burning it or transformed into electricity. One of the main obstacles to the implementation of the so-called hydrogen economy is the lack of production infrastructure, transport and storage of this element.

But not all renewable energies come from the Sun. The gravitational pull of the moon to the Earth produces the energy of the ocean's tides. Also, Earth's internal heat, geothermal energy, is used for many applications such as heating buildings and electric power production.

4.1.1   Wind power

Winds are produced due to the non-uniform heating of the atmosphere by the Sun, the Earth's rotational movement and the variability of the Earth's terrain. Wind flow are altered by the Earth's surface and other obstacles and when they are captured by wind turbines, they can be used to produce electricity. Basically, wind turbines transform the kinetic energy from the wind into mechanical energy and this, by using a generator, can be converted into electricity to supply power for schools, companies or homes.

It is believed that in the long term and if all technical barriers are solved, the potential production of wind energy will be forty times bigger than the current electricity demanded globally. For this propose, more wind turbines will be required especially in areas such as offshore with higher wind resources and wind speeds much stronger that the ones in land. In fact, wind produced almost 3% of the world's total electricity in 2013.

By regions, wind energy is very popular in Europe, USA and Europe. In the last ten years, wind power's installed capacity has been incremented from 47GW to 369GW worldwide. At the beginning of 2015, USA, Germany and China together represented the half of the total world's capacity. Other important countries in this sense are Spain, Denmark or Ireland. Globally, around eighty countries are using wind power with commercial purposes.

About wind energy's benefits and disadvantages, it must be pointed that it is free and a renewable resource, so it is not a problem how much it is used as it will be the same in the future. In addition, wind energy is a non-pulling and clean source of electricity. In this case, wind farms do not send out greenhouse gases neither air pollutants. As an example, according to the Department of Energy in of the United States, wind plants in California avoid the emission 1.000 mill Kg of CO_2.

The main concerns against wind farms are about noise generated by the blades, visual impacts and the avian and bats mortality. To solve and reduce these kind of problems, the tech development and the studies about sitting wind plants have helped a lot.

Possibly, the main challenge is the intermittence of the winds, so it doesn't blow always, but electricity is always needed. While generated electricity can be stores with batteries, wind cannot be saved. Moreover, the best locations always very far away from areas where the most of electricity is demanded (cities and industrial areas).

Due to there is no fuel to purchase and the operational expenses are very low, wind power's costs are much more competitive than other technologies. Despite the cost of wind energy has drop during the last decade, the initial investment requires higher expenses comparing to fossil-fueled generators.

4.1.2 Hydropower

Hydroenergy or hydropower is a type of renewable energy that is generated by the water stored in dams, but also the water flowing in rivers to produce electricity in hydropower plants. It also uses a turbine to help in the production process of electricity.

The rotating blades spin a generator that transforms the mechanical energy of the spinning turbine into electrical energy. The factors which affect to the quantity of electricity generated from each power plant are the flowing water and the height from which the water falls. In some hydropower plants, it is possible to find a PSH or a pumped hydroelectric storage system, so when the electricity demand is not too high, for example at night, water is pumped back to the dam and then, it can be used again when the need of electricity is higher.

Hydropower technology is not something new, in fact, the Greeks already used it to grind wheat into flour. In early 1800s, many factories in USA used it to power their facilities and machines. The first hydroelectric power plant was established at Niagara Falls in late 19th century, so the force of the falling water was used to produce electricity. While the electricity demand was quickly increasing but do not exist so many places such as Niagara Falls to leverage the force of the falling water, engineers started to think about developing places to build dams where turbine mechanisms can be installed. The first peak of hydropower technology was in the 1940s when it represented the 33% of the electricity in the United States.

One of the main benefits of hydropower is its capacity to generate clean energy. Moreover, there are other advantages that are obtained when a hydroelectric dam is built because it implies large recreational value like boating, fishing and water skiing. Besides, dams help to control floods and minimize soil erosion.

However, there are also environmental impacts due to they are structures built by humans. At the end, they affect to organisms living in the water and the rivers are containment as well as huge lakes are transformed. These constructions are an example of how human influence affect to the fish migration.

There are many factors which affected to the decrease of hydroelectric power production: a) damage to the environment and wildlife habitat, b) the increasing popularity of coal-based power plants and c) the high cost required for the construction of a hydropower plant. All three contributed the stagnation of power plants.

4.1.3 Solar energy

The main features of solar energy are that it is an inexhaustible and vast resource. Once the technical facility is settled to convert it into profitable energy, the fuel is free and it is supposed that the swings of the energy market cannot affect it. Moreover, it is a clean alternative to fossil fuels which pollute the water and the air a part from affecting negatively to the public health and increase the global warming. Due to the benefits and the wealth of solar energy, this resource must play a relevant role in the future.

As commented in the introduction, solar energy is the base of most of the other types of renewable energies used nowadays and it will be available for all Earth's life. The heat from the Sun produces different temperatures in different areas, which is the origin of the winds that power turbines. Thanks to the Sun, the plants can grow and these pants can be burned to be used as biomass. Sun makes water to evaporate and when it falls down as rain, it rushes down into the spins of hydroelectric turbines. But when talking about solar energy, it usually makes reference to the ways in which the energy from the Sun directly generates heat, electricity and lighting.

There are several types of solar energy, but there are different divisions depending on how it is converted to into useful energy and by the kind of energy it is converted into. The first group (how it is converted into useful energy) is divided in a) passive solar energy and b) active solar energy. The second group (type of energy it is converted into) is divided in three types: a) solar thermal energy, b) photovoltaic solar power and c) concentrating solar power. Now, this five kinds of solar power are described as follows:

- Passive solar energy: This refers to how to take profit from it without any mechanical device in the middle. For instance, by using south-facing windows to procure heat and natural lighting to the home.

- Active Solar Energy: The collection, storage and distribution to the home or the building is made by using mechanical devices. For instance, in water heating systems, pumps are needed to make the water flow along the circuit.

- Solar Thermal Energy: It is the energy created by converting solar energy into heat. Somel solar applications which can use to take advantage of solar thermal energy are Solar pool heating, solar space heating and solar water heating.

- Photovoltaic Solar Power: It is the energy created by converting solar energy into electricity using photovoltaic solar cells. Applications are solar electricity, photovoltaic cooling and photovoltaic solar lighting.

- Concentrating Solar Power (CSP): It is is a type of solar thermal energy that is used to generate solar power electricity. This technology is aimed at large-scale energy production.

4.1.4 Biomass

Biomass comes from cellular material from dead organisms which are recently dead. The EU Directive on Sustainable Electricity defines biomass as the biodegradable fraction of products, waste and residues from agriculture (including vegetable and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste.

Types of biomass which are used to generate bioenergy include a) Residues from forestry and related industries b) Recycled wood c) Agricultural residues d) Manures e) The organic part of municipal solid waste f) Household waste g) Purpose grown energy crops such as miscanthus grass or short rotation forestry

Biomass is based on combustion and it is a kind and it is a renewable and natural source of fuel for power generation and heat. There are many applications which can differ from stand alone heat plants to individual heating boilers in buildings. Nowadays, to create energy from biomass, the most common is to use a Power production in Combined Heat and Power (CHP) plant, where power and heat are generated from fuel in a single process making optimum use of the energy from biomass.

4.1.5 Geothermal energy

Geothermal energy comes from the heat from the Earth and it is clean and sustainable. Resources of geothermal energy arrive from the shallow ground to hot water and hot rock found a few miles beneath the Earth's surface, and even down to the extremely high temperatures where it is found the magma.

The elements which form a geothermal heat pump are: a) heat pump, b) an air delivery system and c) heat exchanger system with pipes buried in the shallow ground near the place to be heated. In the winter, the heat pump eliminates all the heat from the heat exchanger pumps it into the indoor air delivery system. In the summer, the process inverted, so the heat pump moves heat from the indoor air into the heat exchanger. The heat removed from the indoor air during the summer is usually used to provide hot water for free.

Geothermal power is reliable, sustainable, cost effective and environmentally friendly, but historically, it has been limited to areas near to tectonic plate boundaries. Nowadays, due to the technological advances, geothermal power have been widely expanded to applications like home heating. From the geothermal wells, it is also released greenhouse gases, but those emissions are very low compared to those with fossil fuels. If widely developed, geothermal power can have an inmportant role to fight against the global warming.

No fuel, except for the pumps, is required when using geothermal power. Thus, the fuel cost fluctuations do not affect it. However, there are many risks in the exploration step so capital costs are quite high.

A geothermal projects is divided in several stages of development. Of course, there are risks at each phase. Many projects are cancelled at an early stage of reconnaissance and geophysical surveys, many projects are cancelled, making that phase unsuitable for traditional lending. When a project moves forward from the identification stage, exploration and exploratory drilling often trade equity for financing.

4.2 Top countries and regions

Back in the 1970s, the development of renewable energy as a replacement for the eventual depletion of oil was promoted by environmentalists, In addition, to reduce the dependence on oil. Thus, appeared the first wind turbines to generate electricity. However, the cost of solar panels were too high to build solar farms until 1980.

Based on REN21's 2014 report, RE contributed 19% to the global energy consumption in 2012 and 22% to the electricity generation in 2013. This energy

consumption is divided as 9% coming from traditional biomass, 4,2% as heat energy, 3.8% hydro electricity and 2% is electricity from solar, wind, biomass, and geothermal. Worldwide investments in RE technologies increased to more than US$214 billion in 2013, with countries like the United States and China heavily investing in wind, hydro, biofuels and solar.

According to UNEP's 9th annual Global Trends in RE Investment 2015, developed by the Frankfurt School - UNEP collaborating Centre for Climate and Sustainable Energy Finance and BNEF (Bloomberg New Energy Finance), worldwide investments in renewable energy rised strongly last year, registering a strong 17% rise to $270 Billion in 2014 after two years of declines and overlooking the challenge from sharply lower crude oil prices. The main reasons were huge expansions of solar installations in Japan and China which supposed a record investment in offshore wind projects.

A ongoing severe decline in technology costs, specially in solar and wind, means that every US$ invested in renewable energy brought significantly more generating capacity in 2014. The 103GW of capacity aggregated by new renewable energy sources last year compared to 86GW in 2013, 89GW in 2012 and 81GW in 2011, made 2014 the best year ever for newly installed capacity.

Solar, wind, biomass and waste-to-power, small hydro, geothermal and marine power brought about 9.1% of world electricity generation in 2014, up from 8.5% in 2013. It meant that last year the world electricity system emitted 1.3 Gt of CO_2, practically twice the emissions of the world's airline industry, less than it would have if that 9.1% had been produced by the same fossil-dominated mix which generates the other 90.9% of world power.

Achim Steiner UN Under Secretary General and Executive Director of UNEP), explained that "In 2014, one more time, RE supposed almost half of the net power capacity added worldwide". "These climate-friendly energy technologies are now an indispensable piece of the global energy mix and their relevance will only increase as markets mature, technology prices continue to fall and the need to restrain in carbon emissions becomes ever more urgent".

According to Renewables 2014 Global Status Report (REN21), by the end of 2013, the United State, China, Brazil, Canada, and Germany remained the main countries for total installed renewable power capacity. The top countries for non-hydro capacity were again the United States, China and Germany, followed by India, Spain and Italy. Among the world's top 20 countries for non-hydro capacity, Denmark is the clear leader for total capacity per capita. Uruguay, Mauritius, and Costa Rica were among the top countries investing in new renewable power and fuels relative to annual GDP.

Benefits for any country: jobs and less energy dependency

It is world-known the environmental advantages of the renewable technologies as they are clean and abundant sources of energy which have a much lower environmental impact than traditional and conventional energy technologies. They will be the energy for our children as renewable energy will not run out ever while other sources of energy are finite and will one day be depleted. Related to energy security, renewable energy also has a lot to say. After the oil supply disruptions of the early 1970s, western countries have increased their dependence on foreign oil supplies instead of decreasing it. This increased dependence impacts negatively on the growth of any economy.

Among the reasons to justify how important renewable energies are, it must be highlighted their impact in jobs (see Table 4.1) and economy. The major part of renewable energy investments are dedicated to materials and workmanship to build and maintain the facilities, instead of on costly energy imports. Renewable energy investments are usually spent within a country, frequently in the same region or province, and often in the same town. This means that the energy investment stay at home to create jobs for local economies, instead of going overseas. Meanwhile, renewable energy technologies developed and built in a certain country are afterwards sold overseas, so it enhance the balance of trade balance and therefore the GDP of any country.

Table 4.1: Estimated jobs in renewable energy by industry (2013)

Type	World	China	Brazil	USA	India	Ger	Spain	Rest EU
Biomass	782	240	0	152	58	52	44	210
Biofuels	1.453	24	820	236	35	26	3	82
Biogas	264	90	0	0	85	49	0,5	19
Geoth	184	0	0	35	0	17	1,4	82
Hydro	156	0	12	8	12	13	1,5	18
Solar	2.819	1.930	30	143	153	68	40	184
Wind	834	356	32	51	48	138	24	166

Source: Own elaboration based in REN21 (Thousand jobs)

However, during 2013 and early 2014, taxes and fees on renewable energy were introduced retroactively in many European countries that previously supported renewable technologies. For example, Bulgaria enacted a 20% tax on revenues from wind installations and solar PV; the Czech Republic introduced an open-ended tax of 10% on revenue from solar PV installations which are larger than 30 kW; and Greece placed a 10% tax on revenue from renewable power generation in a retroactively way. Taxes on selfconsumption are being placed or considered as well. On top of existing grid access restrictions and fees, Spain introduced a tax

on the self-consumption of solar PV, while Germany has proposed a similar levy on electricity generated from rooftop systems larger than 10 kW.

Expansion beyond expectations

Scenarios from the renewable energy industry, Greenpeace, the World Bank, the International Energy Agency and others all expected levels of RE for the year 2020 which were already well surpassed by 2010. The energy crises beginning in the 1970s as well as economic downturns after each global oil shock, make made more important the role of energy in national and economic security. Also, a handful group of pioneering countries such as Denmark, Spain, Germany and the United States) created an early markets for renewables, which helped economies of scale and technological advances, helping to the market expansion. See Table 4.2 for a comparasion of the most engaged countries in electrict power capacity from renewable technologies.

Table 4.2: Renewable Electric Power Global Capacity (Top countries, 2013)

Type	World	EU-28	BRICS	China	USA	Germany	Spain	Italy
Bio	88	35	24	6,2	15,8	8,1	1	4
Geoth	12	1	0,1	0	3,4	0	0	0,9
Hydro	1.000	124	437	260	78	5,6	17,1	18,3
Ocean	0,5	0,2	0	0	0	0	0	0
PV	139	80	21	19,9	12,1	36	5,6	17,6
CSP	3,4	2,3	0,1	0	0,9	0	2,3	0
Wind	318	117	115	91	61	34	23	8,6

Souce: Own elaboration based in REN21 (GW)

4.2.1 EU countries

At the European Conference of Berlin that took place in 2004, the EU set itself an ambitious goal: that in 2020 it would reach a 20% use of renewable energies for its total energy consumption. But is it possible to get energy only using renewable sources? A report from the European Environmental Agency confirms that wind energy alone (Europe's onshore and offshore wind energy potential) would generate sufficient energy for Europe without any problem, its output for 2020 will be three times greater than the foreseen demand and this amount will increase to seven times by 2030. Reducing greenhouse gases and abandoning the dependency on petroleum use is therefore an achievable reality.

By 30 June 2010, the Article 4 of the Reneables Directive (2009/28/EC) requiered that every Member State must submit its National Renewable Energy Action Plan. These plans have to provide detailed information about how each country expects to achieve its 2020 target for the share of renewable energy.
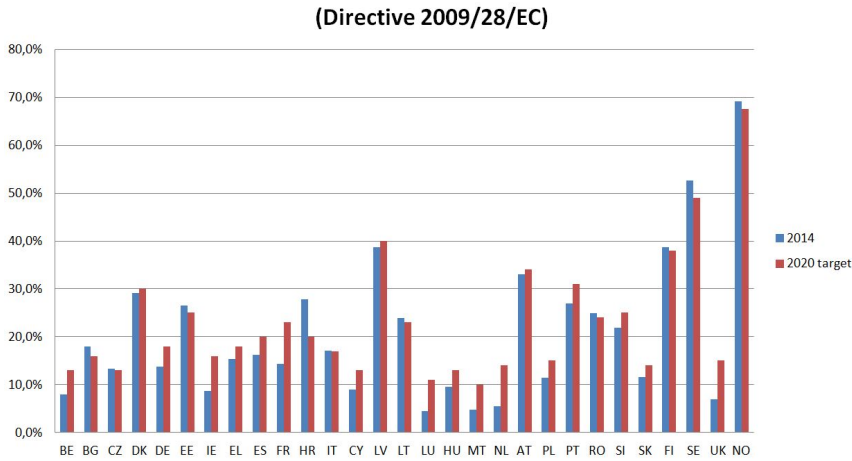
Figure 4.1: Share of energy from renewable sources - Source: eurostat

The latest reports show that the European Union as a whole reached more than the 15% mark. But the combined figure includes some countries already exceeding their targets, while others lag far behind. In fact, Norway and nine European Union member countries (Bulgaria, Czech Republic, Estonia, Croatia, Italy, Lithuania, Romania, Finland and Sweden) have already (in 2014) met their renewable energy goals for 2020. A number of other members are also well on their way to meeting their benchmarks, but othes are very far away. One of the most notably example is the U.K., that it is a long way away (see Figure 4.1).

As said, nine of the 28 EU member states have surpassed their 2020 goals. Sweden had one of the most ambitious goals, planning to produce 49% of its energy from renewable sources by 2020. It's already gone further than that, with 52.6% from renewable sources in 2014. The other countries above mentioned are also producing more than they had been targeting, six years ahead of schedule, due to a substantial growth in wind power, but Biofuels also chipped in a fairly large assist for countries such as Estonia.

Some countries, like Norway, have goals way above the collective 20%, and have already achieving them. Other countries do particularly well in certain technologies, like wind power in Denmark. But other countries are lagging far behind. The UK, which aims to produce 15% of its total energy from renewable sources by 2020, was only managing 7% in 2014. In the same sense, The Netherlands, France, and Ireland are all far away from their aims. Meanwhile, several EU member states have been accused of aiding the export and development of polluting technologies, even while making efforts to clean up at home.

Presented on 16th June 2015, the European Commission's renewable energy progress report reveals that 25 EU countries are expected to meet their 2013/2014 interim renewable energy targets. In 2014, the projected share of renewable energy in the gross final energy consumption was 15.3%. This report is generated every two years and EU countries must report on their progress towards the EU's 2020 renewable energy goals. Based on the national reports, the European Commission produces an EU-wide report which gives an overview of renewable energy policy developments in EU countries.

Findings from the latest EU-wide report in 2015

- 25 EU countries are expected to meet their 2013/2014 interim renewable energy targets

- In 2014, the projected share of renewable energy in the gross final energy consumption is 15.3%

- The EU's 2020 renewable target has resulted in around 326 Mt of avoided CO_2 emissions in 2012, rising to 388 Mt in 2013

- It has also led to a reduction in the EU's demand for fossil fuels to the tune of 116 Mtoe (Million Tonnes of Oil Equivalent).

- The 2014 projected share of renewable energy in transport is 5.7% meaning that achieving the target will be challenging but feasible, with some EU countries making good progress.

- Just three EU countries are falling slightly behind in meeting their targets, and, since the interim targets will become tougher in the coming years, some EU countries will have to intensify their efforts and make use of mechanisms which allow them to cooperate with other EU countries, the report says.

- It also noted that renewable energy is now a widely accepted, mainstream source of energy, with the 2020 targets being a key driver for European-led global investments in renewable's and a source of inspiration for other countries all over the world, which now have their own targets.

- The EU's target for 10% renewable energy in transport. The 2014 projected share is 5.7% meaning that achieving the target will be challenging but feasible, with some EU countries making good progress.

The report shows once again that Europe is good at renewables, and that renewables are good for Europe. In Europe there are three times more renewable power per capita than anywhere else in the rest of the world. Europe has more than one million people working in a renewable energy sector worth over 130 bn a year and we export 35 bn worth of renewable every year, Miguel Arias Canete, Commissioner for Climate Action and Energy, said. The EU's 2020 renewable target has
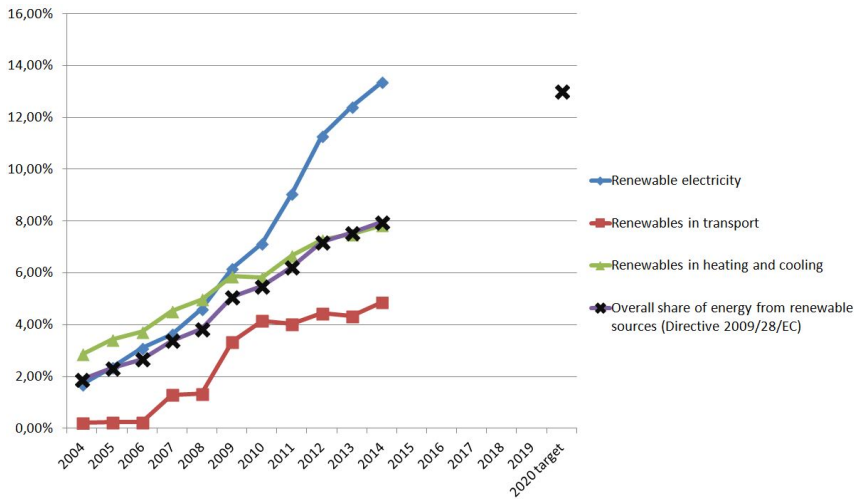
Figure 4.2: Belgium Share of energy from renewable energy - Source: eurostat

resulted in around 326 Mt of avoided CO_2 emissions in 2012, rising to 388 Mt in 2013. It has also led to a reduction in the EU's demand for fossil fuels to the tune of 116 Mtoe, boosting the EU's security of energy supply.

A basic report for the EU countries and Norway is made hereafter. Also, it is shown the 2020 target and the current situation in terms of renewable electricity, renewables in transport and renewables in heating and cooling for each country.

Belgium

Belgium is considered a breeding ground for many successful companies which are at the forefront of renewable energy technology. With world-leading knowledge in the fields of wind, biomass and solar energy (both thermal & photovoltaic), Belgian companies are addressing the current energy challenges in terms of innovtion and creation.

While the law is clearly focus on renewable energy, still there is an energy gap to cover is such a short time. In 2011, the federal and regional Ministers for Energy started a consortium with the Federal Planning Bureau in order to explore the future of renewable resources in Belgium. In December 2012, this consortium published an ambitious report explaining that they believed the country would be able to run 100% on renewable energy by 2050.

The country is still far from the 2020 target (see Figure 4.2), but the tendency regarding the consumption of energy from renewable sources is cleary growing since 2004.
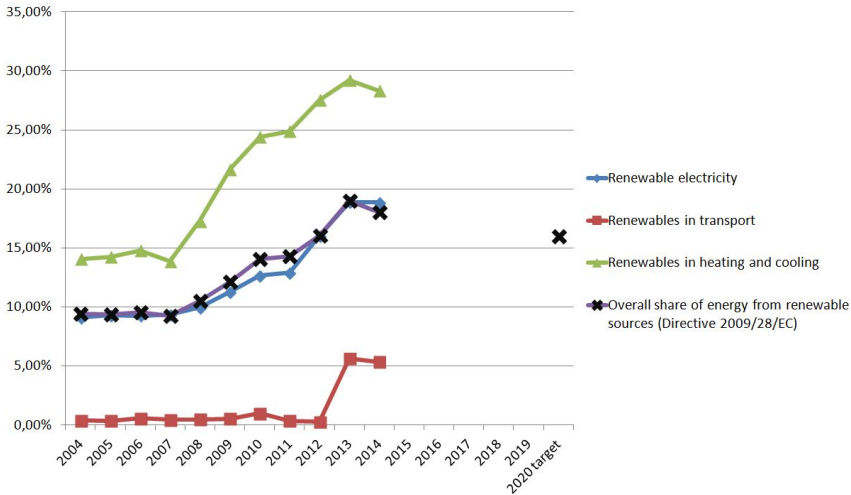
Figure 4.3: Bulgaria Share of energy from renewable energy - Source: eurostat

Bulgaria

According to official reports, Bulgaria has already fully achieved, and very in advance, the target of the "Europe 2020" strategy about the consumption of energy from RE sources. However, the sector is facing a big administrative crisis, confusion and possible disaster, unless a sustainableand long term strategy is quickly set up.

Several organizations say that the majority of the projects were not realistic and their origin was the speculative fever which affected to Bulgaria. Georgi Stefanov, expert on energy and climate change for WWF (World Wildlife Fund) Bulgaria, explains that recent period has been characterised by a very generous goverment attitude and the lack of coordination between the institutions responsible for supporting and managing the development of renewable energy.

Despite the lack of a good strategy from the central goverment, the sector of RE experienced a very fast development, especially for solar energy, wind farms and new hydroelectric power plants. The peak of installed capacity was reached in 2013 when Bulgaria's share of renewables was nearly 20% (see Figure 4.3), against a target of 16% for 2020. A big increase was from 2004 to 2011, when the share of renewables in gross final energy consumption of Bulgaria amounted from 9.6% (year 2004) to 14.6% in 2011.
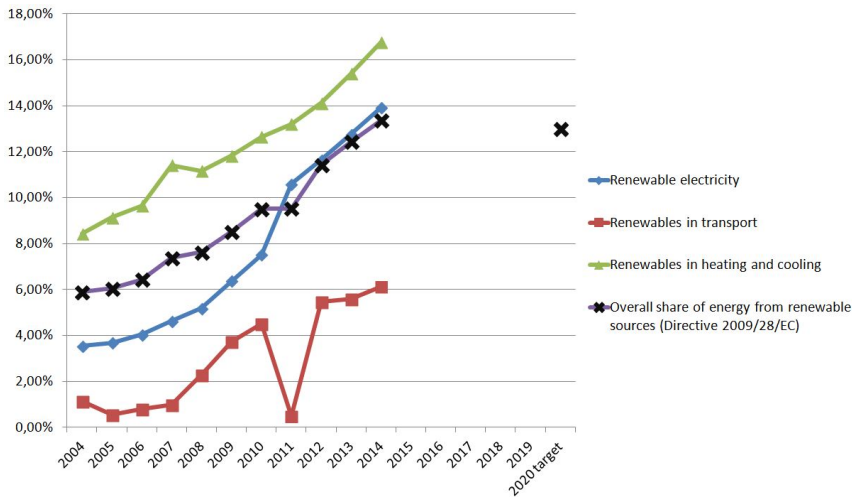
Figure 4.4: Czech Republic Share of energy from renewable energy - Source: eurostat

Czech Republic

The Commission marked a minimum target of a 13% share of energy from renewable sources in gross final energy consumption (see Figure 4.4). The achievment of this target must also ensure a minimum 10% share of energy from renewable sources in transport.

The National Renewable Energy Action Plan for the Czech Republic (hereinafter the National Action Plan) being presented suggests (foresees) fulfilment of a 14% share of energy from renewable sources and a 10.8% share of energy from renewable sources in transport in gross final energy consumption in 2020. Progress is in the right direction, in fact, Czech Republic is one of the countries which already have surpassed the 2020 target in 2014 (13,4%).

Denmark

Denmark really understands renewable energies, in fact, factby 2035 this country expects to use 100% RE, and by 2050 they would not be using fossil fuels anymore. In addition, it is known that it has complete support from the country's political spectrum, which is not something usual in many countries. Moreover, it is Danish government policy that by 2020, Denmark will be a green, sustainable society and it will be among the three most energy efficient countries in the OECD. Besides, government's long term energy political strategy is that Denmark will become independent of fossil fuels.
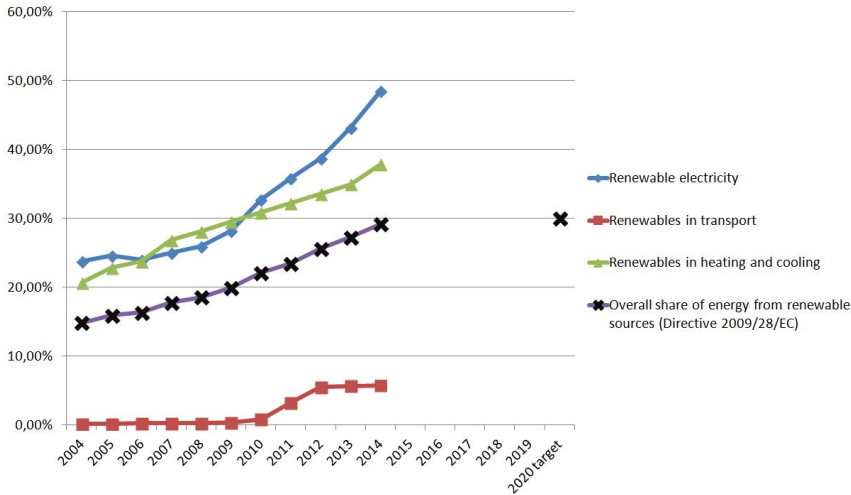
Figure 4.5: Denmark Share of energy from renewable energy - Source: eurostat

Denmark has pursued an active energy policy since the 1970s, with energy saving and renewable energy as high priorities. There is still a need to continue with efforts in these areas in order to deal with the many challenges faced by society today, whether it is in relation to economic considerations, the climate or environment, or ensuring a high degree of supply reliability.

Denmark's share of renewables in gross final energy consumption was 29,2% (see Figure 4.5), against a target of 30% for 2020, so they almost achieve in advance.

Germany

In Germany's energy strategy he development of renewable energies is a key element. The development of renewable energies in Germany is to be carried on in the future. In the long term, the majority of energy supply will be covered by renewable energies.

The National Action Plan under Directive 2009/28/EC states that the development of renewable energies in Germany will continue to be forcefully promoted. In this National Action Plan, the Federal Government estimates the share of renewable energies in gross final energy consumption to be 18% in 2020 (see Figure 4.6). The share of renewable energies in the electricity sector will thereby amount to 38.6%, the share in the heating/cooling sector will be 15.5%, while in the transport sector it will be 13.2%.
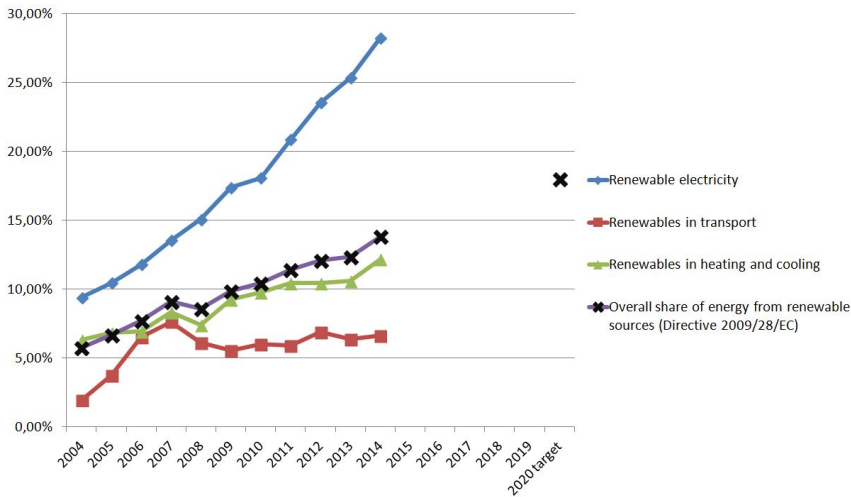
Figure 4.6: Germany Share of energy from renewable energy - Source: eurostat

Estonia

Estonia already reached their 2020 targets in 2012 (see Figure 4.7). This was thanks to the increased of biomass production, that has been criticized for its tendency to increase carbon emissions. But wind output also rose by 23% due to three new wind parks.

The main support measure for the production of energy from renewable energy sources in Estonia is the obligation of the grid operator to buy renewable energy sources at feed-in tariffs. Other support measures include investment subsidies and support for technological investments by the European Union and state budget.

Ireland

It has excellent renewable energy resources, which will be a critical and growing component of Irish energy supply to 2020 and beyond. Indigenous renewable energy already plays a vital role in our domestic fuel mix. It also increases sustainability through the use of clean power sources and enhances energy security by reducing Ireland's dependence on imported fuels. Wind, bio-energy and solar energy could yield additional opportunities for Irish business and domestic consumers.

Under the 2009 Renewable Energy Directive, Ireland is committed to produce from renewable sources at least 16% of all energy consumed by 2020 (see Figure 4.8). This will be met by 40% from renewable electricity, 12% from renewable heat and 10% from the renewable transport sector.
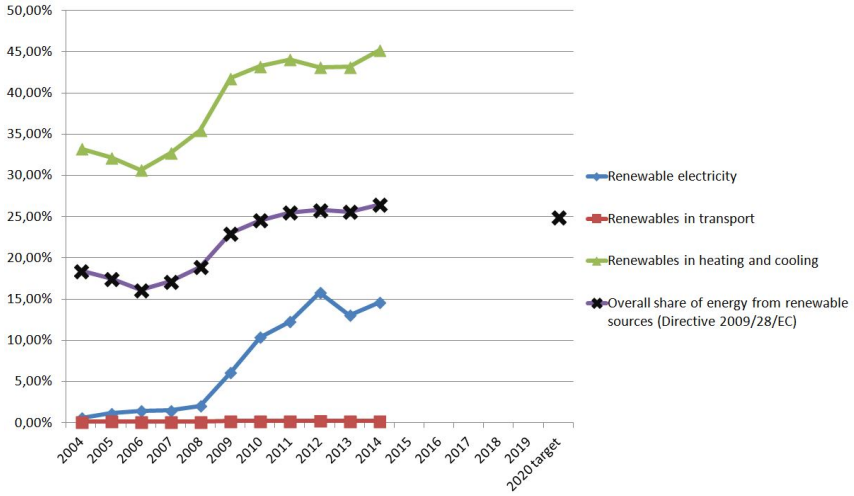
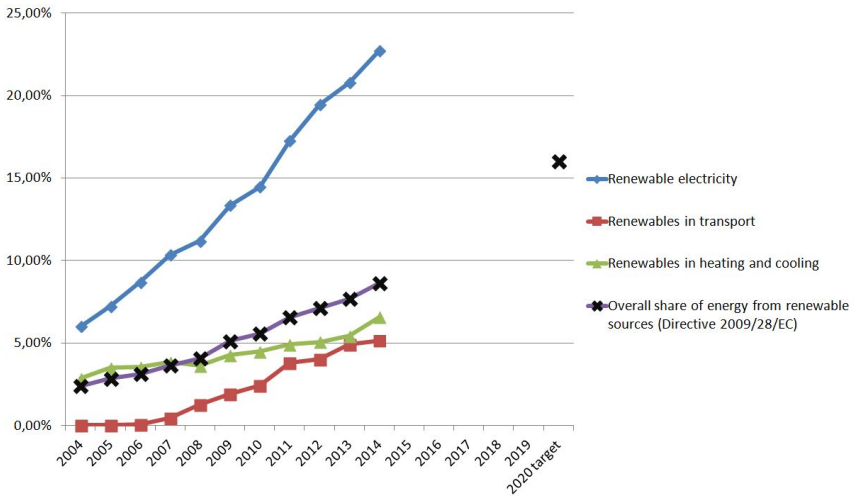**Figure 4.7:** Estonia Share of energy from renewable energy - Source: eurostat

Figure 4.8: Ireland Share of energy from renewable energy - Source: eurostat
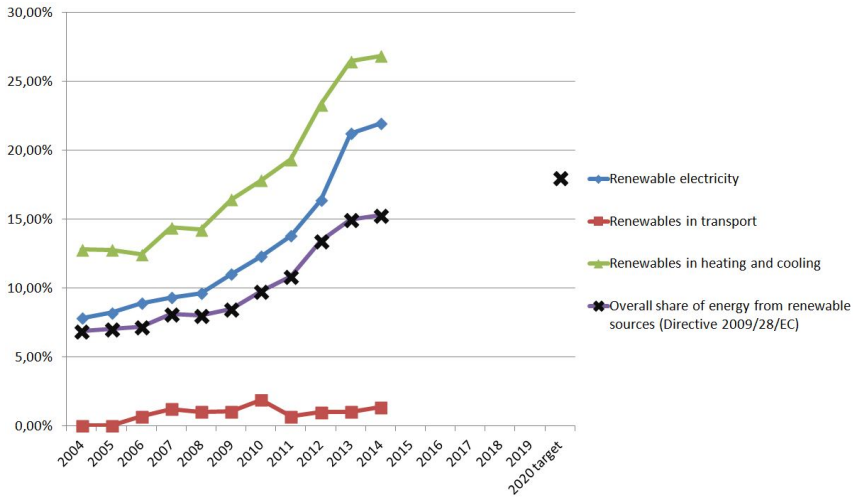
Figure 4.9: Greece Share of energy from renewable energy - Source: eurostat

Greece

The Greek energy sector is still very dependent on fossil fuels, most of which are imported. Domestic energy sources include lignite which accounts for around 50% of electricity generation as well as renewable energy source such as hydro-power, wind, solar energy and biomass. RE currently account for 15,3% of gross final energy consumption in 2014 and a national target of a 18% share by 2020 has been set (see Figure 4.9).

By technology, solar PV is starting to play a substantial role in electricity generation meeting nearly 6% in Greece and it is one of the leaders when talking about PV per inhabitant.

France

France has reaffirmed its commitment in favour of the Mediterranean Solar Plan (MSP). This plan may lead it to put in place cooperation mechanisms (joint projects) with non-member Mediterranean rim countries. In this case, the contribution of additional renewable energies would permit France to exceed its target of 23% of energy produced from renewable resources in the gross final energy consumption in 2020 (see Figure 4.10)

Regarding medium and large scale facilities for renewable energy production, the choice has been made to consider all sources of renewable energy, in order to position France as a major actor in all production technologies. Various incentives and aid schemes have been established: financial aid for research and development
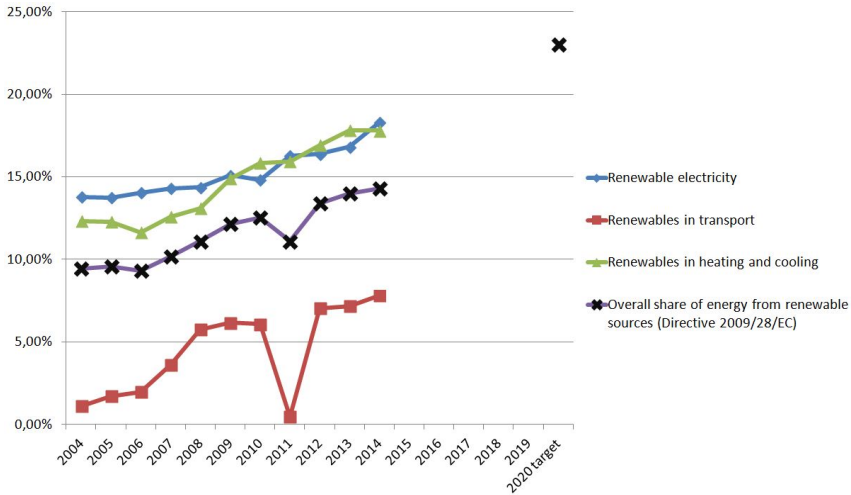
Figure 4.10: France Share of energy from renewable energy - Source: eurostat

projects, aid for the creation of industrial demonstrators, aid for the installation or purchase of equipment, soft loans, etc. France intends to position itself as the leader in technologies as diverse as wind power, maritime energies, solar photovoltaics and thermodynamic and biogas units.

Croatia

At the beginning of August 2015, in Croatia there were 1,207 power plants which use renewable energy sources, while the total capacity of these plants was 430.88 MW, reported the Croatian Energy Association. The energy system now has 130 new solar power plants, one hydroelectric plant, three plants which use biomass and three biogas power plants. By installed capacity, the biggest single plant which uses renewable energy sources is the "Wind Farm Velika Glava, Bubrig i Crni Vrh", with the installed capacity of 43 MW. It is projected that soon another 138 plants with total power of 502.61 MW will start to operate.

In 2013, The Croatian government adopted a national action plan for renewable energy sources until 2020 which shifts the focus from encouraging wind farm construction to energy production from biomass, biogas, cogeneration plants and small hydroelectric power plants, reducing the total incentive costs. The plan is in line with the European Union directive on renewable sources which contains measures through which member countries must ensure 20% of renewables in energy consumption by 2020 (see **??**)
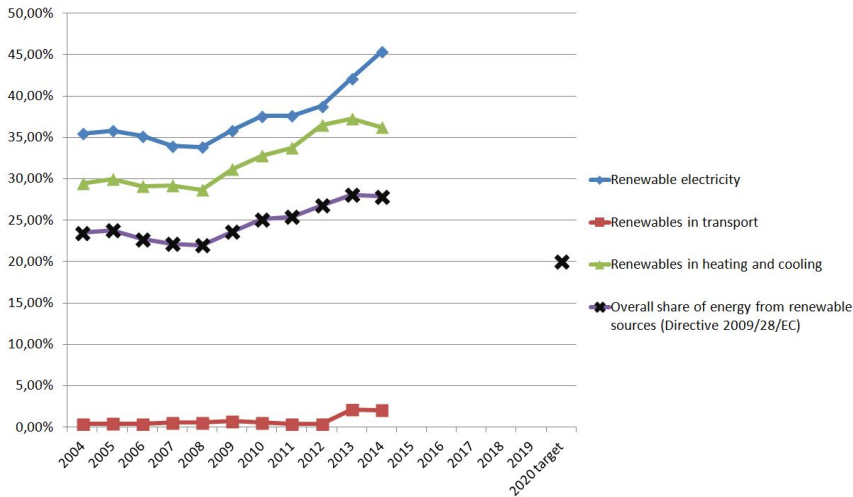
Figure 4.11: Croatia Share of energy from renewable energy - Source: INTRASTAT

Italy

By the end of 2013, it was one of the top countries for non-hydro capacity. In Italy, solar PV met 7.8% of total annual electricity demand. Also, it is one of the top countries for bio-power. For example, Italy alone saw its number of operational biogas plants increase from 521 to 1.264 within a year, driven primarily by a high feed-in tariff and support focussed on small-scale plants. Novozymes and Beta Renewables opened a new commercial plant in Italy which, as of commissioning in October, was the world's largest advanced biofuels facility. The plant will produce ethanol from rice straw, wheat straw and arundo donax (a high-yielding energy crop that is grown on marginal land).

In 2014, Italy already achieved the 2020 target (see Figure 4.12) and the govement's plan is to continue with this tendendy.

Cyprus

At the end of 2012, Cyprus remained the world leader on a per capita basis considering all water collectors, with 548 kilowatts-thermal (kWth) per 1,000 inhabitants, followed by Austria (420 kWth), Israel (385 kWth), Barbados (320 kWth), and Greece (268 kWth). Cyprus also reinstated a solar heating and cooling support programme to provide investment subsidies in the form of grants of up to USD 4,129/kWth.

Under the 2009 Renewable Energy Directive, Cyprus is committed to produce from renewable sources at least 13% of all energy consumed by 2020 (see Figure 4.13).
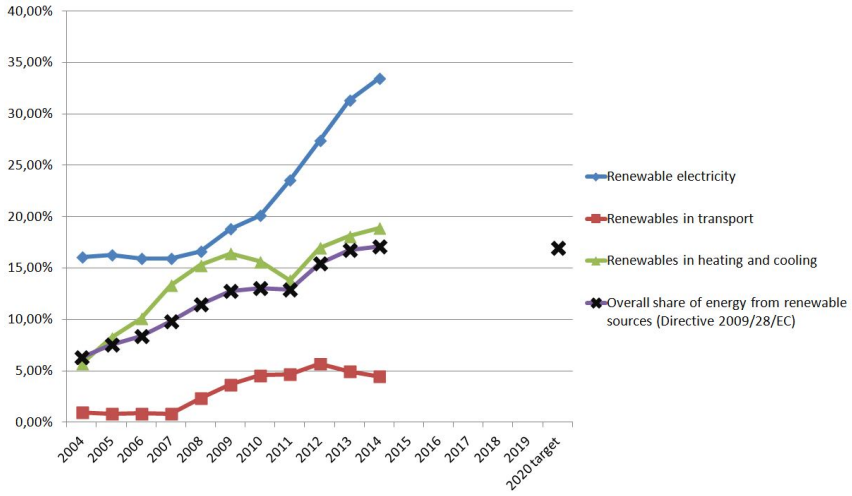
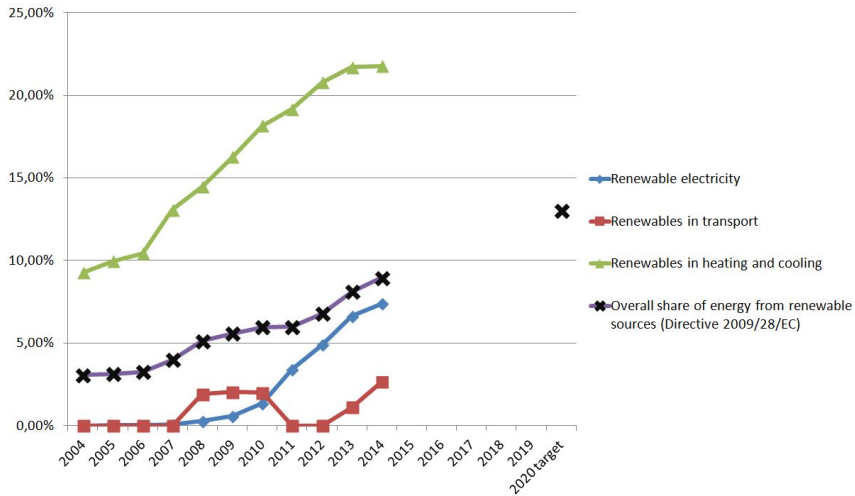**Figure 4.12:** Italy Share of energy from renewable energy - Source: eurostat

Figure 4.13: Cyprus Share of energy from renewable energy - Source: eurostat
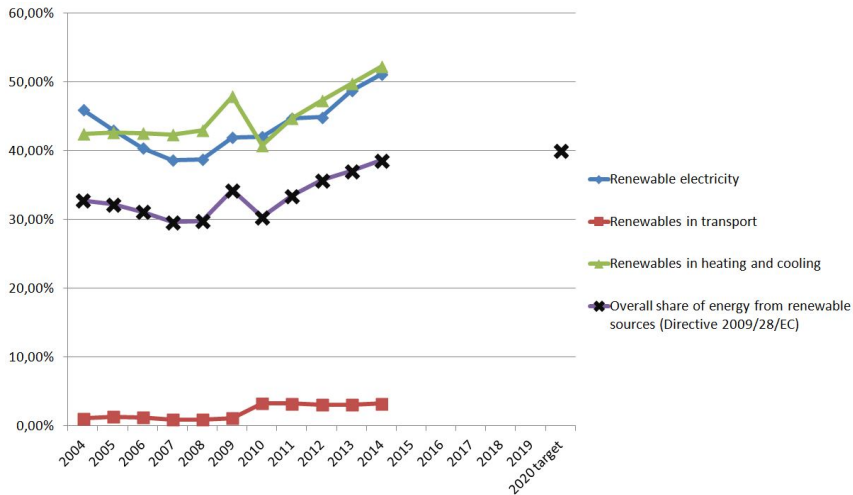
Figure 4.14: Latvia Share of energy from renewable energy - Source: eurostat

Currently, it is only 9%, so it means that Cyprus must focus on covering this gap.

Latvia

In the northern portion of Latvia, which include the Baltic coast and western coast of the Gulf of Riga, wind power is the most viable and developed renewable energy due to with high wind speeds.

The share of renewable energy reached in 2013/2014 was very high. Achieving 37.08% in 2013 and 38.65% in 2014, when Latvia made significant progression in expanding the use of renewable energy. The increase in the RE share in the electricity sector has been supported by a mechanism implemented as a mandatory procurement of electricity. In the heating sector, the installed capacity of CHP plants and boilers using RE is also increasing. In 2012, their total installed heat capacity constituted 19% of the capacity of all the boilers and CHP plants. Whereas, in 2014, the total installed heat capacity increased to up and constituted 28.4% of the total heat capacity. It's expected that this growing tendency in the heating sector will carry on in the next years.

The country is very near from the 2020 target (see Figure 4.14), in fact, the tendency regarding the consumption of energy from renewable sources is cleary growing since 2010.
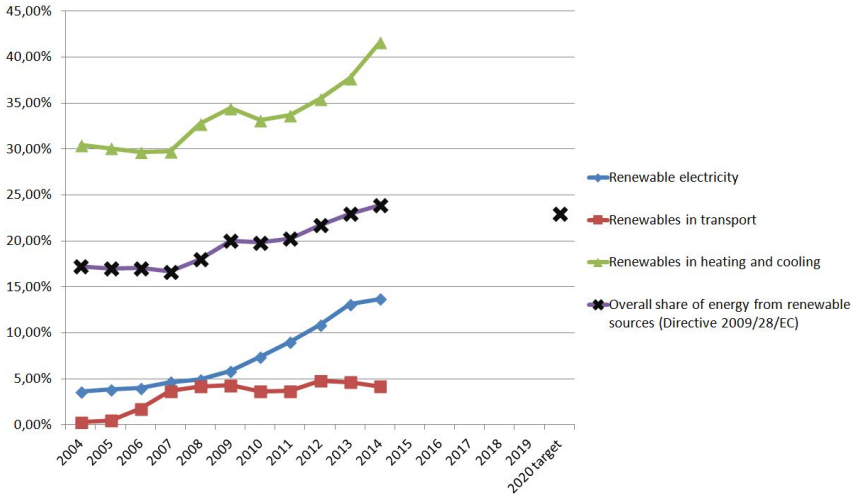
Figure 4.15: Lithuania Share of energy from renewable energy - Source: eurostat

Lithuania

Lithuanian energy policy places an increasingly great emphasis on the development of renewable energy sources. It is considered to be one of the most important priorities of the National Energy Policy. Goverment knows that the development of renewable energy sources will ensure an attractive alternative to traditional energy because the combustion of fossil energy sources substantially increases environmental pollution and accelerates climate warming, which causes natural disasters more and more frequently. The use of renewable energy sources not only helps to resolve problems of climate change, but also creates conditions to combat poverty and problems of energy and economic exclusion.

The aim of the development of renewable energy sources is to ensure that the share of renewable energy sources in the country?s total final consumption of energy would reach at least 23% in 2020 (see Figure 4.15), but in reality, it was already passed in 2014 (23,9%)

Luxemburg

Renewable energies represent to Luxembourg a basic pillar for the establishment of a sustainable energy system. The critical reasons for the promotion of renewable energies in Luxembourg lie in their contribution to supply security, environmental protection and economic development.

Generally the Luxembourg strategy for renewable energies should make an efficient link possible between the energy and economic policies of the country. In this way,
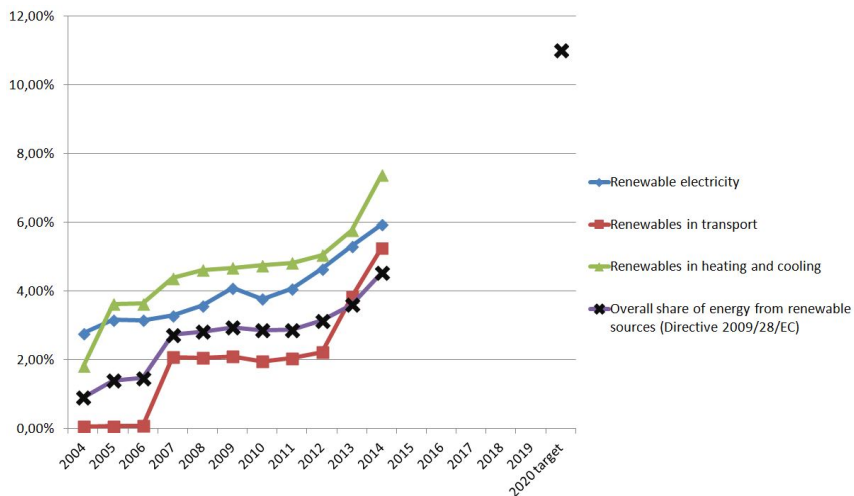
Figure 4.16: Lithuania Share of energy from renewable energy - Source: eurostat

the creation of new jobs and investment opportunities as well as the stimulation of the economy will accompany the plan for the continuous development of renewable energies in Luxembourg. In any case, the country is still far (4,5%) from the 2020 target, which is set at 11% (see Figure 4.16).

Hungary

Hungary is highly dependent on energy source imports, and fulfils 80 percent of its domestic crude oil demand, and over 83% of its natural gas consumption from imports, primarily from former CIS countries (due to the limited hydrocarbon reserves of the country, the share of imports may increase further). Through the use of renewable energy sources, the dependency on imports can be reduced, as the use of renewable energy is planned to be realised from domestic sources.

Hungary is committed to reducing CO_2 emissions and the current document presented as action plan for 2010-2020 sets, in accordance with national interests, the achievement of a realistic target of 14.65% by 2020, which exceeds the obligatory minimum target (see Figure 4.17)

Malta

Renewable Energy Action Plan (NREAP) highlights the need to step up efforts on all fronts for Malta to achieve the 2020 target for a Renewable Energy Share. Malta together with all other European Union member states have agreed on legally binding national targets for increasing the share of renewable energy, so as to achieve a 20% share for the entire Union by 2020.
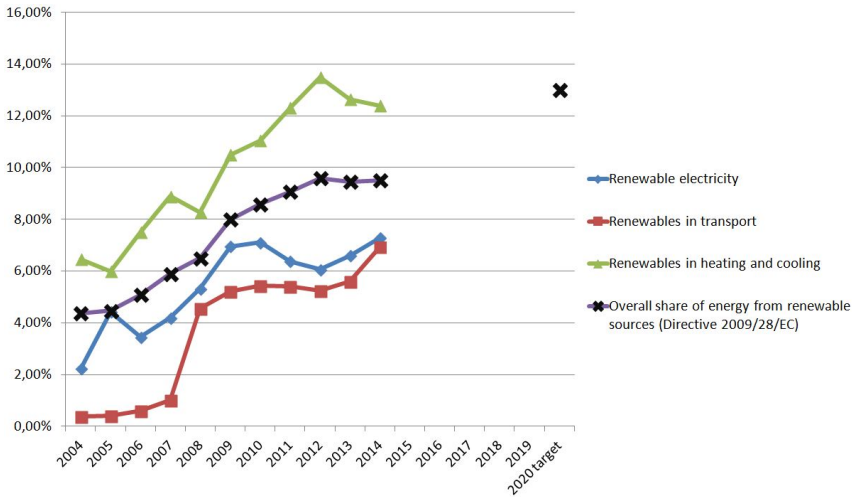
Figure 4.17: Hungary Share of energy from renewable energy - Source: eurostat

Therefore, Malta's main aim is to incentivise and facilitate the renewable energy industry. Large wind farms, micro wind turbines, large solar farms and other smaller commercial initiatives are all potentially capable of absorbing a significant amount of our target output. However, the country is still far from the 2020 target (see Figure 4.18)

Netherlands

Its action plan describes how the Netherlands intends to achieve the Renewable Energy Directive target of 14% renewable energy in 2020 (see ??). The government wishes to tackle these challenges together with society. By doing this, the government can build up greater momentum than it would by imposing measures on society. In this energy transition plan, the government and market work together, focusing particularly on the transition paths which offer the best opportunities for the Netherlands.

These projections contain the indicative development of renewable electricity up to 2020, in which cost effectiveness is a key condition: large scale additional burning and combined burning of biomass in coal-fired power stations, onshore and offshore wind energy are the dominant aspects of this scenario.

There are also good reasons for investing in renewable energy. The Dutch renewable energy policy is driven by the need to help tackle the climate problem, to safeguard a secure energy supply and to maintain the long term affordability of energy. In addition, it is also a major incentive for innovation and economic activity.
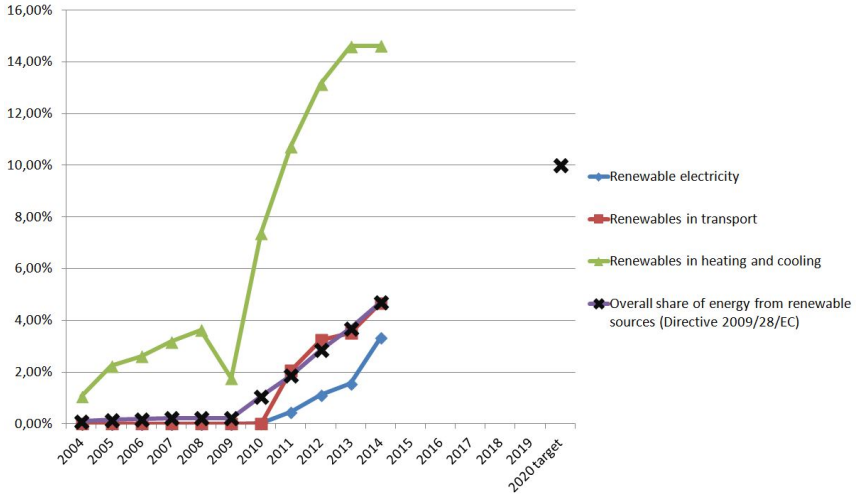
Figure 4.18: Malta Share of energy from renewable energy - Source: eurostat
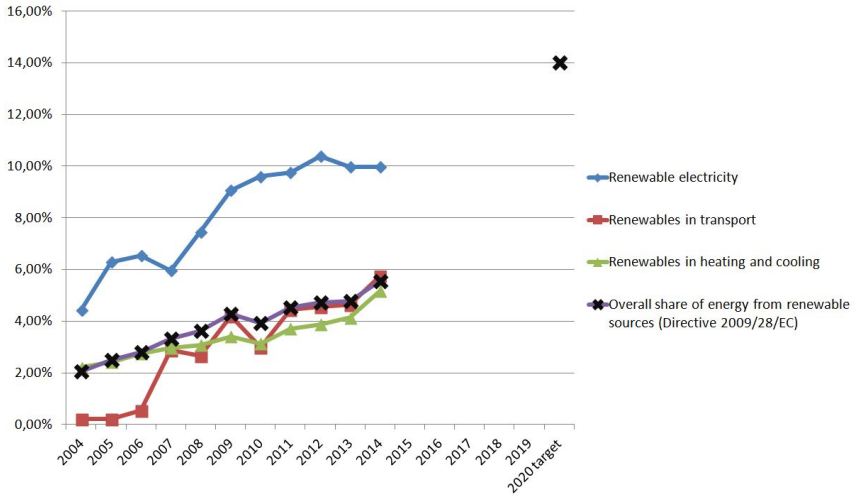
Figure 4.19: Netherlands Share of energy from renewable energy - Source: eurostat
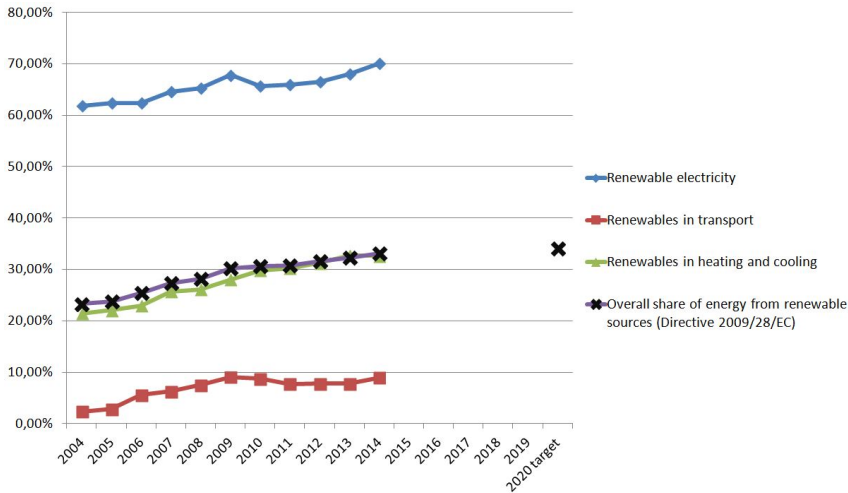
Figure 4.20: Austria Share of energy from renewable energy - Source: eurostat

Austria

Austria is good example of economic development based on renewable energy. Its percentage was 33,1% in 2014, nearing the 34% for 2020 set by the European Union (see Figure 4.20). Biomass has about three years operation in Austria and reflects the country's philosophy on renewable energies, due to it reachead an amazing 90% efficiency.

The strategic goal of the national development of renewable energy sources is to satisfy the demand for energy with local resources to the maximum extent possible, to abandon imported polluting fossil fuel, thus improving the reliability of energy supply and energy independence and to contribute to international efforts to reduce emissions of greenhouse gas by increasing the share of renewable energy sources in the country's energy balance, in the electricity and heating, and transport sectors.

Poland

The document entitled Energy Policy of Poland until 2030 presents the strategy of the country which aims to address the most important challenges that the Polish energy industry must face, both in the short and in the long term, until 2030. In accordance with this document, that was adopted by the Council of Ministers on 10 November 2009, the progress made in wind energy production, biogas and solid biomass production and in transport biofuels it has a decisive importance in the context of achieving the objective of 15% share of energy from renewable sources (see Figure 4.21) in the gross final energy structure by 2020.
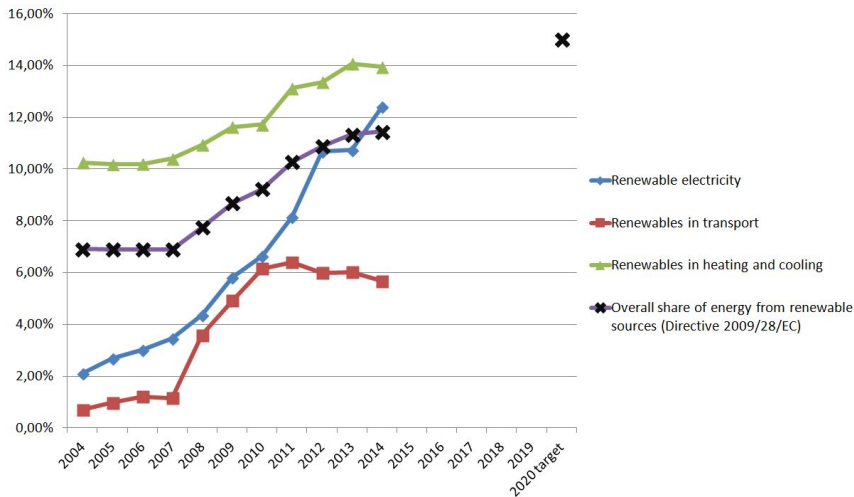
Figure 4.21: Poland Share of energy from renewable energy - Source: eurostat

Taking into account the development of RE in the electricity sector, the development of sources based on biomass and wind energy is primarily expected as well as an increase in the number of small hydro power plants has also been assumed. Taking into account the development of RE in the heating and cooling sector, maintaining the market structure existing until now has been expected, taking into account the development of solar and geothermal energy.

Portugal

From the point of view of security of supply, for a nation like Portugal, which doesn't have have fossil fuel reserves, renewable energy sources play an essential role in reinforcing levels of security, while at the same time they promote the diversification of the energy mix by enhancing the sustainability associated with the production, transmission and consumption of energy. Nowadays, the energy sector plays a structural and fundamental role in society and in the Portugal's economy. In fact, all agents in the sector have unanimously recognised that there is a very significant potential for developing renewable energy in Portugal. This recognition has been reflected in the growing importance of sources of renewable energy in various sectors of activity: ranging from the transport industry to the domestic sector but, above all, in the production of electricity.

To guarantee compliance with Portugal?s commitments in the context of European energy policies and the policies to fight against climate change, one of the main objectives of the national energy plan includes to ensure that 31% of the gross final energy consumption (see Figure 4.22), 60% of the electricity produced and
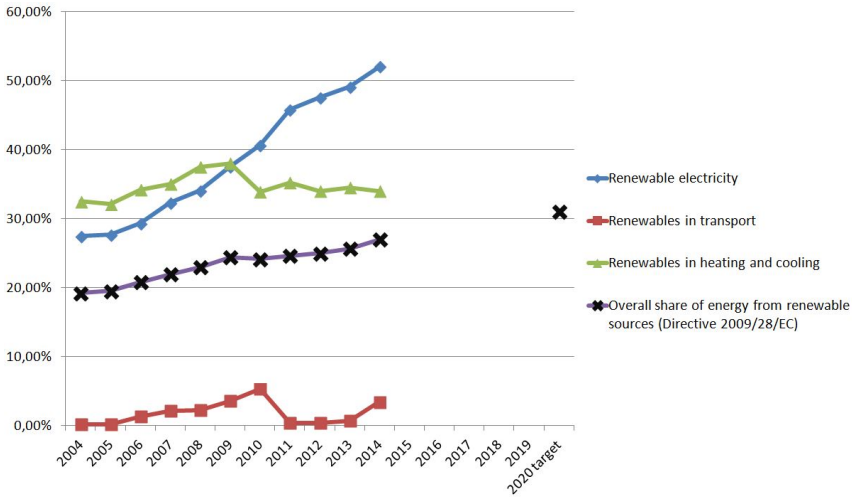
Figure 4.22: Portugal Share of energy from renewable energy - Source: eurostat

10% of the energy consumption in the road transport sector will be derived from renewable sources in 2020

Romania

The renewable energy contribution, such as the forest biomass, the solar energy and the geothermal energy, has already in 2014 achieved the objective of 24% set for 2020 (see Figure 4.23 and assumed through Directive 28/2009.

The country has focus both on the electricity production in the combined power and heating plants by efficiently using the biomass for the production of thermal energy in separate stoves and replacing the classical stoves in the households from the rural area (which have low efficiency below 20%) by systems using modern technologies that have a higher efficiency, about 80%; and by using solar energy for the production of heating and domestic hot water for individual households, tourist establishments, farms and for the public sector such as schools and administrative offices.

Slovenia

In accordance with Directive 2009/28/EC, the measures in the national plan are formulated on the basis of targets regarding the share of energy from renewable sources for 2020 in the following sectors: heating and cooling, electricity and transport. The total value of all three sectoral targets, including the planned use of flexibility mechanisms, must be at least equal to the expected quantity of energy
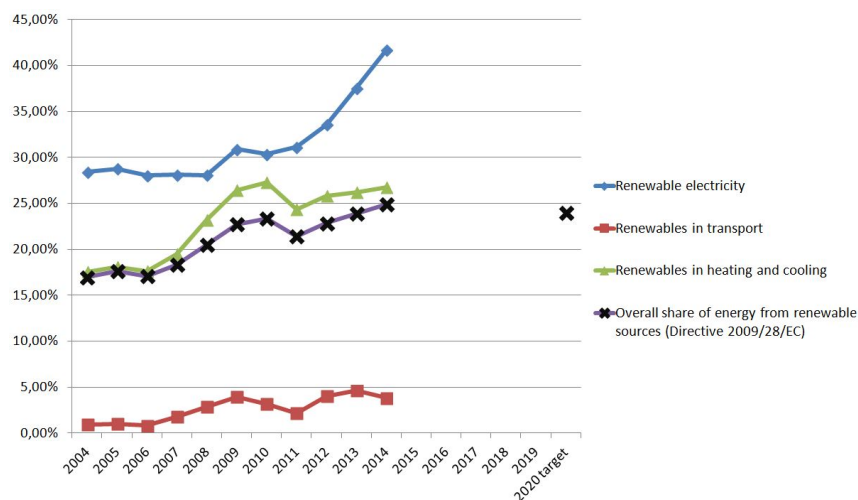
Figure 4.23: Romania Share of energy from renewable energy - Source: eurostat

from renewable sources, the share of which for Slovenia in 2020 is equal to 25% (see Figure 4.24).

The most important renewable source of energy in the country is wood biomass, followed by hydroenergy, while in recent years development has been most dynamic in exploiting solar energy and biogas. The potentials of these energy sources, plus the potentials of wind and geothermal energy, will contribute to increased consumption of renewable energy sources.

Slovak Republic

The gas crisis in early 2009 was an unprecedented situation which saw supplies of Russian gas intended for Slovakia, transmitted via Ukraine, come to a complete standstill for several days. During this period of crisis, the heat sector's high dependence on natural gas highlighted the vulnerability of heat supply security. Slovakia's reserves of individual energy sources indicate that only renewable energy sources (especially biomass) can play a role in reducing overall dependence on natural gas imports.

The expected amount of energy from renewable sources corresponding to the 2020 target of 14% (see Figure 4.25 is based in the use of biomass which can compete with fossil fuels in terms of price, combined with energy savings and geothermal and solar energy. In the field of biofuels, significant growth is projected by around 2020, which will make an appreciable contribution to the target of 10% use in transport.
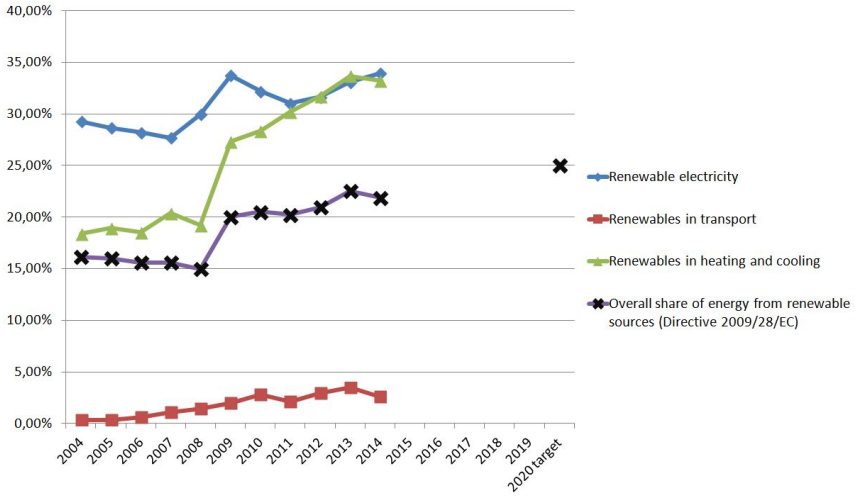
Figure 4.24: Slovenia Share of energy from renewable energy - Source: eurostat
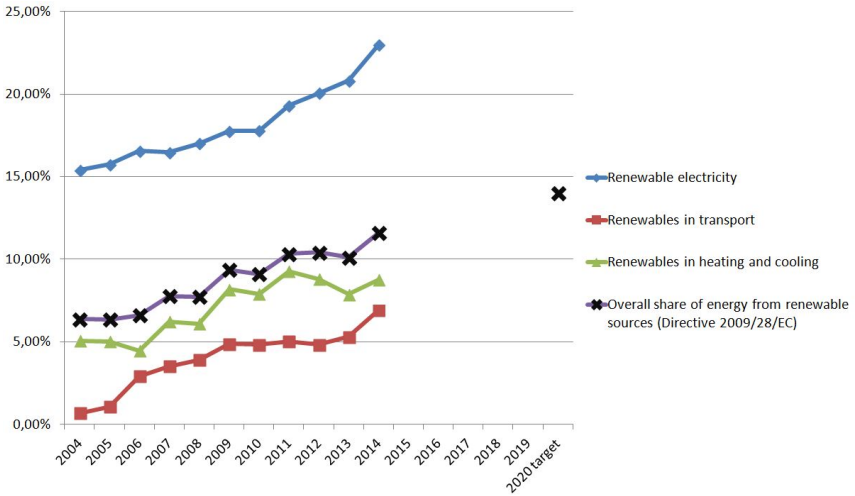
Figure 4.25: Slovak Republic Share of energy from renewable energy - Source: eurostat
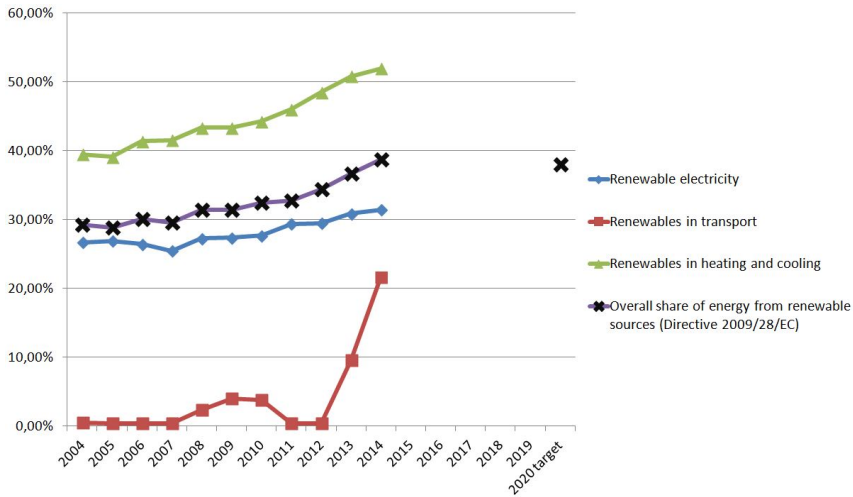
Figure 4.26: Finland Share of energy from renewable energy - Source: eurostat

Finland

Target of energy from renewable sources in gross final consumption of energy in 2020 is 38%, has been already reached in 2014 (see Figure 4.26). Main technologies which have contributed to this objective has been wind power production and the the use of wood chips. But other renewable enery sources like hydropower, heat pumpus, biofuels and biogas also play a very important role for this commitment.

Sweden

Swden is developing while using limited coal, which is also more beneficial for the environment and affordable for the consumer. In addition, that is has been commended by the International Energy Agency (IEA) for its energy policy. By early 2010, the Northen European country already produced more energy from biomass than from petroleum. Eurostat, the main entity that keeps data on the EU, released announces that Sweden leads the way for all EU members with 51% of its energy coming from renewable. It is only surpassed by Norway, that is not an EU member, in renewable production in Europe.

Apart from being one of the first EU countries to surpass its renewable energy goals for 2020 (see Figure 4.27), Sweden's coalition government has established an ambitious program which will involve to the Nordic country an energetic approach that could eliminate fossil fuels in next coming decades. The plan is very ambitious, as the country is closing its nuclear power plants, but not replacing them for other similar, and the idea is to invest more and more in renewable energy.
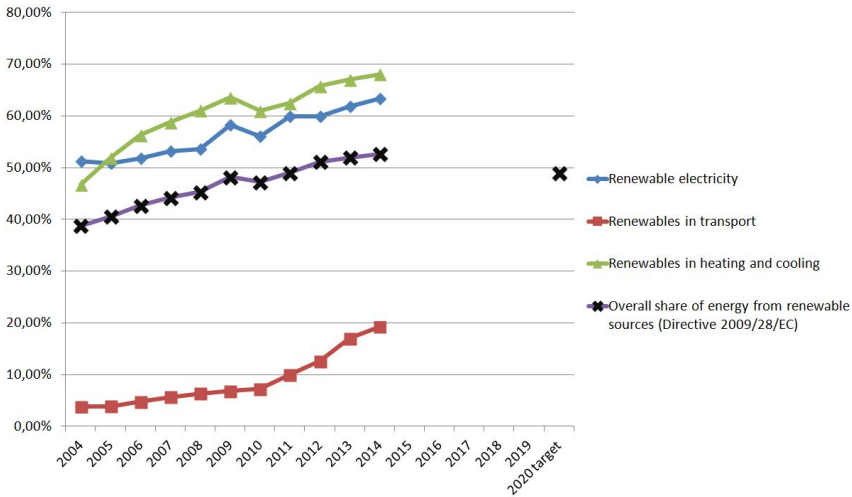
Figure 4.27: Sweden Share of energy from renewable energy - Source: eurostat

United Kingdom

The UK needs to radically increase its use of renewable energy. The UK has a wealth of energy resources, but until now it has relied on the use of their coal, oil and gas supplies to supply homes, transport and businesses.

To increase the proportion of energy obtained from renewable sources will not only increase the security of energy supplies in the UK, it will also provide opportunities for investment in new technologies and new industries. The UK Government will help business to develop in this area to put the UK at the forefront of new renewable technologies and skills.

Regarding the Development of emerging technologies, offshore wind is a key area for development. The UK is working to develop an offshore electricity grid to support our continuing commitment to being world leaders in this technology. This new generation of offshore wind power will play a key role in meeting the 2020 target (see Figure 4.28). Marine energy is also a priority for development in the UK. The UK is a natural place from which to develop marine energy and it is lucky to have such a uniquely rich wave and tidal resource.

Norway

Norway is in a unique position as regards renewable energy. Unlike most other countries, nearly all of Norway's electricity production is based on hydropower. Norway has a share of renewable energy that is much higher than in all EU countries (see Figure 4.29). The high Norwegian ambition in the area of renewable
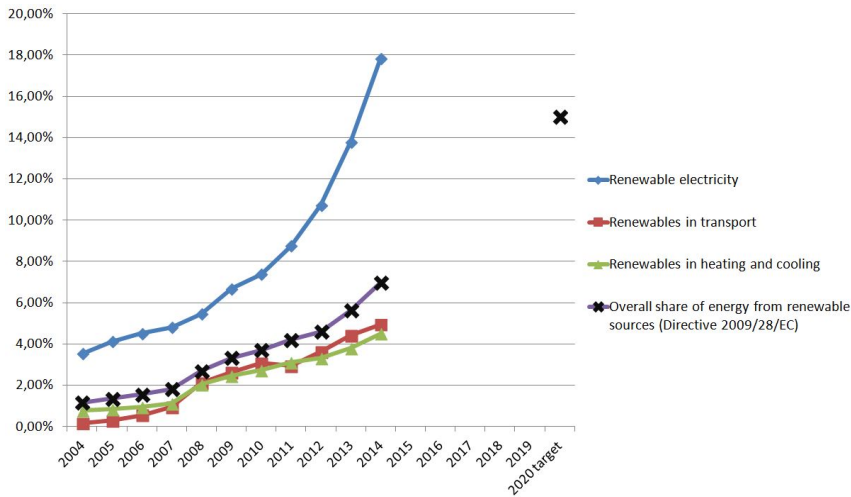
Figure 4.28: United Kingdom Share of energy from renewable energy - Source: eurostat

energy is also shown in the targets established in the agreement on the Renewables Directive. The Norwegian target is a renewable percentage of 67,5 by 2020.

Norway has one of the world's largest fleets of electric cars, and leads the world as regards the number of electric cars per resident. In the first quarter of 2012, electric cars accounted for 2,5% of total car sales

4.2.2 Non-EU countries

By early 2014, at least 144 countries had renewable energy targets and 138 countries had renewable energy support policies in place, up from the 138 and 127 countries, respectively, that were reported in REN21. Developing and emerging economies have led the expansion in recent years and account for 95 of the countries with support policies, up from 15 in 2005. The rate of adoption remained slow relative to much of the past decade, due largely to the fact that so many countries have already enacted policies. Thousands of cities and towns worldwide have policies, plans, and targets to advance renewable energy, often far outpacing the ambitions of national legislation. Policy momentum continued in 2013 as city and local governments acted to reduce emissions, support and create local industry, relieve grid capacity stress, and achieve security of supply.

By the end of 2013, China, the United States, Brazil and Canada remained the top countries for total installed renewable power capacity; the top countries for non-hydro capacity were again China and the United States. China saw by far the biggest renewable energy investments last year, a record $83.3 billion, up 39%
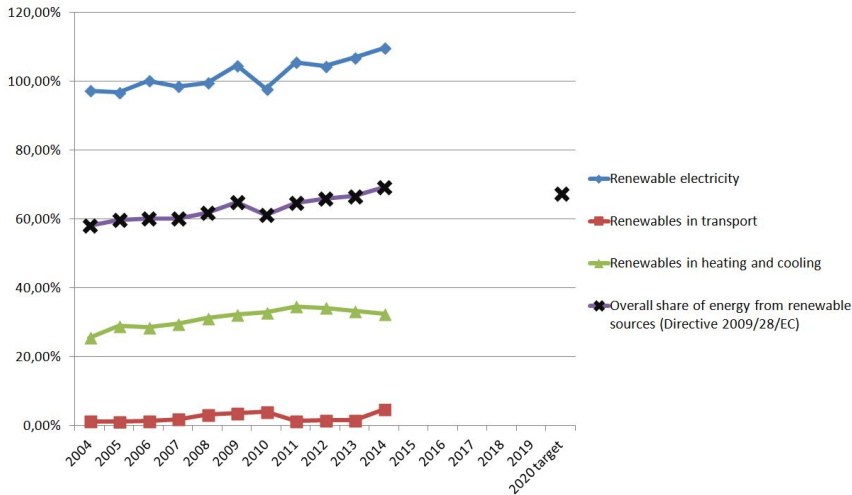
Figure 4.29: Norway Share of energy from renewable energy - Source: eurostat

from 2013. The US was second at \$38.3 billion, up 7% on the year though this is below its all-time high reached in 2011. Third came Japan, at \$35.7 billion, 10% higher than in 2013 and its biggest total ever.

At the national level, the top 10 investors consisted of three developing countries (all BRICS countries) and seven developed countries. China was again in the lead, with an investment of USD 54.2 billion, excluding R&D. It was followed by the United States (USD 33.9 billion), Japan (USD 28.6 billion), the United Kingdom (USD 12.1 billion), and Germany (USD 9.9 billion). The next five were Canada (USD 6.4 billion), India (USD 6 billion), South Africa (USD 4.9 billion) and Australia (USD 4.4 billion)

Asia-Pacific

Asia-Oceania, excluding China and India, where annual investment in renewable energy continued its uninterrupted rise. The Asia-Oceania region saw investment increase 47% over 2012, to a record high of USD 43.3 billion, due largely to the solar boom in Japan, whixh present a record increase in renewable energy investment, up 80% from 2012 to USD 28.6 billion, excluding R&D. The largest part of that commitment was for small-scale solar PV projects, as investors sought to capitalise on the generous feed-in tariff that was introduced in 2012. An increase of 76% in 2013, to USD 23 billion, made Japan the top country for investments in small-scale distributed renewables, followed distantly by the United States and Germany. Japan's asset finance in utility-scale projects nearly doubled, to USD 5.6 billion.

China

China invested more in renewable energy than did all of Europe combined, and it invested more in renewable power capacity than in fossil fuels. In 2013, China's new renewable power capacity surpassed new fossil fuel and nuclear capacity for the first time.

China accounted for USD 56.3 billion (including R&D) of new investment in renewable energy, down 6% from 2012. Asset financing increased, but contributions from public markets and private equity shrank to low levels. Despite the overall decline, China's investment in additional renewable power capacity surpassed fossil fuel capacity additions in 2013 for the first time. The vast majority of the country's investment was for solar and wind power projects, and China was the top country by far for spending on utility-scale projects, followed distantly by the United States and the United Kingdom. China also invested significant sums in hydropower, bringing about 29 GW of new capacity into operation during the year, of which a large portion was projects >50 MW.

By far the most capacity was installed in China (29 GW), with significant capacity also added in Turkey, Brazil, Vietnam, India, and Russia. Growth in the industry has been relatively steady in recent years, fuelled primarily by China?s expansion.

The solar PV market had a record year, adding more than 39 GW in 2013 for a total exceeding 139 GW. China saw spectacular growth, accounting for nearly one-third of global capacity added, followed by Japan and the United States.

United States

The United States, which invested USD 35.8 billion (including R&D), continued to be the largest individual investor among the developed economies. This was despite a decline in investment of nearly 10% in 2013, attributed largely to the impact of low natural gas prices caused by the shale gas boom, and to uncertainty over the continuation of policy support for renewables. U.S. venture capital and private equity investment in renewables fell to just USD 1 billion, the lowest since 2005, indicative of a loss of confidence among early-stage capital providers. However, this decline was offset by a big jump in U.S. public markets investment, from USD 949 million in 2012 to USD 5.3 billion in 2013 (mainly for solar power and biofuels).

Canada

Canada has been a steady investor in renewable energy in recent years and, in 2013, moved into the list of top 10 countries. Investment increased relative during the period 2007-2012, thanks to large-scale wind and solar PV projects in Ontario principally.

India

Investment in India in 2013 fell to just under half of the peak total recorded in 2011 (USD 12.5 billion). Almost all of the decline was due to a slowdown in asset finance, which was particularly apparent in the solar power market. However, small-scale project investment increased in 2013 to a record USD 0.4 billion. Beyond the top three countries in Asia, Thailand, Hong Kong, and the Philippines dominated investment in renewable energy in emerging Asia (collectively investing over USD 3 billion).

Africa

South Africa leads the African continent, although it was down from USD 5.7 the previous year, recording investment of USD 4.9 billion (excluding R&D and small-scale projects). This was almost entirely in the form of asset financing for wind and solar power, including CSP; overall, South Africa was one of the world's most active CSP markets in 2013. The second largest investor in Africa was Kenya (USD 249 million), followed by Mauritius and Burkina Faso.

Latam

Brazil continued to lead in Latin America, despite a 54% drop relative to 2012, which made it the country's weakest year since 2005, and took it out of the list of top 10 investing countries. Brazil's investment, totalling USD 3.1 billion, was dominated by asset finance, with the vast majority (USD 2.1 billion) going towards wind power projects and most of the remainder towards biofuel plant capacity. Outside of Brazil, the region's USD 6 billion invested in renewable energy was widely distributed, with Chile up 72% to USD 1.6 billion in 2013, followed by Mexico, Uruguay, Costa Rica, and Peru.

4.3 The case of Spain

World energy consumption from now until 2030 will increase by approximately 40% according to International Energy Agency (IEA) forecasts, largely due to the growing demand from emerging economies, especially China and India which account for over 50% of the growth in demand. In this scenario, fossil fuels will continue to cover 80% of the world's energy demand with consumption shifting to Asia and the Middle East, where the bulk of the increase in the demand for natural gas will be located. The expected rise in energy demand together with the geographical redistribution of consumption will deplete fossil energy reserves and push up prices in response to an increasing imbalance of supply and demand. Moreover, the environmental impact will foreseeable increase due to growing greenhouse gas emissions associated with increased consumption of fossil fuels. The European Union, whose energy dependence now stands at 53%, has taken note of its in-

creasing energy consumption and energy imports and is concerned about present trends.

In Spain, which shares energy characteristics with the EU, the presence of oil and its derivatives in primary energy consumption is considerably higher than the European average. As a consequence of this, and of low domestic energy production, based almost exclusively on renewable energy resources, nuclear generation and a small contribution from domestic coal, Spain's dependence on outside supply is close to 80%. Historically, Spain has devised energy efficiency and renewable energy plans. The ones currently in force are the Energy Savings and Efficiency Strategy 2004-2012 (E4) implemented through its 2005-2007 and 2008-2012 Action Plans, and the Renewable Energy Plan 2005-2010.

Oil prices and the geographical distribution of energy reserves have shaped the energy options of developed countries for over three decades. Recently, environmental concerns are related to the intense growth of emerging countries and its inflationary effect on primary energy sources, along with the liberalization of Europe's energy sector. Besides, within the scope of the European Union, the need to make coordinated progress in the liberalization of markets, the development of interconnection infrastructures, the assurance of supply and the reduction of polluting emissions along with many other issues has become more and more evident.

Energy policy in Spain has progressed in harmony with other European countries, but at the same time it has a specific response to the main challenges that have traditionally characterized the Spanish energy sector and which can be summarized as follows:

- Higher energy consumption per unit of GDP. Spain consumes more energy than the average of European countries to produce the same unit of GDP, even if it is compared to those countries which have a similar productive and industrial structure and almost the same level of economic development. This situation is caused to a variety of factors and it is not an irreversible situation but rather the effect of the accumulation of energy-intensive economic growth patterns. A concerted effort has been made in the area of energy savings and efficiency over the last several years to correct this tendency, and that has put Spain on the path to convergence with the European mean in terms of energy intensity, a way on which the country must continue over the next years.

- High degree of energy dependency. The limited presence of primary fossil fuel deposits and reserves has historically determined a high rate of energy dependence for Spain. This huge dependence means a higher risk for production processes specially for those which need to ensure the energy supply or are susceptible to the volatility of international market prices.

- High levels of greenhouse gas emissions. These are mostly due to strong growth in electricity generation and the demand for transport over the last decades. In order to face these challenges, energy policy in Spain has developed around three axes: enhancement of the competitiveness of its economy, security of supply and guarantee of sustainable economic, social and environmental development.

4.3.1 Historical trend and current situation

Energy consumption structure of Spain is characterised by the petroleum products domination, which are mostly imported, and this, together with scant contribution from autochthonous resources, has contributed to a high degree of energy dependence and a therefore a low level of self-supply. This situation began to change in 2005 within the framework of the current planning policies in connection with renewable energies and energy efficiency, which have allowed for greater penetration of renewable energies to meet domestic demand and hence an increase in the level of self-supply.

Up to 2009, energy demand, expressed both in terms of primary energy and final energy, has been rising over the last three decades, during which time there have been a number of world energy and economic crises that negatively impacted on the economic activity and energy demand of most developed countries. Nevertheless, at the beginning of the 1970's this circumstance served as a catalyst in most Western countries to implement policies aimed at reducing energy dependence and enhancing efficiency in consumption. Spain was almost a decade late in reacting and did not take action until the end of the 1970s.

The economic expansion enjoyed by Spain since becoming a member of the EU produced a considerable rise in purchasing power and hence an increase in the number of automobiles, domestic appliances and significant development in the building sector. These and other factors have been decisive in the upward trend in energy consumption. At the beginning of the 1990s a new crisis, this time a financial one, lowered energy demand by a small margin. Subsequent developments kept consumption on the rise until 2004, which marked a new stage in the development of demand both in terms of primary and final energy. It was at this turning point that GDP growth was not accompanied by a commensurate rise in energy consumption to sustain that economic activity, which would appear to indicate a delinking of economic activity from energy demand reflected in the fall in energy intensity. 2009, the reference year for the National Renewable Energy Action Plan (NREAP), is an atypical year as regards the trends observed: on the one hand, the underlying positive change over the last several years in terms of improved efficiency and, on the other, the effects of the crisis, two factors which account for a sharp fall in the demand for energy.

The structure of domestic demand for primary energy has undergone significant change over the last several decades but is especially evident since the second half of the 1990's when energy sources such as renewable energies and especially natural gas started to play an important role, resulting in greater energy diversification with a positive effect on the efficiency of the transformation system. To a large extent this has been made possible by the actions comprising the different Gas and Electricity Sector Plans, which have entailed greater development of the energy infrastructures needed for the integration of new energy from renewable sources.

Final energy consumption has followed a similar pattern to that of primary energy and also demonstrated a trend towards stabilisation and a downturn in demand starting in 2004. A look at the sectoral breakdown of demand shows that the transport sector is the number one consumer, which accounts for 40% of the total final consumption, based mostly on petroleum products and is responsible to a large extent for the high level of domestic energy dependence. Second in importance is industry, which accounts for 30% of consumption. However, energy demand from these sectors has decreased slightly in favour of other sectors (the residential and services sectors), in part due to Spain's economy expanding tertiary sector.

The situation at the end of 2009 and Development of primary and final consumption of renewable energies up to 2009 is marked by the development of renewable energies, which in Spain have increasingly contributed to the energy system and this is evident in the coverage of demand expressed in terms of both primary and final energy. This increased contribution has been especially noteworthy since 2005. In 2009, the reference year for the compiling of the NREAP, renewable energies accounted for 9.4% of the primary energy supply and over 12% in terms of gross final energy in accordance with the new methodology for calculating the contribution of renewable energies to the gross final consumption of energy.

Development of electricity generation using renewable energies up to 2009 Electricity generation from renewable sources, which is variable due to climate variations affecting rainfall, has been more stable and on the rise since 2005. Over the last ten years, electricity generation from renewable sources has risen by over 40% and by 2009 accounted for 24.7% of Spain's gross electricity production.

In 2011, primary energy consumption of Spain was dominated by oil (45%), followed by gas (22%) and then nuclear (12%). RE had a share of 11% in 2011 and 12,6% in 2012.

The primary energy consumption in Spain in 2014 was 118,413 Ktep (see Table 4.3 and Figure), with decrease of 1.7% on 2013. This demand is obtained as a result of adding the consumption of final energy consumption in energy sectors and losses (own and consumption in transformation, especially in power generation and oil refineries consumption). In the fall recorded in 2014, lower than the final energy, it has had relevance changing structure of power generation. In concrete to in

2014 the coal generation and the natural gas was reduced. By sources of primary energy in 2014 include:

- The total coal consumption was 11,975 ktoe, an increase of 5.1% over 2013, mainly due to increased electric power generation with this fuel.

- The total oil consumption was 50,740 ktoe, with decrease of 1.1% compared to the previous year, similar to the decline in final consumption of petroleum products, as consumption in power generation has a significant amount slightly over the total.

- The total demand for natural gas was 23,664 Ktep with a decrease of 9.3% compared to 2013, reaching their weight in the total energy consumption by 20.02%. This decline, despite the slight increase in end uses, is due to lesser consumption in power generation due to the evolution of electricity demand and the change in the structure indicated generation.

- The contribution of renewable energies, including hydropower, continues to grow, following the trend of previous years, although the increase is not as pronounced. This contribution is due to the wind and solar hydroelectric generation.

- Hydropower in 2014 was 6.3% higher than in 2013, thus maintaining average levels already achieved in the previous year, after the years 2011 and 2012 very dry.

- The production of electricity from nuclear power increased by 1% in 2014.

Table 4.3: Primary Energy Consumption in 2014

Type	2013	2014	dif
Coal	11.397	11.975	5,10
Oil	51.318	50.740	-1,10
Natural gas	26.077	23.664	-9,30
Nuclear	14.784	14.933	1,00
Hydro	3.163	3.361	6,30
Wind, Solar and Geotherm	7.331	7.617	3,90
Biomass and Biofuels	6.810	6.296	-7,50
Non-recyclabe waste	146	119	-18,40
Electricity Imp Exp balance	-581	-293	-49,50
TOTAL	120.447	118.413	-1,70

Source: Ministery of Industry, Spain
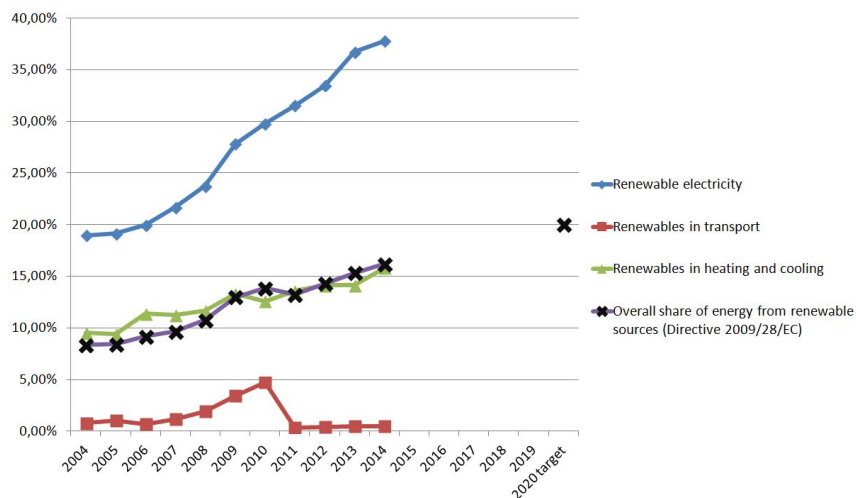
Figure 4.30: Spain Share of energy from renewable energy - Source: eurostat

4.3.2   Overall situation for renewable energy technologies

In accordance with the Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009, it is estblished that for Spain, the target means that renewable sources must account for at least 20% of final energy consumption by 2020 (see Figure 4.30), the same as the EU average, together with a contribution of 10% from renewable sources in the field of transport by that year.

Contractions of thermal and electrical demands recorded during 2014, with falls of 2,2% and 1,9% respectively, have led to a decline in primary energy demand that has affected, to a greater or lesser extent, both conventional energy sources and renewable resources. As far as the latter is concerned, the declines in demand have led to the practical stabilization of their primary consumption in 2014, placing them in 17,275 ktep, with a slight decrease of 0.2% over the previous year. Despite this, the market share of renewable resources in terms of primary energy has increased by just over two tenths of a percent compared to 2013, reaching 14,5% (see Figure 4.31).

While most renewable technologies have reductions in their contributions to primary demand, four have registered growths. Leading this group are placed solar technologies with a set increase of 16% over the previous year. Within these solar thermal power plants they have increased their contributions 24,2% compared to 2013, while solar thermal systems equipped with solar collectors grew by 8.5%. Rounding technologies with positive growth in their primary consumption of biofuels, with growth of 6,7%, and geothermal energy, with a rise of 1,7%.
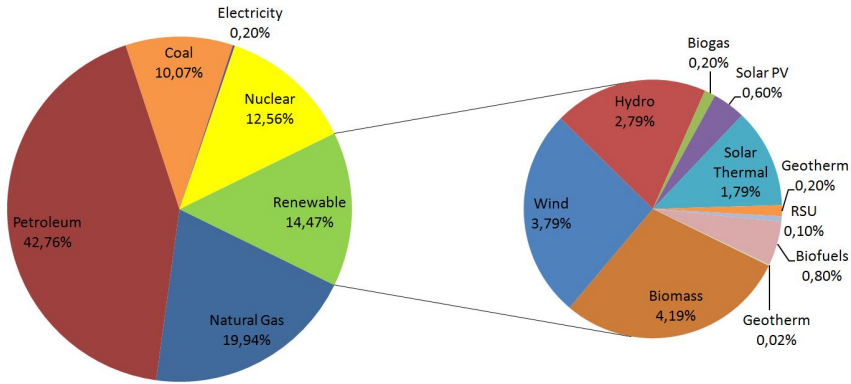
Figure 4.31: Primary energy consumption by energy source contribution - Source: own elaboration from Ministery of Industry, Spain (2014)

Also repeated in 2014, in terms of final energy, similar to that observed in the primary consumption situation with a practical stabilization of consumption of final energy from renewable sources that reach 5,294 ktoe, 6.7% of total (see Figure 4.32). All thermal renewable technologies have increased during 2014 except for those relating to the use of useful heat from cogeneration plants with biomass and/or biogas, significant reversals associated with lower thermal generation recorded last year.

Thus, solar thermal collector technology has increased its contribution by 8.5% compared to 2013, 6.7% biofuels and geothermal technologies and thermal biomass 1.7 and 1.8 percent respectively. Considering renewable thermal input, they are covered by three quarters by biomass: 4,005 ktep of which 524 ktep correspond to consumption of useful heat from power plants biomass and the rest, 3,481 ktoe, to heating systems, boilers, stoves and fireplaces, located in the residential, industrial and services sectors. Biofuels are the second most important renewable resource, providing in total 969 ktep of which just over 80% correspond to biodiesel and the rest with biogasolines.

Solar thermal energy, and totaling more than 3 million m2 of installed surface, representing slightly less than 5% of the total final consumption of renewable energy. Finally, geothermal energy, with significant increases in recent years represents about 1% of final consumption of renewable energy.

Gross production of electricity from renewable energy sources in 2014 totaled 109,957 GWh (see Figure 4.33), excluding electricity generation from pumping installations, representing an increase of 1,3% over the year. This increase, in contrast to a contraction of 2% in gross electricity production has gone hand in hand with thermoelectric solar resources and, to a lesser extent, of water. Thus,
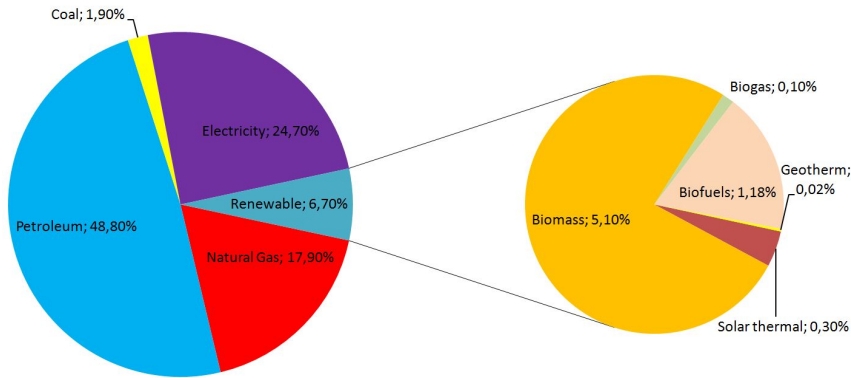
Figure 4.32: Final Energy Consumption (2014) contribution by source of energy - Source: own elaboration from Ministery of Industry, Spain

electricity production with solar thermoelectric and hydraulic resources increased by more than 24%, the first, and by about 5%, the second, with respect to 2013.

Other renewable technologies has experienced over the previous year, setbacks in their electrical production, from 7% for plants fueled by biogas to 1,2% in photovoltaic plants, to fall 3,6% biomass plants, 3% in wind farms and 1,7% in electricity generation plants using municipal solid waste. All this has meant that renewable electricity generation has increased its share in gross electricity production in just over half a percentage point from 2013, reached in 2014 a market share of 39,5%.

Almost half of the gross electricity production from renewable resources, 47% has specifically been supplied by wind power, the second power generation technology in 2014, ahead of production facilities powered by natural gas or coal and only slightly behind nuclear technology. 36% of renewable electricity was generated in 2014 with water resources (except electrical generation from pumping) taking advantage of a major hydroelectric reserves, which amounted to 53% of the reservoir water level at the end of 2014, representing 5 percentage points more than those at the end of 2013, and a hydraulic producible 18% higher than the average historical value, virtually the same as in 2013.

The rest of the basket of electricity production with renewable resources complete the photovoltaic technologies, with 7,4% share, solar thermal power with 5%, biomass represents 3.3% of renewable electricity production and biogas and renewable MSW, with contributions of 0,8% and 0,5%, respectively.

The use given to more than 17 Mtoe of renewable energy consumed in 2014 (see Figure 4.34), about 70% has been allocated to the production of electricity, while
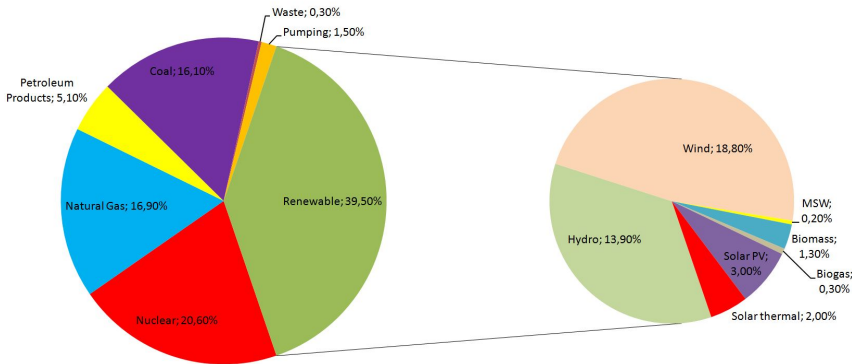
Figure 4.33: Structure of electrical generation (2014) - Source: own elaboration from Ministery of Industry, Spain

heat production has meant a quarter part bio-fuel consumption slightly more than 5,5% of total consumption of renewable energy.

Since 2000, the primary renewable energy consumption has increased by 2,5 times, being about 7 million tep to just over 17 million tep in 2014. The evolution during this period shows an increasing trend in the primary consumption of these resources and virtually stable over the past year.

The composition of the basket of renewable resources in so far this century has also undergone significant changes. While in 2000 biofuels (biomass, biogas, municipal solid waste and biofuels) and hydropower clearly dominated the renewable supply, with a market share of 57% and 37% respectively in 2014 observed higher distribution between the different processing technologies. Biofuels continue to dominate the renewable market, although the incorporation and expansion of new technologies such as wind or solar thermoelectric have resulted in a significant loss of market share of the first of about 20 percentage points. Also hydropower, despite the high availability of resources gives registered in 2014, that year represents 17 percentage points less of the total market share for the year 2000.

Meanwhile, wind power has become the second technology in terms of participation in the primary consumption of renewable resources, rising from about 6% in 2000 to 26% in 2014. In terms of energy solar, solar thermal has evolved from 0,4% in 2000 to 1,5% of renewable primary consumption in 2014, multiplying by more than three times their share of renewable energy mix; photovoltaics, with very little presence at the beginning of the century, accounted, in 2014, the 4,1% of primary energy renewable and solar thermal technology, which in 2000 had no facilities in operation, is 12,4% of renewable contributions to primary energy demand already. Finally, geothermal energy, even with the progress made in recent years, represents only 0,1% of primary demand for renewable energy.
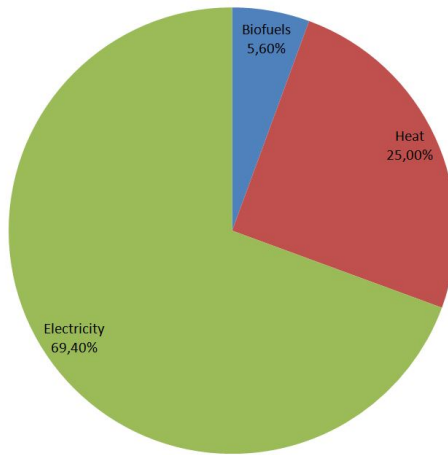
Figure 4.34: Distribution of energy production capacity with RE sources (2014) - Source: own elaboration from Ministery of Industry, Spain

4.3.3 Key renewable energy sources and comparation with other countries

The top countries for non-hydro capacity were again China, the United States, and Germany, (see Figure 4.35) followed by Spain, Italy, and India. Among the world's top 20 countries for non-hydro renewable power capacity, those with the highest capacity amounts per inhabitant were all in Europe. Denmark had a clear lead and was followed by Germany, Portugal, Spain, and Sweden.

By technology, the following are the most important and developed in Spain.

Wind

Wind is the most sustainable renewable energy in Spain and the country is situated among the leading countries for total wind power capacity per inhabitant together with Denmark, Sweden, Germany and Ireland. In 2014, The United States was again the leading country for wind power generation and wind power met more than 20% of electricity demand in several countries, including Denmark, Nicaragua, Portugal, and Spain (see Figure 4.36).

Althoug, most of the world's turbine manufacturers are in China, Denmark, Germany, India, the United States and Japan, Spain also has companies such as GAMESA, which is considered one of the most important manufacturer with a market shares of 4,5% and it is, in 2014, among the top 10 wind turbine manufacturers worldwide.
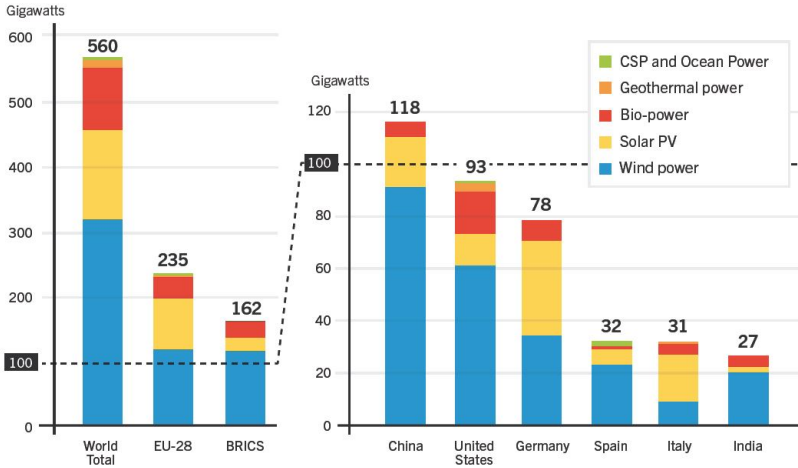
Figure 4.35: Renewable Power Capacities in World, EU-28, BRICS, and Top Six Countries, 2013 - Source: REN21 - hydropower not included
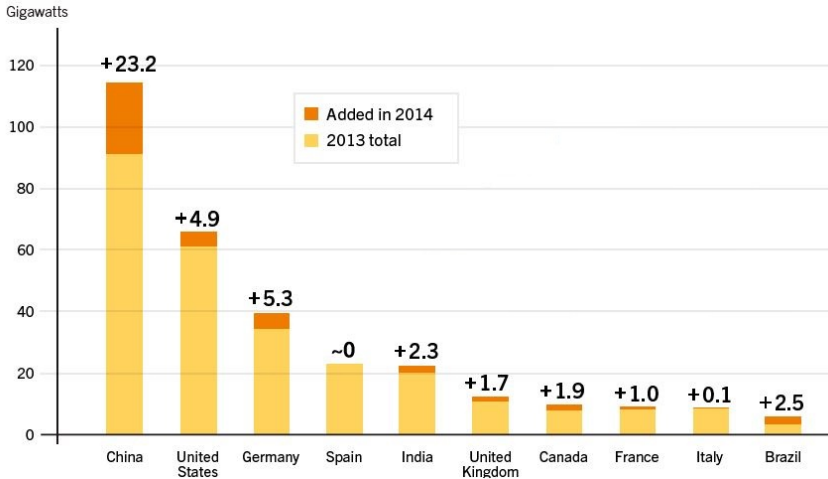
Figure 4.36: Wind Power Capacity and Additions - Top 10 Countries, 2014 - Source: REN21

Solar

According to Greenpeace, Solar power could provide seven times the electricity demand would have the Iberian peninsula in 2050.

In numbers, Spain added a record 2.6 GW of solar power in 2008, increasing capacity to 3.5 GW. Total solar power in Spain was 3.859 GW by the end of 2010 and solar energy produced 6.9 terawatt/hours (TW/h), covering 2.7% of the electricity demand in 2010. By the end of 2012, 4.516 GW had been installed, and that year 8.169 TWh of electricity was produced. (see Figure 4.37)
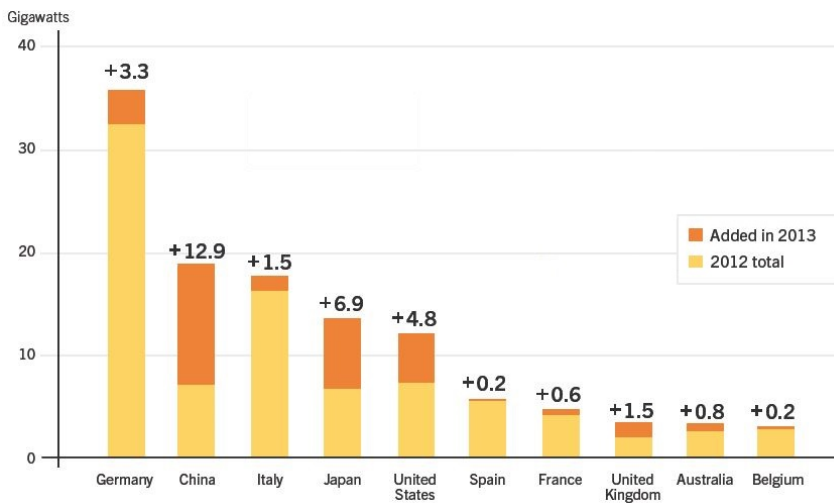
Figure 4.37: Solar PV Capacity and Additions, Top 10 Countries, 2013 - Source: REN21

Through a ministerial regulation in March 2004, the Spanish government removed economic barriers to the connection of renewable energy technologies to the electricity grid. The Royal Decree 436/2004 equalized conditions for large-scale solar thermal and photovoltaic plants and guaranteed feed-in tariffs. In the wake of the 2008 financial crisis, the Spanish government drastically cut its subsidies for solar power and capped future increases in capacity at 500 MW per year.

According to REN21 report, Spain is one of the most advanced countries in the development of solar energy, moreover, the first one in sunshine hours. In 2008 the Spanish government committed to achieving a target of 12 percent of primary energy from renewable energy by 2010 and by 2020 expects the installed solar generating capacity of 10,000 megawatts (MW)

CSP

Global CSP capacity was up nearly 0.9 GW (36%) in 2013 to reach 3.4 GW. Thus, the United States and Spain remained the market leaders. (see Figure 4.38)

According to REN21, Global CSP capacity was up nearly 0.9 GW (36%) in 2013 to reach 3.4 GW. While the United States and Spain remained the market leaders, markets continued to shift to developing countries with high levels of insolation. Beyond the leading markets, capacity nearly tripled with projects coming on line in the United Arab Emirates, India, and China.

	1	2	3	4	5
Investment in renewable power and fuels	**China**	United States	Japan	United Kingdom	Germany
Share of GDP 2012 (USD) invested[1]	**Uruguay**	Mauritius	Costa Rica	South Africa	Nicaragua
Geothermal power capacity	**New Zealand**	Turkey	United States	Kenya	Philippines
Hydropower capacity	**China**	Turkey	Brazil	Vietnam	India
Solar PV capacity	**China**	Japan	United States	Germany	United Kingdom
CSP capacity	**United States**	Spain	United Arab Emirates	India	China
Wind power capacity	**China**	Germany	United Kingdom	India	Canada
Solar water heating capacity[2]	**China**	Turkey	India	Brazil	Germany
Biodiesel production	**United States**	Germany	Brazil	Argentina	France
Fuel ethanol production	**United States**	Brazil	China	Canada	France

Figure 4.38: Total Capacity or generation as of end 2013 - Source: REN21

The concentrating solar thermal power (CSP) market continued to advance in 2013 after record growth in 2012. Total global capacity increased by nearly 0.9 GW, up 36%, to more than 3.4 GW.1 (see Figure 4.39) and Spain sustained its global leadership in existing CSP capacity, adding 350 MW in 2013 to increase operating capacity by 18%, for a total of 2.3 GW at year's end.

An increasing range of hybrid CSP applications emerged, and thermal energy storage continued to gain in importance. Industry operations expanded further into new markets, and global growth in the sector remained strong, but revised growth projections and competition from solar PV in some countries led a number of companies to close their CSP operations. The trend towards larger plants to take advantage of economies of scale was maintained, while improved design and manufacturing techniques reduced costs.

Hydro

Global hydropower generation in 2013 was an about 3,750 TWh. Around 40 GW of new hydropower capacity was entrusted in 2013, increasing total global capacity by 4% to 1,000 GW. By far the most capacity was installed in China (29 GW), with significant capacity also added in India, Brazil, Turkey, Russia and Vietnam.
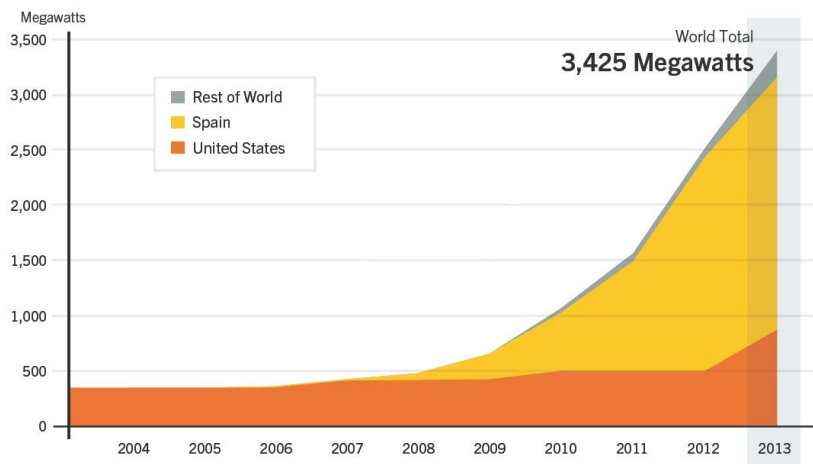
Figure 4.39: Concentrating Solar Thermal Power Global Capacity, by Country or Region, 2004 to 2013 - Source: REN21

Growth in the industry has been relatively solid in recently, conducted primarily by China's expansion. In Spain, the installed capacity presents an rising trend (see Figure 4.40).

Annual electricity generation from hydroelectric sources varies considerably each year. A rough calculation shows that the contribution to total net generation fluctuate approximately between 9% to 17% annually. This variation explains the oscillating annual figures for total renewable energy in Spain (see Figure 4.41)

Others

Development of the consumption of biofuels up to 2009 Progress made in Spain over the last several years in the production capacity of biofuels has been one of the most important advances made in the field of renewable energies. In 2009, biofuel plants in our country reached an annual production capacity of over 4 million toe.

However, growth in production capacity has not gone hand-in-hand with consumption of biofuels. Several incentive measures were taken to encourage the use of these fuels, particularly the approval of Order ITC/2877/2008 of 9 October 2008 setting up a mechanism to encourage the use of biofuels and other renewable fuels used for transport. Consolidation of the scheme laid down in this Ministerial Order, along with the actions implemented by the European Commission to protect the European market from unfair commercial practices, is expected to have a positive effect on Spanish production plant activity.
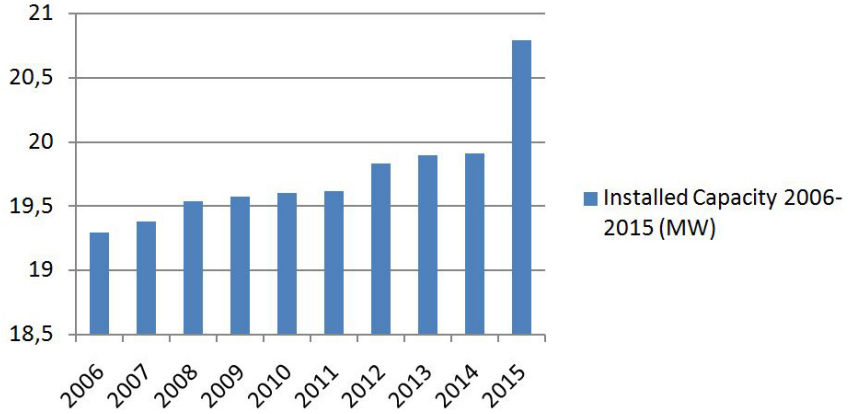
Figure 4.40: Installed Capacity 2006-2015 (MW) in Spain - Source: REN21
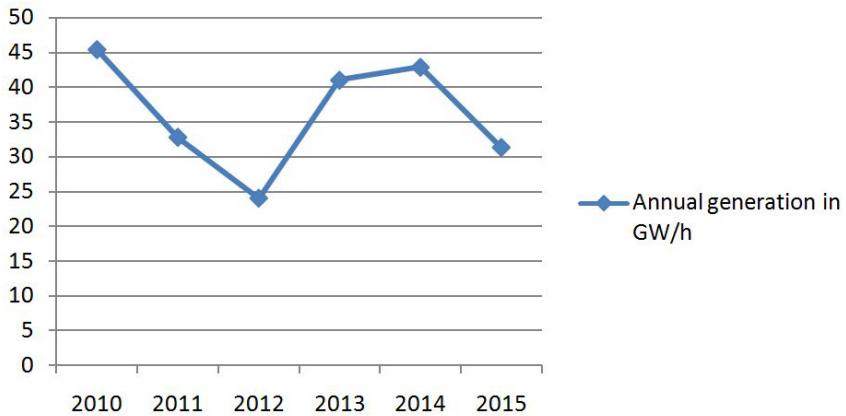
Figure 4.41: Annual generation in GW/h in Spain - Source: REN21

4.4   RE and climate change: key points of Paris COP21

RE sources have an active role providing energy but in a sustainable way and, in particular, in mitigating climate change. Nowadays, RE technologies are well developed and they play an important role in managing climate and natural disaster risk.

The Earth has been warmed due to the high levels of heat-trapping gasses, such as carbon in the atmosphere and this is creating wide raging impacts, like rising sea levels, fires and drought, extreme storms, melting snow and ice, rainfall and floods. Scientists expect that these trends will continue and in some cases even faster, doing significant risks to our quality of life because this is very harmful for our forests, agriculture, freshwater supplies, coastlines, and other natural resources that are vital for human's health.

It is possible to say, after years of climate science researching, that if we fail to reduce carbon emissions, climate change will have deep impacts on our planet. Climate change affects all regions around the world. Polar ice shields are melting and the sea levels are rising. In some regions extreme weather events and rainfall are becoming more common and many others are experiencing more extreme heat waves and droughts. In fact, in 2014 there were more natural catastrophe events than in any single year on record and these impacts are expected to intensify in the coming decades, so the world needs to switch to renewable and clear sources of energy, and stop our reliance on non-efficient fossil fuels and wasteful energy behaviors.

As it was said before, this is a worldwide problem which cannot be solved individually and all countries without exception must collaborate. In this sense, one of the problems was that there was no clear agreement since Kyoto Protocol, which was expired in 2012.

Recently, from 30 November to 11 December 2015, The 21st Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) was hosted by France. The conference was crucial because the result was a new international agreement for climate change, to keep global warming below 2°C. The Paris Climate Pact details a landmark agreement reached can be a turning point in the struggle to contain global warming and some of the most important conclusions of the agreement are the following:

- It demands to hold the increase in the global average temperature to be below 2°C above pre-industrial levels and to make efforts to detract the temperature increase to 1.5°C above pre-industrial levels, assuming that this will reduce impacts and the risks of climate change significantly. This report accepts the scientific conclusions that an increase of more than 2°C in atmospheric temperatures, or 3.6 degrees Fahrenheit, will send the planet

into a future of catastrophic impacts, including more devastating floods, rising sea levels, and droughts, widespread food, more powerful storms and water shortages.

- To get this goal, countries must reach the global peaking of greenhouse gas emissions as quickly as possible, recognizing that peaking will delay developing country parties, and to undertake rapid reductions thereafter. Advocates explain that this compromise is a clear message to the fossil-fuel industry because much of the world's remaining reserves of oil, coal and gas must remain in the ground and cannot be burned. As happened in previous versions, this agreement doesn't call, for reaching greenhouse gas emissions neutrality in the second half of the century, a provision that oil producers intensely resisted. OPEC states lobbied for language that suggests that some fossil fuels must continue to burn, because the greenhouse gas emissions are eliminated by a bigger number of greenhouse sinks like new forests.

- The agreement remarks the importance of minimizing, averting and addressing loss and damage provoked by the adverse effects of climate change. This was extremely crucial by poor and small-island countries which suffer the most from extreme weather and from long-term impacts like dryness. However, this provision does not provide or involve a basis for any liability or compensation, an issue that wealthy nations, which didn't want to be held financially liable for climate change, insisted on.

- A total of 186 countries reported plans, together with the agreement, saying in detail how they will reduce their greenhouse gas pollution by 2025 or 2030. The agreement requires all countries to submit updated plans that will ratchet up the exigency of emissions by 2020 and every five years afterwards, a time frame that the United States and the European Union urged. India had initially requested a ten year review cycle.

- The agreement requires a global stocktaking, an overall evaluation of how countries are doing in reducing their emissions compared to their national plans, starting in 2023 and checking every five years.

- The deal ask for countries to control, verify and report their greenhouse gas emissions using the same system globally. The United States remarked that an exhaustive system of counting and verifying each nation's emissions is essential for the plan to be successful. The United States had also insisted for the creation of an outside panel of experts to control and make sure of the reductions of each nations in theirs emissions. Developing countries, including India and China, had asked for two separate accounting systems, a more stringent one for rich countries and a more lenient one for poor countries. The United States win a victory with the adoption of the single

accounting system, but the details of how it would operate, including the creation of the "carbon auditor" figure, have been postponed to the future.

- The agreement will be effective in 2020 and it calls on nations to set up "a new collective quantified goal" of $100 billion a year in financing related to climate by 2020. It avoids a specific number, and even the $100 billion-a-year aspiration is mentioned in the document's decision part, not the action section, to avoid a review by the United States Senate. But it seems clear that the $100 billion, already promised in 2009 in Copenhagen, is the bare minimum going further.

- When countries update their obligations, they will go for the highest possible value, but the agreement doesn't set a fix and numeric target. It acknowledges common but differentiated responsibilities and respective capabilities, thi id due to different national circumstances. This short of comments is basic to a country like India, which argues that it will require some time before it can reach achieve the peak emissions, given the need to supply 300 million people with electricity. The agreement calls on rich countries to commit on absolute reductions in emissions, while asking to developing ones to carry on supporting their mitigation efforts.

4.5   Financing RE Projects

The aim of this section is to evaluate the available tools and ways for funding renewable energies as it is consider a key question among investors all over the world. The point of how to finance RE is an important matter now and it is proportional to the increase of demand. As Ozkol (2011) said, apart from the commercial banks which have been considered as the main lenders for the renewable energy projects, many other tools such as international organizations, governments, capital markets have come up with attractive conditions to the interested investors. The difference between the commercial banks and other financial ways has been reduced quickly and these methods are positive to develop more renewable energy projects in the near future.

Renewable energy investments are approached by the finance sector in the same manner as any other kind of business. However, renewable energy projects have some peculiarities which needs a higher level of understanding. These include the influence of the government policy and regulation on the viability of an investment, including subsidies, the legal basis, certificates or tax credits. These factors are positioned on top of any financial analysis.

4.5.1 Risks in RE projects

The renewable energy projects are considered to be quite expensive and complex. For those reasons, many investors hesitate when investing their money into them. As the cost of the project rises, the risks in that projects increase. There is no doubt that in order to persuade the investors, the risks pre and post completions of the projects have to be determined, allocated and additionally mitigated. Besides, compared to developed countries, the barriers especially market barriers are more vulnerable in emerging countries as they have inadequate and unbalanced markets in terms of financial and legal structures.

This section shows, what financiers consider before investing in RE assets. For example, in the case of a project finance, from the point of view of fund and private equity context. It must be pointed that there are a set of variables that have big influence in the project success and many others that will change over the project life and all of them must be managed or mitigated. Risks factors are analyzed in details prior to investing both debt and equity, which is known as due diligence. Technical experts and advisers must be consulted during this process, where specific technical knowledge is needed.

The first type of risk to take into account are those related to country and financial:

- **Country risk:** They include economic and political risks, so it can be consider as a term that covers a wide range of risks related to government stability and other issues like the legal system maturity, currency and transparency in business. Also, other issues as wars or strikes can be included.

- **Economic risks:** Inflation rates and changes in local regulation are the most popular economic risks. In Europe, the United States and Canada this is a major concern and institutions do big efforts to control it. However, the rest of the countries, the inflaction rate do not have the same control and it usualy grows quickly every year.

- **Financial risks:** Probability of refinancing, interest rates, asset liquidity and insurance (asset rebuild, business interruption).

- **Currency risks:** These are related to devaluations and currency controls. The main problem comes when loans and revenues are generated in local currency and especially in emerging markets with big fluctuations in economy. Usually, a foreign currency hedge contract is arranged with the supplier or a bank at the time that the contract is signed.

- **Political risks:** This involves not only issues related to the durability and stability of governments. But also other risks such as central bank rates or laws that can be changed suddenly, which can influence in the project viability.

The risks associated to technical and project specific risk are generally assessed by a technical expert on behalf of lenders and investors. Those risks are:

- **Construction risk:** Issues covered in these type of risks are the interconnections among different contracts, protection for project delays, timing and building.

- **Environmental risk:** Depending on the legislation, they can be subjected to an impact assessment.

- **Operation and Management risk:** After the project is settled, it will be necessary to keep the plant in optimal conditions to assure the expected performance. It must be studied the required contracts needed during the operational period

Among the various kinds of risks some of the issues associated with the technology used in the projects can be seen below.

- **Hydro:** From the point of view of cost efficiency, these have been reduced as new construction techniques have been developed. Resource availability and flooding are considered the main risks that hydropower projects must face. Generally speaking and unlike other renewable energies, hydroelectricity is widely used and well-structured.

- **Wind:** Main risks in wind power are those relate to the intermittency of the resource, long lead times, problems in critical components and wind resource and offshore cable laying. Costs are not so critical nowadays because they have dropped during the last ten years due to new technical developed have been installed.

- **Solar photovoltaic:** Risks to be faced are weather, theft, vandalism and component breakdowns. Also in this technology, costs have been reduced a lot and nowadays it is one of the renewable sources that grows faster.

- **Solar thermal heating:** This is becoming one of the most attractive, profitable businesses and challenging models among renewable energy sources. Currently, good quality solar thermal systems have a life of 20-25 years, with extremely low maintenance needs and clearly no costs at all for fuel. It is most likely to reach marketability as the costs are expected to reduce and production techniques are improved. A typical risk of this kind of renewable energy is technology risks such as the issue of combining with the other solar towers, delays in construction due to the licensing procedure or accidents.

- **Biomass:** This works with a kind of fuel that can be stored and used for electricity generation if necessary, particularly fossil fuel. It can be a cost-effective industry. Most of the times; apart from private financing, public

administration support is necessary. It is expected that efficiencies of biomass will increase in the next 20 years. Fuel supply availability, resource price variability and environmental liabilities are regarded to be the main risks.

- **Geothermal:** This energy has its source within earth's core, so it is independent of the sun. Up to now, it has been restricted due to the capital costs needed for installation, but it is adequate to supply human's need. However, for the past few years and thanks to technology developments, interest in geothermal energy has increased due to it can provide good returns in terms of capital. It is possible to say that geothermal has become more competitive. As geothermal projects face many risks such as drilling expenses risks, critical component failures, exploration risk and long lead times, experience and knowledge and play an essential role for the development of the geothermal source.

- **Tidal power:** Coastal tidal waters are increase and decrease by the sun and moon's gravitational field's basis. Due to the very long payback returns, this of energy is not broadly used yet; but, it is strongly believed that it will possible future source of renewable energy. Although, it only contributes 10% of the world's total hydro power, it represents a significant resource. Small scale and long leads, technology risks and survivability in harsh marine environments are the types of risks that tidal and wave power projects contain.

- **Wave energy:** Waves are produced by the flow of the wind over the surface of the sea causing the gradual transfer of energy into the water. Wave power can be competitive in areas where predictable energy sources are costly and wave climate is energetic. Compared to other renewable sources, it is not a popular technology and it is expensive. In general, operating are not high but high capital investment is needed.

A part from the risks that are numbered above, another problem is to finance the renewable energy projects as they are high-priced and investors are reluctant to finance them. Most of the renewable energy projects are highly capital intensive and thus, they will need the developer of the project to increase large amounts of finance well beforehand of the start of operations.

4.5.2   Impact of the financial crisis

The financial crisis significantly constrained banks's ability to lend to each other and to other borrowers. This triggered the breakdown of some major financial institutions by mid-2008, and raised questions about how worthy is the credit of other financial institutions, due to risks they may have on their books.

During a time, lending was severely affected to many sectors of the economy, also to RE, which caused many projects to be delayed and postponed until better market conditions come back. The subsequent economic crisis had also several impacts in the energy sector in terms of less demand and lower prices as the demand for commodities has fallen down together with the slowdown in the business activity, as well as commercial activities have been delayed or cancelled. In any case, RE sector remained as one of the most attractive for equity investors and banks and the contracts have carried out and even new funds appeared.

Among the approaches to minimise crisis impact, different actions have been taken over, both by financial institutions and government stimulus packages to enhance the accessibility to RE funding. These tools may also be essential to the main question of scaling up investment in clean energy to confront energy security and climate change over the longer term.

On the finance side, these have been divided into two main perspectives: a) Reducing risk and then the cost of financing; b) Alternative funds' sources, including direct provision of additional capital from public financing institutions or Treasuries, to surpass the lack of credit.

Alongside public financing decisions, It has been produced structural changes to the fiscal RE incentive mechanisms to deal with specific harmful effects of the financial crisis.

4.5.3   Sources of capital

There are two ways to find capital for a RE project: borrowing it from a bank or with equity capital from selling stakes.

When banks lend money to RE projects, they focus on getting earning a return on the transaction and the debt repaid. Regarding equity capital (usually in form of funds) look for opportunities for investing in projects, companies or project portfolios, and expect the best possible return comparing to the risks they assume. For example, Venture Capital funds which invest in new technology companies can expect more than 20% of their investment will fail and then they ask for a high return. In case of private companies, they can make an IPO (Initial Public Offering) of shares to raise capital from several investors and established companies can launch share capital to finance expansion strategies.

Moreover, some investors and companies can fund projects from their own corporate funds as part of their strategy. These companies are based on capital raised by their account and treasury departments. This money may come from the financial markets or from bank facilities which are available for them or by selling part of their business. Usually, companies will decide if they use corporate facilities or project finance depending on how expensive is the source of funding the project.

Coming back to the issues about risks and return, an important matter about the risks is what to do if a project in which the bank or the investor who has the funds becomes insolvent. If this happens, it will be a hierarchy to determinate who will get the money out first. Bank debt is only lent into the company and therefore ranks ahead of equity which owns the company. That means that the amounts recovered from the insolvent company will be paid to the bank first, which makes that a bank to be less risky than an equity stake in the company. Therefore, banks require a lower return than equity investors.

Banks ussually operate based on the following ways:

- **Corporate Lending:** From the point view of finance, banks support companies' everyday operations. Debt price depends on the previous evaluation of the financial stability and strength of the company. These service put few restrictions about the funds are used by the company.

- **Project Finance or Limited Recourse Finance:** The amount of debt depends on the capacity of the project to generate revenue for a period of time, as this means to repay the debt which is borrowed for a concrete project. Depending on the associated risks, the quantity of debt is adjusted, for instance, the production and sale of the generated power. If there is a problem with the repayment of the loan, banks apply a first charge over business' assets. Usually, the first section of the debt to be payback from the project is called "senior"

  In the context of RE projects and energy sector, the requirements for enormous debt and capital, together with the risks taken part of the large projects, result in the project financing one of the best financing alternatives as financial incentive to reduce long pay back periods would be necessary. At this stage, project finance plays an essential role in renewable energy projects as the industry grows, the need for financing also grows and like any infrastructure project, renewable energy needs to raise long-term finance economically and with tenors that reflect the asset's life.

  Many renewable energy projects have been struggling with some problems about raising finance. Lenders and sponsors are in nature reluctant to take risks which boost to unforeseeable variations in a project's cash flow. From the project finance's standpoint, debt and equities provided by the lenders

and sponsors generally are assurance by credit rating off-take agreements. However, in the case of renewable energy projects, they are arranged as Power Purchase Agreements. Generally, long-term off take agreements facilitate non-recourse finance for so many years.

- **Mezzanine finance:** As per its name, this kind of lending is placed between the senior bank debt (the top level) and the equity ownership of a project. Mezzanine loans have more risks than senior debt due to regular repayments of the mezzanine loan are made after the ones for senior debt, in any case, the risk is lower than equity ownership in the company. Usually, mezzanine loans have a shorter duration and they are more expensive for borrowers, but give a better return to the lenders (mezzanine debt may be provided by a financial institution or a bank). A renewable energy project may look for mezzanine finance if the amount of bank debt it can access is not enough. Mezzaine loan can be a not expensive way to replace some of the additional equity that would be necessary in that situation, and therefore can improve the cost of overall finance (and then the rate of return for owners).

- **Refinancing:** This is when a project or a company has already borrowed money but needs, to change the existing debt arrangements with new ones, same situation when a mortgage is refinanced. Refinancing can be done because there are more attractive terms available in the market or because the duration of the loan facility, for example, loans are often designed to become more expensive with the pass of the time due to the growing risk of changes to regulation or market situation. One of the worst consequences of the financial crisis was that banks became extremely worried to lend for more than 7 years, which provoked that many projects that required longer loans, to be refinanced and to take the risks of the terms available at that moment.

- **Seed and risk capital investment:** In general, Seed Capital is related to the cash needed to be able to start a business. In these types of projects the Bank works as a developer and the projects use to involve wind, PV solar, solar thermal, PV solar, biomass power and minihydro.

- **Solar leasing:** In a solar lease or solar power-purchase agreement (also known as a "PPA"), a customer pays for the solar power system over a period of years, rather than in an up-front payment. Often customers can purchase solar for little or no money down, and often realize energy savings immediately. In a power-purchase agreement, a customer agrees to purchase all the energy from a solar system over a fixed period of time.

- **Sale and lease back:** Off balance sheet financing in which an owner sells an asset or property to a leasing firm and, at the same time, leases it (as a lessee) on a long-term basis to retain exclusive possession and use. Although

this arrangement frees capital tied up in a fixed asset, the original owner loses depreciation and tax benefits. A leaseback arrangement is useful when companies need to un-tie the cash invested in an asset for other investments, but the asset is still needed in order to operate. The lessor benefits in that they will receive stable payments for a specified period of time.

- **Bridge equity facilities:** A short-term loan that is used until a person or company secures permanent financing or removes an existing obligation. This type of financing allows the user to meet current obligations by providing immediate cash flow. In this way, the equity acts as a bridge between the current situation and the future eventuality. Private equity firms often use bridge equity as a way to complete a leveraged buyout of an existing company. Loans known as bridge loans, which are often issued by lenders expecting quick repayment at high interest rates, are another way for companies to receive short-term capital.

In the case of venture capital, private equity and funds:

Renewable energy equity investments taking an ownership stake in a project, or company, involve investments by a range of financial investors including Private Equity Funds, Infrastructure Funds and Pension Funds, into companies or directly into projects or portfolios of assets.

Depending on the type of business, the stage of development of the technology, and degree of risk associated, different types of equity investors will engage e.g. Venture Capital will be focused on "early stage" or "growth stage" (depending on how far from the laboratory and commercial roll out) technology companies; "Private Equity" Firms, which focus on later stage and more mature technology or projects, and generally expect to "exit" their investment and make their returns in a 3 to 5 year timeframe; Infrastructure Funds, traditionally interested in lower risk infrastructure such as roads, rail, grid, waste facilities etc, which have a longer term investment horizon and so expect lower returns over this period; Institutional Investors such as Pension Funds have an even longer time horizon and larger amounts of money to invest, with lower risk appetite.

Funds use Internal Rate of Return (IRR, or "rate of return") of each potential project as a key tool in reaching investment decisions. It is used to measure and compare the profitability of investments. Funds will generally have an expectation of what IRR they need to achieve, known as a hurdle rate. The IRR can be said to be the earnings from an investment, in the form of an annual rate of interest.

In the United States, "tax equity" is also used to finance renewable energy projects: firms with a sizeable tax liability income can use these investments to offset future tax obligations

4.5.4 Completing a transaction

The process of making a transaction generally has similar points in common for both equity or debt. Every financial institution has a protocol to review and check comparing with their own internal risk and return set of criteria. Depending on how precise is the organisation, the process will have more or fewer steps.

Hereafter are summarised steps ussually taken by a bank:

1. Opportunity comes out, there is an initial review and discussions with the cliente to determinate that the interest confirmed.

2. Confidentiality agreements are signed to allow the exchange of relevant information. Then, a first review of risks and return is made and compared to the internal risk tolerance.

3. Detailed project's modelling over its life a part from a stress testing of low and high case risk scenarios and checking debt repayment ability.

4. A full report is made for the internal credit committee which must approve the bank transaction. It must include: -The nature of the company that wants to borrow, its management and experience, financial strength and RE track record. -The relationship between the borrower and the bank. If there are other borrowings of that company with the bank. -The high level outline of the project, lifespan, total capital expenditure(capex), technology, required debt amount, subsidy support. -A detailed report of all the project risks and their mitigation. -Repayment schedule and series of stress tests (for instance, lower electricity prices or inflaction). -The returns earned by bank for the proposed loan. -Contracts and technology as well as a detailed review of the project. -The financial model of the project.

5. Approval, it means that the bank can commit to the outline of a transaction, and funds will be set aside to allow the bank to cover these obligations. Once it is approved, a submission is made to the customer, and may include all the conditions that considers the credit committee.

6. The client accepts the agreement with the bank, which will issue the loan documents and the due diligence of the project. Due diligence will be extensive and and according to the RE technology to be employed. For instance, wind transactions need an analysis of the minimum of twelve months site-specific wind data for speed and direction.

7. When all documents are set, they will reflect the final negotiations between cliente and bank and the findings from the due diligence.

8. Financial closing and documents signed: lenders are awarded a first charge over the assets, equity is provided by the investor and the debt funds are released.

4.5.5 An ilustrative example

An illustrative example of financing renewable energy projects is Banco Santander and how it contributes to the global objective of fighting climate change by providing financial solutions and via its leadership position in renewable energy at the international level.

Moreover, the Bank has known how to adapt to market changes, taking advantage of new business opportunities that have arisen. This commitment is reflected through various financial products and services, and the commitment that the Bank does for the financing of renewable energy, such as:

- **Project finance:** The Bank finances the construction and operation of wind farms, PV solar plants, solar thermal facilities and hydro and biomass plants, with a total installed capacity of 3,205 MW, involving projects in Brazil, Canada, Chile, USA, Italy, Mexico and the UK.

- **Seed and risk capital investment:** In these kinds of projects the Bank acts as a developer. In 2012, Santander invested in projects that, once built, will amount to a total installed capacity of 2,827 MW, mainly in Brazil, Mexico, Chile, Uruguay, USA, Spain, the UK, Italy and

- **Solar leasing:** In 2012, a total 161 photovoltaic leasing operations were carried out in Spain and Portugal, representing an investment of EUR 14.8 million.

- **Sale and lease back:** In 2012, the Bank carried out its first capital investment in renewable energy projects via Sovereign. The Bank participated in a 102.5 MW solar power project in California and a 23 MW wind power project in Puerto Rico.

- **Bridge equity:** In 2012, Santander invested in the development of two solar thermal plants in the US and a third in Spain. Together they will have an installed capacity of 330 MW, with commissioning scheduled for 2013.

In total, in 2012 the Bank financed renewable energy projects in Spain, Brazil, Canada, Chile, the US, Italy, Australia, Mexico, UK and Uruguay, with a total capacity of 6.487MW.

Chapter 5

A MCDM approach for Project Finance selection: an application in the RE sector

5.1   Introduction

Renewable energy (RE) has emerged as a long term solution for a sustainable, cost-effective and friendly source of energy generation for the near future. According to UNEP, renewables accounted for 43.6% of the new generating capacity installed worldwide in 2013, raising its share of world electricity generation from 7.8% in 2012, to 8.5% in 2013 UNEP (2014). However, the transition toward a low carbon-economy requires important investments from public and private initiative. While RE investments have received public support under the form of reduced taxes, direct subsidies or public incentives, private finance has so far played a marginal role, Mathews et al. (2010). This is due to investments in the RE sector are characterized by combining capital intensity with new technologies, which implies high returns but also high risks. Based on the European experience, limited bank lending capacities make the commercial banks unable to fund large projects with traditional loans.

Project Finance is a recent technique applied in large investments projects and its defined by Finnerty (2007) as "the raising of funds on a limited-recourse or nonrecourse basis to finance an economically separable capital investment project in which the providers of the funds look primarily to the cash flow from the project

as the source of funds to service their loans and provide the return of and a return on their equity invested in the project". During the last decades of the 20th century Project Finance has enabled to provide financial solutions for large infrastructure, energy and environmental projects. From the project developers' point of view, Project Finance is usually chosen to reduce lender's recourse to the sponsors, permit an off-balance sheet of the debt and especially to reduce all types of project risks. Moreover, Project finance is a key element when transferring risk from the public to the private sector and when there are high levels of public debt.

Research on new financing techniques for RE projects has gained interest in recent years due to the rising awareness of environmental issues. There is a wide number of contributions underlying the relevance of RE (D'Alessandro et al. (2010), Dovì et al. (2009)). However, there is a lack of research on the financial aspects of RE projects Lüdeke-Freund and Loock (2011). The energy policy literature has seldom incorporated the investor's perspective. Given the relevance of considering a wide set of criteria to better understand the investor's preferences in the decision making process to evaluate Project Finance alternatives, we address the following question: Which RE projects do lenders prefer to finance? To answer this question, we propose a MCDM method as a flexible tool to handle a wide range of variables. This is because traditional single criteria decision-making approaches cannot manage the complex analysis that a multi-dimensional space of different indicators and objectives involves Zeleny (1982), Yu (1985). In RE projects, MCDM have been widely used in areas such as wind farm projects, geothermal projects, hydro-site selection and the main applications have been related to planning, RE evaluation, project selection, allocation and environmental issues Ballestero (2000a), Yazdani-Chamzini et al. (2013), Taha and Daim (2013). In the context of selecting the best RE project to be funded using Project Finance, we apply the Moderate Pessimism Decision Making (MPDM) model to rank several real RE projects by analyzing the most important variables which can make a project succeed or fail Ballestero (2002). The proposed methodology is a recent contribution in which preference weights are derived from an objective way.

The paper aims to make several contributions. First, to provide a better understanding of the Project Finance technique and its use in the RE sector. Second, to fill the gap of research on financial aspects of RE in the literature by reviewing contributions of MCDM to RE project evaluation from the investor's perspective. Third, the proposed MPDM model adds to the rational financial evaluation of investment opportunities a set of non-financial factors that affects the investor's decisions. Finally, within the illustrative example, we apply this multi-criteria decision making process to help banks to decide if they must join a project or not.

The remainder of the paper is structured as follows: First, we introduce the main features of Project Finance including the main agreements and participants. Second,we review the recent use of MCDM methods in RE projects. Third, we develop

the theoretical bases of MPDM applied to RE. Finally, we develop an illustrative example.

5.2   Project Finance for RE projects

In 1992 the United Kingdom government implemented the Private Finance Initiative (PFI) as a way to involve the private sector in the provision of public services. This was a starting point for public-private partnerships (PPPs) as a financial mechanism to obtain private finance and satisfy the political need to increase investment in large-scale projects without affecting public borrowing. As stated by the World Bank, Project Finance is one of the most common financing arrangements for PPP projects.

Initially Project Finance has been used for high-risk infrastructure schemes, such as Oil & Gas, extractive (mining), transportation, telecommunications and energy industries. More recently and especially in Europe, Project Finance increased as the needs for public funding increased. The European PPP Expertise Centre shows that the main applications in Europe of PPP financing are, transport, public order and safety, general public services and the environment. Minor applications are education and healthcare. In the last two decades, Project Finance has played an important role in RE projects. However, non-recourse Project Finance in Europe sustained the biggest impact from the financial crisis with respect to on-balance-sheet finance UNEP (2010).

Although there is no "standard" Project Finance structure, there are some typical features that appear in Project Finance.

- Lenders rely on the future cash flow of the the project rather than the value of its assets.

- There is a specific company whose only business is the project, then this company is legally and economically self-contained, the so–called Project Company or the "Special Purpose Vehicle" Company (SPV).

- There are high levels of leverage, Project Finance debt covering 70%-90% of the total cost.

- It is a non-recourse or limited-recourse finance, that is, the lender has only a limited claim if the collateral is not sufficient to repay the debt.

- Risk is shared between all the parties of the project. A wide number of contracts or agreements provide support to the lenders in order to assure the future cash flows.

In Figure 5.1 the basic structure of Project Finance, with some participants and the corresponding agreements, is represented.
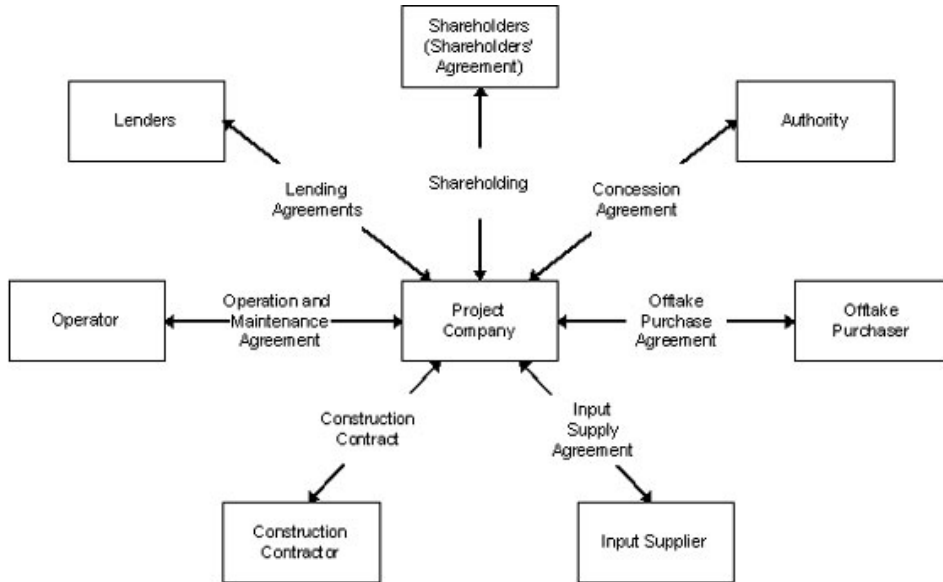
Figure 5.1: Project Finance basic structure: participants and agreements

Project Finance differs from traditional finance as the lender primarily looks at the assets and revenue of the project in order to secure and service the loan. In Project Finance the lender has no recourse to the sponsors of the project. For the lenders it is important to identify, analyze, allocate and manage all the risk associated with the project. The basic principle of risk allocation is "Allocating all project risks to the most suitable participant whose risk preference is higher". Risk allocation is implemented through agreements between the project company and the rest of the participants and allows the project to be financed at low interest rates.

The robustness of Project Finance is based on these agreements, which assures the return of the project Ballestero (2000a), Ballestero et al. (2004b), Garcia-Bernabeu et al. (2015). The rationale of such an agreement relies on the fact that the guarantor is the best at managing sales risks. The "off-take agreement" between the project company and the client plays a central role in most Project Finance structures. In this agreement the client assures a minimum level of sales paying for the balance if the amount of sales remains below this minimum level. Another significant agreement is the Engineering, Procurement and Construction (EPC) Contract, in which the project will be designed and built for a fixed price

on a fixed date. In a "Put-or-pay" contract the supplier is obliged to purchase a minimum amount of inputs at a fixed price for a specific period, or to pay for the shortfall. A project is generally covered by several types of insurances. The coverage of these insurance policies is related to several kinds of risks as for example, force majeure events, employer's liability, contractor insolvency and delays in obtaining permits. Other arrangements with the supplier (supply or pay agreement), the operator (Operating & Maintenance agreement, O&M), or the government enhance the project.

Project Finance arose in the last decades as an innovative financial instrument for RE projects. Traditionally, the majority of RE projects have usually been financed through the syndicated commercial loan market. Then, the decision maker is a bank manager who faces a multitude of criteria to decide which are the best RE projects to be financed.

Banks have a high risk perception of RE projects due to their own specific characteristics such as the need of capital intensive and very long payback periods with no proven track record. For this reason, banks are hesitant to use traditional finance instruments Mills and Taylor (1994).

5.3   MCDM in RE projects

MCDM is a branch of Operations Research models that started to emerge in the 1950s .However, it has not been an active area of research until the 1970s with important contributions from Contini and Zionts Contini and Zionts (1968) and Zionts and Wallenius Zionts and Wallenius (1976). Saaty Saaty and Vargas (2012) (1977a) introduced the Analytic Hierarchy Process (AHP), a multi-criteria method that relies on pairwise comparison of criteria/assets to be evaluated from the decision maker's preferences. Keeney and Raiffa Keeney and Raiffa (1976) established the multiattribute value theory (including utility theory) as a standard reference for decision analysis and MCDM. In the late 1970s MCDM research focused on multiple objective mathematical programming problems, especially related to linear and discrete problems Korhonen et al. (1984). In 1972, Zeleny (1982) and Yu Yu (1985) organized the First International Conference on MCDM at the University of Southern California. This conference was a turning point in MCDM.

MCDM has experienced a growing development from the 1990s until now and many subfields have emerged with a wide number of contributors. In 1992 Simon French edited the Journal of Multi-Criteria Decision Analysis aimed to be the repository of choice for papers covering all aspects of MCDA/MCDM. A significant contribution to MCDM was Ballestero and Romero Ballestero and Romero (1998) with their book "Multiple Criteria Decision Making and its Applications to Economic Problems". Relevant developments in the field of goal programming

are due to Lee Lee (1972b), Ignizio Ignizio (1985), and Romero Romero (2004). A review of the early history of MCDM is made in Köksalan et al. (2013).

According to many authors, MCDM is divided into multi-objective decision making (MODM) and multiattribute decision making (MADM). While MODM is related to problems in which the decision space is continuous, MADM is devoted to problems with discrete decision spaces. Continuous methods seek to identify an optimal quantity, which can vary infinitely in a decision problem. Linear programming (LP), goal programming (GP) and aspiration-based models are considered continuous. Discrete methods include weighting and ranking methods as for example, Multi-attribute value theory (MAVT), multi-attribute utility theory (MAUT), Analytic Hierarchy Process (AHP), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), Elimination and Choice Expressing Reality (ELECTRE), and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). A comparative analysis of MCDM methods VIKOR, TOPSIS, ELECTRE and PROMETHEE is presented in Opricovic and Tzeng (2007).

MCDM draws upon knowledge in many fields including: Mathematics, Behavioral decision theory, Economics, Engineering and Information systems. In RE projects, MCDM has been widely used in areas such as wind farm projects, geothermal projects, and hydro-site selection. A review of multi-criteria applications in RE analysis is made in Taha and Daim (2013). In Table 5.1 a summary of relevant contributions of MCDM in renewable energy is shown.

The main application area of Multi-Objective decision making methods is RE planning. Regarding multiattribute decision making, AHP and ELECTRE are the main methods applied to rank RE alternatives with respect to a number of criteria.

Recently many authors have been interested in comparing and analyzing different MCDM methods when applied to real world problems (see, for example, Chu et al. (2007), Hobbs and Meier (1994), Opricovic and Tzeng (2004)). Applications to renewable energy that compare several MCDM methods can be found in Theodorou et al. (2010), Theodorou et al. (2010), Sánchez-Lozano et al. (2014a).

5.4 MCDM Methodology: MPDM for evaluating RE projects from lenders perspective

Evaluating a Project Finance proposal for RE is a complex analysis that can be defined as a multi-criteria decision-making problem with a multidimensional space of indicators. We propose a Moderate Pessimism Decision Support Model (MPDM, Ballestero (2002)) to rank a set of projects in the RE sector that can be financed using the Project Finance technique. This ranking method does not require elicit-

ing preference weights from particular preferences of the decision maker, namely, there are no particular preferences for the selected criteria.

Before establishing the MPDM model let us begin with some previous definitions as basic postulates for moderate pessimism decision makers:

Definition 1. Moderate pessimism. A decision maker who cautiously assumes that the most favorable state when the action has been taken will not occur is named "moderately pessimism".

A critical issue in MCDM analysis is how to rank a set of alternatives from multiple criteria. Let V_{ij} be the corresponding value reached by the ith alternative from the jth criterion $(i = 1, 2, \ldots, m)$; $(j = 1, 2 \ldots, n)$. A previous needed step is "normalization" to range the values for the j_{th} crieria between O an 1. Then, when the criterion is "the more the better" the normalized N_{ij} value is computed by:

$$N_{ij} = \frac{V_{ij} - V_{jmin}}{V_{jmax} - V_{jmin}} \tag{5.1}$$

If some criterion was 'the more the worse', then, this could be converted into 'the more the better' N_{ij} normalized value by the following equation:

$$N_{ij} = \frac{V_{jmax} - V_{ij}}{V_{jmax} - V_{jmin}} \tag{5.2}$$

Definition 2. Domination. An alternative a_δ is dominated by the $(a_1, a_2, \ldots a_m)$ convex combination of alternatives if the N_{ij} value satisfies the relationships:

$$\sum_{i=1}^{m} a_i N_{ij} \geq a_{\delta j} \quad \text{for all j} \tag{5.3}$$

Traditionally, Project Finance lenders will require that project cash flows pay the debt. Two main analyses are considered: (i) Assessing financial viability of the project; and (ii) Evaluating risks and their coverage mechanisms. While the first analysis is quantitative, in the second analysis qualitative criteria and non-financial considerations prevail.

Taking into account bank managers' preferences a set of criteria is proposed from a Delphi survey conducted in 2014. The choice of criteria should take into consideration not only financial but also technolgical, political-legal and socio-environmental perspectives of the problem. Then, we introduce these four dimen-

sions D_i, $(i = 1, \ldots, 4)$ including a total of fifteen criteria (C_{ij}), (see Table 5.2). Dimensions and criteria are described as follows:

1. Financial. To evaluate a project from the lender's perspective the Debt Service Coverage Ratio (DSCR) is a key financial metric to assess a project's cash flow coverage of both interest and principal repayments. For RE projects the DSCR ranges between 1.0 and 3.0, but the average in this type of projects is around 1.3. However, there are other significant financial criteria that lenders should take into account such as the net present value, the amount of debt, the guaranteed incomes and the currency risk.

2. Political-Legal. Changes in the legal and political framework can affect the risk of the project. Host government regulations promoting environmental policies, including reduction in taxes and royalties, expropriation and nationalization, and even the outbreak of war, among others, are factors which contribute to political risk Farrell (2003). This dimension includes: (i) Country risk measured from Euromoney (http://www.euromoneycountryrisk.com/); (ii) Contracts strength, in which expert consultants advise lending institutions againts changes in market terms and conditions that could affect the financial rating strength of the project. This is an "more the better" criterion where 1 means the lowest score and 10 the highest one; and (iii) Support from the administration based on the ranking carried out by RECAI (Renewable Energy Country Attractiveness Index) which indicates the level of investment in renewable energy and deployment opportunities in this field http://www.ey.com/. This ranking shows countries with strongest commitment to renewable energies. The scale of this criteria varies from 1 to 10, being 10 the highest level and 1 the lowest.

3. Technological. The proliferation of RE is directly related to the technical advances in processing them and the breakthroughs in terms of finding stable sources of green energy. In this dimension, source variability, fuel cost and processing complexity is assessed from the advice of technical consultants. The scale of these criteria varies from 1 to 10, being 10 the highest level and 1 the lowest.

4. Social-Environmental. According to Akella et al. (2009) the use of RE implies the following social and environmental benefits: (i) improved health, (ii) consumer choice, (iii) greater self-reliance, (iv) work opportunities and (v) technological advances. In this dimension we consider as basic criteria contribution to employment (measured by the number of employments generated by installed MW), social acceptance (benefits of each kind of energy, from 1 to 10), and negative impact on the environment (measured from independent consultant reports ranging from 1 to 10).

We propose the use of the variable D_{ih} as the sum of the N_{ij} values for the criteria included.

$$D_{ih} = \sum_{h=1}^{m} N_{ij} \quad i = 1, 2 \dots m \tag{5.4}$$

To develop the MPDM model we follow a two-step approach. In a firt step we select the non-dominated alternatives according to Definition 2. Within the second step we obtain the aggregation weights to construct the ranking of alternatives.

5.4.1 First step. Domination analysis

This step allows us to classify the alternatives in dominated and non-dominated by convex combinations of other alternatives Ballestero (1999). To achieve this classification, the following linear programming can be performed:

$$\min a_\delta$$
$$\text{s.t.}$$
$$\sum_{i=1}^{m} a_i D_{ij} \geq a_{\delta j} \quad \text{for all j} \tag{5.5}$$
$$\sum_{i=1}^{m} a_i = 1$$

with the non-negativity conditions $a_i \geq 0$ for all i. If the result of (5.5) is $a_\delta = 0$, then, the δth alternative is dominated. Conversely, if the result of the minimization (5.5) is $a_\delta = 1$, then the δth alternative is non-dominated.

5.4.2 Second step: Aggregation weights and scoring

This step is undertaken to determine the w_j weights on the following principles: (a) objectivity, namely, the weights should not be colored by subjective opinions; (b) moderate pessimism, as a prudent rule of decision making under uncertainty.

Hereafter, these weights will be stated and justified. Regarding the aggregation weights the following cases can occur.

Case 1. The alternatives are ranked by an individual who is both the decision maker and the user of the ranking. For example, a chief of staff should rank job applicants from criteria such as age, skill, dress style, etc. Then, the

aggregation weights are the individual preference weights for the criteria. To elicit these preference weights, outranking methods such as Analytical Hierarchy Process (AHP; Saaty and Vargas (2012)) are often used, although sometimes without reliability. If the number of items to be compared by pairwise comparison is rather high (around 10 or more), then the AHP results could be unreliable.

Case 2. The ranking of alternatives should be used by a community of individuals, which is a frequent case. Then, the community preferences for the criteria cannot be elicited. In fact, Arrow's Impossibility Theory or Arrow's paradox states that constructing social preferences from individual preferences is rather impossible. More precisely, no rank order voting system can convert the ranked preferences of individuals into a community-wide complete and transitive ranking, when the number of items is 3 or more Arrow (2012)Geanakoplos (2005). In this case, the w_j aggregation weights are not preference weights. Methods to determine them cannot be outranking methods, but domination analysis and decision-making rules under uncertainty.

In Case 2, the criteria should be aggregated by weights objectively established, namely, individual preferences are not used at all to determine the weights. The meaning of these methods are as follows.

1. Consistent weighting in which the weights do not change from an alternative to another. A classical paradigm is Laplace principle of insufficient reason, which assumes equal weight for every criterion (mean value).

2. Flexible weighting in which the weights change from an alternative to another. Lack of consistency is an ongoing concern with flexible weighting. A classical paradigm is Wald's maximin, which assumes extreme pessimism Wald (1950). When Wald's maximin and other flexible weighting rules are used to rank from multiple criteria, there is another inconvenience that these rules do not use all the available information. See Arrow and Hurwicz (1972) as a classic research tool on the matter.

3. Moderate Pessimism Decision Making (MPDM), also called the Principle of Moderate Pessimism Ballestero (2002), which combines advantages of both Laplace and Wald rules. Like Laplace's, this principle relies on consistent weights. Like Wald's, the MPDM method assumes pessimism but not extreme pessimism.

There are some different procedures to determine and justify the MPDM aggregation weights. A first procedure Ballestero (2002) based on the concepts of marginal

fictitious alternatives (MFA) is more abstract than intuitive. Hereafter, a more intuitive procedure is proposed.

Main assumption. Weights w_j satisfy the following relationship:

$$(S_j^* - S_{j*})\, w_j = Q; \quad j = 1, \ldots, n \tag{5.6}$$

where,

$S_j^* = max\, S_{ij}$, namely, the largest S_{ij} value from the jth criterion of the non-dominated set of alternatives.

$S_{j*} = min\, S_{ij}$, namely, the smallest S_{ij} value from the jth criterion of the non-dominated set of alternatives.

$Q = $ Positive constant.

This assumption has the following meaning. Equation (5.6) involves a comparison of maximum value S_j^* and minimum value S_{j*}. The larger the difference $(S_j^* - S_{j*})$ the higher the decision maker's distrust towards the jth criterion, and therefore, the lower the w_j weight to be attached to the j criterion. This is because the decision maker fears that the S_j^* maximum is overestimated with respect to the S_{j*} minimum. Accordingly, equation (5.6) assumes that weight w_j is inversely proportional to $(S_j^* - S_{j*})$. From equation (5.6), the MPDM weights are established as follows:

$$w_j = \begin{cases} \dfrac{1}{(S_j^* - S_{j*})} & \text{if } (S_j^* - S_{j*}) \neq 0 \\[2ex] 0 & \text{if } (V_j^* - V_{j*}) = 0 \end{cases} \tag{5.7}$$

To rank the alternatives, the following scores to rank the alternatives R_i are used:

$$R_i = \sum_{i=1}^{n} w_j D_{ij} \quad i = 1, 2 \ldots m \tag{5.8}$$

where parameters w_j are aggregation weights for the criteria.

5.5   Illustrative example

This application is based on twelve real RE projects that can be considered as a "simulated opportunity set". Bank managers are worried about how to rank them according to a set of financial and non-financial criteria. These RE projects were executed in Spain and Latin America using Project Finance for funding. They involved different types of RE sources such as waterpower, photovoltaic or wind power generation. The projects are shown in Table 5.3.

In Table 5.4 the corresponding N_{ij} normalized values are displayed taking into account the four dimensions D_1, D_2, D_3, D_4 explained in Section 4. Table 5.5 displays the aggregated values for the corresponding dimensions for the RE projects.

From Section 4, the two-step process is numerically developed as follows.

First step. When applying model (5.5), we find $a_1 = a_2 = a_9 = a_{11} = 1$, thus, RE projects 1, 2, 9 and 11 are non-dominated alternatives. The results of minimization (5.5) for the remaining RE projects were O, thus RE projects 3, 4, 5, 6, 7, 8, 10 , 12 were dominated alternatives.

Second step. With the set of non-dominated projects $(P_1, P_2, P_9 \quad and \quad P_{11})$ we obtain the dimension weights by applying Equation (5.7). These weights are computed as follows:

$$w_1(3.74 - 2.95) = w_2(2.83 - 1.17) = w_3(3.17 - 2.07) = w_4(2.48 - 0.94)$$

That is:

$w_1 = 1.28$, $w_2 = 0.60$, $w_3 = 0.91$ and $w_4 = 0.65$.

In Table 5.6 the largest weights values correspond to financial and technologial dimension (D_1 and D_3), while polical-legal (D_2) and socio-environmental (D_4) dimensions are less weighted. These results are consistent with bank manager's preferences that include five and four criteria in D_1 and D_3, while for dimensions D_2 and D_4 only includes three criteria.

Finally, the MPDM scores for the RE projects are computed by applying Equation (5.7). The numerical results appear in Table 5.7. According to the MPDM ranking score, the best RE project is "La Jara", a wind project located in Spain. In this project, political-legal and technological dimensions reach the highest values although the financial dimension ranks second while the social-environmental dimension has intermediate scores. The second best project corresponds to "Artilleros", another wind project built in Uruguay with rather high scores in almost all dimensions.

5.6 Conclusion

RE investments are viewed from academic, managerial and policy making community as one of the most effective instruments to attain CO_2 emission reduction targets set by the Kyoto Protocol. The lack of private finance in the RE market have started to draw attention of researchers who are trying to provide better understanding of rational evaluation RE projects from lenders perspective. Our review shows that the use of MCDM, mainly MCDA methods, to RE projects has grown significantly over the last two decades. AHP, ELECTRE, MAUT, PROMETHEE or TOPSIS are the main outranking methods with applications in the assessment of environmental impact, RE strategies or lyfe cicle stretegies between other. In these MCDA methods the agregation weigths are obtained from particular preferences of the decision maker. The MPDM method proposed in this paper allows to rank a set of RE projects to be funded using Project Finance. For a proposal to be classified as worth funding lenders the debts service coverage ratio is the main reference and is complemented with risk coverage matrix. We addres the problem by considering a set of financial and non-financial criteria grouped by dimensions.

The criteria considered are grouped in four dimensions, financial, political-legal, technological and social-environmental and have been defined by a group bank managers. MPDM allows to rank a set of alternatives from an objective way. Frequently, the agents are interested in increasing the influence of certain criteria on the ranking, which is to be computed by an independent decision maker. A hint on these biases is the presence of ranges which are very high in some criteria as compared with the ranges in other criteria. To correct the scores afected by these biases is the main contribution of MPDM. To use preference weights for this purpose is inapppropriate because preferences are subjective categories.

As a contribution to practice, an application to twelve RE projects illustrate the method through numerial tables concerning basic information of the RE projects, quantitative values for all the criteria considered and ranking scores obtained from MPDM model. This application can help practitioners analyze RE projects from serveral dimensions.

Future research could be conducted to compare results with other ranking methods. The proposed approach requires comparisons not in terms of superiority of one method over others but in terms of appropriateness to the financial problem stated.

Table 5.1: Academic literature in MCDM applied to Renewable Energy Projects

Type	MCDM methodology/Application	Authors
MODM	Multiobjective	Iniyan and Sumathy (2000); Suganthi and Williams (2000)Borges and Antunes (2003); Fadaee and Radzi (2012); Alarcon-Rodriguez et al. (2010); Ren et al. (2010)
	Compromise Programming	Sitarz (2013); García-Cascales et al. (2012)
	Goal Programming	Chang (2015); San Cristóbal (2012); Ballarin et al. (2011); Daim et al. (2010); Kanase-Patil et al. (2010)
MADM	AHP	Aragonés-Beltrán et al. (2014); Yazdani-Chamzini et al. (2013); Suganthi and Williams (2000); Kaya and Kahraman (2010); Heo et al. (2010); Nigim et al. (2004); Kablan (2004); Lee et al. (2007)
	ELECTRE	Polatidis et al. (2015); Sánchez-Lozano et al. (2014b); Beccali et al. (2003); Cavallaro (2010a); Georgopoulou et al. (1997)
	PROMETHEE	Cavallaro (2009); Madlener et al. (2007); Haralambopoulos and Polatidis (2003)
	MAUT	Mattiussi et al. (2014);Kaya and Kahraman (2011); Jones et al. (1990)
	TOPSIS	García-Cascales et al. (2012); Cavallaro (2010b); Chen (2000)
	FUZZY AND OTHERS	Kaa et al. (2014); Borges and Antunes (2003);

Table 5.2: Financial, political-legal, technological and social-environmental dimensions and criteria

D_1	Financial	D_2	Political-Legal	D_3	Technological	D_4	Socio-Environmental
C_{11}	DSCR	C_{21}	Country risk	C_{31}	Source variability	C_{41}	Contribution to the employment
C_{12}	Net Present Value	C_{22}	Contracts strenght	C_{32}	Fuel cost	C_{42}	Social acceptance
C_{13}	Debt	C_{23}	Support from Administration	C_{33}	Processing complexity	C_{43}	Negative impact in environment
C_{14}	Guaranted incomes			C_{34}	Innovation capacity		
C_{15}	Currency risk						

Table 5.3: Simulated portfolio of RE projects: Basic information

No	Project	Type	Power	Investment	Country
P_1	La Jara	Wind	99	89	Spain
P_2	ENCE	Biomass	50	135	Spain
P_3	Alconera	Photovoltaic	15	120	Spain
P_4	Solarpack	Photovoltaic	25	83	Chile
P_5	Paracuru	Wind	24	260	Brazil
P_6	Guanacaste	Wind	75	25	Costa Rica
P_7	Malaspina	Wind	50	81	Argentina
P_8	Tamaulipas	Wind	54	130	Mexico
P_9	Aura Solar	Photovoltaic	300	100	Mexico
P_{10}	Pedrado Sal	Wind	24	11	Brazil
P_{11}	Artilleros	Wind	65	107	Uruguay
P_{12}	Les Borges	Biomass	22	153	Spain

Table 5.4: Normalized values for the j_{th} criteria

		P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_{10}	P_{11}	P_{12}
D_1	C11	0.50	1.00	0.80	0.25	0.50	0.00	0.35	0.70	0.50	0.25	0.75	0.50
	C12	0.16	0.46	0.33	0.40	0.41	0.00	0.58	0.39	1.00	0.08	0.67	0.07
	C13	0.59	0.27	0.26	0.60	0.00	0.52	0.74	0.74	0.61	1.00	0.58	0.29
	C14	0.94	1.00	0.00	0.61	0.83	0.56	0.83	0.89	0.56	0.56	0.83	0.61
	C15	1.00	1.00	1.00	0.71	0.43	0.43	0.00	0.29	0.29	0.43	0.57	1.00
D_2	C21	1.00	1.00	1.00	0.67	0.33	0.00	0.33	0.17	0.33	0.33	0.50	1.00
	C22	0.83	0.00	0.67	0.17	0.83	1.00	0.50	0.83	0.83	0.83	0.83	0.17
	C23	1.00	0.25	0.50	0.75	0.00	0.25	0.50	0.75	0.00	0.25	0.50	0.75
D_3	C31	1.00	0.86	0.86	0.29	0.57	0.00	0.43	0.43	0.57	0.43	0.71	1.00
	C32	1.00	1.00	1.00	1.00	0.33	0.33	0.00	0.33	0.33	0.33	0.33	1.00
	C33	1.00	0.67	0.33	0.00	1.00	0.67	0.33	0.00	1.00	0.67	0.33	0.00
	C34	0.17	0.33	0.67	1.00	0.00	0.33	0.67	0.17	0.17	0.33	0.83	1.00
D_4	C41	0.17	0.11	0.23	0.55	0.81	0.09	0.00	0.13	1.00	0.77	0.62	0.30
	C42	0.20	0.20	0.20	0.20	0.80	0.80	1.00	0.60	0.60	0.80	0.80	0.00
	C44	1.00	0.63	0.50	0.00	0.75	0.88	0.38	0.13	0.88	0.50	0.75	0.13

Table 5.5: Aggregated normalized values for the corresponding dimension

	D_1	D_2	D_3	D_4
P_1	3.20	2.83	3.17	1.37
P_2	3.74	1.25	2.86	0.94
P_3	2.40	2.17	2.86	0.93
P_4	2.58	1.58	2.29	0.75
P_5	2.18	1.17	1.90	2.36
P_6	1.50	1.25	1.33	1.76
P_7	2.50	1.33	1.43	1.38
P_8	3.00	1.75	0.93	0.86
P_9	2.95	1.17	2.07	2.48
P_{10}	2.31	1.42	1.76	2.07
P_{11}	3.40	1.83	2.21	2.17
P_{12}	2.48	1.92	3.00	0.43

Table 5.6: Non-dominanted alternatives and ranking weights $w_1 - w_4$

	D_1	D_2	D_3	D_4
P_1	3.20	2.83	3.17	1.37
P_2	3.74	1.25	2.86	0.94
...	...	...	...	...
P_9	2.95	1.17	2.07	2.48
...	...	...	...	...
P_{11}	3.40	1.83	2.21	2.17
...	...	...	...	...
max	3.74	2.83	3.17	2.48
min	2.95	1.17	2.07	0.94
w_j	1.28	0.60	0.91	0.65

Table 5.7: RE projects ranking and MPDM score

RE Projects	MPDM score
P_1 La Jara	9.57
P_{11} Artilleros	8.87
P_2 Ence	8.74
P_9 Aura	7.97
P_3 Alconera	7.57
P_{12} Borges	7.32
P_4 Solarpark	6.81
P_{10} Pedrado Sal	6.76
P_5 Paracuru	6.75
P_8 Tamaulipas	6.28
P_7 Malaspina	6.19
P_6 Guanacaste	5.03

Chapter 6

Conclusions and future future lines of research

This is the last chapter of the thesis, in which conclusions obtained along these three years of research are highlighted in order to summarize the most relevant points of each chapter. Moreover, other future lines of research to be developed are proposed.

6.1 Conclusions

In an increasingly globalized and competitive environment, the use of technology is essential for business development, thus becoming an effective mechanism for regional economic development. Therefore, due to the importance of developing innovation as a way to find differentiation in business, the initial purpose of this research was to find an alternative channel for funding New Technology Based Firms (NTBF). During this first stage, many conclusive results were obtained regarding the importance of these businesses as a basis for the future and development of advanced societies. Although, the importance of NTBF for the economy and for society is demonstrated, several studies show that the main barriers for NTBF development are related to financial resources. This fact has been reinforced after an analysis of the existing literature, in which there is a broad consensus on the fact the main problem these companies face is the lack of funding and support from both the private sector and public administration.

Therefore, the initial target was to find a model of innovative financing that could encourage the creation and future development of NTBF. For this purpose, we explore the possibility that Project Finance becomes a new method of financing

NTBF. Project Finance is an innovative investment tool that is able to combine private financing and public support. The second goal was to find a new application for the Project Finance as the main sectors so far had been the power and transport sectors.

We have faced many difficulties in making progress with the use of Project Finance in NTBF, bassically, due to the nature of NTBF and the requirements to implement Project Finance. In NTBF, the complexity of their creation, the lack of external financing and the lack of business and commercial experience, are elements that directly conflict with the main point that Project Finance requires: the need for the project to be profitable and to generate returns from the very beginning. In other words, the main difficulties to apply Project Finance to NTBF is the uncertainty in the future cash flow, as this is the basic assumption on Project Finance. The future cash flows should be predictable and stable and must be capable to cover the debt service adequately.

At this stage, we decided to find a new path in the applications of Project Finance. The problem of public financing and budget constraints is a topic on top of policymaker's agenda worldwide that has led to a reconsideration of the need to shift the investment effort to the private sector and to the development of Public Private Partnerships (PPPs). Project Finance has been used to reduce cost agency conflicts and better risk management. Therefore, Project Finance has been introduced when costs and risks are relevant issues to manage and has been chosen by project developers to reduce lender's recourse to the sponsors, permit an off-balance sheet of the debt and especially to reduce all type of project risks. The current financial crisis and governments difficulties in raising funds for new projects has led to an increase in private capital demand in both developed and developing markets. In this sense, Project Finance plays an important role in financing future large investment projects.

By carrying out the literature review, the main interest areas for Project Finance researchers have been identified from both theoretical and practical points of views and we can conclude that Project Finance became a rapidly growing field of finance. Moreover, financial analysis and risk management are the most relevant areas in theoretical papers and the last years they have been the main topics regarding applications, infrastructures and energy sectors.

Considering this literature analysis we can observe that at the beginning Project Finance was initially used in low technological risk level projects involving high investments. Later, Project Finance was exported to less developed countries to construct basic infrastructure. At the same time, in the industrialized countries, Project Finance principles have been applied to other types of projects, such as public infrastructures in which there is an increasing use of private funds. In the last two decades, Project Finance has played a key role in telecom projects and in the field of RE.

Investment in RE technologies were still negligible until the early 2000s. Since then, there has been a significant growth in RE investments registering a solid 17% increase to $270 Billion in 2014 after two years of declines. The main cause were major expansions of solar facilities in China and Japan and record investments in offshore wind projects. Some European countries, such as Sweden, have already, in 2015, surpassed the 2020 objectives marked by the European Commission.

The EU leads the world in the fight against climate change, a prove of that is the Adoption of the Paris agreement (United Nations), in December 2015 in which 195 countries adopted the first-ever universal, legally binding global climate deal. In 2020 the EU countries will have reached a 20% use of RE for their total energy consumption. In the EU there is three times more renewable power per capita than anywhere else in the rest of the world. The United States is the largest individual investor among the developed economies and China invested recently more in renewable energy than Europe countries together. Spain has progressed in harmony with other European countries, but at the same time it must face other challenges that have traditionally characterized the Spanish energy sector, such as, high energy consumption per unit of gross domestic product, high degree of energy dependency and high levels of greenhouse gas emissions.

One of the most effective way to reduce greenhouse emissions is to promote RE investments and its is widely known that the problem of financing RE projects becomes a crucial issue for public and private decision makers. Recent reports (REN21 and European comissions), show that in most countries the investments in RE carried out by the private sector are insignificant compared with the public ones. As a consequence of the financial crisis, the public sector cannot keep the level of investment to achieve the desirable environmental targets. Regarding the private sector, there are two basic ways a RE company can source capital: either by borrowing loans from commercial banks or through equity capital, usually in the form of funds. Loans are used in the short term to support everyday operations, but in the long term equity capital in the form of Project Finance, Venture Capital, Pension Funds or Infrastructure Funds is prefered.

As we said before, since the late 1980s Project Finance has arisen as an innovative PPP tool to fund large scale long term investment projects, including RE investments. Moreover, we have found a lack of research in the existing literature regarding financial decisions in the RE sector. When commercial banks face the problem of assessing RE projects using Project Finance methodology their main concern are related to financial aspects using the Debt Service Coverage Ratio to assess the financial viability of the project. They also consider a matrix of risks that is evaluated in a qualitative way, analysing how these risks can be covered and mitigated although in this analisys the risks are not quantified. When considering financial and non-financial dimension in the decison making process, the analyst could make better decisions. For this reason, this problem can be treated as a MDCM problem.

Recent literature in RE has started to incorporate the financial perspective when RE technologies are evaluated. This fact supports the need of new methogological approaches in the field of MCDM in RE projects that incorporates criteria from the financial, technological, political legal and evironmental dimensions of the problem. The use of MCDM methodologies in RE has grown significantly over the last two decades specially MADM methods such as AHP, ELECTRE, MAUT, PROMETHEE or TOPSIS. Regarding the applications of these methods, the main problems are the assessment of environmental impact, ranking RE strategies or lyfe cicle stretegies.

As a previous step, we propose to consider a set of projects and four dimensions. The four dimensions are (i) Financial, (ii) Political-Legal; (iii) Technological; and (iv) Social-Environmental. Each dimension includes a subset of criteria that is measured for each project. The model implies two basic assumptions: Moderate pessimism and domination.

In most of the previus MCDM methods the aggregation weights for the criteria are established from the DM's subjective perspective. According to Arrow's Impossibility Theorem "constructing social preferences from individual preferences is rather impossible", say, no rank order voting system can convert the ranked preferences of individual into a community-wide complete and transitive ranking. There is a group of MCDM methodologies in which the aggregation weights are obtained following objectivity principles as for example the MPDM methodologies.

MPDM is able to rank a set of alternatives from an objective way. Frequently, the agents are interested in increasing the influence of certain criteria on the ranking, which is to be computed by an independent decision maker. A hint on these biases is the presence of ranges, which are very high in some criteria as compared with the ranges in other criteria. To correct the scores affected by these biases is the main contribution of MPDM.

The proposed MPDM model allows us to rank a set of twelve real projects in the RE sector that have been funded using Project Finance. When applying this model, financial and technological dimensions obtain the highest weights. These results are consistent with bank managers preferences that include five criteria in the financial dimension and four in the technological dimension while for the other dimensions they only include three criteria. This application can help practitioners analyze RE projects from several dimensions.

6.2   Future lines of research

As explained during the thesis, the selection of the optimal source of energy to invest in is an issue which involves many different factors, policies and risky situations. Moreover, the complexity of the decision making process is higher as the number of alternatives, criteria and variables is increased.

In this research, we have shown how a Moderate Pessimism Decision Making (MPDM) method is used to add to the rational financial evaluation of investment opportunities a set of non-financial factors that affects the investor's decisions and how it allows us to rank a set of RE projects to be funded using Project Finance from an objective perspective since weights are obtained from the method. The proposed approach requires comparisons not in terms of superiority of one method over others but in terms of appropriateness to the financial problem in question.

Future research could be conducted to compare results with other ranking methods. So we have already started to work in the next step and we are developing a paper to use the Compromise Ranking Method VIKOR but improving it by introducing the Analytical Hierarchy Process (AHP) in assessing criteria weights.

VIKOR method introduces the multi-criteria ranking index based on the particular measure of "closeness to the ideal" solution. This method focuses on ranking and selecting from a set of alternatives, and it determines compromise solutions with conflicting criteria. The compromise solution could be the base for negotiation, involving the decision makers' preferences by criteria weights. The Analytic Hierarchy Process (AHP) is a decomposition multiple-attribute decision-making (MADM) method in which human decision making process is based on hierarchy, pair-wise comparisons, judgment scales, allocation of criteria weights and selection of the best alternative from a finite number of variants by calculation of their utility functions, thus obtaining a set of preference weights.

In the proposed paper, we show how the VIKOR method is applied to the selection of RE projects to be funded by commercial banks. The method is combined with the AHP method for weighting the importance of the different criteria, which allows decision makers to rank the alternatives from particular preference weights.

Moreover, it would be important to complement this research adding the most important aspects of Fuzzy multi-criteria decision making models. The fuzzy set theory is a powerful tool to treat the uncertainty in case of incomplete or vague information. In Kahraman et al. (2009), fuzzy multicriteria decision-making methodologies are suggested for the selection among renewable energy alternatives and in Sánchez-Lozano et al. (2016) some fuzzy approaches of different MCDM methods are combined in order to deal with a trending decision problem such as onshore wind farm site selection in Spain.

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