**UNIVERSITY OF THESSALY**
**DEPARTMENT OF PLANNING AND REGIONAL DEVELOPMENT**

**POSTGRADUATE PROGRAM IN EUROPEAN REGIONAL DEVELOPMENT STUDIES**

**Dissertation:**

# **ECO-INNOVATION:** POLICIES AND WINDOWS OF OPPORTUNITIES

**Vasiliki V. Georgatzi**

Supervisor: Dr. Yeoryios Stamboulis

June 2012

**ABSTRACT**

The present dissertation is going to examine the need for new technologies that arises because of the negative impacts that industrialization has caused until now to the environment. Innovative technologies are necessary to be embedded in the industrial field in order to help the situation, but is it an easy process? We examine the role that environmental regulations play in the adoption of environmental regulations. We review the barriers that firms/ industries face during the adoption process and the strategies and incentive programs that countries follow so as to enhance and motivate the development and adoption of environmental innovations. Furthermore we go over the principles that regulations have to follow and the conditions under which they are going to be successful and constitute motivation for the adoption of eco-innovations. Finally, we review the technology of electric vehicles as an eco-innovation and the policies that six countries follow so as to enhance the development, improvement and use of electric vehicles as well.

*Keywords: eco-innovation, barriers, environmental policies, environmental innovations, electric vehicles, USA, UK, France, Germany, Japan, China*

**ΠΕΡΙΛΗΨΗ**

Η παρούσα διπλωματική εργασία εξετάζει την ανάγκη για νέες τεχνολογίες που πηγάζει από τις αρνητικές επιπτώσεις που η εκβιομηχανοποίηση έχει προκαλέσει έως σήμερα στο περιβάλλον. Καινοτομικές τεχνολογίες είναι απαραίτητο να ενσωματωθούν στον βιομηχανικό τομέα για να βοηθήσουν την κατάσταση, αλλά πόσο εύκολη είναι αυτή η διαδικασία; Εξετάζουμε το ρόλο που διαδραματίζουν σε αυτή την προσπάθεια οι περιβαλλοντικοί κανονισμοί. Βλέπουμε τα εμπόδια που μπορεί να αντιμετωπίσουν οι επιχειρήσεις κατά τη διαδικασία υιοθέτησης οικο-καινοτομίας καθώς και τις στρατηγικές και τις πολιτικές ώθησης που χρησιμοποιούνται ως κίνητρο από τις χώρες για να κινητοποιήσουν την ανάπτυξη αλλά και την υιοθέτηση των οικο-καινοτομιών. Επίσης μελετάμε τις αρχές τις οποίες θα πρέπει οι κανονισμοί να διέπουν ώστε να είναι επιτυχημένοι και να αποτελούν κίνητρο για την υιοθέτηση οικο-καινοτομίας. Τέλος, κάνουμε μια ανασκόπηση της τεχνολογίας των ηλεκτρικών οχημάτων, ως μια οικο-καινοτομία, και των πολιτικών που χρησιμοποιούν έξι χώρες για να ενισχύσουν την ανάπτυξη, την βελτίωση και τη χρήση των ηλεκτρικών οχημάτων.

*Λέξεις κλειδιά: οικο-καινοτομία, εμπόδια, περιβαλλοντικές πολιτικές, περιβαλλοντικές καινοτομίες, ηλεκτρικά οχήματα, ΗΠΑ, Ηνωμένο Βασίλειο, Γαλλία, Γερμανία, Ιαπωνία, Κίνα*

**ACKNOWLEDGEMENTS**

This dissertation would not have been possible without the guidance and the help of several individuals who in one way or another contributed and extended their valuable assistance in the preparation and completion of this study. First and foremost, my utmost gratitude to my supervisor Yeoryios Stamboulis whose encouragement, guidance, assistance and advice for completing this work I will never forget. I would like also to thank our librarian Evi Kolovou for her kindness, friendship and support and my cousin Despina for her help in language corrections. Last but not least, I would like to thank my family for the patience and personal support during this period.

**TABLE OF CONTENTS**

***LIST OF TABLES***



***LIST OF FIGURES***

## ACRONYMS

ABS: Antilock Brake System

ACE: Advanced Clean Energy

AEV: All-electric Vehicles

BAT: Best Available Technology

BEV: Battery Electric Vehicle

CARB: California Air Resources Board

CFC: Chlorofluorocarbon

ETAP: Environmental Technology Action Plan

EV: Electric Vehicle

EVI: Electric Vehicles Initiative

FCEV: Fuel Cell Electric Vehicle

FIT: Feed in Tariffs

GHG: Greenhouse Gases

HEV: Hybrid Electric Vehicles

ICE: Internal Combustion Engine

IEA: International Energy Agency

METI: Ministry of Economy, Trade and Industry

MITI: Ministry of International Trade and Industry

MOST: Ministry of Science and Technology

OECD: Organization for Economic Co-operation and Development

PHE: Plug-in Hybrid Electric Vehicles

PPP: Polluter Pays Principal

RES-E: Renewable Energy Sources-Electricity

VSC: Vehicle Stability Control

ZEV: Zero-emission Vehicle

# CHAPTER 1: INTRODUCTION

The aim of this dissertation is to explore the nature of eco-innovations and their role in the industrial field and which is the role of regulations in the decision and the adoption process of an eco-innovation. We analyze how eco-innovation can be governed through environmental regulations and if environmental regulations motivate or impede eco-innovations. Environmental regulations and eco-innovations afterwards constitute part of the effort to protect and preserve the environment. Environmental regulations are necessary in order to induce firms to take measures in favor of the environment and eco-innovation is the next step.

Our study was based on literature review and secondary sources. In Chapter 2 we examined eco-innovation and types of eco-innovation regarding the target that each firm has. We analyze the barriers that can arise during the process of eco-innovation adoption and diffusion. We also distinguish the categories of barriers that may emerge and the facts that may affect the rate and the speed of adoption. We analyze the selection environment within which eco-innovation is adopted and the influence that it may have to investors' decision.

In the next chapter we analyze the kind of regulations that exist and the targets that they have regarding eco-innovation. We present the elements that regulations might have and if they can induce or block the adoption of eco-innovation. Furthermore we refer to the most common policies that governments set in order to motivate the adoption of eco-innovation and we analyze some of the encouraging or penalizing instruments that are used by countries. We examine the issues that regulators have to consider in order to make accurate and targeted regulations with feasible goals. Finally, we refer to the role that regulations play in the adoption of eco-innovation and if they can be a motivation or impede this process.

The next step was to select certain case-studies which had a research interest from the aspect of the deployment of electric vehicles. Thus, six countries were selected, USA, the UK, France, Germany, Japan and China which are considered to be the most interesting regarding the fact that most of them have a sizable automobile industry and some of them want to become leaders either in the production of EVs in general or in the production of some key components or technologies of EV, e.g. Japan that wants to be a leader in the production of lithium batteries.

We examine the combination of policies and the strategic niches as a policy used by the countries in order to promote the research for the improvement of EV and the purchasing of it.

We end up with conclusions on eco-innovation and the obstacles that may emerge in the process of its adoption, how would these be overcome and make the adoption process more feasible. We mention the conditions under which can regulations may have a positive influence and motivate businesses to proceed to invest in eco-innovation. The last issue that we refer to is the technology of EVs. We mention some opportunities and challenges that may emerge within EVs' automobile industry and we also examine the policies that countries follow in order to enhance the development, deployment, and use of this technology regarding the market and the industry field as well.

# CHAPTER 2: ECO-INNOVATION: BARRIERS, THREATS AND OPPORTUNITIES

In this chapter we are going to review the meaning of eco-innovation and how eco-innovation is getting adopted by the firms/industries. The process of adopting an eco-innovation is not easy as many barriers can arise. These barriers can be psychological, temporal, techno-economic, organizational or functional. The existence of eco-innovation is really important as it is concerned as a way to exceed the environmental but also the economic crisis. As the process of adoption is not simple, we have to take under serious consideration the selection environment in which the eco-innovation belongs so as to have the best possible results.

## 2.1 WHAT IS ECO-INNOVATION

There are several definitions about what an 'eco-innovation' is. Dewick and Miozzo give a remarkable definition for environmental innovation / eco-innovation. They describe it as: "the use of production equipment, techniques and procedures, and products and product delivery mechanisms that are sustainable (because they conserve energy and natural resources, minimize the environmental impact or footprint of human activity and protect the natural environment)". (Dewick and Miozzo, 2002: 824)

Kemp & Foxon (2007), some years later come to supplement the previous definition by saying that 'eco-innovation' is the production, assimilation or exploitation of a product, production process, service, management or business method that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resource use (including energy use) compared to relevant alternatives. While Hemmelskamp (1997) defines 'eco-innovation' as an innovation that has as its target to prevent or reduce anthropogenic burdens on the environment, clean up damage already caused or diagnose and monitor environmental problems.

In addition, Jiménez (2005) claimed that the term 'eco-innovation' includes the notion of technology diffusion, and more specifically the adoption of innovations that are

environmentally friendly. European Commission[1] states that eco-innovation is about changing consumption and production patterns and market uptake of technologies, products and services to reduce the impact that people cause through them on the environment. Furthermore, they point out that business and innovation have to come together so as to create sustainable solutions for the environment. We all have to make better use of precious resources, reduce the negative side-effects of our economy on the environment and create economic benefits and competitive advantage.

As mentioned by OECD at Frondel et al. (2007), Leitner et al. (2010) and Del Rio et al. (2010), the traditional understanding of innovations is to distinguish them between technical and organizational innovations (such as Environmental Management Systems), while the technical ones are divided into product, process and organizational innovations. To be more specific:

- ✓ Organizational innovations include new forms of management, such as total quality management.
- ✓ Process innovations enable the production of a given amount of output (goods, services) with less input.
- ✓ Product innovations encompass the improvement of goods and services or the development of new goods.

What Rennings (2000) comes to add is that environmental product-innovation is significantly driven by the strategic market behavior of firms, it functions as a market pull effect, while environmental process-innovation is more driven by regulation, namely it functions as regulatory push/pull effect.

One categorization about innovations that is made by Porter and Van der Linde (1995b) refers to the forms that an innovation can take if it happens in response to an environmental regulation. These forms are two and refer to the things that a company/industry has to change so as to deal with its impacts on the environment. The first one refers to the fact that companies are getting ‘smarter’ about how to deal with pollution. They get smarter about how to deal with emissions, how to reduce the amount of toxics in their products or harmful materials generated by the production process. The second form refers to the fact that innovation addresses environmental impacts

[1] European Commission: http://ec.europa.eu/eaci/eco_en.htm (Last accessed: 30/11/2011)

while simultaneously improves the affected product itself and/ or related processes. This second category can easily exceed the cost of compliance to regulation.

Additionally to the previous definitions, Leitner et al. (2010) makes a distinction on eco-innovation. They argue that eco-innovations are defined in two ways:

- ✓ by the effects of the innovation on the environment,
- ✓ by the intention of the innovator to reduce the environmental impact of processes or products.

More specifically, they make a distinction between eco-innovations that are followed so as to reduce the effect that firms have on the environment maybe in order to respond to environmental regulations and to these that are followed because of the willingness of the innovator to reduce the environmental impact. As Huber (2008) argues, environmental innovations tend to be a complex process and this is the reason why most often they require rearrangement of product chains, or even the setting up of new chains from scratch. This is illustrated by the fact that when the term eco-innovation is introduced, what we have to wait for is three types of change. Firstly, there is the technological change that is needed so as to support sustainability. Secondly, there is the social change as firms and people have to adopt the technological change and lastly we have to expect an institutional innovation as institutions have to change so as to facilitate technological innovations to be adopted. But as we have already mentioned many times, eco-innovation happens in response to environmental regulations that governments set so as to protect the environment.

Technological innovation is a key factor for environmental innovation in order to help in environmental protection. Technological innovation may be radical shifts in technology, or incremental ones involving adaptation of prior technologies. On the other hand, radical innovations are these that explore new technology and they are innovations of high risk. This type of innovation causes dramatic changes to the market or even leads to new ones. Incremental innovation happens when a new, in our eyes, technology is produced but in reality it is a product of exploitation of an existing technology as a starting point. It is an innovation of low risk that can improve competitiveness within current markets and industries. As innovation and technological change usually respond to a regulation that exists in the industry market, a fact that is also supported by Ashford et al. (1985), what is necessary so that this response will take

place is adoption of compliance technology, change in process technology, and of course product substitution.

Moreover, we have to bear in mind that innovation systems not only expand the technological capabilities of firms, but they play another role as well. Innovation systems actually transform the structure of costs and benefits of research and development activities. We support this opinion in accordance with Aguayo (2008), as we consider the considerable number of issues that have to be taken into account before innovation. Organizations and processes of knowledge and service exchange, the innovation systems that act as focusing devices as well as problem-solving devices are the factors that act as a supplement to the technology search and assessment capabilities of an individual firm. But despite the positive effects that environmental innovations can have to the environment, sometimes it is difficult to adopt them as barriers can arise.

## 2.2 BARRIERS TO ECO-INNOVATION

In this section we are going to see the obstacles that firms encounter at the time of adopting the innovations that are obliged to in order to respond to governmental regulations. What is needed so as to overcome these barriers is a very important issue that has to be answered. Barriers can be grouped in organizational, financial, institutional, functional and psychological ones and they can be of the external or internal environment.

As Druehl et al. (2011) mentioned, what has changed is the customer awareness about sustainability that has grown remarkably. But what is worth the discussion is that this awareness does not necessarily translate into purchasing behavior. The question that remains is how to develop environmentally friendly innovations that consumers will purchase and use and as a consequence how to overcome the barriers that arise during the adoption and embeddedness process of an innovation. The barriers are grouped in five large categories, we categorize them on organizational, techno-economic, functional, psychological and temporal. This categorization is also shown below in Table 1.

**Table 1: Barriers that environmental innovation encounters**

| Organizational | Techno-economic | Functional | Psychological | Temporal |
|---|---|---|---|---|
| • **Conflict between regulations**<br>• **Unclear scope of regulations**<br>• **Lack of mechanisms to explain regulations**<br>• **Uncertainties over new regulations**<br>• **Difficulties to coordinate with other companies**<br>• **Lack of information about regulations** | • High cost<br>• Lack of internal funds<br>• Lack of financial support<br>• Existence of dominant enterprises<br>• Lack of qualified personnel<br>• Lack of information about new technology<br>• Incompatible technology to existing production process or to regulations | • Risk<br>• Uncertainty<br>• Usage<br>• Value | • Tradition<br>• Image | • Short time limits to address regulations<br>• Short time limits to adopt innovations |

Source: own processing, based on Cleff et al. (2007), Rothwell (1980), Druehl, et al. (2012) and Hezri (2011)

Eco-innovations encounter some obstacles that do not let them be adopted or embedded in the industrial environment. These obstacles are categorized by Del Río et al. (2010). They quote 3 categories:

- Some of these obstacles are related to the external environment surrounding the firm, including the absence of pressures to eco-innovate as well as the institutional environment, including public policies, laws, and organizations.
- Some refer to the internal conditions of the firms that may hinder eco-innovation. Such conditions may be the lack of financial resources, low technological competency to absorb eco-innovations developed by others or to develop their own eco-innovation, and a low priority by the firm for environmental issues.

- Finally, the techno-economic characteristics of eco-innovations may constitute a barrier for eco-innovation. Eco-innovations might be too expensive or incompatible with the existing production process in the firm.

All these three types of barriers tend to interact and as a consequence we cannot single them out. What is also supported is that barriers tend to differ between the types of eco-innovations. For example, barriers are different when we talk about product and process eco-innovations. (Del Río et al., 2010)

Dewick and Miozzo (2002) also support that there are 4 main barriers that delay the adoption of new environmental technologies. The first one is the increase of the risk, because firms usually believe that a new technology may lead them to a less competitive status. Second, there is a lack of information which makes firms be reluctant towards new technologies, as they are afraid of the consequences that they may face after the adoption. The third one is the public awareness that many firms show. And the last one is the high cost that usually accompanies the new technologies and makes the firms be hesitant in adopting these technologies. An additional obstacle mentioned by Rothwell (1980), which is older but of high importance, is that firms do not usually have enough time to address the wills of the regulations and the fact that they do not have enough time to find the optimum solution to adopt. This obstacle is about the administration of the firm/industry.

Agreeing with Dewick and Miozzo (2002), Bruijn and Hofman (2000) also support that new eco-innovations are always of high risk, which constitutes a very important barrier to the adoption of new technology, especially with the current economic crisis that we are facing for the time being. What firms need so as to adopt these innovations is regulatory stability and support, economic and political, in order to reduce those risks. Furthermore, firms can take advantage of the initiatives, knowledge and the capabilities of other partners, like trade associations, consultancy agencies, chambers of commerce, universities and research institutes.

Going a little bit earlier, Rothwell in his paper in 1980, refers to the barriers that the Environmental Protection Agency regulatory action can cause on industry innovation, which are many. More specifically, he quotes 14 barriers which are the following:

- regulatory time pressures leading to non-optimal innovations

- prohibitively high costs of complying with regulations
- unclear scope or implications of regulations
- delays by the agency in promulgating guidelines required by the law
- inability or unwillingness of agency to modify regulations in view of altered circumstances
- disagreement within the agency about the application and meaning of regulations
- inconsistency over time in the agencies application of regulations
- inability of firm to develop or allocate the resources necessary to comply with regulations
- conflicts and inconsistencies between regulations
- inability of firm to meet prescribed deadlines in regulation
- lack of mechanism within the agency to explain regulations
- lack of effective appeal procedure
- differential treatment by the agency of the entities affected by the regulations
- unwillingness of the agency to explain regulations

Some years later, Rothwell (1992), regarding the indirect impacts of government regulations on business industrial innovation, focuses on the three more often encountered, which are the following:

- ✓ There is a high cost of regulatory compliance that can result in a reduction in the rate of investment in new manufacturing equipment.
- ✓ Also, regulation can cause delay in the market launch of new products through lengthening development times
- ✓ Last but not least, uncertainties over new regulations can arise in the pipeline.

Innovation resulting from a specification standard can occur when regulators are willing to set the standard based on the capability of a newly developed technology. But as it is difficult for governments to set regulations that will focus on the technology that is not yet produced, authorities tend to adopt the “best practicable technology” or “best practicable means” approach. This can in some cases be a barrier, as there are firms that wanted to apply technology superior to those the regulation had specified and they have difficulties in persuading the regulator agencies to allow them to use this kind of technology. (Rothwell, 1992)

Another barrier that is the most significant, according to Rothwell (1992), is that "regulatory time pressures leading to non-optimal solutions". The time that regulatory agencies give to firms or companies so as to adopt the new regulations is too short, a fact that does not allow them to take the optimal decisions and sometimes as it is referred to by Chappin et al. (2009), this time restriction leads to a decrease in innovation freedom. The two previous barriers have, as a result, to foster innovators to adopt not the best and more accurate technology but the best available technology (BAT) at the time.

Additionally to the barriers that the previous refer to, Cleff et al. (2007) believe that the obstacles that a company faces while trying to innovate are the following: the cost of the innovation, the lack of internal funds, the lack of financial support outside the enterprise, the dominance of some enterprises, the uncertainty regarding the demand for the new innovative products, the lack of qualified personnel, the difficulty to cooperate with other companies, the lack of information on markets and last but not least the lack of information on technology. In the following table we can see to what degree the companies that tend to innovate think that these barriers are at a high degree so as to be able to influence their willingness to innovate.

**Table 2: Proportion of innovative companies which believe that the following innovation barriers are met at a high rate.**

| Innovation barrier | Innovative Companies |
|---|---|
| **Innovation costs too high** | 25.0 |
| **Lack of funds within enterprise or group** | 23.8 |
| **Lack of finance from sources outside the enterprise** | 17.8 |
| **Market dominated by established enterprises** | 15.3 |
| **Uncertain demand for innovative goods** | 14.7 |
| **Lack of qualified personnel** | 11.4 |
| **Difficulties in finding cooperation partners** | 9.1 |
| **Lack of information on markets** | 6.6 |
| **Lack of information on technology** | 5.3 |

Source: Cleff et al. (2007), pp.66

While the innovative companies think that the most important barrier to innovation is that the cost of innovation is too high, according to the table above, Cleff et al. (2007) believe that the most important barriers that a firm encounters when they want to adopt a new innovation is to manage to come up with the required financial capital, the taxation, the regulations, the demand and of course the human capital that is needed.

On the other hand, Porter and Van der Linde (1995a) support that, after collecting data for the issue of eco-innovation, for instance, the cost of adopting the regulations that refer to the environment can be minimized by the fact that innovations can provide firms with a significant number of benefits that can overlap the cost of adoption. This is supported by the fact that most of the times innovative technologies lower the product costs and boost resource productivity.

Rogers, in the Druehl et al., identified five attributes of an innovation that influence its rate of adoption: "relative advantage (over the incumbent), compatibility (with people and existing products), complexity (ease of use), trialability (opportunity to experiment) and observability (visability)". (Druehl et al., 2011: 5) While similarly to Rogers, Cohen and Murphy, in Druehl et al., refer to "the properties of usefulness (ease of use)", but they also refer to: "interconnectedness (link to other products or services), and symbolism (image)". (Druehl et al., 2011: 5) In addition to the previous factors Bennett and Bennett (2003) talk about the factor of effectiveness or efficiency added by the new technology to the previous outflows of the industries/firms.

On the other hand, Druehl et al. (2011) point out another perspective of the barriers that eco-innovation may encounter at the time of its entrance. They talk about economical, psychological, and those barriers imposed by the convenience of the dominant technology. Furthermore, most of the barriers that a company encounters in the diffusion of an environmentally-friendly innovation are conducive to be overcome due to the innovation capability of the country. Therefore, as it is mentioned in the same article, the successful diffusion of sustainable disruptive innovations will likely require high levels of product integrity. Product integrity represents the seamless fit between the product concept and the needs of the target customer.

The diffusion of innovation depends on the size of each firm. Globally oriented firms usually have their own R&D department. Large firms, as they have the capability, try to help in the diffusion of new technology and innovation. This, according to Maskell

(1996), can be achieved by monitoring the international progress within the firms' field of interest. Sometimes large firms plug into knowledge-pools throughout the world by out sourcing parts of the current research-portfolio and reaping the results, by obtaining access to foreign labs through cooperation or procurement, and by establishing their own facilities in international research hot-spots.

As Dewick and Miozzo (2002) support, effective adoption of innovation and especially innovation that refers to the environment requires the participation and collaboration of all the parties in the industry, a process which is quite difficult as the parties are of a remarkable number and they also have to agree on many issues.

Porter and Van der Linde (1995a) suggested that environmental progress should happen simultaneously with innovation so that resource productivity will be raised and regulation will become not an obstacle but a driver for innovation, and implicitly the more prescriptive the regulation, the more confined the innovation must be.

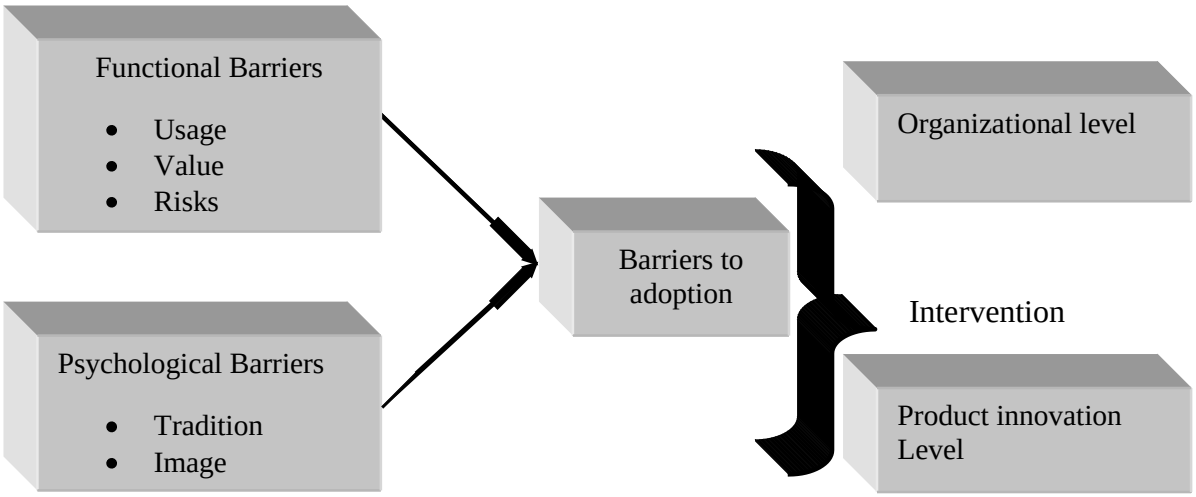
Druehl et al. (2011) claim that consumer resistance constitutes an additional important barrier to innovation diffusion and they make a classification of it into two main categories: the first one refers to functional barriers and the second to psychological.

As **functional barriers,** in the process of adoption of new technology, they quote usage, value and risks. Usage refers to the fact that new innovations require changes to the consumer's mode of operation that may be perceived at the beginning as inconvenient, difficult, or slow to use. The barrier of risk refers to the fact that the new innovation is unknown to the consumer and entails uncertainty. There are 4 types of risks: the physical which imply that the new technology causes harm, the economic according to which people prefer cheaper alternatives, the functional because sometimes people do not have the ability to perform properly, and the social risks which involve people's tendency to follow other people's choices (peers' view). The economic risk is also associated with fear of the product becoming obsolete or the next generation being substantially better and they believe that their current investment will soon be proven not enough. The risk barrier captures uncertainty and this is what makes the innovation diffusion and adoption come late.

In the category of **psychological barriers,** they include tradition and image. Tradition pertains to fear of change in daily routine, habits, customs, and social norms. This

means that many of the potential adopters of the new innovations are afraid of adopting it as they believe that it is going to change their routine and may also bring them bad fortune.

**Figure 1: Functional and Psychological Barriers**




Source: Druehl et al. (2011), p.8

Despite all these barriers and obstacles that we referred to above, there is also the factor of uncertainty that has to be overcome so that an innovation can exist, so that an idea can become an innovation that will begin to be diffused. Hall and Martin (2005) state that the dimensions of uncertainty that have to be overcome, so that an idea will qualify as an innovation, are the following four:

- ✓ Technological Uncertainty: the concept must be feasible technologically, based upon corporate scientific and technological competencies.
- ✓ Commercial Uncertainty: it must be commercially viable and able to compete successfully in the marketplace.
- ✓ Organizational Uncertainty: it should be congruent with the firm's overall strategy and capabilities, complementary assets and its ability to protect intellectual property.
- ✓ Social Uncertainty: the societal impact on or from diverse secondary stakeholders must be recognized and accommodated.

## 2.3 SELECTION ENVIRONMENT FOR ECO-INNOVATION

The selection environment plays a very important role in the adoption of innovations in general and of eco-innovations more specifically. Malloy (2004) points out that the process to catalog and synthesize every factor that affects technology choice is neither feasible nor useful. This is the reason why Malloy suggests focusing on a small set of socio-economic factors otherwise called the "selection environment" by Nelson and Winter and other evolutionary economists. The regulatory obligations and constraints that a firm faces are of critical importance and part of the selection environment. But part of the selection environment for innovation constitutes also the mechanisms by which information about the innovation flows to potential adopters, the attributes of the innovation and its value to the potential adopters, as the benefits and costs of adoption. Another important part of selection environment is the strength of pre-existing routines and behaviors exhibited by relevant individuals and organizations. What is important in analyzing and understanding the selection environment is that by doing this regulatory designers can detect systemic barriers to innovation, identify regulatory alternatives that would specifically address those barriers, and anticipate how the system will likely respond to the various alternatives.

According to Freeman (1992), the selection environment of the innovation process can be divided into three categories:

- Natural environment: Man-made environmental problems or external forces may put selective pressure on society to create new technologies, e.g. phasing out CFCs to protect the ozone layer or forcing energy saving technologies to mitigate climate change.
- Built environment: The built environment consists of physical assets, i.e. the existing infrastructure. The built environment needs decades to depreciate, thus, slowing down innovation and diffusion processes.
- Institutional environment: Profitability can be identified as a key selection criterion in market economies.

As Rennings (2000) claims, when we have to adopt an innovation first we have to define the target. Talking about target we mean that sometimes firms may want to invest in new technology while other times they may want to focus on the product. So, in order to have the desired results new eco-efficient technologies have to be subsumed under

technology push factors, while preferences for environmentally friendly products or image can be subsumed under market pull factors. Another main factor added by Morris (2007) that helps innovation to happen is the direct participation of the leadership, which shows us that regulation is a really important factor in the development and adaptation of innovation.

Another important dimension of innovations that is affected by the conditions in which innovation is adopted is the speed of adoption. Murage et al. points out that innovation adopters' speed vary. Innovation adoption speed depends on a considerable number of factors. Some of these factors are the pathway of information that they use and the education level of the adopter. They claim that the higher the education of adopters, the more likely it is to adopt the innovation. For this reason they support that "for knowledge intensive technologies such as PPT, there are needs for concerted effort to avail proper training to farmers who have no education". (Murage et al., 2011: 532) Moreover, they claim that investors who belong to a group tend to delay their decision for adoption of the innovation because they are exposed to a wide range of ideas which may either cause them to form a favorable or unfavorable attitude towards an innovation and especially to farmers that Murage et al. refer to in their paper. Murage et al.'s opinion makes us think that collective action can cause delay or even be an obstacle to innovation adoption. Additionally to Murage et al.'s opinion we have the opinion of Weiss and Bonvillian (2011), who also claim that collective action is one very important factor that tends to affect innovation adoption.

Furthermore, Diederen et al. (2003) point out that another factor that affects the speed of the innovation is the size of the business that somebody owns. The bigger the business, the more likely it is to adopt the innovation. Also, they claim that the adoption of the innovation is easier for the businessmen when they have their own capitals than when they have to borrow money. In addition, the age of the investor plays an important role as the younger the businessman, the more likely it is for someone to proceed to the adoption of an innovation. Two main factors added by Chappin et al. (2009) that explain the existence of environmental innovation are a set of specific policy instruments and of course the behavior of the firms regarding the adoption of the innovations as well as intra-organizational factors like the level of competition and the level of productivity that they want to reach.

What can be an additional help so as to move to the next step according to Kemp et al., is the existence of strategic niches[2]. The strategy of strategic niche management, as they claim, is valuable for the actor that wants to push new sustainable technologies on to the market. As they state, "Strategic niche management is a concentrated effort to develop protected spaces for certain applications of new technology". (Kemp et al., 1998: 186) Some consider strategic niche management as an experimental process but it is more than that. Strategic niche management aims at making institutional connections and adaptations and as a second aim have to stimulate learning processes about new technologies so as to have further development and use of it. Regarding the second aim of strategic niches we can understand that they are platforms for interaction with the target of searching for options of parallel evolution of technologies and its contexts.

Aguayo (2008) states that firms in order to be able to adopt new technologies and innovations need support by the government and by public authorities in general. Laws and instruments are needed so as to facilitate the adoption process and not to bring obstacles in the adoption and diffusion process. We support Aguayo's opinion that public authorities have to support investors' actions to invest on eco-innovations and other actions that help the environment protection and preservation.

To sum up eco-innovation which is the use of sustainable production equipment, techniques and products and product delivery mechanisms, is necessary in order to reduce the environmental impact that is caused by the action of the firms/industries. However, the adoption of eco-innovations is not a simple process as during the process of adoption barriers may arise. The barriers that a firm/industry may face may be organizational, techno-economic, functional, psychological or temporal. These barriers may be from the internal environment of a firm, such as lack of funds, from the external environment of a firm, such as lack of pressure by regulations, or techno-economic, such as high cost of new technologies. The most important barriers that firms face are the risk of new technologies that usually is high and intercept the adoption of eco-innovation, the lack of funds as sometimes investors want to proceed to the adoption but they do not have the necessary financial support and lastly but not least the time limits

[2]"Strategic niche management is the creation, development and controlled phase-out of protected spaces for the development and use of promising technologies by means of experimentation, with the aim of (1) learning about the desirability of the new technology and (2) enhancing the further development and the rate of application of the new technology." Kemp et al. (1998: 186)

that regulations give. Often the time that regulations give to firms so as to decide which innovation to adopt and the time for its adoption is less than the necessary. As a consequence firms end up adopting the best available innovation and not the optimal one. Crucial is also the role of selection environment as we have to think about the natural and built environment and institutional milieu as well before proceeding to the adoption of eco-innovation. Environmental regulations which perform a very important role in the selection process, constitute also part of the institutional milieu, we are going to examine in the next chapter.

# CHAPTER 3: POLICIES FOR ECO-INNOVATION

As the environmental problem requires immediate confrontation governments have set regulations so as to regulate the environmental impact of the technologies. We examine the types of the regulations, their targets and under which condition can they help in order to have the expected results. But regulations are not always enough by their ones, so public authorities also give some incentives so as to motivate the adoption of eco-innovation. We analyze some of the types of regulations, the instruments that are used so as to convince firms to invest on eco-innovations and the issues that have to be taken into account so as to address correctly the problems that the environment faces and the efforts that governments make within policies so as to lead to sustainability.

## 3.1 REGULATIONS FOR ECO-INNOVATION

In this section we are going to discuss the introduction of regulations, what made them almost necessary to enter our lives and how they influence the decisions of firms, industries and people in general in order to preserve the environment.

It was in the mid-1960s, after a decade of unrestrained industrialization, when society began to think about the impacts that technology at this phase of industrialization had on the environment and on society in general. For this reason, after the enhancement of people's awareness, in the 1970's regulations were introduced by governments so as to control the rate of industrialization, the use of new technology as well as the kind of new technology that is used in the industrial sector and so on, at the local, regional and national levels. Regulations, according to Rothwell (1992), should involve interaction between regulatory bodies and labor unions, industry representatives and the public so as to be more specific and more accurate to the needs that exist. The OECD (2011a) expresses some questions about innovation. From a policy perspective, the main question of this organization is: "What is the best way to support the development and diffusion of eco-innovation?" More specifically, from an environmental policy perspective, policy makers are thinking of the issue of how to stimulate innovation that will benefit the environment and of course the economic development.

Environmental regulations are thought by Renning and Rammer (2010) as government legislation (laws, acts, directives) as well as standards and industry commitments that

have as their target to contribute to the reduction of the burden on the environment and resource consumption. It must be conceded that the primary aim of environmental regulation is to protect the environment and not to stimulate technological change, but as we can understand the two are by no means incompatible. This happens because in order to conserve the environment, scientists try to find ways that are more efficient and they conclude with new and most of the times better technology and as a consequence this sometimes leads them to innovate.

In general, the main targets of environmental regulations as they are mentioned by Porter and Van der Linde (1995a, b), are to:

- ✓ create pressure and make firms innovate
- ✓ improve environmental quality
- ✓ alert and educate companies about opportunities and threats they will face
- ✓ inform industries that innovation is environmentally friendly
- ✓ create demand for environmental improvement
- ✓ level the playing field during the transition period

The fact that some specific targets of regulations differ from case to case, as the needs of each region are different and as the targets and the capabilities of each sector are different, leads us to categorize them into types. To be more specific, Ashford et al. (1985) in their paper refer to five different types of regulations. They group the regulations into those that:

- ✓ require demonstration of product safety prior to marketing
- ✓ require demonstration of the efficacy of products prior to marketing
- ✓ require proof of safety or the control of product use after marketing
- ✓ control production technology to reduce risks to workplace health and safety
- ✓ control emissions, effluents, or wastes.

The first category of regulations includes products like pesticides, food additives, pharmaceutical and new chemicals, namely it refers to the regulations that have to keep the level of safety of a product for the environment, the biodiversity and for human beings in high standards before it is launched in the market. The second category refers to regulations that affect products like pharmaceuticals. Efficacy of medicines has to be known before their consumption. The third type of regulations refers to products that

already contain chemicals and to how much safe they are for workers, consumers and the environment. The next type refers to regulations that control the technology that is used so as to be safer. The last type is regulations about the raw materials that firms use and how to reduce the emissions and the effluents that they have.

From case to case what can also vary, in order to have better results, is the form of the regulation that is applied. Environmental regulations can derive in many forms, with the two main requiring innovations, according to Rothwell:

> New environmental regulation can be met by a variety of means, with perhaps the two main options being basic process change or end-of-pipe[3] effluent control. The first approach will require innovation and might even lead to the development of radical new processes. The second approach will also require innovation, but in this case the innovation will generally derive from equipment suppliers outside the regulated industry. (Rothwell, 1992: 450)

In addition, Ashford et al. (1985) support that there are some elements of the regulations that may either induce or block the innovation. These elements are:

- ✓ the form of the regulation
- ✓ the mode
- ✓ the time for compliance
- ✓ the uncertainty
- ✓ the stringency of the requirements
- ✓ the existence of other economic incentives which complement the regulatory signal.

But additionally to the role of regulations to facilitate the introduction of eco-innovations, environmental regulations can also, according to Jaenicke (2007), create some advantages for companies and firms. These advantages are that:

- ✓ regulations can create or support markets for domestic industries

[3] Methods used to remove already formed contaminants from a stream of air, water, waste, product or similar. These techniques are called 'end-of-pipe' as they are normally implemented as a last stage of a process before the stream is disposed of or delivered. Source: Green Facts http://www.greenfacts.org/glossary/def/end-of-pipe-techniques.htm), [Last accessed: 15/10/2011]

- ✓ regulations, often initiated by regulatory trendsetters and leading to global harmonization, increase the predictability of markets.
- ✓ regulation (real or threatened) can make things easier for business: in contrast to voluntary approaches, affected companies do not have to worry whether their competitors will enact the same measures.
- ✓ regulation also reduces internal impediments in companies to implement technological change

According to OECD (2011a), there are a lot of OECD member countries that have already developed national strategies to support eco-innovation. In Europe, the strategy that countries follow is the Environmental Technology Action Plan (ETAP)[4], which has invited EU member states to develop eco-innovation roadmaps and to report initiatives taken at national and/or local level to support eco-innovation. But also outside Europe, a considerable number of OECD countries have similar initiatives, as examples they mention Korea and the United States that have designed explicit strategies to stimulate eco-innovation.

Achieving the targets that each government sets for the long-run, like cuts in $CO_2$ emissions, will require shifts to new kinds of systems in transport, energy and agri-food domains. In order to manage it, as Bulkeley (2011) argues, what is needed is to have new technologies but also changes in markets, user practices, infrastructures, cultural discourses, policies and governing institutions. In other words, we can see that eco-innovation not only demands new technologies but also changes in the general environment are also necessary so as to help the adoption and the development of it. As a consequence, if governments want firms/companies to conform to the regulation that they set, they also have to give them some motivations that are needed. Governments tend to stimulate firms by giving them both encouraging and penalizing induces. They give financial motivations so as to help firms adopt innovations but they also set taxes so as to make even the more incredulous firms conform to the regulations. This happens, as Rothwell (1980) points out, because innovations are a key factor so as to keep the standard of living at high rates in the advanced Western nations and vice versa,

[4] The Environmental Technologies Action Plan (ETAP) was adopted by the European Commission in 2004. The objective of this ambitious plan is to further environmental technologies to improve the environment and European competitiveness. http://ec.europa.eu/environment/etap/policy/index_en.html [Last accessed: 15/10/2011]

as people's living standard rises, environmental dependence is getting greater and greater and consumers pay higher attention to health and environmental protection.

As referred to by Del Río et al. (2010), the instruments that can promote eco-innovation can be grouped in three wide categories: environmental policy instruments, technology policy instruments, and other instruments. The selection of an instrument, as Leoncini (1998) supports, by the countries can be seen as a push- and- pull device. This device is, as expected, made up of positive and negative inducements. The degree of competition that is met in the market by the companies is the most important negative inducement. Furthermore, there are several dimensions that are related to this. These dimensions are consisted of the price structure, the speed of other firms' reaction to deviant behavior and of course the number of firms that actually react to it. Perez (2010) claims that a combination of multiple forms of public and private support in the different stages of the process of adopting new innovation, depending on the type and size of company, the type of innovation and the target markets that firms have, is required so as to optimize the innovation capabilities[5] and to adjust them to the characteristics of each country or region.

Chappin et al. (2008) make a different distinction for the policy instruments. They make a distinction between top-down regulations, interactive regulations, as well as positive and negative economic instruments. Additionally, OECD (2011b) claims that governments have a number of environmental policy tools so as to promote environmental protection. Such instruments are the regulatory instruments, market-based-instruments (such as taxation and tradable permits), negotiated agreements, subsidies, environmental management systems and information campaigns. In the next section we are going to see some of the most common instruments that are used by the countries to enhance innovation adoption and development. Other of these instruments can be characterized as market pull instruments as they tend to enhance the developments and consumption of the technologies while others can be characterized as technology push instruments as their aim is to promote R&D process for technology improvement. This categorization is shown in Table 3.

[5]"Innovation capabilities" is likely to trigger thoughts about R&D or it may prompt ideas about science-derived, novel technologies that are expected to have major impacts on growth and development. (Bell, 2009: 10)

## 3.2 INSTRUMENTS TO INDUCE ECO-INNOVATION

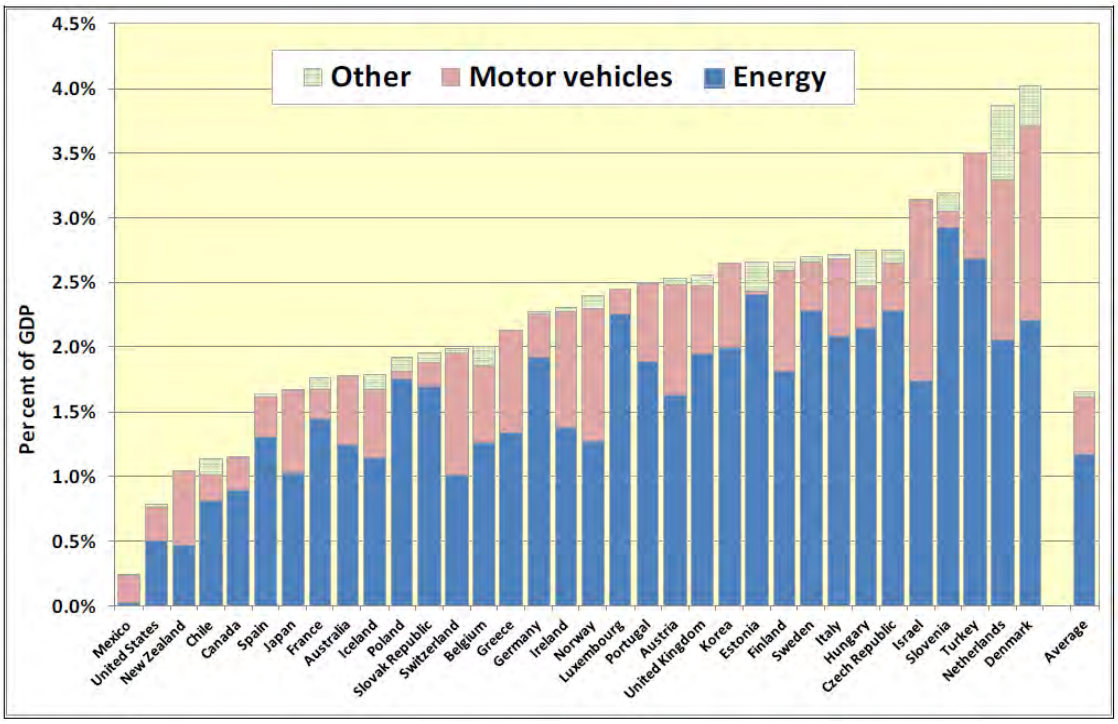
**Penalizing instruments**

Usually penalizing instruments constitute high charges on the firms' activities. These charges may cause firms to innovate in order to reduce pollution levels and of course the amount that they would have to pay and might stimulate innovation and growth in companies producing pollution control equipment. In addition, Jaenicke (2007) supports that the growing business risk for the polluters can become another driving force of "ecological modernization".

One of the negative economic instruments can be the process to fund pollution control by putting pollution charges, as Rothwell (1992) mentions. In this way financial resources will be provided to laboratories so as to examine how they can control pollution. As an example, we must mention the polluter pays principle (PPP) which is mentioned by Rothwell. This principle is referred to as the way by which firms can buy the "right" to pollute. There is the issue that the polluters, the governments or the consumers are these who have to pay the effects of technology on the environment, on social life and on peoples' health. As a consequence PPP and other types of regulations/policies influence the industrial technological change in several ways as Rothwell (1992) mentions.

Taxes on pollution perform as incentive, according to OECD (2011b), to polluters to reduce emissions and to look for alternative technologies. This means that governments can make firms pollute less by putting a direct cost to the damage that they cause to the environment. According to OECD (2011b), environmental taxation is more effective in comparison with regulations, this happens because regulations just set emissions limits or prescribe the use of other technologies while taxation encourages both the lowest cost abatement across polluters and provides incentives for abatement at each unit of pollution. However, as Rennings (2000) claims, the innovation efficiency of taxes may be watered down in the political process and that is why under political stability we have higher efficiency. Energy taxes, as the European Commission cites, in European Wind Energy Agency (2004), reflect that the actual environmental impacts of each technology constitute an effective means to internalize external costs.

**Figure 2: Revenues from environmentally related taxes, in per cent of GDP, 2009**




Source: OECD (2011b), pp.2

We can see in the diagram above that most of the countries tend to pollute the environment and especially the process of producing energy. In some countries we can even say that they prefer paying taxes to introducing new technologies or other innovations that may help to reduce polluting. On the other hand, this money is a really substantial financial source for governments that should fund research and development with these amounts of money.

**Encouraging instruments**

As innovation is a process that costs a lot and also is considered to be of high risk by the investors, governments have also established some encouraging instruments so as to reach the targets that they have set. An instrument that is adopted so as to promote the adoption of new technologies and more specifically the technologies that foster renewable energy is the **Feed-in-Tariffs** (FIT), which is in the category of interactive instruments. Feed-in tariffs (FITs) are generation-based, price-driven incentives. A feed-in tariff, according to Earth Scan[6], is a way that was invented to motivate people, businesses and everyone that is interested in renewables to invest in it. Feed-in tariff is a

[6] Earth Scan: (http://www.earthscan.co.uk/default.aspx?tabid=298) [Last accessed: 20/05/2012]

renewable energy law that obliges energy suppliers to buy electricity produced by renewable resources at a fixed price, usually over a fixed period - even from householders and helps people to be less cautious about their investment and to have the security that they will not make a non-profit decision. As expected, supporters of this model argue that if FIT is implemented effectively around the world, this will lead to an energy revolution that is so desperately required around the world, as Earth Scan supports. Solar PV is one of the most costly technologies supported by FITs and energy derived from PV is the most expensive type of energy.

Furthermore, EU uses **Quota Obligations**, as mentioned at Resch et al. (2007), as an instrument to foster eco-innovation. Quota obligations based on Tradable Green Certificates (TGCs) are generation-based, quantity-driven instruments. A system which involves renewable energy quotas and tradable renewable certificates works as follows: quota is imposed on one category of electricity system "operators" (generators, producers, distributors, retailers, or consumers) to cover produce, supply or consumer/purchase at a certain percentage of electricity from renewable energy sources (RES-E). As a consequence a TGC system, under perfect market conditions (perfect price signals), can minimize generation costs for renewable energy sources.

Comparing the two instruments above and as it is noted down by the Friends of the Earth (2008), a feed-in tariff has many advantages over a quota system. It offers certainty and guarantees for investors, it is transparent, easy to administer, it promotes diversity of supply and it is flexible.

Also, many countries help the firms or the individuals that want to adopt eco-friendly innovations to proceed to an investment in eco-innovation by giving them financial motivations like subsidies. However, Ringel (2006) points out a negative aspect of subsidiaries, as they do not always work well. Although the European Union and other organizations are willing to help innovations to be adopted and to accomplish their targets of lowering the emissions in the environment, the subsidies that they "use" may have negative impacts, the most important one being the weakness of the competitiveness in the market, as most of the times subsidies do not refer to all the innovative products but to some specific ones. For example, many countries have specialized in one or two renewable sources, according to local and national geographical conditions, but these technologies are not always subsidized by the

organizations. And this has sometimes as a consequence the promotion of the best and most profitable solution and not the optimal one.

**Covenants**

As another strategy to promote eco-innovation we can mention the covenants. Kemp (2000) refers to **covenants** as a policy instrument within environmental policy in Europe and the United States. Covenants are contracts between industry or an industrial sector and government in which industry promises to progressively reduce the environmental burden of its activities within a certain period (often five to ten years) according to certain targets. We can say that this is a strategy that Europe has adopted in our days regarding its target to reduce the emissions by 20% and also increase the use of energy produced by alternative sources to 20% by 2020.

**Eco-innovation By Europe**

We can also see that Europe tends to support not only the process of adoption of innovation but also of its diffusion. Europe has started an initiative called Eco-innovation that has as a target to bridge the gap between research and the market. As the European Commission states[7]: "It helps good ideas for innovative products, services and processes that protect and help the environment have fully-fledged commercial prospects, ready for use by business and industry. In doing so the initiative not only helps the EU meet its environmental objectives but also boosts economic growth." In their effort to do so they also have some funds, for the period 2008-2013 nearly €200 million are available to fund projects under the eco-innovation initiative. The target of Eco-innovation initiative is to develop products, techniques, services and processes that reduce $CO_2$ emissions, use resources efficiently, promote recycling and so on. This initiative has five main strands which are:

- Materials recycling and recycling processes

[7]European commission. Available at : http://ec.europa.eu/environment/eco-innovation/about/index_en.htm [Last accessed: 14/02/2012]

- Sustainable building products
- Food and drink sector
- Water efficiency, treatment and distribution
- Greening business.

**Table 3: Instruments encouraging or forcing innovation**

| Instrument | Aims | Intended impacts | Results | Factors | Type of instrument |
|---|---|---|---|---|---|
| **Feed-in-Tariffs (FIT)** | Make firms/people invest on RES (solar, wind energy) | Increase the % of electricity generated by RES | The capital cost of solar PV has fallen substantially | Falling technology costs, risk of high expanding PV | Market pull |
| **Quota Obligations** | Reach the target o energy produced by renewables | To minimize the cost of generating renewable electricity | Increase demand for renewable electricity | A fair distribution of costs and benefits of RES implementation | Market pull |
| **Covenants** | Reduction in energy use | Substitute environmentally hazardous substances | Foster technological innovation | Autonomous technological change, external regulations and evolution on the market demand | Technology push |
| **Eco-innovation** | Help ideas to become feasible and protect the environment | Bridge the gap between research and the market | Many eco-innovation projects already running | SMEs have priority in getting in the Eco-innovation project | Technology push |
| **Polluter Pays Principle (PPP)** | Make firms reduce their emissions | Reduce Greenhouse Gas emissions | Polluters pay for the damage they have caused | We have to know who has rights to use the resources | Market pull |
| **Environmental taxes** | Level the playing field in the electricity markets | Make businesses to adopt new technologies | Internalize external cost | Political stability | Market pull |

Source: Own processing, based on Cleff et al. (2007), Rothwell (1980), Druehl, et al. (2012) and Hezri (2011)

## 3.3 PRINCIPLES THAT POLICIES HAVE TO FOLLOW

### *3.3.1 HOW SHOULD POLICIES BE?*

So that policies can have the expected results, they have to follow some certain standards. Furthermore, an advantage added that makes regulations necessary is the fact that growth may continue only if waste problems are solved even to some extent. This makes essential the existence of regulations so as to address the problems and increase our standard of living.

To begin with, Porter and Van der Linde (1995b) claim that environmental laws and regulations have to follow three substantial steps in the process that they follow so as to be adopted. These three steps are consisted of the actions that firstly phrase environmental rules as goals that may be met in flexible ways, secondly encourage innovation to reach and exceed those goals and finally administrate the system in a coordinating way. But above all regulators have to think about the technological capabilities and resources available to each stage so as to be more accurate in the goals that they set and to make sure that even though difficult they are feasible.

Jaenicke (2007) and Leitner et al. (2010) suggest that governments should concentrate on "smart" regulation as these constitute policy instruments that have a positive effect both on environment and innovation and therefore they might lead firms to sustainability. These "smart" regulations are often more efficient and effective in achieving environmental goals and stimulate companies to view environmental issues as a business challenge and opportunity. Smart regulations, according to Jaenicke (2007), play also a very important role in the political competition for environmental innovation and they are also sometimes identified as a key force that leads to environmental regulation. Leitner et al. also believe that environmental innovation is a means that can certainly contribute to shifting society towards sustainable development.

As a result, they support that there is a need for systematically improved environmental regulation as well as environmentally motivated innovation policy. Furthermore, as Hezri states: "The 'shift' towards sustainable development requires an institutional change, and one which requires a long-term perspective." (Hezri, 2011: 59) So, what is necessary is not only the changes in technology, but in regulations and in institutions as

well so as to have the desired results but this requires a long time in order to be accomplished. In order to have the necessary changes in institutions, six generic principles may be adopted and adapted by governments, according to Herzi (2011), so as to suit varying contexts and as a result have institutional reform. These principles dictate that governments:

- Firstly, have to follow factoring in the long term which means that sustainable development addresses factors operating over decades and centuries.
- Secondly, have to adhere to integrating environment, society and economy in policy that means that sustainability is to account for interactions between the three pillars and to account for especially the environmental and social implications of economic policy.
- Furthermore, have to follow the precautionary principle which requires recognition of uncertainty, encourages proactive rather than reactive policy actions and shifts the onus of proof from those concerned about the environmental effects of policies and developments to those advocating development.
- In addition, have to take into account the global dimensions, as sustainable development is a global issue. This is needed as international concern and policy development have generally outstripped domestic policy in both intent and vigour.
- We should not forget the factor that innovative policy approaches are needed. This happens as policy innovation is required given the complexity of sustainable development problems and the implementation deficit so far.
- Finally, we have to focus on the factor of community participation. This happens because community-based programs tend to be poorly resourced, switched on and off according to near term government need, lacking a clear mandate and a set of responsibilities, and at times they seem to be more about cost-shifting and delegation of implementation tasks than sharing of knowledge and power.

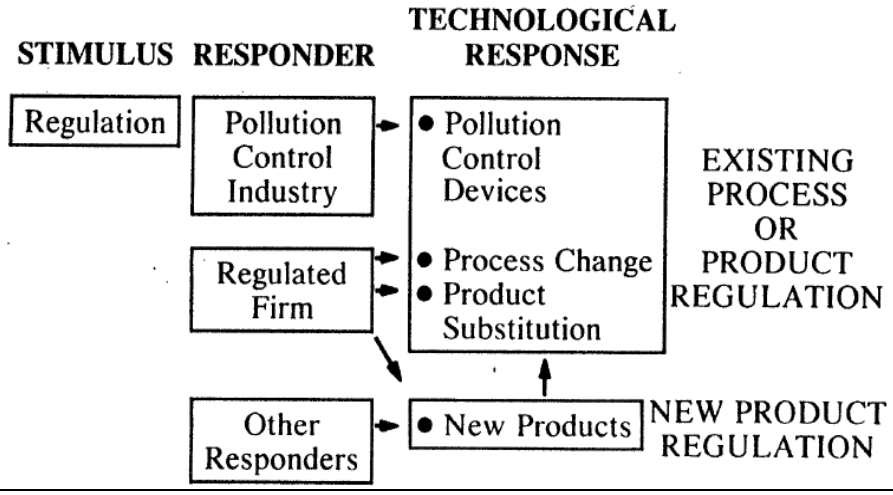
Certainly, the time that is needed to formulate a regulation is not short and regulators have to take into account several important things such as the existing technological capacity when it comes to eco-innovations, and also the capital cycle of firms that are supposed to adapt this regulation. According to OECD, '*What appears to be more important is how the formulation period is used: if it contributes to a sustained process of consultation with industry, it can have a positive effect; lf it provides for an erratic*

*and unpredictable procedure to take place, companies ready to respond innovatively can suffer'.* (Rothwell, 1992: 453)

Furthermore, according to Ashford et al. (1985), regulators have to take into consideration, of course, the process of technological change within the possible responding sectors as well as, the "innovative dynamic" of the sector rather than the existing static technological capacity. More comprehensively, Ashford et al. support that regulators should also take into account the effects that they will have on technological innovation.

The following scheme is made by Ashford et al. (1985) so as to help designers think what their targets are, before designing the regulation.

*A model for regulation-induced technological change*




Source: Ashford et al. (1985), p.423

This diagram is structured to help regulation designers to design regulations. The diagram helps them to see to which target group they want to address the regulation and what results they want to earn. This is a diagram that shows the alternatives that countries have, regarding the targets and the means that each country has.

Porter and Van der Linde (1995a, b) believe that the designing of regulations depends on the goals that each government sets, and as innovation foster consists one of the regulations goals, they claim that regulations have to adhere to three principles, which are that:

1. regulations have to create the appropriate environment so as to reach the maximum opportunity for innovation,
2. regulations have to foster continuous improvement in technology and
3. last but not least, regulations must not leave a huge room for uncertainty at every stage of innovation and adaptation of new technology by the firms.

Wiser and Pickle (1998) claim that policy design should be linked with incentive mechanisms to policy goals, subject to technical, market, and financial constraints. But, this does not usually happen and additionally to political considerations and lack of information, it has as a consequence during the development of policies mismatches between a policy's incentive mechanism and technical, market, or financial constraints. Also, lack of information, as it is mentioned in Murage et al. (2011), is a factor that affects the adoption speed of the innovations. More specifically, Hall et al. (2011) refer to the situations, in which information may not be enough so as to choose the correct next step. They believe that "innovation is thus a knowledge quest and creation process, requiring the reduction of uncertainty." (Hall et al., 2011: 1146) They refer to the opinion of Knight that there are varying degrees of imperfect information, like: true risk, where key interacting variables and outcome probabilities are known, uncertainty, where variables are known but not probabilities, and what has since been termed Knightian uncertainty or ambiguity, where variables and probabilities are unknown. To sum up, Del Río et al. (2010) suggest that so that a policy will be able to influence the rate and direction of eco-innovations, policy makers should be well informed about the barriers that could hinder eco-innovation.

However, Wiser and Pickle (1998) some years later mentioned that while designing the regulations which refer to the renewables, what affects the effectiveness of them is that designers usually ignore or misunderstand the project development and the financing process that is going to be followed. Grubb and Ulph (2002) point out that if the policy-makers wish to encourage firms to introduce cleaner technologies, what is necessary is to use a combination between environmental and technology instruments. Also, they have to use market incentives, as Porter and Van der Linde (1995 a, b) claim, like deposit-refund schemes which draw attention to resource inefficiencies.

*3.3.2 THE RELATION OF REGULATIONS TO ECO-INNOVATION*

The relation between environmental regulations and environmental innovation is controversial. Many scientists have discussed this relationship to examine if regulations are likely to induce or impede innovation. Below we are going to see the opinions of some scientists.

Grubb and Ulph (2002) argue that the influence of environmental policies/regulations in environmental innovations is not strong and that the effects are more visible in the long-run rather than in a short period of time. But regarding the fact that environmental policies usually operate as pollution abatement costs and pollution abatement expenditures, an increase in the generation of innovation is observed and that outcome derives from the increased number of patents, as mentioned in Chappin et al. (2009).

Chappin et al. (2009) claim that the relation between the environmental policies/regulations and environmental innovation is conflicting, as environmental policies/regulations can both induce and impede environmental innovations. Furthermore, Bernauer (2006) claims that environmental regulations facilitate the introduction of environmental innovations. For this reason, governments set some goals that companies and firms have to achieve with the contribution of innovation.

Additionally, Porter and van de Linde (1995a, b) support that environmental regulations, if they are well structured, are a motivation for firms to rethink of some neglected opportunities until now and adopt them from now on. Also, they believe that regulations can promote environmental innovations by establishing market incentives that increase profits. This is an opinion that is also supported by Bernauer et al. (2006). Furthermore, what Jaenicke (2007) believes, is that environmental regulations are a key factor so as to have innovation and also to diffuse processes that follow the adoption of innovations. Frondel et al. (2007) believe that innovation-friendly environmental policies can affect the industrial environment positively in many factors and this is more obvious when cleaner products and cleaner production technologies are used.

To continue we have to refer to the fact that regulations, according to Rothwell (1980), do not usually affect only the companies that they are designed for, but they can also affect other firms. More specifically a regulation happens to be a barrier for one firm when simultaneously it can easily perform as incentive for another. But Rothwell's

opinion is that despite the barriers that they would provoke, regulations often function as motivations for companies to eco-innovate and to control pollution. This comes along with the opinion of Dewick and Miozzo, who state that: *"The regulatory changes will help achieve the government's CO2 target, improve housing energy efficiency and contribute towards sustainable construction and managing the effects of global warming".* (Dewick and Miozzo, 2002: 837)

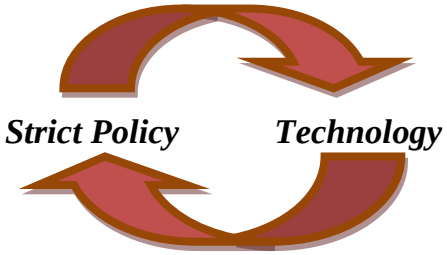
Additionally, Chappin et al. (2009) believe that environmental innovation is a process that will not occur in the industrial environment in the absence of environmental regulations. Innovations are seen as a potentially benign force that helps achieve the goals that regulations set by developing new technologies and new ways of working so as to control pollution, energy consuming and also to use energy more efficiently. Innovations are also described by Jaenicke (2007) as the initial market introduction of a new technology that may improve some or all phases of a product's life cycle, which means that a new technology is crucial so as to have less impact on the environment.

Also, Ashford et al. (1985), Frondel et al. (2007) and Kemp (2000) claim that the important thing regarding regulations and their impact on innovation, is their stringency. The stricter the regulation, the more the innovation induced to firms. And as Kemp (2000) states stringent regulations are considered to be necessary for radical technology responses. Bernauer et al. (2006) support that the effect that regulations can cause to firms depends on how well the firms can adapt the external pressure. However, Marklund, in Leitner et al. (2010) claims that many times firms do not make the optimal decisions or do not innovate, so as to address the regulation, but they use the best available technology (BAT), at the time, so as to become adjusted to the regulations' requirements.

What is observed is that environmental regulations are going to become stricter and stricter in the long-run, as technology develops. For this reason, Minghua and Yongzhong (2011) believe that it is important for the economic stability of a country to construct suitable environmental regulations which are oriented towards technology innovation. From this we can understand that there is a feedback generated from this relation. A circle that never ends starts as the stricter the regulations become, the more technological development they cause. So we can understand that regulations not only help technology to evolve but also generate competitiveness as firms in order to address

regulations tend to adopt or to search for the best technology to adapt to their products so as to gain a good market share.

**Figure 3: Interaction of policies and technology improvement**




Source: Own processing

The reason why firms invest on innovations as Frondel et al.'s opinion claims is the benefits that innovation-friendly environmental policy/regulation causes. This opinion is expressed in their paper by the following phrase:

> Frequently, firms hope that innovations will offset, or at least reduce, the burden and cost induced by environmental regulation. Reduced costs, increased competitiveness, the creation of new markets for environmentally desirable products and processes, positive employment effects etc. are seen as potential benefits of an innovation-friendly environmental policy. (Frondel et al., 2007: 573)

Jaenicke (2007) believes that the regulation and the political instruments that are used, force innovation when they fulfill certain criteria. These criteria are classified in the following table:

| ***Regulations are innovation-friendly when they are:*** | ***Policy Instruments are innovation-friendly when they:*** |
|---|---|
| ***based on dialogue and consensus*** | *provide economic incentives* |
| ***calculable, reliable, and have continuity*** | *act in combination* |
| ***decisive, proactive, and demanding*** | *are based on strategic planning and goal formulation* |
| ***open and flexible*** | *support innovation as a process and take account of the different phases of innovation and its diffusion* |

Source: Jaenicke (2007)

Also, as Walz stated in: *"The innovation friendliness also depends on regulation details and policy stability"*. (Walz, 2008: 17) This makes us understand that the more accurate a regulation is, the more likely the investors are to adopt eco-innovations and especially if there is stability in the policies that its government follows, they have to focus on a target and not change targets and policies very often. This means that firms are ready to adhere to regulations as they believe that the innovation is able to offset the cost and the burden that regulation will cause to them. This opinion is also supported in Table 4 when we can see that many fields have already adopted eco-innovations, in order to reduce their environmental impact. In each of the following sectors/industries, a regulation has been set so as to address environmental issues that could be provoked by their products. The basic consequence is that after the regulations the impacts of the industries are less to the environment but regulations have also led industries to proceed to R&D or to invest in new technologies and processes so as to respond to the regulations. But this is not the only consequence derived by the regulation as there are also other offsets mainly financial. Many times the production cost reduces after an innovation adoption and also the prices of the products are reduced while most of the times what is also affected, is the quality of the products that rises. This chain that progresses shows us the relation between the regulations, the innovations and also the competitiveness that results from this relation.

**Table 4: Environmental Regulation Has Competitive Implications**

| *Sector/ Industry* | *Environmental Issues* | *Innovative Solutions* | *Innovation Offsets* |
|---|---|---|---|
| **Pulp and paper** | Dioxin released by bleaching with chlorine | • Improved cooking and washing processes<br>• Elimination of chlorine by using oxygen, ozone, or peroxide for bleaching<br>• Closed-loop processes (still problematic) | • Lower operating costs though greater use of by-product energy sources<br>• 25% initial price premium for chlorine-free paper |
| **Paint and coatings** | Volatile organic compounds (VOCs) in solvents | • New paint formulations (low-solvent-content paints, water-borne paints)<br>• Improved application techniques<br>• Powder or radiation-cured coatings | • Price premium for solvent-free paints<br>• Improved coatings quality in some segments<br>• Worker safety benefits<br>• Higher coatings-transfer efficiency<br>• Reduced coating costs through materials savings |
| **Electronics manufacturing** | Volatile organic compounds (VOCs) in cleaning agents | • Semiaqueous, terpene-based cleaning agents<br>• Closed-loop systems<br>• No-clean soldering where possible | • Increase in cleaning quality and thus in product quality<br>• 30% to 80% reduction in cleaning costs, often for one-year payback period<br>• Elimination of an unnecessary production step |
| **Refrigerators** | • Chlorofluorocarbons (CFCs) used as refrigerants<br>• Energy usage<br>• Disposal | • Alternative refrigerants (propane-isobutane mix)<br>• Thicker insulation<br>• Better gaskets<br>• Improved compressors | • 10% better energy efficiency at same cost<br>• 5% to 10% initial price premium for "green" refrigerator |
| **Dry cell batteries** | Cadmium, mercury, lead, nickel, cobalt, lithium, and zinc releases in landfills or to the air (after incineration) | • Rechargeable batteries of nickel-hydride (for some applications)<br>• Rechargeable lithium batteries (now being developed) | • Nearly twice as efficient at same cost<br>• Higher energy efficiency<br>• Expected to be price competitive in the near future |
| **Printing inks** | VOCs in petroleum inks | • Water-based inks and soy inks | • Higher efficiency, brighter colors, and better printability (depending on application) |

Source: Porter and Van der Linde (1995a)

To sum up, many times as an answer to environmental regulations, eco-innovations occur. In general, regulations have as their target to create pressure and demand for eco-innovations and also to inform about them. Regulations have some elements that can either induce or block the adoption of eco-innovations. These elements are the form, the mode of regulations and the time of compliance that they give to firms as well. Other characteristics that can influence the adoption of innovations are the uncertainty of the results. In addition, regulations' stringency may influence the adoption as the stricter a regulation is, the more innovation can attract. Regulations, in order to have the expected results, have to be accurate, create the appropriate environment for the adoption of innovation, foster continuous improvement in technologies and not to leave huge room for uncertainty. Furthermore, regulators have to consider socio-economical issues in order to set goals that are feasible for firms/industries. In conclusion, even if eco-innovations are produced, there is a need for incentives because firms/industries tend to proceed to innovation adoption more easily if they have a financial or other kind of support. These incentives can be either encouraging, such as subsidies or penalizing such as environmental taxes.

# CHAPTER 4: ELECTRIC VEHICLES AND NEW TECHNOLOGICAL PARADIGMS?

In this chapter we are going to review the introduction of electric vehicle (EV) technology as a part of solution for the protection of the environment. Electric vehicles as a term includes plug-in hybrids, extended range electric vehicles, all electric vehicles and fuel cell electric vehicles that represent a key pathway for reducing petroleum dependence, enhancing environmental stewardship and promoting transportation sustainability, while creating high quality jobs and economic growth. Although all the major manufacturers are engaged in each of these areas electric vehicles are still in an experimental face. Electric motors are only used in some buses so as to have feedback for next technologies. The key technologies that are in the technological center right now are the in-wheel motor, the fuel cell electric vehicles and the software under which the electric vehicles operate. In order to facilitate the introduction of EVs, countries have adopted some instruments/policies so as to induce the use and production of this certain product.

## 4.1 THE CASE OF EVs

As Van Mierlo and Maggetto said: 'It is both an ecological necessity and a technological challenge to reduce the dependence on oil, from the current level of 98%, by using alternative fuels and improving the energy efficiency of the various methods of transport'. (Van Mierlo and Maggetto, 2007: 165) Electric vehicles constitute an alternative for the process of independence by oil. Even today, electric vehicles even today represent a very small niche market, despite the fact that it has been estimated that with current average European energy supply the greenhouse gas (GHG) emissions of electric vehicles would be less than 50% compared with conventional vehicles, (European parliament, 2010). As Grünig et al. (2011) mentioned, in some countries, non-passenger EVs already hold market shares of up to 10%. In Netherlands the highest share in electric vehicles holds the electric bicycle, while in East Asia and especially in China, there is also a great desire for electric bicycles.

We can tell that electric vehicles constitute an architectural innovation. An architectural innovation as it is defined by Henderson and Clark (1990: 10) is the innovation that

"change the way in which the components are linked together, while leaving the core design concepts (and thus the basic knowledge underlying the components) untouched". A component is, according to Henderson and Clark (1990: 11), "a physical distinct portion of the product that embodies a core design concept….and performs a well designed function". However, most architectural innovations require changes in the underlying components also. So in order to have a successful product development, Henderson and Clark (1990) state that we need to have two types of knowledge. First, it requires component knowledge, or knowledge about each of the core design concepts and the way in which they are implemented in a particular component and second, it requires architectural knowledge or knowledge about the ways in which the components are integrated and linked together into a coherent whole. EVs constitute another architectural innovation that is also a subtle challenge for the firms. Iansiti and Clark (1994) support that in order to have a product development we need to cope with technical and market uncertainty. Also, they support that product development requires a firm that rely on actions such as learning from the environment and implementing new concepts which are actions important for capability building. In other words we can understand that a strategic niche is necessary so as to have feedback for the improvement of new technologies and for EVs in particular. In order to have a successful "new" product it is understood that uncertainties in technical and market issues have to be overcome and also an experimentation period is needed for the improvement of the product.

According to the International Energy Agency (IEA) (2012), 'the ministers are launching the Electric Vehicles Initiative (EVI), which will provide a forum for global cooperation on the development and deployment of electric vehicles, and accelerating their commercial uptake'. This program is one that has global targets with the main one to have more than 20 million EVs on the road by 2020. This program will establish pilot projects in several cities across the globe, for the demonstration of electric vehicles in public transportation and government use. Participating countries may also share experiences from existing pilot projects. Countries that already are in the program are China, France, Germany, Japan, South Africa, Spain, Sweden, the United Kingdom, and the United States. Participating governments will share experiences from at least one of its cities that launched pilot electric vehicles in the public transportation sector or in government fleets.

As it is referred by the IEA (2012) 'the specific technologies that will be the focus of the pilots may include hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), all-electric vehicles (AEVs), and fuel cell vehicles (FCVs)'. The primary objectives of the pilot project are:

1. Promoting cooperation on the research and development, demonstration, and commercialization of electric vehicles
2. Sharing experience in policy, management, data analysis, and publicity, etc. to support the scale-up of electric vehicles
3. Exploring universal standards for vehicle evaluation, infrastructure, and communication protocols and
4. Conducting analyses of the demonstrations, including cost-effectiveness assessments

Oxford is one city that has managed to facilitate a lot the use the use of electric cars. The Oxford[8], network comprises of an initial 64 charging points across the city and surrounding area and creates one of the highest densities of EV charging points anywhere in Europe. A very important issue that arises[9] is that during the process of constructing infrastructures for EVs recharging, new jobs come off and also opportunities for regional development open.

Although the advantages EVs can bring, they are still having difficulty in gaining wide acceptance and usage because many people do not trust them and also because of high prices, something that is also understood by the fact that electric vehicles still represent a small niche market which hardly exceeds 1% of the passenger car market. The technologies of electric cars that seem to slowly become popular are the in-wheel motor electric vehicles and the fuel cell electric vehicles, but we also have to consider the software that is needed so as the vehicle to operate correctly. These are the technologies that we are going to analyze below.

[8]"Oxford becomes electric vehicle capital of Europe". Available at: http://chargemasterplc.com/oxford-becomes-electric-vehicle-capital-of-europe/ , [Last accessed: 29/05/2012]

[9] Ibid.

## 4.2 CHALLENGES AND OPPORTUNITIES FOR EVs

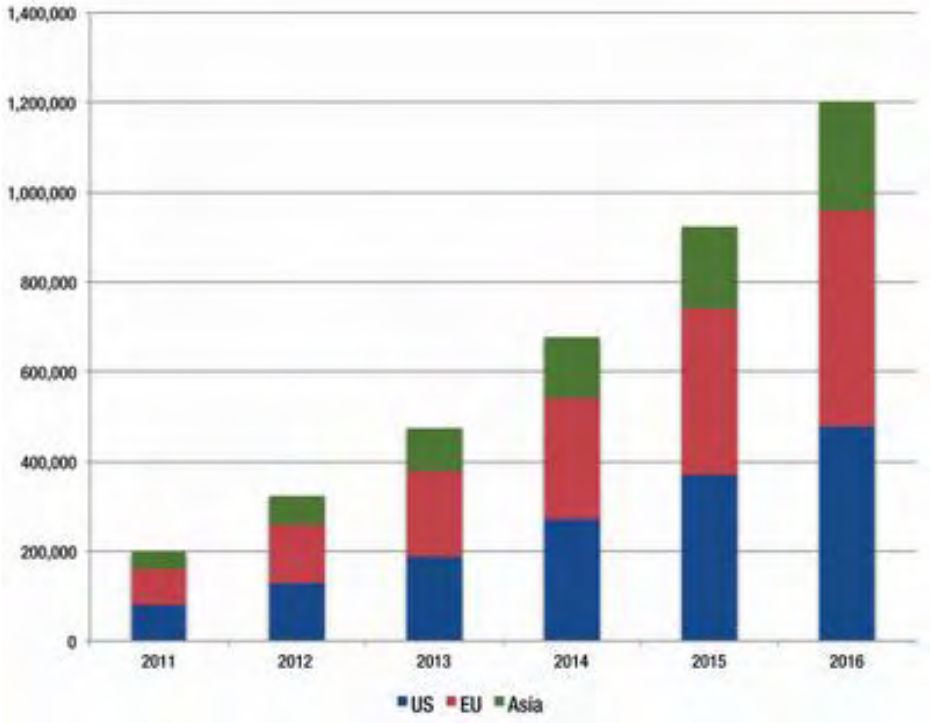
The future of electric vehicles seems to be bright as a consequence the growth of vehicles powered by electricity is expected to provoke a remarkable shift in the current landscape in areas such as design and manufacturing, distribution and aftersales service, energy supply and infrastructure related to EVs. Traditional players as well as new players tend to invest in electric vehicle design and manufacturing. Countries tend to enhance this decision by giving motivations for EVs production, development and purchasing.

New enterprises such as BYD in China that reached the first place in rechargeable batteries or Tesla motors in California with a high place in EVs development have entered the market. Until now the technology that is leading is the hybrid electric vehicle but all-electric vehicles and fuel cell electric vehicles are continuously gaining place. The countries that seem dynamically to enter the market, according to Lutz (2009), of EVs are Brazil, India and China which are the countries that put more focus on the reduction of $CO_2$ emissions.

The fact that the EVs market is developing is also obvious in Figure 4. Scientists believe that within the next four years the EVs that will be on roads in the USA, EU and Asia will be approximately 1,200,000. The high interest in EVs means that the challenges that may emerge have to be addressed in a short-run so as EVs to have a widespread acceptance. Some of the challenges mentioned by Lutz (2009) are the performance of batteries, the infrastructure needed, market acceptance, the price of EVs, the existence of other alternatives, the ecological value and finally the technological maturity of technology used.

Batteries as it is supported by many authors are the primary reason why EVs are not the vehicles we drive today. Cost and range issues have hampered mass adoption of EVs. The performance improvement of EV batteries is one of the biggest issues that the potential take-up of EVs is faced with. (Song et al., 2010) Also, issues like recharging duration and batteries short life-cycle have to be addressed in order EVs to become accepted by consumers. It is also understandable that a parallel development of recharging infrastructure is necessary in order to facilitate EVs use. The drawback is that as batteries have a low range at the moment the investment that is needed so as to have the necessary stations will be really considerable.

**Figure 4: Global Electric Vehicles till 2016**




Source: IQPC energy blog

What is also a challenge that EV manufacturing has to deal with, according to Lutz (2009), is the price of the vehicles. Till now EVs used to be quite expensive as a consequence governments tend to give subsidies to consumers or to give them tax bonuses in order to motivate them purchase vehicles that are environmentally friendly. EVs consider being low emission vehicles but actually their emissions depend on the way that the energy that they use is produced. Also, as the electric vehicles are a late technology entry in the automobile market the standardization of components and technology is immature as a consequence experimental projects are needed so as to have feedback for further development and improvement.

As electric vehicle market tends to rise simultaneously with challenges, opportunities for new disciplines are also emerging. For example, traditional manufactures will need to make a significant shift to their design and manufacturing capabilities. Also, as it is mentioned by Lutz (2009), a need for new products by automotive suppliers will emerge and this may also lead to new suppliers' entrance in the market with purpose-built products. In addition as the technology of vehicles will change service providers must adapt and transform their service in order to be able to provide their help to EVs' owners. At the same time, new players, such as vehicle and battery manufactures or

charging infrastructure provides, will need to master the technology development in order to be able to serve the market.

Electric vehicles are a promising technology that daily gains the interest of manufacturers. After discussions about in-wheel motors and about fuel cells[10], we have concluded that even if these two technologies are crucial, they are not technologies that require high tech knowledge that cannot be provided by Greek universities. As a consequence if there is the right cooperation between universities, institutions and manufactures Greece may have an opportunity to enter the "game" as a new player. In-wheel motors as well as fuel cells for electric vehicles can be developed in Greece and lead to a significant change in Hellenic industry and perhaps to regional development of the region that industries would be placed. However, in order an effort like this to be successful what is also needed is to have the necessary complementary assets. By complementary assets we refer to assets, infrastructure or capabilities needed to support the successful commercialization and marketing of a technological innovation.

## 4.3 IN-WHEEL ELECTRIC MOTORS

As Bullis[11] (2009) states, in-wheel motors have been around for some time: they have been used in several concept cars and experimental low-production vehicles. By putting electric motors in the wheels we put the power-generating elements where power is needed and frees up space for passengers and cargo. Until recently, according to Levine (2011)[12] and Lockström (2010), the biggest reason against using in-wheel motors, was that they create too much unsprung weight. Therefore, Lockström believes that in order for an in-wheel motor axle system to be effective and customer friendly, an in-wheel motor axle unit needs to be as light weight and compact as possible.

[10] Personal interviews with Mr Bourdakis and Mr Tsiakras, at University of Thessaly.

[11] Bullis, K. (2009) 'Wheel Motors to Drive Dutch Buses- The technology moves out of the lab and into commercial vehicles', *Technology Review Published by MIT*. Available by: http://www.technologyreview.com/energy/22328/ , [Last accessed: 29/05/2012]

[12] Levine, M., (2011) 'Driven: Protean Ford F-150 All-Electric Pickup Truck', Pickup Trucks.com. Available by: http://news.pickuptrucks.com/2011/05/driven-protean-ford-f-150-all-electric-pickup-truck.html , [Last accessed: 29/05/2012]

The technology of in-wheel motor


Source: http://www.drives.co.uk/fullstory.asp?id=3449

When an EV is driven by electric motors, according to Hori (2004), it has the following three remarkable advantages:

- motor torque generation is fast and accurate, which means that the electric motor's torque response is several milliseconds, 10–100 times as fast as that of the internal combustion engine (ICE) or hydraulic braking system. Also a "Super Antilock Brake System (ABS)" will be possible.
- motors can be installed in two or four wheels. Small but powerful electric motors installed into each wheel can generate even the antidirectional torques on left and right wheels. Distributed motor location can enhance the performance of Vehicle Stability Control (VSC)
- motor torque can be known precisely. This advantage will contribute greatly to application of new control strategies based on road condition estimation.

Furthermore, Ekopedia (2010)[13] adds other more practical issues, every kind of power transmission becomes redundant, such as gearboxes, differentials, drive shafts and axles. This fact reduces complexity in the transmission of the energy to the wheels, as well as weight and also frees space for the passengers, cargo and more batteries.

[13] Ekopedia (2010), "Wheel motor". Available at: http://en.ekopedia.org/Wheel_motor [Last accessed: 26/05/2012]

On the other hand, in-wheel motor electric vehicles have some drawbacks. Some are noticed by the Ekopedia (2010)[14].

- Although, the solution to compensate for a low torque is a lighter motor that let the car to have higher rotational speed, it is obviously not a possibility with an in-wheel motor, meaning it will generally be heavier.
- It is noticed that the lighter the wheel in comparison to the vehicle, the smoother the ride (unsprung mass), given equal road conditions. This implies that a wheel with a motor in it will be heavier than without it and as a result the ride will be bumpier. However, this effect is not considered to be so serious, though, depending on the mass of rest of the vehicle.
- A vehicle fitted with in-wheel motors will generally be designed to have one in each wheel instead of just two, in order to minimize the mass of each wheel. The fact that an in-wheel electric vehicle carries on it four (or two) electric motors makes it more complicated than a vehicle with just one motor on it.

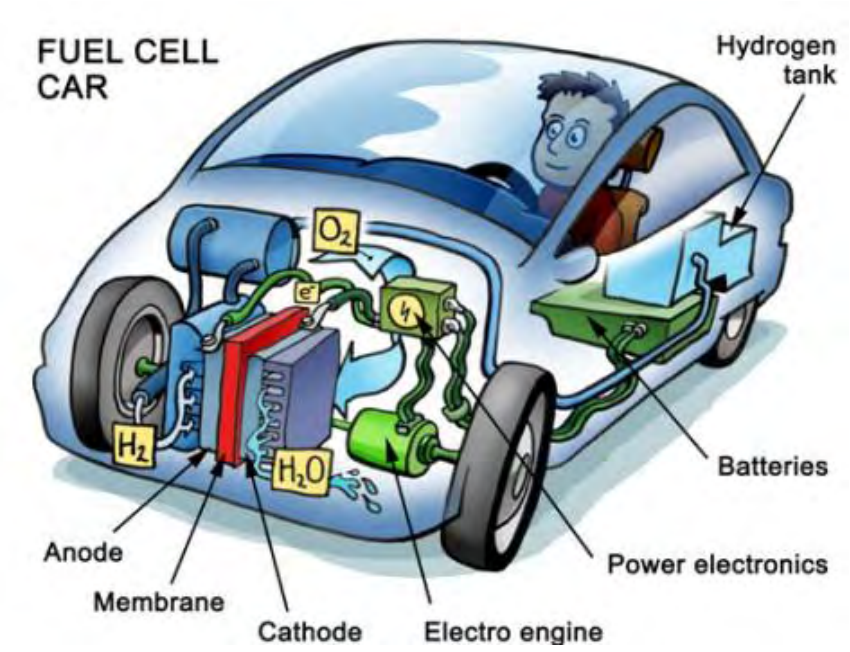
## 4.4 FUEL CELL ELECTRIC VEHICLE

A really promising technology that seems to gain the interest of infrastructures is the technology of Fuel Cell Electric Vehicles (FCEVs) which are a type of hydrogen consuming vehicle which use a series of fuel cells to produce electricity. This electricity powers its on-board electric motor. Fuel cells create electricity that is needed in order to power the electric motor by using hydrogen and oxygen from the air. According to US Department of Energy[15], FCEVs have the potential to significantly reduce the dependence on foreign oil and harmful emissions that cause environmental problems. While the total cost of FCVs might still be higher than fossil fueled vehicles, the environmental impacts of fuel cell vehicles are very small compared to fossil fueled vehicles.

[14] ibid

[15] U.S. Department of Energy, "Fuel Cell Vehicles". Available at: http://www.fueleconomy.gov/feg/fuelcell.shtml [Last accessed: 29/05/2012]

The technology of fuel cell electric car

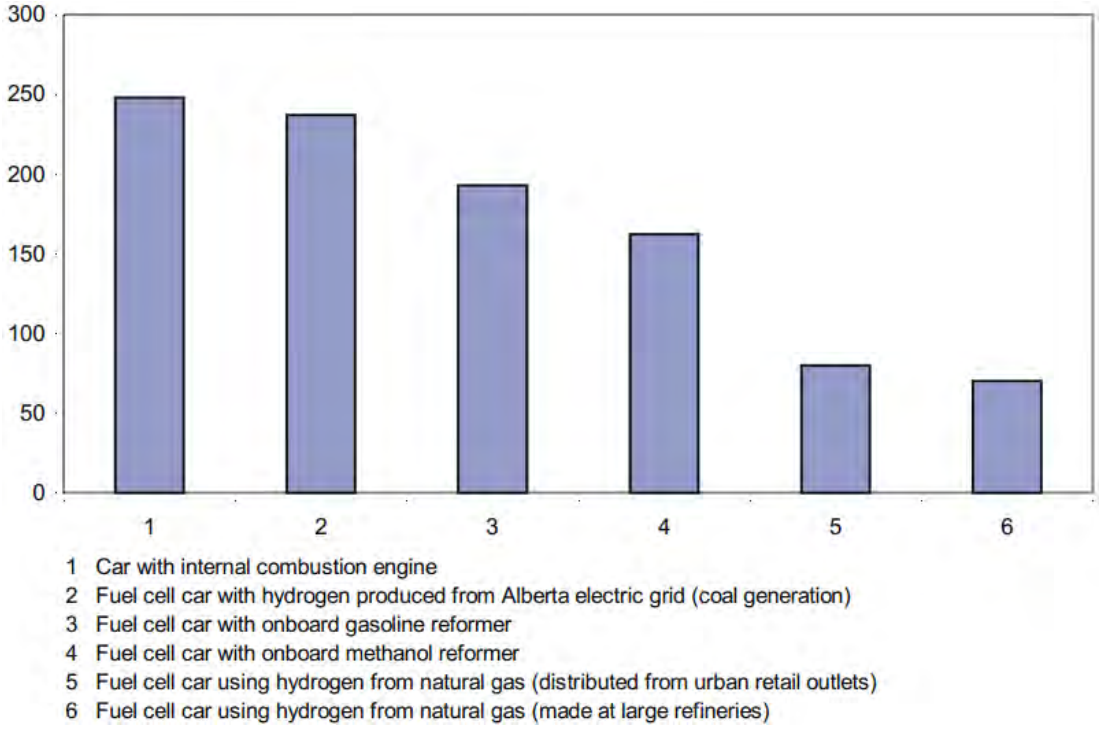



Source: http://blogcarparts.blogspot.gr/2012/04/hydrogen-fuel-cell-vehicles.html

FCEVs run on hydrogen gas rather than gasoline and emit no harmful tailpipe emissions but just water vapor. A significant issue regarding the environmental impact of FCEVs is the source by which hydrogen is generated. FCEV may not have emissions harmful for the environment but which is the benefit of its use if the production of hydrogen is more harmful than ICEs use? For this reason we have to consider the sources of hydrogen which are, as mentioned by DOE[16] natural gas and coal (with carbon sequestration), nuclear, biomass, and other renewable energy technologies, such as wind, solar, geothermal, and hydro-electric power. Automotive manufactures as well as governments have to take under account the source of hydrogen and stimulate the production and use of the one with the less environmental impact. In figure 5 we can see a graph that compares the emissions of some of these types of generated hydrogen with the hydrogen produced by natural gas having the less emissions.

[16]U.S. Department of Energy, (2008). Available at: http://www1.eere.energy.gov/hydrogenandfuelcells/production/ , [Last accessed: 17/06/2012]

**Figure 5: Graph comparing dioxide emissions of cars per 100km, using different types of fuel sources. Source: Cook, B., (2001)**




As Cook (2001) supports, because hydrogen and oxygen gases are electrochemically converted into water, fuel cells have many advantages over heat engines. The advantages that they have are high efficiency, virtually silent operation and, if hydrogen is the fuel, there are no pollutant emissions. We can observe this also by Figure 4 that shows us the emissions of vehicles that consume different fuels, with the one that consumes hydrogen produced by natural gas (made at large refineries), being the one with the less emissions. If the hydrogen is produced from renewable energy sources and not by the electrical grid, then the electrical power produced can be truly sustainable. The good point is that a vehicle powered by a fuel cell engine can have a performance similar to that of ICE. The most important advantage that is noticed by Cook (2001) is that the efficiency of the fuel cell engine is over 60% almost double of that of ICE.

One disadvantage of FCEVs, according to US Department of Energy[17], is that despite the fact that FCEVs are more energy efficient than conventional cars, and hydrogen contains three times more energy per weight than gasoline does, hydrogen gas contains only a third of the energy per volume that gasoline does. This makes it difficult to store

[17] Ibid.

enough hydrogen to go as far as a gasoline vehicle on a full tank—at least within size, weight, and cost constraints and as a consequence it continues to be one of the most technically challenging barriers against the widespread commercialization of hydrogen-fueled vehicles. Hydrogen can be stored to compressed hydrogen tanks but as the pressure increase to store more hydrogen the weight of the tank also increases, to liquid hydrogen tanks but the boil-off of hydrogen requires a lot of energy or to metal or chemical hydrides, but they do not have a high hydrogen capacity yet.

Also they point out that FCEVs are not as durable as internal combustion engines, especially in some temperature and humidity ranges. Even if scientists have increased FCEVs' durability substantially over the past few years from 29,000 miles to 75,000 miles, they believe that a 150,000 mile lifetime is necessary for FCEVs to compete with gasoline vehicles. Fuel cells use catalyst made by platinum which increases the cost of the vehicle, but also constitutes part of another problem which is the lack of rare earths.

Furthermore, in order to have the FCEVs marketed we also need to have the necessary infrastructures for refueling the vehicles, and as the extensive system used to deliver gasoline from refineries to local filling stations cannot be used for hydrogen, new facilities and systems must be constructed for producing, transporting, and dispensing hydrogen to consumers, which will be a really costly project. (Shinnar, 2003)

When comparing the two types of vehicles that are about to replace the internal combustion engine vehicles, BEVs and FCEVs, Thomas (2009) and Veziroglou and Macario (2011) also think that FCEVs are superior to the advanced li-ion BEVs with a range of 300 kilometers, because:

- FCEVs are lighter than EVs
- Fuel cells take less space on the vehicle than the batteries in BEV
- FCEVs generate less GHGs
- FCEVs require less well-to-wheels energy
- FCEVs take less time to refuel
- FCEVs have a lower cost of production.

Thomas (2009) also states that a great disadvantage of battery electric vehicles (BEVs) is that in the US as in many other countries electricity comes from coal. Therefore, greenhouse gases (GHGs) would be much greater for EVs than for FCEVs as he

believes that most hydrogen would be made by reforming natural gas to hydrogen for the next ten years or more.

Van den Bossche et al. (2005) supported that the lithium battery has been hailed as a promising battery solution for the future. The lithium technology can be concretized in several versions, the most interesting for traction purposes being the lithium-ion and the lithium–polymer batteries. Until now lithium batteries have been fitted in several prototype vehicles. Although the lithium batteries are almost on the brink of series production, it still needs further optimization as to life, system safety and stability. These issues make lithium systems not a product ready to be commercially available product yet. Summarizing, a battery can have environmental impact during all its life cycle, as Van den Bossche et al. (2005) have mentioned, it appeared that the energy losses in the battery and the energy losses due to the additional mass of the battery have a very significant impact on the environment. However, how much important is the impact is strongly dependent on the way electricity is produced.

For all the advantages that BEVs and FCEVs have, the governments of almost all countries tend to introduce policies that encourage both the development and the purchase of these technologies. In the next section we have quoted some of the policies that some countries with advanced car industry have already set. Many countries have designed some policies in order to support industry (infrastructure, development of technology) while simultaneously they have designed policies that tend to encourage the purchase of an electric vehicle through subsidizing and operating costs for consumers. But as we can observe, most countries have adopted a combination of supply side policies and demand stimulus policies. More specifically according to Department of Environmental and Climate Change (2009), policies are aimed at:

- Supporting the development of the technology (particularly batteries);
- Supporting the electricity network to adjust to the additional demand from EVs;
- Providing charging infrastructure; and
- Making EVs more attractive to consumers (through subsidizing the vehicle and reducing operating costs – free parking, free charging).

## 4.5 COUNTRY CASES

It is widely known that governments all over the world have already introduce policies so as to enhance the EV manufacturing, use and also improvement. In this section we are going to review some of the policies that the USA, UK, France, Germany, Japan and China have already set so as to force the purchasing of an EV and also to promote the R&D for the improvement of the EVs.

### *4.5.1 USA*

The United States have already done efforts to introduce electric vehicles. In 1990, the California Air Resources Board (CARB) introduced a zero-emission vehicle (ZEV) mandate as part of the Low Emission Vehicle Program. The ZEV mandate's initial target was 10 % of new cars sold in California to be zero emissions vehicles by 2003. But the time of introduction has been abandoned as they realized that the technology was not mature enough to compete in the market. Today, what Californian Government requires by the car manufacturers, is to introduce zero-emission vehicles by 2014, independent of their fleet emission levels within the ZEV mandate.

Also the United States Department of Energy (2011) has located an amount of $2.5 billion on a program for the development of electric-powered cars and the improvement of battery technology. Part of the economic stimulus program in 2009 enacted by the U.S. Congress, constitute another $2billion program that had as target the development of battery and their components, and of course the production of other components needed for EVs, such as electric motors. And also they allocated money to the transportation electrification demonstration and deployment projects.

Furthermore, through the Recovery Act, the United States made an investment to build their domestic manufacturing capacity and secure their position as a global leader in advanced lithium-ion battery technology. This investment includes $2.4 billion in loans to three of the world's first electric vehicle factories in Tennessee, Delaware, and California, so they may continue to produce electric vehicles and $2 billion in grants to support 30 factories that produce batteries, motors, and other EV components.

A really remarkable example in USA constitutes the example of California where the mayors of San Francisco, San Jose, and Oakland have announced a nine-step policy plan to encourage the use of EVs in the Bay Area. The mayors have announced policies to expedite permits for installing charging outlets, create incentives for employers to install charging outlets, secure suitable 110-volt outlets in every government building for charging EVs, develop a plan for installing 220-volt charging outlets throughout each city, and harmonize local regulations and standards to achieve regulatory consistency for electric vehicle companies. Additionally they will also establish programs for buying large numbers of EVs at discount rates for government and private fleets.

Also, US have set some 'bonuses' for the consumers of electric vehicles. These bonuses, are different as the years pass From 2000 to 2005, the federal government offered a $2000 tax deduction for the purchase of any hybrid vehicle, according to Gallagher and Muehlegger (2011), afterwards and more specifically after 2006, as it is mentioned by the European Parliament, and through the US Energy Act which offered from $2000 and up to $7500 federal tax credits, depending on the vehicle's battery capacity. The tax credit is supposed to be more generous than the previous tax deduction and varies by model, depending on the emissions and fuel economy. While Gallagher and Muehlegger (2011) have found that the mean sales tax waiver (value $1077) is associated with over three times the increase in sales of the mean income tax credit (value $2011).

Other states and local governments give other motivations such as reduced parking, registration and toll fees or exempt low-carbon vehicles from emissions testing. Today's USA goal is to put one million electric vehicles on the roads by 2015, as it is mentioned by the Department of Energy of the USA (2011).

To sum up, we can say that the combination of the previous policies and instruments constitute part of a strategic niche management for the EV's market in USA. Funds are ensured for the development and the improvement of EVs, policies are set so as to accommodate the necessary infrastructure and bonuses are given so as to enhance the purchasing of the EVs.

*4.5.2 UK*

UK is also a country that supports the introduction of EVs and their improvement. European Parliament (2010) claims that the UK announced a £ 400 million commitment to encourage development and support of ultra-low-emission vehicles. This effort includes a demonstration project with 100 electric vehicles that will be launched in several UK towns. The project's target is to gather first practical experiences with electrically driven cars within the British borders. Also it was funded with £ 10 million by the British government. At the same time, another considerable amount of money approximately £20 million was dedicated to UK research into improving electric vehicle technologies and the infrastructure needed. The activities above will be coordinated by the Government and funded by the Technology Strategy Board.

Furthermore, the British government has announced a commitment to promote electric vehicles. As a consequence they need to facilitate the roll-out of charging infrastructure through the planning system and to collaborate with other countries in the development of international standards so as to facilitate the drivers when travelling to other countries by their vehicles. (European Parliament, 2010)

In addition the British government was supposed to set in action the plan of an electric car incentive program which was mentioned by the European Parliament (2010). The incentive program mentions that motorists will be offered subsidies of £ 2,000 to £ 5,000 which will encourage them to buy electric or plug-in hybrid cars. This program was supposed to start in 2011 and is part of the government's € 250 million plan to promote low carbon transport over the next five years.

Another incentive by the UK government is the fact that the tax system for vehicles is based on $CO_2$ and as a result this system is in favor of cars emitting less than 100 g/km. The annual circulation for example is £0 for cars below this value but can augment up to £ 400 for cars emitting more than 225 g/km. Another measure that is applied in UK and more specifically in the city of London is that the London congestion charge requires car drivers to pay £ 8 for each day they travel in central London, while 'alternatively fueled' vehicles, including electric vehicles, are exempt from paying the charge. Also, London's Mayor Boris Johnson, a supporter of electric cars, wants to make the city the European capital for electric vehicles by delivering 25,000 charging

points in London's workplaces, retail outlets, streets, in public and station car parks by 2015. (European Parliament, 2010)

We can easily understand that UK is also a country that has already started to support electric vehicles' existence actively. They have set a strategic niche with a combination of policies that support the development and improvement of EVs, the development of needed infrastructures and set bonuses so as to motivate EV's acquisition. Beyond this UK is a country that also set programs which launch vehicles in cities vehicles so as to have feedback for further improvement of the technology.

### *4.5.3 France*

According to Global Automotive Team: 'France is the fourth largest European automotive market after Germany, the U.K. and Italy, with 2,050,283 new registered passenger vehicles, and 5,393,000 secondhand passenger vehicles in 2008.' Just as the UK and the USA, France also has a similar system to induce electric cars. In recent years French government has set up a yearly eco-label on new vehicles with an auto-financed bonus-malus system which has as target to tighten the regulations for $CO_2$ emissions and as a consequence favors low emission vehicles. The national bonus/malus scheme of France sets tax deductions and tax penalties at the purchase of new vehicles on the basis of their tank-to-wheel $CO_2$ emissions of the vehicle. This scheme was applied to new cars that were sold on the French market since January 2008, but since 2009, the scheme sets a new bonus of € 5,000 for new cars and now new light commercial vehicles emitting less than 60 g $CO_2$/km. (European Parliament, 2010; Global Automotive Team 2010)

Furthermore, the French government announced the dedication of € 400 million for R&D and demonstration projects over 2008-2012 on low carbon vehicles. This budget covers many R&D and demonstration activities for the development of vehicles and charging infrastructure. Also, France has set a strategy that foresees the following provisions: local governments will be empowered to set up public charging infrastructure, a quota of parking areas in work places and shopping areas will have to be set for electric vehicles and charging spots, builders of collective residences will be obliged to set up charging facilities at parking places upon request of inhabitants, local

governments will be obliged to equip public parking areas with charging facilities. (European Parliament, 2010)

The French government will also support the electric vehicle market by public and private procurements. This is entirely clear by the statement of European Parliament that:

> A 2008 public procurement programme includes a mass ordering of 5,000 hybrid and fully electric vehicle. The French government plans to set-up a public private procurement plan that coordinates the demand of electric vehicles for public and private vehicle fleets. In this context, the French post plans to procure 10,000 electric vehicles by 2012. (European Parliament, 2010: 22)

France like USA and UK has also set a combination of policies in order to support development, improvement and purchasing of EVs as well. The French government has also set policies to fund the needed infrastructures and aims at enhancing the production of EVs by mass orders for replacement of public and private fleets.

### *4.5.4 Germany*

The German Government has a target to reach the 1 million electric vehicles by 2020 and 5 million electric vehicles by 2030, which was announced by the "Nationale Strategiekonferenz Elektromobilität" in November 2008 (European Parliament, 2010).

Germany is another country that wants to support the R&D for electric vehicles. We can easily understand that by the fact that a € 500 million program has been set up by the German government to accelerate the development and deployment of electric vehicles within the next years. This amount of money is dedicated to several pilot projects and to major German manufacturers of cars and battery systems as well as to utilities and scientific institutes for the necessary research. Also, the German government has funded a program for the research of lithium ion battery (LIB 2015), with € 60 million between 2008 and 2015. This research is also complemented by further investments of € 360 million by an industry consortium. (European Parliament, 2010)

Furthermore, the German government, as it is mentioned by the European Parliament (2010), has planned to start a new tax system since 2009 for vehicles. The annual tax

that cars would pay will consist of a base tax and a $CO_2$ tax. The $CO_2$ tax will be linear at € 2 per g $CO_2$ per km. Cars with $CO_2$ emissions below 120 g/km will be exempt from taxation as well as EVs in the first five years after purchase.

In general, the German government has announced to increase funding of research and innovation for everything necessary for electric vehicles. More specifically they will increase R&D funding for batteries, electric engines and electronics, grid integration, storage management and charging systems, recycling and further development of pilot regions as well. Also, two large German companies, Daimler and RWE, have contributed to this effort as part of the program "E-mobility Berlin". Joint initiatives by these two companies, has shown that electric vehicles can perform well in a city setting. Daimler contributed 100 vehicles, while RWE installed 500 charging stations around the city of Berlin.

Finally as we can understand, Germany is also a country that uses a combination of policies. Germany uses policies so as to accelerate development and deployment of EVs and also funds R&D programs so as to have continuous improvement of the product. The German government uses incentives as well so as to province consumers to purchase EVs, these incentives are mostly financial and related to $CO_2$ emissions of the car.

### *4.5.5 Japan*

Japan is the world leader in regard to the research and development of battery technologies as Grünig et al. (2011) mentioned. Japan has the highest R&D budget for the development of lithium-ion batteries. Since 2001, as it is referred by European Parliament (2010), Japan has introduced instruments to induce the consumption of electric vehicles. More specifically, Japan has introduced tax incentives for fuel efficient vehicles. This initiative has led to an accelerated penetration of fuel efficient vehicles and as a consequence Japan fulfilled the 2010 fuel efficiency standards already in 2004. Their next target for the year 2020 is 5,000,000 sold full cell electric vehicles (FCEVs) sold, according to Ahman (2000). They also introduced tax credits of up to $ 3,500 available for hybrid buyers, but are now being phased out.

In 1997 the Ministry of International Trade and Industry **(**MITI) initiated the Advanced Clean Energy (ACE) vehicle program which is an R&D program extending from 1997 to 2003 with the objective of developing different high-energy efficient hybrid vehicles. The MITI funded programs are usually long (4-10 years) and divided into three phases starting with (i) R&D on basic technologies, then (ii) demonstration and prototype, and the last phase, (iii) production and early deployment. All three phases receive government funding.

Also, Japan has proceed action that can support the production of electric vehicles, for example in May 2001, the government of Japan set the target of replacing the government fleet of about 7000 units with low-pollution vehicles by the financial year 2004. (Electric Vehicle Association of Asia Pacific, 2003)

Furthermore, the Electric Vehicle Association of Asia Pacific informs us that electric and hybrid electric vehicles in Japan, can receive a purchase subsidy of up to 50% of the incremental cost of a vehicle under the Clean Energy Vehicle Introduction Project funded by the Ministry of Economy, Trade and Industry (METI). The cumulative total of electric and hybrid vehicles for which subsidy applications were accepted for fiscal years 1998-2002 reached approximately 40,000 (1300 EVs and 38200 HEVs).

In Japan there is a different policy for those that want to replace an old vehicle and for those that want a new vehicle from the beginning. For those replacing older passenger cars, the vehicle to be replaced must have been first registered 13 years ago or earlier. The replacement model must comply with JFY 2010 fuel efficiency standards. If the replacement model were a standard car or a small car, the consumer would be eligible for a 250,000 Yen ($2,500 at 100 Yen per Dollar) subsidy and if it were a mini-vehicle, the consumer would be eligible for a 125,000 Yen ($1,250) subsidy. For those purchasing a new passenger car without an older car to replace, the new model must have fuel efficiency at least 15 percent better than JFY 2010 fuel efficiency standards and a four-star emissions performance rating. If the new model were a standard car or a small car, the consumer would be eligible for a 100,000 Yen ($1,000) subsidy and if it were a mini-vehicle, the consumer would be eligible for a 50,000 Yen ($500) subsidy while something similar happens with the trucks and the buses the amount of the subsidy depends on their tonnage. The Government of Japan has allocated

approximately 370 billion Yen ($3.7 billion) for the program, which could lead to the sale of up to 690,000 vehicles. (Japan Automobile Manufacturers Association, 2010)

So, Japan tries to promote EVs by giving subsidies to consumers and by replacing the public fleets, so as to enhance the production of electric vehicles but also as they want to remain the world leader in research and technology f batteries they also use funds to promote the R&D of high energy efficient vehicles.

*4.5.6 China*

China wants to become the world's largest producer of EVs. For this reason in 2009 Chinese officials announced a plan to reach their goal. During the 2008 Beijing Olympic Games, as it is noticed by Song et al. (2010), China used 595 vehicles powered by battery, hybrid or fuel cell to carry over three million passengers. During 2010, Shanghai World Expo has decided to use new energy vehicles for all public transportations to and around the Expo Center. They tend to use this kind of initiatives in order to motivate EV's production.

Even if China lags behind the automotive companies of Germany, Japan and the United States in battery issues for EVs, the Chinese automobile industry is the one that leads in some aspects for the electric vehicle. These aspects are the capabilities to develop electric cells, electric machinery and driver for EVs. China, according to Song et al. (2010), is also supposed to be the leading country in the field of lithium battery development.

China's Ministry of Industry and Information Technology (MITI) has offered subsidies of up to $12,000 for taxi fleets and agencies for the purchase of an electric car. Also, according to Song et al.(2010), the Ministry of Science and Technology (MOST), Ministry of Finance and other relevant organs, in order to encourage domestic automobile consumption, accelerate the industry structure adjustment and promote the industrialization of energy conservation and new energy vehicles, jointly launched a national project to promote large-scale industrialization of energy conservation and new energy vehicles. Additionally to the policies that Chinese central government has set, the local governments have also put forward lots of incentive policies. In some provinces EVs are allowed to run on the road and they only have to pay the cost for the

license plate and not a fee for a special purpose license plate. Also, EVs are exempted from the purchase tax for conventional vehicles and also their owners do not have to pay the road maintenance fee, the road passing fee, or parking fee, etc. in addition, some certain provinces like the local government of Hubei province pushed out an act to promote R&D and industrialization of EVs in 2005, providing 10 million RMB (Chinese Renminbi) each year to support the R&D and industrialization of fuel cell vehicle from 2005 to 2010.

Also, China is a country that wants to be technologically independent from other countries. For this reason the Chinese EV industry has launched the “863 Program” or else State High-Tech Development Plan, which according to Hequan in Lockström et al. (2010) ‘is a program funded and administered by the central government of the People's Republic of China intended to stimulate the development of advanced technologies in a wide range of fields’.

In 2008, as it is mentioned by Lockström et al. (2010), the Ministry of Science and Technology developed a large-scale pilot project in ten or more cities to put 1,000 hybrid, fuel-cell and all-electric vehicles on the roads in each of those cities and provide the necessary infrastructure for the project within a three year-period. This certain project is called "Ten Cities, One Thousand Cars" and its aim is to facilitate the adoption of energy-efficient vehicles in urban environments. China is characterized by Lockström et al. (2010) as one of the leading countries in the world in terms of encouraging and incentivizing the development and adoption of new-energy vehicles.

China is the country that I personally believe that have made the biggest effort for the diffusion of EVs within the country. They promoted EVs during the Olympic Games and the Shanghai EXPO 2010 when they did all the transportations with EVS. They have offered subsidies so at to province taxi drivers to replace their vehicles with EVs and they gave incentives like exemption from purchasing car tax, exemption from road maintenance fees, road pass fees, etc. They also fund the R&D for advanced technologies and also they have developed a pilot project with which they plan to provide the necessary infrastructure to ten cities so as to have feedback for further improvement. Namely, they have organized a strategic niche for the improvement and the promotion of EVs.

**Table 5: Policies from countries to reach their targets regarding EVs and FCEVs**

| | USA | UK | Germany | France | Japan | China |
|---|---|---|---|---|---|---|
| **Target** | • One mil. EVs on roads by 2015 | • Encourage ultra-low-emission vehicles' development and use | • One million EVs by 2020<br>• 5 million EVs by 2030 | • Tighten the regulations for $CO_2$ emissions<br>• Favor the low emission vehicles | • Five mol. units of FCEVs sold by 2020 | • Roll out 4,000,000 BEVs by 2020 |
| **Technology Push Policies** | • Fund programs for EVs' and battery's technology development<br>• Install charging outlets in each city<br>• Harmonize local regulations and standards for companies' consistency | • Fund research into improving EV technologies<br>• Fund the effort for needed infrastructure | • Fund EVs' R&D and deployment<br>• Fund li-ion battery research<br>• Fund electric motors and electronics R&D<br>• Fund energy storage R&D | • Fund R&D for development of EVs<br>• Demonstration activities<br>• Fund charging infrastructure | •Highest budget for R&D of li-ion batteries<br>•Funds for R&D and industrialization of EVs | • '863 program' aims at the development of advanced technologies<br>• "Ten cities, one thousand cars" program |
| **Market Pull Policies** | • Set programs for buying EVs at discount rates (for public and private fleets)<br>• Tax credits for purchasing EV<br>• Reduced parking prices<br>• Reduced toll fees<br>• Exemption from emission test | • Launch 100 EVs in several cities to have feedback<br>• Subsidies for buying EV<br>• Low emission cars pay less taxes<br>• Exempted from annual circulation<br>• Congestion charge for non-EVs cars (London) | • New tax system for vehicles based on $CO_2$ emissions | • Bonus of €5000 for buying low carbon vehicles<br>• Tax penalties for purchasing a non low emission car<br>• Mass orders for public and private fleets | • Tax incentives for EVs<br>• Replace government fleets with EVs<br>• Subsidies of up to 50% of the incremental cost of a vehicle (1998-2002)<br>• Subsidies depending on the age of replaced vehicle and its tonnage | • During Olympic games and Shanghai expo all the vehicles were electric<br>• Subsidies for taxi fleets<br>• Reduced registration fees<br>• Exempted from purchase tax<br>• Exempted from road maintenance fees, road pass fees, parking fees |
| **Aim** | Secure their position as a global leader in li-ion batteries | London as European capital of EVs | | | Remain leader in battery's R&D | Become the leading country of producers of EVs |

Source: Own processing, based on DOE (2011), Electric Vehicle Association of Asia Pacific (2003), European Parliament (2010), Gallagher and Muehlegger (2011), Japan Automobile Manufacturers Association (2010), Ahman (2006)

Therefore, it is common belief that state tax incentives are positively correlated with increased EVs adoption, something that is also supported by Gallagher and Muehlegger (2011). Also, gasoline prices are positively correlated with EVs sales, although the effect operates almost entirely through the most fuel-efficient hybrid vehicles. Moreover, Gallagher and Muehlegger (2011) claim that both gasoline prices and federal incentives increased alternative fuel vehicle sales. More specifically they support that hybrid vehicle sales in 2006 would have been 37% lower had gasoline prices remained at 1999 levels and would have been 20% lower absent federal tax incentives. As a matter of fact the efficacy of the incentives depends on the generosity and the type of the incentive, while generosity varies substantially by state, model, and time.

To sum up, we have to notice that the transition from combustion engines to electric vehicles, as Kemp and van Lenteb (2011) supports, 'will only be sustainable when not only the vehicles change (powered by fossil fuel or electricity, respectively), but also the way in which they are used'. The electric vehicle technology has become a protected niche product in the regime of ICE cars. As expected the introduction and the development of electric vehicles need some support -especially financial- by the public authorities and a combination of policies both for promote the technology of EVs and their demand as well, as can already be seen by the policies that the USA, UK, France, Germany, Japan and China have followed to introduce electric vehicles in their routine. Most of these instruments are economic, as economic instruments are perceived to be the most effective in promoting green options even if they are not sufficient to stimulate behavioral change. Also we have to consider that the success of the EV, depends on the safety, reliability, performance, maintainability and serviceability that is provides as well. As we can understand, the opportunities that can arise are related to the R&D for promoting electric vehicle technology and their range, its components such as batteries or electric motors, infrastructures for recharging the plug-in electric vehicles or if it is for fuel cell vehicles, infrastructures for refilling them with hydrogen.

## CHAPTER 5: CONCLUSIONS

This dissertation focuses on eco-innovation and relevant policy issues. We examine the nature of eco-innovation and its dimensions, the obstacles that can occur. We review the role of regulations in the process of adoption eco-innovation and the policies that are used in order to facilitate this process. Environmental regulations constitute a key factor in the adoption of new technology innovations by firms and industries. When eco-innovation is produced it needs some appropriate regulatory regime in order to be adopted. We review the policies of USA, UK, France, Germany, Japan and China use in order to facilitate the development, deployment, improvement and use of EVs, as a concrete case of eco-innovation.

Eco-innovation is defined as the production, animation or exploitation of a product, production process, service, management or business methods that are novel and result in the reduction of environmental risk, impact and other negative influences that are caused by the human activity. As a consequence technological innovation and diffusion are necessary in order to have more sustainable activities. Eco-innovation has two aims which are to make businesses smarter and to address environmental problems. By smarter we mean that firms are getting informed about how to deal with emissions, how to reduce the amount of toxics in their products or harmful materials generated by the production process. The second aim refers to the fact that innovation addresses environmental impacts while simultaneously improves the affected product and/or related processes itself and can easily exceed the cost of compliance to regulation.

In order to have eco-innovation we also expect to have three types of changes: technological, social and institutional. We expect new technologies to replace the old ones, social changes so as investors to be more willing to adopt the eco-innovation and lastly we expect institutional change in order eco-innovation adoption to be more feasible. But feasibility does not depend only in the previous factors as during the adoption process of eco-innovation many barriers may emerge. These barriers may be related to the internal or external environment of the firm or may be related to the techno-economic characteristics of the eco-innovation. When we refer to external environment we refer to obstacles such as the absence of pressure by regulations or the lack of information about new technologies or about the regulations. The term internal environment refers to issues such as lack of financial resources or low technological

competency in order to absorb eco-innovation developed by others. Barriers that are related to techno-economic characteristics are the incompatibility of the new technologies with the existing production process in the firms or the high cost of the new technology. These barriers tend to coexist and it is hard to deal with them separately in practice.

Another issue that has to be considered is that in order to have eco-innovation political stability and support are needed. Also a co-operation of chambers of commerce, universities and research institutions is necessary in order to have better and more accurate eco-innovations.

On the other hand there are also barriers regarding the rate of eco-innovations' diffusion. These barriers can be the perception that new technology may not be convenient (usage), the perception that new technologies are expensive in comparison with substitutes (value) or the uncertainty that tends to dominate them regarding their efficiency (risk). Also many businesses hesitate to adopt new technologies as they believe that the new technology will disturb their routine or bring them bad fortune (tradition). Last but not least some times the image that some have about particular technology does not allow them to adopt it as we believe that it is inferior to the one that we already use.

What is also important in the adoption process of the eco-innovation is the selection environment within, which it happens. Eco-innovation may come as an answer to man-made problems, which are part of the natural environment. The built environment is this that can cause delay to a new investment as a long-time is necessary so as to depreciate a previous one. The institutional environment is also a factor that can influence the adoption. The institutional environment includes the regulations and laws that may facilitate the process of eco-innovation adoption. Strategic market niches constitute a selection environment within which new technologies' development, deployment and adoption are facilitated. For this effort institutional connections and adaptations and stimulate learning processes take action in order to have further development and use of eco-innovation.

Parts of the selection environment are also the regulations that are set by governments in order to solve environmental problems. Regulations in order to be specific and accurate, should involve interaction between regulatory bodies and labor unions,

industry representatives and the public in order to be more accurate regarding the needs and the capabilities that exist. The targets of environmental regulations are to create pressure for eco-innovation, to improve environmental quality, to alert and educate companies about opportunities and threats that they may face, to inform industries that innovation is environmentally friendly, to create demand for environmental improvement and finally to level the playing field during the transition period. The main target of environmental regulations is to protect the environment and not to stimulate the technological change but as we can understand the two of them are incompatible, as new technologies are these that will bring better and sustainable use of resources. As one of the goals that regulations have is to foster innovation, regulations have to adhere to three principles. They have to create the appropriate environment to reach the maximum opportunity for innovation, foster continuous improvement in technology and not to leave huge space for uncertainty.

The way that regulations are designed and their elements may influence the innovation. The form of regulation, its mode, the time of compliance that it sets, the uncertainty that it causes to investors, its stringency and the existence of economic incentives are factors that can either induce or block the adoption of innovation. The stricter a policy is the easier it induces eco-innovation. Countries all over the world have adopted strategies so as to address environmental problems. For example Europe has adopted the ETAP program that requires Member States to develop eco-innovation roadmaps and report initiatives taken at national or local level to support eco-innovation. The targets that are set to reduce the $CO_2$ emissions require also shifts in transport, energy and in the agri-food sector.

In order the environmental goals to be reached what is also necessary is to have changes in markets, user practices, infrastructure, cultural discourses, policies and government institutions. Also new technologies and changes in the general environment are required but motivations and incentives are also necessary to induce and facilitate the innovation adoption.

Countries all over the world have adopted some policies so as to induce the adoption of eco-innovation. We have analyzed some of the most common in this dissertation. Policies may be penalizing like environmental taxes that are a way for firms to internalize their external cost. A penalizing example policy is the polluter pays principle

(PPP) which requires by the firms that pollute to pay for their environmental impact. Another type of policies is encouraging/pulling such as Feed-in–Tariffs (price-driven-incentive) that reduce the risk that firms/industries are taken by securing the price of the energy or Quota Obligations (quantity-driven-incentive) that set a production quantity target. There are also covenants that are contracts between the government and firms or industry sectors with which they promise to reduce the environmental burden of their activities within a certain period.

The influence of policies in the decision of adopting eco-innovation is conflicting. There are scientists that support that eco-innovation would not be possible without regulations' existence and other that believe that there is not a strong relation between these two. In order for regulations to be successful in attracting eco-innovation they must follow three principles which are: 1) to phrase environmental rules as goals that may be met in flexible ways, 2) to encourage innovation to reach and exceed those goals and 3) to finally administrate the system in a coordinating way, which means that the different parts and levels of the governments have to coordinate in order firms not to have to deal with multiple parties with different requirements.

Regulators when designing regulations have to take into consideration the technological capabilities, the recourses available and the innovative dynamics of each sector so as to set feasible goals. Regulators should also be well informed about the risk that an eco-innovation may provoke and the barriers that could hinder eco-innovation. What also affects regulations' designing is that designers usually ignore or misunderstand the project development and the financing process that is going to be followed.

So what is needed is well structured regulations, with accuracy, and strict. The optimal is countries to use a combination of environmental and technology instruments so as to lead to innovation inducement. It is believed that eco-innovation can lead to sustainable development but changes in the institution and political stability are conditions for this to happen.

An eco-innovation that tends to gain the interest of the governments, industry and market lately is the electric vehicle. It is a global necessity to get independent from oil as its price rising and the environmental impact that is has is substantial. Electric vehicles constitute an architectural innovation as its core design is the same but the way in which the components are linked changes in underlying components. In order to have

a successful architectural innovation we need two types of knowledge. The first one is "component knowledge: or knowledge about each of the core design concepts and the way they are implemented in a particular component. But architectural knowledge or knowledge about the ways in which the components are integrated and linked together into a coherent whole.

The development of a new product requires also coping with market and technical uncertainty. For this reason strategic niches are necessary to develop protected spaces within which the new product would spend an experimental period so as to have the necessary feedback for further development of it. Many countries have already set policies in order to enhance the development, deployment and use of EVs. The primary objectives that they have are to promote cooperation in R&D, demonstration and commercialization of EVs, to share experience in policy, management, data analysis of EVs, explore universal standards for vehicle evaluation, infrastructure and communication protocols and finally to conduct analyses of the demonstration.

Technologies of electric vehicles that have attracted the interest of the market are in-wheel motor and fuel cells. The technology of in-wheel motor is a promising technology as the power generating elements are where power is needed and as a consequence torque generation is fast and accurate and the transmission of the energy to wheels becomes less complex. The serious drawback is the unsprung weight that emerges but this is dealt by regulating the mass of the rest of the vehicle. FCEVs are also a promising technology as the emissions that it has are just vapor water. An important advantage of FCEVs is that they are of high efficiency, as they can take advantage of the 60-75% of the energy produced (while ICEs can take advantage of the 20-30%) and they are silent during their operation. However, hydrogen is difficult to be stored because despite the fact that hydrogen contains three times more energy per weight than gasoline does, hydrogen gas contains only a third of the energy per volume that gasoline does. Another disadvantage of this technology is that FCEVs are not as durable as ICE. What automobile manufacturers have to take into account is the source by which hydrogen is produced so as not to transfer the pollution to another sector.

In order to understand how seriously countries are thinking about the technology of EVs we have examined the policies and the targets that six countries with substantial

automobile infrastructure have adopted. The USA has as target to have one mil EVs on roads by 2015 and for this reason use policies that fund R&D, infrastructures and purchasing of EVs. UK has as target to make London the European capital of EVs and its government uses also a combination of polices to enhance the development and the market of EVs. Germany, with one of the most respectable automobile industries has as target to promote EVs progressively within the next 20 years. They fund development of the battery technology and electric motors and use a new tax system for vehicles based on $CO_2$ emissions. France is also a country that tends to favor low emission vehicles by funding the improvement of technologies needed for the electric vehicles, and the purchasing by giving bonuses to those that proceed to EV purchase. Japan is the country that wants to have five mil. of FCEVs by 2020. Japan is the leading country regarding the R&D of battery technology and in order to remain they continue to fund the R&D in this sector but in the industrialization of EVs as well, they also give subsidies to consumers, in order to enhance the force EVs production. Last but not least, the China that wants to become the world's leader of producing EVs. In order to accomplish this target Chinese government has set experimental projects in order to have feedback about EVs operation and be able to solve the problems that may emerge. They have also set policies in order to motivate people to buy EVs.

Concluding, we have to notice that the transition from combustion engines to electric vehicles, as Kemp and van Lenteb (2011) supports, 'will only be sustainable when not only the vehicles change (powered by fossil fuel or electricity, respectively), but also the way in which they are used'. The process of developing the EVs as a technology and the infrastructure needed for EVs and FCEVs will have as a consequence the creation of new jobs and the enhancement of regional development. In addition, while EVs' manufactures have to make an effort to remain competitive, new players can change the market share and opportunities for new disciplines are emerging. As a conclusion we have to mention that the successfulness of a new technology is also depended on whether the complementary assets would be the appropriate ones in order to enhance the development and deployment of the new technology.

**REFERENCES**

Aguayo, F. (2008) "Selection environments and innovation regimes: Micro-macro innovation dynamics in late development". Available at: http://smartech.gatech.edu/bitstream/handle/1853/35836/Francisco_Aguayo_Selection_environments.pdf?sequence=1 [Last accessed: 15/05/2012].

Ahman, M. (2006) "Government policy and the development of electric vehicles in Japan". *Energy Policy,* Vol.34, pp. 433–443.

Ashford, N., Ayers, Ch. and Stone, R. (1985) "Using regulation to change the market for innovation", *Harvard Environmental Law Review,* Vol. 9 (2), pp.419-466.

Bell, M. (2009) "Innovation Capabilities and Directions of Development". *STEPS Working Paper* (33). Brighton: STEPS Centre.

Bennett, J. and Bennett, L. (2003) "A review of factors that influence the diffusion of innovation when structuring a faculty training program". *Internet and Higher Education,* Vol.6, pp. 53–63.

Bernauer, T., Engels, S., Kamerer, D. and Seijas, J. (2006) "Explaining green innovation, ten years after Porter's win-win proposition: How to study the effects of regulation on corporate environmental innovation?" *Working Paper* (17) Zurich: Center for Comparative and International Studies.

Blind, K. (2010) "The influence of regulations on innovation: A quantitative assessment for OECD countries". Paper presented at the *International Schumpeter Society Conference 2010 on Innovation, Organization, Sustainability and Crises*. Aalborg, June 21-24, 2010.

Bourdakis, V. (2012) Personal interview. In-wheel motor. At University of Thessaly, with Vasiliki Georgatzi and Yeoryios Stamboulis, 28 May, 2012.

Bruijn, T.J.N.M. and Hofman, P.S. (2000) "Pollution prevention and industrial transformation: Evoking structural changes within companies". *Journal of Cleaner Production,* Vol.8, pp.215-223.

Bulkeley, H., Castán Broto, V., Hodson M. and Marvin, S. (2011) "Cities and low carbon transitions". London: Routledge.

Chappin, M., Hekkert, M., Meeus, M. and Vermeulen, W. (2008) "The intermediary role of an industry association in policy-making processes: the case of the Dutch paper and board industry". *Journal of Cleaner Production,* Vol.16, pp. 1462-1473.

Chappin, M., Vermeulen, W. Meeus M. and Hekkert, M. (2009) "Enhancing our understanding of the role of environmental policy in environmental innovation: adoption explained by the accumulation of policy instruments and agent-based factors". *Environmental Science & Policy,* Vol.12, pp.934-947.

Cleff, T., Grimpe, Ch., Rammer, Ch., Schmiele, A. and Spielkamp, Al. (2007) "Analysis of regulatory and policy issues influencing sectoral innovation patterns". Sector report eco-innovation, Interim paper (draft), Sectoral Innovation Watch, Work Package 9, at *ZEW - Centre for European Economic Research,* Mannheim.

Cook, B., (2001) "An introduction To fuel cells And hydrogen technology". Available at: http://fuelcellstore.com/products/heliocentris/INTRO.pdf [Last access: 12/06/2012].

Del Río, P., Carrillo-Hermosilla, J. and Könnölä, T. (2010) "Policy strategies to promote eco-innovation: An integrated framework". *Journal of Industrial Ecology,* Vol.14, (4), pp. 540-557.

Department of Environmental and Climate Change of Australia (2009) "Economic Viability of Electric vehicles".

Dewick, P. and Miozzo, M. (2002) "Sustainable technologies and the innovation-regulation paradox", *Futures,* Vol. 34, (9), pp. 823–840.

Diederen, P., van Meijl, H., Wolters, A. and Bijak, K. (2003) "Innovation adoption in agriculture: Innovators, early adopters and laggards". *Cahiers d'Économie et sociologie rurales,* n. 67.

Dikeman, N. (2007) "Cleantech vs Greentech". Available at: http://www.cleantechblog.com/2007/07/cleantech-vs-greentech.html [Last accessed: 30/10/2011].

Druehl, C., Naor, M. and Bernandes, E. (2011) "Designing and diffusing environmentally-friendly innovations: An exploratory case study of a sustainable transportation infrastructure in Israel". *Transactions on Engineering Management,* working paper submitted to POM.

Earth Scan. Available at: http://www.earthscan.co.uk/default.aspx?tabid=298 [Last accessed: 20/05/2012].

Ekopedia (2010), "Wheel motor". Available at: http://en.ekopedia.org/Wheel_motor [Last accessed: 26/05/2012].

Electric Vehicle Association of Asia Pacific (2003) "Incentives for EV & HEV". Available at: http://www.evaap.org/pdf/incentive.pdf [Last access: 01/05/2012].

Emissions free cars (2012). Available at: http://emissionsfreecars.com/ [Last accessed: 14/06/2012] Front page cover image.

European Commission. (2012) "Eco-innovation action plan: Policy". Available at: http://ec.europa.eu/environment/etap/policy/index_en.html [Last accessed: 15/10/2011].

European Wind Energy Association (2004) "Wind energy: The facts". Available at: http://www.ewea.org/fileadmin/ewea_documents/documents/publications/WETF/Facts_Volume_5.pdf [Last access: 20/052012].

European Parliament, (2010) "Challenges for a European market for electric vehicles". Available at: http://www.europarl.europa.eu/document/activities/cont/201106/20110629ATT22885/20110629ATT22885EN.pdf [Last accessed: 26/04/2012]

Freeman, C. (1992) "The economics of hope". London: Pinter Publishers.

Frondel, M., Horbach, J., and Rennings, K. (2007) "End-of-pipe or cleaner production?: An empirical comparison of environmental innovation decisions across OECD countries". *Business Strategy and the Environment,* Vol. 16, pp. 571-584.

Gallagher, K.S. and Muehlegger, E. (2011) "Giving green to get green?: Incentives and consumer adoption of hybrid vehicle technology". *Journal of Environmental Economics and Management,* Vol.61, pp. 1–15.

Green Facts (2012) "End of pipe techniques". Available at: http://www.greenfacts.org/glossary/def/end-of-pipe-techniques.htm [Last accessed: 15/10/2011]

Grubb, M. and Ulph, D. (2002) "Energy, the environment and innovation", *Oxford University Press and the Oxford Review of Economic Policy Limited*, Vol.18, (1) pp. 92-106.

Grünig, M., Witte, M., Marcellino, D., Selig, J. and van Essen, H. (2011) "An overview of Electric Vehicles on the market and in development". Available at: http://ec.europa.eu/clima/policies/transport/vehicles/docs/d1_en.pdf [Last access: 12/06/2012].

Hall, J. and Martin, M. (2005) "Disruptive technologies stakeholders and the innovation value chain: A framework for evaluating radical technology development". *R&D Manage*. Vol.35, (3), pp.273–284.

Hall, J., Matos, S., Silvestre, B. and Martin, M. (2011) "Managing technological and social uncertainties of innovation: The evolution of Brazilian energy and agriculture". *Technological Forecasting & Social Change,* Vol.78, pp.1147–1157.

Hemmelskamp, J. (1997) "Environmental policy instruments and their effects on innovation". *European Planning Studies*, Vol. 2, 177-194.

Henderson, R., M., and Clark, K.B. (1990) "Architectural innovation: The reconfiguration of existing product technologies and the failure of established firms". *Administrative Science Quarterly,* Vol. 35, (1), pp. 9-30.

Hezri, A.A. (2011) "Sustainable shift: Institutional challenges for the environment in Malaysia", *Akademika,* vol.81, (2), pp. 59-69.

Hori, Y. (2004) "Future vehicle driven by electricity and control: Research on four-wheel-motored 'UOT Electric March II'". *IEEE Transactions on Industrial Electronics*, Vol. 51, (5) pp. 954-962.

Huber, J. (2008) "Pioneer countries and the global diffusion of environmental innovations: Theses from the viewpoint of ecological modernisation theory". *Global Environmental Change,* Vol.18, pp. 360– 367.

Iansiti, M. and Clark, K. (1994) "Integration and dynamic capability: Evidence from product development in automobiles and mainframe computers". *Industrial and Corporate Change*, (4), pp. 557-605.

IQPC energy blog, (2011) "Where Smart Grid meets Electric Vehicles: The Networked EV". Available at: http://iqpc-energie.blogspot.gr/2011/03/where-smart-grid-meets-electric.html . [Last accessed: 15/06/2012]

International Energy Agency (2012) "Renewable energy coming of age". *The journal of International Energy Agency,* (2), Spring 2012, Available at: http://www.iea.org/IEAEnergy/IEAEnergy_Issue2.pdf . [Last accessed: 29/04/2012]

Jaenicke, M., (2008) "Ecological modernization: new perspectives". *Journal of Cleaner Production,* Vol. 16, pp. 557-565.

Japan Automobile Manufacturers Association (2010) "Fact Sheet - Japanese government incentives for the purchase of environmentally friendly vehicles". Available from: http://jama.org/pdf/FactSheet10-2009-09-24.pdf [Last accessed: 01/05/2012].

Jiménez, O. (2005) "Innovation-oriented environmental regulations: Direct versus indirect regulations: An empirical analysis in small-and-medium-sized enterprises in Chile". *Environment and Planning A,* Vol. 37, (4), pp.723-750.

Kemp, R., Schot, J. and Hoogma, R. (1998) "Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management". *Technology analysis and strategic management,* Vol.10, (2), pp. 175-198.

Kemp, R. (2000) "Technology and environmental policy: innovation effects of the past policies and suggestions for improvement". In: OECD "Innovation and the Environment: sustainable development" Workshop, 19 June 2000, Available at: http://kemp.unu-merit.nl/pdf/oecd.pdf [Last accessed: 15/12/2011].

Kemp, R. and Foxon, T. (2007) "Eco-innovation from an innovation dynamics perspective". MEI, UNU-MERIT, project (D1). Available at: http://www/merit.unu.edu [Last access: 12-06-2012].

Kemp, R. and van Lenteb, H. (2011) "The dual challenge of sustainability transitions", *Environmental Innovation and Societal Transitions,* Vol. 1, pp. 121–124.

Lockström, M., Callarman, T. and Lei, L.. "The Electric Vehicle Industry in China and India: The Role of Governments for Industry Development". In Ohara, M., Vijayabaskar, M. and Lin, H. (eds.) *Industrial dynamics in China and India: Firms, clusters, and different growth.* Basingstoke: Palgrave Macmillan.

Leitner, A., Wehrmeyer, W. and France, C. (2010) "The impact of regulation and policy on eco-innovation: the need for a new understanding". *Management Research Review,* Vol. 33, (11), pp.1022-1041.

Leoncini, R. (1998) "The nature of long-run technological change: innovation, evolution and technological systems". *Research Policy,* Vol.27, pp.75-93.

Levine, M., (2011) 'Driven: Protean Ford F-150 All-Electric Pickup Truck', Pickup Trucks.com. Available by: http://news.pickuptrucks.com/2011/05/driven-protean-ford-f-150-all-electric-pickup-truck.html , [Last accessed: 29/05/2012]

Lutz, B. (2009) "Electric Vehicles: A Force for the Future" available at: http://www.e3car.eu/documents/Electric_Vehicles__A_Force_for_the_Future.pdf [Last accessed: 15/06/2012]

Malloy, T.F. and Sinsheimery, P. (2004) "Innovation, regulation and the selection environment". *bepress Legal Series,* Paper 242

Maskell, P. (1996) "Learning in the village economy of Denmark. The role of institutions and policy in sustaining competitiveness", *Danish Research Unit For Industrial Dynamic, Working paper* (96-6)

Minghua, L. and Yongzhong, Y. (2011) "Environmental regulation and technology innovation: Evidence from China". *Energy Procedia*, Vol.5, pp.572-576.

Morris, L. (2007) "Creating the innovation culture: Geniuses, champions, and leaders", An Innovation Labs White Paper. Available at: http://www.innovationtools.com/PDF/CreatingInnovationCulture.pdf [Last access: 12/06/2012].

Murage, A.W., Obare, G., Chianu, J., Amudavi, D.M., Pickett, J. and Khan, Z.R. (2011) "Duration analysis of technology adoption effects of dissemination pathways: A case of 'push-pull' technology for control of Striga weeds and stemborers in Western Kenya". *Crop Protection*, Vol. 30, pp. 531-538.

OECD (2011a) "Better Policies to Support Eco-innovation, OECD Studies on Environmental Innovation", OECD Publishing.

OECD (2011b) "Taxation, Innovation and the Environment: A Policy Brief". Available at: http://www.oecd.org/dataoecd/24/25/48178034.pdf [Last accessed: 13/02/2012]

Oxford becomes electric vehicle capital of Europe". Available at: http://chargemasterplc.com/oxford-becomes-electric-vehicle-capital-of-europe/. [Last accessed: 29/05/2012]

Perez, C. (2010) "The financial crisis and the future of innovation: A view of technical change with the aid of history". *Working Papers in Technology Governance and Economic Dynamics* (28).

Porter, M. and Van der Linde, C. (1995a) "Green and competitive: Ending the stalemate". *Harvard Business Review*, pp.120-134.

Porter, M. and Van der Linde, C. (1995b) "Toward a new conception of the environmental- competitiveness relationship". *Journal of Economic Perspectives*, Vol.9, (4), pp. 97-118.

Rennings, K. and Rammer, C. (2010) "The impact of regulation-driven environmental innovation on innovation success and firm performance". *ZEW-Centre for European Economic Research Discussion Paper* (10-065).

Rennings, K. (2000) "Redefining innovation-eco-innovation research and the contribution from ecological economics", *Ecological Economics*, Vol. 32, pp. 319 – 332.

Resch, G., Ragwitz, M., Held, A., Faber, T. and Haas, R. (2007) "Feed-in tariffs and quotas for renewable energy in Europe". *CESIfo DICE Report* Vol. 5(4), pp. 26-32. Available at: http://www.cesifo-group.de/portal/pls/portal/docs/1/1193138.PDF [Last accessed: 24/10/2011]

Ringel, M. (2006) "Fostering the use of renewable energies in the European Union: The race between feed-in tariffs and green certificates". *Renewable Energy*, v.31, pp. 1-17.

Rothwell, R. (1992) "Industrial innovation government environmental regulation: Some lessons from the past". *Technovation*, Vol. 12:7, pp. 447-458.

Rothwell, R. (1980) "The impact of regulation on innovation: Some U.S. data", *Technological Forecasting and Social Change*, Vol.17, pp.7-34.

Shinnar, R. (2003) "The hydrogen economy, fuel cells, and electric cars", *Technology in Society*, Vol. 25, pp. 455–476.

Song, Y., Yang, X. and Lu, Z. (2010) "Integration of plug-in hybrid and electric vehicles: Experience from China". Paper presented at the *IEEE Power and Energy Society General Meeting*. Minneapolis, 25-29 July 2010.

Thomas, C.E. (2009) "Fuel cell and battery electric vehicles compared". Available at: http://www1.eere.energy.gov/hydrogenandfuelcells/education/pdfs/thomas_fcev_vs_battery_evs.pdf [Last accessed: 29/05/2012].

Trigg, T. (2012) "The third age of electric vehicles". *The Journal of International Energy Agency*, (2), pp.30-31.

Tsiakaras, P.(2012. Personal interview. Fuel cells. At University of Thessaly, with Vasiliki Georgatzi and Yeoryios Stamboulis, 30 May, 2012

U.S. Commercial Service Global Automotive Team (2011) "Electric vehicles: Europe in brief: A reference guide for U.S. exporters". Available at: http://export.gov/build/groups/public/@eg_main/@byind/@autotrans/documents/webcontent/eg_main_035287.pdf [Last accessed: 29/04/2012].

United States of America. Department of Energy, (2008). Available at: http://www1.eere.energy.gov/hydrogenandfuelcells/production/ , [Last accessed: 17/06/2012]

United States of America. Department of Energy (2011) "One million vehicles by 2015: February 2011 status report". Available from: http://www.youtube.com/watch?v=fVbWDoC3dyI [Last accessed: 29/04/2012].

Van den Bossche, P., Vergels, F., Van Mierlo, J., Matheys, J. and Van Autenboer, W. (2006) "SUBAT: An assessment of sustainable battery technology". *Journal of Power Sources*, (162), pp. 913-919.

Van Mierlo, J. and Maggetto, G. (2007) "Fuel cell or battery: Electric cars are the future", FUEL CELLS 07, No. 2, pp.165–173.

Veziroglu, A. and Macario, R., (2011) "Fuel cell vehicles: State of the art with economic and environmental concerns". *International Journal Of Hydrogen Energy*, Vol. 36, pp. 25-43.

Walz, R., Schleich, J. and Ragwitz, M. (2011) "Regulation, innovation and wind power technologies: An empirical analysis for OECD countries". Paper presented at the *DIME Final Conference*, 6-8 April 2011, Maastricht. Available at: http://www.dime-eu.org/files/active/0/Walz_etal-final.pdf [Last accessed: 17/10/11].

Weiss, Ch., Bonvillian, W. (2011) "Global obstacles to disruptive innovation in sustainable agriculture and energy". Paper presented at the *Atlanta Conference on Science and Innovation Policy.* Atlanta, 15-17 September 2011.

Wiser, R. and Pickle, S. (1998) "Financing investments in renewable energy: The impacts of policy design". *Renewable and Sustainable Energy Reviews,* Vol.2, pp.361-384.