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EUROPE INNOVA
Sectoral Innovation Watch

Potential for eco-innovation in nine sectors of the European economy

Final Report

Task 4 Horizontal Report 4

December 2011

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cip competitiveness and innovation framework programme 2007-2013

European Commission
Enterprise and Industry

Consortium

Europe INNOVA Sectoral Innovation Watch

This publication is financed under the Competitiveness and Innovation Framework Programme (CIP) which aims to encourage the competitiveness of European enterprises.

Europe INNOVA Sectoral Innovation Watch

Detailed insights into sectoral innovation performance are essential for the development of effective innovation policy at regional, national and European levels. A fundamental question is to what extent and why innovation performance differs across sectors. The second SIW project phase (2008-2011) aims to provide policy-makers and innovation professionals with a better understanding of current sectoral innovation dynamics across Europe

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Central to the work of the Sectoral Innovation Watch is **analysing trends in, and reporting on, innovation performance in nine sectors** (Task 1). For each of the nine sectors, the focus will be on identifying the innovative agents, innovation performance, necessary skills for innovation, and the relationship between innovation, labour productivity and skills availability.

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Biotechnology: Christien Enzing (Technopolis)	Space and Aeronautics: Annelieke van der Giessen (TNO)
Construction: Hannes Toivanen (VTT)	Textiles: Bernhard Dachs (AIT)
Electrical and Optical Equipment: Tijs van den Broek (TNO)	Wholesale and Retail Trade: Luis Rubalcaba (Alcala) / Hans Schaffers (Dialogic)
Food and Drinks: Govert Gijsbers (TNO)	

The **foresight of sectoral innovation challenges and opportunities** (Task 2) aims at identifying markets and technologies that may have a disruptive effect in the nine sectors in the future, as well as extracting challenges and implications for European companies and public policy.

Sector Innovation Foresight: Matthias Weber (Austrian Institute of Technology)	
Automotive: Karl Heinz Leitner (AIT)	Knowledge Intensive Business Services: Bernhard Dachs (AIT)
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Task 3 will **identify and analyse current and potential bottlenecks that influence sectoral innovation performance, paying special attention to the role of markets and regulations.** Specifically, the analysis will cover the importance of the different factors in the propensity of firms to innovate.

Role of markets and policy/regulation on sectoral patterns of innovation: Carlos Montalvo (TNO)	
Helena Rozeik (PRAXIS)	Klemen Koman (IER)

Task 4 concerns **five horizontal, cross-cutting, themes related to innovation**. The analyses of these horizontal themes will be fed by the insights from the sectoral innovation studies performed in the previous tasks. The **horizontal reports will also be used for organising five thematic panels** (Task 5). The purpose of these panels is to provide the Commission services with feedback on current and proposed policy initiatives.

Horizontal reports	
National specialisation and innovation performance	Fabio Montobbio (KITes) and Kay Mitusch (KIT-IWW)
Organisational innovation in services	Luis Rubalcaba (Alcala) and Christiane Hipp (BTU-Cottbus)
Emerging lead markets	Bernhard Dachs (AIT) and Hannes Toivanen (VTT)
Potential of eco-innovation	Carlos Montalvo and Fernando Diaz-Lopez (TNO)
High-growth companies	Kay Mitusch (KIT-IWW)

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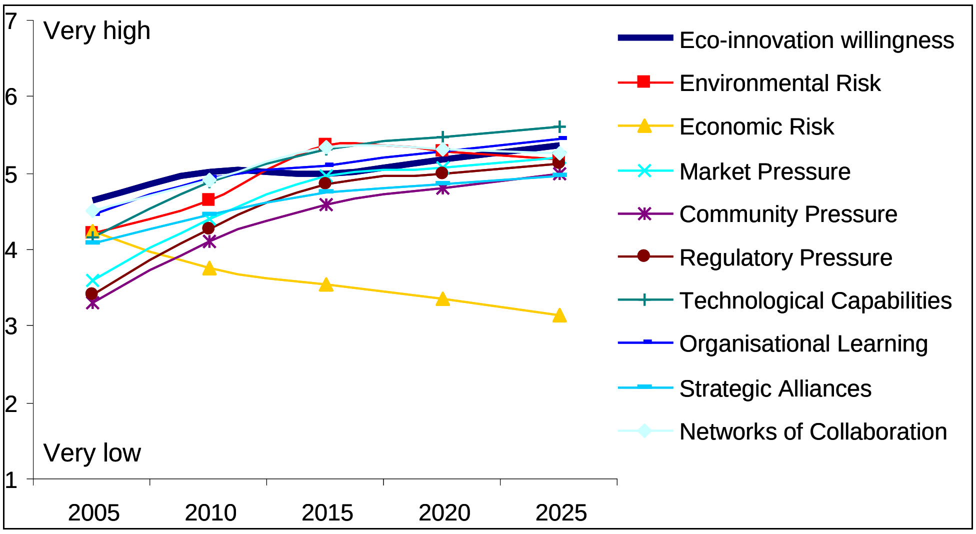
1 Introduction

Recently eco-innovation has come to the forefront of policymaking discussions and forums. Evidence of this fact is found in the agendas of recent meetings held at the highest political level (e.g., OECD, World Economic Forum, UNEP, UNFCCC, etc.). In these forums policy makers have already considered eco-innovations as very real economic multipliers. The environmental driver of eco-innovation has been reinforced by issues like the financial crisis and the resulting economic meltdown.

In Europe, the EU 2020 strategy highlights that smart, sustainable and inclusive growth are mutually reinforcing priorities. In these ambitions, eco-innovations are envisaged as key enablers for securing a knowledge-based, resource efficient, greener, and competitive European economy. As a result, manifold expectations have been raised around the young field of eco-innovation. In principle, it is expected that it could bring solutions to environmental challenges such as climate change and resource scarcity, but also to represent a key source of economic growth, job creation and associated prosperity.

The expectations highlighted above reflect that a new era for environmental related innovation is met by the growth of investment in energy generation and efficiency technologies; the overall business perception towards technologies directly related to environmental performance and the recent policy developments at the global and European levels. Recent studies show a clear upwards trend on several indicators related to the diffusion of eco-innovations. Figure 1-1 below shows trends on propensity to eco-innovate and related drivers.

Figure 1-1 Drivers of eco-innovation 2005-2025



Source: Montalvo et al (2007)

These propelling forces are related to environmental and economic risk perceptions; social pressures coming from the market, regulation and different communities, and capabilities to eco-innovate like technological, learning & collaborative capabilities. All these drivers show very positive signs into the future towards 2025. A general trend worth to be noticed is that the economic risk associated to eco-innovation decreases while other factors increase, such as market, community and regulatory pressures, etc. (see Montalvo et al., 2007). In other words, as time passes, the propensity and attractiveness for investing in eco-innovations also increases. This is confirmed by recent trends on venture capital investments in the last ten years, where the US and Europe are the major players in global markets for eco-energy generation technologies.

Recent developments in markets and policy indicate that this type of innovation might come to complement an ICT driven growth. This is suggested by the rate of growth of environmental technologies markets in the last years. Three indicative examples are now provided. The growth rate of the European 'environmental goods and services industry' was 7 to 8% (in nominal terms) during the 2004 to 2006 period. The performance of this industry in terms of productivity was higher compared to the average in European manufacturing sectors (Bilsen et al., 2009a). A conservative estimation of the global value of six lead market areas of eco-innovation was €1.4 trillion in the year 2006.[1] The growth expectancy of the same markets was estimated at €3.5 trillion by the year 2020 (see Henzelmann et al., 2007, Edler et al., 2007). The latest estimation of the value of the eco-innovation market was provided by the Green Transition Scoreboard® (by Ethical Markets Media).[2] This source reported in August 2011 a $2.4 trillion cumulative investment in eco-innovation during the period 2007-2011. The expected cumulative investment by the year 2020 was estimated at $10 trillion (Ethical Markets Media, 2011).

It is against this backdrop the aim of this report is to capture eco-innovative activity and provide a detailed examination of the potential for eco-innovation in nine sectors: biotechnology, automotive, electrical and optical equipment, aeronautics and space, construction, knowledge intensive business services, wholesale and retail trade, textile and clothing, and food and drinks.[3] Given the large number of eco-innovation opportunities identified, these are clustered around few environmentally thematic areas used to define eco-innovation market segments. In addition, this report aims to provide an analysis of the potential of policy and regulation to foster eco-innovation.

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[1] The lead markets analysed were: renewable energy generation (power generation), energy efficiency, material efficiency, sustainable water management, sustainable mobility (transport) and waste management and recycling.

[2] This scoreboard monitors (non-public) investment in the following areas: renewable energy, sustainable construction, cleantech (energy storage, energy infrastructure, sustainable transportation, water and wastewater, air & environment, eco-materials, smart manufacturing, sustainable agriculture, and recycling and waste), smart grid and corporate (environmental and energy) R&D.

[3] The NACE (rev1.1) codes for the different sectors are: biotechnology (NACE code 73.1), automotive (NACE code 34), electrical and optical equipment (NACE codes 30, 31, 32, and 33), aeronautics and space (NACE code 35.3), construction (NACE code 45), Knowledge Intensive Business Services (NACE codes 72.1, 72.2, 72.3, 72,4, 72.5, 72.6, 73.1, 73.2, 74.2, and 74.3), wholesale and retail trade (NACE codes 50, 51, and 52), textile and clothing (NACE code 17 and 18), and food and beverage (NACE codes 15 and 16).

1.1 Key findings

- Eco-innovation is a horizontal issue that cuts across all sectors, thus, eco-innovation opportunities and potential exist in all stages of the value chain in all the sectors of interest of SIW-II.

- The strongest global players in eco-innovation are the US and Europe, where Europe follows the US by a relative small margin.

- The fastest growing eco-innovation market is underpinned to energy efficiency, storage and infrastructure. The largest venture capital flows have been accrued also in this type of technologies. It is likely that global markets on energy generation and management have already well defined players.

- Relative to energy technologies other eco-innovation thematic clusters are neglected. The role of policy here is to raise awareness of the large number of eco-innovation opportunities and create the necessary incentives for current markets up scaling.

- The top-five sectors that report the largest potential for eco-innovation are biotechnology, construction, knowledge intensive business services, automotive, and electrical and optical equipment.

- Strategic eco-innovators included in scope of this study in average expect their market to double current size over the next five to seven years.

- The association between regulation and eco-innovation is strong and positive. Thus, those firms under stringent regulation engaged more frequently in eco-innovation.

- Regulation and eco-innovation across sectors. The aerospace and construction sectors show a relative larger number of regulations that resulted significantly related with environmental regulations. In the middle we found the textiles and clothing, wholesale and retail, automotive. The lower end corresponded to electrical and optical equipment, KIS, biotechnology and food and drinks. It must be noted that for all sectors - with the exception of the aerospace and construction sectors – the association of environmentally motivated regulations with innovation was weaker than other regulations affecting the behaviour of business.

1.2 Methodology

In this section we put forward the most important definitions to be used in this report and briefly discuss the antecedents of eco-innovation research in the Sectoral Innovation Watch initiative. In addition, we present the methodology to identify eco-innovation potential as well assessing the role of regulation across sectors.

1.2.1 Antecedents and definitions

Antecedents

The present report is preceded by a report on eco-innovation elaborated within the Sectoral Innovation Watch (phase 1, 2006-2008). The first report gave valuable insights on a number of micro, meso and macro aspects in the field of eco-innovation (see Reid and Miedzinski, 2008). The report provided a clarification of the term adopting a resource efficient, life cycle approach focus. In addition to reviewing a number of academic references, the project team performed a literature review of previous publicly-funded projects in the topic, notably: Impress (Bartolomeo et al., 2003), STRATA (Rennings et al., 2003), MEI (Kemp and Pearson, 2008), Fundetec (Coogan et al., 2008), and ECODRIVE (Huppes et al., 2008). This report also included a synthesis of the main messages from the cross-sector analyses performed within the project. Such analyses referred to regulatory and policy issues influencing eco-innovation (Cleff et al., 2008), socio-cultural factors affecting eco-innovation (Bruno et al., 2008) and strategic innovators driving innovation performance (Hollanders, 2008). The main contribution of the overall SIW-I work can be related to the following elements:

(a) A clarification and mainstreaming of the term eco-innovation and the provision of an explicit link between innovation and resource efficiency,

(b) The provision of an overview of the resource impact of innovation and reduced environmental impact in European firms using CIS-3 and CIS-4 data (micro focus). The results pointed out the finding that most companies do not give environmental and resource efficient concerns a primary role in their innovation strategies.

(c) The recognition that different innovation modes are present in firms (micro approach); in order to identify group differences a differentiated analysis was made among innovators, namely strategic innovators, intermittent innovators, technology modifiers and technology adopters.

(d) A literature-output analysis of relevant knowledge fields in relation to eco-innovation (macro focus); the use of bibliometric indicators provided an insight on ‘eco-innovation knowledge’ leaders namely the USA, the UK, Germany and France.

(e) A first attempt to measure innovation performance and resource performance (macro focus); albeit no significant correlation could be obtained between these variables.

Some of the limitations of the SIW-I Eco-innovation report include: 1) it provided limited evidence on eco-innovation at the meso level. The latter is related to the analysis of impacts of eco-innovation across sectors and the identification of eco-innovations with high potential using a systemic-value chain approach; 2) Eco-innovation was treated as a sector. This assumption limits the analysis of cross sectoral spill overs and to unveil eco-innovation specific dynamics; 3) It did not address sector-specific barriers and drivers to eco-innovation (including regulation).

Definitions

This SIW-II[4] report aims to identify the eco-innovation potential in nine sectors and clusters of eco-innovations. It addition, it assesses the potential of policy and regulation to promote eco-innovation. The method used in this report is also based on contributions from the most recent EU-funded eco-innovation projects and the most up-to-date scholarly work in the topic. Based on early works we propose a number of definitions that are relevant for the making of the present report.

To date, several definitions related to eco-innovation have been suggested.[5] In a broad sense eco-innovation can be related to: "new production processes, new products or services, and new management and business methods. Eco-innovation means all forms of innovation reducing environmental impacts and / or optimising the use of resources throughout the lifecycle of related activities".[6] This is the definition adopted in this report.

Eco-industry: The environmental goods and services industry is defined by Eurostat (2009, p 31) "…as a heterogeneous set of producers of technologies, goods and services that measure, control, restore, prevent, treat, minimise, research and sensitise environmental damages to air, water and soil as well as problems related to waste, noise, biodiversity and landscapes and resource depletion". In essence, the notion of eco-innovation includes the EGS industry, but its scope is much broader. Eco-innovation includes areas not traditionally classified as environmentally- related, such as smart manufacturing systems, new materials, etc. Eco-innovation also includes technological and non-technological change at the firm level which is not commercialised but used to improve the firm's own competitiveness

A life cycle-resource efficiency view of eco-innovation:. Following Huber's (2008) contribution analysing eco-innovations under a life-cycle perspective (product chains and innovation life cycle), the first SIW report on eco-innovation highlighted the need to adopt a life cycle perspective of eco-innovation. The consideration of eco-innovation opportunities implied building on a resource efficiency/resource intensity vision and adding the notion of eco-effectiveness (Braungart et al., 2007) The basic rationale for this choice is based on the acknowledgement that resource and energy efficiency features of eco-innovations are of key importance as preventive measures for minimising the resource use (resource intensity) of production systems with positive effects in productivity. Such an approach was further supported by the evidence and analysis provided by the European Parliament eco-innovation report (Bleischwitz et al., 2009) and the latest OECD report on eco-innovation in industry (OECD, 2010) (see chapter 2)

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[4] Sectoral Innovation Watch (phase 2, 2008-2011)

[5] See Diaz Lopez (2011) for a review of definitions and associated issues.

[6] This is the definition used in the CIP Eco-innovation market replication programme. It constitutes also the basis for the approach of the European Eco-innovation Observatory.

Strategic eco-innovators: The first stage of SIW provided some pointers in relation to the need to understand much better the motivations and dynamics of strategic (eco-) innovators. The latter was defined by Hollanders (2008, p. 4) as: “innovators [which] have all introduced a product or process innovation that they developed at least partly in-house, they perform R&D on a continuous basis, they have introduced at least one product that is new to their market, and they are active in national or international markets. These firms will be the source of many innovative products and processes that are adopted by other firms throughout their domestic economy and internationally”.

Eco-innovation clusters: The technical offer of this study indicates the identification of eco-innovation clusters as one of the research activities and deliverables. Clusters of eco-innovation in this report do not refer to geographical agglomeration of industries or firms. As will be noticed along this report eco-innovation is an intrinsic horizontal issue where it is typical that eco-innovations generated within one sector or somewhere else are applied across several sectors. Along the research activities this clustering was indeed found necessary to define eco-innovation market segments and thus enabling to assess the market potential per sector. Thus, the notion of clusters in this study is related to eco-innovations that could be allocated to a group sharing similar features in terms of environmental relevance, sector applicability, and fit to an eco-innovation market segment. This issue is explained in the next section.

1.2.2 Identification of eco-innovation activities and potential

As defined above eco-innovations are characterised by their potential to reduce environmental stress while generating economic activity. Thus the identification of eco-innovation potential includes the identification of opportunities to contribute to environmental sustainability and the corresponding potential for economic opportunities. These two characteristics are inherently linked to the definition of eco-innovation markets. The questions this report aims to answer are: In terms of environmental relevance where are the opportunities at the sector level? How is Europe doing in current and well identified eco-innovation markets? Are there any emerging eco-innovations sector specific market opportunities and if so, what is their potential?

In competitive and competition analysis the definition of market boundaries is a primer problem for market power estimation. The nature of competition in markets underpinned by technological innovation is quite different from competition in other markets. Market definition and market power are extremely difficult to measure. The central question involves identifying products that compete and form a market (Pleatsikas and Teece, 2001). All reasonable technological applications and market segments belonging to the domain must be identified. Such identification may be relatively straightforward in many (though probably not all) mature industries but not in emerging ones. The latter is the case of the eco-innovation market domain. There are several characteristics that help to define a market, amongst others we can include: industry or public recognition of the market as a separate economic entity; the innovation peculiar characteristics and uses, and a distinct set of customers and specialised vendors (Yao and de Santi, 1993, Pleatsikas and Teece, 2001).

These characteristics are present in the eco-innovation market. First, recently there is the recognition that eco-innovation underpins an industry where some market segments are well defined, like the case of the energy generation sector. Second, the vendors are strategic eco-innovators that have a clear leading strategy for designing, developing and commercialising eco-innovations and opening market opportunities. Their business strategy builds around a core value proposition that includes care for the environment. Third, the characteristics and uses of new technologies are defined in the European environmental priority areas. More specifically, the usage of eco-innovations is oriented towards eco-design, resources efficiency, energy efficiency, greenhouse gas reduction, waste minimisation, new advanced materials and reuse and recycling. A summary definition of these areas is provided in Table 1-1 below.

Table 1-1 European environmental priority areas[7]

Priority area	Rationale/description
Greenhouse gas abatement	Emissions of greenhouse gases (GHGs) include CO_2 emissions from energy and non-energy use of fossil fuels and from non-fossil fuel sources. Non-CO_2 gases are also included in this category (e.g. methane, N_2O, etc.). Innovations that help to reduce the generation of GHG, and therefore that have a mitigation potential at an affordable costs, have been signposted as the most important short-term option for climate change mitigation.
Energy efficiency	Energy efficiency is related to the delivery of more services/product for the same energy input, or the same services/product for less energy input. In simplify, improvements in energy efficiency improvement are referred to one of the available options being more efficient end use of electricity.
Material efficiency	The amount of natural raw materials extracted and its relation to productivity and exports are an important measure for estimating the amount of resources used. Eco-innovations aiming to reduce such a ratio are considered a key element for the sustainable-production status of existing production systems. Material efficiency and resource use is an area clearly associated to cost-reduction strategies of firms.
Waste minimisation	The EC defines waste prevention as those means taken before a substance, material or product has become waste. Such measures reduce the quantity of waste, its adverse impacts and the content of harmful substances. The industry uses the term waste minimisation and it is related to those measures and/or techniques that reduce the amount of wastes generated during any domestic, commercial and industrial process. At the facility level, waste minimisation implies reducing waste streams through source reduction, reuse, and recycling of materials. It also includes reallocation of resources and technological change in production systems.
Eco-design	The EC defines eco-design as the integration of environmental aspects into product design with the aim of improving the environmental performance of the product throughout its whole life cycle. For the industry eco-design is a preventive approach, designed to optimise the environmental performance of products, while maintaining their functional qualities. It is considered as a mean which provides genuine new opportunities for manufacturers, consumers and society as a whole.
Recycling and reuse	Reuse is the actual reutilisation of materials in its present form. Recycling is a type of reuse which involves changing the composition or properties of materials in one way or another. A broad definition of (in-process, on-site, and/or off-site) recycling involves turning products or materials at the end of their useful like into usable raw materials to make another product.
New advanced	The term “advanced materials” or “new advanced materials” is used to describe those

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[7] The area of water use not included in the analysis is also relevant to European environmental policies. Recent studies focusing on water use as an important environmental policy area, especially in terms of standards (Mudgal Benito et al 2009) and integrated product policy (Tukker, Diaz Lopez et al 2011). In this report, chapter 2 identified a number of water-related innovations used in a number of sectors, such as closed-loop water systems, improved irrigation and distribution and monitoring systems. Nonetheless, it was not possible to assess the relevance of water use in the TNO eco-innovation Futures survey due to a low response rate in this category.

eco-materials	components which structure and properties have been modified and improved at the mili/ micro/ nanoscale level. As a result, advanced materials possess new and different types of internal structures and exhibit *avant-garde* properties and higher added value, with an unprecedented range of applications. Advanced materials are an important component in a number of energy efficiency applications, where material performance is a critical issue. More and more advanced eco-materials are used in environmentally-related applications.

Source: compiled by the authors, after Kemp et al (2008)

The environmental priority areas presented in the table above are widely accepted and serve several purposes. For instance, they are currently seen as both, labels for likely markets of eco-innovations or as likely strategic market segments. Most of these areas underpin broader general strategy of business greening or greening of products brought to market by specialised vendors. In addition, these seven environmental priority areas also underpin European innovation and environmental policy making. This is a fact reflected in many policy documents. For example, in relation to resource efficiency see (EC, 2011), energy (EC, 2007c), climate change (EC, 2007a); waste management (EC, 2011), recycling (Franckx et al., 2008), eco-design (EC, 2008a), advanced materials (EC, 2009b, Moskowitz, 2009, Rammer et al., 2010a), and for the promotion of sustainable innovativeness and competitiveness see (EC, 2004b, 2004a, 2006, 2008b, 2007d).

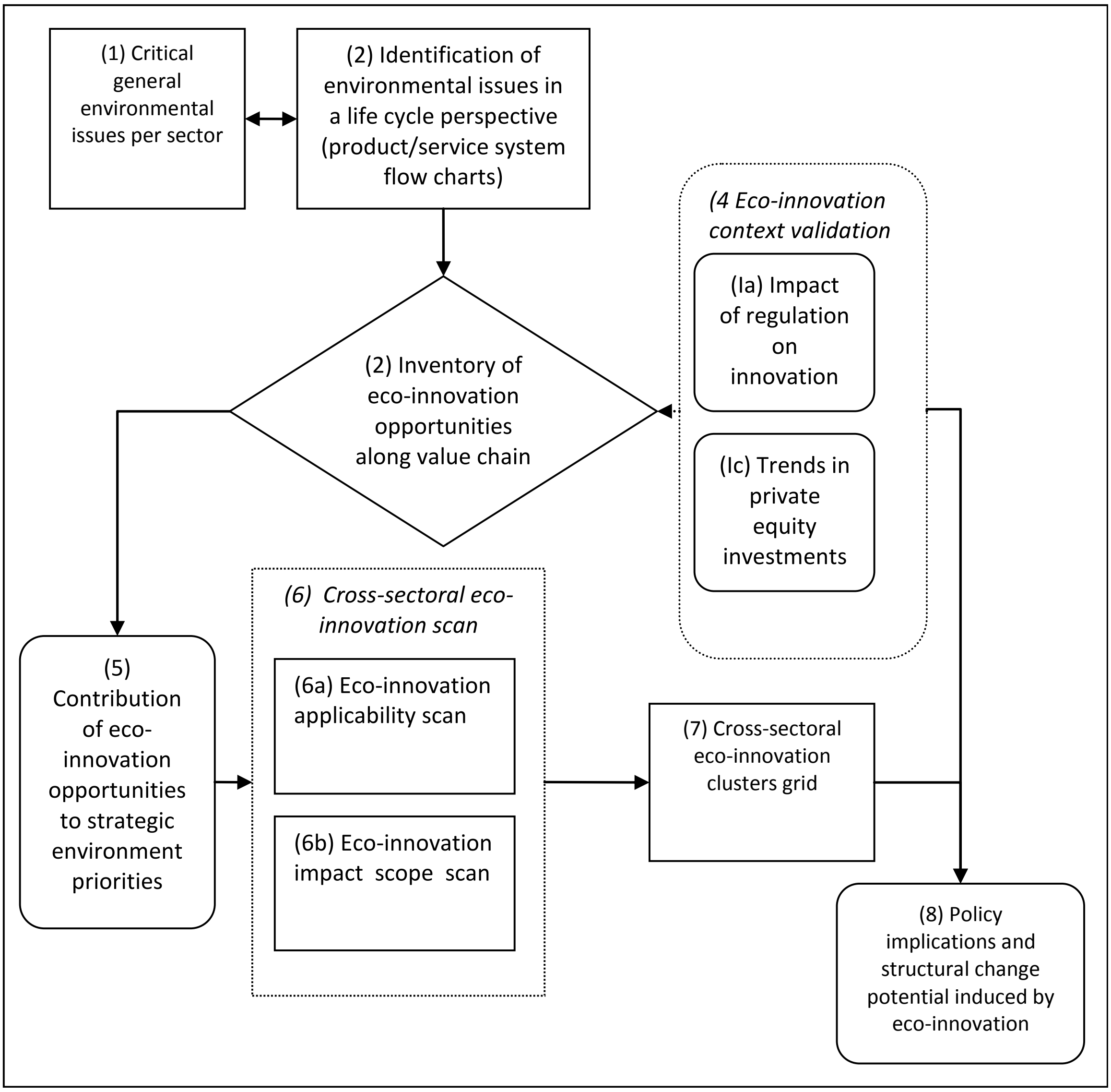
Hence, we consider the environmental priority areas defined above as generic useful thematic clusters for organising the large number of eco-innovations identified in chapter two. As mentioned above the first step in defining a market entails the identification of all relevant competing technologies. The later enables the definition of potential markets segments and market opportunities like the well-defined and evolving energy generation technologies market.

Following the heuristics offered by Pleatsikas and Teece (2001) and Lopatka (2011) the identification of eco-innovation opportunities and market segments required a stepwise approach. The main blocks of the method are shown in Figure 1-2 (next page), and outlined below. It is highlighted that each of the chapters included in this report contain further clarifications of the different criteria employed in each of the steps presented below.

1. **Sector general environmental issues (chapter 2):** The analysis of eco-innovation opportunities is sectoral. Thus, the purpose of this first step is to identify general issues related to the environmental sustainability and resource scarcity pressures of each sector.
2. **Identification of critical environmental issues along the value chain (chapter 2**). For each sector, this step uses a life cycle (value chain) perspective to identify critical environmental aspects along the product or service system flow diagram. This is a graphic step that is seen in the figures included in the section corresponding to the description of environmental sustainability issues per chapter. The identification of critical issues was done by consulting the literature on environmental management in the sectors of interest and locating the stages of the supply and production chain of the each sector.
3. **Identification of eco-innovation opportunities (chapter 2)** This step is related to the identification of current and recent eco-innovation opportunities that both amend the problems identified in the above and fulfils a number of aspects of ‘eco-innovation potential’. The

outcome of this step is the presentation of summary tables with an overview of the eco-innovation identified and a number of examples in the early market or prime unfolding stages. Hence, this exercise follows an innovation life cycle approach. The identification of each eco-innovation must satisfy a number of criteria described in Table 2-1

Figure 1-2 Methodology for the identification of eco-innovation potential



4. Eco-innovation context validation (chapters 3 and 4)

The eco-innovation context validation provides information on investment trends and regulations effects. It consists in two elements:

4a. Impact of regulation on eco-innovation (chapter 3). This step is based on the results of literature review and the application of a SIW survey analysing the impact of innovation on environmentally related regulations (see description in section 3.1,).

4b. Investment trends in eco-innovation and market development trends in eco-innovation (chapter 4). This step is based on the outcome of describing investment trends in financial data for eco-innovation in the period 1999-2009. This data is on venture capital and private equity and disclosure of mergers and acquisitions and initial public offerings. The information is presented per world region, investment type and/or eco-innovation categories (see e.g. Figure 4-4 on global venture capital investments,).

Steps 5 to 7 below are based on a survey of strategic eco-innovators in 24 European countries (see description in section 5.1). The survey targeted companies developing and commercialising eco-innovations. This survey was directed to strategic eco-innovators, that is, firms that see the environment as the main driver of their innovation activity.

5. **Eco-innovations according to environmental priority areas (chapter 5)**
   This step test of the market segment boundaries, i.e., market definition, this step test how well the eco-innovations identified fit a specific market segment. As mentioned above the market segments are defined by the European eco-innovation and environmental sustainability strategic or priority areas. The analysis is presented in in section 5.3.
6. **Cross-sectoral eco-innovation scan (chapter 5)**
   This step includes the description of a scan evaluating the current and potential diffusion of eco-innovation across sectors (see section 5.3.10). This step has two components:
   - 6a. Current and potential usage across sectors of the eco-innovations identified. The results are reported for all nine SIW-II sectors.
   - 6b. Assessment of possible scope effects of eco-innovation adoption, namely at the activity, firm, sector and market levels. This step also describes the type of innovation developed by strategic eco-innovators.
7. **Cross-sector eco-innovation opportunities grid (chapter 5)**
   This step involves performing a clustering exercise of those eco-innovation opportunities identified in the sectors and grouped in eco-innovation policy priority areas. The clustering arises via frequency ranking of positive values of response. This integration is made along the sector categories and along the categories provided by environmental policy priorities. The results are summarised in an eco-innovation cluster grid, for both current and potential application.

1.3 Report structure

This report is organised in six chapters. The main aim of chapter two is to provide sector overviews of eco-innovation opportunities in the nine sectors. Each sector description is divided in two sections: the first section describes the complexity of the value chain of the sector and the environmental problems which can be tackled via eco-innovation. Section two introduces a brief description of eco-innovation opportunities areas within each sector. Chapter three provides sector results of a survey analysis on the impact of regulation on innovation. Chapter four presents recent trends in venture capital and private equity investments regarding early market formation comparing Europe with the rest of the world. Chapter five presents a cross-sector analysis on eco-innovation opportunities that are translated into clusters of eco-innovations. The analysis presented in this chapter is based on the result of a survey of strategic eco-innovators and the degree applicability and structural change potential of their eco-innovations. Chapter six gives some conclusions and policy implications derived from this study.

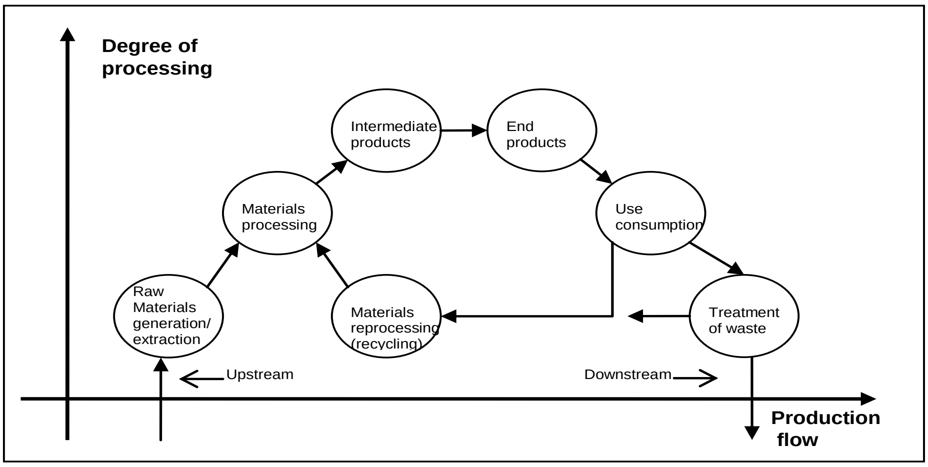
2 Eco-innovation opportunities

One of the overall aims of this study is to show in detail the eco-innovation activity conducted in the nine sectors of interest of SIW-II. This chapter presents an inventory of eco-innovation opportunities in these nine sectors. Eco-innovations are to bring environmental and economic benefits and this chapter addresses the environmental dimension of eco-innovation by identifying critical environmental issues and the respective innovative solutions while identifying a good number of potential applications that will help to define the eco-innovation market segments. The extensive explanation of the method used to identify eco-innovations aims to justify and limit the amount of eco-innovations included in the analysis later in the report. Each sub-chapter includes a section on the main environmental issues under a value chain lens, including a product/service system diagram.

The diagram indicates in green the stages of the production process where critical environmental issues are present and where the eco-innovations identified have their application. This aims to give a clear indication of the overall coverage of the inventory presented. The stages along the value chain selected for analysis in each sector are different due to the fact the critical environmental issues across the sectors are placed in different stages of the supply chain. The rest of the report builds upon the inventory of eco-innovation opportunities and facts presented here.

The identification of eco-innovation opportunities assumes a life cycle of innovation and value chain perspectives. The EEA (1998) defines a life cycle as those “consecutive and interlinked stages of a product system, from raw material acquisition or generation of natural resources to the final disposal. This popular approach is also known as “from cradle to grave” and is closely linked to material flow analyses approaches. Following Huber (2008), we aimed to identify those environmental problems along the value chain that required eco-innovations (see figure 2.1 below). For the section on environmental sustainability under a value chain lens we are interested in highlighting the contribution of the sector to climate change, the use of resources and to enquiring at a broad level what environmental problems in the sector may require the use/diffusion of eco-innovations.

Figure 2-1 Life cycle of innovation and value chain perspective



Source: modified from Huber (2008)

In this report we used secondary sources to identify particular unit processes (blocks within each product or service system) having the highest environmental impacts. The areas that have the most critical environmental impact were graphically identified in the product or service system flow diagrams drawn for each sector. The main data sources included BREF documents[8], industrial handbooks, relevant academic references and project results such as the EIPRO/IMPRO series of studies.[9] For services sectors we relied on secondary sources and expert advice.[10]

In practice, the identification of critical environmental stages in a value chain can be performed using a material flows analyses or a life cycle assessment (LCA) methods. None of these options were feasible for the SIW-II eco-innovation report. For the case of LCA analyses, even when studies are available, it is difficult to identify the main environmental issues at the appropriate level of disaggregation. A large number of studies are pollutant or product specific, its complexity makes its interpretation difficult for the non-experts and it is difficult to related to specific products and technologies with high degree of novelty (EEA, 1998, Nieminen et al., 2007). Resource/material flow analyses are possible to be performed, but linking them to innovation systems and radical innovations is an area currently under development (Ravetz, 2006). On-going efforts for producing extended input-output models and data are expected to contribute to the development of better support systems for sustainability policies. This would ideally contribute to a better understanding of the environmental impacts and resource efficiency gains in sectors, industries, and new products and technologies (e.g. see Tukker et al., 2009b, Tukker et al., 2011).

For each economic sector of interest in SIW-II we provide a summary table of eco-innovation opportunities developed by European firms.[11] In some cases, where no European firm could be identified a non-European example was provided for illustrative purposes. A number of different sources were used. In particular, the search strategy employed a combination of documentary methods, review of existing literature, specialised industrial magazines, analysis of company's press releases, and the TNO Eco-innovation futures database. The selection of eco-innovation opportunities followed the criteria depicted in the table below. Among the factors considered we include the

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[8] BREF documents refer to Best Available Technologies Reference documents providing information on a specific industrial/agricultural sector in the EU, techniques and processes used in a sector, current emission and consumption levels, techniques to consider in the determination of the best available techniques (BAT) and emerging techniques. The full list of BREF documents is hosted at the website of the European IPCC bureau, at: http://eippcb.jrc.es/reference/

[9] The EIPRO (Environmental Impact of Products) is considered one of the most complete studies analysing the environmental impact of product groups (Tukker at al 2006). The IMPRO (Improvement Potential of Products) series of studies (car, meat and diary, textiles, buildings and diet change) was the follow up of EIPRO. The former series of studies provided insight analyses and signposted future avenues of research for identifying and quantifying the environmental improvement options of products and technologies (see: Nemry et al 2008a,b, Weidema, et al 2008, Uihlein and Eder, 2008a, b, Le Guern & Beton 2008, Nemry et al 2009, and Tukker et al 2009).

[10] Environmental issues may also exist in those areas not included in our review that require eco-innovations. Each section makes clear what other areas or stages in the chain are not included our review so they are considered outside the scope of this report.

[11] The information contained in each table should be seen as examples of specific eco-innovations. No interpretation should be given as innovations with the highest economic or environmental potential.

contribution of the innovation to resource efficiency, the intentionality of the innovation, the type of innovation (product, service, etc.), and the degree of change potentially induced. The definitive factor was in relation to innovations in the ready-to-market, early market or prime unfolding stages of their innovation cycle.

Table 2-1 Main filtering criteria followed for the inventory of eco-innovation opportunities

Criteria	Main features of pre-selection criteria	Categories
Resource efficiency contribution	One of the prime aspects of the identification of eco-innovation opportunities is their potential contribution to resource efficiency under a life cycle lens.	• Eco-efficient • Eco-effective
Intentionality of eco-innovation	In this report attention is given to both, eco-innovations that are intentional and those that result as unintended consequences of innovations conducted with different objectives other than improving environmental performance.	• Intentional • Unintentional
Type of eco-innovation	This report considers potential for eco-innovation not only on technological areas but also in non-technological aspects of innovation. In this sense, an attempt is made to distinguish eco-innovation opportunities in different forms following the definitions provided by the Oslo Manual from OECD/Eurostat (2005). See definitions in section 1.2.1.	• Products • Services • Organisational • Marketing
Degree of change and novelty	It is acknowledged that a general view of innovation is related to change. It is important to consider both the degree of change of novelty involved in eco-innovations, as these tend to differ for each case and combinations of them may have implications for its potential. For the identification of eco-innovation opportunities the categories of new to the market and the world may bring the most potential.	• Incremental or radical • New to the firm, market or world
Stage of eco-innovation in the innovation life cycle.	A very important aspect to note is that, eco-innovations in the early stages of market penetration are prioritised in this review (take off stage in a “S” curve).	• Early market • Prime unfolding

The review presented in this chapter intends to contribute to a better understanding of eco-innovation options on a sector basis. Summing up, the following sections present the description of each sector of interest to the Sectoral Innovation Watch as described above. Each section contains: a summary of the main environmental issues of the sector, an identification of those critical environmental stages of the value chain and a summary of eco-innovation opportunities.

2.1 The biotechnology sector

Modern (industrial) biotechnology is considered to be one of the key enabling technologies with most potential for sustaining European competitiveness (Rammer et al., 2010b). This sector is seen as an enabler of more radical forms of technological change and innovation processes in a wide range of sectors (EC, 2007b).[12] Many applications in healthcare, primary production, environmental remediation, and other industrial processes are related to biotechnological innovations. These applications are expected to result in a significant share of the “bio-economy” in relation to the economic output of nations (OECD, 2009a). In the European Union, this sector is considered to have

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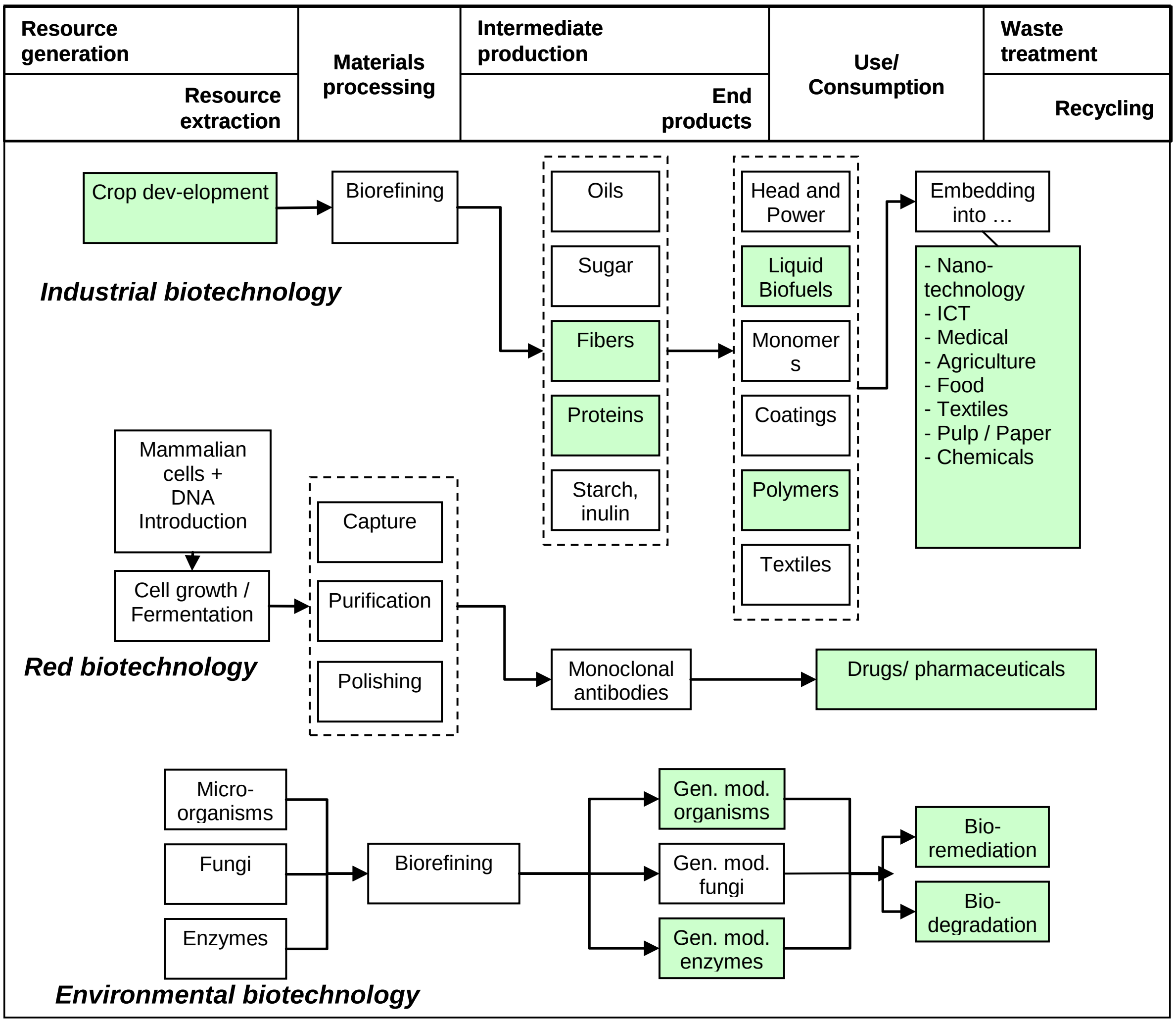
[12] For an overview of the innovation performance and foresight trends of this sector, please refer to the sectoral innovation reports of the Europe INNOVA-SIW for the Biotechnology sector

a large potential to contribute to major targets in relation to economic growth, employment, health, safety and environmental sustainability (Zika et al., 2007, EC, 2009b).[13]

2.1.1 Sector value chain and environmental sustainability

The value chain of the biotechnology sector cannot be put into one single horizontal line, because both manufacturing process and production output and applications are rather diverse. In general, biotechnology can be divided into three areas: green biotechnology when related to agricultural activities, red biotechnology when related to drug development, and white or industrial biotechnology when applied to industrial processes (see the figure below). For the identification of eco-innovation opportunities in this report we mainly refer to eco-innovation in industrial biotechnology, but we also include some environmental applications of biotechnology.

Figure 2-2 Eco-innovation opportunities in the value chain - Biotechnology sector



Source: TNO

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[13] For a comprehensive analysis of the industrial biotechnology as a key enabling technology and its impact on European competitiveness, please refer to Rammer, C., B. Aschoff, D. et. al (2010).

Because of the enabling nature of this sector the contribution of the sector to climate change and the exact environmental consequences of biotechnology activities along the value chain cannot be precisely estimated (Zika et al., 2007). The understanding of own environmental issues of industrial biotechnology and the development of tools for assessing the environmental sustainability of biotechnology eco-innovations has been at stake for over a decade now (e.g. see OECD, 2001). Albeit some critical issues have been identified (e.g. see Enzing et al., 2007), studies about long-term climate change related effects and sustainability performance of the whole sector are not yet available. More critically, the resource intensity of the biotechnology sector as a whole is poorly studied (Zika et al., 2007). In general, a considerable amount of attention around modern biotechnology has been biased towards the topic of competition with food, land degradation and the risks associated with the production of genetically modified organisms (e.g. see Tamis et al., 2009). It is interesting to note that current definitions of industrial biotechnology explicitly relate it to its application to environmentally friendly production methods and technologies but hardly take into account its own environmental impacts (e.g. see Festel, 2010). In spite of the environmental benefits of biotechnology-based processes translated into cost reductions and less energy and materials consumption compared to chemical processes, these still consume substantial amounts of resources when calculated on a per-molecule basis – particularly for water consumption. As an example of this, Graedel and Howard-Greenville (2005) estimated that 1 kg of synthetic organic material produces 100 kg of waste water.

2.1.2 Identification of eco-innovation opportunities

As mentioned in the previous section, industrial and environmental biotechnology applications are considered to have an important potential to improve the environmental footprint of industrial processes, to induce energy savings, to removal pollutants, to avoid GHG, carbon emissions and waste (Zika et al., 2007). Industrial biotechnology applications offer many opportunities to increase environmental performance of processes within many different sectors, ranging from traditional industries such as textiles, leather and paper, to state-of-the-art industries such as pharmaceuticals, renewable energy generation and chemical specialities (OECD, 2009a). Environmental applications of biotechnology often have a remediation, end-of-pipe character used by companies to help ensuring their compliance with regulations. Bio-sensors, also driven by regulation, are expected to contribute to the monitoring of biodiversity and biosecurity (OECD, 2009a).

Table 2-2 contains the description of nine eco-innovation areas focusing on the application of industrial and environmental biotechnology. It is important to note that these eco-innovations do not look at opportunities for improving the own eco-efficiency of biotechnology companies. Overall, in the table below, we can identify a number of opportunities related to the application of biotechnology in production processes, second and third generation biofuels and industrial feedstock from bio-mass, bio-catalyst processes, and the development of new advanced eco-materials (bio-chemicals, bio-polymers, bio-fibers). In addition, other monitoring and control environmental applications of biotechnology are also mentioned, such as bioremediation, bio-leaching and bio-sensors for industrial and environmental applications. The OECD recently published the results of their Bioeconomy to 2030 project, where a number of examples of industrial and environmental applications of biotechnology are included. The description of examples in OECD (2009a) correspond insofar to the categories presented in this section.

Table 2-2 Eco-innovation opportunities in industrial and environmental biotechnology

Eco-innovation	Brief description	Example
Bio-fuels	Bio-fuels are an alternative to fossil fuels and are derived from plant materials. First-generation biomass fuels are produced from sugar, grain or vegetable oil, which are fermented into bio-alcohol (e.g., bio-ethanol) and biodiesel. Second-generation biomass fuels are related to non-food crops (e.g. waste biomass, cellulosic biomass, etc.), and 3rd generation bio-fuels are made from algae, which produces more energy/area. Renewable biofuels, produced in bio-refineries, such as biodiesel, bioethanol, biogas and biomass, and a number of by-products are of key importance to energy generation, bio-chemical components and bio-materials.	• Proprietary technology of glycerine to bioethanol via Syngas from Dutch Bio-MCN • Diaforce® technology for algae biodiesel production from Belgium SBAE
Bio-chemicals	In general these refer to products involving a combination of chemical and biological reactions and processes. This can be done using living cells, substances derived from, or their components to effect desired physical or chemical changes. In this category we mainly refer to bio-chemical intermediate platforms and building blocks in secondary chemicals.	• Voxtar ® platform of pentaerythritol products from Swedish Perstorp • XYX® catalytic technology for furanic building blocks from Dutch Avantium
Bio-catalyst	Catalysts are substances that accelerate a chemical reaction. Bio-catalysis use enzymes (proteins) for the transformation of organic compounds. Many enzymes are produced using bio-engineered micro-organisms in order to improve its efficiency, but the enzyme itself is not necessarily modified. The use of enzymes in different bio-catalytic processes is the distinctive feature of eco-innovations.	• Spezyme® enzyme for improved starch liquefaction from Danish Genecor • Cellusoft® Combi for bio-textile applications from Danish Novozymes
Bio-polymers	Polymers are natural or synthetic materials composed of chains of monomers. Bio-polymers are environmental friendly alternatives to oil-based or non-biodegradable materials, usually made from renewable biomass resources, like corn, wheat, or potatoes. They encompass a wide variety of products, such as bio-plastics, bio-based polymers, cellulose, natural rubber, and composite materials.	• Polylactic acid (PLA) technology from Pyramid, Purac, and Total-Galactic. • Bioplast TPS® thermoplastic from German Biotec
Bio-fibres	Fibres may be either natural or synthetic filament material similar to threads. Synthetic fibres are often produced from cellulose, mineral or petrochemical derivates. Hence, bio-fibres are materials produced from renewable sources rather than oil derivates.	• Ekolab® fibres from Norwegian Helly Hansen • Eco-circle® fibre (eco-polyester) from Swedish Fjall Raven
Bio-solvents	These are solvent replacements from biological sources, especially aiming at VOC reduction. Bio-solvents have found a niche application in the printing industry, but it is of key interest the substitution of solvents in the oil and chemical industry, especially for shoreline clean up and bio-remediation (from oil spillages) and in solvent free speciality chemicals.	• Envirosolv® range of products from British HDP Ltd • CytoSol Biosolvent® from US Cytoculture Inc.
Bio-remediation	End-of-pipe (on-site) treatment of contaminated water (sewage), soil, air and waste with living organisms to degrade or transform hazardous organic pollutants. Although bio-remediation applications have a long history (e.g. in farming), a relatively novel area of application is bio-filtration. Bio filtration offers the possibility to remove a mixture of pollutants from the air (e.g., H_2S) that are turned into water, carbon dioxide and salts. Another area is bio-degradation, for biological breakdown of pollutants – often in waste treatment technologies but with a growing area of applications e.g. for desulphurisation of water streams or selenium removal.	• Bio-filtration systems (biological waste gas treatment, biotrickling filters, bioreactors, etc.) from Dutch Bioway B.V. • THIOPAQ® gas desulphurisation, BIOPAC-AFR® or BIOMETEQ® removal technology from Dutch Paques
Bio-leaching	Bioleaching is part of bio-hydrometallurgical technologies product of the interaction of metal extraction processes and biological organisms. This encompasses bioleaching, bio-remediation, etc. Bioleaching uses bacteria to extract specific metals from their mineral sources, which is considered a better alternative than the use of traditional heap leaching through cyanide.	• BACOX ® bioleaching technology from Canadian Bactech • Zinzex Modificado® technology for indirect bioleaching from Spanish Tecnicas Unidas SA
Bio-sensors	Biosensors are detection and/or monitoring devices that combine an immobilised biological component applied to generic optical detection principles for chemicals/pollutants detection. Very recent developments are based on biomimic principles and often include combinations of technology platforms from optics, bio-chemistry, physical-chemistry, advanced materials and micro/nano electronics.	• Selective bio-chemical layer sensor from Dutch Optisense • Eukaryotic microbial biosensors from Remedios Ltd, a spinoff from Aberdeen University

Source: own compilation based on Whiteley and Lee (2006), Zika, Papatryfon et al. (2007), IEA (2008), OECD (2009a) and other specialised sources.

As mentioned in section 2.1.1, we highlighted those areas where biotechnology applications have an important role as an enabler of eco-innovation. The environmental benefits of biotechnology eco-innovations often depend on the application area and the outcome of the benchmark evaluation of each new eco-innovation in terms of their cost-benefit and eco-efficiency analysis (OECD, 2001). What can be said is that biotechnology is favourable when it replaces environmental-harmful or resource-intensive chemical or physical processes in a cost-effective way (Kircher, 2010). For example. certain biorefinery mechanisms aiming to produce bio-chemical substitutes are more efficient in terms of energy and resource consumption and produce less waste (Woodley, 2008). An additional example are bio-catalyst processes which operate at lower temperatures, produce less toxic waste and fewer emissions (Gavrilescu and Chisti, 2005). But certain environmental biotechnologies may not be entirely sound throughout their entire life cycle. For example, some bio-leaching processes do avoid the release to the air of acid gases (e.g. arsenic trioxide) but leave unsolved the generation and disposal of carcinogenic compounds (e.g. ferric arsenate) (Whiteley and Lee, 2006).

A number of recent studies have signposted a number of opportunity areas that are expected to drive eco-innovation in this sector. The results of the BIO4EU project presents a detailed account of applications, prospects and market potential of industrial biotechnology among other application areas up to the year 2005 (see: Zika et al., 2007, Enzing et al., 2007, Reiss et al., 2007). This study also attempts to present the environmental issues of 10 selected industrial biotechnology applications namely: bioethanol, biopolymers, cephalosporing, enzymes for detergents, enzymes for fruit juice processing, enzymes for pulp and paper, enzymes for textile processing, lysine, riboflavin and biosensors. However, lack of aggregated data made this task rather difficult. The aforementioned study also left unclear the magnitude of the application of industrial biotechnology for producing bio-chemicals (excluding enzymes).

2.2 The automotive sector

The European Union is the largest manufacturer of motor vehicles in the world. Hence the automotive sector is an essential driver of several aspects of the European economy.[14] This sector is nowadays strongly challenged by issues of climate change and energy efficiency and a great deal of R&D and applied technology is currently under development. Non-technological innovations are also high in the agenda of this sector, especially in relation to alternative modes of transport (OECD, 2010).

2.2.1 Sector value chain and environmental sustainability

Automotive is a highly dynamic and competitive industry with global players within an extensive network of suppliers and sub-suppliers along its value chain. In this tier system, lower level organisations provide input to the higher level supplier until the final car assembly. Currently major automakers exclusively contract with Tier 1 suppliers, which assemble automotive components into

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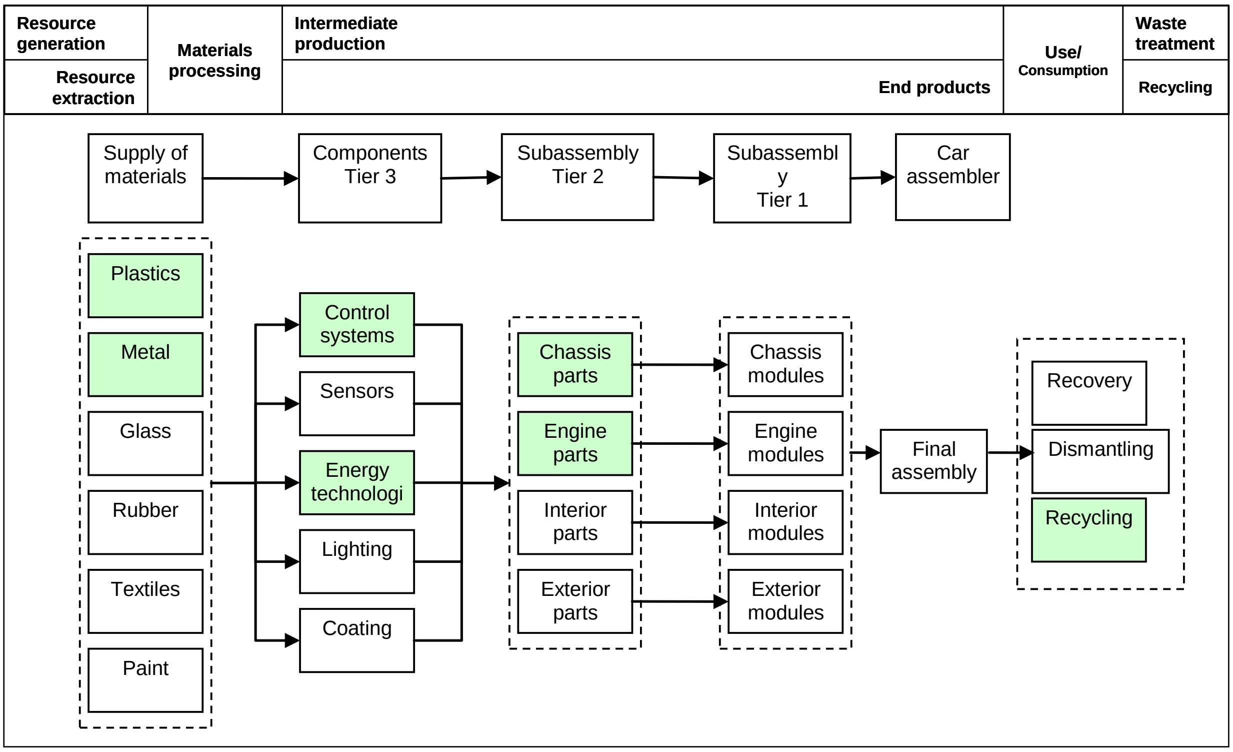
[14] For an overview of the innovation performance and foresight trends of this sector, please refer to the sectoral innovation reports of the Europe INNOVA-SIW for the automotive sector.

large modules. To create these modules, they use parts from Tier 2, Tier 3, or even smaller suppliers. The components industry gains on importance regarding value added, because vehicles are getting equipped with more and better components, plus there is also a growing tendency towards outsourcing (AutoBlog, 2009). Modern car manufacturing production processes are often time critical, thus the cooperation between suppliers and final assembler is more and more a key issue in supply chain management.

The manufacturing process of motor vehicles includes the transformation of raw materials and energy, which results into a variety of environmental consequences. The most important of these are the negative impact on climate change and the depletion of non-renewable resources. In addition, there are also other environmental stresses associated with the use and disposal of cars. The use of motor vehicles releases harmful gases to the atmosphere, such as nitrogen oxides, volatile organic compounds, sulphur dioxide, carbon dioxide, carbon monoxide, particulates, and other pollutants. The use of cars in combination with their manufacturing process (e.g., iron and steel production: 2%) and all necessary petroleum refining (4%) contribute to CO_2 production and thus to climate change (EEA, 2009).

Figure 2-3 Eco-innovation opportunities in the value chain - Automotive sector



Source: TNO

Road transport accounted for 23% of all CO_2 emissions in the EU-15 in 2007 (EEA, 2009). According to the EIPRO study transport accounts for about 15% of the environmental impacts related to global warming. The two more important contributors were driving motor vehicles and passenger car bodies with 15% and automotive repair shops and services with 1.22% of the impacts (Tukker et al., 2006).[15]

Energy, metal and fossil fuels are accounted in the list of resources used in this sector. It has been estimated that almost 20% of energy consumed throughout the whole life of a car is spent during the manufacturing process. An indicative figure suggests that 66-105 gigajoules of energy are necessary to produce a motor vehicle, depending on how much recycled materials are used. This is equivalent to the energy contained in 2000-3100 litres of gasoline, or the amount of fuel consumed by 16000-26000 km of driving (Environment Canada, 2009). Another resource is metal, from which 70-80% of a car is made. The extraction, smelting and refining of metal for the manufacturing process give rise to various environmental problems, such as land disturbances, leaching of metal from mine tailings, acid mine and saline drainage, and runoff of milling effluent containing toxic reagents. A considerable amount of metal used in a car can be recovered or recycled at end of life stage – but it is not possible to re-use all of the metal because of technological or cost-related reasons. Finally, the use and consumption of fossil fuels in the combustion engine is not only depleting the earth’s non-renewable resources, but is also accompanied by many environmental damages which are related to the exploration, extraction, refining, storage, delivery, and the disposal of fossil fuels. It is well know that a car motor causes pollution due to combustion, which can lead to a number of environmental and human health problems (Environment Canada, 2009).

2.2.2 Identification of eco-innovation opportunities

Eco innovation opportunities in the automotive industry can be found along the entire value chain. Nonetheless, it has been suggested that the stage of (intermediate and end) production is perhaps the most interesting in terms of policy and economic relevance (Nemry et al., 2008).

The table below contains nine eco-innovation opportunity areas focusing more on the intermediate and end product stages of the value chain. Within the production process, automation and optimisation techniques are predominant to reduce material and energy use. New alternative energy sources are the main driver for innovations, such as bio-fuels, hybrid or hydrogen power trains to create more efficient and environmental-sound engines. Also new materials are developed to reduce the weight and thus fuel consumption and CO_2 emissions of motor vehicles. Next to this, new materials are also investigated from a recycling perspective, where vehicles could be either dismantled in a more efficient way or vehicle parts could be recycled and reused. Eco-innovation opportunities in the use-phase of the car life cycle are not covered in our review, in particular related to driving behaviour or optimisation of air conditioning systems. The previous two blocks of the chain are well covered in the IMPRO-car report (see Nemry et al., 2008).

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[15] This study also presents the results for the following categories (not reported here): abiotic depletion, acidification, ecotoxicity, eutrophication, human toxicity, ozone layer depletion and photochemical oxidation.

Table 2-3 Eco-innovation opportunities in the automotive sector

Eco-innovation	Brief description	Example
Biofuels	See description in table 2.2. Bio-fuel-powered cars are still an emerging market. Current developments in the automotive industry are related to developing biofuel powered complementary engines and power trains.	• E85 bio-fuel mixtures (mostly 1st generation)
Fuel cells	Fuel cells generate electricity through a reaction between a fuel and oxidant. The combination of fuel and oxidant are manifold, e.g. hydrogen (fuel) and oxygen (oxidant), hydrocarbons and alcohols (fuel) with chlorine and chlorine dioxide (oxidants), etc. Fuel cells vehicles e.g. hydrogen based have been already developed by major car manufacturers and are seen as a promising option for the coming years.	• Fuel cells: • Fuel cell vehicles: Honda's FCX Clarity, DaimlerChrysler F-Cell, Toyota's highlander. GM's Chevy sequel, Ford Focus FCV, etc
Hydrogen storage	Hydrogen storage is a long-term complementary hybrid system to hydrogen fuel cells. The goal is to store H_2 in a compact, lightweight and efficient way in order to use it in motor vehicles and other mobile applications. There are several parallel developments for hydrogen storage, such as high pressure cambers or cryogenic containers. But the most promising approach is based on chemical reactions, where hydrogen is stored in a hydride form and reversibly extracted upon heating.	• H2 multi-capillary arrays storage technology from Swiss C.En. Ltd
Advanced batteries	High-capacity long-lasting batteries with longer life cycles are a core complement of electric vehicles. Advanced batteries aim to reduce the pressure on infrastructures (e.g. charging stations), while enabling longer travelling time. The continuous reduction of safety concerns (e.g., malfunctions, explosions) and the increased applicability of these batteries (e.g., extreme temperatures, shocks) further improve the rate of adaptability for electric cars.	• Silicon anode technology for next generation Li-ion batteries from British Nexeon Ltd
Hybrid vehicles	Given current limitations in alternative batteries and fuel cell technologies hybrid configuration which includes an internal combustion engine and an electric motor is currently seen as the most competitive power train alternative. Hybrid technology options, such as electric motor assistant and electric drive, are becoming increasingly available from almost every car manufacturer. Current eco-innovations lie in combining different energy sources. Hybrid cars with gasoline or diesel engine in combination with an electric engine can leverage the advantages of both systems. Smaller eco-innovations for hybrids are for example regenerative braking or similar energy management tools.	• Several car makers have prototypes of hybrid-electric (HEV); a plug-in hybrid electric (PHEV); and battery-electric (BEV) vehicles
Vehicle components & engineering	This category refers to incremental innovations to improve the efficiency of engines and drive trains to reduce fuel consumption. One example are incremental innovations to improve the efficiency of engines and drive trains to reduce fuel consumption, which is seen as an intermediate solution until it is feasible to make a more radical transitions to alternative energy sources. Another example is the development of continuous variable transmissions, which reduces the driving resistance of cars. This is achieved by sleeplessly changing through an infinite number of gears. This flexibility makes it possible that the engine runs at its most fuel-efficient ratio (RPM = rounds per minute), regardless of the travelling velocity of the car.	• Green Gen II ® active transfer case technology for improved torque distribution /fuel economy from Global supplier Magna Inc. • Optimiser ™ technology for multi-fuelling system (diesel/LPG) of simultaneous combustion from British G-volution
Automotive powertrain retrofitting	An alternative to end-of-life vehicle disposal is automotive power train retrofitting of used and new vehicles, reaching European labels 4 and 5. Power train retrofitting is a plausible alternative for vehicles driving more than 100,000 miles a year e.g., taxis/cabs, limos, shuttle buses, police vehicles, etc. and for campers, all-terrain vehicles, and luxury cars. The feasibility of vehicles to be retrofitted also depends on a good condition of the car's body and chassis (e.g., better preserved in dry environments).	• Electric drive train retrofitting of luxury and all-terrain vehicles from British Liberty Electric Cars Ltd • Electric and hybrid train retrofitting of taxi cabs from British EVO-electric
Nano/bio catalyst	Eco-innovations concerned with developing new catalyst and carrier materials in order to reduce CO_2 emissions. Older catalysts in motor vehicles were only able to eliminate other pollutants, such as CO or NO_x. New biotechnology and nanotechnology catalysts can transform CO_2 to less harmful or even useful new substances.	• -XTS ™ catalyst reformer for stationary hydrogen fuel stations from Swedish ReformTech
Advanced (nano)materials	This category includes new materials for the car body in order to improve corrosion resistance. New lightweight materials, such as high speed steel, aluminium alloy sheets and advanced plastics reduce the overall weight of vehicles and improve fuel economy.	• Lightweight Structural Composite material from UK-based Amber Composites

Source: compiled by the authors

Eco-innovation opportunities in the automotive sector attempt to respond to minimise their contribution to climate change and the environmental impacts of their manufacturing activities. But these innovations are not radical in nature –they do not challenge the concept of mobility as we know it. Eco-innovations are aimed to ease impacts of the sector due to the current high consumption of fossil fuels, which in turn results in large amounts of CO_2 emissions. There is a wide range of incremental eco-innovations in this sector, covering almost all environmental aspects of motor vehicles and for different time horizons. In the short-term, there are eco-innovations in the fields of electric and hybrid vehicles, new intelligent car components, materials and catalysts, which aim to reduce CO_2 emissions through achieving higher efficiency levels. On the long-term, developments in bio-fuels, fuel cells, advanced batteries and hydrogen storage may have a larger potential to foster an automotive industry less dependent of fossil fuels. In addition to this, some eco-innovations in materials technology have the potential to also be applied to other sectors, such as aeronautics and space.

A number of recent studies have signposted a number of opportunity areas that are expected to drive eco-innovation in this sector. Recent studies, such as the IMPRO-car study (Nemry et al., 2008), provide an overview of new technologies with potential for environmental improvements. In the IMPRO-car study changes to the power train were identified as the category with the most environmental potential.

2.3 The electrical and optimal equipment sector

The electrical and optical (E&O) equipment sector encompasses manufacturers of goods that can be categorised in consumer goods (telephones, radios, TVs, watches), capital goods (personal computers, transmission equipment), and intermediate goods (electronic and optical components, like conductors, wiring) (Eurostat, 2008). [16] This sector is one of the fastest growing industries next to biotechnology. This rapid evolution of state-of-the-art technology has major effects on final products but also on the manufacturing process itself. Production operations are continuously under transition, because of short product life cycles and high product obsolesce frequency (Graedel and Howard-Greenville, 2005).

2.3.1 Sector value chain and environmental sustainability

In general, the E&O equipment industry has a wide variety of manufacturing processes along its value chain (see figure below). If we only look at electronics, several distinct processes can be identified – the manufacturing of integrated circuits, the manufacturing of printed wiring boards, and the assembly of integrated circuits and other elements on the printed wiring boards. These modules in turn are further processed by the electronic sector for the final assembly in end-products, such as personal computers, mobiles and the like. In addition to this, electronic products are also delivered to the assembled products sector, where electronic elements are included in other applications, ranging from microwave ovens to airplanes (Graedel and Howard-Greenville, 2005).

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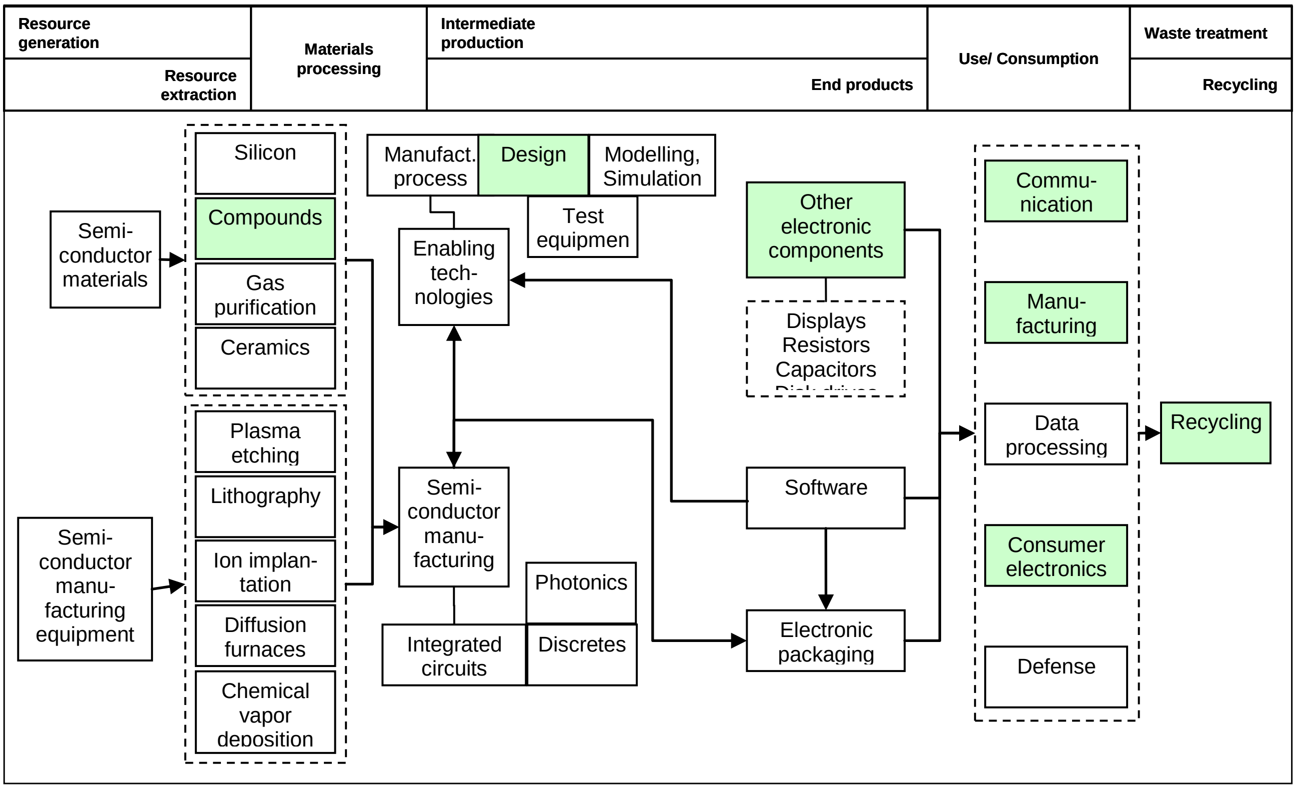
[16] For an overview of the innovation performance and foresight trends of this sector, please refer to the SIW sectoral and foresight reports for the electronic and optical equipment

Figure 2-4 Eco-innovation opportunities in the value chain - E&O equipment sector



Source: TNO

Some of the most evident environmental sustainability concerns in the E&O equipment sector are related to the emission of greenhouse gas, material/resource loss, use of chemicals associated with the production process and in the end product, e-waste, energy consumption and water use.[17] These issues are briefly discussed below.

The production of E&O equipment, such as semiconductors, liquid crystal displays or photovoltaic cells, contributes to the climate change in terms of emissions of gases with global warming potential e.g. perfluorocarbons (PFCs), sulfur hexafluoride (SF6), nitrogen trifluoride (NF3) and fluoroforms (HFC-23) (IPCC, 2006). It is acknowledged that information and communication technologies (ICT) are one of the most rapid evolving sources of greenhouse gas emissions but it is also seen as one of the most promising enablers of emission reductions (The Climate Group and GeSi, 2008). On the one hand, ICT contributes 2-4% of the world's CO_2 emissions and doubles this figure every three to four years (Fry, 2009). On the other hand, it is expected that the ICT sector will contribute to offsetting CO_2 emissions five times its own footprint by 2020 (The Climate Group and GeSi, 2008).

In terms of use of resources, the E&O equipment sector uses large amounts of metal and oil-based plastics. An indicative figure suggests that 1.8 tonnes of various materials are used to produce a desktop computer, including 240 kilograms of fossil fuels and 1,500 litres of water (Williams, 2003). A

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[17] Greenpeace campaigns concerned with the use of toxic chemicals in electronics, e-waste dumping and exports and the greening of ICT are some of the expressions of the growing environmental concerns about this sector

number of steps in the manufacturing of electronics involve the use of a number of chemical elements (e.g., Fe, Sn, Cu, Pb, Cr, etc.). Thus, the E&O equipment industry is indirectly linked to almost all subsectors which are concerned with the extraction and refining of raw materials (Graedel and Howard-Greenville, 2005). The E&O sector makes use of etching materials and other aggressive chemicals which can be harmful to the environment.

Electronic waste is an increasing environmental issue, because electronic appliances show lower economic lifetimes, these are replaced within shorter periods of time and there is illegal dumping and exports of e-waste (Van Erp and Huisman, 2010). Energy consumption also accounts in the share of resources used, but this variable is lower in comparison with other industries. The largest share of energy use in the manufacturing process is associated with filtering the air used to protect chips form dust particles. The energy consumption for integrated circuits manufacturing is around 2,5% of the total lifetime energy use of the final product. Compared to this, up to 80% of energy is consumed during the use of the final product (Graedel and Howard-Greenville, 2005). Finally, water consumption is also an issue especially on a per kilogram basis. Depending on the manufacturing process up to 1000 gram of water are used for every gram of the final product (Graedel and Howard-Greenville, 2005). An indicative example suggest that the water footprint of a 32 megabyte memory chip weighting only 2 grams corresponds to approximately 32 litres of water (Gadrey, 2009b).

2.3.2 Identification of eco-innovation opportunities

Since a number of environmental concerns in this sector are associated to energy consumption, material use and e-waste a large share of eco-innovation focus on tackling these problems. The table below presents 12 eco-innovation areas. Examples are highly energy-efficient devices and development of new organic materials, which can be even bio degradable. When looking on the ICT side of the E&O sector, innovations in process optimisation and logistics (e.g. RFID chips) contribute to (direct or indirect) reduced energy and material consumption. Finally, innovations associated with electrical grid systems, which can transfer electricity in two ways, support the development of home-made energy solutions. It is important to note that eco-innovations aiming to improve the overall environmental efficiency of the sector (e.g. use of chemicals or process efficiency) are not discussed in this short review.

Table 2-4 Eco-innovation opportunities in electrical and optical equipment

Eco-innovation	Brief description	Example
Smart grid	A smart grid system consists of advanced grid components, smart devices, integrated communication technologies, programmes for decision support and human interfaces, and advanced control systems. The application of smart grids with local energy generation seems to favour some technologies. For example, micro CHP (combined heat and power) got a lot of attention during the development of smart power systems. But also other forms of distributed power generations have a lot of potential for the coming years, such as on-site photovoltaic cells and wind turbines.	• SASensor and Virtual private network Technology from Dutch Locamation • Gridstream components from Swiss Landis+Gyr
Smart metering	Smart metering is a part of energy infrastructure which allows end users to measure energy and water consumption on an individual level and transfers the data to the energy and water provider for monitoring.	• ZONOS metering platform from German Cuculus
Smart lighting systems	This category encompasses optical components (e.g., LEDs) and optical equipment (entire lighting systems) which contribute to energy efficiency and generation.	• Smart control lighting system and LED luminaires from UK-

Eco-innovation	Brief description	Example
		based Thorlux Lighting
ICT-based transportation & logistic systems	In addition to widely available navigation and driving assistance systems, this category includes solutions for traffic control to optimise vehicle flows, electronic reservation systems or vehicle detection systems to organise urban traffic more efficiently.	• Intelligent transport software from UK-based Zircon
High capacity PV	This category includes innovations in the generation and storage of environmental-friendly energy. In general photovoltaic refers to the use of panels to convert solar radiation into electricity. Panels contain a semiconductor material that exhibit a photovoltaic effect, such as some silicon derivatives. In principle, high capacity photovoltaic cells offer less material use per unit, less embodied energy, higher energy density, better cost efficiency and sometimes even higher recyclability rates.	• Lightweight, low-embodied energy, high capacity PV technology from British WhitfiedSolar • Organic photovoltaic panels from German Heliatek
Advanced batteries and charging systems	Advanced batteries includes a variety of forms of energy storage devices, ranging from lithium/high temperature, advanced lead/acid, Ni/MH, Ni/Zn, enzyme catalysed batteries, battery/super-capacitor hybrids, etc. It may also include systems for battery management and charging systems.	• Effpower LIC™ lead/acid bipolar battery from Swedish-Austrian venture Effpower and Banner Batteries • EV fast-charging technology from Dutch Epyon
E-waste recycling technologies and collection systems	This category includes recycling technologies for particular waste streams vis-à-vis with the automation and optimisation of production systems is the recycling of electronic and optical equipment. It also includes recycling systems explicitly designed to help firms and consumers to meet WEEE requirements.	• Engitec's CX® lead-acid batteries recycling and lead production system from Italian Engitec • Recolight collection scheme in the UK
Advanced materials	Advanced materials allow the production of smaller and lighter electrical and optical equipment, using less material, less toxic components and higher rates of material recycling and degradation. These innovations aim at replacing traditional raw materials with alternative organic materials, aiming to alleviate material scarcity and e-waste generation.	• Ultra-low super-conducting electronics • linear polyphenylene sulfide (PPS)
Radio-frequency identification chips	Patented since 1973 but only available at the commercial scale since early 2000s, RFID chips can increase supply chain performance through real-time monitoring and processing of products. In this way, the concept of just-in-time, which is already widely used in large assembly operations, could be applied to almost every sector. The indirect environmental side effect of this would be lower energy consumption because of fewer and/or optimised storage facilities.	• EBM energy reduction technology incorporated into wireless radio frequency sensors from German Nanotron
Automation and optimisation of production systems	Automation is often defined as the technology by which a process or procedure is accomplished without the intervention of humans. It is basically composed by a programme of instructions and a control system that executes the former. New developments in ICT have boosted automation as a source of large eco-efficiency potential	• Extended Automation System for a fully automated bio-ethanol production from ABB
Sensors	Detection and/or monitoring devices that combine a … optical or chemical component applied to generic optical detection principles for chemicals/pollutants detection Examples for such ICT solutions are electrochemical sensors and nano-carbon tubes. These can be applied to process monitoring or smart grids.	• Wave-Phire™ ultrahigh temperature sensors in renewable energy generation from British OxSensis
Inspection robots	Developing and manufacturing electronic and optical components is often accompanied by large amounts of defects. Advances in miniaturisation of electronics add even more to this development. Here, inspection robots can be a remedy to the above problem to achieve higher yield enhancement. A new are of application are inspection robots in renewable power generation (e.g. off-shore wind turbines)	• RIWEA turbine inspection robot from Fraunhofer

A number of recent studies have signposted a number of opportunity areas that are expected to drive eco-innovation in this sector. The ELECTRA study suggested that ICT-enabled eco-innovations promise to deliver most of the energy efficient solutions with applications in a number of areas. Intelligence is called to be an important driver for the ICT challenge for environmental sustainability and energy efficiency. An example linking ICT and automation is an ambient-intelligent interactive monitoring system for energy use optimisation that can be used in manufacturing SMEs, stores and warehouses. Nonetheless, the ELECTRA study reported that in spite of their savings potential, the adoption rate of some of these eco-innovations (e.g. motors, drives, lighting systems) has not been as speedy as anticipated (ELECTRA, 2008).

2.4 The space and aeronautics sector

The European aerospace sector represents a relatively small share of the European economy. Nonetheless, this sector is of high economic importance ensuring high levels of mobility and of high technological importance for wider spill-over effects in innovation. Commercially, the significance of the two segments, aeronautics and space, differs substantially, with aeronautics generating the largest share of them. In Europe, the sector is dominated by three countries: the UK, France and Germany all having a long history in aerospace research). An important difference between aeronautics and space is the market structure and customer base. The space market is much smaller and characterised by more, smaller highly specialised firms (Poliakov et al., 2008). Secondly, the space market with military and public institutions as main customers is highly institutionalised, compared to the aeronautics market with airlines and financial investors (lease firms) as largest customer groups (ASD, 2007).[18]

2.4.1 Sector value chain and environmental sustainability

Both aeronautics and space activities can be characterised as 'system integrating'. A small number of large firms (E.g. Boeing, EADS, Raytheon, Finmeccanica, Thales etc) sit at the top of the value chain integrating a number of high-tech technology (sub-) systems and components into final products. This requires very complex sourcing and technology management processes, having implications for innovation in the sector (Brandes and Poel, 2009). Tight linkages exist between the different tiers of suppliers (Niosi and Zhegu, 2005). Essentially, this means that new products and processes at supplier level need to be coordinated with the system integrator to assure market success. With many different technologies and subsystems to integrate into one final product this means that sometimes new (eco-) innovations have difficulties to be developed as they only play a small role in the final product (see example of coatings in section eco-innovation opportunities.

Climate change and sustainability are positioned high on the global agenda for both governments and industry driving new legislation and consumption patterns in the aeronautics industry. While significant technological progress has been made in terms of efficiency and noise reduction of aircraft over the last 50 years, the overall increase in demand has offset these efforts (NASA, 2006). For the space segment contribution to climate change of manufacturing activities is up to now not a relevant issue. ACARE (2009) highlights that the environmental impact of air transport, aircraft manufacturing, maintenance and disposal still has knowledge gaps. Consequently, the direct (and indirect) environmental problems caused by manufacturing activities are currently not dealt with at sector level, but in line of overall environmental regulation.

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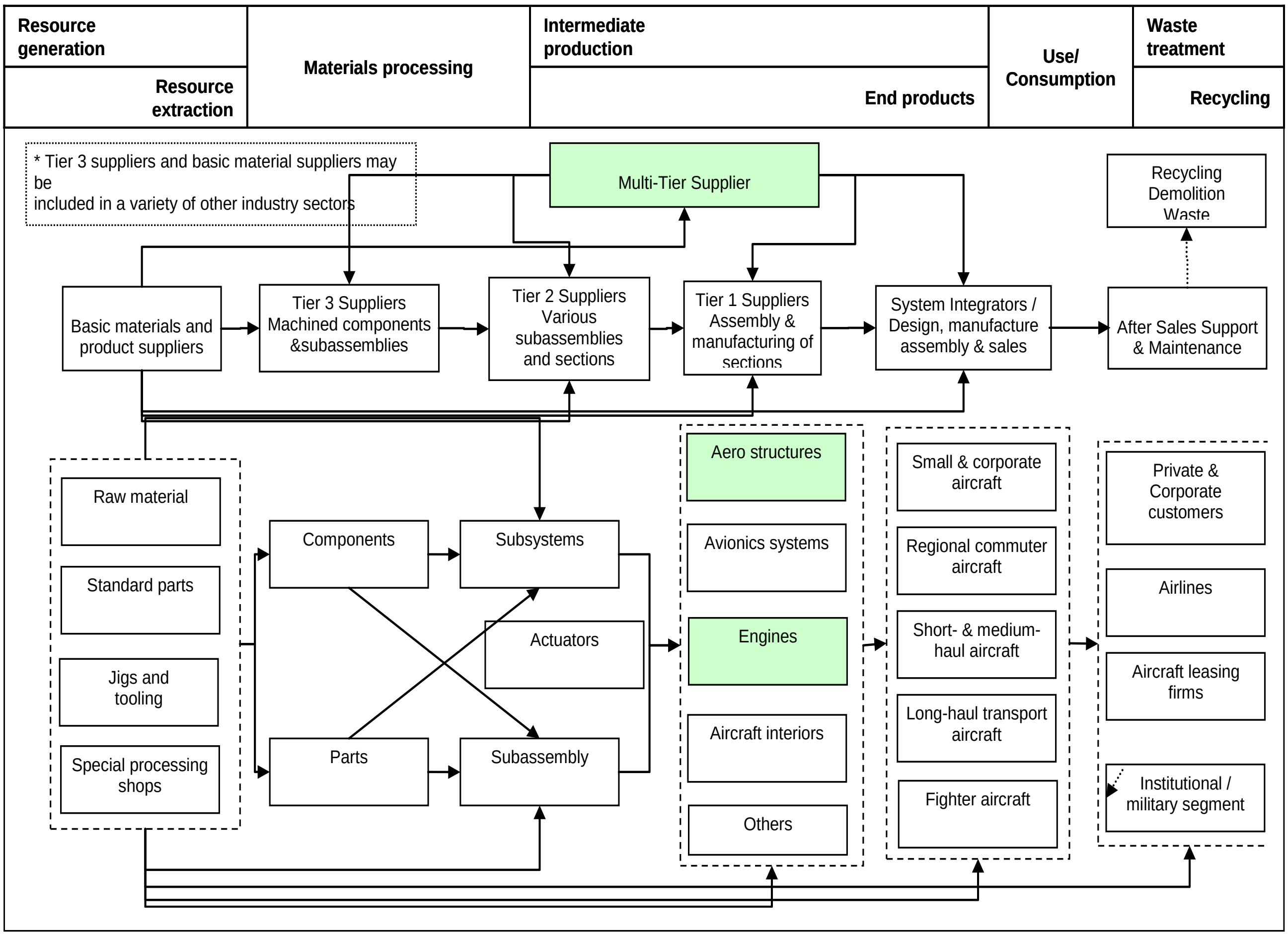
[18] For an overview of the innovation performance and foresight trends of this sector, please refer to the SIW sectoral and foresight reports for the aeronautics and space sector.

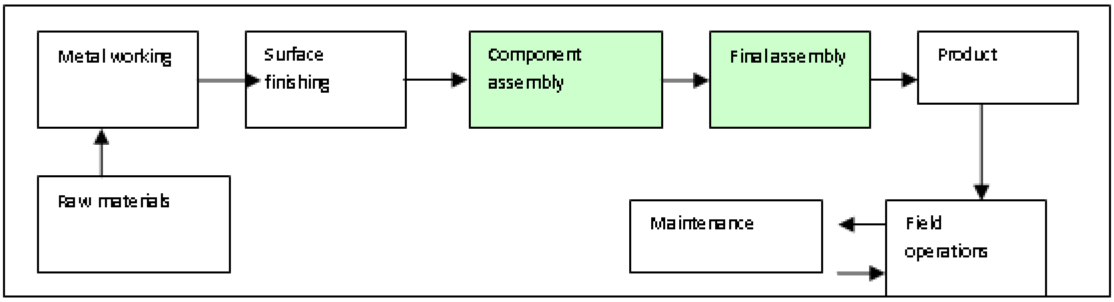
Figure 2-5 Eco-innovation opportunities in the value chain - Aerospace sector



Source: TNO

While the above highlights the different technology systems and actors involved in the value chain, analogous the following picture shows the different steps of manufacturing processes. In combination this allows pointing not only to specific actors and subsystems but also manufacturing processes for the identification of eco-innovation potential.

Table 2-5 The aeronautics and space manufacturing process



Source: EPA (1998b) after Aerospace Industries Association Newsletter, October 1994

Air travel contributes with 2% of global man-made CO_2 emissions – 1,7% civil air transport 0,3% military air traffic (ACARE, 2008). The contribution to climate change of the sector is mostly discussed in context of emissions of air travel rather than the direct (and indirect) emissions of manufacturing activities. The reason being that only very few percentage points of total GHG emissions over the life-cycle of an aircraft are attributed to the manufacturing process (Chester, 2008).[19] Evidence from the UK suggests that transport sectors, particularly aviation and shipping, are among the fastest growing sectors (WRAP, 2009), the majority of which can be associated with international aviation and shipping (Agnolucci et al., 2009)). These are the two sectors currently outside the Kyoto Protocol.

The US Environmental Protection Agency in its sector notebook on aeronautics and space (EPA, 1998b) list a comprehensive overview of pollutants as direct output of aeronautics and space manufacturing activities. Metals are shaped and finished to primarily protect from corrosion requiring a number of distinct processes. Plating processes for example involve immersing the article to be coated or plated into a series of baths consisting of acids, bases, salts, etc. A wide variety of materials, processes, and products are used to clean, etch, and plate metallic and non-metallic surfaces. Typically, metal parts or work pieces undergo one or more physical, chemical, and electrochemical processes. During production steps aeronautics and space components are frequently cleaned (masking; chemical milling; anodising; passivation; pickling; polishing; conversion coatings) also posing environmental impacts (EPA, 1998b).

2.4.2 Identification of eco-innovation opportunities

Overall, the aeronautics and space sector plays a key role for eco-innovation lowering the carbon footprint of air transport services. So far eco-innovation opportunities are to a lesser extent identified for manufacturing processes although emissions of chemical substances are dealt with through environmental regulation. But frequently exceptions are made to wider environmental regulation due to reasons of flight safety (e.g. chromates in coatings). Environmental regulation and safety regulation are hence potentially in tension.

For aeronautics and space, the largest potential for eco-innovation does not lie with the sector itself (manufacturing activities) but within the use sectors. In the case of aeronautics the sector can help reduce environmental impact of air travel. It is of key importance to place the sector activities in context of the product use and life-cycle. Eco-innovation opportunities have been identified for five areas: new materials for light weight aero structures, new materials for engine performance improvements, fuel cell as alternative propulsion, bio-fuels to lower the carbon footprint of air transport, and aeronautics and space coatings reducing chemical emissions in manufacturing and reducing fuel consumption of aircraft. The last category, aerospace paints and coatings, represent an

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[19] Aircraft operation was modelled with average the U.S.A. data which is not necessarily representative of specific U.S.A. conditions or international conditions. Aircraft operation outside of U.S.A. average conditions should be carefully evaluated before use of inventory results.

important step in manufacturing and being responsible for a large share of VOC emissions. The use of bio-fuels also generates high expectations to lower carbon emissions during aircraft operations.

Table 2-6 Eco-innovation opportunities in the aeronautics sector

Eco-innovation	Brief description	Example
Lightweight & composite materials in airframe structures	New materials play a crucial role in airframe structures, engine components and in related systems and devices. This category includes both composites and metallic cellular structures enabling weight reductions for vehicle structures.	• Airbus A320 Winglets (part of Next generation composite wing) using Atkins Carbon Critical Design ™ tools
Materials engines	This category includes high performance alloys for jet engines help improve jet engine efficiency by increasing pressure and temperature of steam cycles. Refractory metal alloys (RM) represent a revolutionary alternative for jet engine efficiency but challenges of oxidisation under high temperatures need to be overcome.	• Rolls Royce's Trent XWB™ engine • Scnema's LEAP-56™ engine
Alternative propulsion systems	Alternative propulsion systems are currently being envisioned as auxiliary power systems. Boeing developed a 2-seat civilian aircraft running on electricity of a fuel cell combined with a battery, showing the technical feasibility of the technology for small aircraft.	• Antares DLR-H2, a prototype by DLR and Lange Aviation
Biofuels	These represent drop-in alternatives of kerosene – renewable fuels that can be added and used in the current kerosene. Since 2005 different mixes have been tested by several airlines, mainly using camelina, jatropha and algae.	• Bio jet fuel from Dutch SkyNRG
Coatings	Coatings represent a weight factor and provide the outer shell and hence influence air drag of the aircraft. But the weight and smoothness have to be balanced against environmental factors, airframe integrity, and legislation issues in the development of new aerospace coatings to protect the aircraft structure against the extreme conditions they are exposed to daily.	• Toluene, xylene and chromate free engine coatings from British Indestructible Ltd` • DeSoto® chromate free exterior nano primer coating from PPG Aerospace

Source: compiled by the authors

Space applications can help monitoring and managing climate change. It is expected that the space sector can play an important role in the future to lower environmental impact of many sectors improving resource management and efficiency. Nonetheless, this area will not be covered in this review as their likely impacts on eco-innovation have indirect effects. On the other hand, space applications (downstream services) have the potential to address many societal challenges (OECD, 2005) providing opportunities for eco-innovation. Societal challenges refer to environmental degradation including natural resources such as water, forestry, but also climate change posing high environmental costs. Applications in this context refer to Earth Observation (EO) and Global Navigation Satellite Systems (GNSS) that help monitoring the environment, manage energy use, water management, precision agriculture and the mobility challenge. Earth observation, for example, can be used to select locations for renewable energy, assess and monitor water resources, increase the effectiveness of forestry and prevent deforestation, help farmers to monitor crops and monitor treaties and hazardous goods (OECD, 2005).

The availability of recent studies signposting a number of opportunity areas that are expected to drive eco-innovation in this sector is limited. Further research outputs are expected over the coming years with for example a number of on-going research projects in this field financed by DG Research (EC, 2009d). EU-funded projects VITAL and NEWAC promise to deliver solutions. For the latter no access to deliverable reports could be accessed at the time of performing this analysis.

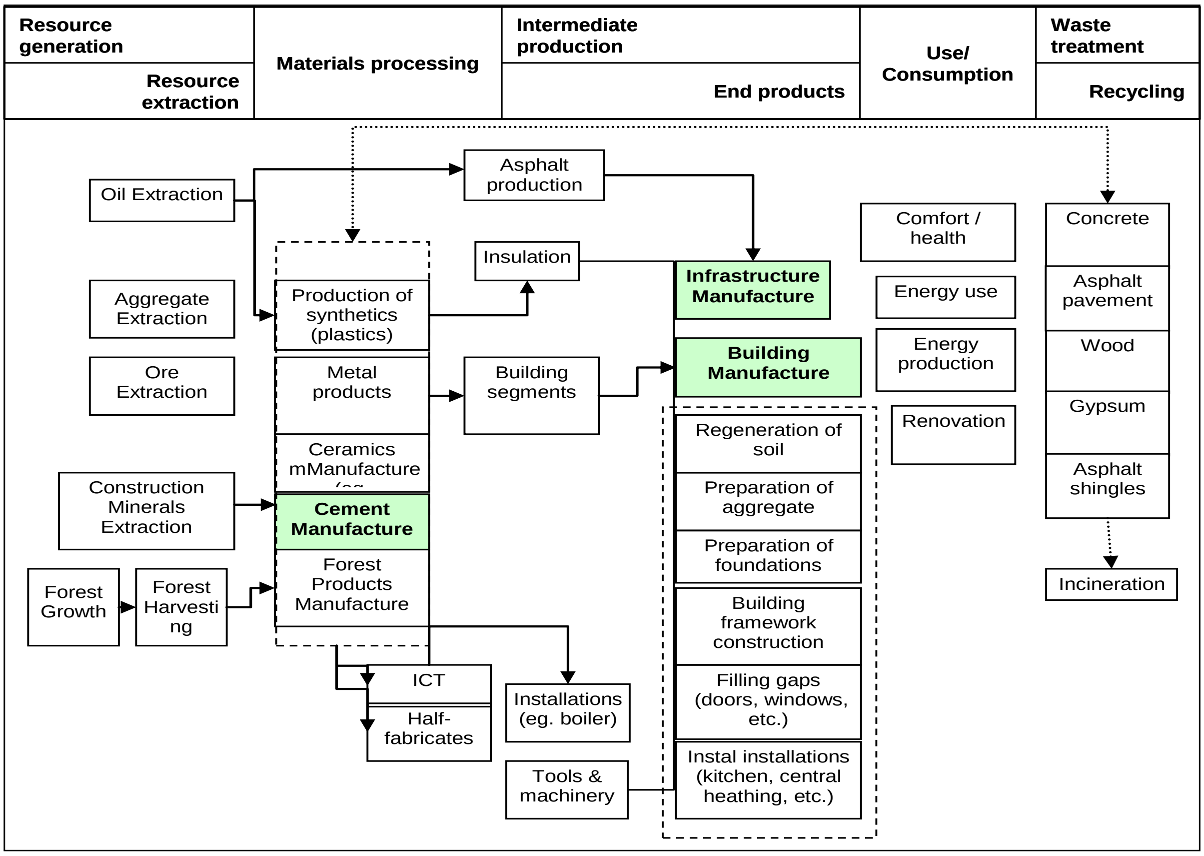
2.5 The construction sector

According to recent figures for the EU 25 (Bilsen et al., 2009a), the construction sector it is the largest industrial employer in the EU. Buildings are one of the products with the longest time-span for usability, usually for several decades and even for more than a century. The length of service life of buildings varies according to many factors including location, materials, construction methods, use and maintenance practices, etc. (OECD, 2002).

2.5.1 Sector value chain and environmental sustainability

The construction process for buildings and infrastructure includes a large number of different steps. The building sector has major impacts not only on economic and social life, but also on the natural and built environment. Various building activities, such as the design, construction, use, refurbishment and demolition of buildings, directly and indirectly affect the environmental performance of the sector (OECD, 2002). Inherently, a number of actors are involved in its value chain, from architects, design buffets, material suppliers, maintenance and refurbishment companies, demolition contactors, etc.

Figure 2-6 Eco-innovation opportunities in the value chain - construction sector



Source: Modified from (Graedel and Howard-Greenville, 2005) p 408

Residential and commercial buildings are responsible for approximately 30% of the primary energy use in OECD countries (2003, OECD, 2002). The built environment accounts for 40% of CO_2 emissions in the EU (Uihlein and Eder, 2009) and 42% of total EU final energy consumption (Bilsen et al., 2009a).

It has been estimated that around 40 - 50% of all materials extracted from earth are transformed into construction materials and products (OECD, 2003). Most of these materials are abundant and considered as low-tech in terms of sourcing. The extraction, refining, processing and transport of these materials take up a considerable amount of energy, with associated emission of greenhouse gasses and environmental damage (e.g., large amounts of windblown dust) (Graedel and Howard-Greenville, 2005). A critical material is cement, which manufacturing contributed in 2007 with 107.570 Gg CO_2 equivalents (European Environment Agency, 2009). The construction sector uses vast amounts of energy in the first three stages of the production process: resource generation, resource extraction and intermediate product manufacture (Graedel and Howard-Greenville, 2005). The major source of energy consumption during the construction process is related to transport of people and materials to the building site (EPA, 2009b).

During the production process and after the product lifetime a large quantity of waste is generated. The construction industry is accountable for 10-30% of all solid waste globally (Graedel and Howard-Greenville, 2005). According to results from the APPRICOD project, waste arising from European construction and demolition (C&D) alone amounts to around 180 million tonnes each year. This is over 480 kg per person per year, which makes C&D waste one of the most important waste streams (the commonly accepted European average is 30%). However, only about 28% across the EU-15 is re-used or recycled – the rest is land filled (APPRICOD, 2006).

Hazardous materials are used in the construction sector, mainly for painting and finishing of buildings. While there have been efforts to properly dispose of hazardous liquids, there has been little effort to reduce its use (Graedel and Howard-Greenville, 2005). Directives demanding the eradication of lead from paint have not foreseen the additives being used, which often had the same or even worse effects on the environment.

Another issue is related to the quality of buildings, since it has a direct effect on the health of end-users. Health problems from indoor air pollution have been highlighted as one of the most acute environmental problems related to building activities (OECD, 2002). Related to the above, work in the construction industry is physically demanding and often hazardous. Heavy lifting and difficult working conditions lead to many physical problems. As a result, there are a high number of serious incidents and the fatality rate in the construction industry is considerably high, only behind the records from the mining sector (Schartinger, 2009).

2.5.2 Identification of eco-innovation opportunities

In the following paragraphs the most important eco-innovation opportunities will be addressed in terms of material extraction, use of building, maintenance, and deconstruction. In this way the following nine eco-innovation opportunities are described in their sequence of occurrence in the value chain: production of materials (e.g., eco- materials), project design (e.g. passive solar design), construction process (e.g. eco-integrated planning), building in-use (e.g. energy management), deconstruction (e.g. design for easy dismantling). Clearly, the intermediate categories of design, construction (including renovation projects) and use are related to the notion of smart buildings. Smart or intelligent buildings are notions which refer to the automatic adjustment of buildings or components to various external changes. This is also related to enabling the communication of components and systems in order to optimise their use (e.g. sensors control lighting, heating, air quality, fire detection, security etc.)

Table 2-7 Eco-innovation opportunities in the construction sector

Eco-innovation	Brief description	Contribution
Eco-materials	This category includes advanced eco-materials (e.g. nano, bio, etc.) to improve energy efficiency (e.g. through better insulation properties) and material efficiency (e.g. less material use) of products. Eco-materials should be inherently less toxic, safer and more resistant compared to traditional materials. The use of eco- materials may also provide additional waste reduction savings during the construction phase.	• Cellular Lightweight Concrete (CLC) • EnviroShield Performance™ ITO • Isolgreen® insulation materials from French Green Ingenierie
Building segments	This category includes products that reduce material use in construction projects. In general building elements include window-stills, panels, etc. The main eco-feature of pre-fabricated building elements is the reduction of on-site work and waste generation. These may reduce the environmental impact coming from transportation of building materials in combination with optimised logistical planning.	• Pre-fabricated concrete floors from Dutch VBI
Passive solar design and components	Passive solar design enables buildings to attain a comfortable temperature without the need of heating or air-conditioning systems. Measures amongst others include shading, windows, ventilation and insulation.	• Renovent HR heat recovery unit
Eco-integrated building	Eco-integrated building planning and management uses long term horizon estimates and cradle to cradle principles. This eco-innovation is particularly useful for eco-friendly cost estimation and the integration of the supply chain. Similar approaches can be found in e.g., DCM contracts (Design, Construct and Maintain), Total Cost of Ownership (TCO) approach, Performance Based Building, Design Quality Method, etc.	• Sustainable Building tools from UK Hamson Partnership
Lean construction	This category corresponds to activities and techniques to shorten the construction time and materials used for new buildings projects and infrastructure. Typically improvements are measured and achieved by establishing targets in terms of productivity gains (%), reduction of defects (%), time improvement of planned activities (man-hours), etc.	• SECBE's lean construction approach
Environmental assessment of buildings	This category refers to methods for evaluating the environmental impact of buildings and facilities, in order to avoid since the design stage, or to minimise during the use stage.	• BREEAM (BRE Environmental Assessment Method)
Waste reduction	This category refers to waste management plans and cut costs activities by reducing wastes incurred during construction and use of the building. It may also include refurbishment audits, procurement site management, intelligent waste collectors, etc.	• Waste management and resource efficiency tools (CLIP, CALIBRE, and SMARTWaste.) from UK-based BREE
Building automation and control systems	Building automation systems often refer to the use of networked technology within a building infrastructure, used to monitor, control and provide real-time information about different elements of its architecture. It basically consists of interrelated sensors, controllers, actuators and software.	• Home automation box from French Ijenko
Retrofitting of residential & commercial buildings	This category refers to cost-effective measures that can be undertaken without a major renovation of residential/commercial buildings such as: sealing points of air leakage around baseboards, electrical outlets and fixtures, plumbing, the clothes dryer vent, door joists and window joists; weather stripping of windows and doors; and adding insulation in attics, to walls or wall cavities, etc.	• Retrofitting preparatory studies by UK-based Stroma Ltd
Energy management in existing	This category involves management methods and technologies for reducing the energy demand of existing buildings. Insulation of buildings is one of the most practical solutions to establish prevention of heat lost. Remaining energy	• Heating & Cooling Switching Modules from UK-based

Eco-innovation	Brief description	Contribution
buildings	demand can be meet from renewable sources or micro-combined heat and power units. An example of tool is the energy triangle method.	SeamlessSensing Ltd • RESTful API software for energy management accountability from UK-based Amee
Easy adaptable buildings	This category refers to methods for extending the use period of existing buildings and infrastructure. Adaptations are often made in terms of energy and materials use is a way to increase its efficiency, often aiming to reduce waste from renovation projects.	• EPA's programme Design for Easy Dismantling
Deconstruction	This category includes selecting methods for facilitating the recovering of construction and demolition materials for reuse, recycling or re-processing. Among such materials we account: includes bricks, concrete, masonry, soil, rocks, lumber, paving materials, shingles, glass, plastics, aluminium (including siding), steel, drywall, insulation, asphalt roofing materials, electrical materials, plumbing fixtures, vinyl siding, corrugated cardboard, tree stumps, etc. Examples of deconstruction-related methods include pre-demolition audits, construction and demolition plans, hand-dismantled recovery, etc.	• Eco-park Emmeloord with Dutch BGM Nederland BV as initiator

Source: own compilation based on EPA(2000) , OECD (2002), , IPCC (2007), UKSTB (2008) and other relevance sources

It is expected that eco-innovations in the construction sector will provide a significant potential of improvement for the whole of the built environment. Eco-innovations range from new eco-materials, via smart materials and buildings, eco-performance based buildings to actual improved tools for construction and assembling. The environmental impact reduction may come from designing buildings that actually reduce energy use, limit the amount of materials used in construction, and improves the recyclability and reuse rate after demolition. The latter category involves pre-design techniques which facilitates keeping a recovery value of waste. The minimisation of waste during the construction and demolition phase is more and more included in lean construction and deconstruction methods.

The market for eco-efficient buildings is populated by a huge variety of concepts with a lack of clear definitions or a common understanding what is exactly meant by each one of them. Eco-efficient buildings include terms like sustainable buildings, green buildings, passive houses, low-impact-buildings, low-energy-buildings, zero-energy buildings, energy plus buildings, etc. (UK Technology Strategy Board 2008, Torcellini, Pless et al, 2006). What they all have in common is the general objective of reducing CO_2 emissions. Eco-buildings may vary in the timeframe to achieve its CO_2 reduction target. Equally the actions taken for the improvement of the environmental characteristics of the buildings in the construction stage may vary. This situation highlights the need of eco-design of buildings foreseeing the use of materials with low embodied energy (low energy for transportation, low energy for manufacturing and building materials etc.) and low service frequency (e.g. high level of physical durability, easy maintenance of buildings, physically adaptable to change of use). In the use stage, it is increasingly be necessary to improve the energy efficiency of buildings (e.g., thermal insulation, air tightness etc.) and to improve the energy efficiency of appliances (space heating and cooling, ventilation, hot water etc.). Finally, the maximisation of renewable energy use (active solar heating, passive solar heating, photovoltaics etc.) is a compelling element in eco-efficient buildings.

A number of studies have signposted a number of opportunity areas that are expected to drive eco-innovation in this sector. The fourth assessment report of the IPPC (Levine et al., 2007) suggests, among others, the following eco-innovation areas with the highest mitigation potential: (1) reduce heating, cooling and lighting loads, (2) active solar energy and other environmental heat sources and sinks, (3) increase efficiency of appliances, heating and cooling equipment and ventilation, (4) commissioning and improve operations and maintenance, (5) change behaviour related to energy use in buildings, (6) system approaches to building design, (7) eco-design, considering building form, orientation and related attributes, (8) minimisation halocarbon emissions in building components – notably air conditioning and refrigeration systems, foam products used for insulation and other purposes and fire protection systems, (9) passive solar heating, and (10) energy-efficient HVAC design, etc.

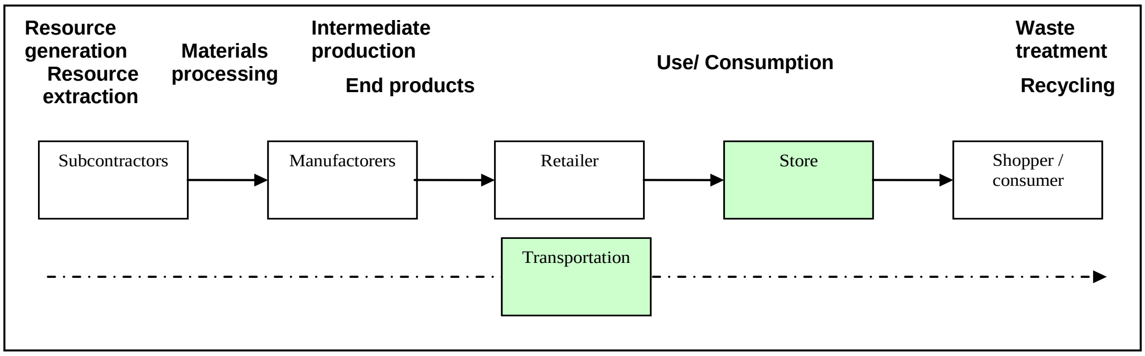
2.6 The wholesale and retail trade industry

Services act as an interface between primary and secondary industry and household consumers (WRAP, 2009). Wholesale and retail trade is mainly concerned with procuring products from a manufacturer, storing the goods in a warehouse and selling them to business and final consumers. The wholesale trade sector is composed by firms selling to retailers or industrial, commercial, institutional and professional users.[20]

2.6.1 Sector value chain and environmental sustainability

Retailing and trading activities should not only be considered as a service for consumers, since they are an integral part of the value chain of many sectors which brings end-products to the market. Giesecke, Merino et al (2009) note that various distinctions can be made; for example between non-specialised and specialised retailers; between food and non-food retailers, between in-store and other retailers (e.g., markets, door-to-door, remote); and between new and second hand goods.

Figure 2-7 Eco-innovation opportunities in the value chain - wholesale and retail trade sector



Source: based on Giesecke, Merino et al (2009)

It is commonly assumed that most services have little or no environmental impact. Since the wholesale and retail trade industry provides a service to a large number of manufacturing industries, four stages can be distinguished along the value chain where environmental impacts may arise: (1) the

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[20] For an overview of the innovation performance and foresight trends of this sector, please refer to the SIW sectoral and foresight reports for the wholesale and retail trade sector

environmental impact caused by the production of the products, (2) the environmental impact from the transportation of the product, (3) the environmental impact of the operations of the wholesaler/retailer (e.g. from heating and electricity use in buildings and generation of waste), and (4) the environmental impact of the product during its life time and after disposal.

Environmental sustainability issues in the wholesale and retail sector are mainly attributed to store and warehouse operations and the transportation of products (boxes highlighted in the figure above). Energy consumption (heating, cooling and electricity use), the use of refrigerants and water and the generation of waste are the main aspects in this sector which provide room for environmental improvements (EC, 2009g). The European Commission has estimated that energy consumption in the services sector is about 15% of EU25 energy use (EC, 2009g). Another important environmental issue is the generation of waste. Evidence from the UK suggests that wholesale and retailers generate 1.6 million tons of food waste (WRAP, 2009b).

In terms of contribution to climate change, evidence from the UK suggests that wholesale and retail trade are one of the two largest 15 emitting sectors. This sector contributed (during the period 1992 - 2004) with about 40 Mt CO_2e greenhouse gas along the global supply chain (WRAP, 2009). Suh (2006)) found that 85% of emissions associated with services are induced from the supply chain (service./product delivery). The EIPRO study estimates that transportation of goods contributes with about 3% to global warming potential (Tukker et al., 2006). It should be taken into account that not all of transportation is related to products sold through the wholesale and retail sector. Taking the example of France, it is estimated that 52% of greenhouse gas emissions of households is attributed to products, corresponding to 16.4 tonnes of CO_2 equivalents/year per household (EC, 2009g).

The use of resources in the wholesale & retail sector mainly occurs at store and warehouse operations and of products transportation which is linked to non-renewable energy consumption and the use of refrigerants. It is estimated that energy consumption in the services sector is about 15% of EU25 energy use. The direct sources for energy consumption within the wholesale- and retail industry are mostly attributed to store and warehouse operation. These include energy use for lighting, heating and cooling (EC, 2009g). Water is also an important resource used by this sector (EC, 2009g). Evidence from the US suggests that households consume 86% primary sector outputs and 44% secondary sector outputs indirectly, mainly through services. In addition, office-related materials are also a common set of goods used in this sector.

2.6.2 Identification of eco-innovation opportunities

Opportunities for eco-innovation are mainly non-technological in character. These mainly exist in making environmental friendly products available and promoting them. Wholesale and retail organisations can stimulate their suppliers to make their products more eco-friendly. In addition, an eco-innovation opportunity exists for large retail organisations to make the packaging of their own brands more eco-friendly. Eco-innovation opportunities also exist in improving the business processes of wholesale and retail organisations. Additional options are found in waste management and logistics optimisation. In addition, wholesale and retail organisations can improve the energy efficiency of stores and warehouses to reduce their environmental impact.

The table below contains a list of 11 eco-innovation areas aiming to reduce the environmental impact of wholesale and retail trade. These areas mainly refer to energy efficiency of wholesale & retail buildings, the availability, and promotion, information and labelling of 'green products', new stores built under environmental principles of design, waste management, packaging optimisation, logistics optimisation and online shopping. In the table below the example column includes the name of a retailer which has implemented any of the identified eco-innovations either by itself or in cooperation with technology/service providers.

Table 2-8 Eco-innovation opportunities in wholesale and retail trade

Eco-innovation	Brief description	Example
Energy efficiency of retail stores	In the field of store energy management (SEM), the largest energy savings can be obtained within energy consumption which is directly related to buildings, lightning and appliances. Energy efficient lamps (e.g. solid state lightning) and smart lightning systems can be used. Energy saving in appliances measures are related to 1) switching off appliances for heating, ventilation, air conditioning and refrigeration, 2) improving their maintenance and performance and 3) refurbishing energy using appliances.	• Alliance Boots (UK) store energy management • Energy efficiency and renewable (solar) energy use at Carrefour (France and Spain) • Tesco's energy champions programme
Green marketing	This category refers to marketing initiatives that integrates environmental aspects which respond to the ethical and environmental concerns of modern consumers. Green marketing is gaining importance due to increasing consumer and societal awareness about environmental and social issues, and constitutes a more specialised strategy than traditional marketing.	• Änglamark green marketing from Swedish Coop • Green marketing of cloth from organic raw material from Danish Earth A'Wear
Codes of conduct and green supply chain management	This category refers to the integration of environmental concerns into the supply chain management, including reverse logistics. This is typically related to organisational innovations aiming to set up goals, guidelines, corporate codes of conducts, and overall programmes to green their procurement practices and to green their supply chain. Green supply chain management often serves as a benchmark/best practice standard for less advanced firms.	• IKEA's Way on Purchasing Home Furnishing Products" (IWAY) • H&M's Chemical Restrictions code • WBCSD/WRI Greenhouse Gas Corporate Accounting and Reporting Standard
Eco-labelling	The criteria set up by the labels are found to go in many different directions. Some of these schemes monitor the level of environmental "friendliness" of their products, in terms of presence of pesticide residues, others the additives and preservatives, whereas other schemes stress other characteristics (e.g., organic or precision farming). With advances in the ICT field, the relation of labelling schemes with traceability of supply chains is an eco-innovation area to follow (particularly in food).	• European eco-label • Ecocert in France • BioSiegel (Bio Seal) in Germany • Stats Kontrolleret Økologisk in Denmark • Carbon's trust (UK) carbon label with carbon footprint information of products
Green procurement	Incorporation of environmental criteria in purchasing decisions	• Waitrose green procurement practice of only buying food from local British farmers' with the Linking Environment and Farming (LEAF) standard
Eco-store concept	Eco-stores not only aim to incorporate eco-design principles for construction and more efficient resource use (e.g., energy and water), but also organisation aspects related to promote greener choices and behavioural change (e.g. low carbon management).	• C&A eco-store in Germany, in cooperation with Redevco Europe (a leading real estate firm), with energy savings of around 50% • Tesco (UK) zero carbon store in Ramsey
Waste management	In spite of waste management being a well-established field in many different sectors, it constitutes a relatively new approach for the European W&R sector. Opportunities in the field of waste management are mainly concerned with organisational innovation to implement waste management programmes.	• Carrefour's waste management programme in France, Spain, Italy and Belgium
Combined heat and power systems	A CHP or cogeneration system consists of the facility simultaneously to produce and use heat and power. An example are bio-methanisation units, which recycles organic waste sorted by local stores (from grocery, bakery, fruit and vegetable sections) and produces compost and electricity from biogas. A more conventional option is combined cooling and heating power (CCHP)	• Bio-methanisation unit's installed in Carrefour's stores in France, Spain and Belgium • Sainsbury's (UK) use of combined cooling and heat

Eco-innovation	Brief description	Example
	schemes, which consist of a combination of absorption refrigeration and engines or turbines with their respective electric generators.	power systems at stores
Packaging optimisation	Packaging optimisation is not exclusive of food producers, but it is also feasible for own brands; it requires strategic investment and changes in product design among some other factors. Options varies from change and redesign of different sorts of packages, e.g., paper and board, plastic films, recycled plastics, reusable transit packaging, steel containers, retail ready packaging, etc.	• A number of WRAP (UK) projects of packaging optimisation with food retailers • Tesco's greener packaging efforts
Logistics optimisation	Transportation of goods in the wholesale and retail industry typically takes place to transport the goods from the supplier to the warehouse and from the warehouse to the store, or directly to the customer. Innovations to reduce the environmental impact of transportation can be found in improved logistics.	• C&A smart logistics programme • Teco's eco-friendly transportation plan
Online shopping	Innovations that potentially improve the environmental impact of wholesale and retail is related to the shift to virtual shops. This reduces the kilometres spend for customers to come to the shop. E-commerce is generally considered as beneficial for the environment by consumers as it is linked with dematerialisation.	• Tesco's online shopping and delivery system, with battery-powered delivery vans

Source: elaborated from (Carbon Trust, 2006), (WRAP., 2009c, 2009a), Mont (2009), and other relevant sources

Although the environmental impact of the manufacturing and products are not their primary concern, wholesalers and retailers do have a direct influence on products they offer to their customers. Furthermore, wholesalers and retailers play an important role in the information provided to the customer. Innovations to improve the environmental impact of the production process of a particular product or to reduce its environmental impact during its life time could be attributed to the manufacturing industry, and is therefore out of scope. Similarly, wholesalers and retailers make intensive use of the transport industry. Innovations to improve logistics within the operation of the wholesale and retail industry are considered. Conversely, innovations which improve the energy efficiency of transport (e.g., a more fuel efficient motor) could be attributed to the automobile industry and this out of scope for this research as well.

In terms of recent studies, the EC (2009g) commissioned a study on the current environmental performance of retailers. The assessment of eco-practices of retailers was done along four lines: promoting the purchase of green products; encouraging measures that improve green supply chains; improving retailers' own environmental performance; and better informing consumers. This project found that retailers have implemented over 27 actions related to the areas above. Some examples include: renewable energy production and use, refrigerant management, waste management, communication to promote green products, buildings refurbishment, green procurement, local sourcing of vegetables and fruits, etc.

2.7 The knowledge intensive business services sector

Knowledge intensive business services (KIBS) is a sector which relies heavily upon professional knowledge.[21] Thus, their employment structures are heavily weighted towards scientists, engineers, and experts of all types. Many of them are practitioners of technology and technical change and, irrespectively from their technological or professional specialty; they also tend to be rely on information

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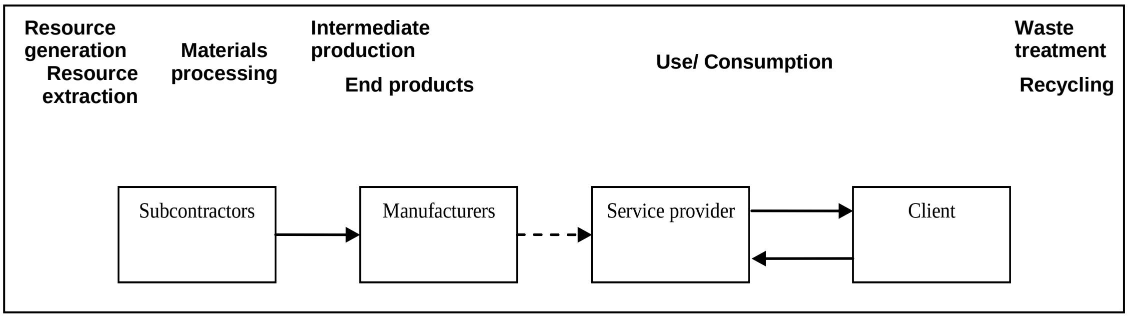
[21] For an overview of the innovation performance and foresight trends of this sector, please refer to the SIW sectoral and foresight reports for the knowledge intensive business sector

technologies or specialised equipment to support their activities. In addition, KIBS will either supply products which are by themselves primarily sources of information and knowledge to their users (e.g., measurements, reports, training, consultancy), or will use their knowledge to produce services which are intermediate inputs to their clients' own knowledge generating and information processing activities (e.g., communication and computer services) (Miles et al., 1995a). A considerable amount of KIBS provide advice to organisations or help organisations in their daily operations (Djellal and Gallouj, 2009).

2.7.1 Sector value chain and environmental sustainability

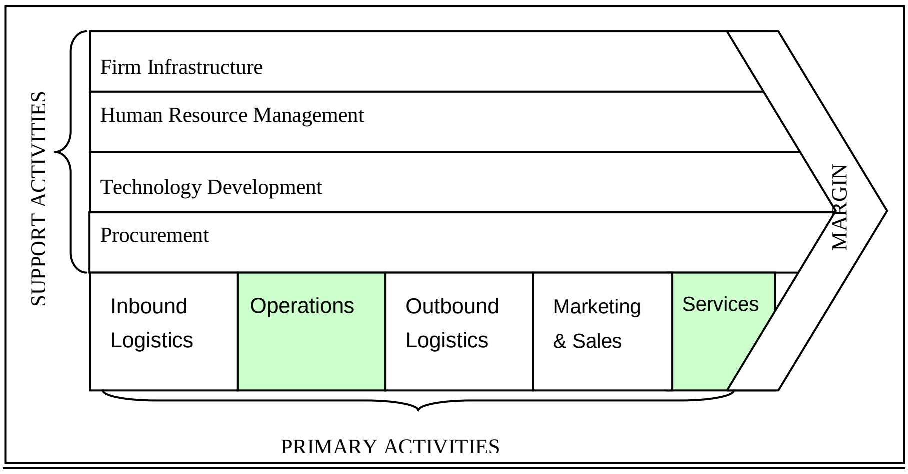
Before analysing the environmental sustainability of this sector along its value chain two things should be noted. First, there is an intrinsic relation between the service provider and manufacturers. Products are enablers in the delivery of a service, but mainly in the form of tools (e.g. a computer used to write a report or a data centre to provide internet services). Second, KIBS are rarely provided in a traditional producer-consumer relation. A service is delivered in interaction or even cooperation with the client (see figure below).

Figure 2-8 Value chain diagram for the KIBS sector



In practice, it is difficult to establish a common value chain for all individual firms within this sector. For the purpose of this report, we presume the value chain of a typical knowledge intensive service provider follows the common value chain as provided by Porter (1985). According to this model, activities are divided into primary and support activities. Primary activities include inbound logistics, operations (e.g. manufacturing), outbound logistics, marketing and sales and after-sales service. Support activities include firm infrastructure (e.g. finance, planning), human resource management, technology development, and procurement.

Figure 2-9 Porter's value chain for knowledge intensive business services



Source: (Porter 1985)

It is difficult to attribute GHG emissions to KIBS to its value chain or its operation since generally no distinction is made between services and knowledge intensive business services (Gadrey, 2009b). For the case of ICT-based KIBS an indicative figure could be provided since the ICT industry is responsible for 2-4% of global CO_2 emissions (OECD, 2009b). Another figure suggests that travelling by car, public transport and air typically amounts to 7-30% of the carbon footprint of service companies (Huang, 2009).

Accounting the amount of resources used by the KIBS sector is again a difficult task. The use of resources as a part of the service provided is not entirely explicit and it has been poorly studied. Services are delivered on-site which requires the presence of the deliverer. Other services are conducted from a central place, which requires a building which clearly consumes resources (e.g., electricity, heating, etc.). Although services do not provide tangible products, they are often sold in combination of a product or contain a tangible element (e.g., product service systems). Services make use of tangible tools to deliver the service but the sources of resource usage are difficult to estimate. Another relevant aspect of the resource impact of services may be related to the tools used for the delivery of a service. Mostly these are tools for communication like telephones, computers or event commercial cars. For repair-services other specialised equipment and transport cars are needed (Gadrey, 2009b). An indicative example of consumption of resources in KIBS is the access to internet. Electricity consumption of data centres which are used to store the information contained by the internet accounts for almost 0.2% of the world electricity production. At the same time the server utilisation in data centres rarely exceeds 6% and facility utilisation can be as low as 50% (McKinsey, 2008).

The environmental impact from traditional services is mainly attributed to travelling, buildings and tools. Although KIBS have limited CO_2 emissions as compared to other industries, countries with a strong orientation towards services are considered in the top global polluters. It has been argued that the dematerialisation of the economy does not necessarily leads to a reduction of the environmental impact of a country. Yet, this environmental pressure is only indirectly related to the service industry. Therefore, opportunities for the reduction of environmental impact partially lies within the scope of the way services are offered (Gadrey, 2009b).

2.7.2 Identification of eco-innovation opportunities

When speaking of KIBS that may fall within the eco-innovation realm, it is difficult to distinguish KIBS that deal with energy and environment as a specific target from those professional services traditionally provided by the eco-industry (e.g., environmental services for industrial cleaning, soil remediation, environmental audits, process safety management, etc.). Available studies do not necessarily help to clarify the limits or boundaries of one another. Zaring, Bartolomeo, et al (2001) considered that eco-efficient producer services can be divided into product-based services (e.g. chemical management services, combined club cars and park and ride services, etc), electronic substitution services (e.g. videoconferencing, e-learning, etc) and information-based services (e.g. advice and consultancy, traffic information services, etc). The OECD (2006) reports a distinction between different types of services in KIBS related to innovation, namely: renewal services (e.g., innovation management, training, etc.), routine services (e.g., administrative services, ISO accreditation, etc.), compliance services (e.g., compliance with tax or environmental regulations), and network services (e.g., knowledge exchange in formal networks, etc.).

In our view, and due to the general eco-innovation definition adopted by this report, all of the categories described above may provide guidance in order to classify the lists of eco-innovation opportunities in this sector. In our review we use a combination of the categories above: product-based services (analogous to product-service systems), electronic substitution services, information based services, renewal services, and network services. Given the rather intrinsic nature of both KIBS and eco-industry services and the wide (and better established) provision of services of the latter, we provide no account of traditional services related to compliance. The list of eco-innovations also excludes ecosystem services and eco-tourism services. Given the sectoral nature of the Sectoral Innovation Watch, this report does not include the examples related to the (sustainable) mobility domain (e.g. park and ride schemes or car clubs). The following table contains five eco-innovation generic areas with around 38 eco-innovation options. Eco-innovation opportunities for KIBS exist in both their own operations and in the services they offer.

Table 2-9 Eco-innovation opportunities in knowledge intensive business services sector

Eco-innovation	Brief description	Example
ICT for improved KIBS operation	This category includes organisational innovations in the operations of KIBS firms. These may be found in the reduction of transportation and travelling of employees through improved logistics. Additional measures include teleconferencing, ride sharing, fleet tracking, and traffic monitoring software and transportation efficiencies, etc.	• Teleconferencing system 'TelePresence' from Cisco
Energy efficiency in KIBS firms	This category includes options related to increasing the energy efficiency of appliances. Examples include energy efficient computers and data centres.	• Energy efficient data centres solutions and best practices from Cisco
Product based services	Chemicals management	• Chemical management services from UK-based Glower Chemicals
	End of life management services	• Disposal or confinement of waste

Eco-innovation	**Brief description**	**Example**
	Energy management services	• Energy Services from Global KBC's
	Eco-integrated building planning and management	• Eco-integrated building advice4 from UK-based BREE
	E-waste management services, logistics and recycling	• European Advanced Recycling Network for WEEE compliance
Information-based services	Corporate social responsibility (CSR)	• CSR consulting from Irish Jim O'Brien CSR Consulting
	Eco-efficiency in manufacturing processes	• Eco-efficiency best practices
	Eco-efficiency of existing products	• Industrialised LCA consultancy from French Greenext • Eco-efficiency
	Sustainable product design services	• Cradle to cradle consulting from MBDC • Sustainable product design from German E-concept
	Resource efficiency consultancy	• Resource Efficiency & Action Programme
	Sustainable innovation R&D	• Eco-lab, Fraunhofer, Universities, TNO, etc
	Carbon footprint assessment	• Carbon footprint services for manufacturers and retailers from French Greenext
	Cleaner production assessments (CPa)	• CPa consultancy services from Finish Oy Enemi Ltd
	Corporate sustainability consultancy	• Consultancy service from global think-thank SustainAbility
	Public sector innovation and environmental policies advise	• Consultancy services from 'French Bio-Intelligence Services
	Eco-labelling	• European and Nordic eco-label certification services from Finish Korpi Consulting
	Eco-efficiency tools	• BASF eco-efficiency services
	Eco-textile design	• Eco-textile research from the University of the Arts London's Textile Futures Research Centre
	Energy efficient store management methods	• Consultancy services from UK-based In-built
	Energy management of industrial processes and certification	• Consultancy services from UK-based Green Energy Partners
	Environmental management and certification	• Consultancy services from German Fichtner
	Environmental communication consultancy	• GPM Network services (UK)
	Green marketing	• Grean Leaf Ltd consultancy services in the UK
	Green product procurement	• Consultancy services from Danish Cowi Group
	Green supply chain management	• Consultancy services from UK PA Group
	Industrial ecology	• Industrial ecology research at Swedish KTH
	Innovation and environmental management/strategies	• Consultancy services from UK based Giraffe Innovation
	Eco-efficient and sustainable construction –housing	• Building energy rating (BER) from Irish Eco-efficiency Ireland Ltd
	Eco-efficient and sustainable construction – infrastructures	• Pre-Construction Specification Report (PCSR) from Irish Eco-efficiency Ireland Ltd
	Performance-based building methods	• Consultancy services from UK Base Building Consultancy
	Risk and process safety management	• EIA - Risk Assessment – SEVESO services from Greek Eco-efficiency Consulting and Engineering Ltd
	Sustainable water management in agro-food	• Research and advice from Portuguese MegaPesca
	Sustainable water management in manufacturing processes	• Research and advice services from Chartered Institution of Water and Environmental Management
	Waste management programmes in retail stores	• Waste management advise for retails stores from UK Waste & Resources

Eco-innovation	Brief description	Example
		Action Programm (Wrap)
	Water restoration	• Lake and water courses restoration services from Swedish Vattenresurs
	Zero emission systems or closed loop manufacturing	• Zero emissions research services from Austrian Graz University of Technology
Electronic substitution services	Eco-intelligent network/supply chain management	• Global Traceability Network (GTNet) from Norwegian TraceTracker AS.
Networking services	Innovation or environmental brokers	• Greenovate! European matching services
Renewal services	Business Environmental Training Initiative Plus (BETI+) for ISO 14001	• Chartered Institution of Wastes Management (CIWM) Waste Awareness Certificate

Source: compiled by the authors from (McKinsey, 2008), (Business Cost Consultants, 2009) and a number of specialised sources

KIBS services are perceived as a solution to the environmental problems in other sectors. Consulting services can implement ICT applications which reduce energy consumption in other industries and products through energy saving applications such as smart homes, smart buildings, or smart transportation systems (OECD, 2009b). Little is said about the environmental impact of KIBS so identifying eco-innovation opportunities that may alleviate its carbon footprint is difficult. Eco-innovation opportunities which are related to the environmental impacts of KIBS organisations themselves may entail implementation of new communication technologies, improvements in logistics and technological improvements to decrease the environmental impact of tools. In the case of organisational and process innovation, eco-innovation opportunities which are directly related to the environmental and energy efficiency impacts of KIBS entail: e.g., implementation of new communication technologies, improvements in logistics and technological improvements to decrease the environmental impact of tools. Service innovation opportunities for eco-innovation for KIBS organisations mainly lie in the development of environmental services which help other companies to reduce their environmental impact. These information-based services include, among many others, providing energy management advice, environmental friendly product and process design consultancy and policy design services. The list of consultancy topics provided below is by no means exhaustive but provides an indication of topics being demanded (and supplied).

A number of studies have signposted a number of opportunity areas that are expected to drive eco-innovation in this sector. Zaring, Bartolomeo, et al (2001) provides a number of examples of eco-efficient services in the categories earlier described. The OECD (2006) also reported a number of examples but only a few related to the environmental domain, mainly training and compliance services (e.g., compliance with tax or environmental regulations). Tukker, Diaz Lopez, Mont, et al, (2009a) provide a very comprehensive European-wide policy effectiveness evaluation and inventory of business initiatives in sustainable consumption and production. This inventory contains a number of cases describing knowledge intensive business services in the environmental domain. Finally, the COWI Report presents a number of cases from the mobility domain and product service systems (COWI Group, 2008).

2.8 The food and drinks sector

In the food and drinks (F&D) sector agricultural products are transformed into nourishment and drinks consumed on a daily basis. Food and drinks is one of the most important sectors for the European economy. The landscape of firms in this sector in Europe is primarily composed by micro and small firms. Large multinational European food and drink companies can be easily identified since they compete in global markets with a large array of products[22]. Conversely, SMEs focus on local markets and generally concentrate on regional differences (Banse et al., 2008). Large firms often possess their own innovation/R&D centres which normally lead new developments in this industry (Enzing, 2009). Both small and large firms alike perceive the pressures to become a more environmentally sustainable industry, especially due to their large contribution of the various environmental impacts of private consumption in Europe, with meat and dairy products contributing the most (Tukker et al., 2006). [23]

2.8.1 Sector value chain and environmental sustainability

F&D is considered a rather diverse sector, and is dependent on other areas throughout the food and drinks value chain (see figure 2.10). F&D manufacturing involves not only the sourcing of ingredients, processing, preservation and packaging, but also product research and design, taste-testing and marketing. The sector is considered a key link in the food chain, which comprises agriculture and fishing, food and drink manufacturing, distribution and warehousing, wholesaling, retailing, food services and catering (Banse et al., 2008), The amount of different operations and final products require different levels of intermediary processing (e.g., minimal processing of fruits vs. substantial secondary processing of dry cereals). In essence, most of the physical operations of this industry are rather similar for most of the production processes involved. This is particularly true for separation, cleaning, cutting, crushing, blending, grounding, and packaging methods. Chemical and biological operations do differ – which often share basic principles with those in the chemical and biotechnology industry. These operations are related to fermentation, homogenisation, hydrogenation, curing, drying, pigmentation, and conservation. In addition, and in spite of its controversial perception in Europe, irradiation processes for food preservation have been used for quite a while (especially in the US). Finally, we have the processes of meat packing, bottling, packaging, storage and food equipment cleaning and sanitising (Bralla, 2006).

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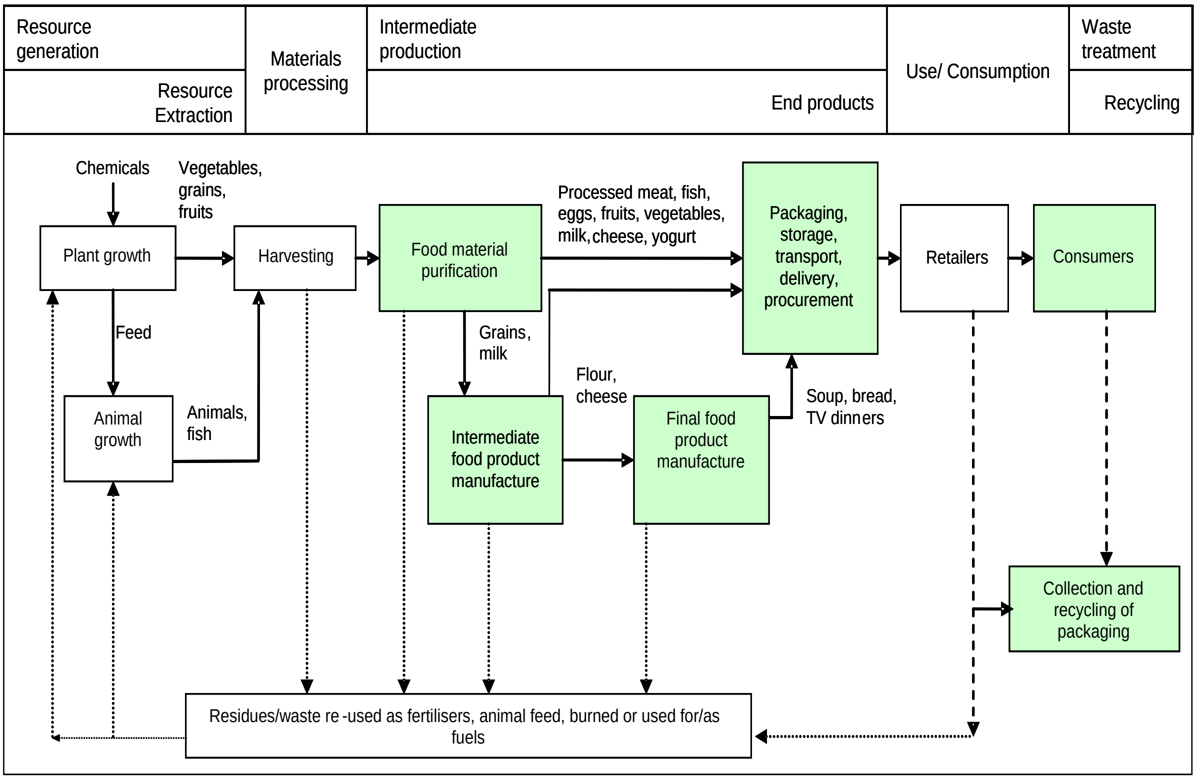
[22] The Forbes Global 2000 list includes in their top 500 positions the European names of Nestle (top 32), Unilever (top 79), Anheuser-Busch InBev (top 136), Danone (top 189), Diageo (top 210), SAB Miller (217) and Pernod Ricard (372).

[23] For an overview of the innovation performance and foresight trends of this sector, please refer to the SIW sectoral and foresight reports for the food and drinks sector.

Figure 2-10 Eco-innovation opportunities in the value chain - food and drinks sector



Source: modified from Graedel and Howard-Greenville (2005)

Sustainability issues in the F&D sector can be related to several different fields, ranging from efficiency of the food production and consumption to health issues, from the local and seasonal food production to organic food, from the exhaustion of food sources such as fish population to energy consumption of different diets, etc. (Diaz Lopez et al., 2008). Environmental problems in the F&D sector are often perceived through agricultural production, processing and transportation of food. The effects of health and safety issues are rather indirect in eco-innovation, as these are mainly associated to avoiding potential risks to consumers and hence, avoiding waste (e.g. through food monitoring). Recently, attention is given to the environmental impact of food miles and consumers' drinking and eating habits. These two aspects are not considered in our review of environmental sustainability concerns. The cited environmental issues or pressures from the use of materials presented below are not described in any particular order of relevance

In terms of contribution to climate change, it is estimated that food and drink products are responsible for 20 to 30% of the various environmental impacts of private consumption in the EU25. The latter includes the full food production and distribution chain 'from farm to fork'. Meat and meat products are the most important contributors to global warming, followed by dairy products (Tukker et al., 2006). The IMPRO-meat and dairy study estimated that the four main product groups (dairy, beef, pork and poultry products) contribute respectively 33-41 %, 16-39 %, 19-44 %, and 5-10 % to the impact of meat and dairy products consumption in EU-27 on the different environmental impact categories (Weidema et al., 2008).

The main environmental issues of the food industry are related to waste water, high concentrations of biochemical oxygen demand, suspended solids and fertiliser chemicals, and greenhouse gases emissions derived from energy use (e.g., cooling and heating). Environmental concerns in the drinks sector are related to water use and greenhouse gas emissions. It has been suggested that the wastewater volume of "soft drink processes" is lower than in other food-processing sectors, but fermentation processes are higher in biochemical oxygen demand (BOD) and overall wastewater volume compared to other food-processing sectors (EPA, 1998a). Overall, the F&D sector is considered one of the largest producers of wastewater (Graedel and Howard-Greenville, 2005).

In addition to raw materials coming from plant or animal harvesting (agriculture sector) other relevant resources are used in this industry. Food and drinks production requires different energy forms, such as electricity, process steam and thermal energy – which in most cases are produced from fossil fuels (Bernstein et al., 2007). This sector has traditionally been a large consumer of water, both of drinking quality and raw water. In both the food and drinks industries water of drinking quality is used as an agent of the manufacturing process and to transport raw materials in a processing unit. Raw water is used as wash-down water used to clean ingredients and equipment, and for heating and cooling purposes. In the wine industry, for example, 30 to 150 litres of water are used to ‘vinify’ (ferment) 100 litres of must (unfermented grape juice). Finally, chemical agents are used at different stages of processing and alter the biochemical properties of waste streams (Graedel and Howard-Greenville, 2005). Waste generation (organic waste, packaging waste) is a concern shared by both industries. Most steps in food and drink processing generate residuals, which typically go to waste and/or reuse for different purposes e.g., manures are used as fertilisers whereas general waste can be geared towards furnaces and ovens as fuel for energy generation (Graedel and Howard-Greenville, 2005). A growing area which originates solid waste is related to packaging materials, which in Europe is required to be recovered by law.

2.8.2 Identification of eco-innovation opportunities

From the review above it is clear that most of the prominent environmental pressures in the food and drinks sector come from their use of resources and waste generation. In addition, an increasing area of concern is related to human eating and drinking habits in terms to greening consumer choices. A clear related area is the provision, choice and selection of greener products. Recent studies highlight that current and emerging eco-innovation trends in the F&D sector focus on: the use of more sustainable resources (organic and/or regional food), sustainable food processing, eco-supply/network management, more sustainable outputs (e.g., biomass energy), packaging and waste recycling (e.g., smart/eco packaging), monitoring of the food (e.g., intelligent labels) and industrial processes (e.g., automation and monitoring), eco-labelling (e.g., referred to organic products), solutions to bio-energy-food competition, etc. (e.g. see Wessberg et al., 2008, Leis et al., 2009, Aslesen, 2008). The following table includes a description and examples of 7 eco-innovation opportunities

Table 2-10 Eco-innovation opportunities in food and drinks

Eco-innovation	Brief description	EXAMPLE
Sustainable water management	Sustainable water management primarily focuses on closing water cycles, water quality management and control, removal of substances from water such as regain of materials from sludge, alternative processes, and control of bio-fouling, scaling and corrosion.	• Sustainable water management consultancy from global firm Arup
Zero emission systems for food production	A zero emission project implies looking at three basic steps. First, it analyses the material and energy flows through the production system. This is followed by a study of the various possibilities to prevent the generation of wastes (e.g., in terms of energy demand, water and waste water, etc.). The third step concentrates on identifying, analysing and designing potential offsite recovery and reuse options. It also entails the identification of remaining wastes, cost-benefits analyses, and the design of a reasonable method toward zero emissions	• Methods for rainwater harvesting • Zero emission projects for the food industry from the Graz University of Technology
Automated systems for monitoring and control	Automation is not uncommon to the food processing industry, especially in the drinks, dairy and specialty products sub-sectors. For example, chemical sensors operating at high temperatures are in use since 1975. Sensors can be used to control process temperature, humidity, pH, flow rates, and contamination levels. There has been a trend toward producing control and automation products that can be used in a wide variety of applications throughout a food or beverage plant, rather than mixing and matching systems and vendors from one part of the plant to another. These products include input/output, controllers, common graphical interfaces (HMIs) and graphic control panels, machine vision systems and industrial networking products	• Siemens and ABB automation for the food industry • TM smart track (water free) automated transport conveyors from Austrian Thonhauser • Persulfate technology (PST) from Austrian Thonhauser
Smart-packaging	Packaging is an important application in the field of materials technology. Traditionally, plastics are used to protect products or provide static information. An alternative focuses on a trend in packaging where materials are not are only used to simply package goods, but also e.g., to react to environmental conditions or to provide information (intelligent materials). In addition, smart-packaging materials can be used in combination with light-weighting packages and containers to reduce the size and space in storage facilities.	• Akulon ® PA6 resins from Dutch DSM
Bio-packaging	Bio-polymers are nature-derived and man-made macromolecules which have been processed which goes beyond mechanical shaping. Non-food starch, cellulose polymer and alky resins are increasingly important bio-polymers. Packaging has been the dominant application area for starch blends; as they can be used in applications including bio-degradable films for compost bags, packaging films, shopping bags, strings straws, technical firms, wrap films, etc.. Given their technical properties, they are also useful in fog-free packaging of warm foodstuffs, catering services (e.g., food trays, forks, etc.), and even in the durable plastics market (e.g., as bio-propylene)	• BIOPLAST TPS®, from the German Biotec. • Ecovio® product line from global BASF
Alternative-easily recyclable and bio-degradable packaging	Paper and carton board products are a feasible alternative eco-packaging or alternative material to bio-plastics and plastics. In particular, dispersion-coated packages are seen as an attractive alternative (and even as a substitute) to plastics packaging and fluoro-chemicals on greaseproof packages (e.g., in the fast food industry). Perhaps, the best-selling point of this type of packaging is their recyclability rate. In addition, since it replaces plastic extrusion coatings with paper board, indirect environmental and economic benefits can potentially be obtained by avoiding water and non-renewable raw materials consumption	• Tecta® compostable dispersion-coated packaging from Finish Stromsdal
Food sensing and monitoring	By tracking and tracing, measuring the presence or exceeding of amounts of certain ingredients, toxics or processes, the quality of food can be measured and the origin of the food and critical process step can be traced back. In an indirect way (since it is mainly targeted for avoiding health risks), the monitoring of food is an interesting option linked to avoiding waste generation.	• Food ozone sensors from American EcoSensors Inc
Waste recycling and waste management	Recycling technologies are available for dealing with food waste-to-energy. Currently and in the short term, co-generation to produce electricity (for own use or to share/sell to other facilities) is seen as a feasible technological eco-innovation. Mechanical biological treatment (MBT) is a method of particular relevance for waste management leading to separation of materials high calorific value from waste partly for composting and partly for landfill	• Mechanical biological treatment (MBT) from ORA Ltd or from WRG Ltd

Source: compiled by the authors based on (Ngoc and Schnitzer, 2008, p. 320). (Pitkola, 2006). (Shen et al., 2009), (Farhang, 2009)., (Wessberg, Diaz Lopez et al. 2008) (Bundesministerium für Umwelt Naturschutz und Reaktorsicherheit, 2009). and other relevant sources

It is clear that most of the prominent environmental pressures in the food and drinks sector come from their use of resources and waste generation. As a consequence, eco-innovation opportunities in this sector have a strong focus on sustainable manufacturing (e.g. zero emission systems, process automation, etc.). For the food sector the use of more sustainable resources (organic and/or regional food), eco-packaging and waste recycling, and monitoring of the food (e.g. intelligent labels), are also particularly relevant for the food sector. The drinks sector is primarily focused on eco-innovations related to water and waste management and energy efficiency. Inherently, these options are more related to pollution prevention and good housekeeping of the production process. Waste management (e.g. organic waste), water reuse (e.g. in the wine industry), energy conservation, substitutes for restricted ozone depleting refrigerants in chillers, reducing bottling losses, inventory control, process efficiency, and zero emission systems are accounted here. Since an increasing area of concern is related to human eating and drinking habits in terms to greening consumer choices, a clear eco-innovation area for both sub-sectors is related to the provision, choice and selection of greener products. Eco-labelling (e.g. of organic products), green marketing, etc. are areas which imply cooperation with actors along the value chain, in particular with wholesale and retail traders. Another cross sector area is found in eco-supply/network management, introduced in the KIBS sector. Food retailing, bio-catalysis, ICT applications in food production, ICT applications for green supply chain management, and eco-efficiency analyses of food products are also of interest to the wholesale and retail, biotechnology, E&O and KIBS sectors and a number of additional examples may exist.

The availability of recent studies signposting a number of opportunity areas that are expected to drive eco-innovation in this sector is limited. The IMPRO-meat and dairy project identified a number of improvement options for this sector which could be considered as eco-innovation opportunities (Weidema et al., 2008). Improvement options have been identified in three main areas, namely household improvements, agricultural improvements and energy savings in farming, food industry, and retail, catering and household. Strictly speaking, options for energy savings in the food industry could be the only ones of relevance to our sectoral review of eco-innovation opportunities. In this category the IMPRO-meat and dairy study highlights two improvement options, both related to energy efficiency. The first related to new cooling appliances (A+ or A++) used to reduce electricity consumption). The second related to power saving measures in farming, food industry, retail, and catering. The rest of the improvement options are directly relevant to precedent and subsequent stages in the food value chain, such as optimised protein feeding in pig and dairy farming and home delivery of groceries. The reference document (BREF) for the food, drink and milk industries (EIPPCB, 2006) constitutes a valuable framework for environmentally sound manufacturing of this sector. Many of the BATs (Best Available Techniques) suggested in the BREF (08.2006) document are operational in nature, mostly housekeeping-oriented and easy to implement (e.g., related to environmental management, equipment and installation cleaning, waste water treatment, minimisation of air emissions, etc.). A shortcoming of the list is that they are often related to end-of pipe techniques/procedures. A final issue of the list provided by the BREF document is that the amount of emerging techniques is rather limited (e.g., it only contains the use of UV/ozone in absorption for odour abatement) and a number of eco-innovation opportunities may be neglected by omission. Interestingly, there is a number of organisational eco-innovations (and methods) that can integrate best practices with more advanced and novel production technologies. Perhaps further reviewing of the BREF document could include some of these eco-innovations, but this analysis is beyond the scope of our study.

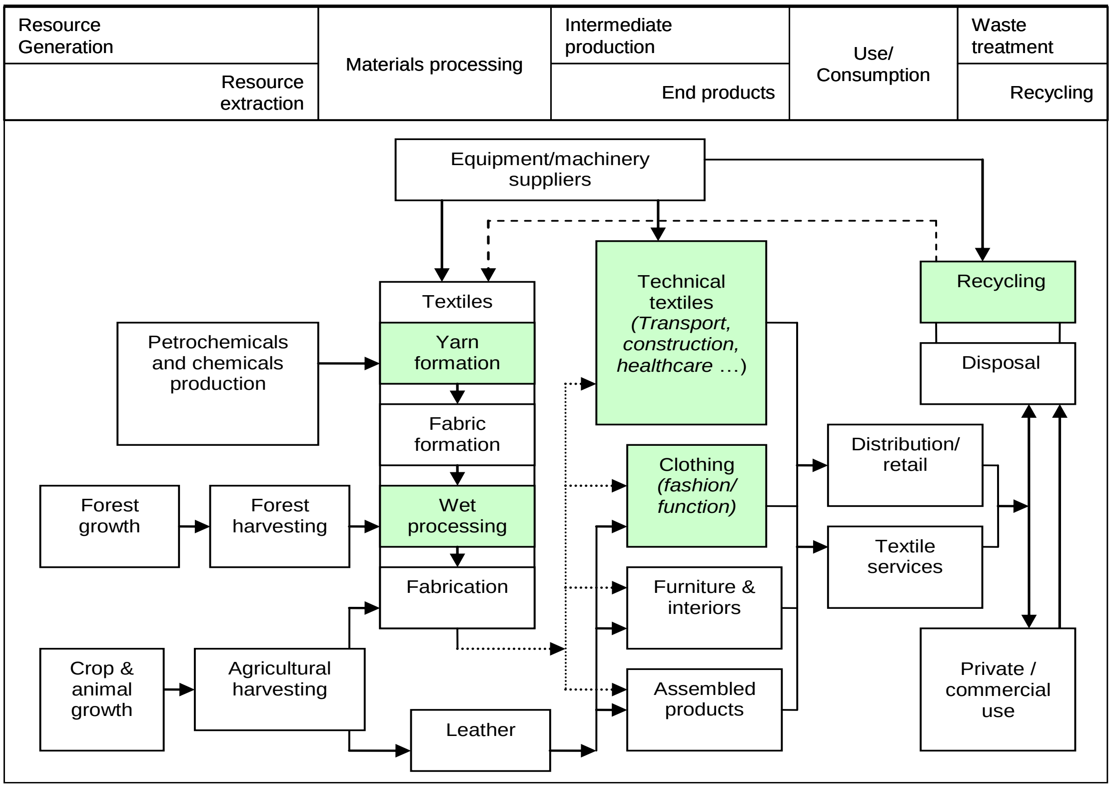
2.9 The textiles and clothing sector

The textiles and clothing (T&C) sector once constituted the leading engine of the first industrial revolution, but in recent years its economic performance has been declining (Euratex 2008). This sector produces fibres and fabrics which are fashioned/functioned into a wide range of products used in our daily life (e.g., textiles for technical use, interior textiles, clothing and upholstery). The SIW-II work has highlighted that the competitiveness of enterprises in textiles and clothing is, to a considerable degree, based on non-technological aspects of innovation (especially for clothing). [24] Mega trends associated to environmental pressures, consumer preferences and climate change effects have also posed new challenges for improving the environmental and social performance of the T&C sector and the greening of their products and operations along the supply chain

2.9.1 Sector value chain and environmental sustainability

The textiles and clothing chain covers the entire production cycle from the production of raw materials (man-made fibres), semi-processed materials (yarns, woven and knitted fabrics with their finishing process) and final/consumer products (carpets, home textiles, clothing and industrial use textiles) (EIPPCB, 2003). A broad view to textiles and clothing manufacturing is presented in the figure below.

Figure 2-11 Eco-innovation opportunities in the value chain - textiles and clothing sector



Source: Modified from Graedel and Howard-Greenville (2005) p.258, Bralla (2006), EURATEX (2004), and EMCC (2008) p. 2

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[24] For an overview of the innovation performance and foresight trends of the textiles and clothing sector please refer to the sectoral reports of the Europe INNOVA-SIW by Dachs and Zahradnik (2009) and Zahradnik and Dachs (2009).

The EIPRO study suggested that textile products account for about 5 to 6% of total GHG emissions along its life cycle. If we add transport, this figure would increase to about 13% (Tukker et al., 2006). In general, the contribution of this sector to climate change is often attributed to its requirements for burning fossil fuel related to electricity for heating water and air in laundering in the manufacturing stage (Allwood et al., 2006). The EIPRO study highlighted that the use (and washing) of clothes clearly dominates the list of environmental impacts of the products of this sector, followed by shoes and accessories. In particular, energy and water used for washing in the use are dominant causes for environmental impacts related to clothe use (Tukker et al., 2006).

Most of the environmental problems of the textiles industry originate at the stages of fibres and colorants production (spinning, fibber transport, wet treatments (for finishing) and weaving (Nieminen et al., 2007). Bleaching and washing also constitute an important environmental issue. Typical pollutants include mineral and knitting oils; fibre finishes, softeners, and hydrocarbons, urea, and dyes residues (EPA, 1996). The apparel manufacturing is not considered, by itself, a great threat to the environment. Nonetheless, it has been argued that waste generated by the export of apparel products does constitute a large environmental problem (Claudio, 2007). Waste generation has also been driven by the advent of the ‘fast fashion’, ‘mass market’ and ‘shortened selling seasons’ business models. Another issue of growing attention is the presence of toxic compounds (hazardous chemicals) in consumer products, such as textiles, carpets and curtains (Peters, 2003). Recently, a concern has been generated around the use of metallic materials as part of intelligent textiles and implications for washing and release of silver to the environment (Geranio et al., 2009).

Textile products are manufactured from synthetic and natural raw materials. The former group assembles different types of fibres derived from petrochemicals (e.g., inorganic polymers, polyester, polyamide, acrylic, polypropylene, elastane, etc.) and natural sources such as timber (e.g., viscose, acetate). In the latter group we account renewable and natural materials such as cotton, wool, silk, jute, and animal hides (EIPPCB, 2003). Apparel care is especially demanding in terms of energy use – especially in dry cleaning.

2.9.2 Identification of eco-innovation opportunities

The following section contains eight eco-innovation opportunities focusing on: sustainable textile manufacturing (e.g., automated monitoring and control, bio-enzymes, plasma technologies, etc.), recycling and waste technologies, the use of advanced/ new/ bio/ recycled fibres, etc. In the apparel sector, there is an important opportunity for the reuse and recycling of old clothes and conversion into recycled fibres and the use of eco-fibres for functional garments.[25]

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[25] Similar to the cases presented in the food and drinks sector, eco-innovation opportunities in the agriculture sector are considered beyond the scope of this review.

Table 2-11 Eco-innovation opportunities in the textiles and clothing sector

Eco-innovation	Brief description	Example
Enzymes for textiles manufacturing	Substituting chemicals with enzymatic solutions throughout the manufacturing process is one of the principles of bio-innovation in textiles. By applying principle of green chemistry, and green engineering , re-designing conventional processes and incorporating sustainable/bio-technological-based ones leads to reduced manufacturing costs, increased competitiveness, better profits and higher quality fibres and fabrics	• Cellusoft® Combi from Danish Novozymes
Improved textile methods for dyes and auxiliary chemicals	For vat and sulphur dyeing, an attractive alternative technique for the reduction and oxidation of the dyes is the application of electrochemical methods instead of the conventional chemical reducing and oxidation agents. Supercritical CO2 is another alternative to be used as a solvent to disperse dyestuffs and fat and therefore, can be used for dyeing of textile substrates, especially of PES and PP fibres. Eco-dyes and auxiliary chemicals aim to reduce the environmental burden of textile processing.	• Clariant's 4E concept and eco-dyes line
Eco-finishing of clothes	The substitution of regular dyes for GOTS (Global Organic Textile Standards) approved dyestuffs has been one of the very first selected approaches for vintage eco-finishing. Another alternative is the use of natural dyes, such as indigo heads. Apparel firms now use customised production methods (e.g., on demand products vs in-stock products), on-site waste minimisation (e.g., via modification/automation of cutting patterns), and use less chemicals for finishing and packaging material substitution. Colour denim have been developed to process coloured denim garments in a more environmentally friendly manner without the over-use of dye chemistry or auxiliary chemicals	• Vegetable dyes (the red dye, Rubia Red) from Dutch Rubia Pigmenta Naturalia • Colour Denim System from Spanish Eurotrend
Automated systems for monitoring and control	Improvements have been made in recent years in the automation of traditionally manual process steps in textile manufacturing, such as the preparation and dosing/dispensing of chemicals (e.g., aqueous solutions, powder or pastes) and even laboratory operations. Recent advances in technologies for interiorising and exploiting customer needs and preferences, advanced computer-aided design software, computer aided modelling and simulation, and virtual prototyping solutions, flexible customised production systems, intelligent logistics, internet-based communication systems along agents along the supply chain etc. enable textile and clothing manufacturers to develop mass customisation operations. An example is on-line monitoring which can clearly increase the process reliability, save energy and auxiliaries and/or reduce the amount of rework. Examples for this second eco-innovation can be found in the monitoring of chemical oxygen demand in a rinsing bath, concentration of oxidised or reduced agents on the textile or redox-potential during vat dyeing.	• Self-learning software systems for improving process control
Plasma technology for eco-wet processing	Plasma and laser technology are interesting alternatives for improving the way finishing of textiles is made, especially for denim clothes (e.g., for stone washed or whiskers effects). Plasma is a dry processing technique which offers the possibility to obtain typical textile finishes without changing the key textile properties. Plasma treatment has the potential to modify surface properties of a fibre and make it stain and shrink resistant, improve dying ability and spin ability, make it water and/or stain repellent and give it anti-bacterial properties. In simplify, the use of this technology could reduce the amount of dyes used for colouring fabrics, reduce water requirement, reduce pollution and conserve energy	• Easy Laser from Spanish Eurotrend • Plasma equipment developers e.g. Europlasma - Belgium, Grinp-Italy, Softal-Germany
Intelligent textiles	A considerable amount of specialist firms in niche markets for functional, performance and protective textiles and clothing have emerged in the past few years (e.g., outdoors, health, sports, etc.). Most of these products have been labelled under the name of intelligent or smart textiles, albeit there is no precise definition of these terms. Intelligent or smart materials are hence able to react upon stimuli from the surrounding.	• Climatex®, from Rohner Textile AG and DesignText
Eco-fibres	The need to "green" textile products have made companies to approach strategies for a simple conversion of existing styles into clothes that use environmentally friendly fabrics. Examples of these include: soy, hemp, recycled polyester, flax, bamboo, organic wool, polyactic acid-based fibres from corn (PLA), etc.. Technical challenges of some natural fibres (e.g., 100% PLA is very difficult to spin on typical equipment) are slowing down the use of "pure" materials and favouring the development of "blended" alternatives.	• Ekolab fibers from Norwegian Helly Hansen (HH)
Reused and recycled textiles	Re-used and recycled textiles are perhaps one of the oldest and best established options. Collection and re-selling of clothing, handbags, shoes, bedding, and curtains is nowadays a very profitable business. for about a decade now, collection systems (clothing banks) are put in place (especially by local governments and private firms) in order to facilitate this process.	• Ecotex collection systems in the UK

Source: own compilation based on (Mowbray, 2009), Eurotrend (2009), (Buyle, 2009). (Nieminen et al., 2007) and other relevant sources

Textiles and clothing is a sector which has traditionally used resources in an intensive scale. Eco-innovation opportunity areas for the textile sector are related to areas where the use of resources can be optimised. In particular, the area of sustainable textile manufacturing (or smart production) in combination with biotechnology, and green chemistry and engineering offer some of the most promising options (e.g. bio-enzymes, alternative dyes and chemicals, etc.). As part of smart production, automation and advanced monitoring and control of textile manufacturing is an important eco-innovation area. In addition, an area well covered by the BREF documents is related to water recovery technologies (e.g. during yarn making, packaging, etc.). Recycling and waste technologies, advanced packaging, and the development of advanced/new/bio/recycled fibres, are key areas to follow. In the apparel sector, there are important opportunities for the recycling of old clothes and conversion into recycled fibres, the use of eco-apparel methods (e.g. custom made clothes), low-impact methods for finishing (e.g. in denim jeans), and the use of eco-fibres for functional garments (e.g. in outdoors) and mass-market clothes. The area of high street fashion is considering the option of re-use and recycling materials.

State of the art studies signposting a number of opportunity areas that are expected to drive eco-innovation in this sector are hardly available. The degree of maturity of traditional textile manufacturing is relatively high. Since the early 1990s, the availability of methods and guidelines for cleaner production in this industry is notable – via pollution control/prevention strategies and techniques, environmental/waste management procedures, introduction of best available technologies, etc. (e.g. Modik 1991; UNEP 1994; Hendrickx and Boardman 1995; EPA 1996; EIPPCB 2003). At the European level, the results of the COST 28 project[26] represent the most up-to-date collection of striking environmental issues of textiles manufacturing which require technological and organisational innovation (Nieminen et al., 2007). All of these guidelines, studies and methods constitute the core of the know-how for environmentally friendly manufacturing in this sector but provide little room for more radical eco-innovations.

2.10 Conclusion

This chapter has been drawn on a large amount of sector specialised literature to show that although there are a significant amount of environmental issues in the sectors of interest, there is also a significant level of eco-innovation activity across all sectors considered. It was shown with a considerable number of eco-innovations, that there are opportunities all along the supply value chain to reduce environmental stress and generate economic activity. In the next chapter we will explore the potential for policy and regulation to promote and foster eco-innovation across the sectors included in the Sectoral Innovation Watch.

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[26] European cooperation in Science and Technology's project: Life Cycle Assessment of Textile Products, Eco-efficiency and Definition of Best Available Technology (BAT) of Textile Processing

3 Regulation and eco-innovation

This chapter corresponds to the stage of validation of eco-innovation in sectors, in particular in relation to the relation of regulation with eco-innovation. The relationship between regulations with environmentally proactive behaviour in firms has been widely studied in the past. In general, relationship of businesses with regulatory institutions has been conflictive as business imputed negative effects upon their competitiveness. More recently, the relationship of regulation with innovation and in particular with eco-innovation is characterised with better outcomes, where frequently regulation indirectly drives the competitiveness and performance of those business adopting new technologies and practices.

The content of this chapter is divided in eleven sections. Next section presents a brief description of the method of analysis and survey data employed to assess the role of policy and regulation to promote eco-innovation. The other sections present the results of our analysis, per sector. The final section presents the main conclusions of the analysis.

3.1 Method of analysis and survey data

The assessment of the potential of regulation and policy to promote eco-innovation is underpinned by a brief account of sector specialised literature on effects of regulation on eco-innovation. This is followed by a test of the relationship between regulation and innovation. Where appropriate, each sector section includes a brief case illustrating the relation between regulation and other eco-innovation drivers. This chapter partially draws from the work conducted in SIW-II on regulation and innovation (see Montalvo et al., 2011).

The Sectoral Innovation Watch had access to CIS4 micro data for 21 countries in the EU. The latest two versions of the community innovation survey (CIS4 and CIS5) contain only one question concerning the effect of regulatory compliance on innovation. For this reason, a module on eco-innovation was included in the survey conducted within SIW-II (See Montalvo et al., 2011). This survey enabled the assessment of relationships between different types of environmental regulations and different types of innovations at the firm level. The survey data is complementary to the CIS4 analyses presented in the SIW-II sectoral reports. Section two of the survey questionnaire enquired respondents about the impact that different regulations had on their innovation activities in the past three years.

The results presented in this section are based on a survey that included 6776 firms in the sectors of interest of SIW-II. The rate of response was 11.18% resulting in 758 questionnaires completed with 441 usable cases retained and included in the analyses. The size of the firms captured in the survey resulted to be 60.9% small, 15.9% medium and 23.3% large, a clear majority of small firms. Above 80% of the respondents in the firms addressed were in medium and high ranking management levels. The analysis of the impact of regulation on eco-innovation based on survey data used crosstabulations and correlation analyses between innovation types and 33 regulation types related to the environmental and energy topics.

Table 3-1 shows hypothetical relationships between several types of regulation and innovation. In the horizontal axis are the types of innovations included in the Community Innovation Survey 2008, while the vertical axis shows the types of regulations that appear in the fields of environment and innovation research literature. These hypotheses provide the basis to test the relationship between regulation and eco-innovation while adding differentiated empirical evidence by type of innovation across the sectors of interest of SIW-II.

Given the small size of the survey sample the correlations reported in the following sections for each of the sectors analysed are only those that were found highly significant to be neglected. Only correlation values above 0.4 were included in the analysis, very few cases with correlations below this value were included. The innovation categories shown at the top of Table 3-1 are the same definitions provided by the Eurostat/OECD Oslo Manual used in the EU-Community Innovation survey (CIS).[27] The variable SINNOV, in Table 3-1(horizontal axis, left), is a scale composed by all types of innovation. The reliability of this scale is highly satisfactory; its reliability test achieved a Crombach alpha of 0.79.[28] Having the scale tested for potential correlation with different types of regulation gives a good and reliable indication of the overall association of innovation with regulation. The following sections of this chapter address each of the sectors of interest of SIW-II.

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[27] CIS 2006 is based on the Oslo Manual (2nd edition, 1997). It gives methodological guidelines and defines the concept of innovation, and on Commission Regulation No 1450/2004.

[28] According to normal practice in self-report questionnaire design the reliability of a scale above 0.60 is considered acceptable (Crombach, 1994).

Table 3-1 Table of correlations - regulation type vs. innovation type

<table>
<tr><th>Innovation type
Regulation type</th><th>SINNOV</th><th>Product</th><th>Services</th><th>Manufacturing methods</th><th>Logistics, delivery & distribution</th><th>Supporting activities</th><th>Production organisation layout</th><th>Relations with others</th><th>Designs</th><th>Sales and distribution</th></tr>
<tr><td>Pre-emption of regulatory risks
Environmental protection
• Hazardous materials regulations
• Waste regulations
• REACH
• Energy regulations
• Alternative materials regulations
• Energy regulations
• Other environmental regulations
Agriculture and food
• Agriculture regulations
Commerce
• Trade regulations
• Competition regulations in Europe
• Consumer protection regulations
• Price regulations
• Interoperability-compatibility (Between old and new machinery & equipment)
• Interoperability-compatibility (Between old and new standards)
• Industrial standards
• Intellectual property rights regimes
Communications
• Communication regulations
Defence
• Security regulations
Foreign relations
• Foreign relations regulations
• Judicial differences across Europe
Government
• Fiscal and taxation regimes
• Financial regulations
• Public procurement regulations
Health and safety
• Health regulations
• Workforce safety regulations
• Genetically modified organism regulation
• Animals protection regulations
• Safety regulations on product usage or service delivery
Housing and community development
• Land regulations
• Housing, buildings and community development regulations
Labour
• Labour regulations
• Occupational regulations
Transportation
• Transport regulations</td><td colspan="10">Correlations*
*Correlation between two or more variables does not imply causality or certainty of effects of one variable upon another variable. Correlation indicates only association.</td></tr>
</table>

3.2 The biotechnology sector

According to the OECD (2009a), the shape of the world's bio-economy will be determined by a combination of factors in addition to regulation, such as public research support, social factors, energy consumption (and prices), the availability and cost of key resources such as energy, food and water, and both supporting and competing technologies. In general, biotechnology is considered a highly regulated technological area, especially when it comes to pharmaceuticals and food (Gassmann et al., 2004). Biotechnology firms in the European Union have to comply with European and national regulations and laws. An illustrative example shows that member states have been given a lot of freedom to formulate laws related to R&D in stem cells, which contributes to the divergence of regulations.

For the case of industrial and environmental biotechnology, literature on the impact of regulation on innovation is restricted to a number of application areas (e.g. bio-fuels, bio-materials, etc.). It is envisaged that the DG Energy's Biofuels Directives and Biomass Action Plan will constitute an important boost to the biobased economy (Jarekrans, 2008).

According to Reiss et all., (2007), for the case of bio-fuels quota obligations in EU member states are considered as potential drivers of innovation in the sector. France and the UK have strict obligations for the oil companies to offer certain blends in an ever higher percentage of bio-ethanol as a fuel every year. The Netherlands and Germany started obligations in 2007. In the UK, the Renewable Transport Fuels Obligation encourages investments in renewable fuels (Arthur D Little, 2009). For the case of biomaterials, in Germany the Packaging Ordinance comprises a new distinct regulation for certified compostable packaging made from biodegradable polymers. These products are exempted during the market introduction phase until the end of the year 2012, giving room to innovation (Reiss et al., 2007). The OECD (2009a) suggests that the use of biotechnology for chemical production (renewable chemicals) is likely to continue to increase, driven by rising energy costs, new chemical legislation (e.g. REACH in Europe), and increasingly stringent environmental regulations.

The relevance of standards (and its interoperability) as drivers of innovation may be important given the application of industrial biotechnology in a number of sectors. An example of a promising standard convergence is the American ASTM 6400 standard for compostable plastics and Europe's EN13432 standard on biodegradability, which could potentially contribute to supporting the international deployment of bio-based materials. Environmental performance standards based on life cycle analysis (LCA) methods (e.g. ISO 14044-2006) are expected to be a driver for eco-innovations in industrial biotechnology, especially when lower carbon footprints are rewarded in the market (OECD, 2009a).

The biotechnology sector is seen as one of the key enabling technology areas with large potential to contribute to eco-innovation and sustainability. Like in other fast changing sectors that are science based, regulation lags behind technological developments. Thus we could expect that direct regulation hardly drives eco-innovations in the biotechnology sector. This statement is confirmed by our survey results, with a relative lack of associations found between environmentally motivated regulations and all kind innovations considered. The exception to this is the regulation on Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). This could be expected as biotechnology, despite oriented to handling living material, is also strongly supported by all kinds of enabling chemicals.

Table 3-2 Correlations between regulation and innovation (biotechnology)

Innovation type	SINNOV	Products	Services	Manufacturing methods	Logistics, delivery or distribution methods	Supporting activities	Management systems	Layout changes of production organisation	Industrial relations	Design of a good or service	Sales or distribution methods
Regulation type											
Pre-emption of regulatory risks											
Hazardous materials regulations											
Waste regulations											
REACH	🟨 0.670**		🟨 0.445*							🟨 0.550*	🟨 0.474*
Energy regulations											
Alternative materials regulation											
Other environmental regulations											
Other regulations											
Labour regulations	🟩 0.704**		🟨 0.518*	🟨 0.480*	🟨 0.579*	🟨 0.527*		🟩 0.578**		🟩 0.621**	🟩 0.496*
Agriculture regulations				🟨 0.579*						🟨 0.559*	🟨 0.576*
Workforce safety regulations						🟨 0.512*		🟨 0.504*			
Safety regulations on product usage or service delivery			🟨 0.533*								
Intellectual property rights regimes									🟨 0.407*		
Interoperability-compatibility (Between old and new standards)		🟨 0.523*				🟨 0.592*		🟩 0.741**	🟨 0.540*		
Communication regulations			🟨 0.518*	🟨 0.475*				🟨 0.588*			
Occupational regulations			🟨 0.579*					🟨 0.487*	🟨 0.482*		

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Source: Innovation Watch Survey 2009

🟩 Highly correlated
🟨 Moderately correlated
⬜ No Correlation

European regulations are moderately correlated with innovation in products and supporting activities that are not environmentally motivated. Other regulations not ecologically motivated show stronger correlations with innovation in general. Amongst others, the strongest ones are labour regulations and the interoperability between old and new technology standards. The latter being a typical barrier to the diffusion and uptake of biotechnology across other sectors. Economic and environmental benefits of biotechnology innovations are often linked to each other, because certain industry standards have to be fulfilled in order to get approval by legislation and to be accepted within the industry (Montalvo et al., 2007).

Case evidence seems to support survey evidence that suggests that the European regulations and REACH have a positive impact on product innovation (see box 3.1). The case of bio-materials below exemplifies a case where a combination of technical capabilities, business opportunities in one sector (renewable chemicals), low market development (biofuels) and quota obligations (Biofuels directive) are collectively driving innovation in the sector.

Box 3-1 Second generation bio-fuels (bio-methanol) from non-food raw materials

An example of the production of second generation bio-fuels from non-food sources is glycerine for bio-ethanol production. Glycerine is a by-product of the production of bio-diesel, which is subsequently purified, evaporated and cracked to obtain a synthesis gas, which is used to synthesise bio-methanol. Dutch-based Bio-MCN is the first company with a commercial scale manufacturing process of bio-methanol. This makes the company to be the largest 2nd generation producer of biofuels in the world. The feasibility of the glycerine-to-methanol process was demonstrated on a pilot plant scale in March 2008 (20,000 ton of product). In the first term of 2009 they succeeded in operating a process unit with a capacity of 200,000 tonnes per year and in early 2010 they were able to produce 250 million litres of bio-methanol, which are enough to cover the entire Dutch bio-fuel obligation of a minimum of 4% blended into gasoline. Bio-MCN has reported capabilities to accommodate three additional units, adding up to an installed capacity of 800,000 tonnes/yr of bio-methanol (BioMCN, 2010). Other well established companies recently announcing the use of glycerine for chemicals manufacturing include Cargill Dow, Solvay, Ashland, Arken and Huntsman Corp (Thomson and Youngman, 2010). The evolution of new renewable chemicals products is an eco-innovation area closely linked to industrial biotechnology that is causing a great deal of attention. The first half of 2010 experienced a skyrocket increase of venture capital investment in renewable chemicals firms This event highlights the importance of joint ventures between small dedicated biotech and biofuel firms and well established chemical firms for high value and bulk chemicals production. The former is providing proprietary technology for chemical building blocks platforms whereas the latter contributes with large scale R&D, production and engineering capabilities, corporate funding, and access to consolidated networks and distribution channels (Thomson and Youngman, 2010).

Source: Eco-innovation futures database, TNO

3.3 The automotive sector

It is often perceived that the automotive sector is one of the most dynamic and innovative of all, bringing many innovations into the market in yearly basis. For more than a decade, a large number of technological options called to contribute to lower GHG emissions of car manufacturing continue to be developed and commercialised around the dominant design of petrol or diesel passenger cars (e.g. the options listed in Weiss et al., 2000). Alternative and more systemic transport solutions are needed and acknowledged, but the focus of the European environmental policy of products is at the stage of assessing the environmental impacts and identifying and assessing eco-innovation options related to car efficiency and car usage (Nemry et al., 2008).

A survey conducted by DuPont and the Society of the Automotive Industry (SAE) reveals that for the first time in 14 years, environmental concerns outrank cost reduction to top the list of challenges facing the automotive industry (DuPont Automotive, 2008). In the Dupont and SAE survey more than half of the surveyed automotive designers and engineers said that environmental factors, such as fuel economy, emissions or clean air regulations, are the industry’s biggest challenges.

As mentioned in section 2.2.1 there are several environmental issues along the value chain in the automotive industry. The automotive sector is one of the most regulated ones in developed economies. In emerging markets the level of legislation is increasing at a higher pace than many markets are. For the case of the European Union, climate change and other environmental issues have been important concerns for policy makers. To address these issues, a large variety of policies and legislations were put in place, putting car makers and suppliers under increasing pressure to confirm with all regulations regarding the use of resources, manufacturing processes, plant operations and recycling of products (Bilsen et al., 2009a). This is due to the fact, that legislations about environmental issues are often not synchronised with the automotive innovation cycles. This problem might give car makers in Europe a disadvantage over other countries, (e.g., Japan, Korea) (Gottschalk and Kalmbach, 2007).

The European Commission adopted a proposal for legislation in December 2007 to reduce the CO2 emissions of new passenger cars by 19% until 2012. In principle this proposal provides car manufacturers an incentive to decrease emission gases by imposing an excess emission premium in case the levels are above the regulation. Since most manufacturers are likely to meet this target, this legislation is expected to be a driver for innovation (EC, 2009f). The same holds for other regulations, such as the EU Directive on alternative car fuels, the end-of-life vehicles directive (2000/53/EC) and the Euro 4 and 5 emission limit values (Kuik, 2006). It is reported that strict emission standards and environment regulations may influence the current well-established supply chain structure, because organisations with environmental friendly technologies replace others or are added to the supply chain network. Next to this, currently adopted standards and regulations regarding the allowable levels of hydrocarbons, carbon monoxide, and nitrogen oxides in car emissions will be further tightened in the future. In order to achieve the targets set by the Kyoto Protocol, CO_2 emission levels of cars have to be reduced by 7% compared to vehicles in the mid-1990s. This means, that the average fuel efficiency has to improve by 25% (Shibata et al., 2008, p. 5). Although these regulatory changes are introduced in steps, it puts continuously pressure on automakers and suppliers to accommodate their processes and products to these regulations because the automotive industry operates in a complex social, economic and legal environment.

The discourse and to a great deal marketing and competition by different brands give now emphasis to fuel efficiency and CO_2 reduction. The general wisdom in the literature indicates that the environmental challenge is driving eco-innovation in the sector (e.g., Ploder et al., 2009; Montalvo et al., 2007). Despite the apparent pressure in major brands the survey results conducted by SIW-II indicated that the overall size and frequency of environmental regulations significantly associated with innovations is relatively low compared to other sectors monitor in SIW-II. This is indicated by the number of correlations between innovation type and regulation type found significant. The findings of the survey could be interpreted as not reflecting the trends in the sector if we consider the eco-innovative behaviour of major brands.

Table 3-3 Correlations between regulation and innovation (automotive)

Innovation Type	SINNOV	Products	Services	Manufacturing methods	Logistics, delivery or distribution methods	Supporting activities	Management systems	Layout of production organisation	Industrial relations	Design	Sales or distribution methods
Regulation type											
Pre-emption of regulatory risk											
Hazardous materials regulations	0.553*				0.583*	0.477*	0.530*			0.629**	
Waste regulations					0.540*					0.480*	
REACH					0.689**						0.566*
Energy regulations					0.494*						
Alternative materials regulations	0.583*			0.479*	0.709**				0.527*	0.747**	0.559*
Other environmental regulations					0.565**				0.490*		0.453*
Other regulations											
Safety regulations					0.582*		0.600**		0.556*		0.587*
Intellectual property rights regimes						0.597*					
Public procurement regulations					0.562*		0.600*	0.730**		0.581*	0.566*
Interoperability-compatibility					0.602*					0.524*	
Industrial standards										0.463*	
Consumer protection regulations					0.520*						

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Source: Innovation Watch Survey 2009

🟩 Highly correlated
🟨 Moderately correlated
⬜ No Correlation

The findings above can also indicate what is happening in the sector in tier 1 to tier 3 companies. Along the value chain these are companies that bring all kinds of inputs and components to integrate a final product. Most of the regulatory attention focused on energy efficiency in final automotive goods the rest of the provision system is not pressured directly by regulation to eco-innovate. The pressure might be transmitted through the supply chain management dominated by main brand companies. Normally, the dominating company indicates desired changes in intermediate goods to suppliers through new standards and designs modifications. This is supported by the strong and significant correlations between innovations on designs and regulations on alternative and hazardous materials. This is also supported by the strong relationship between innovation in logistics, relations with others and sales and distribution methods. These three types of organisational innovation indicate a chain of associations with regulation through innovation in logistics. Logistics is the type of innovation that holds the strongest relationship with environmental regulations. Furthermore, the lack of association of any type of innovation with the prevention of regulatory risk indicates that to a large extent firms down the supply chain have a more reactive rather than active innovative behaviour in the face of potential environmental regulations. Their eco-innovation could be mainly driven by pressure coming from major brands, their clients and reason of existence.

The case in box 3.2 below illustrates the effort of this sector to provide solutions to this sector regarding alternative vehicles, where a number of regulation-related issues can be identified. The lack of a dominant design in alternative cars components and engines makes it difficult to predict the outcome of the effect of regulation on innovation. Nonetheless, it is clear that the setting up of European Directives for hydrogen powered vehicles seem to motivate innovation in the sector. For the case of hydrogen vehicles, safety issues among other factors will determine to a large extent its success.

Box 3-2 Case: hydrogen-powered passenger vehicles

Hydrogen fuel cells are a promising development area for the coming decades, especially for the automotive industry, since it could replace fossil-based gasoline and diesel in vehicles. In addition to this, no harmful exhaust gases would be emitted, since hydrogen fuel cells only produce clean water as a side product. FCVs can, potentially, be twice as efficient as similarly sized conventional vehicles. Further innovations in this field could significantly increase efficiency levels of hydrogen cars, which have been already developed (at least at the concept stage) by most car manufacturers (e.g., Honda's FCX Clarity, the DaimlerChrysler F-Cell, Toyota's highlander. GM's Chevy sequel, Ford Focus FCV, Mercedes Class A, etc.). Many advances have already been achieved, but there are still some important issues to tackle. For example, hydrogen has a lower energy density by volume compared to currently used hydrocarbons, meaning that fuel tanks have to carry more hydrogen fuel in order to drive the same distance. This puts pressure on the design and weight of new vehicles. Additional challenges include: cold weather operation, cost (e.g., due to electrolyte membranes), safety issues related to hydrogen handling (e.g., by new users), new facilities for re-fuelling, and public acceptance.

The European Parliament has advocated for hydrogen powered motor vehicles (Directive 2007/46/EC and Regulation No 79/2009), where is envisaged that one of the major issues for the successful introduction of hydrogen-powered vehicles (especially L M and N categories) on the European market depend, to a large extent, on its safety, on whether the appropriate hydrogen filling station network could be timely established throughout European soil, and the eventual use of pure hydrogen produced from renewable sources (with mixtures being accepted for a transitional period). To this end, the results of EU's FP6-funded demonstration projects are hoped to bring new insights on how to overcome issues related to hydrogen infrastructure for supplying fuel cell passenger vehicles.

An example is the project Zero Regio[29], which includes the peers of Infraserv GmbH, Höchst KK and Daimler AG among others. In addition, a number of EU-funded projects are also expected to contribute towards the adoption of fuel-cell vehicles. Among such projects we account: EIHP, HyFFLEET, HyChain, HyApproval, HyLights, Naturalhy, Storhy, HyWays, and HySAFE (EC funded Network of Excellence). The available results so far seem to demonstrate the environmental and energetic feasibility of hydrogen-fuelled cars and surrounding infrastructure. The experience and promotion from the US-EPA and the Department of Energy (e.g., the testing programme "Fuel Cell Delivery Vehicle Testing Programme" in partnership with UPS and Daimler/Chrysler during 2003 to 2006) has also been an important contributor for the safety and security features of hydrogen-powered vehicle fuelling station and the general acceptance of FCVs (see EPA, 2004, 2007, 2009a).

Source: Eco-innovation futures database, TNO

3.4 The electrical and optical equipment sector

The literature suggests a number of existing policy instruments to encourage E&O equipment companies to engage in innovation. The need for energy efficiency is an important demand driver, but may not be the only force. Institutions also influence eco-innovation. Legislations for energy labelling, eco-design, waste and safety, may encourage eco-innovation in two ways: giving companies a competitive advantage by making state-of-the-art products to differentiate from others, but also creating a positive public image of companies due to visible energy or recycling labels (e.g., energy star logo). According to the ELECTRA (2008) report, the E&O sector clearly supports the main

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[29] The final report of this project was not available at time of analysis. For further details on the project and to request a copy of this report check: http://www.zeroregio.com/front_content.php?idcatart=186&lang=3&client=5.

features of European directives, but considers essential to achieve regulatory stability so that companies can work in a legally certain environment. The ELECTRA report does not mention the influence of regulation on innovation in the sector.

The REACH regulation, which started in June 2007 throughout the European Union, hopes for radical changes within the legislative environment for chemicals (and associated sectors) (EC, 2007e). Although at first glance it seemed to affect only chemical manufacturers, it also had many implications for E&O equipment producers and suppliers. While REACH is a driver for product development within the chemical industry, it might at the same time pose a challenge for firms along the supply chain (upstream/downstream users). Implementing (consultancy) firms have suggested that E&O manufacturing companies may require re-arranging large parts of their supply chain, because these regulations required new standards, new materials and new processes (ERA, 2009). This framework, evidently, is seen as a threat to well-established production systems in the sector. In our view it might be a positive factor for eco-innovation. Next to the REACH regulation, there are also other legislations concerning the material use in electrical and optical products. For example, E&O equipment for the automotive industry has also to comply with the end-of-life vehicles regulation (ELV), the global automotive declarable substance list (GADSL) and the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS).

The Eco-design directive (2005/32/EC) establishes a framework for harmonised eco design requirements in products consuming energy during use and products which have an impact on energy consumption (and a progressive rate of adoption). Eco-design is a pillar of European sustainable industrial policy, and the E&O industry has dully contributed to the development and implementation of this directive. It is seen as one of the more evident innovation drivers for new and existing product development, this due to their complementarities with voluntary agreements set by industry (EC, 2009c). Additionally, the Energy-using Products (EuP) directive aims at more energy-efficient products.

In relation to hazardous materials and electronic waste, EU legislation aiming to modify the innovative behaviour of this sector include: RoHS, restricting the use of hazardous substances in electrical and electric equipment (Directive 2002/95/EC) and the collection and recycling of such equipment (Directive 2002/96/EC, known as the WEEE directive). These directives have motivated producers to redesign their products for reasonable features related to reuse and recyclability. The WEEE directive came into force in 2007 with the aim of improving the environmental performance of manufacturing, supplying and recovering E&O equipment. The overall goal is to use less materials and increase the rates of reuse and recycling. It has been argued that this goal is in conflict with many firms along the E&O supply chain, because on the one hand it requires investment to be more environmental friendly by removing certain materials from products (e.g., lead-based solders) while at the same time sales decrease because of the higher recycling rate.

Therefore, companies have the opportunity to not only developing new innovations concerning products, but also concerning new business models. Furthermore, the WEEE directive raises the entry barrier for new players, giving larger and established companies a competitive advantage (Mock and Perino, 2008, ELECTRA, 2008). While WEEE put pressure on the supply chain and manufacturing process, it is expected to be an innovation driver for the recycling and waste industry related to the E&O sector (Mock and Perino, 2008). Recycling companies operating at the national level have perceived the effects of such a regulatory environment, which has motivated innovation in recycling technology for mixed wastes coming from this sector. Nonetheless, differences in recycling measures at the national level may hamper innovation for firms operating at the multinational level. In several countries, it is not explicit who is accountable for recycling issues, so this constitutes a problem for firms (EC, 2009e).

Regulation has played a significant role in the reduction of electrical and optical equipment waste. In particular the European WEEE Directive has promoted better designs considering the end life of products for better recycling. The results of the survey for the electrical and optical equipment sector indicate that those regulations that are directly targeting environmental performance of firms have little or no association with almost all innovations considered in the sample. The only two regulations that resulted moderately significant are the European REACH and those regulations related to the enforcement of alternative materials. Other environmental regulations are moderately associated with innovation in management systems. Other regulations like the safety of workforce, interoperability between new and old standards, and trade and financial regulations are shown to have a much stronger association across all the different types of innovation in this sector (see lower section of table 3.4 below).

Table 3-4 Correlations between environmental regulations and innovation (E&OE)

Innovation type	SINNOV	Products	Services	Manufacturing methods	Logistics, delivery or distribution methods	Supporting activities	Management systems	Layout changes of production organisation	Industrial relations	Design of a good or service	Sales or distribution methods
Regulation type											
Pre-emption of regulatory risks	0.456*					0.445*	0.513*			0.656**	0.602**
Hazardous materials regulations											
Waste regulations											
REACH							0.406*				
Energy regulations											
Alternative materials regulations							0.388*				
Other environmental regulations						0.325*					
Other regulations											
Labour regulations	0.419*			0.434*		0.351*	0.427*		0.544**	0.492**	0.390*
Workforce safety regulations	0.511**			0.457**	0.516**	0.414*	0.440**		0.589**	0.428*	0.504**
Competition regulations in Europe	0.368*			0.385*	0.339*				0.383*	0.386*	
Interoperability (Between old and new standards)	0.429*				0.461**	0.438*	0.642**	0.372*		0.453**	0.453**
Occupational regulations	0.568**			0.538**	0.557**	0.444*	0.548**		0.504**	0.594**	0.415*
Financial regulations	0.495**			0.497**	0.387*		0.503**	0.361*	0.468**	0.500**	0.573**
Trade regulations							0.483**		0.402*		0.488**

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Source: Innovation Watch Survey 2009

🟩 Highly correlated
🟨 Moderately correlated
⬜ No Correlation

Two aspects worth be highlighted here might be associated with the future of eco-innovation in the electrical and optical equipment sector. The first one refers to the fact that the pre-emption of regulatory risk resulted strongly associated to innovations in the design of goods and services and innovations in sales and distribution methods. In this sense, regulation could still be considered a driver of eco-innovation in the sector. Those firms that reported to have higher pressures from regulation were also the most innovative. Hence, safe guarding against the treat of future regulations that might affect business seems to promote the engagement on innovation. This finding indicates that here regulation might be inducing indirect effects on the environmental performance of products, processes and services. Box 3.3 below illustrates a case of innovation partially driven by the WEEE directive.

Box 3-3 Eco-innovation for complex material recycling driven partially by WEEE Directive

Recycling objectives are dictated by current regulations affecting waste streams from the E&O equipment sector (WEEE Directive). A new process eco-innovation has been recently developed for the recycling of flat screens coming from the E&O equipment sector. This is a unique process technology that significantly reduces time and labour for recycling flat screens derived from electronic wastes. This project was developed by a Spanish firm in the recycling business with the participation of a local RTO. Public funding for R&D projects was a key source of capital used for developing this eco-innovation. In addition to corporate money, this project was co-financed with public funds from the EC’s Eranet Susprise and the Basque regional government. The latter has a vast amount of programmes for this purpose (and these have a good perception among users) whereas the former has been specifically designed for the promotion of eco-innovation –related R&D projects of small firms.

An additional driver for the development and use of this eco-innovation is related to very nature of the eco-services market. The innovation manager of the firm in question suggested that the providers of eco-services have a very high eco-innovation potential since there is an on-going need for new technology development. According to the interviewee, there are a number of waste streams that have no specific recycling processes developed –so the opportunities for eco-innovation in specialised recycling are immense.

Source: Eco-innovation futures database, TNO

3.5 The space and aeronautics sector

The aerospace sector is strongly shaped by international standards and agreements and health and safety regulation. This makes changes to current standards a complex process, acting as a potential barrier for innovation. A clear driver for eco-efficiency in aeronautics is planned global emission policies. The Emission Trading System for example use economic incentives to further improve energy use during aircraft operations. However, this cost driver has been very strong in the sector for some time caused by levels of hyper competition between airlines that struggle to earn their cost of capital. Other regulations are often also locally administered. Noise reduction is another important driver for eco-innovation with stricter regulation especially for night flights.

While public policies can act as driver, often different policies work against each other. EASA, the European Aviation Safety Agency, is the centrepiece of the EU's strategy for aviation safety in Europe. Aircraft and components must be certified to meet standards of airworthiness. The aerospace industry is also affected by other policy initiatives and EU regulations (e.g., REACH; environmental and transport initiatives), which impact time-to-market and development costs (EC, 2009a). This complexity in public policy means that ACARE calls for certification and qualification processes that facilitate the rapid introduction of new and innovative technologies into production models (ACARE, 2009 p.84).

Furthermore, goals for GHG emission reductions (impact climate change) during product operations might be counterproductive to the environmental impact of aerospace manufacturing overall. The reason being that so called ‘new materials’ available for, for example, high performing jet engines require much purer raw materials and special alloys that use a lot of energy and have high environmental impact. This makes assessing policy tools for overall impact on the life-cycle important to prevent counterproductive outcomes for other environmental characteristics.

The space and aeronautics sector arises in the survey as the sector most sensitive to regulation. Our correlation analyses reveals that in this sector all types of environmentally regulations are associated with almost all types of innovations, thus is very likely that many innovations are at least partially environmentally driven. Surprisingly, energy efficiency regulations resulted moderately associated only with innovation in manufacturing methods and relations with others but not in end products. Like in the case of the automotive sector, this finding contrasts with the great effort that, for example, manufacturers are putting in the improvement of their efficiency of their products (the survey includes only 2nd and 3rd tier companies). Although environmental regulations resulted associated with different types of innovations, other types of regulation were found correlated more frequently and with stronger associations with all types of innovations considered (see table 3.5). Other regulations that resulted with stronger associations with innovation include: Safety, health, pricing, housing and community development, IPRs and interoperability between new machinery and equipment. Thus although environmental regulations might be playing a role in motivating eco-innovations in this sector, the type of correlations found in this sector indicate that other types of regulation might be motivating more innovations of other character rather than eco-innovations.

Table 3-5 Correlations between regulation and innovation (space and aeronautics)

Innovation type	SINNOV	Products	Services	Manufacturing methods	Logistics, delivery or distribution	Supporting activities	Management systems	Layout of production organisation	Industrial relations	Designs	Sales or distribution methods
Regulation type											
Pre-emption of regulatory risks	0.675*				0.642**		0.632*	0.571*			0.558*
Hazardous materials regulations	0.587*	0.423*		0.432*		0.462*		0.526*	0.651**	0.556*	0.537*
Waste regulations				0.471*		0.450*		0.564**	0.545**		0.462*
REACH	0.627**	0.484*		0.654**				0.556*	0.525*		0.646**
Energy regulations				0.481*					0.487*		
Alternative materials regulations									0.632**		
Other environmental regulations	0.530*			0.464*	0.433*	0.462*	0.449*	0.516**	0.571**		0.480*
Other regulations											
Workforce safety regulations	0.490*				0.501**	0.692**	0.703**	0.589**	0.427*		0.674**
Safety regulations on product usage or service delivery	0.504*					0.506*		0.603**	0.544**		0.580**
Health regulations					0.442*	0.612**	0.535**	0.636**	0.429*		
Housing, buildings and community development regulations	0.746**	0.672**		0.675**	0.579*	0.511*			0.525*	0.728**	0.686**
Intellectual property rights regimes	0.686**			0.475*	0.505*	0.500*			0.575**	0.482*	0.578*
Price regulations	0.701**	0.548*		0.628**	0.548*	0.467*		0.498*	0.597**	0.629**	0.492*
Interoperability-compatibility (Between old and new machinery and equipment)	0.729**		0.602**	0.479*	0.692**	0.697**	0.636**	0.597**	0.592**		0.595**

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Source: Innovation Watch Survey 2009

🟩 Highly correlated
🟨 Moderately correlated
⬜ No Correlation

Box 3.4 below illustrates a case of eco-innovation driven by regulation that has a combination of regulations on advanced materials and waste minimisation for aeronautic products. The following example of a new coating for the aerospace sector highlights drivers and barriers for eco-innovations. Many of the aspects are applicable to the sector more generally. In principle, waterborne coatings have long been used in the automotive sector. However, the product specifications for coatings are much higher in the aerospace segment with most internal, structural parts of an aircraft sealed into areas of the structure that cannot be accessed during the life of the airframe – and this can be as long as 30 years. In addition, safety regulations are very high for air transport making innovation adoption very complex and time consuming processes. With improvements in nanotechnology, further eco-innovation opportunities in coatings should arise. But the barriers are less of technological nature but more of institutional and organisational nature.

Box 3-4 New waterborne coatings for planes

As such eco-innovation in aerospace coatings can help reducing environmental impact, resource use, and weight of aircraft and air drag of aircraft during flight operations. But the weight and smoothness have to be balanced against environmental factors, airframe integrity, and legislation issues in the development of new aerospace coatings to protect the aircraft structure against the extreme conditions they are exposed to daily. The US Environmental Aviation Agency in 1998 stated that alternative coatings – solvent free – have been developed but may be prohibited by FAA (Federal Aviation Agency, USA) guidelines (EPA, 1998b).

Recently, a European chemical firm has introduced a new coatings series to the aerospace market that is waterborne reducing VOC emissions, contains 75% less chromates, lowers paint consumption and requires up to 20% less coating weight. This product line was developed for a large European aircraft manufacturer that needed to reduce its emissions to comply with European regulation. Aircraft manufacturers prefer trusted products and are reluctant to take-on innovative solutions. While it takes time to develop new market uptake it takes even longer to get old products out the market. An aircraft has a lifetime of 30 years. Coatings used for maintenance and repair must be made to original (old) product specifications which means that new products take very long to penetrate the whole market. Now that customers are convinced that the new product (water borne alternative) works, the next step is to convince them to adapt their production (processes). Water borne coatings differ substantially in their physical properties to old coatings requiring physical investments and adaptations in production structures of aircraft manufacturers.

Source: Eco-innovation futures database, TNO

3.6 The construction sector

The literature considers construction as a regulation driven market (Bilsen et al., 2009a). An important driver for eco-innovation in relation to the life-time of buildings is the “Energy Performance in Buildings” directive (Directive 2002/91/EC). The directive regulates the introduction of performance targets and a certification system for buildings. By these measures the energy efficiency is expected to increase and, thereby, reduce emission of GHGs. Regulation of energy performance in new buildings has already been implemented in most countries for many years (Montalvo et al., 2007). In general, building codes, certification and labelling focussing on energy are envisaged as drivers for eco-innovation in the sector (Blok et al., 2007). Voluntary initiatives such as BREEAM are also expected to induce innovation in the sector. The BREEAM (BRE Environmental Assessment Method) is the leading and most widely used environmental assessment method for buildings. It sets the standard for best practice in sustainable design and has become the measure used to describe a building's environmental performance (BREEAM, 2009).

According to results from our correlation analyses, in the construction sector, similar to the aerospace and wholesale and retail trade sectors, environmental regulations are highly correlated with all types of innovation. The type of innovations that resulted highly associated to environmental regulations are management systems and the organisation of production. Contrasting with strong and frequent associations in most innovation types, product innovation is not associated with regulations at all. This is a finding that requires further exploration. Given that all other areas of innovation are associated with regulation it can be stated that the effects on product eco-innovation are indirect. It is very likely that the indirect effects here come from those regulations that have the strongest association with eco-innovation. These are those that in general regulate the qualities, life cycle and the flow of materials in the construction sector (i.e., waste, alternative materials and REACH). The regulation of waste in the sector, the strongest set of correlations, is also strongly correlated with regulations dictating the use of alternative materials and REACH. These findings tend to confirm that although product innovation seems not to be affected by regulation, regulation along different spots of the supply chain and different areas of innovation is very likely to drive to a good extent eco-innovation in the construction sector. Here, regulations at the national and European level are strongly associated with innovations in logistics, production layouts, management systems, and design and sales methods.

Table 3-6 Correlations between regulation and innovation (construction)

Innovation type	SINNOV	Products	Services	Manufacturing methods	Logistics, delivery or distribution	Supporting activities	Management systems	Layout of production organisation	Industrial relations	Designs	Sales or distribution methods
Regulation type											
Pre-emption of regulatory risks											0.405*
Hazardous materials regulations	0.384*		0.380**				0.351*	0.333*			
Waste regulations	0.459**		0.343*	0.363**		0.365**	0.402**	0.424**			
REACH	0.543**				0.440*		0.524**	0.479*		0.395*	0.435*
Energy regulations								0.306*			
Alternative materials regulations	0.499**		0.469**	0.350*	0.303*		0.382**	0.413**		0.324*	0.418**
Other environmental regulations	0.485**				0.333*		0.361**	0.400**		0.323*	0.335*
Other regulations											
Housing, buildings and community development regulations	0.356*		0.325*				0.297*	0.401**			
Labour regulations	0.354*		0.301*			0.310*	0.300*			0.303*	0.319*
Health regulations	0.334*							0.374**			
Security regulations	0.387*		0.287*			0.294*	0.356*	0.318*			
Transport regulations	0.519**			0.358*	0.399*	0.415**	0.501**	0.340*	0.355*	0.347*	0.373*
Competition regulations in Europe	0.436*				0.378*		0.375*			0.338*	0.418*

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Source: Innovation Watch Survey 2009

🟩 Highly correlated

🟨 Moderately correlated

☐ No Correlation

The following example describes a case where regulation in the Netherlands plays a smart role for fostering innovation, all in combination with subsidies and business opportunities. The city of Amsterdam has established the ambition to become the first European city to run on smart grids infrastructure and to improve the overall carbon footprint of its building environment. In combination with energy performance regulation in buildings, the local government is running a pilot scheme of subsidies to incentivise home owners to invest in smart meters.

Box 3-5 Smart building controls in the Netherlands

Smart building controls are an example of innovations that have an effect on the environment. Dutch households making investment to increase energy efficiency are eligible to a subsidy in the cost up to 50% of the total cost of the investment. With the Home Control Box electrical appliances (lights, heating, electronics etc.) can be turned on or off automatically. The system is operated with a control unit with touch screen and through a website. In July 2009, 500 households in Amsterdam were used as a pilot testing of different energy saving services: a website for operating the thermostat and an online "wizard" for collecting data about the energy use of appliances. Main goal of the project is 14% energy and CO_2 reduction.

The project is an initiative of Dutch energy supplier Nuon, IBM and Cisco. The services are developed by Home Automation Europe in collaboration with Nuon (Home Automation Europe, 2009). As a result of the success of the project, local authorities in Amsterdam have commissioned its innovation intermediary “Amsterdam Innovation Motor’ to foster the follow up of this initiative. Cisco has recently announced its contribution to a 1 billion Euro investment (together with IBM, Accenture, and Alliander) to make Amsterdam the first smart grid city. It is expected that the whole of city of Amsterdam will be on smart meters by 2011.

Source: Eco-innovation futures database, TNO

3.7 The wholesale and retail trade sector

Literature on the impact of regulation on eco-innovation for the wholesale and retail trade sector is scarce. Forum for the Future (2009) performed a survey among top European retailers. Their findings suggest that strict standards for waste management, packaging and energy efficiency may be key drivers for innovation in the sector. Conversely, respondents suggested that high regulation may result in the loss of competitive advantage as their customers could be less concerned about the sustainability of individual retailers. Low regulation can therefore be a stimulant for competitive behaviour of retailers moving ahead on the policy agenda.

An issue paper of the European Retail Forum gives room to imply that energy efficiency regulations may foster innovation in the sector (European Retail Forum, 2009). This may be true since the energy efficiency of a retail location is mainly defined by the technical equipment used and the building itself. A regulation that may induce energy saving in wholesale and retail stores is the EU framework directive on energy end-use efficiency and energy services (2006/32/EC). Member States also set national quantitative targets for saving energy in sectors not covered by the EU Emissions Trading Scheme (ETS), sometimes addressing the tertiary sector. Another regulation is the Directive on the Energy Performance of Buildings (EPBD). According to the European Retail Forum (2009) European retailers are affected by this directive because it specifies binding energy standards for commercially used buildings (new buildings and existing buildings that are subject to major renovation).

Implementing measures under the directive for Energy-using Products (EuP) will very likely have a direct effect on the business activities of European retailers. In particular when purchasing equipment like refrigerators and freezers, boilers, air conditioning or lighting. According to the European Retail Forum (2009) separate national targets for the increased use of renewable energies could equally have a positive effect on the energy efficiency strategies adopted by retailers. Some countries are planning extensive measures to advance the construction of renewable energy installations (e.g. solar collectors, geothermal heat pumps etc.). An illustrative example is Spain, where new commercial building projects are mandatorily required to use renewable energies. Linked to the construction sector, voluntary initiatives such as BREEAM are also expected to induce innovation in the sector.

Our survey results suggest that in the wholesale and retail sector environmentally driven regulations resulted strongly associated with innovation in management systems, layout of production organisation and relationships with others and weakly associated with innovation in supporting systems, services and products. Waste regulations have been applied to the sector in the past in Europe. Currently waste management is a normal practice in this sector. Waste regulation was found associated with product innovation. As a whole, the scale capturing the whole meaning of innovation (SINNOV) resulted highly correlated with environmental regulations as well. This indicates that environmental regulations are very likely driving innovation in this sector. Changes in the layouts of organisation have stronger associations with all environmentally driven regulations. It is worth to highlight that innovation in logistics and distribution resulted not associated with environmentally driven regulation nor with transport regulations, this despite the important role that transport plays in this sector. In addition, is important to notice that, relatively speaking, a larger block of non-environmentally motivated regulations have stronger associations with innovation activities at the firm level in this sector. Examples include European competition regulation, interoperability and industrial standards.

Table 3-7 Correlations between regulation and innovation (wholesale and retail)

Innovation type	SINNOV	Products	Services	Manufacturing methods	Logistics, delivery or distribution	Supporting activities	Management systems	Layout of production organisation	Industrial relations	Designs	Sales or distribution methods
Regulation type											
Pre-emption of regulatory risks											
Hazardous materials regulations	0.389*		0.430**	0.356*		0.387*	0.516**	0.522**			
Waste regulations		0.314*		0.344*				0.511**			
REACH				0.544*				0.477*			
Energy regulations			0.356*	0.358*				0.424**			
Alternative materials regulations							0.344*	0.349*	0.376*		
Other environmental regulations	0.470**	0.377*	0.372*	0.441**		0.325*	0.433**	0.632**	0.397**		
Other regulations											
Workforce safety regulations	0.393*	0.467**	0.408**	0.404**		0.380*	0.388*	0.442**	0.351*	0.357*	
Safety product usage or service delivery	0.333*	0.446**	0.401**	0.394*	0.314*	0.336*		0.361*	0.339*		
Health regulations	0.426*	0.425**	0.439**	0.404*	0.359*	0.405**	0.388*	0.478**	0.316*	0.384*	
Competition regulations in Europe	0.584**	0.458*	0.503**	0.633**	0.387*	0.488**	0.585**	0.716**	0.521**	0.525**	0.431*
Interoperability-compatibility (Between old and new standards)	0.611**	0.454**	0.491**	0.648**	0.398*	0.479**	0.626**	0.671**	0.517**	0.490**	0.364*
Industrial standards	0.511**	0.513**	0.466**	0.594**	0.408*	0.430*	0.501**	0.640**	0.398*		
Occupational regulations				0.368*			0.447**	0.478**	0.397*		
Trade regulations	0.365*			0.395*		0.369*	0.527**	0.496**	0.375*		

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Source: Innovation Watch Survey

🟩 Highly correlated

🟨 Moderately correlated

☐ No Correlation

The following example describes the case where regulations in combination with the greening of business and cost reduction strategies of supermarkets. This is a case where energy regulations play a combined role with the European Waste directive to incentivise firms to adopt combined heat and power units running on bio-gas.

Box 3-6 Waste management in European supermarkets

Giant French supermarket Carrefour claims to be committed to responsible commerce and waste management is one of their five core actions in this area. The first steps given by Carrefour are in the area of packaging waste (total withdrawal of disposable plastic bags by 2010), paper catalogues (100% of recycled paper use by 2010), and consumer magazines (100% of recycled wood fibre and/or sustainable forest management -FSC certified).

Carrefour is also reducing the volume of store waste by replacing wooden boxes and crates by reusable plastic containers (used for merchandise shipping). In Spain and Belgium, Carrefour has benefited from the development of bio-methanisation units, which recycles organic waste sorted by the local stores (from grocery, bakery, fruit and vegetable sections) and produces compost and electricity from biogas. This system has also been tested in France. *Carrefour (2009a, 2009b)*

Source: Eco-innovation futures database, TNO

3.8 The knowledge intensive business services sector

The effect of environmental regulations on innovation is mentioned in KIBS literature, but little empirical evidence has been provided. Most of the evidence refers to case studies. To attempt to amend this shortcoming from KIBS literature, we reviewed a number of studies analysing the eco-industry and product-service systems that provide some light on the issue on the impact of regulation on eco-innovation.

A number of authors has suggested that manufacturing and services should always be analysed together. According to Toivonen (2004) the increase in public regulation in manufacturing sectors has enhanced the need for services, especially legal and compliance services. This view is supported by the OECD (2006), which asserts that compliance services (e.g. auditing services) are only linked to stimulating innovation when regulation is related to health, safety and environment – but no empirical evidence was provided. Based on case study evidence, Miles, Kastrinos et al. (1995b) found that environmental regulations in manufacturing have made the regulatory environment more complex for firms. This has promoted a demand for inputs of knowledge from specialist services. These authors sustain that services are heavily and politically sensitive to environmental impacts, especially transport services. This situation gives room to environmental services suppliers to help coping with these problems.

In addition, differences in environmental regulations across Europe do make a difference to the growth of environmental services, as these are largely stimulated by the need to comply with regulations (e.g. GIS applications have been stimulated by environmental regulations in the Netherlands). Based on evidence from Germany, Hipp and Grupp (2005) found that the knowledge intensive companies comply to a significantly extent with environmental and safety requirements. It their Probit model these authors identified that safety/ecological regulations had a significance level of 1%. A problem arises when trying to identify the impact on innovation of one or another (safety vs environmental regulation), as their model used a composite factor that includes a number of variables. Finally, Tovoinen (2004) suggested that the need to seek for expert advice is applicable to private firms and to various levels of government alike, but seems to be more related to labour, property rights and competition law.

Work in the environmental goods and services industries on the effects of market-based instruments may provide some further guidance on this topic (e.g. David and Sinclair-Desgagné, 2005). The analysis of the eco-industry by Sinclair-Desgagné (2008) categorically posits that demand for environmental goods and services to manage pollution has been traditionally pulled by environmental regulation and policy. Supply has relied exclusively on private business, where most clients are regulated industries. Purchases of eco-services arise mainly from a desire to comply with social demands and current or future regulations (mandatory and/or voluntary), not from the actual composition of a particular end product. Moreover, this author affirms that environmental policy determines the market power and profitability of the eco-industry. Canton et al (2008) further suggest that environmental regulations should consider eco-industries' innovation strategies. The understanding of the influence of each environmental policy instrument on innovation is an open ended question, which answer should be able to provide insights on different innovation strategies from different eco-industries.

From a product service perspective, Roy (2000) suggested that EU regulation has encouraged the use of life cycle design approaches in firms for quite some time now. This author suggested that this has been the case of EU regulation on eco-labelling and energy labelling and a Dutch government Eco-design programme aimed at SMEs –but no empirical evidence was provided. In a review of 40 case studies of eco-efficiency business services and scenario development techniques, Zaring, Bartolomeo et al. (2001) found that the influence of environmental regulations acting as a driver for the development of eco-innovations was partly true. Among the cited regulations the authors mentioned: emissions, end of life vehicles, energy regulations, energy efficiency, packaging, electronic waste (WEEE), eco-labels, employment, etc. Some of these regulations were under development at the time the study was conducted. Interoperability between standards was also seen by Zarig and peers as a positive driver for innovation.

An interesting point made by Zaring, et al. (2001) is that a number of eco-efficient service providers became active in fields related to their innovations well before legislation was put in place. The strategic reasoning behind this was to anticipate future regulation developments and to secure competitive advantages over possible competitors. This was the case for recycling and reuse and waste minimisation-related innovations (e.g. design for recycling and take-back schemes). Another interesting note is that most reviewed studies suggested that de-regulation is seen as factor supporting the growth and internationalisation prospects of KIBS firms, especially in energy-related services (e.g. Strambach, 2008, Zaring et al., 2001). As opposite, Gadrey (2009a) suggests that the current scenario of environmental crisis and social challenges could well require that KIBS could be re-regulated and that severe restrictions could be placed on the current short-term competitive principle shaping their operation.

Our survey results found a weak relationship between environmental regulations with different types of innovation activities in the KIBS sector. Product innovation is associated with environmental and energy regulations. Innovation in designs is associated with hazardous and alternative materials regulations as well as with waste regulations. Weak associations were found also between waste regulations and REACH and innovation in services and sales and distribution methods, respectively. It must be noticed that other regulations that are not environmentally motivated resulted with considerably stronger associations with innovation. Despite weak associations found between eco-innovation and regulation in this survey it is still possible provide some anecdotal evidence of the existence of services aiming to support eco-innovation. In the evidence provided, the services described intuitively hold relation with European directives and regulations on waste minimisation and optimisation of energy and resources.

Table 3-8 Correlations between regulation and innovation (KIBS)

Innovation type Regulation type	SINNOV	Products	Services	Manufacturing methods	Logistics, delivery or distribution	Supporting activities	Management systems	Layout of production organisation	Industrial relations	Designs	Sales or distribution methods
Pre-emption of regulatory risks											
Hazardous materials regulations									0.342*	0.325*	
Waste regulations					0.284*					0.302*	
REACH											0.349*
Energy regulations		0.276*	0.251*								
Alternative materials regulations							0.316*		0.345*	0.346*	
Other environmental regulations		0.302*							0.270*		
Other regulations											
Labour regulations					0.327**		0.313**	0.347*	0.263*		0.263*
Agriculture regulations					0.429*					0.460**	0.369*
Workforce safety regulations					0.340**				0.368**	0.277*	
Price regulations					0.280*	0.395**	0.426**				0.350*
Fiscal and taxation regimes	0.402**			0.350*	0.330*	0.418**	0.445**	0.304*	0.373**	0.303*	0.275*
Interoperability	0.324*					0.340*	0.336*		0.388**	0.320*	
Occupational regulations					0.323*	0.305*	0.330**		0.270*		
Animals protection regulations	0.529**			0.476**	0.393*	0.411*	0.459**		0.465*	0.481*	0.378*

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Source: Innovation Watch Survey

🟩 Highly correlated
🟨 Moderately correlated
☐ No Correlation

The following case provides an example of energy management services. This is a clear outcome of the pressures perceived by manufacturing sectors that hire products and services from KIBS companies. In this case energy management services can be seen as both a product and a service innovation, depending on the point of view of the user or provider.

Box 3-7 Examples of eco-innovation knowledge intensive services: resource and energy efficiency management

An organisational eco-innovation dealing with energy efficiency management is provided by the ABB Group. The world largest automation supplier is engaged in the consultancy business helping energy intensive industries to improve their overall energy efficiency. As energy tends to represent one of the top three production costs, ABB's energy efficiency programme seeks to screen, and identify energy savings opportunities, followed by the design and implements a tailored energy management master plan. This plan is then carried through as part of an energy performance contract between the client and ABB, with savings shared between the two of them over the duration of the contract. In average, most of the energy improvements (ranging from 5 to 20% of a site's utility consumption) identified by ABB's methodology have payback periods of just over 12 months. ABB's also supports companies to implement and monitor the client's energy strategy from a tactical to an operational stage pursuing corporate energy efficiency objectives.

Taking a full energy value chain approach, this method also takes into account monitoring organisational changes (e.g., structure, leadership commitment) and individual site improvements (e.g., in case of multi-facility firms) with the aid of statistical techniques and automated tools for data collection and data analysis, Benchmarking energy consumption, process optimisation, specific improvement projects, verification mechanisms and communication of progress results are generally accounted among the most common actions in targeted implementation plans (resulting from energy efficiency management processes).

Source: KBC (2009) and MacCabe (2008)

See also the case presented in section 3.9, where KIBS firms are contributing to greening the supply chain of manufacturing sectors.

3.9 The food and drinks sector

The Integrated Pollution Prevention and Control (IPPC) directive (2008/1/EC) for minimising pollution from industrial sources was introduced to reduce sources of pollution in sectors considered of high priority. As a consequence, it has the potential to foster organisational and technological change. An IPTS report suggested that this was the case in those areas where installations were not previously regulated, such as in the food and drinks sector. Noticeable positive effects were encountered in firms where management of environmental effects was (traditionally) high. The IPTS evaluation found that primary/front end measures have had a generally positive impact on productivity and plant performance, especially for plants with a strong environmental performance (Hitchens et al., 2002). An study commissioned by the EC reports that depending on the sub-sector and regional differences process change may achieve different results, but no mention is made to the effect on innovation (see e.g. Kotronarou and Iacovidou, 2001). National evaluations of the impact of the IPPC directive do not treat the impact of this regulation on innovation beyond the adoption of best available technologies (see e.g. DEFRA, 2008).

According to Fanckk et. al. (2008)., the Waste Framework Directive 2006/12/EC is expected to be an important driver for eco-innovation diffusion in the F&D industry – at least for waste management. Since the new Waste Framework Directive introduces an important new element on energy recovery through anaerobic digestion of biodegradable waste, it is expected that the introduction of technologies for co-generation could be speed up. The literature also reports that public intervention may constitute an important driver for eco-innovation in packaging. All Member States have set up return, collection and recovery systems for packaging waste. Most have adopted measures aiming to encourage the use of recycled material. According to Franckx, van Acoleyen et al. (2008), a negative point is that certain national measures and an incorrect application of the Directive have led to partitioning of the internal market, in particular in the drinks sector. The Commission foresees flexibility with respect to incentives aimed at encouraging prevention and reuse of packaging (Franckx et al., 2008).

Our correlation analysis suggests that, with the notable exception of service innovation, the effect of regulation in the promotion of eco-innovation in the food and drinks sector is almost absent. This is the case for almost all types of innovation and all types of regulation. The exception to this finding is the correlation with innovation in services. The absence of correlation is also confirmed by CIS4 data analysis where the rank correlation places regulation in 34th/39th place of importance in relation to other factors affecting innovation. In relation to other sectors in the SIW-II survey of regulation, food and drinks is the sector where regulation showed the lowest degree of association with regulation. These findings must be considered with care as it is well known that the food and drinks sectors is heavily regulated to ensure health and safety of intermediate inputs and final products to consumers. The relationship between of eco-innovation and regulation in the sector requires further research.

Table 3-9 Correlations between regulation and innovation (food and drinks)

Innovation type	SINNOV	Products	Services	Manufacturing methods	Logistics, delivery or distribution	Supporting activities	Management systems	Layout of production organisation	Industrial relations	Designs	Sales or distribution methods
Regulation type											
Pre-emption of regulatory risks			0.423*								
Hazardous materials regulations			0.412*								
Waste regulations											
REACH (Registration, Evaluation,			0.498*								
Energy regulations											
Alternative materials regulations											
Other environmental regulations											
Other regulations											
Labour regulations			0.386*								
Agriculture regulations			0.387*								
Safety regulations on product usage or service delivery			0.393*								
Health regulations			0.405*								
Security regulations			0.422*								
IPR		0.414*									
Interoperability						,397*					
Genetically modified organisms										0.455*	
Occupational regulations					,443*	,509**					
Consumer protection regulations			0.365*								

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Source: Innovation Watch Survey

🟩 Highly correlated
🟨 Moderately correlated
☐ No Correlation

The following example shows how food companies are adopting service innovation with the aim to green their supply chain and ensure regulatory compliance. This case is a combination of the direct pressures in the adopter sector (food and drinks) and the opportunity perceived by a provider sector (KIBS), a sort of indirect effect on the latter. Food companies may perceive regulatory pressure coming from chemical substances (REACH), hazardous materials and regulatory risks, but this may not necessarily motivates them to exert it in product innovation. Service innovation might be the preferred option. In the case below it is noticeable that the Norwegian firm in the KIBS is combining in-house knowledge in combination with highly sophisticated technology coming from the E&O equipment sector. This combination enables them to deliver traceability services for greening the value chain of food companies, at the time the latter firm can show to their consumers that their products are ethically produced and in an environmentally conscious way. On a very interesting note, a subsidiary company was created by a large Danish food company in combination with a global ICT/KIBS firm. The nutrition division of a German conglomerate followed a similar strategy, and decided to launch an area of KIBS services, and not a spin-off firm. These examples show the role of large corporations in the food value chain and its impact of eco-innovation.

Box 3-8 Electronic traceability of the food supply chain

The Global Traceability Network (GTNet) is operated by the Norwegian firm TraceTracker AS. This is a subscription-based service enabling organisations to implement electronic traceability both in the corporate and across organisations. In simplify, it constitutes an online, decentralised exchange of information between independent players along the entire value chain. The GTNet offers the possibility of tracing and tracking from the upstream origin to the downstream destination of items in the value chain, in any business or industry. This service has been particularly attractive for the food sector, under the notion of “from farm to fork” of the food chain. GTNet covers the needs for both internal and global chain traceability at all levels of detail. The subscription gives access to a comprehensive hosted service including platform and systems operation and support. The service is always based on the latest released version of the TraceTracker GTNet software, and systems maintenance and upgrades are performed as part of the hosted operations. The standard data model of the GTNet includes data fields (properties) required by the “US Bioterrorism Records Maintenance Requirements” as well as “EU Food Law 178/2002”.

The use of traceability tools seems to have a huge potential and may be already skyrocketing. Global firm IBM and Danish-based Matiq (a subsidiary of Nortura, Norway's largest food supplier) is using radio frequency identification (RFID) technology to track and trace meat products from the farm through the supply chain and right onto the supermarket shelves. In addition, IBM’s product portfolio offers the IBM Food Safety Manager which is an IT solution connected to the GTNet. BASF nutrition division has launched the S.E.T initiative (Sustainability, Eco-efficiency and Traceability) which combines eco-efficiency analyses with traceability features and is TÜV-certified. As it would be expected, the SET initiative allows feed and food manufacturers to trace exactly which ingredients were used and which conditions applied in the manufacture of a product. By applying eco-efficiency analyses over the life cycle of a product, consumers can easily verify the data related to the origin and destination of food products. Oracle has enhanced its Product Lifecycle Management (PLM) tool aimed at enabling food and beverage manufacturers to more easily address, during the design phase, growing regulatory requirements and product complexity. This software includes not only aspects of safety and regulatory compliance, but also to product record throughout the lifecycle. Containing the rich information that uniquely defines all aspects of a product at each stage in its lifecycle, the product record includes all of the information required by the across a global product network to conceptualise, design, source, build, sell, service and dispose of products.

Source: Case elaborated from BASF (2009), Foodprocessing-technology (2008), IBM (2007, 2009) Tracetracker (2007a, 2007b) and Oracle (2009)

3.10 The textiles and clothing sector

Regulation in the textiles sector from an environmental perspective is hardly mentioned in the literature of innovation and regulation studies. Results from SIW-I reported that regulation seemed to be of less importance in the textiles sector. SIW-I suggested that this result was intuitively clear as the sector usually does not go along with a considerable harming potential of the environment. These report claimed that regulation was of relatively low importance to the textiles sector. The dominating measure of regulation in textile was technical norms .

As previously noted, the Integrated Pollution Prevention and Control (IPPC) directive (2008/1/EC) establishes a general framework for integrated pollution prevention and control aiming to prevent/reduce emissions into air, water or soil of about 50,000 large industrial installations across the EU27. The T&C sector is considered part of the priority sectors covered by this directive. There are a number of reports that cite the IPPC directive (and the accompanying reference document for the textile industry) as a positive driver for compliance and technological change, especially for water and energy consumption of textile processing. The REACH regulation (EC 1907/2006) is expected to impact the innovative efforts, clearly aligned with environmental aims, of this sector. In addition to the

IPPC and REACH, the European Emission Trading System (Directive 2009/29), the Biocides Directive (98/8) and the European Eco-label scheme are important and positive drivers for this sector. Waste and landfill regulation are also reported to act as both a driver and a barrier for eco-textiles.

Our survey results point out correlations with eco-innovation mainly in two types of innovation, these are supporting activities and design, the latter in terms of environmental implications quite an important one. Waste and disclosure of chemicals used (REACH) might be affecting decisions on eco-innovation in textiles design. Relatively speaking other regulations are more likely to drive innovation in the textiles sectors. Amongst others the intellectual property rights regime seems to be important for a good number of innovations, but not for eco-innovation. Similarly, European regulations play no role on driving innovation in general in the textile sector. Conversely, technical norms (industrial standards) could be interpreted as a possible form of regulation likely to be driving eco-innovation in this sector, as noted by its correlation to the SINNOV variable.

Table 3-10 Correlations between regulation and innovation (textiles and clothing)

Innovation type	SINNOV	Products	Services	Manufacturing methods	Logistics, delivery or distribution	Supporting activities	Management systems	Layout of production organisation	Industrial relations	Designs	Sales or distribution methods
Regulation type											
Pre-emption of regulatory risks	0.823**				0.733**	0.689**	0.760**	0.700**	0.645*	0.721**	0.556*
Hazardous materials											
Waste regulations	0.561*				0.504*	0.659**				0.650**	0.562*
REACH									0.610*	0.816**	0.604*
Energy regulations											
Alternative materials regulations						0.708**					
Other environmental regulations					0.502*	0.650**					
Other regulations											
Labour regulations	0.506*				0.519*	0.596**	0.509*		0.671**		
Agriculture regulations											0.675*
Workforce safety regulations					0.495*	0.656**	0.680**				
Safety on usage or delivery		0.508*				0.544*	0.547*				
Intellectual property rights regimes	0.700**	0.539*	0.578*	0.714**	0.667**	0.585*	0.680**	0.669**		0.589*	
Industrial standards	0.595*				0.522*	0.661**	0.575*				
Land regulations	0.730*						0.777**	0.773**	0.744**		
Financial regulations	0.562*				0.527*		0.509*				

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
Source: Innovation Watch Survey

🟩 Highly correlated
🟨 Moderately correlated
☐ No Correlation

The example provided below suggests that the anticipation to REACH regulation, in combination with pioneer strategies in niche markets is motivating functional garment apparel companies to develop a great deal of eco-innovation in eco-design. In fact, a large number of examples can be found in a number of apparel companies' website where statements are being made around the message that "REACH is an important driver for environmental responsibility in our company". Most of textile or apparel producers are seeking to be fully compliant with the new law and is progressively introducing REACH. They claim to be closely working with European Notified Bodies in the understanding of responsibilities and implementation of REACH. As a result, they are actively sourcing alternative "greener" substances and materials.

In reality since the early 1970s specialised firms in this sub-sector have delivered and produced functional outdoor clothing with environmental considerations, particular incorporating recycled or natural fibres. In the past, problems of specifications of fabrics in terms of flame retardant features signified a barrier to a wider adoption of intelligent textiles[30] (Storey, 2002). The REACH regulation is expected to contribute to overcome these issues. A number of pioneer firms in Europe are anticipating the requirements imposed by REACH on the elimination of listed chemical substances. Due to their strong R&D capabilities, most specialised outdoor clothing companies have incorporated corporate codes of conduct (something important in the apparel sector), but laggard firms are not necessarily engaged into developing of eco-materials. Clearly, innovation in design (eco-design) is a cornerstone to develop such products.

Box 3-9 Eco-fibres in European functional outdoor clothing products

Since early 1970s, the American-based company Patagonia has been making functional outdoor clothing that is made with environmental considerations. Since 1993 the company is making fleece products made from post-consumer recycled plastic soda bottles. Nowadays Patagonia uses different types of eco-fibres in a number of their products; in particular: recycled and recyclable polyester, organic cotton, hemp, organic wool and chlorine-free wool.

Scandinavian competitors have also started adopting a similar trend for the use of eco-materials into their products. Norwegian-based outdoors clothing manufacturing Helly Hansen (HH) launched in winter 2008 its Ekolab R&D project. In anticipation to the REACH regulation, the first series of new eco-materials eliminated the use of PTFE (polytetrafluoroethane) thermoplastics for waterproof breathable membranes, and started using polyurethane membranes and fluorocarbon-free coating materials. PTFE was invented patented in mid 1940s and is associated to PFOA (perfluorooctanoic acid) emissions. Textile products such as carpets and fabrics are products which contribute to these emissions, since they contain PFOA. In addition, HH also reports using environmentally friendly dyes in their eco-nylon fabrics and have developed a fleece made of 60% recycled material. A similar trend is followed by the Swedish-based company Fjall Raven, which includes natural (e.g., natural cotton and bamboo) and eco-fibres (e.g., eco-polyester labelled as eco-circle) which is recycled in a closed-loop system developed by Teijin. Fjall Raven claims that this technology reduces energy consumption by 84% compared to production of new polyester material (from oil) and that CO_2 emissions are cut by 77%.

Finally, this firm ensures that no extra chemicals are added in any of their products, as a result of having clear guidelines in terms of code of conduct (social responsibility), product, environmental and animal policies. Another set of cases are the French-based companies Quechua and LaFuma. The former firm has not only developed products under eco-design principles (since 2007) using (organic cotton and) recycled polyester, but it has also introduced (since 2005) environmental management considerations in existing product lines (e.g., logistics, packaging, optimisation of textiles consumption, environmental accounting, etc.). The latter firm has developed a barometer of environmental friendliness of their products (Pure Leaf Grade), by measuring the use of eco-materials (which include life cycle analyses and eco-design), energy use, green supply chain management, sustainable transport and recyclability. Swiss-based Mammut reports using organic cotton for jumpers under the brand bioRe® and offsets the CO2 emissions from rope production (climate-neutral rope production) through the MyClimate initiative.

In contrast, e.g.,, UK-based companies Trespass, Berghaus and Regatta, Dutch-based Gaastra, Czech-based Loap, and the Spanish firm Trangoworld do not seem yet to be including eco-fibres in their current product portfolio (of functional outdoor apparel). But overall the description of their materials/technologies does not include any reference to eco-fibres. On the positive side, some of

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[30] E.g. Climatex had great success in the American market but failed to penetrate the European market in the 1990s. See the case description in Annex 1

these companies do have an ethical trading policy (e.g., Regatta), reporting first steps towards corporate social responsibility and long term corporate sustainability (e.g. Tresspass), or having the intentions to do so (e.g., Berghaus). This is probably due the fact that, in addition to fashion ability and attractiveness, the right combination of materials is chosen and tested to perform a function (e.g., waterproof, breathable, repelling insects, compactness, warmness, etc.) to provide comfort in the use of the product. Functional outdoors clothing producers are in close contact with user's needs (e.g., hikers and mountaineers), whose social demands are clearly interested on nature conservation, fair trade and third world countries development and organic farming/clothing. This case shows that proactive companies are taking the lead in relation to using eco-products for gaining rents in the market.

Source: Patagonia (2007), Helly Hansen (2008), Fjällräven (2009a, 2009b), Décathlon (2009), La Fuma (2009), Trespass (2009), Berghaus (2009), Regatta (2009), Gaastra (2009), Piccollo (2009),and Trangoworld (2009)

3.11 Regulation and eco-innovation: Lessons learnt

One of the objectives of this study is to assess the potential for policy and regulation to foster eco-innovative. Over the last four decades regulation has been the most important policy instrument related to the environmental behaviour of entire sectors of the economy. In the past, regulation has been seen frequently as a negative factor hindering competitiveness. The number of environmental issues along the supply chain at the sector level as outlined in chapter two indicates that the room for regulatory intervention has been ample and could have affected negatively some industries. The fact that industry and services must meet policy and regulatory demands have had a negative conation in the business side, frequently this implied net cost to business operations.

The new evidence brought in this chapter suggests a likely evolution of the relationship between regulation and environmentally related behaviour at the sector level. Eco-innovation offers a different dynamic where businesses and environmental protection enter a win-win situation. Evidence found in the sector specialised literature; the case studies presented by sector where regulation promoted eco-innovations, and the quantitative evidence presented indicate so.

In the survey results presented, the correlation between regulation and innovation indicates that those firms in average with higher scores in regulation questions (i.e., reported higher regulatory pressure) also reported in average higher number of innovations in the last three years prior to the survey. A number of environmental regulations were assessed including waste, hazardous materials, REACH, alternative materials, energy, other environmental regulations not mentioned in the questionnaire and associated pre-emption of regulatory risk. The correlations found in the sectoral analyses indicate that in some sectors their respective innovative activity is underpinned by environmental considerations. An additional finding is that in general, with the exception of the construction sector, other regulations other than environmentally driven, resulted more frequently and with more significance associated with innovation.

The presentation in the previous sections gave a varied landscape of the relationship between regulation and policy with eco-innovation. We identified three types of sectors concerning eco-innovation intensity and regulation intensity. At the top the aerospace and construction sectors show a relative large number of regulations that resulted significantly related with environmental regulations. In the middle we found the textiles and clothing, wholesale and retail, automotive. The lower end corresponded to electrical and optical equipment, KIS, biotechnology and food and drinks. It must be noted that for all sectors - with the exception of the aerospace and construction sectors – the association of environmentally motivated regulations with innovation was weaker than other regulations affecting the behaviour of business.

A cross sector analysis brings a significant and strong policy finding that concerns the indirect effect of regulation in all kinds of innovations, including innovations with an environmental motivation. It is very likely that regulation has a strong role in motivating eco-innovation across all sectors, two pieces of evidence support this. First, there is a strong inter-correlation between all types of innovation. This is proven by the high Cronbach alpha value found for the scale "SINNOVA" defined in Table 3-1. This suggests that any type of innovation implemented (e.g., product or process) is very likely to be accompanied or followed by other types of innovation (e.g., services or marketing). Second, when analysing the SIW-II survey data for the nine sectors, a similar pattern of strong inter-correlation was also found between the environmental regulations (i.e., waste, hazardous materials, REACH, alternative materials, energy, etc.) and all types of innovation. This strongly suggests that there are many indirect effects of regulation in the final eco-innovative behaviour at the sector level. This is likely to happen when policy or regulation target a specific type of innovation activity (product, process, service, marketing, etc.) and by association implicitly affecting other type of innovations, including eco-innovation.

4 Eco-innovation new markets formation

4.1 Introduction

Access to financing is one of the most frequently cited factors hampering innovation. The investment on innovation is risky and returns come frequently with a considerable time lag. Thus, timely investments and their focus make the difference in successful business. To a large extent this is the same for the current and future technological specialisation of sectors and regions. Signals of early market formation are of critical importance for policies aiming to promote eco-innovations that could underpin future growth while ameliorating environmental stress.

The use of financial data for the analysis as an indication of the early market growth of eco-innovations was suggested in previous EU-funded studies, but no empirical evidence was provided (e.g. in Coogan, Earhart et al. 2008; Huppes, Kleijn et al. 2008; Kemp and Pearson 2008). In this regard, private equity investments provide insights into the development of early markets of eco-innovations. In spite that there are many other financing options to bring new innovation to the market,[1] venture capital is an attractive source especially for risky investments which is associated to the emerging nature of novel eco-innovations. Because of the intrinsic nature of patenting of novel technologies, there is a bias towards VC investments in technological eco-innovations. Start-up companies, very frequently in the category of small and medium enterprises (SMEs), require investment to fully scale and/or deploy their innovations.

In attention to the above, this chapter presents an analysis about the levels of investment made on eco-innovation, where this is located, what innovations have been favoured and where the likely gaps are. All opportunity areas identified in chapter two are included in the analysis. This analysis includes traditional areas related to environmental technologies (e.g., monitoring and control of air pollution, recycling, wastewater, etc.), energy efficiency, energy infrastructure, energy storage, sustainable production, transport and eco-materials. We also include data from agro-food eco-innovations and renewable energy generation. The previous is made under the idea to provide elements to connect and compare our analysis with recent reports of the European eco-industry.

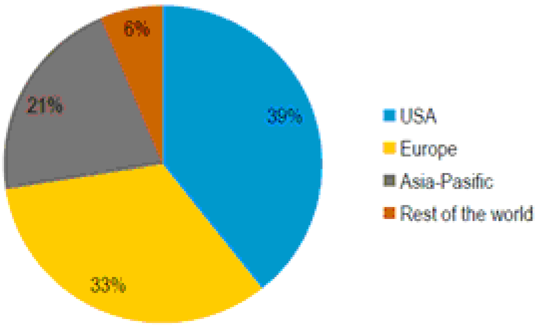
The content of this chapter is as follows. Section 4.2 provides a general picture of the European eco-industry, its estimated value, the European market share of environmental technologies and the value of six lead market areas of eco-innovation. Section 4.3 provides an overview of market growth of European eco-innovation markets in comparison to global trends (using risk capital investments, merger and acquisitions and IPOs in selected eco-innovations as a proxy). This analysis attempts to provide an answer to where eco-innovation investments are located (North America, Europe, BRICs, or elsewhere). Section 4.4 shows the geography and type of eco-innovation. Here we identify which eco-innovation markets have received venture investments, and if there are eco-innovation market areas where investments are currently lacking. Section 4.5 summarises the findings of this chapter.

4.2 Europe’s eco-innovation global market position

The purpose of this section is to provide a brief overview of what we know of the size and value of eco-innovations markets. We show that in more mature areas of eco-innovations there are well defined players already positioned in the markets.

The reports on the eco-industry commissioned by the EC (Bilsen et al., 2009a, Bilsen et al., 2009b) and the studies commissioned by the German Ministry of the Environment (Edler et al., 2007, Henzelmann et al., 2007, Buchele et al., 2009) are the latest point of reference for the analysis of how more traditional eco-innovation markets are allocated and the economic contribution to the European economy. The following paragraphs provide a summary of (1), the market position of Europe compared with other world regions in well-established eco-innovation areas and recent estimations of the size of the eco-industry and six lead markets for eco-innovation (2).

Figure 4-1 World's environmental market share 2008

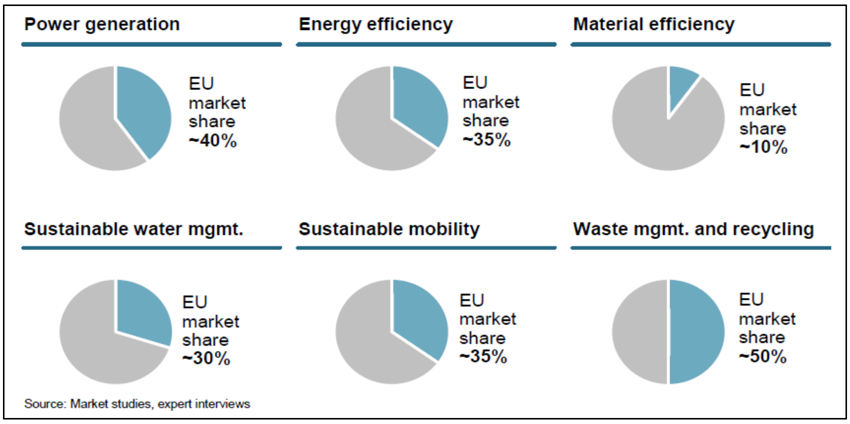


Source: STC (2009) after Datamonitor estimations

There are several estimates of the current and expected eco-innovation driven growth. Bilsen et al.,(2009a) suggests that Europe has a leading role in the world picture with market shares ranging from 30% to 50% depending on the particular sub-sector (Bilsen et al., 2009a). Estimations from the Swedish Trade Council (STC) shares that view. The STC reported that, for the year 2008, a 33% share of the world’s environmental market corresponded to European firms (Swedish Trade Council, 2009).

The current market share of Europe compared to other world regions was also estimated. These refer to waste management and recycling (50%) power generation (40%), sustainable water management (30%), sustainable mobility (35%) and energy efficiency (35%) (Edler et al., 2007).

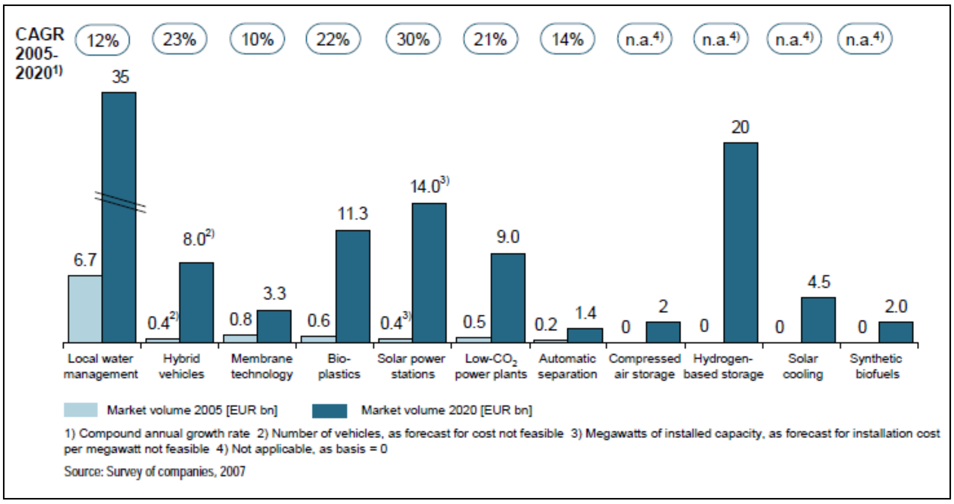
Figure 4-2 European market shares in selected eco-innovation areas



Source: Edler et al. (2007)

According to Henzelmann et al.(2007), market growth for six lead eco-innovation markets would reach €2,200 billion by 2020. These lead markets include water management, hydrogen based storage, solar power stations, bio-plastics, low-carbon power plants and hybrid vehicles are expected to experience high rates of market growth (Henzelmann et al., 2007).

Figure 4-3 Estimated growth of selected eco-innovation markets 2005-2020



1) Compound annual growth rate 2) Number of vehicles, as forecast for cost not feasible 3) Megawatts of installed capacity, as forecast for installation cost per megawatt not feasible 4) Not applicable, as basis = 0

Source: Survey of companies, 2007

Source: (Henzelmann et al., 2007) Edler, Blazejczak et al. (2007), p.16

Buchele, et al. (2009) estimated the size of the same six lead global eco-innovation markets in about €1,400 billion in the year 2007 and €3,100 billion by the year 2020. According to this estimation the energy efficiency market in the year 2007 was the largest of all with €540 billion. This was followed by sustainable water management (€361 billion), sustainable mobility (€200 billion) and power generation and storage (155 €billion). At the bottom of the list are material efficiency (€95 billion) and waste management and recycling (€35 billion).The projected market size by 2020 of the above mentioned categories is estimated in €1030 billion (~90% increase), €805 billion (~120% increase), €300 billion (~50% increase), €615 billion (~295% increase), €335 billion (~253% increase), and €55 billion (~57% increase), respectively (Buchele et al., 2009).

In a similar vein, a study on the size of the European eco-industry (during the year 2006) mentions € 300 billion and 3.4 million of employees (Bilsen et al., 2009a, 2009b). The growth rate of the eco-industry was estimated in a rate between 7 to 8% (in nominal terms) and the performance (in terms of productivity) was higher compared to the average in manufacturing sectors of the European economy (for the 2004 to 2006 period). In terms of revenues, with the notable exception of renewable energy, it is less profitable than the manufacturing industry (Bilsen et al., 2009a).

The latest estimation of the value of the eco-innovation market was provided by the Green Transition Scoreboard® (by Ethical Markets Media). This scoreboard monitors (non-public) investment in the following areas[31]: renewable energy, sustainable construction, cleantech (energy storage, energy infrastructure, sustainable transportation, water and wastewater, air & environment, eco-materials, smart manufacturing, sustainable agriculture, and recycling and waste), smart grid and corporate (environmental and energy) R&D. This source reported in August 2011 a $2.4 trillion cumulative worldwide investment in eco-innovation during the period 2007-2011. The expected cumulative investment by the year 2020 was estimated at $10 trillion. One of the key messages of this report is that investment in moving away from traditional sectors, and being directed to emerging areas of eco-innovation such as the ones presented in chapter 2 (Ethical Markets Media, 2011).

In general, neglecting differences in market shares and projections of growth the reports available indicate a good global position of the European eco-industry. Despite the global financial crisis, the reports above highlight the importance of creating an attractive climate for investors, where European policy makers are recognised to have remained committed to environmental and sustainability goals. The following section presents an analysis of private equity investments in eco-innovation for Europe, its position compared to world, and in a number of eco-innovation markets currently in formation.

4.3 Eco-innovation new markets formation

Given that there are emerging eco-innovation markets it is of interest to map Europe's current global position. The estimation of the degree of growth and maturity of a market is a particularly difficult task mainly due to the definition of boundaries and scale (micro vs. macro). It is acknowledged that a sound estimation of the growth rate of a market provides a good estimate of the stage in the innovation/product life cycle. In general, at the micro level, rates of market growth are associated to a number of variables such as: R&D costs, marketing costs, product margins –often with reference to sales, and rising investment (Tidd et al., 2001). Considering some time lag, the level of venture capital investments and merger and acquisitions are a good indication of new market formation and consolidation activity (Kogut et al., 2007, Hekkert et al., 2007, Johnson and Jacobsson, 2000).

In this section we use private equity investments on eco-innovation and mergers and acquisitions as a proxy for early market formation. As noted in the introduction, using data on venture capital investments is one way of gaining insights into the development of novel and emerging eco-innovation technologies and markets. Venture capital investments are a form of investment with clear exit strategies with returns on investment horizons between five to seven years. While there are many other financing options to bring new technologies to the market, venture capital is an attractive source especially for risky investments (OECD, 1996) –such is the case of emerging eco-innovations. To get a better overview of the development stage of the technology/market also investment volumes from floatation on the stock exchange (IPOs) and mergers and acquisition (M&A) transactions are included

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[31] The main data sources used for their calculations include data from the Cleantech Group, LLC, and other reporting sources such as Bloomberg, Yahoo Finance, and the NASDAQ OMX Green Economy Global Benchmark Index.

in the analysis.[32] The M&A transactions give a good indication of market consolidation and maturation.

The analyses presented below are based on data that cover the whole investment cycle from venturing (seed, first-round, follow-up, private equity) over IPO's to Mergers & Acquisitions (M&A) (acquisitions, merger, joint venture, divesture, management buyout, etc.). To allow for a comparison between the most important economic regions the data is grouped into the following four competitive regions: North America, Europe, the BRICs and 'Others', which is a rest category for example comprising Japan, South Korea and Australia. The data cover the period between 1999 and 2009; where 2009 only comprises transactions for the first three quarters. Given the data available and the difficulty to measure organisational aspects of innovation using venture capital, a clear bias is unavoidable towards technological eco-innovations. The reason for this is based on the fact that most venture capital investments are made in high growth firms based on the commercial application of technological innovation (OECD, 1996, Carleton, 1986).

4.3.1 Geography and type of eco-innovation investments

The graph below shows that total investments in venturing, IPOs and M&A transactions for the 1999-2009 period, which seems to be concentrated in North America (USA and Canada) and Europe. The BRICs and other countries (including Japan, South Korea and Australia) lag behind. Over the last 10 years, investments in North America totalled roughly $50bn. Europe follows closely with about $45bn dollars of investment. However, the investments concentrate heavily in one technology segment: energy generation.[33]

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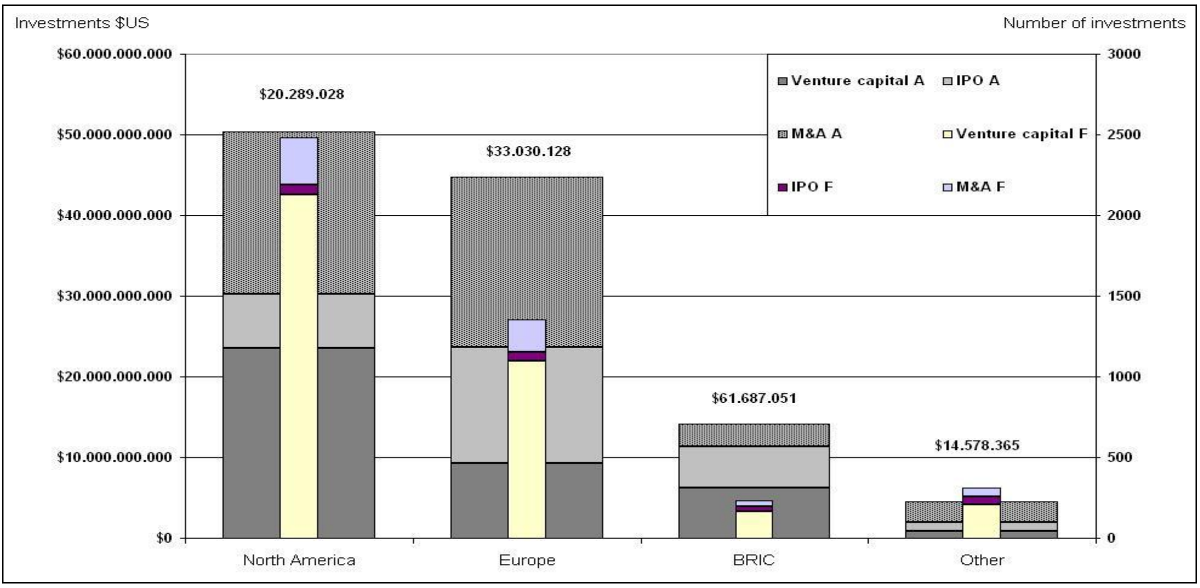
[32] Floatation on the stock exchange (IPOs) and mergers and acquisition (M&A) transactions provide a better overview of the development stage of the innovation/market investment volumes. The rationale for including M&A in the analysis of eco-innovation is twofold. First, mergers and acquisitions are an indication of growth of capital and production capacity in small firms and hence an investment growth in innovations that are already in the market. Secondly, the same variable is an indirect indication of corporate activity in eco-innovations. The meaning of this is that well established players may be acquiring assets of new firms and providing expertise or access to markets, hence contributing to its growth and survival. For the case of IPOs, this is a variable related to market consolidation, where small and young firms issue common stock or share to the public seeking more capital to expand and hence become publicly traded. IPO is considered they inflection point where investment gains can be redirected back to venture capital investment funds. See Carleton (1986) and OECD (1996).

[33] Energy generation includes renewable energy technologies such as wind and solar power, biofuels, but also more prospective technologies such as geothermal and marine technology.

Figure 4-4 Global venture investments in eco-innovation by competitive region 1999-2009[34]



Source: TNO estimations based on Cleantech Group data

Figures on the share of energy generation investments in terms of volume and number of investments for the different competitive regions show a clear European leadership closely followed by BRICs. In total (all regions), 68% of investments fall in this category by volume and 35% by number of investments. This share is higher for Europe (83%) and the BRICs (77%) showing the high level of activity in this segment in these markets. In North America this value lags behind, with 53% of investments.

Excluding data on energy generation clearly shows that investments in the rest of eco-innovation areas are highly concentrated in North America. Out of the total global investments, 86% are represented by venture capital investments, whereas 3% are represented by IPOs and 11% by M&A transactions. Nevertheless, the average investment size is larger in North America ($14m) compared to Europe ($9.5m). Only in the BRICs the average investment is much higher ($29m) (see figure below).

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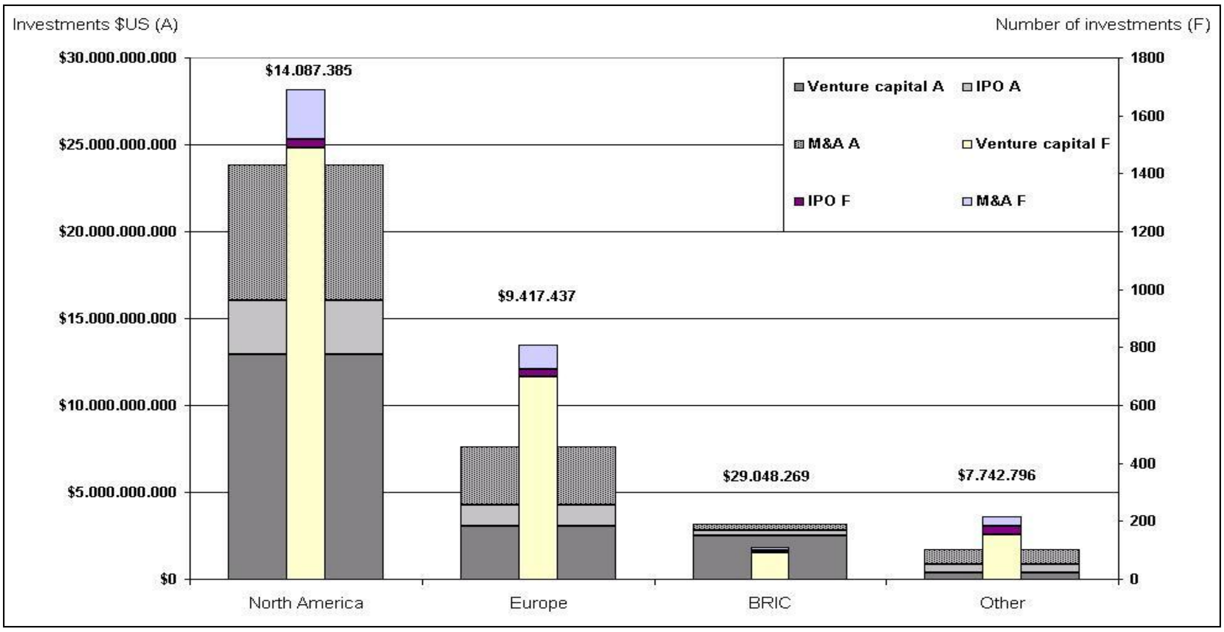
[34] In the rest of this chapter figures showing trends on eco-innovations venture investments are presented by investment type (venture capital vs. IPOs vs. M&A transaction) and competitive region. All graphs display not only the investment volume (US $) but also the number of investments (frequency) to allow for a more objective comparison between regions. The investment volume is always displayed by the wider column in shades of grey, whereas the frequency is displayed by a thin, coloured column. Please note that the figures provided above of each column indicate average size of investments values (total volume of investments/ number of investments).

Figure 4-5 Global venture investments in eco-innovation 1999-2009 (excluding energy generation)



Source: TNO estimations based on Cleantech Group data

The share in number of investments is roughly equal between the different investment types in North America, Europe and the BRICs. The share in terms of volumes differs greatly. North America commits more than half of total investment volume to venture capital, the BRICs almost 80%, whereas in Europe only 40% of funds flow in this category. Instead, in Europe the share in volume of M&A transactions is much higher.

Table 4-1 Share of investment types in total investments between competitive regions

Category	North America	Europe	BRIC	Other	Total
Number of Venture investments	88%	86%	84%	71%	86%
Number of IPOs	2%	3%	5%	13%	3%
Number M&A transactions	10%	10%	12%	15%	11%
Volume of Venture investments	54%	40%	79%	21%	52%
Volume of IPOs	13%	16%	9%	31%	14%
Volume of M&A	33%	44%	12%	47%	34%

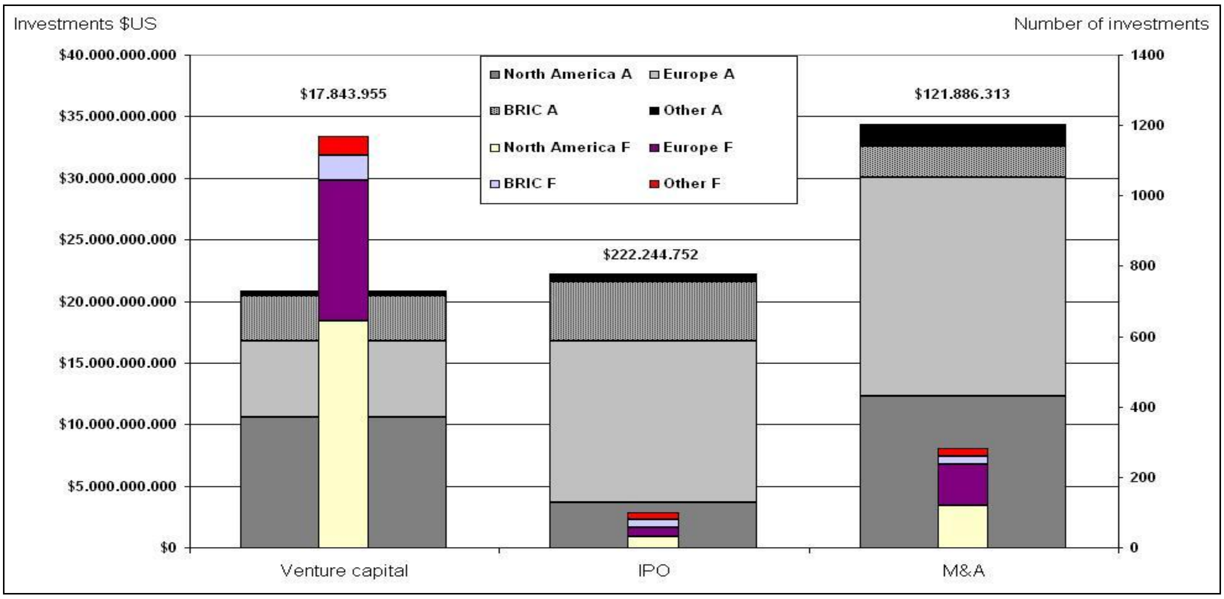
Source: TNO estimations based on Cleantech Group data

4.3.2 Venture investments in renewable energy generation

Given the current attention on low carbon renewable sources, the area of energy generation has received a considerable amount of venture investments. Examples of eco-innovation areas in the field of energy generation include biofuels (e.g., ethanol, algae biodiesel, biogas), wind (e.g., turbines, fans), solar (e.g., concentrated PV, thin films), hydro-marine (e.g., tidal, ocean floor), and geothermal.

Energy generation is relatively a mature technology segment, with IPO and M&A investments outweighing venture capital investments in terms of volume. This segment attracts around 2/3 of total investments; this clearly indicates the importance and maturity of the technology area. The figure below suggest that in renewable energy generation markets - given the nature of venture capital and the high level of consolidation indicated by mergers and acquisitions - Europe is very likely to continue to be one of the leaders in the global markets.

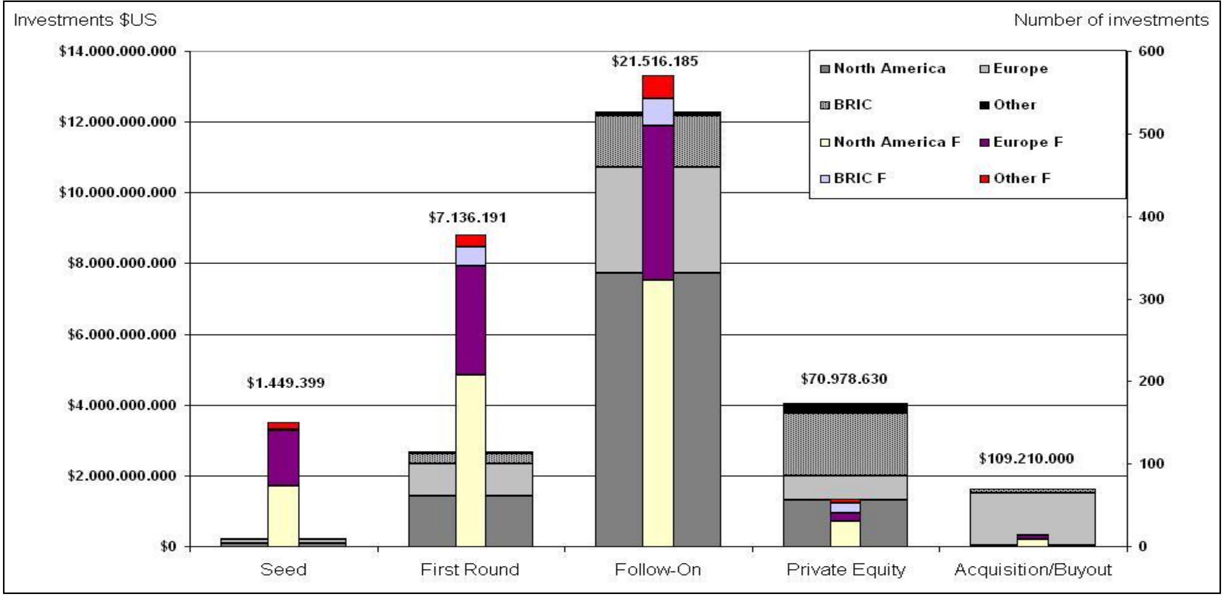
Figure 4-6 Global venture investments in energy generation by financing type



Source: TNO estimations based on Cleantech Group data

This is further supported by data looking at the different financing stages, with relatively high levels of private equity and buyout activity taking place in energy generation compared to the other eco-innovation areas.

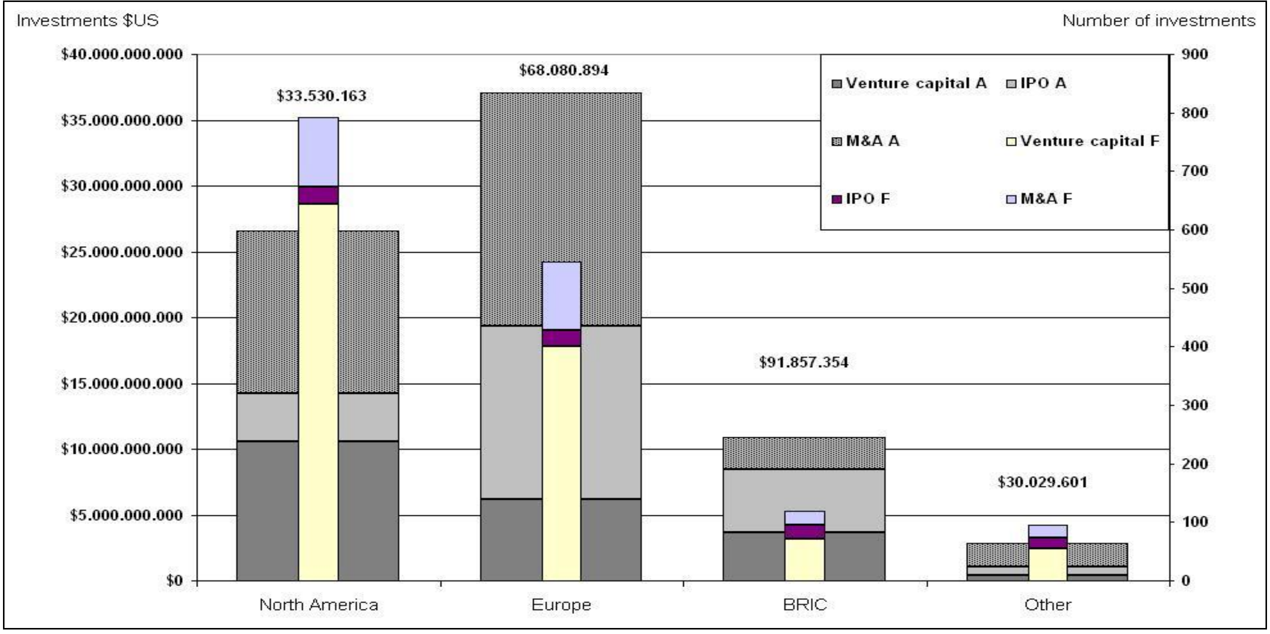
Figure 4-7 Global venturing investments in energy generation by financing stage



Source: TNO estimations based on Cleantech Group data

Europe has a clear lead in terms of total investment volume in energy generation, with much higher IPO and M&A investments. However, the total number of investments is larger in North America, just as the amount of venture capital invested (first round and follow-up investments), which are crucial financing stages for entrepreneurs.

Figure 4-8 Global venture investments in energy generation by competitive region



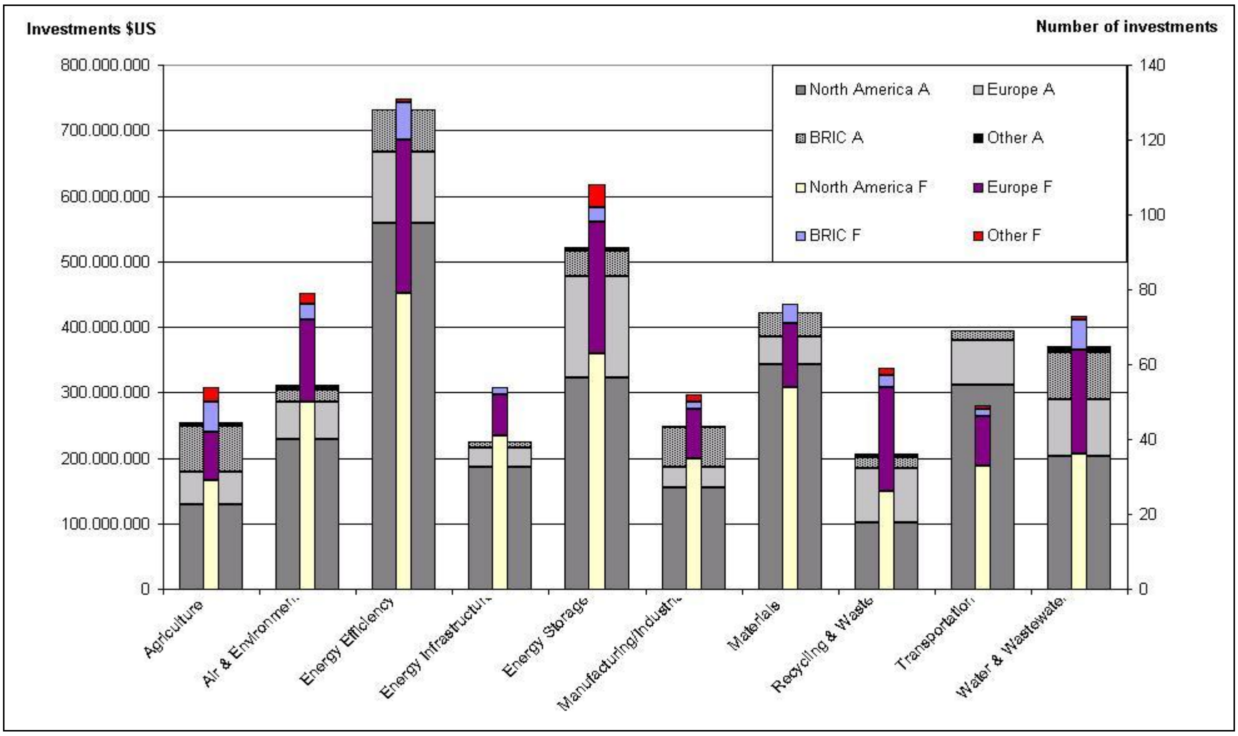
Source: TNO estimations based on Cleantech Group data

It is clear from the data above that energy generation constitutes an important share of the total investment of eco-innovation in Europe and the world. It is relevant to mention that, however, in the past three years the amount of global investments in renewable energy technologies has decreased. Albeit not radical, solar technologies have seen a decrease in investment since 2007. In 2009 alone, venture investments in solar technologies decreased 60%. In contrast, energy efficiency (+ 47%), and sustainable transportation (+ 39%) reached record levels and are now closing the gap with solar in terms of investment levels (around $1billion in 2009). Bio-fuels are also experiencing, for four years in a row, a decrease in the value of venture investments (investment in 2009 halved the one in 2006). Wind technologies have also been down four years in terms of investment. On the contrary, smart grid technologies are also moving up in the field of venture investments ($414 million) whereas water and waste water signed a record number of deals and agriculture has equalled the investment values of the latter category (Cleantech Group, 2010). The previous reflects a process of diversification and growth in a number of investment areas not fully exploited before. In order to obtain a much better picture of the market growth of other eco-innovation areas, for the remainder of our analysis we exclude the area of energy generation.

4.3.3 Venture investments in other eco-innovation markets

In order to provide a picture of how dynamic investments have been in Europe compared to the rest of the world, the following graph presents a comparison of venture investments by competitive regions in terms of frequency (F) and value (A). Venture investments by competitive regions have seen the dominance of North America which is confirmed across a number of eco-innovation areas. However, there a number eco-innovation areas where the share of European venture investments is higher than average in terms of frequency (of investments). These are by far: energy efficiency energy storage, recycling & waste, and water & water management. However, this high share in number of investments is not reflected in terms of volume of investment for energy efficiency and water & water management. This is actually a tendency across eco-innovation areas, with smaller average investment size, particularly compared to North America.

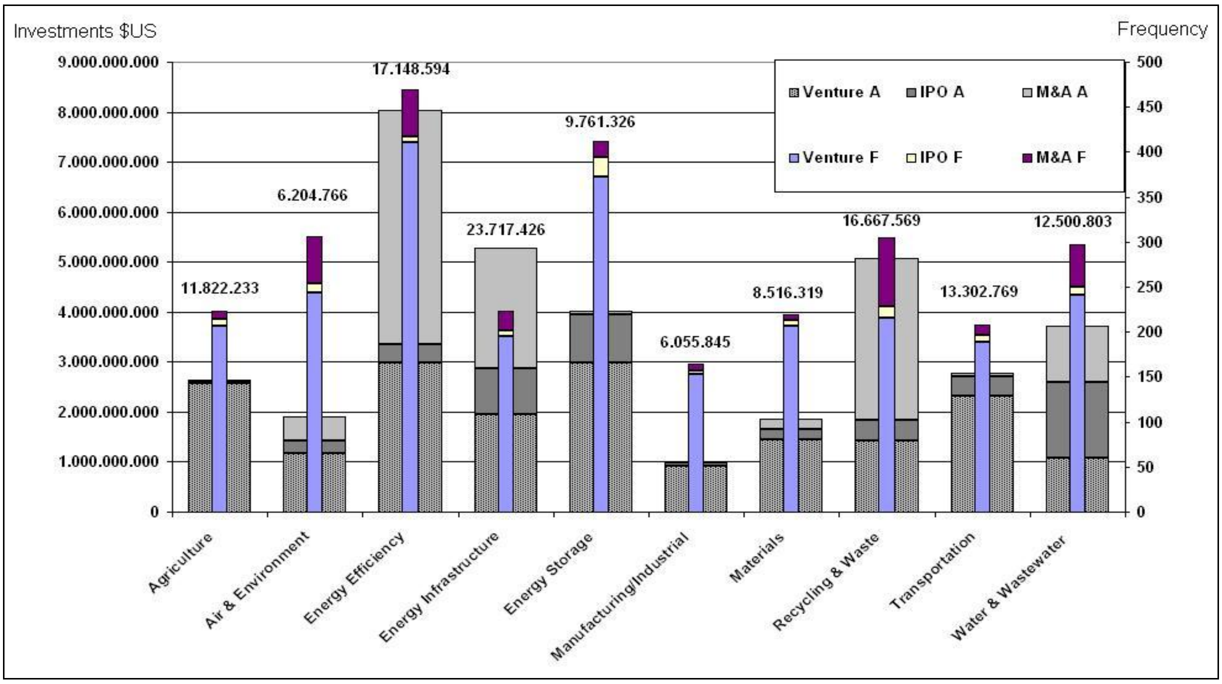
Figure 4-9 Global venture investments by competitive region (excluding energy generation)



Source: TNO estimations based on Cleantech Group data

The eco-innovation areas (excluding energy generation) which have attracted the highest investment volume at the global scale are: energy efficiency, energy infrastructure, recycling & waste, energy storage and air and environmental control. The first three have attracted particularly high volumes of M&A transactions indicating a more mature technology / market. On the other hand, energy storage, agriculture, manufacturing, transportation and materials have largely attracted venture capital with little or few IPO and M&A activity indicating an emerging technology / market. This pattern can be depicted from the graph below.

Figure 4-10 Global venture investments in eco-innovation 1999-2009 (by investment type)

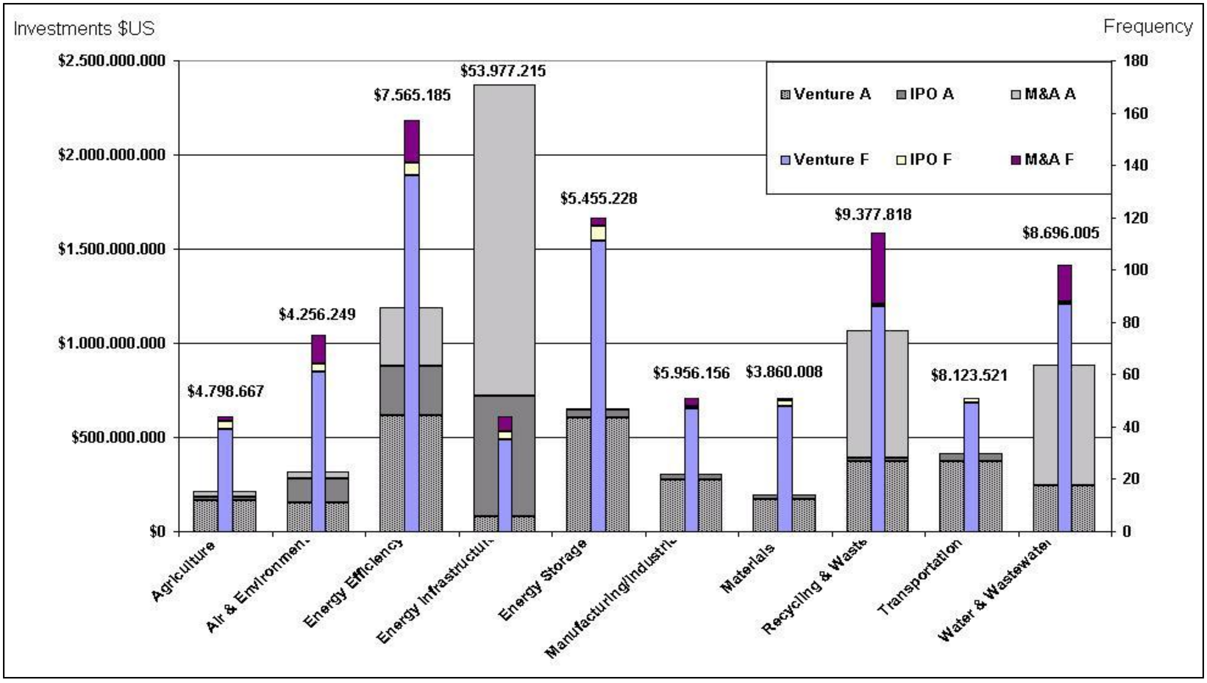


Source: TNO estimations based on Cleantech Group data

In Europe, the eco-innovation areas which have attracted the highest investment volume are related to ‘energy efficiency’, ‘energy storage’ ‘recycling & waste’, ‘transportation’ and ‘and water and wastewater’. All these areas, with the exception of transportation, have attracted particularly high volumes of M&A transactions indicating a more mature technology / market. Air & environmental control and agriculture present a rather small margin of M&A activity, whereas the rest of the areas have no activity.

An explanation for the intense M&A activity in the recycling industry could be due to the high concentration of the sector in a few players and a large number of buyout and divestment operations in the past few years. A similar case is found in the area of water and waste water eco-innovation. In terms of IPO activity, the areas of energy infrastructure and energy efficiency present notable activity, followed by air & environment. The areas of energy storage, transportation, manufacturing/ industrial, materials and agricultural eco-innovations show the first signs of IPO activity. The previous is also an indication of an emerging technology/market.

Figure 4-11 European venture investments in eco-innovation 1999-2009 (by investment type)



Source: TNO estimations based on Cleantech Group data

4.4 Conclusion

Although one of the aims of this report is to bring to the forefront eco-innovation activities and opportunities at the sector level, we have conducted an analysis in this chapter regarding the levels of investment made on eco-innovation to complement the last two chapters. To do so we followed the classification found in the literature. We identified where investments are located, what innovations have been favoured and where the likely gaps are.

Europe has a strong global competitive position of Europe in traditional eco-innovations. We used venture capital investment levels as an indication of new market formation activity. There has been a steady growth on investment activity in energy generation technologies over the last decade. The strongest global players are the US and Europe, where Europe follows the US by a relative small margin. It is likely that the markets on energy generation have well defined players in the global markets. The flow of investment to other technologies has been directed mainly to energy technologies (efficiency, storage and infrastructure), recycling and waste and monitoring and control equipment.

As mentioned in the introduction to this section, signals of early market formation are of critical importance for policies aiming to promote eco-innovations. According to the analysis above new eco-innovation markets in the early stage of formation that require further support for up scaling in Europe include advanced materials, advanced manufacturing, agro-foods, and sustainable transportation. Excluding data on energy generation the analysis indicates that most investments in other eco-innovations in terms of numbers and volume are focused in North America. In general Europe has proportionally followed the international trends on eco-innovation investments. Investment trends confirm the well-known fact that Europe commits fewer resources to venture capital and more to M&A transactions compared to North America and especially the BRICs. In Europe more than three quarters of all investments made is located in Western European countries.

These insights refer to markets already in formation where venture capitalists have already identified the opportunities. Given the relative low investments these markets can still be tapped in Europe with the right policy support. In the next chapter we identify further eco-innovation opportunities not necessarily produced within the sectors of interest of the SIW-II, but that find application across several sectors and contribute to the amelioration of environmental stress in the seven environmental priority areas of the European Union.

5 Future eco-innovation markets

The previous chapter discussed the competitive position of Europe in the current global eco-innovation markets. Europe has a strong position in markets like traditional environmental technologies and energy generation (e.g., wind and solar). It also shows a relative strong position in some eco-innovation early markets but with a considerable gap compared to the U.S. In chapter 2 we identified a large number of eco-innovations that are currently applied at the sector level. There was not data found on venture capital and mergers and acquisitions for those specific eco-innovations identified in chapter 2. The questions here are: considering these eco-innovations are there any emerging market opportunities across sectors? If so, what is their potential? In this chapter we define the likely boundaries and future eco-innovation markets for the sectors of interest in SIW-II.

This section is divided into three parts. Section 5.1 includes a brief description of the survey on strategic eco-innovators. The survey aimed to provide elements to test the eco-innovation market segments fit to the environmental priority areas defined in the introduction to this report. Section 5.2 briefly validates the market segments proposed in the introduction to this report, provides an indication of the current and future levels of diffusion by market segment, and shows what types of innovations are more frequent. Section 5.3 shows the levels of current and potential diffusion in each of the eco-innovation market segments for each sectors of interest in SIW-II. The last section highlights the main findings and conclusions of the chapter.

5.1 Strategic eco-innovators survey

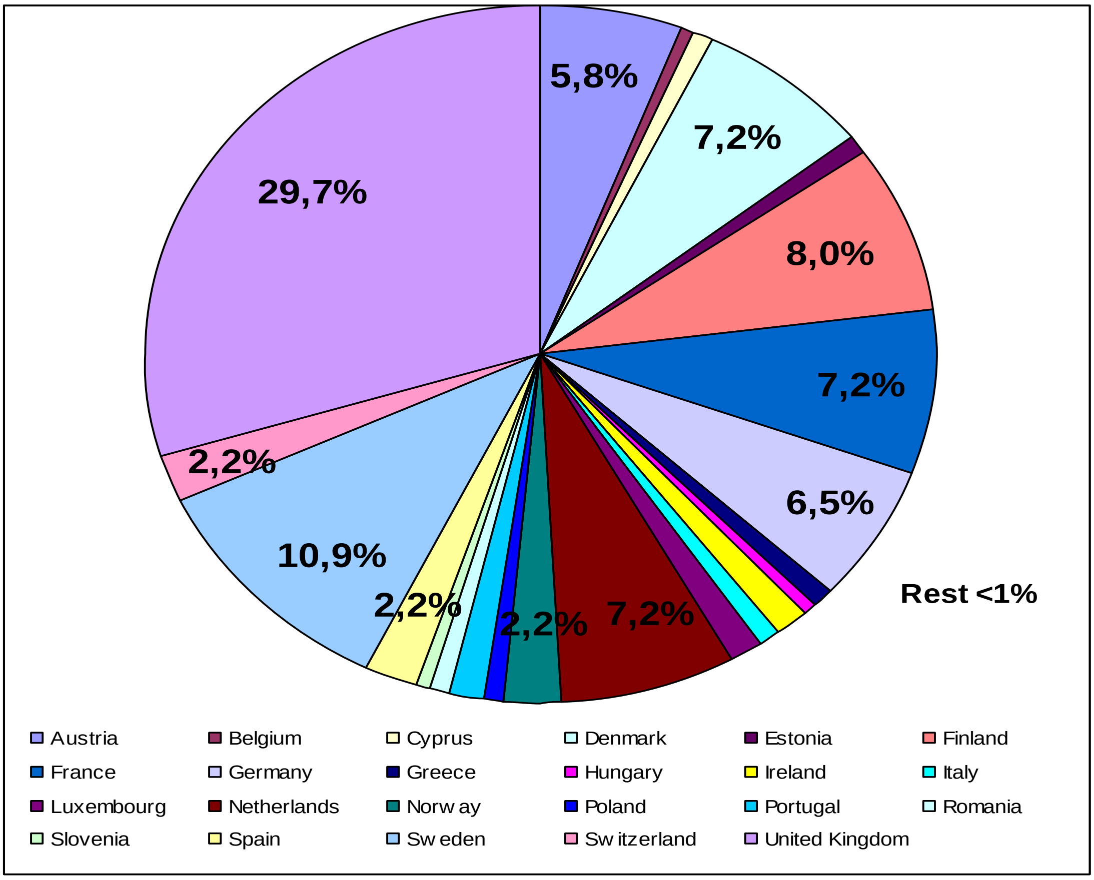
In the previous chapter we presented two different types of indicators to give a picture of the level of diffusion of eco-innovation, namely the levels of venture capital and mergers and acquisitions, and the market sizes of specific technologies. The latter all measured in monetary terms. The latter is one of the forms to present a picture of innovation diffusion. There is an alternative measure that is based in the types and numbers of technologies or units of applications in a market in a given period (Rogers, 2004). In this chapter we will follow this approach.

The results presented in this chapter are based on the ’TNO “Eco-innovation Futures survey”. Amongst other issues, the survey enquired strategic eco-innovators about the applicability and relevance of their eco-innovations to the market segments proposed and the current and potential application in the sectors of interest of SIW-II. The condition of a strategic eco-innovator was validated in the sample by the inclusion of a question where firms were asked if they had “a clear and explicit strategy to care for the environment leading the way to develop new opportunities created by eco-innovations”. The results showed that 91% of firms in the sample felt within the category of eco-innovation leaders; namely strategic eco-innovators.

The survey included 1819 firms developing eco-innovations currently being diffused in the sectors of interest of SIW-II. Above 97% of the respondents in the firms addressed were in high ranking management levels, mostly CEOs and/or innovation strategy directors. The rate of response was 10%. Only 151 usable questionnaires were finally included in the analyses.

The size of the firms captured in the survey were 45% micro (<10 employees), 33% small (<50 employees), 10% medium (<250 employees) and 12% large (>250 employees); hence, 88% of the respondents were SMEs. The survey included a sample from 23 European countries with the UK as the larger contributor with around 30% of firms (see figure 5.1). This was followed by number of firms from Sweden (11%), Finland (8%), Denmark (7.2%), France (7.2%), the Netherlands (7.2%), Germany (6.5%), and Austria (5.8%). Respondents from Spain, Norway, and Switzerland represented each 2.2% of the sample. Ireland, Luxembourg and Portugal contributed with 1.4% each. The rest of the countries contributed to the sample with less than 1% of respondents, namely Belgium, Cyprus, Estonia, Greece, Hungary, Italy, Poland, Romania, and Slovenia.

Figure 5-1 Geography of the sample of strategic eco-innovators



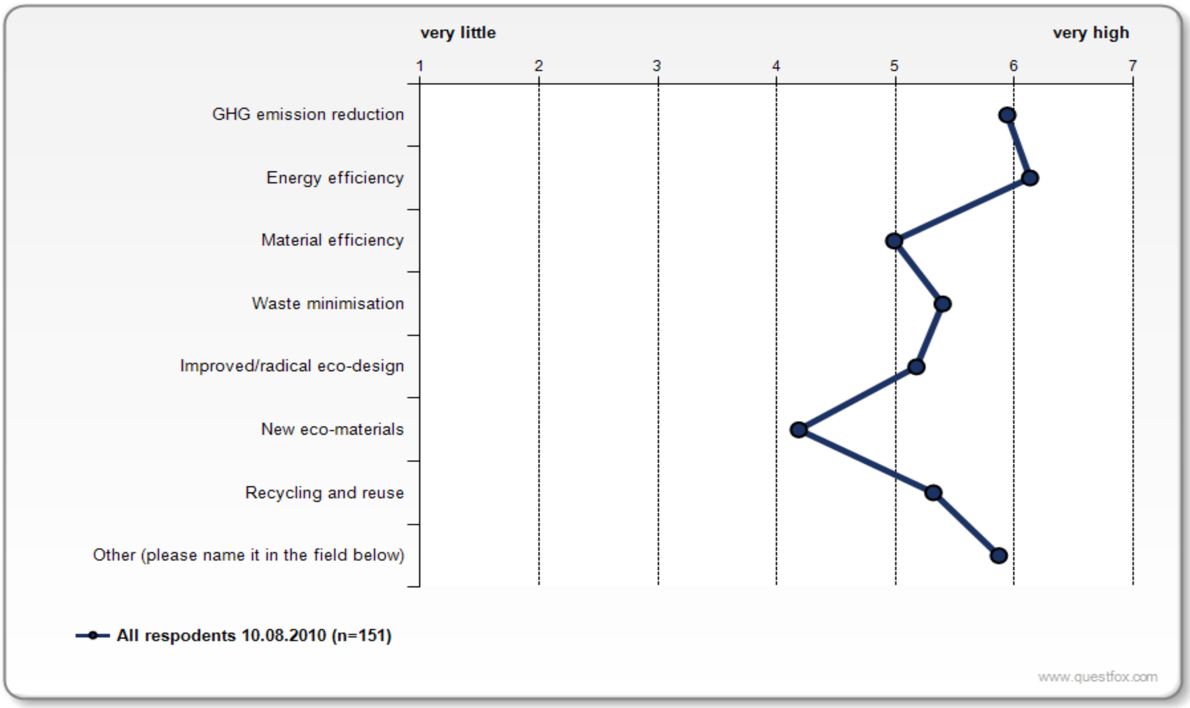
Following the heuristics for market definition presented at the outset of this report, a total of 174 eco-innovation opportunities identified in chapter 2 were included as items in the survey to test the market segments proposed. The survey included an item explicitly asking eco-innovators about the fit of their eco-innovations to a specific market segment defined by environmental priority area (as defined in section 1.2.2). The list of eco-innovations included in the survey questionnaire was not pre-imputed to any of these environmental priority areas. This was done to avoid response bias. At the beginning of the report we stated that it is primarily focused on eco-innovations in the ready-to-market and early market stages of diffusion. The survey questionnaire included a question about the market stage of the eco-innovations, 100% of responses indicated that their eco-innovations fitted in the category of early market.

5.2 Market definition fit and eco-innovation diffusion

In the introduction to this report, seven eco-innovation clusters or market segments were proposed to organise the innovations identified in chapter two. These were: eco-design, resources efficiency, energy efficiency, greenhouse gas reduction, waste minimisation, new advanced materials and reuse and recycling. In this section, we test the fit of the eco-innovations identified to a specific market segment and the current and potential diffusion across sectors.

One of the criteria mentioned in the methodology of this reports to define market segment boundaries regards the industry or public recognition of the market as a separate economic entity. In the case of the technologies surveyed, many are of general purpose and their applicability cuts across several sectors. The likely recognition of the market is arising by the policy relevance that environmental priority areas are taking at the European level and the recognition of the business sector that their technologies have a relevant role to play in those issues. The survey enquired firms about the fit that their eco-innovations have in each of the market segments defined. The fit is defined by the level of contribution their technologies have to reduce environmental stress. Figure 5.2 below shows that in general the technologies surveyed have a good fit to the market segments defined.

Figure 5-2 Fit to eco-innovation market segments definition

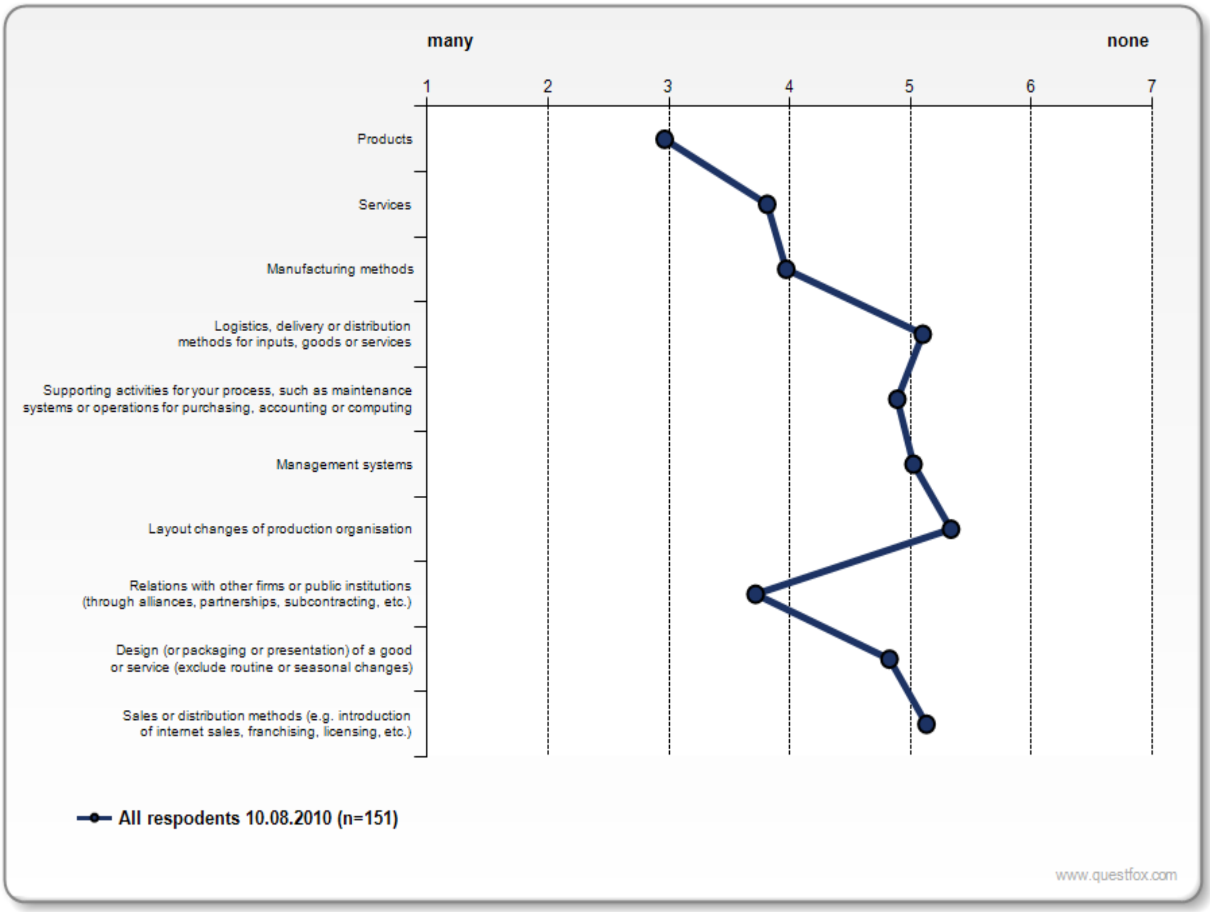


Source: TNO Eco-innovation Futures survey

Results suggest that the firms in the survey have high expectations in terms of the contribution of their eco-innovations to the area of energy efficiency and GHG emissions reduction. The areas of waste minimisation and recycling and reuse, eco-design and material efficiency form a group of variables with intermediate importance. The area of new advanced eco-materials was reported at the bottom of the list representing a relatively lower fit to the market segment definition. The reason is, that innovation in new materials, given their intrinsic generic application in all kinds of industries, can potentially cut across many markets. Saying this, new materials with benign environmental properties are by definition extremely important for sustainability.

The eco-innovation inventory presented in chapter 2 pointed out that the main types of innovations identified were intermediate inputs and final products ready for consumers. The survey enquired what type of eco-innovations currently promoted were the most frequent in the sample of firms. Figure 5.3 below reveals that product innovation is the type of eco-innovation with the largest mean value (i.e., larger number of eco-innovations). The second type of innovation most frequent is on industrial relations; closely followed by 'service innovation' and 'manufacturing methods'. On average, fewer innovations were promoted or offered for sale in the categories of 'design', 'supporting activities', 'management systems', ' logistics, delivery or distribution' and 'sales'.

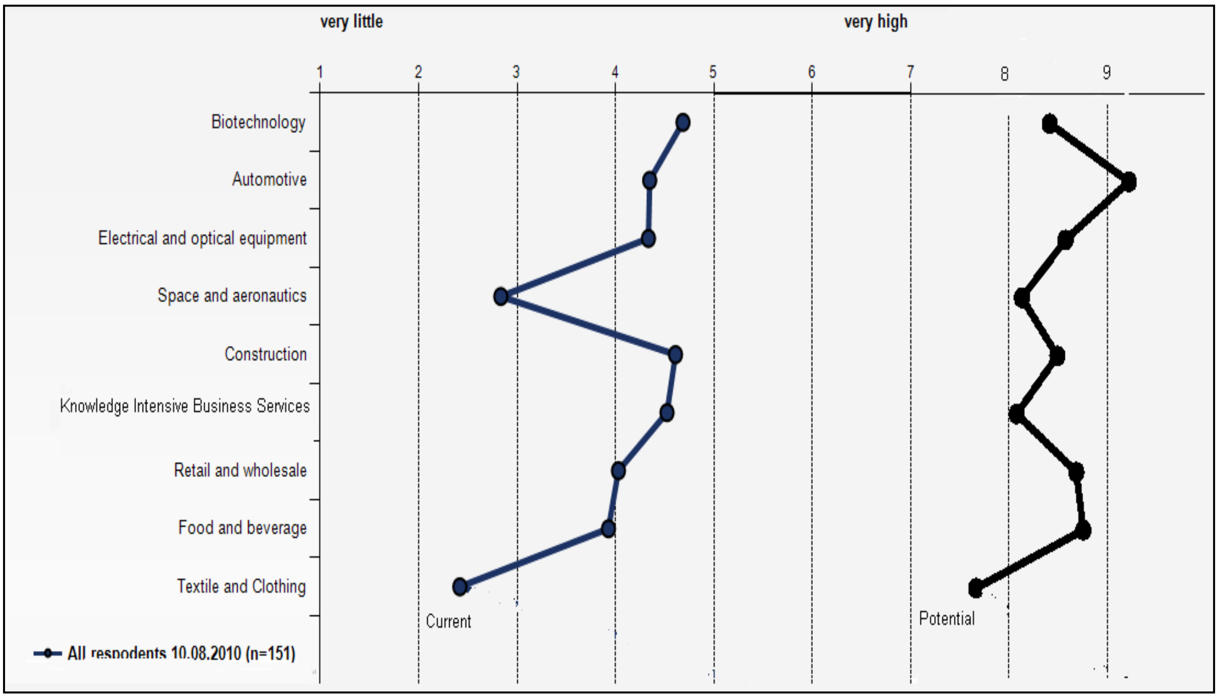
Figure 5-3 Types of eco-innovation in defined market segments



Source: TNO Eco-innovation Futures survey

Figure 5.4 below indicates that the potential of eco-innovations diffusion in all sectors is high. The potential diffusion is the gradient between the current and potential mean values. The survey reports that an increase in the diffusion and application of eco-innovation over the next three years is at least as large as the one reported now. A similar pattern is observable in the space and aeronautic sector. For the amount of potential application of eco-innovations (not currently diffused), the survey reveals that automotive is by far the sector with the highest potential. This is followed by very high expectations on potential eco-innovation diffusion in the food and drinks and wholesale and retail trade. In the figure below it is clearly observable that the highest jump in diffusion could be seen in the textile and clothing sector and space and aeronautics, with a twofold potential increase. In the next section we will explore which market segments present higher penetration of eco-innovation and what is the expectative for further market growth.

Figure 5-4 Eco-innovation diffusion potential in all SIW-II sectors



Source: TNO Eco-innovation futures survey

5.3 Eco-innovation potential

This section presents a measure of eco-innovation diffusion potential in those sectors of interest to SIW-II. As noted earlier, we use seven environmental priority areas as the basis for defining eco-innovations market segments. In the following, we give insights in the current and potential diffusion in sectors. At a more general level we give provide indication on eco-innovation activities at the sector level while implicitly showing the relevance of the broad environmental issues pressing the sectors surveyed. The presentation of diffusion patterns uses pie charts. In each pie chart the coloured area (right hand side of each pie chart) represents the applicability and fit to a market segment.

Figure 5.5a, below gives the percentage of technologies in the inventory that are relevant for the market segment and are currently applied and diffused. The potential market growth percentage is depicted in figure 5.5b. The grey area in both pie charts (left hand side of each pie chart) represents the eco-innovations that were found not relevant by eco-innovators for the market segment. In addition, some of the eco-innovations reported in this work may be encountered in more than one of the eco-innovation market segments defined in the introduction to this report. This implies that potential for eco-innovation diffusion must be conceptualised as the potential number of different applications possible across different market segments and sectors.

Figure 5-5 Current and potential diffusion of eco-innovation

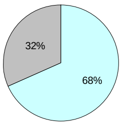
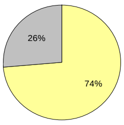
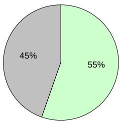
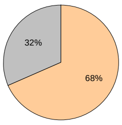
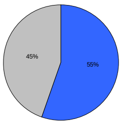
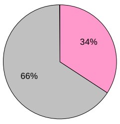
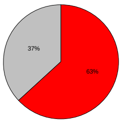
a. Energy efficiency (current diffusion) **b. Energy efficiency (not currently applied)**

For example, figure 5.5a above indicates that 74% of the total inventory of technologies included in the survey currently sold and applied solve issues of energy efficiency, while 26% of the technologies in the inventory are not relevant for the market segment. Figure 5.5b indicates that 75% of the technologies in the inventory could be applied and marketed in other sectors but that it is not happening now. Figure 5.5b is the diffusion potential unlikely to be realised by market dynamics only. In the remaining of this section we conduct a detailed analysis of the current and potential for eco-innovation in nine sectors.

5.3.1 The biotechnology sector

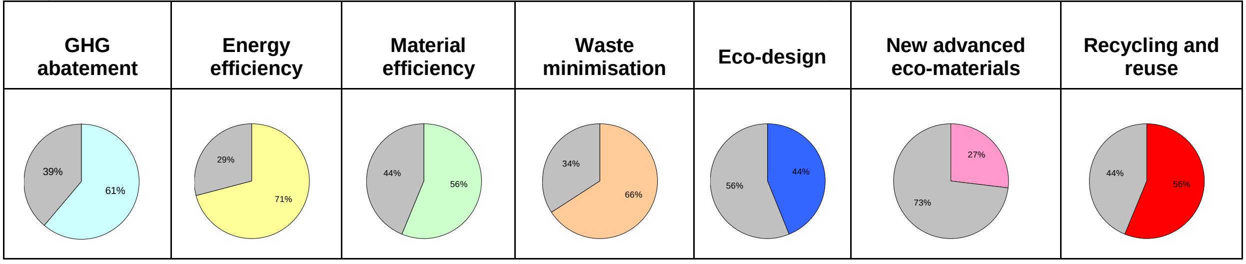
The figure below presents the eco-innovations that are being applied now in the biotechnology sector. The application of biotechnology eco-innovations to a particular environmental priority area is highest in the energy efficiency field, with 74% of the technologies in the inventory are being sold and applied to biotechnology firms. This is followed by GHG abatement and recycling and reuse (68% and 63%, respectively). New advanced eco-materials is the market segment with the lower number of technologies being applied (34%).

Figure 5-6 Eco-innovation diffusion – biotechnology sector

GHG abatement	Energy efficiency	Material efficiency	Waste minimisation	Eco-design	New advanced eco-materials	Recycling and reuse
						

The figure below shows the potential of eco-innovation diffusion. In the figure below a similar pattern is observable like in the previous figure, with energy efficiency (71%) at the top and new advanced eco-materials at the bottom of the list (27%). The figure suggests that the potential diffusion is twice as much as the current one. Eco-innovation opportunities of biotechnology linked to new eco-materials are manifold but the penetration in the market is low. For example, bio-based products are established in higher value business segments in the chemical industry, but these are still represent a niche of about 6% of the total products (Festel, 2010).

Figure 5-7 Potential eco-innovation diffusion – Biotechnology sector

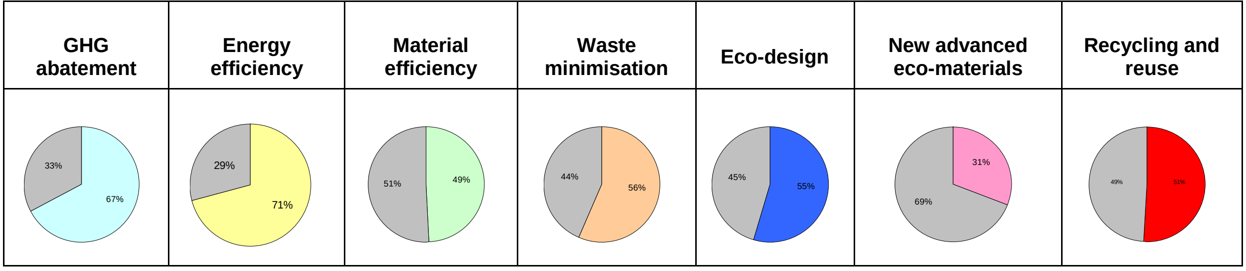


For the specific case of bio-polymers, a recent study suggested that their share in comparison to general polymers is only 2%, but the annual growth of this market in Europe (for 2003 - 2007) has been around 50% compared to 38% at a global scale (Shen et al., 2009). Technology and price competition from other well established technologies, economies of scale, competition among bio-technological platforms in terms of energy source (from biomass itself in refineries vs. from sunlight and carbon from atmosphere), and cost advantages constitute a major issue to overcome for the entire supply chain of many industrial biotechnology eco-innovations (OECD, 2009a).

5.3.2 The automotive sector

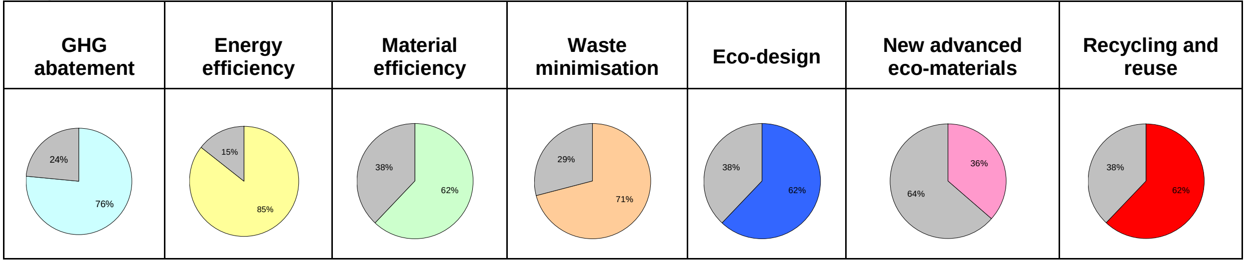
In the automotive sector the market segments of energy efficiency (71%) and GHG abatement (67%) show the largest number of eco-innovation applications. This is followed by waste minimisation (56%), with recycling and reuse (51%), eco-design (55%) and material efficiency (49%) next in line. New advanced eco-materials present lower diffusion (31%).

Figure 5-8 Eco-innovation diffusion – automotive sector



In terms of eco-innovation potential of automotive the energy efficiency (85%) and GHG abatement (76%) are the market segments with the largest potential for diffusion. This is followed by waste minimisation (71%), with material efficiency, eco-design and recycling and reuse next in line with 62% each. New advanced eco-materials similar to the biotechnology sector it has a 36% of the technologies in the inventory relevant to this market segment.

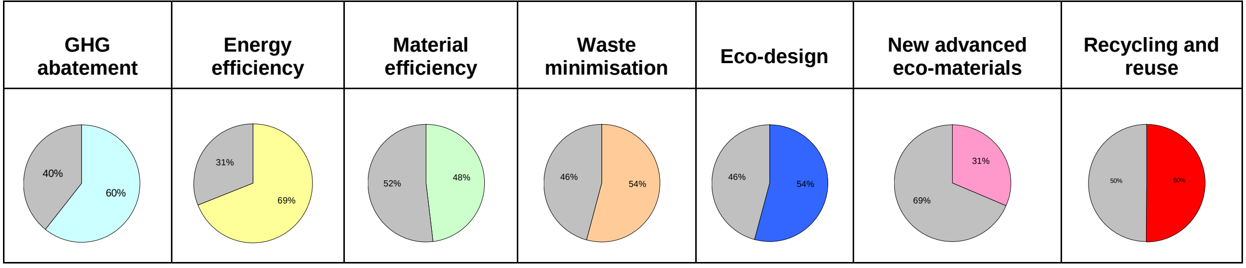
Figure 5-9 Potential eco-innovation diffusion – automotive sector



5.3.3 The electrical and optimal equipment sector

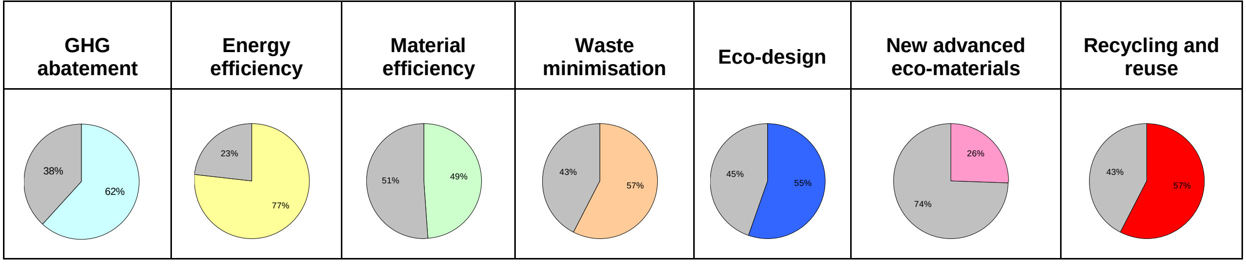
In the E&O equipment sector the market segment of energy efficiency has the highest level of eco-innovations applications 69%, followed by greenhouse gas abatement with 60%. Waste minimisation and eco-design received a similar qualification, of 54% of current application in the sector.

Figure 5-10 Eco-innovation diffusion – electrical and optical equipment sector



In terms of eco-innovation potential of E&O equipment eco-innovations energy efficiency (77%) and GHG abatement (62%) are the market segments with the largest potential. This is followed by waste minimisation and recycling and reuse with 57% each. This is followed by eco-design (55%) and material efficiency (49%). Technologies falling the market segment of new advanced eco-materials are show lower application in the sector (26%).

Figure 5-11 Potential eco-innovation diffusion – electrical and optical equipment sector



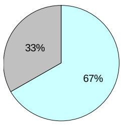
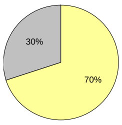
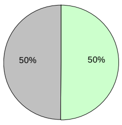
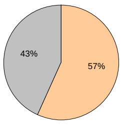
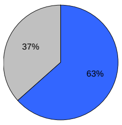
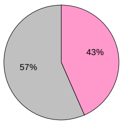
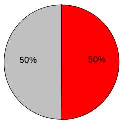
In relation to GHG abatement and energy efficiency, the global-oriented Kyoto agreement puts great responsibility on the E&O equipment sector (especially to the ICT industry). The same applies of the high expectations that many sectors have about the contribution of ICT for improving their energy efficiency. In this context, the European ambitions in relation to achieving the Kyoto objectives, fighting climate change and reduction of greenhouse gases, securing Europe's energy efficiency, and the objectives of the Strategic Energy Technology plan may be important drivers for innovation influencing the expectations of eco-innovations in relation to the contribution to the abovementioned areas. [35] Energy efficiency and GHG abatement could have a twofold objective, of not only to make the E&O equipment sector more environmental-friendly, but also to support other sectors in their effort to reduce their ecological footprint (e.g., construction, automotive, energy generation and distribution) (Cleff et al., 2007).

Waste minimisation is the third eco-innovation market segment where growth could be most significant. As noted in chapter 2, electronic waste is an increasing environmental issue because electronic appliances show lower economic lifetimes, these are replaced within shorter periods of time and illegal dumping and exports of e-waste (Van Erp and Huisman, 2010). The total amount of waste from electric and electronic equipment (WEEE) in Europe is estimated to increase by five million tons per year (or 14 kg per inhabitants). According to the European Commission, e-waste is expected to grow between 1995 and 2020 by 45% constituting the fastest growing waste stream in Europe (Basel convention, 2006).

5.3.4 The space and aeronautics sector

The current application of eco-innovations in the space and aeronautics sector shows that energy efficiency (70%) and GHG abatement (67%) are the largest market segments. This is followed by eco-design (63%) and waste minimisation (57%). Recycling and reuse and material efficiency are next in line with 50% each. New advanced eco-materials show lesser diffusion in the sector (43%) but relatively higher compared to the biotechnology, automotive sectors.

Figure 5-12 Eco-innovation diffusion – aerospace sector

GHG abatement	Energy efficiency	Material efficiency	Waste minimisation	Eco-design	New advanced eco-materials	Recycling and reuse
						

In terms of eco-innovation diffusion potential in space and aeronautics energy efficiency (76%) and GHG abatement (68%) are the market segments with the largest potential. This is followed by waste minimisation with 66%. Recycling and reuse, eco-design and material efficiency are next with 55% each. New advanced eco-materials with 39%.

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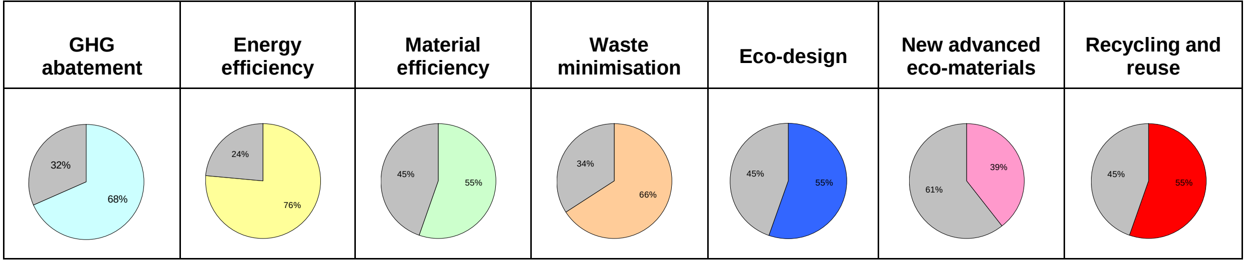
[35] Expressed in different communications to the European Parliament, e.g., COM (2005) 35, COM (2007) 354, COM (2007) 1, COM (2007) 2, COM (2007) 723, COM (2007) 757, etc.

Figure 5-13 Potential eco-innovation diffusion – aerospace sector



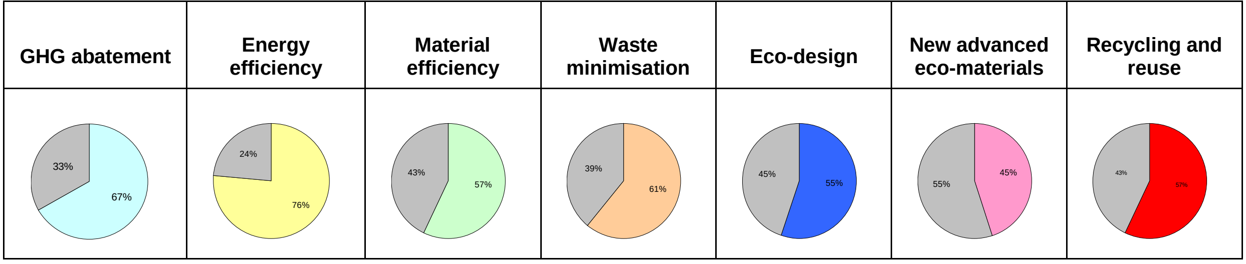
Energy efficiency in aeronautics is of prime importance. Currently aeronautics relies on kerosene as it provides high energy density and a very low freezing point, compared to other fuels. Eco-innovations in aeronautics have been centred around fuel efficiency and to some extent in relation to improved materials and aerodynamics. Due to a combination of rising prices, scarcity and environmental pressures the past years have seen a shift to looking into alternatives to alternative sources of aircraft fuel. The jet bio-fuel market is far from being fully developed, but a growing number of airlines have performed test flights with different combinations of bio-fuels and kerosene, ranging from 20 to 50% mixes (cameline, algae, jatropha, coconut). It is expected a significant deployment once jet bio-fuels get both certificates from ASTM and DEFSTAN (Marcus, 2010).

In terms of GHG emissions, at the policy level environmental issues related to the aeronautics and space sector mostly focus on emissions of aircraft during operations – not the manufacturing process. For example the DG Enterprise and Industry website listing environmental issues of the aeronautics and space sector only refers to emissions of aircraft contributing to climate change and noise pollution (EC, 2009d). Hence, the lesser emphasis to material efficiency during the manufacturing process is understandable. In relation to new-advanced eco-materials, the space and aeronautic sector already used a number of composite materials in a number of aircrafts (especially for interiors and some lightweight structures), but the performance-based specification of materials may inhibit its further use.

5.3.5 The construction sector

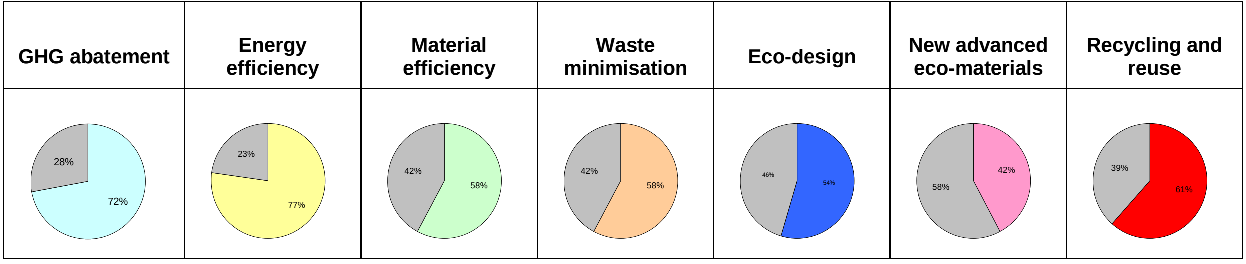
In the construction sector the market segment of energy efficiency shows the highest level of eco-innovation applications with 76% of the technologies in the inventory being applied, this is followed by greenhouse gas abatement with 67%. Waste minimisation is next with 61% of eco-innovations being diffused. Material efficiency and recycling and reuse market segments show similar diffusion pattern in the sector , (57%) of current application. Eco-design shows 55% of eco-innovations diffused whereas new advanced eco-materials 45%.

Figure 5-14 Eco-innovation diffusion – construction sector



In terms of eco-innovation potential of construction eco-innovations energy efficiency (77%) and GHG abatement (72%) are the market segments with the largest potential. This is followed by recycling and reuse with 66%. Waste minimisation and material efficiency are next with 58% each. Eco-design shows 54% of potential diffusion whereas the new advanced eco-materials 42%.

Figure 5-15 Potential eco-innovation diffusion – construction sector

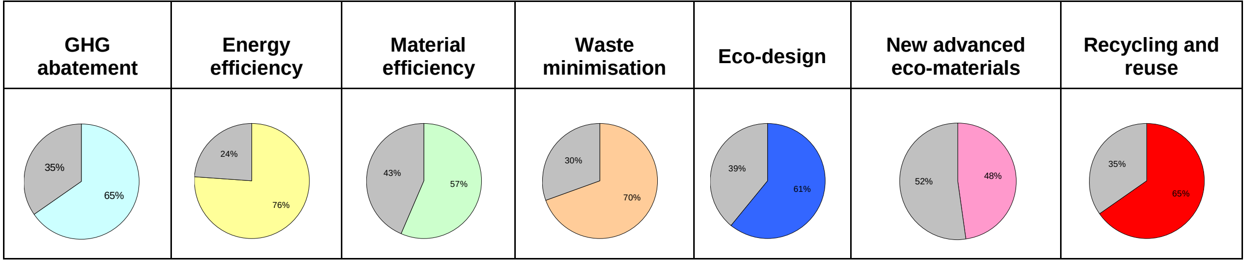


A possible reason of a high potential in energy efficiency is related to the current emphasis of EU regulations in energy performance of buildings. According to a EC communication on energy performance of buildings (Directive 2002/91/EC) an estimated 60 to 80 Mtoe energy/year and 160 to 210 Mt/year of CO_2 could be saved by year 2020 with the implementation of energy performance requirements for new and retrofitted buildings, energy performance certificates and the inspection of heating and air conditioning systems. Therefore, one can state that there is a significant potential of energy efficiency gains in the construction of buildings.

5.3.6 The knowledge intensive business services sector

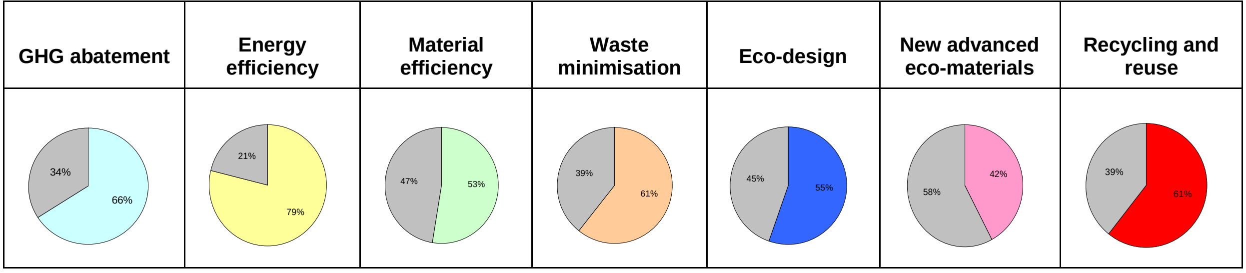
The current application and diffusion of KIBS eco-innovations to a particular eco-innovation market segment is largest in energy efficiency field, with 76%. Waste minimisation shows a level of diffusion of 70% of the total number of technologies included in the inventory. This is followed by GHG abatement and recycling and reuse with 65% each. Eco-design (61%) and material efficiency (57%) are next in the list. New advanced eco-materials is the category with the lesser diffusion (48%).

Figure 5-16 Eco-innovation diffusion – KIBS sector



In terms of eco-innovation diffusion potential of KIBS eco-innovations energy efficiency (79%) and GHG abatement (66%) have the largest potential. This is followed by waste minimisation and recycling and reuse with 61% each. Eco-design (55%), material efficiency 53% and new advanced eco-materials (42%) of potential penetration of eco-innovation .

Figure 5-17 Potential eco-innovation diffusion – KIBS sector

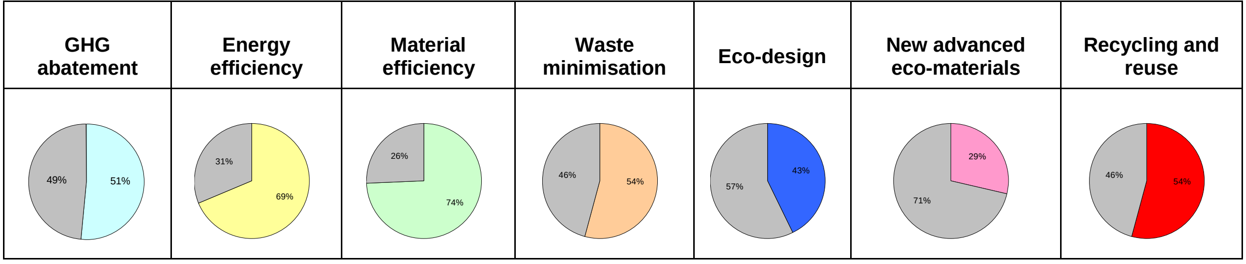


A possible explanation for the high contribution to GHG and energy efficiency may be related to the role that information-based services have for mitigating GHG emissions and improving the energy efficiency of user sectors. However, it is difficult to estimate the final effects of ICT applications on the environmental sustainability of the KIBS industry itself, simply because recent studies have used traditional approaches used to measure it which have proved to be insufficient (Yi and Thomas, 2007). ICT consultancy leader Gartner estimated that by the year 2009 one-third of ICT consultancy firms would have at least one environmental criteria into their purchasing guidelines, and by 2010 half of these firms will have incorporated environmental and energy efficiency targets into their business strategies. As a result, it is expected that two thirds of these firms would have achieved a 25% reduction of GHG sources (compared to 2007 levels), simply by behavioural changes in clients and own devices (especially related to data centres) (Mingay, 2007).

5.3.7 The wholesale and retail trade sector

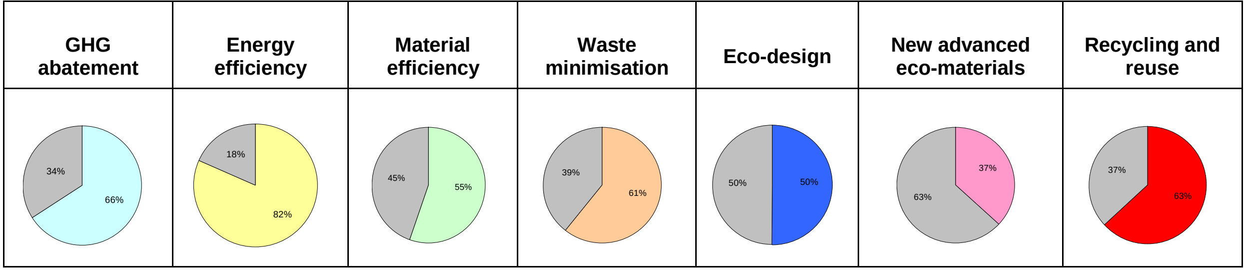
In the wholesale and retail trade eco-innovations in the inventory used in the survey find currently the largest level of application in the market segment of material efficiency (74%). This is followed by energy efficiency 69%, waste minimisation and recycling and reuse (54% each). GHG abatement and eco-design are next with 51% and 43%, respectively. New advanced eco-materials is the category with the less current penetration (29%).

Figure 5-18 Eco-innovation diffusion – wholesale and retail sector



In terms of eco-innovation diffusion potential in wholesale and retail trade eco-innovations energy efficiency (82%) and GHG abatement (66%) are the segments with the largest potential. This is followed by recycling and reuse (63%) and waste minimisation (61%), with material efficiency (55%), eco-design (50%) and new advanced eco-materials (37%) with a more discrete diffusion.

Figure 5-19 Potential eco-innovation diffusion – wholesale and retail sector

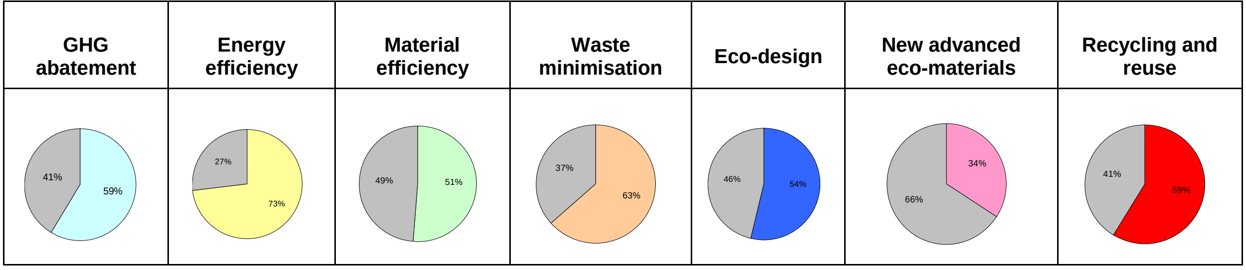


Some reasons for the energy efficiency high potential in the wholesale and retail sector may be found in the fact that waste management and material use has been a focus of attention for quite some time now. In principle, energy efficiency is the next big target of wholesale and retail traders. It has been suggested that 20% cut in energy costs represents the same bottom line benefit as a 5% increase in sales. In the field of store energy management (SEM), the largest energy savings can be obtained within energy consumption which is directly related to buildings, lightning and appliances. In case of lightning energy efficient lamps can be used (e.g., solid state lightning). Also lighting can be manually or automatically switched off when there are no persons in the room (smart lightning systems). This could save up to 15% of energy usage for lightning. Opportunities for reducing heating temperatures by just 1°C can cut fuel consumption by 8%. Also installing revolving doors reduces heating costs, while customers maintain easy access to the store

5.3.8 The food and drinks sector

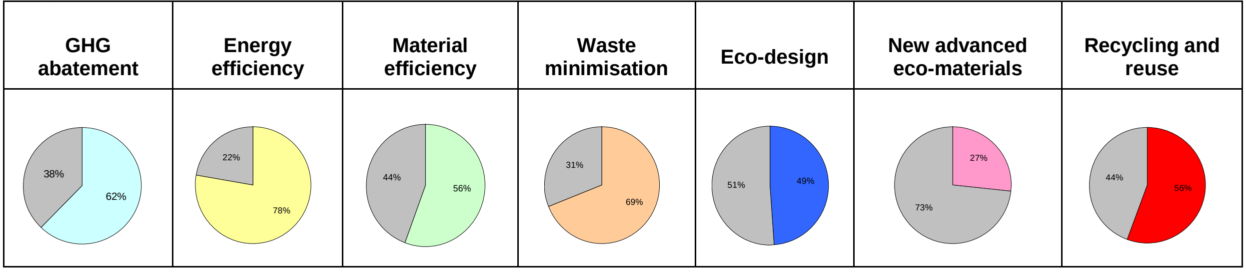
The current contribution of food and beverage eco-innovations to a particular eco-innovation priority area is led by the energy efficiency field, with 73%. Waste minimisation shows a contribution of 63%. This is followed by GHG abatement and recycling and reuse with 59% each, whereas eco-design has a 54% contribution. New advanced eco-materials is the category with the lesser contribution (34%).

Figure 5-20 Eco-innovation diffusion – food and drinks sector



In terms of eco-innovation diffusion potential of food and beverage eco-innovations the segments of energy efficiency (78%) and waste minimisation (69%) remains as the markets with the largest potential. This is followed by GHG abatement (62%), whereas material efficiency and recycling and reuse are next in line with 56% each. New advanced eco-materials is the area with the lesser contribution to diffusion growth in the sector (27%).

Figure 5-21 Potential eco-innovation diffusion – food and drinks sector

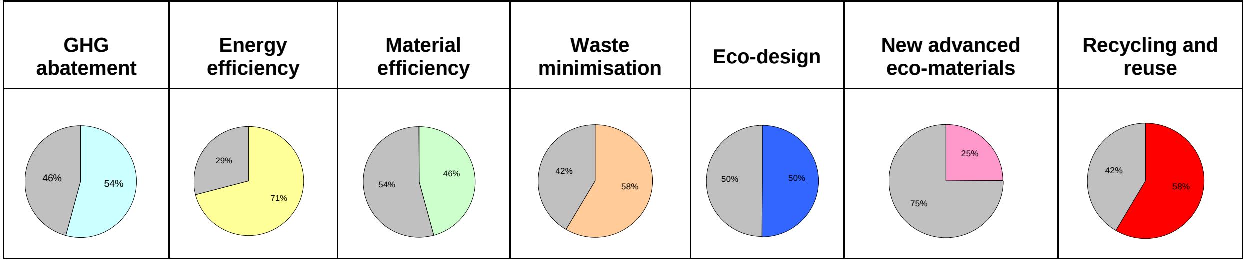


The food and drinks sector is a mature sector where pollution prevention and waste minimisation has been the focus for a number of years. As noted in chapter 2, waste generation (organic waste, packaging waste) is a concern shared by both industries. Most steps in food and drink processing generate residuals, which typically go to waste and/or reuse for different purposes e.g., manures are used as fertilisers whereas general waste can be geared towards furnaces and ovens as fuel for energy generation (Graedel and Howard-Greenville, 2005).

5.3.9 The textiles and clothing sector

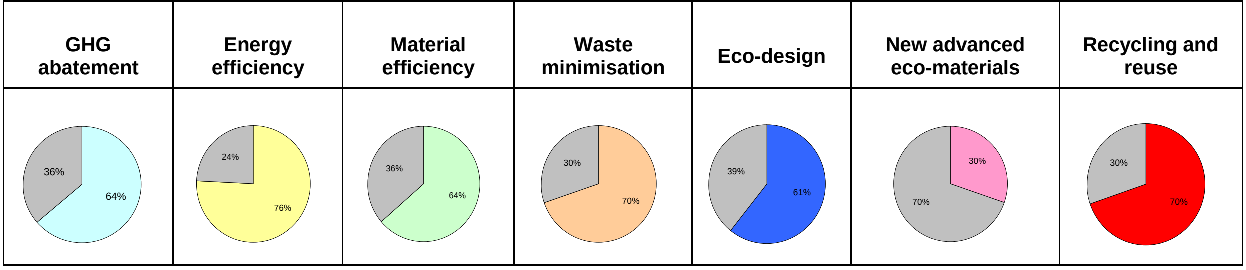
In the textiles and clothing sector the current diffusion of eco-innovations in the different markets is highest in the energy efficiency segment with 71% of the technologies applied in this segment. This is followed by waste minimisation and recycling and reuse with 58% each. GHG abatement and eco-design are next in priority (54% and 50%, respectively), followed by material efficiency with 46%.

Figure 5-22 Eco-innovation diffusion – textiles and clothing sector



The eco-innovation diffusion potential in the segments of energy efficiency (76%), waste minimisation (70%) and recycling and reuse (70%) have the largest potential. This is followed by GHG abatement (64%), material efficiency (64%) and eco-design (62%). New advanced eco-materials is the area with the lesser contribution (30%).

Figure 5-23 Potential eco-innovation diffusion – textiles and clothing sector

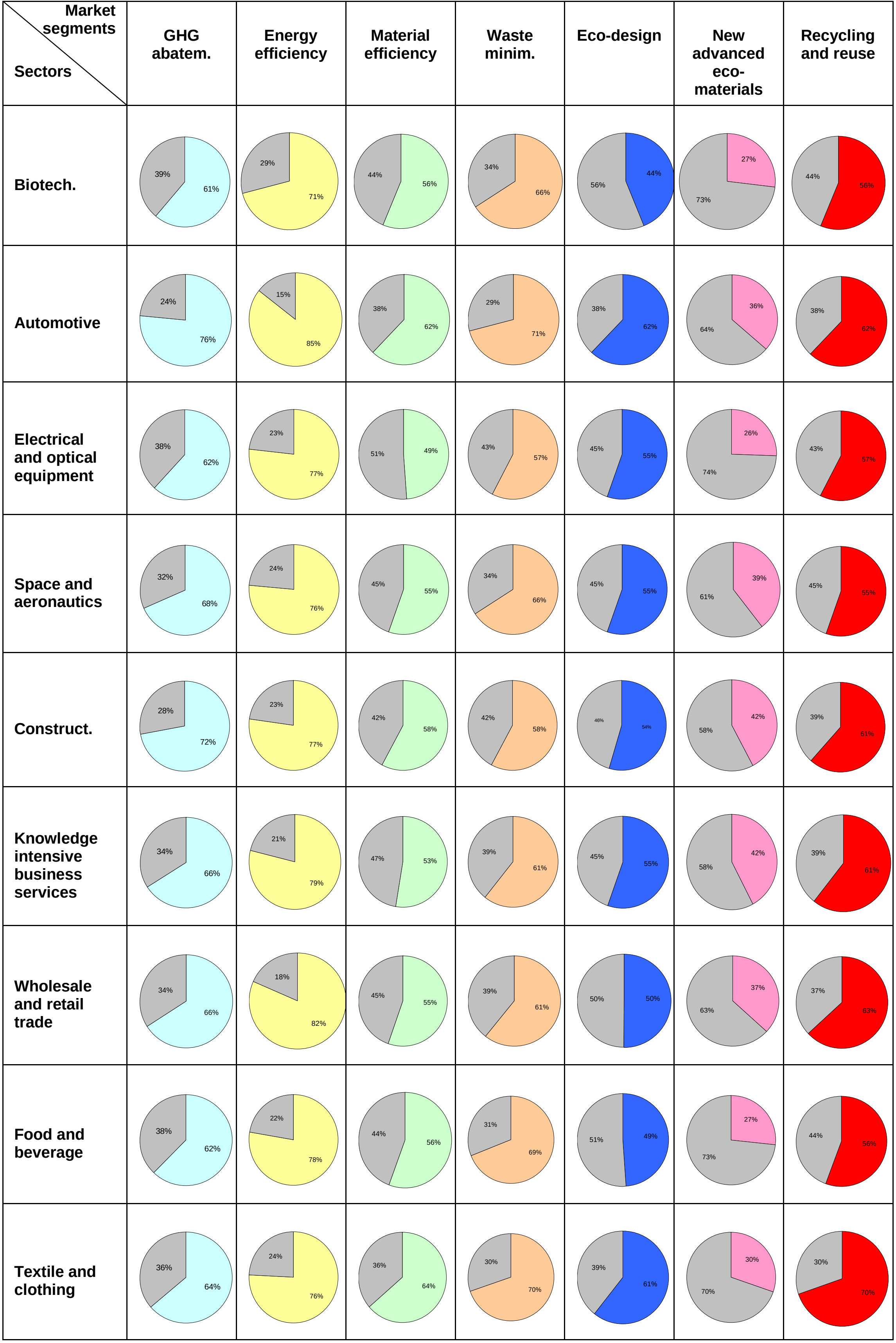


5.3.10 Total sectoral eco-innovation potential

The presentation of current and potential diffusion of eco-innovations above provides insights on the eco-innovation activities at the sector level while indicating the relevance of the broad environmental issues pressing the sectors. In this section, we provide an indication of the potential diffusion within the sectors and in each of the market segments identified. Table 5.1 below shows all the same pie charts indicating potential eco-innovation diffusion shown in the preceding sections. The horizontal axis shows the potential application at the sector level in terms of the percentage of the technologies in the inventory surveyed (178 technologies). The vertical axis displays the eco-innovation potential diffusion per market segments.

A horizontal reading of table 5.1 shows a rather heterogeneous pattern of potential diffusion in all sectors across the market segments. An aggregation of all potential diffusion per market segment shows, with small differences, similar patterns in the level of potential applicability and diffusion across all sectors. This finding reinforces the notion that eco-innovation is a horizontal issue that is likely to penetrate the structure of industry in a homogeneous fashion. So no front runner sector within sectors could be expected by policymakers and those firms engaged in the development and commercialisation of eco-innovations in Europe. Still, there are some differences in the market potential across the different sectors.

Table 5-1 Cluster grid for potential application of eco-innovation in SIW-II sectors



Market segments Sectors	GHG abatem.	Energy efficiency	Material efficiency	Waste minim.	Eco-design	New advanced eco-materials	Recycling and reuse
Biotech.	39% 61%	29% 71%	44% 56%	34% 66%	56% 44%	27% 73%	44% 56%
Automotive	24% 76%	15% 85%	38% 62%	29% 71%	38% 62%	36% 64%	38% 62%
Electrical and optical equipment	38% 62%	23% 77%	51% 49%	43% 57%	45% 55%	26% 74%	43% 57%
Space and aeronautics	32% 68%	24% 76%	45% 55%	34% 66%	45% 55%	39% 61%	45% 55%
Construct.	28% 72%	23% 77%	42% 58%	42% 58%	46% 54%	42% 58%	39% 61%
Knowledge intensive business services	34% 66%	21% 79%	47% 53%	39% 61%	45% 55%	42% 58%	39% 61%
Wholesale and retail trade	34% 66%	18% 82%	45% 55%	39% 61%	50% 50%	37% 63%	37% 63%
Food and beverage	38% 62%	22% 78%	44% 56%	31% 69%	51% 49%	27% 73%	44% 56%
Textile and clothing	36% 64%	24% 76%	36% 64%	30% 70%	39% 61%	30% 70%	30% 70%

Source: TNO calculations

The automotive sector has the highest potential for eco-innovation diffusion in the segments of GHG abatement and energy efficiency. In terms of material efficiency, the textile and clothing sector is the sector at the top of the list. Automotive and textile and clothing sectors go hand in hand in terms of waste minimisation and eco-design potential markets growth. Construction and KIBS have the same eco-innovation potential regarding new advanced eco-materials. Finally, in the segment of recycling and reuse sectors like automotive, construction, electrical and optical equipment, and textiles and clothing show excellent potential for eco-innovation diffusion.

A vertical reading indicates some of the low hanging fruits where now most of the policy effort is focused. Energy efficiency and GHG abatement are in overall the two issues that seem to have more expected deployment of eco-innovation in the next five years. This is followed by waste minimisation, recycling and reuse and materials efficiency. The lowest diffusion could be expected in eco-design and new advanced materials. One must remember here that we are talking of technology flows into the sectors. Eco-design and materials substitution activities are of prime importance for environmental sustainability but at the same time are intrinsically the most difficult to achieve.

The analysis above and the trends in venture capital investments in energy technologies relative to others indicate that policy intervention and regulation will play a decisive role in the promotion of eco-innovation in specific sector. Energy technologies have received a large extent of policy support in the last fifteen years. It is well known that structural change in the long run occurs depending on the diffusion of multiple purpose innovations in convergence with shifts in demand that favour the application of new technologies. Here eco-innovations show clearly a large degree of applicability across sectors, like ICTs have shown in the past years.

Summing up, in consistency with the identification of a number of market segments in the of early market stage, strategic eco-innovators indicated a large number of number of eco-innovation opportunities that are not fully diffused but have large potential. The current level of diffusion could be four folded over the next five to seven years. The picture presented in table 5.1 is consistent with the expectations of strategic eco-innovators presented in section 5.1. Relatively the space and aeronautics and textile and clothing are the sectors with the lowest level of eco-innovation diffusion, these two sectors also are seen as having the largest diffusion potential. The automotive, food and beverage, construction, biotechnology and electrical and optical equipment sectors present similar eco-innovations diffusion patterns. The most frequent eco-innovators reported relates to product eco-innovation. Relations with others, service innovation and manufacturing methods, follow in importance.

6 Conclusions

There is currently a considerable interest among policymakers and business circles in the opportunities that eco-innovation might bring in environmental and economic terms. Aiming to analyse the eco-innovation potential at the sector level, this report captured eco-innovative activity with a combination of a quantitative and qualitative approach. It also conducted an assessment of the potential for policy and regulation to foster eco-innovative activity. Our empirical findings support those expectations as eco-innovation was found to be a realistic dynamo of economic activities where some benefits, both environmental and economic, could be materialised in the medium term. The report presented material and information that give support to a few conclusions. These refer to the place of Europe in the global eco-innovation competitive landscape, the main traits of the next wave of eco-innovations and the potential for market creation, the role of policy and regulation in eco-innovation. These are discussed below:

The place Europe in the global landscape

The recent literature specialised on eco-innovation indicate that the strongest global players in traditional environmental technologies are the US (36%) and Europe (33%) with along tail of other players. A very similar trend is found regarding energy generation technologies, mobility, recycling, and water technologies that to some extent present relatively well-identified markets. Other eco-innovation market segments that are less mature but growing in importance include energy efficiency, storage and infrastructure. Underpinned by global debates in energy sufficiency and climate change, these technologies are expected to be the next fastest growing eco-innovation market. The largest venture capital flows have been accrued also in these types of technologies. It is likely that global markets on energy generation and management have already well defined players. Europe has a significant gap on investments in these types of technologies relative to the US, but still in second place at the global level. Relative to energy technologies other eco-innovations in mobility, agriculture, and new materials receive less financing support in private capital to upscale new markets. The role of policy here is to raise awareness of the large number of eco-innovation opportunities and create the necessary incentives for current nascent markets up scaling.

To a large extent the competitiveness of Europe in traditional environmental technology is based on a combination of technical expertise and financial services. In the medium term, given the massive international reserves of some new global players (China, Brazil, Russia and Korea) and their technological accumulation, these two competitive factors are likely to be eroded making more real the likelihood of Europe being less competitive. This calls for the tapping of new eco-innovation opportunities.

New eco-innovation opportunities

The number of eco-innovations identified in the selected stages of the supply value chain in each of the sectors was large. The eco-innovations generated and intended for one sector are frequently finding application in other sectors. Eco-innovation is a horizontal issue that cuts across all sectors, thus, eco-innovation opportunities and potential exist in all stages of the value chain in all the sectors of interest of SIW-II. The next wave of eco-innovation diffusion is likely to be propelled also by developments in the business side by strategic eco-innovators and policy development along the seven European environmental priority areas (eco-design, resources efficiency, energy efficiency, greenhouse gas reduction, waste minimisation, new advanced materials and reuse and recycling). Two pieces of evidence support this assertion: first, there is a significant number of policy documents signalling the importance of the environmental priority areas at the European and member state levels. Second, the empirical evidence provided in chapter five indicates that these environmental priority areas are also seen as are real market segments where eco-innovation entrepreneurs already operate. According to the survey the top-five sectors with the largest potential for eco-innovation are biotechnology, construction, knowledge intensive business services, automotive, and electrical and optical equipment. Relative to the current level of diffusion, these sectors present a more than two folded potential for eco-innovation diffusion over the next five to seven years.

Regulation and eco-innovation

Over the last two decades the role of environmental regulation on competitiveness has seen by many as negative. Currently the perception of some business towards the environment is far more positive and in some instances is now seen as positive factor for business performance, through innovation. Despite the potential of negative attitudes towards regulation in industry the role of environmentally driven regulations in general is positive. This is based on the fact that those firms that reported to have introduced the most number of innovations where also subject to higher regulatory pressure. Now, eco-innovation offers a different dynamic where businesses and environmental protection enter a win-win situation. This is supported by evidence found in the sector specialised literature; the case studies presented by sector where policy and regulation promoted eco-innovations, and the quantitative evidence presented in chapter three.

It is very likely that regulation has a strong role in motivating eco-innovation across all sectors. The empirical evidence strongly suggests that there are many indirect effects of regulation in the final eco-innovative behaviour at the sector level. This happen when policy or regulation targets a specific type of innovation activity (product, process, service, marketing, etc.) and implicitly affecting other type of innovations, including eco-innovation.

Concerning eco-innovation intensity and environmental regulation intensity the sectors could be located in three levels. The aerospace and construction sectors show a relative large number of regulations that resulted significantly related with environmental regulations. The textiles and clothing, wholesale and retail, automotive presented lower number of regulations associated with eco-innovation. The electrical and optical equipment, KIS, biotechnology and food and drinks sectors show the lowest number of environmental regulations associated with innovation. It must be noted that for all sectors - with the exception of the aerospace and construction sectors – the association of environmentally motivated regulations with innovation was weaker than other regulations affecting the behaviour of business.

Last remarks

From the analysis presented above it is clear that Europe is relatively a strong player in the likely emerging markets. The analyses conducted in chapters two to five indicated a large number of grey areas where no data is available. Many of the technologies where the flow of investment has been stronger are the usual suspects. That is, the portfolios of investments include technologies, especially energy generation that are well and widely known with prospects of large infrastructural investments for energy generation. This promises great returns to investors. In this sense, we could be talking here of a low hanging fruit as many of these technologies were already developed for more than 30 years. It is only now that markets are taking off. The uptake and diffusion of other technologies where large government procurement programs are likely not available, as is the case for advanced materials, advanced manufacturing, agro-food and sustainable transport could be more problematic. Most likely this the case for many of the technologies described in chapter two where the markets are considerable smaller and more difficult to access due to more difficult and fragmented substitution effects.

We have seen that in absolute terms the US dedicates more venture capital than Europe to bridge the relatively well funded stages of research activities to the up-scaling of technological experimentation and innovation. One of the first policy actions in Europe is necessarily the setting up of a platform for private-public partnerships to underpin the bridging the valley of death for many European entrepreneurs seeking seed capital. As we have mentioned in the introduction to this study, the conditions are ripe, with many of the elements in place to foster eco-innovation in Europe.

The eco-innovation opportunities described in this study a just but the tip of the iceberg as not all technologies where included in the analysis. Not all links in the supply chain of the sectors considered were explored. What is clear from the study is the horizontal and polyvalent nature of eco-innovations. They are produced in one sector and find applications in many others. This indicates a clear parallel with previous waves of structural changes like steam engine or ICTs where the character of polyvalence and multiple-purpose was a key feature of the technologies underpinning changes in the structure of the aggregates. The new European strategy for industrial development calls for a smart specialisation. Given the large potential to contribute to sustainability and business creation eco-innovation seems a good option for smart specialisation in Europe.

References

ACARE (2008) Aeronautics and air transport: ”Beyond vision 2020 (2030+). Background document., Advisory Council for Aeronautics Research in Europe.

ACARE (2009) Addendum to the Strategic Research Agenda. Advisory Council for Aeronautics Research in Europe.

AGNOLUCCI, P., EKINS, P., IACOPINI, G., ANDERSON, K., BOWS, A., MANDER, S. & SHACKLEY, S. (2009) Different scenarios for achieving radical reduction in carbon emissions: A decomposition analysis. *Ecological Economics,* 68**,** 1652-1666.

ALLWOOD, J. M., LAURSEN, S. E., MALVIDO DE RODRÍGUEZ, C. & BOCKEN, N. M. P. (2006) Well dressed? The present and future sustainability of clothing and textiles in the United Kingdom. Cambridge, University of Cambridge Institute for Manufacturing. Cambridge University.

APPRICOD (2006) Towards Sustainable Plastics Construction and Demolition Waste Management in Europe. Brussels, Assessing the Potential of Plastics Recycling in the Construction and Demolition Activities.

ARTHUR D LITTLE (2009) Quantitative Modelling of Industrial Biotechnology and Renewable Chemicals. . Cambridge, Arthur D Little Ltd on behalf of the UK Department of Business, Enterprise and Regulatory Reform.

ASD (2007) In Focus. Aerospace and Defence Industries Association of Europe.

ASLESEN, H. W. (2008) Prospective Innovation Challenges in the Textiles and Clothing sectors. Oslo, Europe INNOVA Sectoral Innovation Watch. Project on behalf of the European Commission, DG Enterprise and Industry.

AUTOBLOG (2009) GM to bypass Tier 1 and pay Tier 2 suppliers directly.

BANSE, M., KADITI, E., MCDONALD, S., ROBINSON, S., SWINNEN, J., GAY, S. H., M’BAREK, R. & SANTUCCIO, F. (2008) Analysis of the European Food Industry. *JRC Scientific and Technical Reports.* Seville, European Commission, Joint Research Centre, Institute for Prospective Technological Studies.

BARTOLOMEO, M., KEMP, R., RENNINGS, K. & ZWICK, T. (2003) Employment impacts of cleaner production: theory, methodology and results. IN RENNINGS, K. & ZWICK, T. (Eds.) *Employment Impacts of Cleaner Production.* ZEW Economic Studies. Heidelberg, New York, Physica-Verlag, ZEW.

BASEL CONVENTION (2006) Creating innovative solutions through the Basel convention for the environmentally sound management of electronic wastes.

BASF (2009) Press Release: Food Safety in the Spotlight. Ludwigshafen, BASF SE.

BERGHAUS (2009) Technologies. Clothing. Berghaus.

BERNSTEIN, L., ROY, J., DELHOTAL, K. C., HARNISCH, J., MATSUHASHI, R., PRICE, L., TANAKA, K., WORRELL, E., YAMBA, F. & FENGQI, Z. (2007) Industry. IN METZ, B., DAVIDSON, O. R., BOSCH, P. R., DAVE, R. & MEYER, L. A. (Eds.) *Climate Change 2007 - Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the IPCC.* Cambridge, United Kingdom and New York, NY, USA., Cambridge University Press.

BILSEN, V., RADEMAEKERS, K., BERDEN, K., BINDA ZANE, E., DE VOLDERE, I., JANS, G., MERTENS, K., REGECZI, D., SLINGENBERG, A., SMAKMAN, F., STOUTHUYSEN, P. & UNTERSTALLER, A. (2009a) Study on the Competitiveness of the EU eco-industry. Final Report – Part 1. *Project commissioned by the European Commission - Directorate-General*

Enterprise & Industry, within the Framework Contract of Sectoral Competitiveness Studies – ENTR/06/054. Brussels, ECORYS, Tecknologisk Institut, Cambridge Econometrics, CES ifo, IDEA consult.

BILSEN, V., RADEMAEKERS, K., BERDEN, K., BINDA ZANE, E., DE VOLDERE, I., JANS, G., MERTENS, K., REGECZI, D., SLINGENBERG, A., SMAKMAN, F., STOUTHUYSEN, P. & UNTERSTALLER, A. (2009b) Study on the Competitiveness of the EU eco-industry. Final Report – Part 2. *Project commissioned by the European Commission - Directorate-General Enterprise & Industry, within the Framework Contract of Sectoral Competitiveness Studies – ENTR/06/054.* Brussels, ECORYS, Tecknologisk Institut, Cambridge Econometrics, CES ifo, IDEA consult.

BIOMCN (2010) Process. Delfzijl, BioMCN.

BLEISCHWITZ, R., GILJUM, S., KUHNDT, M., SCHMIDT-BLEEK, F., BAHN-WALKOWIAK, B., IRREK, W., SCHEPELMANN, P., LUTTER, S., BOHUNOVSKI, L., HINTERBERGER, F., HAWKINS, E. & PRATT, N. (2009) Eco-innovation - putting the EU on the path to a resource and energy efficient economy. . Brussels, Report Commissioned by the European Parliament to Wuppertal Institute, SERI, CSCP and the Factor Ten Institute.

BLOK, K., GENG, L., HARVEY, D., LANG, S., LEVERMORE, G., MONGAMELI MEHLWANA, A., MIRASGEDIS, S., NOVIKOVA, A., RILLING, J. & YOSHINO, H. (2007) Residential and commercial buildings. IN METZ, B., DAVIDSON, O. R., BOSCH, P. R., DAVE, R. & MEYER, L. A. (Eds.) *Climate Change 2007: Mitigation.* Cambridge, united Kingdom and New York, NY, USA.

BRALLA, J. (2006) *Handbook of manufacturing processes. How products, components and materials are made,* New York, Industrial Press.

BRANDES, F. & POEL, M. (2009) Aerospace. Sectoral Innovation Foresight. Delft, Europe INNOVA Sectoral Innovation Watch. Project on behalf of the European Commission, DG Enterprise and Industry.

BRAUNGART, M., MCDONOUGH, W. & BOLLINGER, A. (2007) Cradle-to-cradle design: creating healthy emissions - a strategy for eco-effective product and system design. *Journal of Cleaner Production,* 15**,** 1337-1348.

BREEAM (2009) What is BREEAM? The Environmental Assessment Method for Buildings Around The World. BRE Global Ltd.

BRUNO, N., MIEDZINSKI, M., REID, A. & RUIZ YANIZ, M. (2008) Socio-cultural determinants of eco-innovation. Brussels, Technopolis on behalf of the Europe INNOVA Sectoral Innovation Watch (phase I).

BUCHELE, R., EMRICH, A., ENGEL, M., HENZELMANN, T., HOFF, P., MOOG, F., SEIDMANN, S., WIEDEMANN, A. & ZELT, T. (2009) *GreenTech made in Germany 2.0. Environmental Technology Atlas for Germany,* Munchen, Federal Ministry of the Environment, Nature Conservation and Nuclear Safety. Verlag Franz Vahlen.

BUNDESMINISTERIUM FÜR UMWELT NATURSCHUTZ UND REAKTORSICHERHEIT (2009) Green Tech made in Germany 2.0. Environmental Technology Atlas for Germany. Munich, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

BUSINESS COST CONSULTANTS (2009) Energy Conservation.

BUYLE, G. (2009) Nanoscale finishing of textiles via plasma treatment. *Materials Technology,* 24**,** 46-52.

CANTON, J., SOUBEYRAN, A. & STAHN, H. (2008) Environmental Taxation and Vertical Cournot Oligopolies: How Eco-industries Matter. *Environ Resource Econ,* 40**,** 369-382.

CARBON TRUST (2006) Retail; Energy management - the new profit centre for retail businesses.

CARLETON, W. T. (1986) Issues and Questions Involving Venture Capital. *Advances in the Study of Entrepreurship, Innovation and Economic Growth. A Research Annual.* London, JAI Press Inc.

CARREFOUR (2009a) Au Couer De La Vie. Rapport Développement Durable 2008. Levallois Perret, Groupe Carrefour.

CARREFOUR (2009b) Réduire l'impact de nos magasins. Paris, Le Group Carrefour.

CHESTER, M. V. (2008) Life-cycle Environmental Inventory of Passenger Transportation in the United States. UC Berkeley: Institute of Transportation Studies.

CHRISTENSEN, A. (2007) Food Safety, Quality and Customer Requirement: applying information technology to food safety to lower costs, improve traceability, and add value for customers. *Food Safety Manager White Paper.* London, IBM.

CLAUDIO, L. (2007) Waste couture: Environmental Impact of the Clothing Industry. *Environmental Health Perspectives,* 115**,** 448-454.

CLEFF, T., GRIMPE, C., RAMMER, C., SCHMIELE, A. & SPIELKAMP, A. (2007) Analysis of Regulatory and Policy Issues Influencing Sectoral Innovation Patterns, Europe INNOVA Innovation Watch [interim paper].

CLEFF, T., GRIMPE, C., RAMMER, C., SCHMIELE, A. & SPIELKAMP, A. (2008) Regulatory and Policy Issues Influencing Innovation in the Eco-innovation Sector. Final Report. Manheim, Centre for European Economic Research - ZEW on behalf of the Europe INNOVA Sectoral Innovation Watch (phase I).

COOGAN, A., EARHART, R., AGGL, B., HANDKE, V., KAMBUROW, C., KRAUTH, V., MARSHALL, A. & ERMEN, R. (2008) FUNDETEC. Comparison and Assessment of Funding Schemes for the Development of New Activities and Investments in Environmental Technologies. Brussels, TBLI Consulting Group, Forseo GmbH, IZT, SDRC, EPE.

COWI GROUP (2008) Promoting Innovative Business Models with Environmental Benefits. Kongens Lyngby COWI on behalf of Directorate General Environment, European Commission.

DAVID, M. & SINCLAIR-DESGAGNÉ, B. (2005) Environmental Regulation and the Eco-Industry. *Journal of Regulatory Economics,* 28**,** 141-155.

DÉCATHLON (2009) La politique d'éco-conception de Quechua Villeneuve d'Ascq Décathlon S.A.,.

DEFRA (2008) Assessment of the Implementation of the IPPC Directive in the UK. London, Department for Environment, Food and Rural Affairs.

DEWULF, W. & DUFLOU, J. (2006) Integrating EcoDesign into business environments. A multilevel approach. IN D. TALABĂ, D. & ROCHE, T. (Eds.) *Product Engineering. Eco-Design, Technologies and Green Energy.* Heidelberg, Springer Netherlands.

DIAZ LOPEZ, F. J. (2011) *Eco-innovation in Firms. A methodological guide for corporate environmental sustainability,* Leiden, Ann Arbor, Maralte.

DIAZ LOPEZ, F. J., TUKKER, A. & LINDT, M. (2008) Systemic theories, instruments and cases for SCP. Annex 3 to the final report "Sustainable Consumption Policies Effectiveness Evaluation (SCOPE2)". FP6 project - Contract no: 044256. Delft, TNO- Netherlands Organisation for Applied Scientific Research.

DJELLAL, F. & GALLOUJ, F. (2009) The contribution of public and private services to European growth and welfare, and the role of public-private innovation networks (Deliverable: D1.1-A3a).

DUPONT AUTOMOTIVE (2008) Environmental Leads SAE Survey Results.

EC (2004a) Fostering Structural Change: an industrial policy for an enlarged Europe. Brussels, Commission of the European Communities.

EC (2004b) Stimulating Technologies for Sustainable Development; and Environmental Technologies Action Plan for the European Union. Brussels, Commission of the European Communities.

EC (2005) Taking sustainable use of resources forward: A Thematic Strategy on the prevention and recycling of waste. Brussels, Commission of the European Communities.

EC (2006) Putting knowledge into practice: A broad-based innovation strategy for the EU. Brussels, Commission of the European Communities.

EC (2007a) Adapting to Climate Change in Europe - options for EU action. Brussels, Commission of the European Communities.

EC (2007b) BioPolis – Inventory and analysis of national public policies that stimulate biotechnology research, its exploitation and commercialisation by industry in Europe in the period 2002-2005. Brussels, European Commission,,.

EC (2007c) An Energy Policy for Europe. Brussels, Commission of the European Communities.

EC (2007d) A lead market initiative for Europe. Brussels, Commission of the European Communities.

EC (2007e) REACH in brief. Brussels, European Commission Directorate-General Enterprise and Industry, Directorate-General Energy.

EC (2008a) Communication from the commission to the council and the European Parliament - Establishment of the working plan for 2009-2011 under the Ecodesign Directive. Brussels, Commission of the European Communities.

EC (2008b) Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on the Sustainable Consumption and Production and Sustainable Industrial Policy Action Plan. Brussels, Commission of the European Communities.

EC (2009a) Aerospace industries – Regulatory Environment. Brussels, European Commission Directorate-General Enterprise and Industry.

EC (2009b) COMMISSION STAFF WORKING DOCUMENT accompanying the COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS Preparing for our future: Developing a common strategy for key enabling technologies in the EU". Current situation of key enabling technologies in Europe. Brussels, Commission of the European Communities.

EC (2009c) Eco design your Future. How eco design can help the environment by making products smarter. Brussels, European Commission Directorate-General Enterprise and Industry, Directorate-General Energy.

EC (2009d) Environmentally Friendly, InterCity Aircraft powered by Fuel Cells. Brussels, European Commission Directorate-General for Research.

EC (2009e) The potential of market pull instruments for promoting innovation in environmental characteristics. Directorate General Environment.

EC (2009f) Reducing CO2 emissions from light-duty vehicles. Brussels, European Commission Directorate-General Environment.

EC (2009g) Towards a greener retail sector. Brussels, BIO intelligence service, project on behalf of DG Environment, Commission of European Communities.

EC (2011) COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN ARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF REGIONS. A resource-efficient Europe - Flagship initiative under the Europe 2020 Strategy. Brussels, Commission of the European Communitites.

EDLER, D., BLAZEJCZAK, J., WALZ, R., OSTERTAG, K., EICHHAMMER, W., ANGERER, G., SARTORIUS, C., DOLL, C., BÜCHELE, R., HENZELMANN, T. & ZELT, T. (2007) Wirtschaftsfaktor Umweltschutz. Vertiefende Analyse zu Umweltschutz und Innovation. Dessau, Umweltbundesamt und Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit, Umwelt Bundes Amt

EEA (1998) Life cycle assessment (LCA). Copenhagen, European Environment Agency.

EEA (2009) Annual European Community greenhouse gas inventory 1990-2007 and inventory report 2009. Copenhagen, European Environment Agency.

EIPPCB (2003) *Integrated Pollution Prevention and Control. Reference Document on Best Available Techniques for the Textiles Industry. ,* Seville, European IPPC Bureau, Institute for Prospective Technological Studies (IPTS), European Commission's Joint Research Centre (JRC) Directorate General, European Commission.

EIPPCB (2006) *Integrated Pollution Prevention and Control. Reference Document on Best Available Techniques in the Food, Drink and Milk industries,* Seville, European IPPC Bureau, Institute for Prospective Technological Studies (IPTS), European Commission's Joint Research Centre (JRC) Directorate General, European Commission.

ELECTRA (2008) Twenty Solutions for Growth and Investment to 2020 and beyond. Brussels, ELECTRA.

EMCC (2008) Trends and drivers of change in the European textiles and clothing sector: Mapping report. Dublin, European Foundation for the Improvement of Living and Working Conditions.

ENVIRONMENT CANADA (2009) Environmental implications of the automobile.

ENZING, C. (2009) *Product innovation in the Dutch food and beverage industry. A study on the impact of the innovation process, strategy and network on the product's short and long-term market performance.,* Wageningen, Wageningen Academic Publishers.

ENZING, C., VAN DER GIESSEN, A., VAN DER MOLEN, S., VAN ZANDVOORT, C., VAN GROENESTIJN, J., MEESTERS, K., KOIVISTO, R., WIRTANEN, G., MIETTINEN-OINONEN, A., PERE, J. & GAISSER, S. (2007) Consequences, Opportunities and Challenges of Modern Biotechnology for Europe - Task 2. Case Studies Report on the Impact of Industrial Biotechnology Applications. Annex to Report 3. Seville, TNO Innovation Policy Group, VTT Innovation Studies Group and Fraunhofer Institute for Systems and Innovation Research on behalf of ETEPS AISBL and the Institute for Prospective Technological Studies.

EPA (1996) Best Management Practices for Pollution Prevention in the Textile Industry. Cincinnati, U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, Center for Environmental Research Information.

EPA (1998a) Clean Technologies in U.S. Industries: Focus on Food Processing. Cincinnati, U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, Center for Environmental Research Information.

EPA (1998b) Profile of the Aerospace Industry. Sector Notebook Project EPA/310-R-98-001. Washington, United States Environmental Protection Agency.

EPA (2000) Building Savings. Strategies for Waste Reduction of Construction and Demolition Debris from Buildings. United States Environmental Protection Agency.

EPA (2004) Safety and Security Analysis: Investigative Report by NASA on Proposed EPA Hydrogen-Powered Vehicle Fueling Station. Washington, Assessment and Standards Division, Office of Transportation and Air Quality, U.S. Environmental Protection Agency.

EPA (2007) Fuel Cells & Vehicles Washington, Office of Transportation and Air Quality, U.S. Environmental Protection Agency

EPA (2009a) Fuel Cell Vehicles. Washington, US Environmental Protection Agency, US Department of Energy.

EPA (2009b) Potential for Reducing Greenhouse Gas Emissions in the Construction Sector. Washington, US Environmental Protection Agency. National Construction Sector Lead.

ERA (2009) REACH - a brief guide. Leatherhead, ERA Technologies LTD.

ETHICAL MARKETS MEDIA (2011) Green Transition Scoreboard® August 2011 Update. St. Augustine, Ethical Markets Media.

EURATEX (2004) European Technology Platform for the Future of Textiles and Clothing. Brussels, EURATEX, The European Apparel and Textile Organisation.

EUROPEAN ENVIRONMENT AGENCY (2009) Annual European Community greenhouse gas inventory 1990–2007 and inventory report 2009.

EUROPEAN RETAIL FORUM (2009) Issue paper on Energy Efficiency of Stores. Brussels, European Commission, EuroCommerce, European Retail Round Table.

EUROSTAT (2008) European business 2007 – Facts and figures,. Strasbourg, Eurostat.

EUROTREND (2009) Eurotrend Group. Valencia, Eurotrend Group.

FARHANG, B. (2009) Nanotechnology and Applications in Food Safety. IN BARBOSA-CÁNOVAS, G., MORTIMER, A., LINEBACK, D., SPIESS, W. & BUCKLE, K. (Eds.) *Global Issues in Food Science and Technology.* Burlington, London, New York, Academic Press.

FESTEL, G. (2010) OECD workshop on “Outlook on Industrial Biotechnology”. Discussion Paper - Session II "Industry Structure and Business Models for Industrial Biotechnology". Paris, Organisation for Economic Cooperation and Development.

FJÄLLRÄVEN (2009a) Eco circle - recycled materials. Örnsköldsvik, Fjällräven.

FJÄLLRÄVEN (2009b) Quality Time Policy. Örnsköldsvik, Fjällräven.

FOODPROCESSING-TECHNOLOGY (2008) Sustainable Food Production From Farm to Fork. London, Net Resources International.

FORUM FOR THE FUTURE (2009) Sustainability trends in European retail. London, Forum for the Future.

FRANCKX, L., VAN ACOLEYEN, M., VAN DEN BROUKE, D., HOGG, D., HOLMES, A., MONTAG, H., TAYLOR, S. & COULTHURST, A. (2008) Optimising Markets for Recycling. *Project commissioned by the European Commission - DG Environment 07/13105/LF.* Antwerpen, ARCADIS, Eunomia Research and Consultancy.

FRY, B. (2009) The greening of ICT, Web Host Industry Review.

GAASTRA (2009) Materials. Amstelveen, Gaastra International Sportswear.

GADREY (2009a) The environmental crisis and the economics of services: the need for revolution. IN F., G. & F, D. (Eds.) *The Handbook of Innovation and Services* Cheltenham, Edward Elgar Publishers.

GADREY, J. (2009b) The contribution of public an private services to European growth and welfare, and the role of public-private innovations in networks (deliverable: D1.1-A3b).

GASSMANN, O., REEPMEYER, G. & VON ZEDTWITZ, M. (2004) Leading pharmaceutical innovation: Trends and drivers for growth in the pharmaceutical industry. Heidelberg, Springer-Verlag.

GAVRILESCU, M. & CHISTI, Y. (2005) Biotechnology--a sustainable alternative for chemical industry. *Biotechnology Advances,* 23**,** 471-499.

GERANIO, L., HEUBERGER, M. & NOWACK, B. (2009) The Behavior of Silver Nanotextiles during Washing. *Environmental Science & Technology,* 43**,** 8113-8118.

GIESECKE, S., MERINO, F., RUBALCABA, L., SCHAFFERS, H. & VELSING, E.-J. (2009) Retail and wholesale trade. Patterns and performance of sectoral innovation. Brussels, Europe INNOVA Sectoral Innovation Watch. Project on behalf of the European Commission, DG Enterprise and Industry.

GOTTSCHALK, B. & KALMBACH, R. (2007) Mastering Automotive Challenges. Kogan Page Limited.

GRAEDEL, T. & HOWARD-GREENVILLE, J. (2005) *Greening the Industrial Facility. Perspectives, Approaches and Tools,* New York, Springer.

HEKKERT, M., HARMSEN, R. & DE JONG, A. (2007) Explaining the rapid diffusion of Dutch cogeneration by innovation system functioning. *Energy Policy,* 35**,** 4677-4687.

HELLY HANSEN (2008) Ekolab Jacket and Pant. Oslo, Helly Hansen.

HENZELMANN, T., MEHNER, S. & ZELT, T. (2007) Umweltpolitische Innovations- und Wachstumsmärkte aus Sicht der Unternehmen. Berlin, Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit und Umweltbundesamt durchgeführt von Roland Berger Strategy Consultants.

HIPP, C. & GRUPP, H. (2005) Innovation in the service sector: The demand for service-specific innovation measurement concepts and typologies. *Research Policy,* 34**,** 517-535.

HITCHENS, D., FARRELL, F., LINDBLOM, J. & TRIEBSWETTER, U. (2002) The Impact of Best Available Techniques (BAT) on the Competitiveness of European Industry. Seville, European Commission Joint Research Centre (DG JRC) / IPTS.

HOLLANDERS, H. (2008) Strategic innovators drive innovation performance at the Sector Level: A sectoral Analysis of Innovation Modes. Maastricht, UNU-MERIT on behalf of the Europe INNOVA Sectoral Innovation Watch (phase I).

HOME AUTOMATION EUROPE (2009) Company homepage.

HUANG, A. Y. (2009) Categorization of scope 3 emissions for streamlined enterprise carbon footprinting. *Environmental Science & Technology,* 43**,** 7.

HUBER, J. (2008) Technological environmental innovations (TEIs) in a chain-analytical and life-cycle-analytical perspective. *Journal of Cleaner Production,* 16**,** 1980-1986.

HUPPES, G., KLEIJN, R., HUELE, R., EKINS, P., SHAW, B., ESDERS, M. & SCHALTEGGER, S. (2008) ECODRIVE. A Framework for Measuring Eco-innovation: typology of indicators based on causal chains. EU FP6 funded project, Priority FP6-2005-SSP-5-A. Leiden, CML-Leiden University, PSI, CSM.

IBM (2009) Smarter Food. Farm-to-table tracking. New York, IBM.

IEA (2008) From 1st to 2nd generation Biofuel Technologies. An overview of current industrial and RD&D activities. Paris, Organisation for Economic Cooperation and Development/International Energy Agency.

IPCC (2006) 2006 Inventory Guidelines. Cambridge, UK, Intergovernmental Panel on Climate Change (IPCC).

JAREKRANS, M. (2008) Benchmarking Study on Industrial Biotechnology. Stockholm, VINNOVA.

JOHNSON, A. & JACOBSSON, S. (2000) The emergence of a growth industry - a comparative analysis of the German, Dutch and Swedish wind turbine industries. *Paper to be presented at the 8th Joseph A. Schumpeter Society conference 'Change, Development and Transformation'.* University of Manchester, UK.

KEMP, R. & PEARSON, P. (2008) Final report MEI project about measuring eco-innovation. EU FP6 funded project 044513. Maastricht, UM-MERIT, ZEW, DTU, ICL, LEIA.

KIRCHER, M. (2010) OECD workshop on “Outlook on Industrial Biotechnology”. Discussion Paper - Session Trends in Technology and Applications. Paris, Organisation for Economic Co-operation and Development.

KOGUT, B., URSO, P. & WALKER, G. (2007) Emergent Properties of a New Financial Market: American Venture Capital Syndication, 1960â€“2005. *Management Science,* 53**,** 1181-1198.

KOTRONAROU, N. & IACOVIDOU, K. (2001) Integrated pollution control, compliance and enforcement of EU Environmental legislation to Industries (IPPC and non IPPC) of the food production/processing sector. Athens, National Observatory of Athens. IMPEL Network. European Commission. Hellenic Ministry for the Environment.

KUIK, O. (2006) Environmental Innovation Dynamics in the Automotive Industry – A case study in the framework of the project “Assessing innovation dynamics induced by environment policy”.

LAFUMA (2009) Pure Leaf Grade. Pure Leaf Project -ecoconcepts by Lafuma. Anneyron, Groupe LaFuma.

LEIS, M., GIJSBERS, G. & VAN DER ZEE, F. (2009) Food and Beverages Sector. Sectoral Innovation Foresight. Delft, Europe INNOVA Sectoral Innovation Watch. Project on behalf of the European Commission, DG Enterprise and Industry.

LEVINE, M., ÜRGE-VORSATZ, D., BLOK, C., GENG, L., HARVEY, D., LANG, S., LEVERMORE, G., MONGAMELI MEHLWANA, A., MIRASGEDIS, S., NOVIKOVA, A., RILLING, J., YOSHINO, H., BERTOLDI, P., BOARDMAN, B., BROWN, M., JOOSEN, S., HAVES, P., HARRIS, J. & MOEZZI, M. (2007) Residential and commercial buildings. IN METZ, B., DAVIDSON, O. R., BOSCH, P. R., DAVE, R. & MEYER, L. A. (Eds.) *Climate Change 2007 - Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the IPCC.* Cambridge, United Kingdom and New York, NY, USA., Cambridge University Press.

LOPATKA, J. (2011) Market Definition? *Review of Industrial Organization,* 39**,** 69-93.

MARCUS, S. (2010) Embarking on a new journey: aviation biofuels are preparing to take off. *Executive Brief.* London, Cleantech Group.

MCKINSEY (2008) Revolutionizing data center energy efficiency.

MILES, I., FLANAGAN, K., BILDERBEEK, R., HERTOG, P., HUNTINK, W. & BOUMAN, M. (1995a) Knowledge-Intensive Business Services; users, carriers and sources of information.

MILES, I., KASTRINOS, N., FLANAGAN, K., BILDERBEEK, R., DEN HERTOG, P., HUNTINK, W. & BOUMAN, M. (1995b) KNOWLEDGE-INTENSIVE BUSINESS SERVICES. Users, Carriers and Sources of Innovation. Manchester, Delft, PREST and TNO report to DG13 SPRINT-EIMS.

MINGAY, S. (2007) Green IT: The New Industry Shock Wave Stamford, Gartner.

MOCK, D. & PERINO, G. (2008) Wasting innovation: barrier to entry and European Regulation on waste electronic equipment. *European Journal of Law and Economics,* 26.

MONT, O. (2009) Inventory and Assessment of Business Initiatives. Annex 2 to the Sustainable Consumption Policies Effectiveness Evaluation (SCOPE2) Final Report. IN TUKKER, A., DIAZ LOPEZ, F., LINDT, M., MONT, O., LOREK, S., SPANEBERG, J. & GILJUM, S. (Eds.). Lund, Lund University/TNO/SERI.

MONTALVO, C., P. TEN BRINK, C. SARTORIOUS, M. SOTOUDEH, D. STROMBERG, C. BOWYER, M. FERGUSSON, J. ANDERSON, F. SPREI, A. ALHBACK, J. NASSÉN, R. NEMESKERI, P. BODO, S. SCHILDER, F. HEIL, G. ANGERER, O. WOLF, L. DELGADO, M. VAN DIJK & LIPPMAN, F. (2007) Policy pathways to promote eco-innovations (POPA-CTDA) – Scientific summary report. *European Sixth Framework Program, Contract no. 502487.* Delft, TNO - The Netherlands Organisation for Applied Scientific Research.

MOSKOWITZ, S. (2009) *The Advanced Materials Revolution. Technology and Economic Growth in the Age of Globalization,* Hoboken, John Wiley & Sons Inc.

MOWBRAY, J. (2009) Light Fantastic. *EcoTextile News. The Magazine for Sustainable Textiles and Clothing.* Pontefract, EcoTextile News, Mowbray Communications Ltd.

MUDGAL, S., BENITO, P., VINCENT, J.-B., DIAS, D. & KONG, M. A. (2009) Study on water efficiency standards. . Brussels., BIO Intelligence Service/Cranfield University, for DG ENV.

NASA (2006) Aeronautics Innovation: NASA's challenges and opportunities. Committee on Innovation Models for Aeronautics Technologies, National Research Council.

NEMRY, F., LEDUC, G., MONGELLI, I. & UIHLEIN, A. (2008) Environmental improvement of Passenger Cars (IMPRO-car). Seville, Institute for Prospective Technological Studies.

NGOC, Y. N. & SCHNITZER, H. (2008) Zero emission systems in food processing industry. *WSEAS Transactions on Environment and Development,* 4.

NIEMINEN, E., LINKE, M., TOBLER, M. & BEKE, B. V. (2007) EU COST Action 628: life cycle assessment (LCA) of textile products, eco-efficiency and definition of best available technology (BAT) of textile processing. *Journal of Cleaner Production,* 15**,** 1259-1270.

NIOSI, J. & ZHEGU, M. (2005) Aerospace clusters: Local or Global Knowledge Spillovers. *Industry and Innovation,* 12.

OECD (1996) Venture Capital and Innovation. Paris, Organisation for Economic Co-operation and Development.

OECD (2001) *The Application of Biotechnology to Industrial Sustainability,* Paris, Organisation for Economic Cooperation and Development.

OECD (2002) *Design of Sustainable Building Policies. Scope for Improvement and Barriers,* Paris, Organisation for Economic Cooperation and Development.

OECD (2003) Environmentally Sustainable Buildings: Challenges and Policies. Paris, Organisation for Economic Co-operation and Development.

OECD (2006) Innovation and Knowledge-Intensive Service Activities. Paris, Organisation for Economic Cooperation and Development.

OECD (2009a) *The Bioeconomy to 2030. Designing a Policy Agenda,* Paris, Organisation for Economic Cooperation and Development.

OECD (2009b) Towards green ICT strategies; assessing policies and programmes on ICT and the environment.

OECD (2010) Eco-Innovation in Industry: Enabling Green Growth. Paris, Organisation for Economic Cooperation and Development.

ORACLE (2009) Oracle Unveils New Release of Oracle's Agile Product Lifecycle Management (PLM). Miami, Oracle Corporation.

PATAGONIA (2007) Homepage.

PETERS, R. (2003) Hazardous chemicals in consumer products. Project report 34629. Apeldoorn, Project commissioned by Greenpeace Netherlands to TNO-Netherlands Organisation for Applied Scientific Research.

PICCOLLO (2009) Materials. Praha, Piccollo s.r.o.

PITKOLA, S. (2006) Taking back the packaging advantage. Helsinki, High Technology Finland

PLEATSIKAS, C. & TEECE, D. (2001) The analysis of market definition and market power in the context of rapid innovation. *International Journal of Industrial Organization,* 19**,** 665-693.

POLIAKOV, E., BREMMER, C., LIESHOUT, M. & ROSO, M. (2008) EU Space policies and its potential for EU industrial sector competitiveness. Luxembourg, European Parliament.

PORTER , M. E. (1985) *Competitive Advantage: Creating and Sustaining Superior Performance* United States, Free Press.

PUJARI, D. (2006) Eco-innovation and new product development: understanding the influences on market performance. *Technovation,* 26**,** 76-85.

RAMMER, C., ASCHOFF, B., CRASS, D., CREMERS, K., GRIMPE, C., KLEIN WOOLTHUIS, R., BRANDES, F., DIAZ LOPEZ, F. J., MAYER, M. & MONTALVO, C. (2010a) European Competitiveness in Key Enabling Technologies. Background study to the European Competitiveness Report 2010. Mannheim, Delft, Centre for European Economic Research (ZWE) and the Netherlands Organisation for Applied Scientific Research TNO on behalf of the European Commission DG Enterprise.

RAMMER, C., MONTALVO, C., ASCHOFF, B., CRASS, D., CREMERS, K., GRIMPE, C., KLEIN WOOLTHUIS, R., BRANDES, F., DIAZ LOPEZ, F. J. & MAYER, M. (2010b) European Competitiveness in Key Enabling Technologies. Background study to the European Competitiveness Report 2010. Mannheim, Delft, Centre for European Economic Research (ZWE) and the Netherlands Organisation for Applied Scientific Research TNO on behalf of the European Commission DG Enterprise.

RAVETZ, J. (2006) Regional industrial ecology and resource productivity: new approaches to modelling and benchmarking. IN GREEN, K. & RANDLES, S. (Eds.) *Industrial Ecology and Spaces of Innovation.* Cheltenham, Edward Elgar.

REGATTA (2009) Ethical Trading Policy. Manchester, Regatta Group Ltd.

REID, A. & MIEDZINSKI, M. (2008) Eco-Innovation Final Report. Sectoral Innovation Watch in Europe. Brussels, Technopolis Group.

REISS, T., GAISSER, S., DOMINGUEZ LACASA, I., BUHRLEN, B., SCHIEL, B., ENZING, C., VAN DER GIESSEN, A., VAN DER MOLEN, S., VAN ZANDVOORT, C., VAN GROENESTIJN, J., MEESTERS, K., KOIVISTO, R., AUER, S., ALBERS, W., SIITARI, H., WIRTANEN, G., MIETTINEN-OINONEN, A., MENRAD, K., PETZOLDT, M., FEIGL, S., HIRZINGER, T., GABRIEL, A., TAIT, J., BRUCE, A., SHELLEY-EGAN, C., ROSIELLO, A., NICHOLLS, N., BUTTERFIELD, G., YOGENDRA, S., LYALL, C., SUK, J., PLASTOW, G., HUZAIR, F., RYAN, J., FORDE, T., SMITH, S., COZZENS, S. & ARUNDEL, A. (2007) Consequences, Opportunities and Challenges of Modern Biotechnology for Europe - Task 2 Main report. Seville, Fraunhofer Institute for Systems and Innovation Research, TNO Innovation Policy Group, VTT Innovation Studies Group, University of Applied Sciences of Weihenstephan, University of Edinburgh, CIRCA Group Europe and MERIT on behalf of ETEPS AISBL and the Institute for Prospective Technological Studies.

RENNINGS, K., KEMP, R., BARTOLOMEO, M., HEMMELSKAMP, J. & HITCHENS, D. (2003) Blueprints for an Integration of Science, Technology and Environmental Policy (BLUEPRINT). Strata Project.

ROY, R. (2000) Sustainable product-service systems. *Futures,* 32**,** 289-299.

SCHARTINGER, D. (2009) Construction. Sectoral Innovation Foresight. Brussels, Europe Innova Sectoral Innovation Watch. Project on behalf of the European Commission, DG Enterprise and Industry.

SHEN, L., HAUFE, J. & PATEL, M. K. (2009) Product overview and market projection of emerging bio-based plastics. Utrecht, Copernicus Institute for Sustainable Development and Innovation Utrecht University.

SHIBATA, K., CANTOR, B., GRANT, P. & JOHNSTON, C. (2008) Future Vehicles and Materials Technologies. *Automotive Engineering – Lightweight, Functional and novel Materials*.

SINCLAIR-DESGAGNÉ, B. (2008) The environmental goods and services industry. *International Review of Environmental and Resource Economics,* 2**,** 69-99.

STOREY, P. (2002) Exploring New Horizons in Product Design. *MCDC: Monthly Feature Story.* MCDC.

STRAMBACH, S. (2008) Knowledge-Intensive Business Services (KIBS) as drivers of multilevel knowledge dynamics. *International Journal of Services Technology and Management,* 10**,** 152-174.

SUH, S. (2006) Are Services Better for Climate Change? *Environmental Science & Technology,* 40**,** 6555-6560.

SWEDISH TRADE COUNCIL (2009) The U.S. Environmental Technology Market. Stockholm, Swedish Trade Council.

TAMIS, W. L. M., VAN DOMMELEN, A. & DE SNOO, G. R. (2009) Lack of transparency on environmental risks of genetically modified micro-organisms in industrial biotechnology. *Journal of Cleaner Production,* 17**,** 581-592.

THE CLIMATE GROUP & GESI (2008) SMART 2020: Enabling the low carbon economy in the information age. London, The Climate Group on behalf of the Global e-Sustainability Initiative.

THOMSON, A. & YOUNGMAN, R. (2010) The growing importance of renewable chemicals. *Executive Brief.* London, Cleantech Group.

TIBBS, H. (1993) Industrial Ecology. An Environmental Agenda for Industry. Emeryville, Global Business Network.

TIDD, J., BESSANT, J. & PAVITT, K. (2001) *Managing innovation :integrating technological, market and organizational change,* Chichester, Wiley.

TOIVONEN, M. (2004) EXPERTISE AS BUSINESS. Long-term development and future prospects of knowledge-intensive business services (KIBS)

Department of Industrial Engineering and Management. Helsinki, Helsinki University of Technology.

TRACETRACKER (2007a) The Global Traceability Network (GTNet). V3.4 Solution brief. Oslo, Tracetracker.

TRACETRACKER (2007b) Maximising Trade through Safety and Efficiency. Traceability in Food Value chains. Oslo, Tracetracker, tracesoft, EURO TechBridge.

TRANGOWORLD (2009) Catalogo de Productos. Zaragoza, Trangoworld SA.

TRESPASS (2009) Technology. Glasgow, Trespass

TUKKER, A., DIAZ LOPEZ, F., LINDT, M., MONT, O., LOREK, S., SPANEBERG, J. & GILJUM, S. (2009a) Sustainable Consumption Policies Effectiveness Evaluation (SCOPE2). Final Report. Delft, Lund, Cologne, and Vienna, Netherlands Organisation for Applied Scientific Research TNO, Lund University, SERI.

TUKKER, A., DIAZ LOPEZ, F., MUDGAL, S., TINETTI, B., FANINGER, T. & DE PRADO TRIGO, A. (2011) Analysis of the future application of product policy instruments in the EU. *Contract/Tender EU IPTS-2010-J06-45-RC.* Delft, Paris, Netherlands Organisation for Applied Scientific Research TNO and BIO Intelligence Services for DG JRC IPTS, European Commission.

TUKKER, A., EDER, P., VERCALSTEREN, A., WIEDMANN, T., TISCHNER, U., CHARTER, M., BELMANE, I., TIMMERS, G., VLUGT, M. & HAAG, E. (2000) Eco-design: European State of the Art. Seville, Spain, ESTO/IPTS.

TUKKER, A., HUPPES, G., SUH, S., HEIJUNGS, R., GUINEE, J., DE KONING, A., GEERKEN, T., JANSEN, B., VAN HOLDERBEKE, M. & NIELSEN, P. (2006) Environmental impacts of products. Seville, Spain, ESTO/IPTS.

TUKKER, A., POLIAKOV, E., HEIJUNGS, R., HAWKINS, T., NEUWAHL, F., RUEDA-CANTUCHE, J. M., GILJUM, S., MOLL, S., OOSTERHAVEN, J. & BOUWMEESTER, M. (2009b) Towards a global multi-regional environmentally extended input-output database. *Ecological Economics,* 68**,** 1928-1937.

TUKKER, A. & TISCHNER, U. (2006) *New Business for Old Europe. Product Service Development, Competitiveness and Sustainability,* Sheffield, UK, Greenleaf Publishing.

UIHLEIN, A. & EDER, P. (2009) Towards additional policies to improve the environmental performance of buildings.

VAN ERP, J. & HUISMAN, W. (2010) Smart regulation and enforcement of illegal disposal of electronic waste. *Criminology & Public Policy,* 9**,** 579-590.

WEIDEMA, B., WESNAES, M., HERMANSEN, J., KRISTIANSEN, T., HALBERG, H., EDER, P. & DELGADO, L. (2008) Environmental Improvement Potentials of Meat and Dairy Products. Seville, European Commission, Joint Research Centre, Institute for Prospective Technological Studies.

WEISS, M., HEYWOOD, J., DRAKE, E., SCHAFER, A. & AUYEUNG, F. (2000) On the road in 2020. A life-cycle analysis of new automobile technologies. Cambridge, Energy Laboratory, Massachusetts Institute of Technology.

WESSBERG, N., DIAZ LOPEZ, F., HOOGENDOORN, J. & KÖNNÖLÄ, T. (2008) Future outlook on Cleaner Production. IN WESSBERG, N. & DIAZ LOPEZ, F. (Eds.) *Deliverable D1.1b2 from TESTNET (Towards European Sectorial Testing Networks for Environmental Sound Technologies) project.* Delft, Helsinki, Netherlands Organisation for Applied Scientific Research TNO, VTT Technical Research Centre of Finland

WETERINGS, R., KUIJPER, J., SMEETS E, ARNOKKE´E GJ & MINNE, B. (1997) 81 options, technology for sustainable development. Delft, TNO/STB.

WHITELEY, C. G. & LEE, D. J. (2006) Enzyme technology and biological remediation. *Enzyme and Microbial Technology,* 38**,** 291-316.

WILLIAMS, E. (2003) Environmental impacts in the production of Personal Computers. IN KUEHR, R. & WILLIAMS, E. (Eds.) *Computers and the environment. Understanding and managing their impacts.* Dordrecht, Kluwer Academic Publishers, United Nations University.

WOODLEY, J. M. (2008) New opportunities for biocatalysis: making pharmaceutical processes greener. *Trends in Biotechnology,* 26**,** 321-327.

WRAP (2009) Meeting the UK climate change challenge: The contribution of resource efficiency. WRAP Project EVA128. . Stockholm Report prepared by Stockholm Environment Institute and University of Durham Business School, WRAP.

WRAP. (2009a) An Introduction to Packaging and Recyclability. Banbury, WRAP - Waste & Resources Action Programme.

WRAP. (2009b) Non-household Food Waste. Banbury, WRAP - Waste & Resources Action Programme.

WRAP. (2009c) Packaging optimisation: the impact to date. Banbury, WRAP - Waste & Resources Action Programme.

YAO, D. & DE SANTI, S. (1993) Innovation issues under the 1992 Merger Guidelines. *Antitrust Law Journal,* 61**,** 505-521.

YI, L. & THOMAS, H. R. (2007) A review of research on the environmental impact of e-business and ICT. *Environment International,* 33**,** 841-849.

ZARING, O., BARTOLOMEO, M., EDER, P., HOPKINSON, P., GROENEWEGEN, P., JAMES, P., DE JONG, P., NIJHUIS, L., SCHOLL, G., SLOB, A. F. L. & ORNINGE, M. (2001) Creating Eco-efficient Producer Services. Gothenburg, Gothenburg Research Institute.

ZIKA, E., PAPATRYFON, I., WOLF, O., GÓMEZ-BARBERO, M., STEIN, A. & BOCK, A.-K. (2007) Consequences, Opportunities, and Challenges of Modern Biotechnology for Europe. Seville, Joint Research Centre. Institute for Prospective Technological Studies.