eco-innovation observatory

Future Trends

Creating the environment for eco-innovation evolution

EIO Horizon Scanning Report

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Eco-Innovation Observatory

The Eco-Innovation Observatory functions as a platform for the structured collection and analysis of an extensive range of eco-innovation information, gathered from across the European Union and key economic regions around the globe, providing a much-needed integrated information source on eco-innovation for companies and innovation service providers, as well as providing a solid decision-making basis for policy development.

The Observatory approaches eco-innovation as a persuasive phenomenon present in all economic sectors and therefore relevant for all types of innovation, defining eco-innovation as:

“Eco-innovation is any innovation that reduces the use of natural resources and decreases the release of harmful substances across the whole life-cycle”.

To find out more, visit **www.eco-innovation.eu**

Any views or opinions expressed in this report are solely those of the authors and do not necessarily reflect the position of the European Commission.

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A note to Readers
Any views or opinions expressed in this report are solely those of the authors and do not necessarily reflect the position of the European Union. A number of companies are presented as illustrative examples of eco-innovation in this report. The EIO does not endorse these companies and is not an exhaustive source of information on innovation at the company level.

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Table of contents

List of Figures ..... **V**
List of Tables ..... **V**
Executive Summary ..... **VI**

1 | Setting the scene: results from the search engines **10**
1.1 | General keywords with Google.com **10**
1.2 | More specific keywords with Google.com **11**
1.3 | Eco-innovation and Web of Science® **12**

2 | Future trends creating framework for emerging eco-innovation **17**
2.1 | Resource scarcity **18**
2.1.1 | *Critical metals* **19**
2.1.2 | *Phosphorus* **20**
2.1.3 | *Water scarcity* **21**
2.2 | Globalization **24**
2.3 | Environmental threats **26**
2.4 | "Eco-trends": the trend of greening markets **27**

3 | Emerging technologies and eco-innovation **29**
3.1 | Main field: New Materials **29**
3.1.1 | *Phosphorus removal from water bodies* **30**
3.1.2 | *Field gypsum to enhance phosphorus recycling in agriculture* **31**
3.1.3 | *Green concrete* **32**
3.2 | Main field: Biotechnology **34**
3.2.1 | *Natural plastic showing significant reductions in greenhouse emissions* **35**
3.2.2 | *Biodegradable bags* **36**
3.2.3 | *Technologies utilizing the agriculture by-product biomass* **38**
3.3 | Main field: Environmental technology **39**
3.3.1 | *Urine separation toilets as a solution for phosphorus recycling from human excreta* **40**
3.3.2 | *Phosphorous extracted from wastewater and reused as fertilizer* **42**
3.3.3 | *Main field: Nanotechnology* **43**
3.3.4 | *Iron nanoparticles to clean contaminated groundwater more efficiently* **44**
3.4 | Main field: Information and communications technology (ICT) **46**
3.4.1 | *Smart Buildings that regulate their energy use* **47**
3.5 | Beyond technology: Social and system eco-innovations **48**
3.5.1 | *Future residential eco-building* **49**
3.5.2 | *Sustainable city project: Masdag City* **52**
3.5.3 | *Showing the path for future eco-cities: Dockside Green* **54**

4 | Concluding remarks **56**

List of Figures

Figure 1 | Foresight activities of EIO Work Package 3 7
Figure 2 | Results of query for generic keywords of eco-innovation. 10
Figure 3 | Results of query for thematic keyword combinations for eco-efficiency 11
Figure 4 | Results of query for sectoral keyword combinations for material efficiency 12
Figure 5 | Number of articles in Web of Science® under the topic "eco-innovation" per year. Total number of articles: 53 13
Figure 6 | Number of articles in Web of Science® under the topic "eco-innovation" by country of origin. Total number of articles: 53 14
Figure 7 | Domestic Material Consumption in the EU-27, 2000-2007 18
Figure 8 | World consumption of lithium by end-use, 2000-2009. 20
Figure 9 | Fertilizer nutrient consumption in the EU-27. 21
Figure 10 | Total actual renewable water resources per inhabitant in the World in 2005. 22
Figure 11 | Total gross abstraction of freshwater in the EU Member States, 1996-2007. Unit: millions cubicmeters (logarithmic scale). 23
Figure 12 | Mauro F. Guillén's indicators of globalization, 1980-2005. 25
Figure 13 | Greenhouse gas emissions in the EU-27, 1990-2008. 27
Figure 14 | By removing phosphate from the water column and preventing its release from sediments, Phoslock essentially deprives algae of an important food source and the profileration of algae, particularly blue green algae, is reduced 31
Figure 15 | Green concrete is an emerging technology 34
Figure 16 | Harmless-Compost is according to the producer ideal as an envelope for mailing magazines and publications or as a carrier bag or waste bag. 37
Figure 17 | Slow-release fertilizer, Crystal Green® fertilizer with a combination of nitrogen, phosphorus and magnesium (5-28-0 +10% Mg) 43
Figure 18 | Nanotechnology: Small structures – big impact. Global market volume of nano-optimized products (in billions of USD) 44
Figure 19 | Design of a future eco-building 50
Figure 20 | Masdag City Plaza – a day view 53
Figure 21 | A view of Dockside Green 55

List of Tables

Table 1 | Number of articles in Web of Science® under the topic "eco-innovation" by subject area of the journal. Total number of articles: 53. 15

Executive Summary

Introduction

Eco-innovation Observatory's (EIO) primary objective is to provide an integrated information source on the current and emerging eco-innovation trends for companies and innovation service providers, as well as to become a solid decision-making basis for policy development. The efforts of the EIO in the duration of 3 years time will encompass following activities:

1. Collection and analysis of information and data on future market and technology trends in this field, taking into account the situation of Member States and in specific market segments of eco-innovation;

2. Publication and further dissemination of an annual report on the situation of selected market segments eco-innovation in the Union;

3. Provision of market and technology intelligence customized to SMEs as well as innovation support providers' information needs for SMEs from the data collected in this activity for the annual reports, including developments in financing; and

4. Recommendations on how SME specific eco-innovation information beyond the resent activity can best be made available

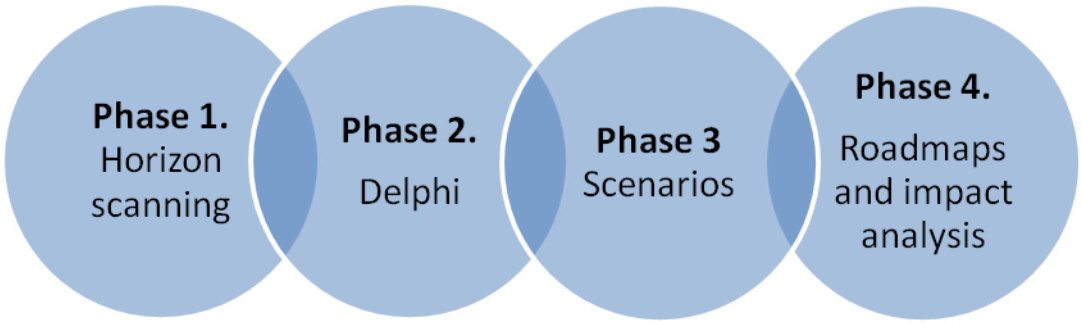
Foresight analyses are among key activities undertaken by the Observatory and are to enrich and interpret historical analyses based on the past trends.

Horizon scanning in the overall scheme of Eco-innovation Observatory's activities

The report at hand is one piece in a long chain of foresight activities described above in EIO-consortium activities. Horizon scanning is a starting point to various foresight activities following, and as a starting point it is not meant to be exhaustive. Because different foresight activities will be undertaken continuously during the project, the extensiveness of the reports will improve in the two years to come. This approach allows the team to learn from and expand on the initial efforts as project evolves.

The activity of grasping of future trends, emerging technology fields and eco-innovations will provide information for the upcoming Delphi-technique used to collect expert data for the following future scenarios, and further for the roadmaps and impact analysis activities. Foresight activities can be thus illustrated as a chain of events in which each phase will provide information for the next one (figure 1).

Figure 1 | Foresight activities of EIO Work Package 3



Each phase will provide information for the next phase. WP 3 uses information provided by WP 2 and givers input to other WPs of the EIO.

In this context, the aim of the horizon scanning is:

1. to analyse the global environmental trends creating the platform for eco-innovation evolvement;
2. to recognise the main technology fields where eco-innovations may emerge;
3. to search background information to build a scope for the EIO consortium about the given thematic areas;
4. to recognise those specific fields and sub areas, where the potential innovations may be found within each thematic area;
5. to find relevant keyword combinations for scanning the thematic areas.

Horizon scanning methods and sources

Internet search

There has been a systematic approach on scanning relevant eco-innovations and the related broader trends. The trends are selected on the basis of scanning a large number of future-oriented studies listing and describing megatrends, among which the most relevant from the eco-innovation perspective have been selected. These megatrends are also used.

A comprehensive **Internet search** was made by keyword search. The keywords were selected taking into account the definitions, scope and thematic areas of the Eco-Innovation Observatory described in more detail in the methodological report of the Observatory (EIO 2010). Results of keyword-based queries describe the popularity of the selected keywords. The first sets of keywords were selected from three perspectives:

1. keywords giving general information about the popularity of eco-innovation: the term itself and "synonyms" such as "environmental innovation" and "ecological innovation"

2. keyword combinations which describe the focus of the observatory, i.e. selected Lead market Initiative areas and other areas defined in the Methodological Report (EIO 2010)

3. keyword combinations which describe the popularity of "material efficiency" in the most important material-intensive human activities.

Main results from these queries are presented in Chapter 2.1 and Chapter 2.2 of this report. All results are available in Appendix 2. As search engines give large number of hits per keyword or keyword combination, there is a constant evolvement of keyword combinations in practical horizon scanning activities.

Scientific journals

In addition to Internet search, **selected scientific journals** have been scanned through their 2010 volumes. At the first stage, journals were used for outlining the relevant content of thematic areas of the Eco-Innovation Observatory, including material recycling and re-use, bio-based products, sustainable construction, phosphorus and sustainable nutrient flows as well as critical metals. The results from this activity have had influence on the structure of this first horizon scanning report, especially on Chapter 1 and Chapter 2. The list of scanned journals is included in Appendix 1.

In addition the use of scientific journals as background material, a query describing the popularity of the keyword "eco-innovation" was made by using an academic citation index service Web of Science®. Results of this query are presented in Chapter 1.3 of this report.

Media monitoring

Examples of actual eco-innovations have been scanned through **a media monitoring system, Meltwater News Service**. It monitors and analyses online news in more than 110 countries, and in more than 115 000 online publications (http://www.meltwater.com/products/meltwater-news/). The service uses an unlimited number of keywords given for different "agents". Keyword combinations can be tailored so that the service finds the most relevant information. The keyword combinations used in the first horizon scanning are listed in Appendix 1. Both Internet search and the up-to-date media monitoring give clues for further search on relevant eco-innovations. With both systematic information gathering methods, it is significant to constantly assess the relevance of certain keyword combinations and modify them if necessary. On the other hand, these methods allow follow up of temporal development which is crucial for the objectives of the Eco-Innovation Observatory, However, this requires that major keyword combinations in the Internet search and the agents and related keyword are not changed over time. The goal is to find a constant set of agents and keywords for follow-up.

All methods described above provide a sample of relevant materials for emerging technologies and actual eco-innovations as well as related broader trends described later on in this report.

Structure of the first horizon scanning report

After the general introduction, results from Internet search will be presented in Chapter 1 for setting the scene for shifting the focus to future trends creating the platform for eco-innovation evolvement (Chapter 2). Key megatrends laying the ground for new eco-innovations are (1) resource scarcity including materials,

water, and energy, (2) globalization of the economy which consists of economic development, change in the locations of production, raw materials and markets, as well as increasing significance of communication, and (3) environmental threats including climate change, acidification, eutrophication, loss of biodiversity, desertification, and other global or local environmental problems.

These future trends in combination are producing a fourth trend set called “Eco-trends”, the greening of the economy. These sections in Chapter 2 are descriptions of the basis for future demand. At the end of each trend description, there is a brief estimate of the eco-innovations for which there is demand for due to the future trend.

As Chapter 2 describes the demand side of future eco-innovations, in Chapter 3 the examination proceeds to supply. In Chapter 3, five fields of future eco-innovations are presented: (1) new materials, (2) biotechnology, (3) environmental technology, (4) nanotechnology and (5) information and communications technology (ICT). These main fields are illustrated with examples of eco-innovations or good practices, which have recently made advances towards a more sustainable direction in comparison to prevailing technologies. Some of these technologies are “future promises”, which could significantly reduce natural resource consumption and the release of harmful substances across the whole life-cycle.

As technologies are always tied to their users, the society and often to each other, there is a necessity to widen the scope of eco-innovation analysis to social and system eco-innovations. In the last section of Chapter 3, contemplation moves beyond mere technologies. Like emerging technologies, also social and system eco-innovation types are illustrated with some examples. The theme areas chosen for observing include (1) bio-based products, (2) material recycling and re-use, (3) sustainable construction, (4) phosphorus and sustainable nutrient flows, and (5) critical metals (EIO 2010). Three of the thematic areas belong to the EU Lead Market Initiative (LMI) areas: bio-based products, material recycling and re-use, and sustainable construction. Two of the chosen thematic areas are related to scarcity issues, namely phosphorous and sustainable nutrient flows and critical metals. Reserves of phosphor and critical metals are declining and these substances are non-renewable, therefore focus in these issues is in conserving and possibly replacing a limited resource.

Finally, in Chapter 4, concluding remarks are made including summary of necessary improvements to the second horizon scanning report, and deliberation shifts to following stages of the future process.

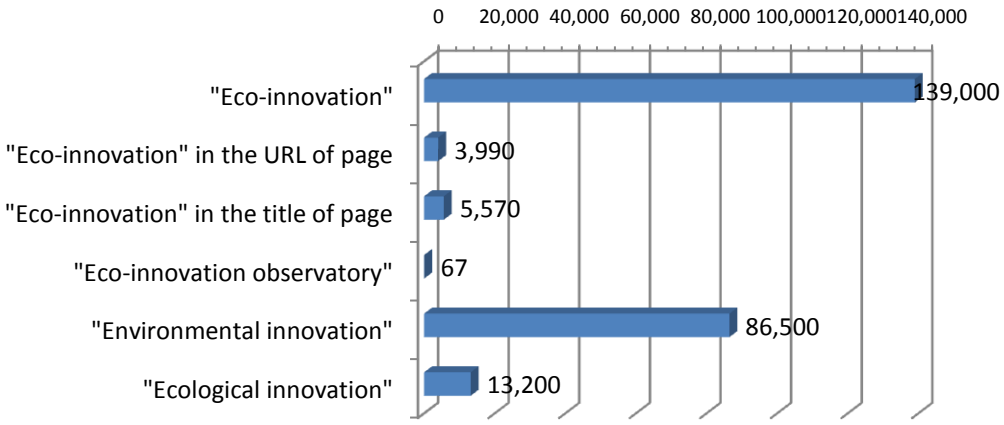
1 | Setting the scene: results from the search engines

In this Chapter, the results from keyword-based Internet searches are presented. The objective of this activity was get a general view to the number of “hits” by using more specific keyword combinations in relation to eco-innovation with the most popular search engine, Google. The first results are presented by using the English language only; this can be later extended to include other EU languages as well.

1.1 | General keywords with Google.com

The first keyword set includes generic keywords of eco-innovation. Used as a keyword as such in Google.com, eco-innovation provided 640 million hits (14.10.2010). When eco-innovation is used as a keyword with quotation marks (“eco-innovation”), Google.com gives only pages where the keyword appears as such plus recognizes also pages where the keyword is written as one word “ecoinnovation”. The number of hits is now radically smaller, instead of 640 million only 139,000. Figure 2 shows the results from queries for “eco-innovation” also in the URL and title of Internet pages. The results show that eco-innovation is quite popular topic in the Internet – there are almost 4,000 URLs and over 5,500 webpage titles including this keyword. Also substitutes of eco-innovation such as “environmental innovation” and “ecological innovation” were used as keywords in the first set. The keyword “environmental innovation” gives quite a high number of hits, 86,500 which clearly indicates that “environmental innovation” cannot left out from further horizon scanning activities. “Ecological innovation” is not so obvious substitute, but provided as much as 13,500 hits. As a curiosity, keywords “material innovation”, “material flow innovation” and “material eco-innovation” were tested as well (see Appendix 2) – as much as 174,000 hits for “material innovation” but only nine hits for “material flow innovation” and only one hit for “material eco-innovation” so only the first one is a relevant keyword to be taken into account in further horizon scanning activities.

Figure 2 | Results of query for generic keywords of eco-innovation.



Source: Date of the query 14.10.2010

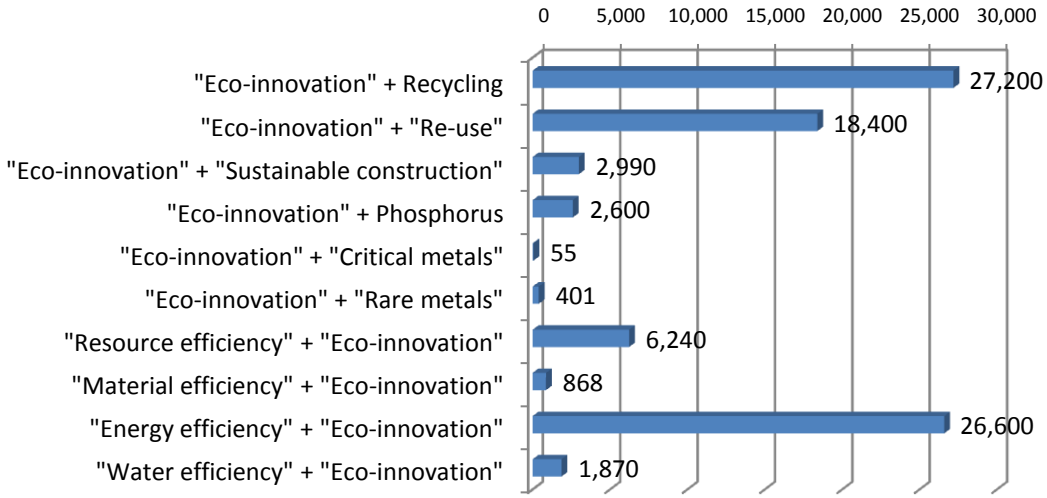
1.2 | More specific keywords with Google.com

Two other keyword sets were used in the Internet search in order to obtain information about the relative popularity of the keyword “eco-innovation” when compared to other keywords describing the focus of Eco-Innovation Observatory. These keywords were selected from the three Lead Market Initiative (LMI) areas (material recycling and re-use, bio-based products and sustainable construction) and two additional themes added by the EIO consortium (phosphorus and critical metals) to the thematic focus described in the methodological report (see EIO 2010).

The results (see Figure 3) show that in the Internet, recycling and re-use are much more often connected to eco-innovation than the other themes. “Critical metals” provided only 400 hits in the context of eco-innovation, and changing the keyword to a substitute “rare metals” did not increase the number of hits.

Four important efficiencies relevant from the EIO’s material-focused perspective (“resource efficiency”, “material efficiency”, “water efficiency” and “energy efficiency” were also selected as keywords and combined with “eco-innovation” in the queries. The results (see Figure 3) show that “energy efficiency” combined to eco-innovation produced 26.600 hits and is almost five times more common in the Internet than “resource efficiency”, and about 30 times more common than “material efficiency” with eco-innovation. “Water efficiency” gained 1,870 hits.

Figure 3 | Results of query for thematic keyword combinations for eco-efficiency

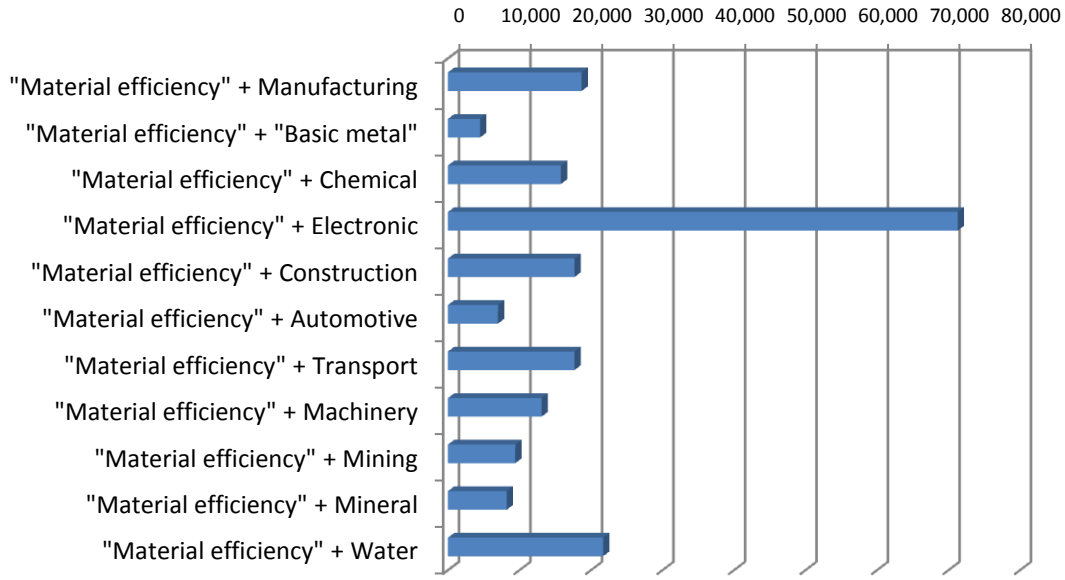


Source: Date of the query 14.10.2010

A third keyword set for Internet search was formulated on the basis of selected technology fields slightly following the NACE Rev. 2 classification of economic activities. Used keywords included “material efficiency”, the most important character of eco-innovation in the EIO focus plus selected general keywords describing the selected industrial branches.

The results show that the keyword “electronic” was the most common in the context of “material intensity”, which is somewhat surprising at the first glance. Another important result is that the differences between selected keyword sets were rather small. “Material efficiency” combined to a keyword describing a field of industry provides thousands of hits, typical range is between 5,000 and 20,000 hits. These results are preliminary examples and the used keyword set needs development and modifications.

Figure 4 | Results of query for sectoral keyword combinations for material efficiency



Source: Date of the query: 14.10.2010

1.3 | Eco-innovation and Web of Science®

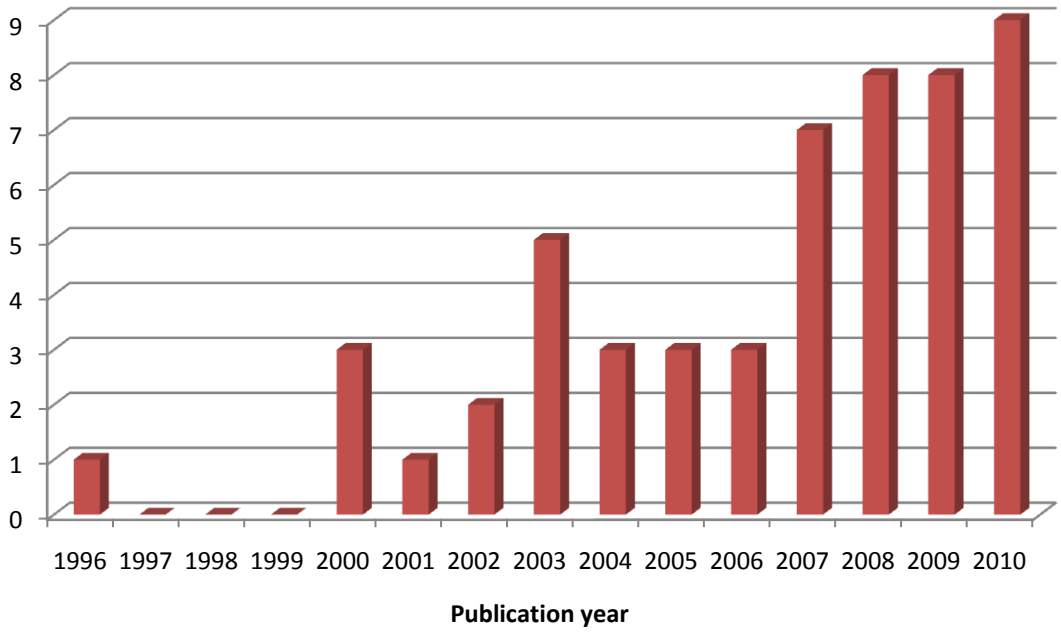
In addition the use of scientific journals as background material for building a framework where trends create a need for eco-innovations and emerging technologies and other ideas provide the actual eco-innovations, a generic query in order to describe the popularity of the keyword “eco-innovation” in scientific context was made by using an academic citation index service, Web of Science® (see http://thomsonreuters.com/products_services/science/science_products/a-z/web_of_science).

The website of Web of Science® provides the following basic information of the service: Its content covers over 10,000 of the highest impact journals worldwide, including Open Access journals and over 110,000 conference proceedings across 256 disciplines. Current and retrospective coverage in the sciences, social sciences, arts, and humanities is to the year 1900.

The queries presented in this report focus only on the keyword “eco-efficiency” in the field tag “topic” (defined by title, abstract, and keywords) of the article, the other field tag related to the content is “title”. The results clearly show that in scientific journals included in the Web of Science, “eco-innovation” is not a popular topic because the total number of articles including this topic is only 53. Figure 5 shows the record, “eco-innovation” appeared first time as a topic in 1996, and the number of articles per year has slightly

increased since then. In the 2010s the number of articles can be expected to further increase. The low number of articles can be explained by the novelty and vagueness of the topic, which relates to the lack of generally accepted definition fulfilling any scientific criteria. Thus it can be concluded that information on scientific articles dealing with actual content of eco-innovations requires more specific keywords.

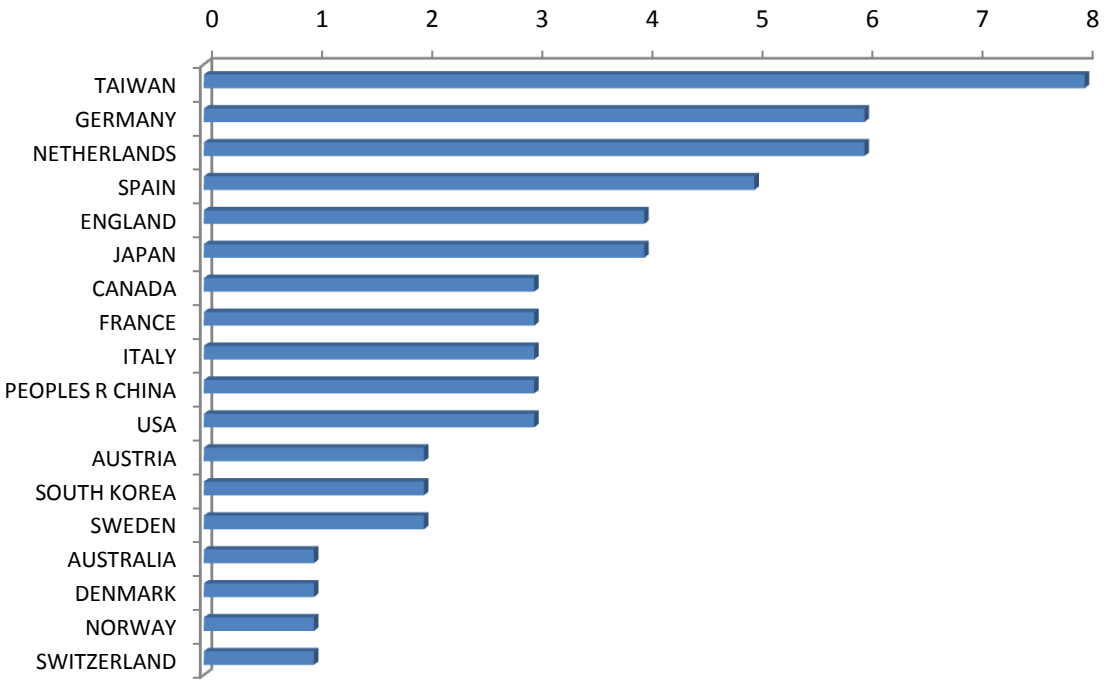
Figure 5 | Number of articles in Web of Science® under the topic “eco-innovation” per year. Total number of articles: 53



Source: Date of the query 2.11.2010

Figure 6 shows the countries from which the main authors of the articles including the keyword “eco-innovation” come from. Of the total 53 articles, 60 % (32) of the main authors come from nine EU Member States. The leading EU Member States are Germany (6) and the Netherlands (6), followed by Spain (5). To generalize, eco-innovation seems to be a European catchword in scientific journals. This needs to be analysed also at a more general level by using Internet search engines.

Figure 6 | Number of articles in Web of Science® under the topic “eco-innovation” by country of origin. Total number of articles: 53



Source: Date of the query: 2.11.2010

Table 1 shows how the 53 articles including the keyword “eco-innovation” in Web of Science are distributed over different disciplines. Here the total number of hits (116) is larger than the total number of articles (53), which indicates that a single journal or article may belong to more than one discipline. As expected, the most important results are that (1) 41 % of the hits are in engineering journals of different fields and (2) two disciplines are clearly the most popular, environmental engineering (19 hits) and environmental science (17 hits).

Table 1 | Number of articles in Web of Science® under the topic “eco-innovation” by subject area of the journal. Total number of articles: 53.

Subject Area Of The Journal	Number Of Articles
Engineering, Environmental	19
Environmental Sciences	17
Engineering, Manufacturing	9
Engineering, Industrial	7
Business	5
Economics	5
Environmental Studies	5
Engineering, Electrical & Electronic	4
Engineering, Multidisciplinary	4
Management	4
Planning & Development	4
Ecology	3
Operations Research & Management Science	3
Construction & Building Technology	2
Energy & Fuels	2
Engineering, Chemical	2
Engineering, Civil	2
Nanoscience & Nanotechnology	2
Agronomy	1
Chemistry, Analytical	1
Computer Science, Artificial Intelligence	1
Computer Science, Information Systems	1
Computer Science, Interdisciplinary Applications	1

Computer Science, Software Engineering	1
Education, Scientific Disciplines	1
Engineering, Mechanical	1
Ethics	1
Food Science & Technology	1
Geography	1
Horticulture	1
Marine & Freshwater Biology	1
Materials Science, Multidisciplinary	1
Materials Science, Paper & Wood	1
Optics	1
Water Resources	1

Source: Date of the query - 2.11.2010

2 | Future trends creating framework for emerging eco-innovation

Future trends shape the world we will live in the 21st century. Some trends lead to shifts in demand. This is in comparison to the emerging technologies and innovations that affect the supply structure in economy, such as new materials, environmental technology, biotechnology, nanotechnology, ICT and social and system innovations. The future trends are able to boost productivity in multiple economic sectors simultaneously and create a platform for eco-innovation evolvement.

We will describe three "megatrends" that are strongly affecting the future economics, namely (1) **resource scarcity** including materials, water, and energy[1], (2) **globalization of the economy** which consists of economic development, change in the location of production, raw materials and markets as well as increasing significance of communication[2], and (3) **environmental threats** caused by environmental impacts of climate change, acidification, eutrophication, loss of biodiversity, and other environmental problems[3]. All these three megatrends are well-known and interrelated, and have an impact on each other at different levels of the society. They are also listed in several publications dealing with future prospects, not necessarily from the exact point of view of eco-innovations, but from many different perspectives. We will also describe as a fourth megatrend a phenomenon called "Eco-trends, greening the markets which also deals with the change in thinking, attitudes, and policy, which determine the circumstances where response to the challenges of other megatrends emerge. These four trends build a general platform for the eco-innovation evolvement.

All the above mentioned trends are strengthened by the Internet and demographic changes. The Internet brought about the removal of technological barriers to enable goods to be ordered across the globe and export of services possible. Since 1987 the volume of global trade has quadrupled. Internet also reinforces the acceptance of values and ideas supporting "eco-trends" and green marketing as these ideas reach people globally at the similar form and are spreading fast. One growing internet tool for information, ideological sharing and marketing is social media. For example the most popular social media platform Facebook has already 590 million users (2010) and it has been estimated that the role of social media is continually taking bigger part of people's everyday lives, especially among young adults, the future decision makers, business leaders and consumers.

Even though the world is more and more interconnected, demographic divide is increasing. It is estimated that by 2030 the world population has increased to roughly 8 300 000. At the same time population is ageing and shrinking in half of the world, mainly in certain developed regions in Europe and Japan. In other half population keeps on growing and remaining relatively young. The center of gravity seems to be shifting

1 The Club of Rome's publication "Limits to Growth" (see Meadows et al 1972) was a big boost to resource scarcity as a popular issue and as a topic of literature.

2 There is a large and growing literature on globalization and its effects.

3 Public awareness on environmental problems and related literature has strongly increased since the late 1960s.

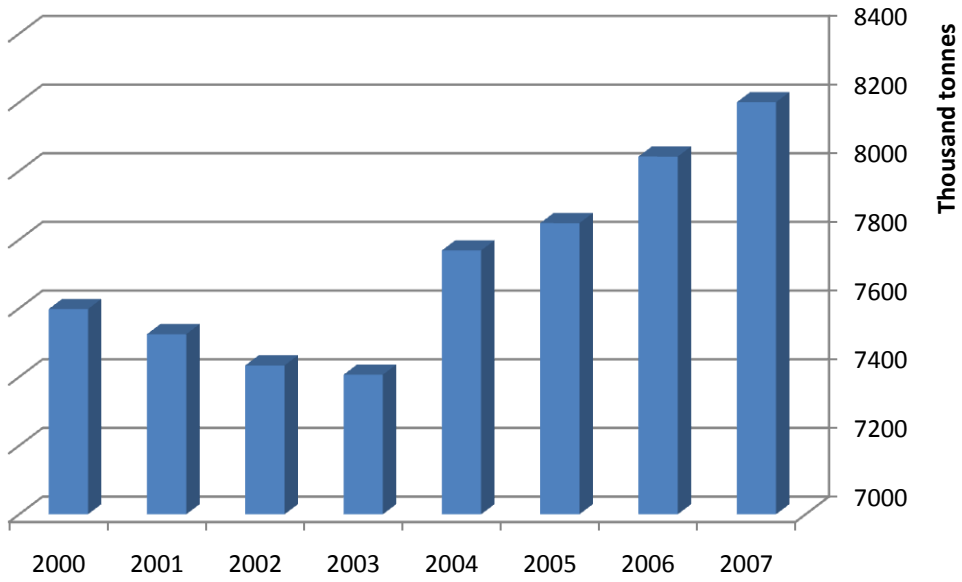
toward Asia in the 21st century. This is due to the continuing globalization and world population growth. Asia already accounts for 60 % of the world population, holds close to half of all foreign exchange reserves, about 32 % of the global value creation (adjusted for purchasing power). (Allianz Global Investors 2010; UN 2008.)

With the estimated world population growth, the number of consumers will increase dramatically and add strain on the world's already scarce natural resources. This means that there is enormous need for resource efficiency and new and more sustainable consumption patterns. There will be market demand for eco-innovations and on the other hand, resource scarcity will most likely drive innovators towards eco-innovations.

2.1 | Resource scarcity

Materials play an increasingly important role in our everyday lives. They have a huge impact on all areas of life from food production to transport, security, information and communication technology and sustainable technologies. In the European Union, material flows when measured by domestic material consumption DMC) decreased in the beginning of the 2000s but have started to increase again after the year 2003 (Figure7).

Figure 7 | Domestic Material Consumption in the EU-27, 2000-2007



Source: Eurostat. EIO database, original

Material scarcity is the shortage of metal and mineral resources expected in the following decades. Material scarcity is controlled by two factors: the supply of the material versus its demand. With a growing world population and growing consumption, the demand for material resources exceeds the supply. In the past century the exploration of new locations and technological innovations in mining and extraction kept the material reserves in balance with the demand. However, according to the present knowledge this balance

will not continue in the 21st century as for a number of material resources the peak production is already in the past. The decreasing reserves are also a subject to international political influence as the reserves are not uniformly distributed over the globe. For example, 60% of the iron ore in the world comes from three countries: Australia, Brazil and China (M2i study 2009) and 83 percent of the world's exploitable phosphate rock is in Morocco, China and South Africa (Vaccari 2010). In the first horizontal scanning the emphasis is on critical metals and phosphorus, as the scarcity in both areas is increasing and hence building a platform for the eco-innovation evolvement.

2.1.1 | Critical metals

A critical metal is a metal which is essential to an industrial process and for which there is no actual or commercially viable substitute. There are many critical metals in various areas of industry and the interest of this subject will increase in the future as the scarcity of these metals may affect our lives significantly. Some raw materials can be considered to be particularly critical, because of their significant economic importance for key sectors, demand growth, high supply risks, lack of substitutes and recycling restrictions. (Öko-Institute 2009; European Commission 2010.)

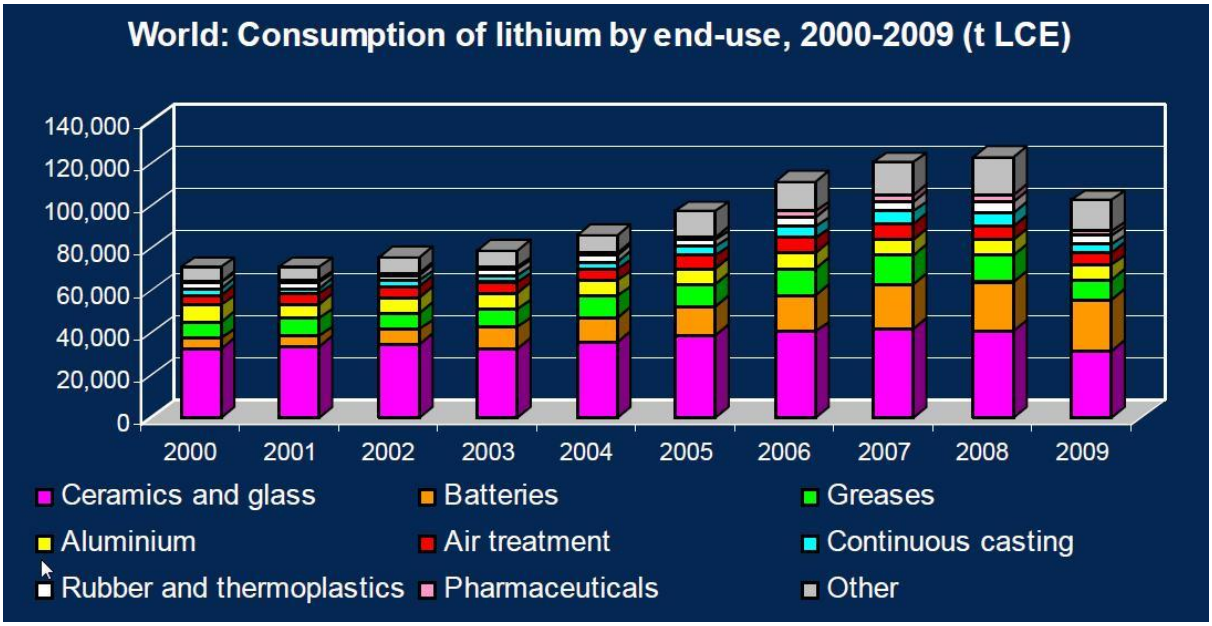
Many of the listed critical metals are such that are critical for the future sustainable technologies, such as renewable energies and energy efficient technologies. Those technologies will make use of Indium, Germanium, Tantalum, Platinum Group Metals (PGMs: Platinum, Palladium, Iridium, Rhodium, Ruthenium, and Osmium), Rare earths (yttrium, scandium, lanthanum and so called lanthanides) and other "high tech metals". (Öko-Institute 2009.)

One of the most powerful forces influencing the economic importance of raw materials in the future is technological change. In many cases, their rapid diffusion can drastically increase the demand for certain raw materials. Hence, the list of the "most critical raw materials" will vary depending on the needs of the emerging technologies. (European Commission 2010.)

The trend in scarcity of critical metals will create platform for such innovations which enhance the recycling of the critical metals or critical metal-containing product, find substitutions for such metals or improve the material efficiency of the critical metal.

Time series data on critical metals seems to be difficult to find, but as an example, Figure 8 describes Lithium, which is considered as a critical metal due to its demand for a wide range of uses and its unique properties: It is the lightest of all the metals and is highly reactive and flammable. Perhaps the best known use of lithium is for batteries. Figure 8 shows that during the 2000s, lithium consumption has increased until the year 2008 but turned down in 2009.

Figure 8 | World consumption of lithium by end-use, 2000-2009.

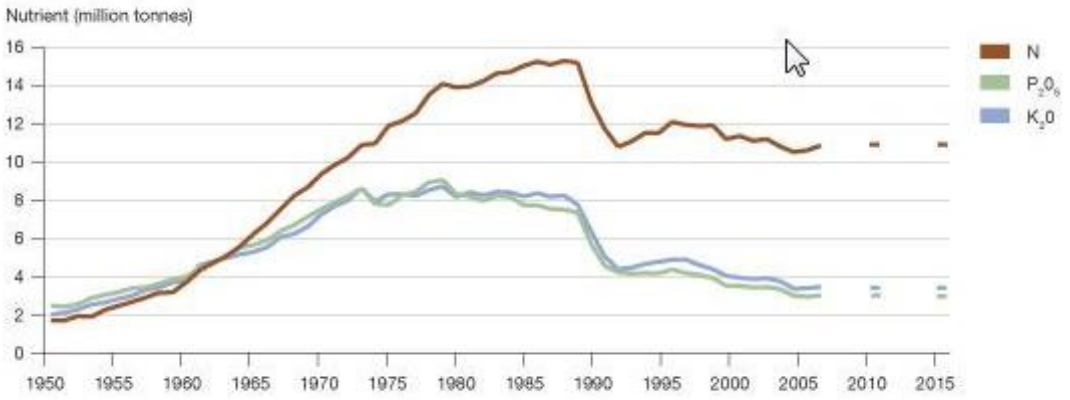


Source: Roskill 2010.

2.1.2 | Phosphorus

Phosphorus (P) forms the backbone of DNA and of cellular membranes, and it is the crucial component in the ATP (molecular adenosine triphosphate), the cell's main form of energy storage. Plants require phosphorus to grow, it cannot be substituted (USGS 2005), and thus it is vital for the food production. The demand of phosphorus is predicted to increase 50 – 100 % by 2050 with increased global demand for food and changed diets. Two significant contributors to the increasing demand for phosphorus have been the increasing popularity of meat- and dairy based diets, especially in the growing economies like China and India, and the expansion of the biofuel industry. Hence, acquiring enough phosphorus to grow food and material for growing biofuel industry will be a significant challenge for humanity in the near future. Phosphorus is like oil, a non-renewable resource. According the current rates of extraction, global commercial phosphate reserves will be depleted in 90 years. (Reviewed by Cordell et al. 2009; Vaccari 2009). According to the data provided by Fertilizer's Europe (former EFMA), consumption of fertilizers, among them phosphorus, started decreasing in the European Union in the late 1980s but this trend seems to have slowed down or even stopped (Figure 9).

Figure 9 | Fertilizer nutrient consumption in the EU-27.



Source: Fertilizer's Europe 2010.

Historically, crop production relied on natural levels of soil phosphorus and the addition of locally available organic matter like manure and human excreta. To keep up the with increased food demand due to rapid population growth in the 20th century, guano and later rock phosphate were applied extensively to food crops (Smil 2000). At the moment, the primary source for farmers is mined phosphorus in commercial fertilizers. In 2008, farmers worldwide applied 170 million tons of mined phosphorus on their fields to produce their crops (Sustainable Phosphorus Initiative 11.8.2010). Excess of phosphorus from concentrated animal feeding operations, urban sewage and runoff and agriculture ends up in lakes and oceans, where it spurs massive blooms of cyanobacteria and algae. Once they die and fall to the bottom, their decay starves other organisms of oxygen, hence creating dead zones followed by a depletion of fisheries. Thus, increasing concentrations of phosphorus in aquatic systems are causing ecological and economic damage.

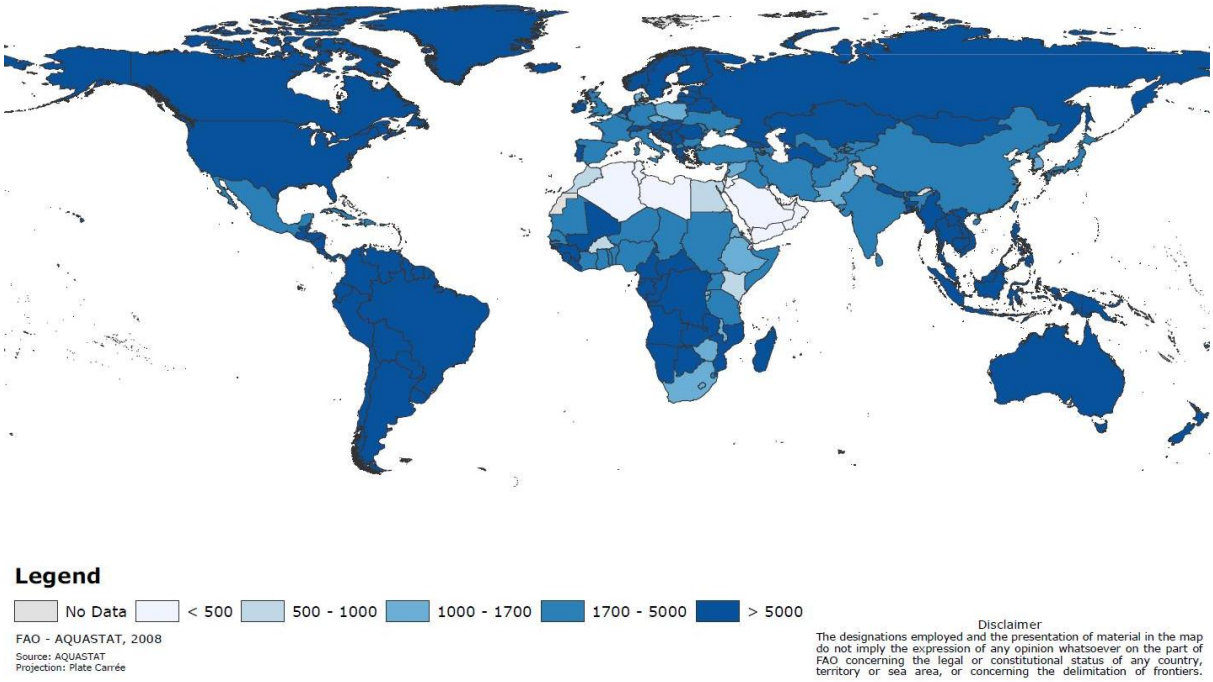
To summarize, the problem creating the platform for eco-innovations is twofold. On one hand, the phosphorus reserves are decreasing with the increasing demand of fertilizers in agriculture and thus, phosphorus must be conserved or the future food production will be collapse. On the other hand, the aquatic systems must be conserved from the excess of phosphorus from the waste water or the aquatic systems will collapse. Thus, the innovations should seek solutions to restore the balance to the phosphorus cycle.

2.1.3 | Water scarcity

Water is essential for socio-economic development and for ecosystems. Population increases and development requires increased allocations of groundwater and surface water for the domestic, agriculture and industrial sectors. Water scarcity is affected by the unbalance between water availability and demand, the degradation of groundwater and surface water quality, and interregional and international conflicts (WHO 2007). Water scarcity is a serious concern and thus can be named as a trend, which will strongly affect the future economics and eco-innovation evolvement.

Water use has been growing at more than twice the rate of population increase in the last century, and, although there is no global water scarcity as such, an increasing number of regions are chronically short of water. The UN suggests that each person needs 20 – 50 litres (7.3-18.25 m3 per year) of safe freshwater a day (to ensure their basic needs for drinking, cooking and cleaning). More than one in six people worldwide, that is 894 million people, don't have access to this amount of safe freshwater (cf. Figure 10). About 20 % of the world's population lives in countries where water is scarce, or where they have not been able to access the natural sources available. (UN Water statistics 7.10.2010; WHO 2007.)

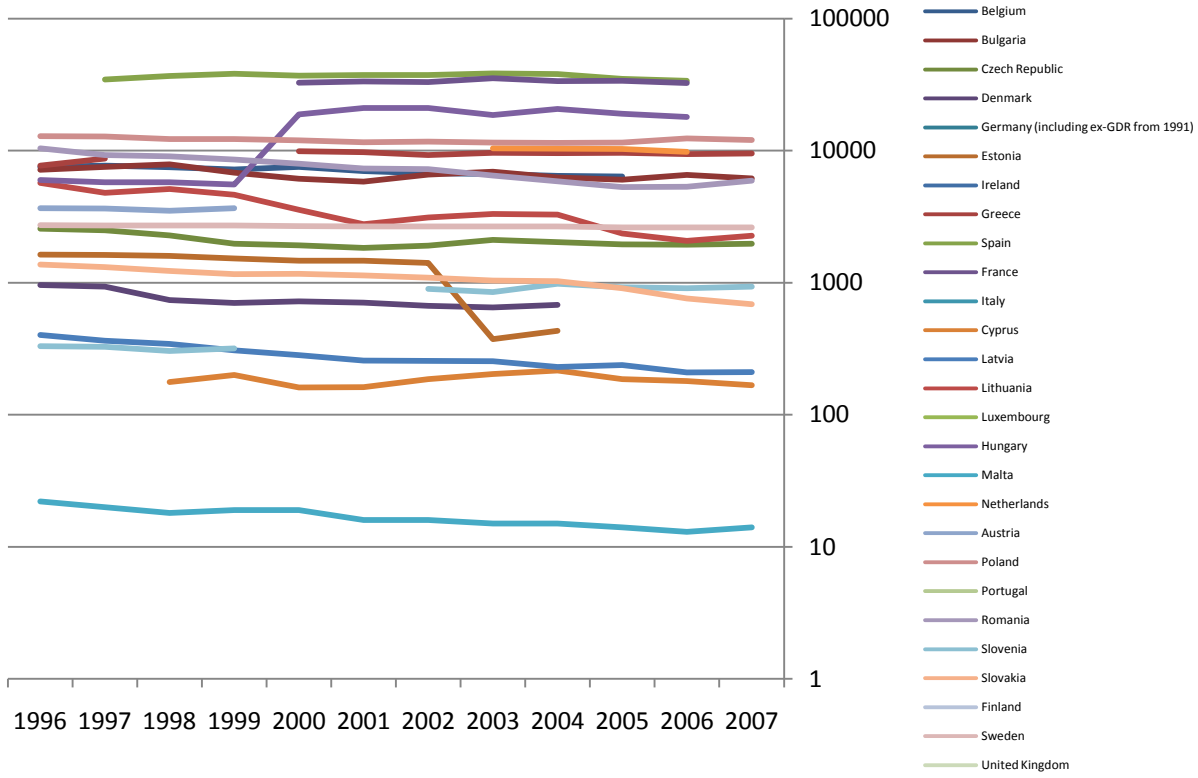
.Figure 10 | Total actual renewable water resources per inhabitant in the World in 2005.



Source: AQUASTAT/FAO 2010.

In the European Union, water consumption when measured by total gross abstraction of freshwater (Figure 11) has been rather stabile in many countries which indicates slight improvements in water efficiency

Figure 11 | Total gross abstraction of freshwater in the EU Member States, 1996-2007. Unit: millions cubicmeters (logarithmic scale).



Source: Eurostat

Climate change is affecting water resources in both developed and developing countries. The existing gap in water availability is likely to further widen: in the North, rainfall is increasing, while in the South, drought periods are becoming longer. A country with increasing threat to its water supply is known as 'water stressed'. It has been estimated that, by 2025, 1 800 million people will be living in countries or regions with absolute water scarcity, and two-thirds of the world population could be under stress conditions. (WHO 2007.)

Increasing water productivity holds the key to future water scarcity challenges. Without further improvements in water productivity or major shifts in production patterns, the amount of water used for agriculture, industrial and domestic activities will increase by 60–90 percent by 2050, depending on population, incomes and assumptions about water requirements for the environment. For example, in agriculture alone, the total volume of water used in crop production would be 11 000–13 500 km^3, almost double the 7 130 km^3 of today. (WHO 2007.)

Water scarcity alleviation creates a platform for innovations that would enhance water productivity (the volume of production per unit of water) in domestic, agriculture and industrial sectors. Furthermore, innovations that protect and restore the ecosystems that naturally capture, filter, store and release water, such as rivers, wetlands, forests and soils, are crucial to increasing the availability of water of good quality.

2.2 | Globalization

Globalization can be defined as a process by which local, regional or national economies, societies, and cultures become integrated worldwide through a network of communication, transportation, and trade. Typically, globalization refers to integration of markets and economies through trade, investment, capital flows, technology diffusion and global environmental problems. Globalization is usually recognized as being driven by a combination of economic, technological, socio-cultural, political, and biological factors. The term includes transnational circulation of ideas, languages, or popular culture. Globalization has several different consequences, some of them positive and some others negative, and the effects of globalization is a widely discussed and disputed issue.

Globalization is a megatrend which can be described by using a set of globalization indicators if time series data is available long enough. Horizon scanning provided an example by Mauro F. Guillen's (2001) indicators of globalization, the newest data is however as old as from the year 2004 (Figure 12). The data shows that the share of exports and imports of goods and services in GDP has increased, more in developing countries than in developed countries. Foreign investments and cross-border bank loans have also increased. On the other hand, international migration has increased but quite in line with population growth. There is a rapid increase of Internet users and even more rapid increase in the number of published books on the topic of globalization.

In the context of eco-innovation, globalization broadens the market for eco-innovative products and services, and is an important megatrend creating a platform for eco-innovation evolvement.

Figure 12 | Mauro F. Guillén's indicators of globalization, 1980-2005.

Mauro Guillén's Indicators of Globalization, 1980-2005

Indicators:	1980	1985	1990	1995	2000	2005
A. Economic:						
Exports + imports of goods & services, % world GDP	38.8	38.7	38.3	42.0	50.0	52.1[k]
Developed countries, % GDP	39.8	39.9	38.1	40.5	48.2	49.6[k]
Developing countries, % GDP	33.9	32.6	39.3	48.3	57.2	63.5[k]
Inward foreign direct investment stock, % world GDP	6.7	8.4	9.3	10.3	18.3	22.7
Developed countries, % GDP	4.9	6.2	8.2	8.9	16.3	21.4
Developing countries, % GDP	12.6	16.4	14.8	16.6	26.2	27.0
Exports of foreign affiliates, % total world exports	…	31.9	27.5	32.3	33.3[h]	33.3
B. Financial:						
Daily currency exchange turnover, % world GDP[a]	0.7	1.3	3.8	5.6	6.8	4.6[k]
Cross-border bank loan stock, % world GDP[b]	13.9	19.9	34.3	33.1	37.6	34.2
Cross-border banking claims stock, % world GDP[b]	13.7	19.9	28.1	28.5	34.2	47.5
C. Internet:						
Users, % world population:	…	…	0.1	0.8	6.5	13.7
Developed countries, % population	…	…	0.3	4.0	31.9	52.7
Developing countries, % population	…	…	0.0	0.1	1.6	8.4
D. Demographic:						
Stock of international migrants, % world population	2.2	2.3	3.0	2.9	2.9	3.0
Refugee population, % world population	…	…	…	0.3	0.2	0.1
E. Political:						
Nation-states with membership in the United Nations	154	159	159	185	189	191
International organizations, number:						
Intergovernmental	337[i]	378	300[j]	…	243	244
Non-governmental	4265[i]	4676	4621[j]	…	6357	7412
F. Social & Cultural						
International tourist arrivals, % world population	3.5	6.7	8.6	9.5	11.4	11.4
International calls, minutes per capita	…	…	7.1[f]	11.1	19.5	22.8[k]
Books in Print on the topic of globalization[•]	86	173	825	2236	5395	6222

Notes: … Data not available. [a] Data are for 1979, 1984, 1989, 1995, 1998 and 2004. [b] Data are for 1981, 1986, 1991, 1995, 2000, and 2005. [d] Excludes international calls using cellular phones or private networks. [•] Books with the subject or title keywords "global" or "globalization," published in any language until each year. [f] 1991. [g] 2002. [h] 1998. [i] 1981. [j] 1989. [k] 2004.

Sources: *World Development Indicators*; *World Investment Report*; Bank for International Settlements; International Telecommunication Union, *Key Global Telecom Indicators*; *Yearbook of International Organizations*; Bowker's Global Books in Print.

For background information, see Mauro F. Guillén, "Is Globalization Civilizing, Destructive or Feeble? A Critique of Five Key Debates in the Social-Science Literature." *Annual Review of Sociology* 27 (2001):235-260.

Compiled by Mauro F. Guillén, The Wharton School of the University of Pennsylvania, guillen@wharton.upenn.edu

Source: Guillén (2005)

2.3 | Environmental threats

"Climate change is one of the gravest threats to our planet. Acting against climate change is imperative. Today, we have agreed on a set of ambitious, but realistic targets which will support our global efforts to contain climate change and its most dire consequences. I urge the rest of the developed world to follow our lead, match our reductions and accelerate progress towards an international agreement on the global emission reductions"

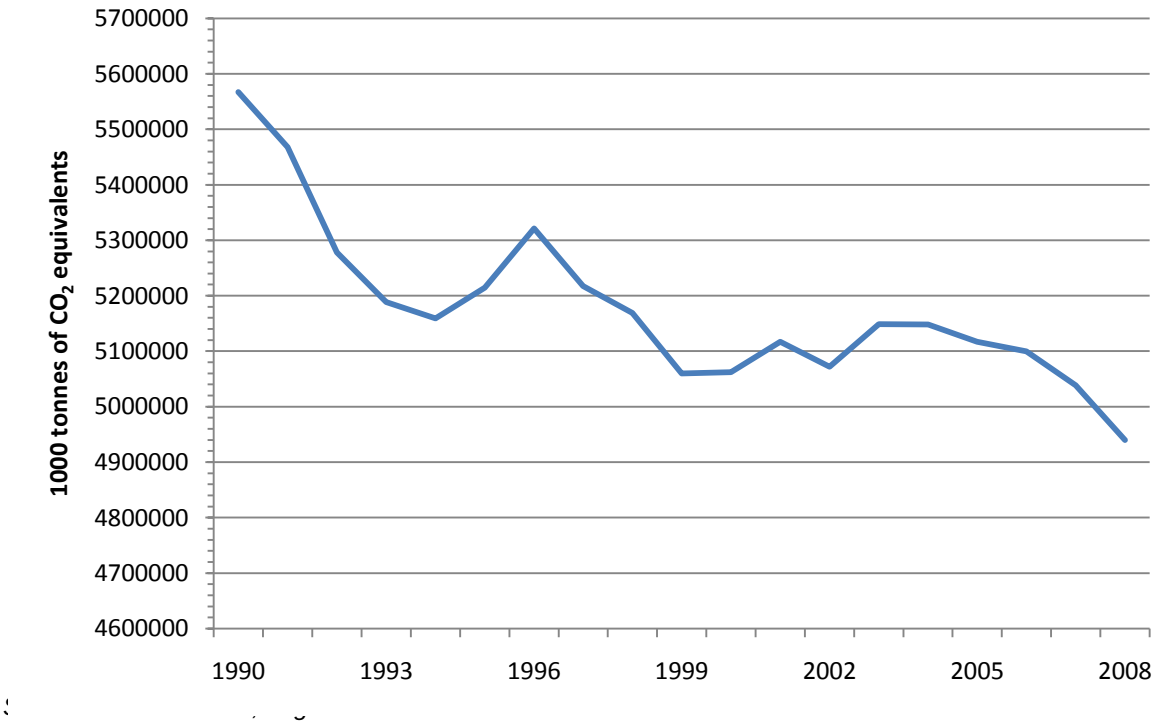
(Stavros Dimas, Commissioner for the Environment on EU Commissions proposition to integrate energy and climate change package to cut emissions for the 21st century)

Climate change is one of the few environmental problems with targets and policies negotiated at the global level. It is widely acknowledged that there exists a scientific uncertainty of the true effects of climate change on the environment in the timescale of our foresight which reaches to the year 2030. Although natural phenomena are hard to predict, on a governance level European Union has made clear legally binding targets to be met in the year 2020. These targets and national The EU Climate and Energy package states the following targets for the year 2020 (EUROPA 10.9.2010):

- A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels
- 20% of EU energy consumption to come from renewable resources
- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

National target sharing decisions of EU give each member state individual targets to be met with national policies each country sees fit. (EUROPA 10.9.2010.) The negotiations for the targets past the year 2020 and for the year 2030 are ongoing. The trend of greenhouse gas emissions in the EU is decreasing (Figure 12). In 2008, the sum of GHG emissions in EU-27 Member States were 11.3 % lower than the sum of emissions in the same countries in 1990.

Figure 13 | Greenhouse gas emissions in the EU-27, 1990-2008.



These legally binding targets and national policies utilized to reach their own targets provide a framework for energy-related eco-innovation markets. In sustainable construction energy-efficiency demands are tightening during the next decade and this provides a platform for eco-innovations. Also there is a demand for eco-innovations relating to renewable energy systems being integrated in the buildings. Monitoring and controlling systems integrated to the buildings to save energy will most likely increase their market share. In relation to material recycling and re-use, these targets provide a market for eco-innovations that e.g. use bio waste and dung for energy, thus diminishing methane emissions to the atmosphere and provide a renewable energy source.

2.4 | "Eco-trends": the trend of greening markets

Globalization, demographic change, climate change, scarce resources, greater consumer awareness of the environment and of the responsibility all together will lead to structural change in the economy, titled "Eco-Trends" by Allianz Global Investors (2010) and hence creating a platform for eco-innovation evolvement. The consumption of the environment is becoming a cost and scarcity factor and thus the environment has "price". The trade in CO_2 emission rights is one evidence that environmental costs are being increasingly internalized i.e. polluters are being asked to pay their own way. The global economic system has already taken environmental protection, resource conservation and corporate social responsibility on board in many areas- especially in the industrialized countries (Allianz 2010.)

There is a growing consumer interest in buying sustainable products and services. Evidence for this heightened interest are the numerous surveys released over the last few years that have found that a majority of consumers care about sustainability issues, and that they are either willing to pay more for

goods produced in a more sustainable way or will choose the more sustainable product. For example, the recent results from the Eurobarometer (European Commission 2009) show that large majority of EU citizens think that a product's impact on the environment is important in their purchasing decision and often, or always, take energy-efficiency into consideration when buying. Also, over half of the EU citizens rate environmental impact more important than a product's brand name in terms of influencing their product purchasing decisions.

Beside consumer interest and values, there are also a variety of other reasons making environmental issues prominent for the business and hence building the green markets: companies are pushed by NGO campaign groups, employees are pushing the environmental issues on the agenda, and some companies see how environmental issues are impacting their value chains. Hence, "Eco-Trends" are building the green climate of opinion among different sectors (consumers, businesses, governments), providing demands to be answered by eco-innovations, hence acting as a driver for the eco-innovation evolvement.

3 | Emerging technologies and eco-innovation

The future trends of climate change, water and resource scarcity and “eco-trends” are boosting new technologies and other innovations to emerge. In the following we have identified through the Horizon scanning efforts five main technology fields, from which the new eco-innovations emerge. These main technology fields are (1) New Materials (2) Biotechnology (3) Environmental technology, (4) Nanotechnology and (5) ICT. However, these main fields are not clear cut as they overlap each other. As one of the cross-cutting elements of the EIO Consortium’s approach is to adopt a pervasive definition of eco-innovation considerably wider than past work on eco-industries, and as technologies are always tied to their users and social structures, in the last chapter, analysis is taken further to describe social and system eco-innovations.

Each emerging technology field and social and systemic innovations are illustrated by practical examples of emerging eco-innovations. The practical eco-innovation examples relate to the theme areas of sustainable construction, bio-based materials, material recycling and reuse, phosphorous and sustainable nutrient flows and critical metals, selected by Eco-innovation Observatory. When in the previous chapter (chapter 2) future trends leading shifts in demand were presented, in this chapter the focus is on supply of eco-innovations emerging either from technologies or the society.

3.1 | Main field: New Materials

New materials are defined here as material innovations, which seek solutions for environmental problems. The area is wide and in the first Horizontal scanning report we will introduce material innovations that 1) help rebalancing the phosphorus cycle and 2) an example of a sustainable construction material designed to combat climate change.

New materials helping to balance the phosphorus cycle: Eutrophication is the enhancement of the natural process of biological production in rivers, lakes and reservoirs, caused by an increase in nutrient levels, usually phosphorus and nitrogen compounds. Eutrophication can result in visible cyanobacterial or algal blooms. It is accepted that phosphorus control is more achievable than that of nitrogen, because, unlike nitrogen, there is no atmospheric source of phosphorus that is bio-available. The decay of algal matter may lead to the oxygen depletion in the water, which in turn can cause secondary problems such as fish kills from lack of oxygen and liberation of toxic substances or phosphates that were previously bound to oxidized sediment. Phosphates released from sediments accelerate eutrophication, thus closing a positive feedback cycle.

One way to prevent increasing concentrations of phosphorus in aquatic systems is to remove the excess of phosphorus. There is increasing interest in research to find techniques and materials for removal of phosphorus (Turtola E. *et al.* 2010.) and thus, this field will provide growing number of innovations in the **future.** The problem with phosphorus is twofold as the phosphorus reserves are decreasing (described in chapter 3.1 Resource scarcity), and the innovations should also find materials and techniques that transform the agricultural runoff phosphorus into a valuable source of fertilizer. We will describe a material innovation that removes phosphorus form water **Phoslock,** and a material innovation that both removes the excess phosphorus and transforms it into fertilizer **Yara land clay.**

3.1.1 | Phosphorus removal from water bodies

Eco-innovation effects	**Reduces release of harmful substances: phosphorus**
Name of the example product	Phoslock®
Name of the example producer	Phoslock Water Solutions Ltd
Country of the example producer	Australia
Sector of application	Phosphorus and sustainable nutrient flows
Type of eco-innovation	Product innovation, Process innovation
Phase	Continuous commercial production was commenced in May 2005.
Short description	Phoslock is a modified clay product which removes phosphorus from water bodies and breaks the algal cycle. Once phosphorus is bound to Phoslock, it is no longer bioavailable for use by algae for assimilation and growth. This lack of nutrients in the water body has a direct impact on the ability of algae to proliferate.
Source	www.phoslock.com.au

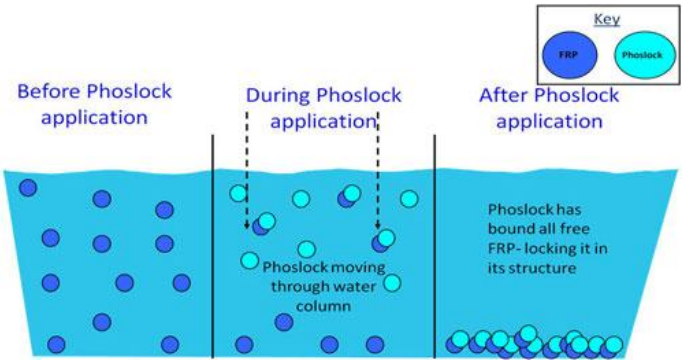
Description

Phoslock is bentonite, which has been modified through the introduction of the rare earth element lanthanum into its clay structure. Phoslock works by utilizing the ability of lanthanum to react with phosphate. Removal of phosphate by lanthanum is highly efficient and has a molar ratio of 1:1.

Phoslock granules are generally mixed with in situ water and applied to a water body as slurry. As the slurry settles, phosphate anions in the water column are bound to the lanthanum cations contained within the bentonite clay. Once Phoslock has settled on the sediment water interface, it forms a thin layer, usually less than 1 mm in thickness. As long as sufficient binding sites remain on the clay, this layer continues to remove any phosphorus that would normally be released from the sediment into the water column when anoxic conditions develop (Phoslock website 1.8.2010.)

Unlike other methods that could be used to immobilize phosphorus in water and sediments, Phoslock is insensitive to the range of redox, temperature and pH conditions that are naturally found in lakes and reservoirs. Furthermore, buffering is not required prior to an application (Phoslock website 1.8.2010.)

Figure 14 | By removing phosphate from the water column and preventing its release from sediments, Phoslock essentially deprives algae of an important food source and the profileration of algae, particularly blue green algae, is reduced



Source: Phoslock website 1.8.2010

3.1.2 | Field gypsum to enhance phosphorus recycling in agriculture

Eco-innovation effects	**Reduces the use of natural resources: phosphorus**
Name of the example product	Field gypsum for phosphorus recycling in agriculture
Name of the example producer	Yara International ASA / Yara Suomi Oy
Country of the example producer	Finland
Sector of application	Phosphorus and sustainable nutrient flows
Type of eco-innovation	Process innovation
Phase	In development. In market at the beginning of Autumn 2010.
Short description	Field gypsum is spread on cultivated fields, where it dissolves and improves soil phosphorus retention capacity by reducing erosion and dissolved phosphorus leaching.
Source	http://www.yara.com/sustainability/sustainable_agriculture/Environmental_research/
Description Field gypsum (calcium sulphate dehydrate) is spread on cultivated fields (3 – 5 tn/ha) by ordinary farm machinery like lime or manure spreaders. After soil tillage or alternatively without any tillage, gypsum dissolves in wet cultivated fields to calcium- and sulphate ions. These ions improve soil phosphorus retention capacity by two mechanisms. First, by reducing erosion, i.e. transportation of soil particles to water courses by turbid runoff. Secondly, gypsum increases soil electrical conductivity which enhances dissolved phosphorus retention and thus control dissolved phosphorus leaching. The effect is most remarkable in soils which have high phosphorus	

status after high application rates of manure or fertilizers. Phosphorus trapped by gypsum remains plant available for cultivates crops. The innovation thus gives an option to improve phosphorus recycling from soils to plants and back to soils via plant residue and manures with decreased (50%) discharge to waters. The innovation allows normal farming practices and food production. Raw material of field gypsum comes from Siilinjärvi apatite rock, which with sulphuric acid produces gypsum and phosphoric acid. Gypsum is then processed for farm application (YARA website 1.8.2010.)

3.1.3 | Green concrete

There is a need for new materials to be designed to combat climate change. The cement industry, for instance, contributes about 5% to global anthropogenic CO_2-emissions, thus making the cement industry an important sector for CO2-emission and climate change mitigation strategies. CO_2 is emitted from the 32ntensity32n32 process of limestone, from combustion of fuels in the kiln, as well as from power generation. (Worrell & Price 2001, 303 – 329).

In the following, an emerging new cement technology, called **Green concrete** is introduced. This technology promises a negative carbon footprint on cement.

Eco-innovation effects	**Reduces the use of natural resources: CO_2**
Name of the product, service, technology :	Green Concrete
Name of the developers / innovators:	Novacem, Calera
Country of the developers / innovators:	United Kingdom, United States of America
Sector of application:	Sustainable Construction
Type of eco-innovation:	Product innovation
Phase:	Future Promise
Short description:	Cement that is supposed to absorb more carbon dioxide than is released during its manufacture. It can catch as much as 100 kilograms of greenhouse gas per ton.
Sources:	http://www.greenconcrete.info/ http://novacem.com/ http://www.calera.com/ Bradley, David (2010): Storing Carbon Dioxide in Cement Green Concrete. Technology Review; May/Jun2010, Vol. 113 Issue 3, p56-56, 2/3p
Description Green cement that is promised to absorb more carbon dioxide than is released during its manufacture. It is supposed to catch as much as 100 kilograms of greenhouse gas per ton. Production process of the cement is	

based on 20 years of research on the mineral carbonation of magnesium silicates. These minerals are broadly dispersed with available worldwide reserves estimated to considerably surpass 10,000 billion tons. One of the developer companies Novacem has developed cement, which according to Technology Review (2010) demonstrates performance already sufficient for a number of important applications (e.g., masonry products), and which is repeatedly being optimized and improved (David 2010.)

Main environmental benefit is the carbon negative footprint of the product. Currently making cement for concrete entails heating pulverized limestone, clay and sand to temperature of 1,450 °C using fuel like coal or natural gas. The process produces a large amount of carbon dioxide. Producing one metric ton of commonly utilized Portland cement discharges 650 to 920 kilograms of it. In 2009 the combined cement production of 2.8 billion metric tons worldwide contributed roughly 5 % of all carbon dioxide emissions (David 2010.)

As an example Novacems green cement solution is based on magnesium oxide (MgO) and hydrated magnesium carbonates. The production process of the cement utilizes accelerated carbonation of magnesium silicates beneath elevated levels of temperature and pressure (i.e. 180^{o}C/150bar). The carbonates produced are heated at low temperatures (700^{o}C) to produce MgO, with the CO_2 generated being recycled back in the process. The utilization of magnesium silicates eradicates the CO_2 emissions from raw materials processing. Additionally, the low temperatures needed permit the use of fuels with low energy content or carbon intensity (i.e. biomass), consequently further diminishing carbon emissions. Furthermore, production of the carbonates absorbs CO_2; they are produced by carbonating part of the fabricated MgO using atmospheric/industrial CO_2. On the whole, the production process to make 1 ton of Novacem cement absorbs up to 100 kg more CO_2 than it emits, making it a carbon negative product. The technology concerning green cement is developed e.g. also by the company called Calera (David 2010.)

Barrier to this new greener construction material is that introducing an immensely new material to a very conservative industry is tough. In addition, it faces a challenge like most new technologies, the scaling of their technology up to industrial levels.

Awards or other acknowledgment: MIT Technology Review selected green concrete to be one of the 10 most important emerging technologies of the year 2010. It was selected on a basis that it is believed to change the world by tackling the global warming.

Figure 15 | Green concrete is an emerging technology

Source: Going green website 16.9.2010

3.2 | Main field: Biotechnology

Biotechnology is a field of applied biology that involves the use of living organisms and bioprocesses in engineering, technology, medicine and other fields requiring bio material. Biotechnology has the role in eco-innovation development especially when applied in non food (industrial) uses of crops and other products (e.g. biodegradable plastics, vegetable oil, bio fuels). The first horizontal scanning report will emphasize on bio-based products.

The term “bio-based” expresses that the products are made from biological raw materials such as plants and trees that are renewable raw materials. It also includes non-food new bio-based products and materials such as bio-plastics, bio-lubricants, surfactants, enzymes and pharmaceuticals. It excludes food, traditional paper and wood products, but also bio-mass as an energy source. Bio-based products are neutral in terms of greenhouse gas and leave a smaller ecological footprint, i.e. generate less waste, use less energy and water. Less consumption of natural resources lowers production cost and is better for the environment.

Any organic material produced by the photosynthesis process provides renewable biomass feedstock, which is available for conversion into bio-materials and –products. The biomass feedstock includes crops and their residues, wood and its residues, animal and municipal wastes, and aquatic plants. Thus, there is a plenty of biomass available for utilization and to provide material for new innovations. Increased utilization of biomasses (without increased deforestation) through technological or product innovations is an essential step in sustainable development, which disconnects the dependency between carbon dioxide emissions and economic growth.

In the first Horizon scanning report we will introduce three examples of the eco- innovative possibilities the bio-based materials can provide through biotechnology : 1) **Ingeo™**, a biopolymer to substitute petroleum-based plastics, 2) **Harmless Packaging by Cyperback**, a range of truly compostable products, and 3) **Formico technologies** taking advantage of the by-product biomass.

3.2.1 | Natural plastic showing significant reductions in greenhouse emissions

Eco-innovation effects	**Reduces the release of harmful substances: Co_2 waste**
Name of the example product	Ingeo™
Name of the example producer	Nature Works LLC
Country of the example producer	United States of America
Sector of application	Bio-based product, Recycling and reuse
Type of eco-innovation	Product innovation
Phase	Globally available
Short description	Ingeo™ is the world's first polymer showing a significant reduction in greenhouse gas emissions.
Website	http://www.natureworksllc.com/

Description

Derived from 100% annually renewable resources such as plants Ingeo is the world's first polymer showing a significant reduction in greenhouse gas emissions. Polymers are fibers made from renewable resources (plants), as opposed to oil. The process to create Ingeo makes use of the carbon naturally stored in plants by photosynthesis. Plant starches are broken down into sugars. The carbon and other elements in these natural sugars are then used to make a biopolymer through a process of simple fermentation and separation. The resulting resin, called Ingeo biopolymer (PLA), can then be injection molded into plastics goods, extruded for film applications, thermoformed into packaging, or extruded for use in textiles applications (Nature works LLC 1.8.2010.)

Ingeo™ biopolymers are already proving themselves in success commercial applications in the areas of fiber and nonwovens, films, extruded and thermoformed containers, and extrusion and emulsion coatings. Ingeo™ biopolymer is a natural fit for many applications currently using polyester, polyolefins, polystyrene and cellulosics. With performance properties that span these materials, as well as its ease of processability, Ingeo™ biopolymer can offer cost and productivity advantages that constitute a competitive advantage for the customers (Nature works LLC 1.8.2010.)

At present Ingeo produces 43% less greenhouse gases and uses 48% less non-renewable energy (NREU) than traditional polymers like PET, PS, PP, PE & PVC. (Nature works LLC 1.8.2010).

3.2.2 | Biodegradable bags

Eco-innovation effects	**Reduces the release of harmful substances**: plastic waste
Name of the example product	The Harmless Packaging
Name of the example producer	Cyberpack
Country of the example producer	United Kingdom
Sector of application	Bio-based product, Recycling and reuse
Type of eco-innovation	Product innovation, Material flow innovation
Phase	Globally available
Short description	Harmless Packaging is a range of products that use a hydro-degradable plastic that completely dissolves in water and leaves no damaging residue afterwards.
Source	http://www.harmlesspackaging.co.uk/

Description

The Harmless Packaging Range utilizes starch based resources to produce Harmless-Compost, Wrap and Air. Harmless-Compost is a line of bags and envelopes that will, according to the manufacturer, completely biodegrade into naturally occurring substances. They are used in packaging magazines and publications, bin and dissolvable dog waste bags and carrier bags. Utilizing the same technology; Harmless-Wrap and Air are an operational, protective packaging solution that can be disposed of in industrial composting sites to help reduce the mountain of plastic clogging up the globe. From protecting wine to micro-chips, soft toys to books; Harmless-Wrap and Air have a multitude of uses (Harmless 1.8.2010.)

Many traditional, fossil fuel plastics like polythene can be made degradable by including a special additive in the mix. However, when discarded this mix will still be environmentally damaging. Harmless Packaging by contrast works with renewable and sustainable resources for its products. Harmless-Dissolve is derived from corn or potato starch – a renewable resource that absorbs carbon dioxide as it grows. Once Harmless products have reached the end of their useful life, they can be industrially composted to allow them to re-enter the life cycle (Harmless 1.8.2010.)

To be classed ‘compostable’, a material must meet the stringent EN 13432 standard. The testing process involves mixing the material with organic waste and leaving it for 12 weeks under commercial composting conditions. After this time the material must show evidence of being biodegraded due to microbial action. This means breaking down into water, carbon dioxide and biomass, rather than just breaking up into pieces, as degradable oil-based plastics do. To meet the standard, less than 10% of the remaining fragments are allowed to be larger than two 36ntensity36n. The composted material is then tested for toxicity, to make sure it’s suitable to grow food crops. Finally, it’s sown with summer barley to check that it will support plant life (Harmless 1.8.2010.)

Figure 16 | Harmless-Compost is according to the producer ideal as an envelope for mailing magazines and publications or as a carrier bag or waste bag.

Source: (Harmless 1.8.2010)

3.2.3 | Technologies utilizing the agriculture by-product biomass

Eco-innovation effects	**Reduces the release of harmful substances**: **CO_2, waste**
Name of the example product	Fo**rmico**® technologies
Name of the example producer	Chempolis Ltd
Country of the example producer	Finland
Sector of application	Bio-based products, Recycling and re-use
Type of eco-innovation	Process innovation
Phase	New in the market
Short description	Fo**rmico**® is a **technology that converts** a wide range of non-food biomass generated as agricultural by-products into bioethanol, biochemicals, and papermaking fibres.
Website	http://www.chempolis.com/

Description

Formico technologies are environmentally sustainable biorefining technologies and production solutions for industrial utilization of non-wood and non-food feedstocks. These materials include straws, grasses, bagasse, energy crops, bast and leaf fibres, among many other biomass resources. The core technologies include formicofib™, formicobio™ and formicochem™ processes, which are designed for environmentally friendly production of pulp, biofuels and biochemicals from non-wood and non-food raw materials (Chempolis 15.8.2010.)

Because the 38ntens® processes do not exploit forest resources and they are self-sufficient in terms of energy, they are effective solutions for minimizing the carbon footprint of pulping, papermaking, and transportation. (Chempolis 15.8.2010).

Due to limited forest resources, non-wood materials are the most potential raw material in the growing paper markets. Production of non-wood pulp will increase together with improved education and economic growth. With conventional technology, production of each ton of non-wood pulp generates more than two tons of carbon dioxide. Application of formicofib™ technology in pulping of non-wood feedstocks can potentially reduce annual carbon dioxide emissions up to 100 million tons (Chempolis 15.8.2010.)

Lignocellulosic raw materials, and especially non-wood feedstocks, are the most potential alternative for replacing crude oil as the source of liquid fuels for transportation. Currently, the annual emissions of petroleum burning are approximately 3 billion tons. Compared with current practice, use of formicobio™ technology in the production of biofuels and biochemicals can potentially reduce the carbon footprint of these products by more than 80 % (Chempolis 15.8.2010.)

3.3 | Main field: Environmental technology

Environmental technology (or green technology or clean technology) is the application of the environmental science to conserve the natural environment, the resources, and to curb the negative impacts of human involvement to promote sustainable development. Environmental technologies are applied for example in recycling, water purification, air purification, sewage treatment, environmental remediation, solid waste management, renewable energy, and energy conservation. All these applications provide solutions to mitigate the problems caused by the future trends described in chapter 2: material and water scarcity, and climate change. In the first horizontal scanning report we describe environmental technologies that will help balancing the phosphorus cycle and at the same time provide solutions for water scarcity.

Firstly, we describe the ecological sanitation as a technology to balance the phosphorus cycle and to enhance water conservation. The phosphorus in our diet goes through the waste treatment plants and mostly ends up in landfills or waterways. Reducing, recycling and reusing of urban waste can return phosphorus (and nitrogen) to the land, not to the aquatic systems to reinforce eutrophication (see also chapter 2.1. and 2.2). Each person's urine and manure contain approximately enough nutrients to produce enough food to feed that person (Jeavons 2005). By properly managing urine, treatment costs as well as fertilizer costs can be reduced. Feces also contain recognized nutrients, and could be used for modern agriculture, as micronutrient deficiency is a significant problem. Separating toilets also conserve water resources as often water used in flush toilets is of drinking quality. Only 1% of global water is drinkable, therefore, every effort made to conserve this precious resource is highly important (see also chapter 2.3).

Fertilizing urban agriculture with phosphorus recovered from organic urban waste could be also a significant step towards reaching the Millenium Development Goals on eradicating hunger and poverty, and providing the access to safe sanitation (Cordell *et al.* 2009). Today 2.5 billion people, including almost one billion children, live without basic sanitation. Every 20 seconds, a child dies as a result of poor sanitation, which means 1.5 million preventable deaths each year (UN Water statistics 7.10.2010). There are numerous documented practical examples of ecological sanitation around the world in developing countries and the cost of such ecological sanitation systems globally could be offset by the commercial value of the phosphorus (and nitrogen) they yield (Cordell *et al.* 2009). To give an example, Gumbo (2005) has studied the potential of reusing human exectra in urban Zimbabwe to short cut the urban phosphorus cycle. Gumbo found in his studies that the fertilizer value of the urine produced by urban dwellers in the case study catchment could sustain the agricultural activities in the surrounding area (Gumbo 2005.)

Urine and faeces collection will provide one step further in developing techniques for balancing phosphorus cycle. As an example innovation we will describe **Urine separation toilets (No-mix technology)**.

3.3.1 | Urine separation toilets as a solution for phosphorus recycling from human excreta

Eco-innovation effects	**Reduces the use of natural resources: water & energy** **Reduces the release of harmful substances**: Chemicals
Name of the example product	Urine separation toilets, NoMix technology
Names of the example producers	Several producers e.g. Separett and Duravit
Country of the example producers	The first No-Mix flush toilet in Sweden, another producer country Germany
Sector of application	Phosphorus and sustainable nutrient flows
Type of eco-innovation	Product innovation , Process innovation, System innovation
Phase	Just introduced to the market
Short description	Toilets that separate urine and faeces thus making phosphorus recycling easy
Websites	www.separett.com www.duravit.com

Description

The principle of the urine separation toilet is straightforward: when the user sits on the toilet, urine is collected at the front and drained into a separate tank, while at the back the faeces are flushed away in the normal manner. The appliance thus, in effect, consists of a toilet with a built-in urinal.

Half the phosphorus we excrete is in our urine, from which it would be relatively easy to recover. (Vaccari 2009). Urine is essentially sterile and can provide more than half the phosphorus required to fertilize cereal crops (WHO, 2006). If urine is not mixed with faecal matter in the toilet, the urine can be used safely through simple storage, and sanitized faecal matter can be used as a soil conditioner (WHO 2006).

Cordell *et al.* (2009) explain as an example how two Swedish municipalities have mandated that all new toilets must be urine separation toilets. The typical arrangement in these cases involves either a dry or flush urine-diverting toilet to collect the urine. The urine collected from the separation toilet is piped and stored in a simple 1-3 kg storage tank under the house or piped to a communal urine storage tank. Local farmers then collect the urine (appr. once a year) for a use as liquid fertilizer. This example of the urine collection, storing and use in Sweden shows that the system can work relatively easily but requires arrangements and regulations (Cordell *et al.* 2009.)

Lienert and Larsen (2009) reviewed surveys on acceptance of No-Mix-technology in seven European

countries and summarise that the technology is well accepted. However, for the future success of the technology, the writers recommend authorities to follow an integral strategy when people will find the No-Mix technology appealing and support the innovation (Lienert & Larsen 2009.)

No-Mix technology is also a way to conserve water, energy and money and diminish the use of chemicals. Often, water used in flush toilets is of drinking quality. Only 1% of global water is drinkable, therefore, it is a precious resource. Water fit to be drunk is being used for other purposes that can use lesser quality water, such as toilets (Lienert & Larsen 2009.)

Mixing faeces and urine makes treatment difficult. All waste water treatment plants use some biological processes, but nature does not normally have this waste water, so there are no microbes that can deal with this mix. In order to treat waste, treatment plants have to do this in stages. Each stage treats a different component of the mix by creating the right environment for microbes to do their work (aerobic, anaerobic, anoxic and the right pH). This is costly and requires energy. A mix of domestic and industrial effluent in water cannot be treated properly, for heavy metals and other pollutants make this water unsuitable for reuse. This is normally discharged into the ground or water bodies. Because of the complexity of the treatment process, treatment plants tend to be large. This requires costly infrastructure to build and maintain it, often out of the reach of poorer communities (Lienert & Larsen 2009.)

Another innovative environmental technique for balancing phosphorus cycle is the process for struvite crystallization and the use of struvites as fertilizers. Struvite is ammonium magnesium phosphate crystals high in phosphorus, which can be recovered from urban and livestock wastewater. Struvite crystallization and recovery is a promising technological process that has the potential to both remove phosphorus from wastewater byproducts efficiently and provide an alternative source of phosphate fertilizer (Jaffer *et al*. 2002). In their article Shu *et al.* (2006) showed that approximately 1kg of struvite can be crystallized from 100m3 of wastewater, and the struvite produced annually from a wastewater treatment plant that processed 100m3/d, could be applied on 2,6 ha of arable land as fertilizer. If struvite would be recovered from wastewater treatment plants worldwide, 0.63 million tons of phosphorus (asP2=5) could be harvested annually, reducing rock mining by 1.6% (Shu *et al.* 2006). Crystallisation is profitable compared to chemical and biological removal of phosphorus due to savings from the reduction in 1) chemicals used for precipitation and sludge disposal, 2) downtime for cleaning unwanted struvite formed during chemical and biological removal (Shu *et al.* 2006).

In the following, as examples are described a commercial Struvite crystallization-technique **Ostara's Pearl® technology** and the use of struvite (Ostara's Pearl® technology) as fertilizer **Crystal Green®**.

3.3.2 | Phosphorous extracted from wastewater and reused as fertilizer

Eco-innovation effects	**Reduces the use of natural resources: phosphorus**
Names of the example products	Ostara's Pearl® technology and Crystal Green®
Names of the example producers	Ostara Nutrient Recovery Technologies Inc.
Country of the example producers	United States of America
Sector of application	Phosphorus and sustainable nutrient flows, material recycling and reuse
Type of eco-innovation	Product innovation, Process innovation
Phase	Introduced to the market in 2009
Short description	Ostara's Pearl® Nutrient Recovery Process recovers and transforms critical nutrients such as phosphorus and nitrogen into Crystal Green®, a slow-release fertilizer.
Sources	http://www.ostara.com/technology http://www.crystalgreen.com/

Description

Phosphorus content in wastewater can be reduced by recovering a portion of the phosphorus as a crystalline product called struvite. Struvite is relatively easy to dry and handle and shows potential as a slow-release fertilizer. Clean water services will use the Ostara process to produce fertilizer grade struvite. The patented Ostara process (a fluidized bed reactor) controls the struvite formation process so that small, hard, rounded fertilizer prills are formed. Struvite produced "naturally" is not useable as a fertilized product because it is in larger, more angular chunks or sheets that can't be handed and spread easily as fertilizer. Ostara's proprietary wastewater treatment technology, called the Pearl® Nutrient Recovery Process, recovers phosphorus and other nutrients from sludge liquids preventing the buildup of struvite scale in plant infrastructure and converting the recovered nutrients into a premium commercial fertilizer called Crystal Green®. Crystal Green is a struvite based fertilizer product that contains nitrogen (5%) phosphorus (27%) P205 5%) and magnesium (10%). Crystal Green is the world's first slow-release, renewable and environmentally safe fertilizer. Crystal Green is the only slow-release fertilizer with a combination of nitrogen, phosphorus and magnesium (5-28-0 +10% Mg).

Unlike traditional phosphorus fertilizer which is mined and the production of which is highly energy consuming and polluting to the environment, Crystal Green is harvested from a previously untapped source of phosphorus – wastewater. This process makes Crystal Green a sustainable and renewable source of phosphorus, and ensures stability of supply and price.

Figure 17 | Slow-release fertilizer, Crystal Green® fertilizer with a combination of nitrogen, phosphorus and magnesium (5-28-0 +10% Mg)

Source: Website http://www.crystalgreen.com/

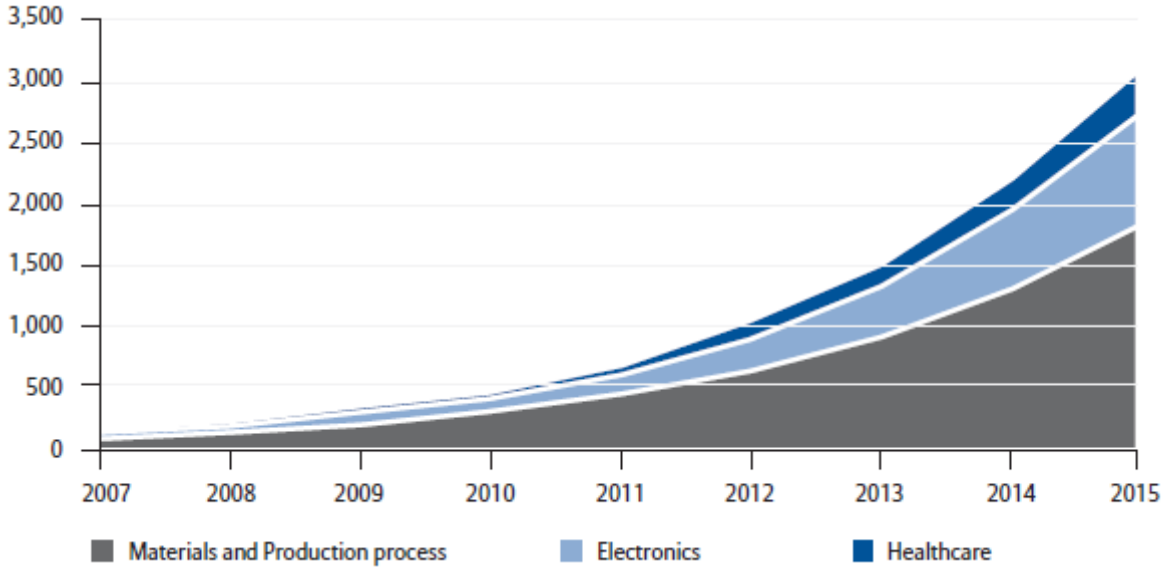
3.3.3 | Main field: Nanotechnology

Nanotechnology is the study and manipulation of materials at the nanometer scale. One nanometer is one billionth of a meter (about 100 000 times smaller than the diameter of a human hair, a 1000 times smaller than a red blood cell, or about half the size of the diameter of DNA). This can be achieved by reducing the size of the smallest structures to the nanoscale or by manipulating individual atoms and molecules into nanostructures. Nanotechnology is an enabling technology. It enables the making of contemporary equipment smaller and the enhancement of current materials (Personal communication with Dr Jarkko Saarinen 20.9.2010.).

Materials exhibit different properties at a nanoscale and the manipulation of this phenomenon allows the development of new products with new functionalities. Gold is a good example: in normal macroscopic form this soft and chemically inert metal changes the color and the reactivity when the size of the gold particles changes into nanoscale size. Nanotechnology has great promise, but also grave risks related to possible health and environmental impacts of nanoparticles. (Personal communication with Dr Jarkko Saarinen 20.9.2010.)

Nanotechnology is already a megatrend and it is expected to be a major economic driver for this century, impacting all industries including healthcare, agrifood, transport, energy, materials (construction, coatings, textiles etc), and Information and Communications Technologies (ICT). It also holds promise for improving the environment- by both reducing waste materials, energy consumption and our dependence on non-renewable natural resources, and for cleaning up existing pollution (environmental remediation). It has been estimated that nanotechnology in global economy is worth of thousands of billions of euros in 2015 (Figure 17; Allianz Global Investors 2010).

Figure 18 | Nanotechnology: Small structures – big impact. Global market volume of nano-optimized products (in billions of USD)



Source: Allianz 2010

There are already several eco-innovative applications such as very light but durable structures that enable energy savings in airplane traveling or ironic nanoparticles that reduce environmental toxins into safe organic compounds. In the following, an emerging process innovation in the nanotechnology field is provided as an example of this cluster of technologies. We will describe the possibilities of this technological field more thoroughly in the future Horizontal scanning reports.

3.3.4 | Iron nanoparticles to clean contaminated groundwater more efficiently

Eco-innovation effects	**Reduces the use of natural resources: Palladium** **Reduces the release of harmful substances: Contaminants**
Name of the example process	More efficient utilization process of Iron Nanoparticles to clean e.g. the contaminated groundwater.
Example researchers / innovators	Researchers Yan *et al.*
Country of the example developers / innovators	United States of America & China
Sector of application	Critical Metals, (Material Recycling and re-use)
Type of eco-innovation	Process innovation
Phase	Future promise: better efficiency, handling and

	storing methods are expected in the future
Short description	There is ongoing research and development in enhancing methods of handling and storing the particles, and of collecting and reusing the palladium (which is defined as a critical metal by EU) after it has neutralized contaminants.
Sources:	Yan, Weile, Herzing, Andrew A., Li, Xiao-Qin, Kiely, Christopher J. & Zang, Wei-Xian (2010): Structural Evolution of Pd-Doped Nanoscale Zero-Valent Iron (nZVI) in Aqueous Media and Implications for Particle Aging and Reactivity. Environmental Science and Technology 2010, 44, 4288 – 4294. http://www.azonano.com/news.asp?newsID=18120

Description

The palladium-coated particles have remediated more than 50 toxic waste sites in the U.S. and other countries in one-tenth the time, and at a significantly greater economy of scale, compared to traditional "pump and treat" methods. (Nanotechnology 1.10.2010).

At the present stage researchers Yan *et al.* have gained new insights that could advance the efficiency and extend the applications of the powerful nanoparticles. For the first time the researchers used scanning transmission electron microscopy (STEM) and X-ray energy dispersive spectroscopy (XEDS) to capture the evolution in the nanostructure of the bimetallic particles as they remove contaminants in water. (Yan *et al.* 2010)

The advanced imaging instruments at Lehigh University captured intriguing details of the reactions within nanoparticles. As they react with pollutants such as trichloroethene (TCE), a toxic industrial solvent, the nanoparticles exhibit massive structural changes. The particle core hollows out, the iron diffuses outward, and the palladium, a catalyst that makes up 1 percent of particle mass, migrates from the outer surface to the interior surface of the iron (Nanotechnology 1.10.2010.)

Nanoparticles' capability to remove toxins diminishes as the particles "age" and undergo structural change with exposure to water. Yan et al. suggest based on their research that the nanoparticles' age and storage environment play a critical role in influencing their effectiveness as remediation agents. The nanoparticles, which were invented by Zhang, average 50 nanometers in diameter (1 nm equals a billionth of a meter). Islands of palladium on the iron's outer surface measure 2 to 5 nm in diameter. The particles have so far removed pesticides, vinyl chloride, TCE and other contaminants in 10 states and in Europe and Asia. Treated sites include landfills, an electronics manufacturing plant, chemical plants and military facilities (Nanotechnology 1.10.2010.)

Once injected into groundwater, the nanoparticles flow with the water and react with and detoxify contaminants. Their tiny size and larger proportional surface area give them more reactivity with toxins than larger quantities of the same catalyst. This enhanced reactivity enables the particles to remediate a toxic site in less than a year, compared to the 10 to 20 years required by pump-and-treat methods. According to

the Association of University Technology Managers “it takes only six ounces of the tiny nanomaterials, versus a ton of larger compounds, to make sweeping changes in cleaning up contaminated environments.” The result is thus that the nanoparticles are now one of the world’s most widely used nanomaterials (Nanotechnology 1.10.2010.)

The new focus in research of the iron nanoparticles is to experiment and get results to help researchers develop superior methods of handling and storing the particles, and of collecting and reusing the palladium after it has neutralized contaminants. Palladium, used in catalytic converters, electronic devices and fuel cells, is a rare and often expensive metal. Palladium is one of the critical metals defined by EU. According to Yan et al. the expected results can also be used to improve the ability of iron-based nanoparticles to capture and remove heavy-metal toxins from contaminated sites (Nanotechnology 1.10.2010.)

3.4 | Main field: Information and communications technology (ICT)

New areas of technology are increasingly converging with traditional IT-infrastructure. Especially in the efforts to attain energy reduction and renewable energy targets, new structures are developed for entities like buildings and infrastructures such as electricity networks. Advances in the metering technology has enabled development were ICT is converged with electricity networks to enable decentralized small scale renewable energy to be added in the electricity network and be sold by energy consumers (such as farms) which have evolved into consumer-producers (farms producing their own energy by renewable energy sources and selling excess energy to the grid). (For more information see: Smart Grids: European Technology Platform for the Electricity Network of the Future webpage Read: 29.9.2010).

Resent advances in ICT converging to new areas are due to several reasons. Production costs of motorized systems have reduced significantly, and standardization within the automation industry has helped to improve system reliability. Microprocessor technology continues to shift in the direction of low cost, low power, small-form-factor design implementations, allowing for a greater distribution of embedded network intelligence. Combining these advances with diverse computational tools, sensors, and environmental modeling, a “new era of innovations” is enabled (Adaptive Building Initiative 30.9.2010.)

Building automation systems (BAS) that control heat, air conditioning, lighting and other building systems are thus evolving. Modern high science and technology is integrated in the building structures. Through digital monitoring systems, measurement and verification systems and controllability of these systems, the energy usage and carbon dioxide emissions can be self-optimized by intelligent building. In addition, due to the uncertainty around the true effects of climate change, it’s considered important to be able to adjust to varying weather conditions and in their part smart buildings might provide solutions for this requirement in the future. In the following, two examples are provided (in one sheet) of the emerging technology group of smart building products and systems.

3.4.1 | Smart Buildings that regulate their energy use

Eco-innovation effects	**Reduces the use of natural resources: energy**
Name of the example product, service, technology	Intelligent buildings; Smart structure insulation
Examples of the developers / innovators	Adaptive Building Initiative; Vahanen Oy
Country of the mentioned developers / innovators	Multinational company with head office in United States of America; Finland
Sector of application	Sustainable construction
Type of eco-innovation	Product innovation
Phase	The “next generation” of adaptive technologies is being developed. In smart structure insulation’s case European and international patent is being applied. Also a test building is being constructed. Therefore technologies are a future promise.
Short description	Different technologies are developed, where information and communication technologies are integrated in the building design to be able to monitor and control the amount of energy consumed by the building.
Sources:	http://www.wwf.org.uk/what_we_do/working_with_business/green_game_changers/constructionmaterials.cfm http://www.adaptivebuildings.com/why-adaptivity.html http://www.vahanen.com/In_English.iw3

Description

Intelligent buildings that are adaptive and use less energy by regulating their own heating, cooling and lighting with intelligent sensor networks and motorized systems that automatically respond to changes in temperature and weather are group of technologies developed by Adaptive Building Initiative. Higher levels of self-optimization can notably reduce the amount of energy that large buildings consume, through intelligent shading and ventilation. The technology can enable buildings to harvest renewable energy and rain water (Adaptive Building Initiative 30.9.2010.)

Vahanen Oy develops a smart structure insulation system, where sensors are placed to the walls or the ceiling will gather information, according to which the insulation capacity will either be increased or decreased based on the outer or inner air. Smart structure insulation relates to a method for moving thermal energy and/or moisture in a shell structure of a building and a shell structure. The smart structure adjusts the insulation capacity of a structure according to the outer and inner air conditions (Vahanen 1.8.2010.)

This innovation is designed to radically cut down energy consumption of the building. Energy consumption is

intended to be decreased both in heating and cooling. Energy can be transferred between the different surfaces of the thermal insulation and this will create energy savings. Smart insulation structure is according to the developers suitable for all kinds of buildings from small houses to large office buildings (Vahanen 1.8.2010.).

Drivers of the innovation are the efforts to battle climate change. European Union has established clear goals to be met by the year 2020: cut down in EU greenhouse gas emissions of at least 20 % below 1990 levels, 20 % of EU energy consumption to come from renewable resources and a 20 % reduction in primary energy use compared with projected levels to be achieved by improving energy efficiency.

In addition, as the climate changes and as there is uncertainty of the development of the weather conditions in the future, it's essential also to adapt to the changes. These technologies could provide a way for the constructed surroundings to do that.

3.5 | Beyond technology: Social and system eco-innovations

The Oslo Manual distinguishes four different types of innovation including product (goods or services), process, marketing and organizational innovation. In addition to these types of innovations, the Eco-Innovation Observatory is interested in material flow eco-innovation, which deals with reduction of material intensity (See Oslo Manual 2005.)

As technologies/innovations are not developed or utilized in a vacuum, they are always tied to the users and their abilities, and in a larger scale, to the societies and the structures and the elements of these societies. User-led social innovations and socio-technical system transferring system innovations introduce wide range of new actors to the innovation processes. In addition to businesses, also the public sector and NGO's can be involved in the innovation process. These types of innovations aim for social change and value.

Social innovations can be defined as alterations in lifestyles and consumer behavior. In regard to eco-innovation, social innovation aspect is important, because effective environmental policy requires understanding not only of technological, but also lifestyle dynamics. For example, environmental social innovation can be a shift of modal slit from car transport toward bicycling. Also creating an environmentally friendly atmosphere in companies can be regarded as a social innovation. According to Klaus Rennings different innovations go often hand in hand, and it might even be important that any technical innovations should be accompanied by organizational and social innovations. (Rennings 2000, 319 – 332)

Social innovations can be user-led innovations, where there is a high involvement of individual end-users in innovation process. End-users can typically be involved with the design or planning process. Involvement of the end-users may result in technologies being more widely disseminated. A collective planning of ecological buildings by prospective users is an example of user-led eco-innovation. End users can e.g. appropriate unconventional building technologies and design solutions in the course of collective planning process (Ornetzeder & Rohracher 2003, 1099 – 1110.)

Creative power of society is another matter related to this social aspect of eco-innovation. This creative power of society can lead to green living concepts or corporate social responsibility. Social eco-innovation

covers wide range of issues, from which Eco-innovation Observatory is mainly interested in demand for eco-innovation from the society or special user groups and the option of user-led innovation processes.

In the following example of a social eco-innovation is illustrated through a design of possible future eco-building, where sustainable lifestyles of the end-users are enhanced through a novel design.

3.5.1 | Future residential eco-building

Eco-innovation effects	**Reduces the use of natural resources: Energy, water, food** **Reduces the release of harmful substances: waste**
Name of the example product, service, technology	Structurally and socially connected self-reliant future eco-buildings
Developers / innovators of the example	Anto Gloren & Sayali Athale
Country of the mentioned developers / innovators	India
Sector of application	Sustainable construction
Type of eco-innovation	Social innovation
Phase	Future promise
Short description	Design of a future eco-building
Sources:	http://www.bustler.net/index.php/competition/hp_skyline_2020/ http://www.treehugger.com/files/2010/09/hp-competition-winner-has-rooftop-farms-plugin-units.php

Description:

Futuristic vision of a future eco-building was introduced by the contest winners of the Hewlett Packard (HP) Skyline 2020 competition (open only to Indian citizens), which “outlined fresh visual imaginations for the skyline discarding preconceived notions” and “allowed students and professionals to partner and elucidate their visions and designs that would change the skyline thereby transforming the city itself.”

The form of the building is obtained by stacking blocks in a spiral pattern. This structure allows sufficient amount of space between two vertical blocks, which is essential for solar access to the farms of the blocks (Bustler 30.9.2010; Treehugger 8.10.2010.)

In their design block of apartments are built with structures that are adaptable to high density usage. Each unit allocates 100 square meters for four occupants. Rest of the area in each unit (i.e. 40 square meters) is allocated e.g. to functions such as offices or institutions. The units are horizontally connected at different levels. By adding public pathways and promoting mixed usage neighborhood development can be enhanced at the design phase of the building or block of buildings. The vertical connections channel services such as water,

sewage, elevators, circulation and so forth (Bustler 30.9.2010; Treehugger 8.10.2010.)

End-users are taken into account at the design phase, for according to their desires, units can be of any size or shape, just as long as it provides required amount of agricultural land for the residents. In this structure farms are an essential part of the design and the occupants are responsible for them. The decision on the plants, vegetation and fruit grown at the building will be made according to the climate, the solar access and the interdependent requirement of each community, which enables organically grown products to be available from one resident to another and vice versa (Bustler 30.9.2010; Treehugger 8.10.2010.)

Sewage from the upper levels flows to the units on lower levels through a reverse osmosis and the minerals in the sewage are used as fertilizer for the plants. The sewage is circulated through every lower level farm where it intermingles with the sewage of the unit in which it arrives. According to the designer sewage moves in a spiral manner around the service core and thus significantly reduces biological oxygen demand (Bustler 30.9.2010; Treehugger 8.10.2010.)

The lowest block in the building will service the whole vertical building. There sewage will undergo tertiary treatment. Agricultural biomass and other waste will in this design then be anaerobically decomposed or incinerated to create at least a part of the energy demand in the whole vertical building.

The designers of the eco-building which can be extended to a neighborhood or a city try to address the food crisis, the water crisis and the energy crisis (Bustler 30.9.2010; Treehugger 8.10.2010.)

Figure 19 | Design of a future eco-building

Source: Treehugger 8.10.2010

System innovation: Future Eco-city. Environmental problems are typically complex problems and call for systemic solutions. Different systems and functions are interrelated and shaped by different groups of societal actors in relation to existing structures of the society.

Technologies and artifacts have an importance in societal functions, for instance in transportation, communication, housing or energy systems. Trains, ships and cars can be named as necessary means for transportation; telephones and the internet as technologies enabling long-distance communication. But these technologies do not fulfill societal functions on their own: human agents, societal structures and organizations are needed for that. In real life situations artifacts are always bound by the context, and there is a combination of "the social" and "the technical". According to Hughes societal development both shapes the technology and is shaped by the technology. When considering societal functions, it's evident that a group of elements are interlinked to achieve functionality, e.g. technology, regulation, user practices and markets, cultural meaning, infrastructure, maintenance networks, and production systems. This cluster of elements Frank Geels introduces as "socio-technical system" (Geels, 2005; Hughes 1996, 101 – 113.)

Technologies realize functionalities in concrete user contexts. User contexts are made up of users, their competences, cultural values, preferences and interpretations. A range of existing artifacts, infrastructures and regulations affect user context. For example the existing transport infrastructure can affect the level of desirability of using a train over a privately owned car (Geels et al. 2004.)

System innovations are multi-actor processes. Not only are there interactions within an societal group such as firms, suppliers, universities and knowledge institutes, public authorities, public interest groups and users, but also between all these groups. All these societal groups possess their own perception of the future, values, preferences, strategies and resources (such as money, contacts, knowledge). With some degree of autonomy, these societal groups are interrelated Socio-technical transitions emerge, as multiple actors navigate their way through huge amount of uncertainties. (Geels *et al.* 2004; Eltzen *et al*. 2004.)

System innovation may include elements or combinations of other types of innovation (product, process, marketing, organizational or social). Eco-cities of the future can be seen as system innovations. UN estimated (2007) that by the year 2008 half of the world's population will be living in urban areas (and this number of urban residents is likely to grow in the future). (UN 2007). Residents of these urban areas consume massive amount of natural resources and also provide markets for eco-innovation. In the following there are two examples of sustainable city projects presented: sustainable city project under construction in Masdag, Abu Dhabi, United Arab Emirates and a sustainable housing project Dockside Green in Victoria, Canada. These examples provide some examples of best practices and the beginning of path of which eco-cities in the future might follow.

3.5.2 | Sustainable city project: Masdag City

Eco-innovation effects	**Reduces the use of natural resources: Energy** **Reduces the release of harmful substances: waste, CO_2**
Name of the example product, service, technology etc	Masdag City
Name of the producer	Abu Dhabi Future Energy Company
Country of the producer	United Arab Emirates
Sector of application	Sustainable construction, recycling
Type of eco-innovation	System Innovation
Phase	Construction process ongoing. Future promise.
Short description	Sustainable city project, which aims to reduce carbon footprint waste, use eco-friendly materials whilst building the city. In addition city will rely on renewable energy and public transportation solely (i.e. private cars are banned from the city).
Source	http://www.masdarcity.ae/en/index.aspx

Description

Masdag City is a project in Abu Dhabi, United Arab Emirates. The core of the project is a planned city, which drives to rely solely on renewable energies, has zero-waste philosophy (aim is that all waste is recycled and minimal amount of trash is sent to landfills) and aspires towards a low carbon footprint both during construction and operation of the city. It will host the headquarters of International Renewable Energy Agency, intends to serve as global clean technology hub and a platform for commercial-scale demonstration of sustainable technologies. Automobiles are banned within the city and public mass transit and personal rapid systems will provide transportation (Masdag city 1.8.2010.)

Masdag City Sustainability Objectives are (Masdag city 1.8.2010):

- Utilization of sustainable construction material in the build of the city
- Construction with significant waste diversion from landfill
- Low carbon footprint throughout operational existence of the city
- City is powered by renewable energy
- There is a major decrease in construction footprint
- Paperless documentation practice is used in the city
- Claims-free environment is provide

- No accidents in the city area
- Sustainability practically demonstrated as a business value
- Operated as a community, which is the base of innovation and learning about renewable technologies and systems
- City provides a global showcase of sustainable living

Driver of the project is institutional: His Highness Sheikh Mohammed bin Zayed Al Nahyan, the Crown Prince of Abu Dhabi is behind the Masdag Initiative. In addition, majority of seed capital is provided by the government of Abu Dhabi (Masdag city 1.8.2010.)

On the down side, critics claim that city will be just a symbol to Abu Dhabi and merely a luxury development for the wealthy.

Figure 20 | Masdag City Plaza – a day view

Source: Masdag city website 3.8.2010

3.5.3 | Showing the path for future eco-cities: Dockside Green

Eco-innovation effects	**Reduces the use of natural resources: Energy & water** **Reduces the release of harmful substances: waste, Greenhouse gases**
Name of the example product, service, technology	Dockside Green
Name of the producer	Vancity Credit Union (Canada's largest Credit Union) & Windmill West (A partnership)
Country of the producer	Canada
Sector of application	Sustainable construction, Material Recycling and re-use
Type of eco-innovation	System innovation
Phase	Development
Short description	Dockside Green is notable for its developers' insistence on abiding to the strictest possible path in following the tenets of sustainable architecture or green building. Environmental, social, and economic responsibilities are considered whilst building the development.
Source	http://docksidegreen.com/index.php?option=com_frontpage&Itemid=1

Description

Dockside Green is a mixed use sustainability community project located in Victoria, Canada. The project entails residential, office, commercial and light industrial uses and it will eventually encompass 1.3 million square feet including 26 buildings and 2,500 residents. The Projects first neighborhood, Dockside Wharf was completed in 2009. Dockside Green is a model for holistic and closed-loop design. Eco-residential and eco-industrial development is intended to function as a total environmental system in which form, structure, materials, mechanical and electrical systems will be interrelated and interdependent. Dockside Green is for the most part self-sufficient and sustainable community where waste from one area will supply fuel for another (Dockside Green 5.8.2010.)

Dockside Green is LEED® (Leadership in Energy and Environmental Design) Platinum targeted project. (Platinum rating is the highest level to be attained from the LEED® Green Building Rating System™ in use in Northern America which promotes and accelerates global implementation of sustainable green building and development practices through the formation and implementation of universally understood and recognized tools and performance criteria.) Dockside Green's standards are stated as new urbanism, smart growth, green building and sustainable community design in the development plan. Dockside Green has an advanced sewage treatment, with the goal to treat 100 % of all sewage on site. The development and the developer have received numerous environmental and excellence awards (Dockside Green 1.8.2010.)

Figure 21 | A view of Dockside Green

Source: GreenSource 16.09.2010

4 | Concluding remarks

In the present Horizon Scanning report we have summarized the activities carried out so far in WP 3.1 of the Eco-Innovation Observatory. This report is a starting point to various foresight activities following: Delphi, scenarios, impact assessment and roadmaps. All these foresight activities will build upon each other and will interlink with other activities of the whole Eco-innovation Observatory consortium. To enhance the process of foresight analyses and to accumulate relevant information on eco-innovation to best be benefitted by our target audience, namely SME's and policy developers both in EU and national levels, foresight process will be repeated annually during the Eco-Innovation Observatory project. Hence, this report builds both the base and the frame for the future work within WP3. The results of the scanning are based on a literature survey, use of search engines in Internet search, and media monitoring service plus discussions with relevant experts and internal discussions within the project team.

The fundamental part of this report was to analyze the megatrends creating the platform for eco-innovation evolvement. The recognized megatrends relevant from this perspective include resource scarcity (including materials, water, and energy), globalization, and environmental threats such as climate change and other environmental problems. These future trends in combination with value change are producing a fourth trend set called "Eco-trends", the greening of the economy. These trends lead shifts in demand and thus, reinforce the eco-innovation evolvement. This part builds the base for the work within WP3.

The second part of this report was to describe the supply base for the emerging eco-innovations. The innovations based on technological development were divided in five overlapping main fields: (1) new materials, (2) biotechnology, (3) environmental technology, (4) nanotechnology and (5) ICT. However, as the technologies are always tied to their users and social structures, the analysis was taken further to describe social and system eco-innovations. The description and scanning of social and system eco-innovations is also part of the EIO Consortium's approach to adopt a wider definition of eco-innovation. The second part of the report builds the frame for the work within WP3.

The results from Internet search by using different keywords and keyword combinations did not fully support the view of eco-innovation gaining popularity over other environmental keywords. However, the number of webpages focusing on eco-innovation is quite high, there are thousands of webpages with eco-innovation in the title or URL of the page only in the English language. It is obvious that eco-innovations are not dealt with by using this term exactly, "environmental innovation" is a popular substitute and specific issues are often called as innovations only, not eco-innovations - which seems to be quite a generic term. The conclusion is that in Internet, "eco-innovation" may reflect the actual popularity of issues belonging to its content and definition to some content, but this is not the case when looking at scientific articles: in Web of Science, only 53 articles with eco-innovation as a topic were found over time.

Each emerging technology and social and systemic innovation was illustrated by providing examples of already existing or emerging eco-innovations. The example innovations relate to the theme areas of sustainable construction, bio-based materials, material recycling and reuse, phosphorous and sustainable nutrient flows and critical metals, selected by the Eco-Innovation Observatory as thematic focus in the EIO project. Each described eco-innovation has been selected among numerous recent innovations because

the proliferation of these innovations would significantly reduce natural resources consumption and the release of harmful substances across the whole life-cycle. Thus these eco-innovations are “future promise”.

As a preliminary scanning, the analysis of each described trend and technological field are not intended to be exhaustive as the scanning work is an ongoing process throughout the project. It is intended to stimulate the following work within the WP3, and to provide a base and a frame for subsequent analysis in the following two horizontal scanning reports. In the following stages, more in-depth analysis of the technologies and the related innovations will be carried out. This will include evaluating the relative importance of the technologies under consideration and their likely time of entering the market and widespread use. Also, new examples of eco-innovations will be listed to stimulate further discussions and bringing new ideas about the possibilities of each technological field. Additional materials in the horizon scanning will be included, such as patent registers for actual examples of emerging technologies and a more comprehensive analysis of scientific journals by adding more keywords to queries in Web of Science and/or Scopus depending on their availability in the future for the EIO partners. The keyword combinations will be developed and Internet searches will be developed to include also other EU languages than English.

The present deliverable will be updated in 2011 and 2012, and followed by other foresight activities in WP3 annually. The next activity carried out in the foresight process will be Delphi-study. The thematic area selected for this year’s (2010) Delphi and further foresight Activities such as scenarios, impact analysis and roadmaps, is sustainable construction.

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Appendix 1

Methodology of Horizon Scanning

Introduction

The EIO Methodological Report introduced the general methodology of horizon scanning. In this appendix, the methods and related choices actually used in this first Horizon scanning report are described. The overall horizon scanning was limited to sources and materials available online in the Internet. The sources and methods vary depending whether the generic or specific part of horizon scanning was performed, and whether we were looking for emerging technologies and trends related to eco-innovation or concrete examples of eco-innovations. We have to emphasize that the empirical results presented in this report are examples. For example, the number of hits from general queries made with Internet search engines is very large even with most keyword combinations (see Appendix 2), and it has not been possible to browse them systematically. In practice, search engines such as Google, AltaVista and others are more useful in searching for more information when a glue of a relevant emerging technology, concrete example of eco-innovation, or a related trend has been identified (by any means).

Scanning for emerging technologies and trends related to eco-innovation

The information scanned was restricted to the online sources. As the thematic areas were conceptually wide and integrated and the potential key words and their combinations numerous, the number of scanned sources must be restricted. As shown by the enormous number of hits when using the search programs (Appendix 1), getting started with the scanning process needed more restricting tool. Also, scientific citation tracking systems such as Web of Science and Scopus, Google Scholar and major publishers' journal portals such as ScienceDirect (http://www.sciencedirect.com/) offer possibilities to make queries on scientific articles, and even books and conference proceedings. These sources are useful in horizon scanning aiming at trends related to eco-innovation and emerging technologies, but concrete examples are quite rare in these sources. The above mentioned sources are especially useful for the background information and more detailed scoping of the EIO thematic areas.

For this Horizon Scanning report, the 2010 volumes so far available of the following scientific journals and magazines popularizing science relevant for future trends were scanned:

- Foresight
- Futurist
- Journal of Industrial Ecology
- McKinsey Quarterly
- Nature
- New Scientist
- Progress in Industrial Ecology

- Research Policy
- Science
- Scientific American
- Technological Forecasting and Social Change
- Technology Review
- Technovation

Scanning for examples of eco-innovations

For the purpose of identifying eco-innovations fulfilling the requirement of “new to the market”, we decided to use a media monitoring service. The selected service was Meltwater News (http://www.meltwater.com), which has a global coverage with more than 115 000 online media sources in 110 countries and a flexible searching system with a limitless number of keywords for a selected number of “agents”, which in EIO represent the generic and specific parts of horizon scanning (in specific scanning, each LMI area is an agent). The setting of keyword combinations can be tailored for each of the agents so that the service finds the relevant information. The agents and related keyword combinations used for the service were the following:

1. **Recycling**: (“Recycling” or “reuse”) and (“material intensity*” or “material efficienc*” or “energy 62ntensity*”)
2. **Bio-based products**: (“Bio based product*” or “biobased product*” or “bio-based product*”) near (“biodegradable” or “material*” or “renewable material*” or “manufacturing” or “innovation*” or “substitution” or “use”)
3. **Sustainable construction**: “sustainable construction” and (“eco” or “insulation” or “ventilation” or “solar” or “material*” or “product*” or “material efficiency” or “innovation*”)
4. **Sustainable phosphorus cycle**: “Phosphorus” near/12 (“cycle” or “removal” or “sustainable” or “innovation*” or “nutrient flow*” or “waste management”)
5. **Critical metals**: “substitution” near/12 (“alumin*” or “copper” or “gallium” or “gold” or “indium” or “lithium” or “manganese” or “magnesium” or “molybdenum” or “neodymium” or “palladium” or “platinum” or “ruthenium” or “rhodium” or “iridium” or “silver” or “tantalum” or “titanium” or “tungsten” or “vanadium”)- ***Agent changed on July 6. Below the formatted key words:*** (“substitution” or “recycling” or “reuse” or “eff* use”) near/12 (“Antimony” or “Beryllium” or “Cobalt” or “Fluorspar” or “Gallium” or “Germanium” or “Graphite” or “Indium” or “Magnesium” or “Niobium” or “Platinum Group Metal*” or “PGM*” or “Rare earth*” or “Tantalum” or “Tungsten”)
6. **Eco innovation**: “eco innovation” “ecological innovation” “environmental innovation” “eco-innovation”
7. **Green labeling and branding**: “eco label*” “eco brand*” “eco certific*” “green label*” “green brand*” “green label*”

We found the service to be very useful in finding new examples of eco-innovations, good practices and emerging technologies. After finding the examples, we continued finding information on the topic by using other online tools, journals and reports. The service finds innovations that have exceeded the news threshold and thus, the example innovations are topical and indicate the public interest. The service also has a statistics tool, which will help to follow hits within thematic areas and between different parts of the world (e.g. USA vs. EU countries). Hence, using the service throughout the project will collect data that may give signals for the direction of future trends, and also give information how the trends may vary geographically. The first results of the follow up will be reported in the second Horizon Scanning Report.

Appendix 2

Results of queries with a set of selected general and specific keywords, search engine Google.com, 14.10.2010. Includes data for Figures 2-4 in the text.

Keyword/Keyword combination	Number of "hits" in Google.com
"Eco-innovation"	139 000
"Eco-innovation" *in the URL of page*	3 990
"Eco-innovation" i*n the title of page*	5 570
"Eco-innovation observatory"	67
"Environmental innovation"	86 500
"Ecological innovation"	13 200
"Eco-innovation" + "Energy efficiency"	26 600
"Eco-innovation" + Recycling	27 200
"Eco-innovation" + "Re-use"	18 400
"Eco-innovation" + "Sustainable construction"	2 990
"Eco-innovation" + Phosphorus	2 600
"Eco-innovation" + "Critical metals"	55
"Eco-innovation" + "Rare metals"	401
"Material innovation"	174 000
"Material flow innovation"	9
"Material eco-innovation"	1
"Product eco-innovation"	3 120
"Service eco-innovation"	455
"Process eco-innovation"	150
"Social eco-innovation"	9
"Organisational eco-innovation"	9
"System eco-innovation"	9 060
"Emerging technology" + "Eco-innovation"	3 330

“Eco-innovation” + Market	56 000
“Eco-innovation” + Trend	28 500
“Eco-innovation” + “Market trend”	107
“Green market” + Trend	46 800
“Green market” + Innovation	35 700
“Green market” + “Eco-innovation”	5 840
“Green brand”	91 500
“Green brand” + Trend	9 410
“Green brand” + “Eco-innovation”	232
“Resource efficiency” + Innovation	156 000
“Material efficiency” + Innovation	15 500
“Energy efficiency” + Innovation	4 080 000
“Eco-efficiency” + Innovation	71 900
“Resource efficiency” + “Eco-innovation”	6 240
“Material efficiency” + “Eco-innovation”	868
“Energy efficiency” + “Eco-innovation”	26 600
“Water efficiency” + “Eco-innovation”	1 870
“Emissions reduction” + “Eco-innovation”	1 810
“Resource efficiency” + Manufacturing	225 000
“Material efficiency” + Manufacturing	18 700
“Emerging technology” + Manufacturing	240 000
“Resource efficiency” + “Basic metal”	306
“Material efficiency” + “Basic metal”	4 490
“Emerging technology” + “Basic metal”	198
“Resource efficiency” + Chemical	194 000
“Material efficiency” + Chemical	15 800
“Emerging technology” + Chemical	162 000

“Resource efficiency” + Plastic	50 100
“Material efficiency” + Plastic	11 500
“Emerging technology” + Plastic	75 700
“Resource efficiency” + Glass	57 900
“Material efficiency” + Glass	7 520
“Emerging technology” + Glass	85 200
“Resource efficiency” + Electronic	167 000
“Material efficiency” + Electronic	71 300
“Emerging technology” + Electronic	384 000
“Resource efficiency” + Electrical	98 000
“Material efficiency” + Electrical	16 500
“Emerging technology” + Electrical	171 000
“Resource efficiency” + Construction	307 000
“Material efficiency” + Construction	17 700
“Emerging technology” + Construction	222 000
“Resource efficiency” + Automotive	53 500
“Material efficiency” + Automotive	7 000
“Emerging technology” + Automotive	92 600
“Resource efficiency” + Vehicle	76 100
“Material efficiency” + Vehicle	6 500
“Emerging technology” + Vehicle	134 000
“Resource efficiency” + Transport	223 000
“Material efficiency” + Transport	17 700
“Emerging technology” + Transport	159 000
“Resource efficiency” + Machinery	51 500
“Material efficiency” + Machinery	13 100
“Emerging technology” + Machinery	58 500

“Resource efficiency” + “Metal processing”	3 100
“Material efficiency” + “Metal processing”	217
“Emerging technology” + “Metal processing”	1 130
“Resource efficiency” + Mining	66 100
“Material efficiency” + Mining	9 420
“Emerging technology” + Mining	83 800
“Resource efficiency” + Mineral	26 700
“Material efficiency” + Mineral	8 220
“Emerging technology” + Mineral	38 100
“Resource efficiency” + Water	438 000
“Material efficiency” + Water	21 700
“Emerging technology” + Water	227 000
“Resource efficiency” + Energy	18 500
“Emerging technology” + Energy	351 000

About the Eco-Innovation Observatory (EIO)

The Eco-Innovation Observatory (EIO) is a 3-year initiative financed by the European Commission's Directorate-General for the Environment from the Competitiveness and Innovation framework Programme (CIP). The Observatory is developing an integrated information source and a series of analyses on eco-innovation trends and markets, targeting business, innovation service providers, policy makers as well as researchers and analysts. The EIO directly informs two major EU initiatives: the Environmental Technologies Action Plan (ETAP) and Europe INNOVA.

This first horizon scanning report explores how eco-innovation is visible in the Internet, scientific publications, and in the electronic media. It shows how key megatrends create a platform for eco-innovation evolvement, and identifies potential areas where eco-innovations improving material efficiency are needed. These areas include new materials, biotechnology, environmental technology, nanotechnology and information and communication technologies and a set of examples of eco-innovations in these areas are introduced. The concept of eco-innovation is extended beyond technology by highlighting the importance of social and systemic innovations spiced with a few examples.

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