Sectoral Innovation Foresight
Construction
Interim Report

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# Table of contents

1  Introduction ................................................................................................................... ...........1
2  The current situation of the construction sector in Europe .................................................1
3  Drivers of innovation and change – trends and trendbreaks ...............................................6
   3.1 Demand-side drivers ............................................................................................................ ....6
   3.2 S&T drivers .................................................................................................................... ..........9
4  Emerging innovation themes ...............................................................................................12
   4.1 New products, processes, technological trajectories .............................................................12
   4.2 Organisational change and firm strategies.............................................................................16
5  Institutional and structural requirements and implications ...............................................17
   5.1 Skills requirements and the knowledge base .........................................................................17
   5.2 Institutional change ........................................................................................................... .....20
   5.3 Structural change.............................................................................................................. .....21
6  First elements of scenarios ...................................................................................................23
7  Key Questions .....................................................................................................................27
8  Literature............................................................................................................................28
1 Introduction

This interim report is part of Task 2 (Sectoral Innovation Foresight) of the Europe INNOVA Sectoral Innovation Watch (SIW) project. The aim of the report is to introduce first findings on possible future developments in the sector under study. Particular emphasis is put on the one hand on future changes that are likely to significantly influence the evolution and emergence of innovation activities and associated markets, and on developments that are likely to be of cross-sectoral relevance to innovation on the other. Sectoral innovation foresight thus complements Task 1 of the SIW project, which analyzes current sectoral innovation performance.

The main objectives of Task 2 can be summarised as follows:

- Explore and identify the main drivers of change in the nine sectors. These drivers will be both internal and external to the sectors, with several of them being of a cross-cutting nature.
- Identify and assess key future developments in the nine sectors as well as in terms of cross-cutting developments. The emphasis is put on likely future innovation themes and emerging markets, more specifically also on the requirements and impacts they raise in terms of skills requirements, organisational, institutional and structural changes in the sectors concerned.
- Develop scenario sketches for the sectors under study.
- Highlight key policy issues for the future, with a view to enhancing the innovation performance and competitiveness of firms operating in these sectors.
- Stimulate debate and contribute to the creation of expert networks, based on the participatory elements of this task.

The time horizon of these foresight papers is five to ten years (2015-2020), depending on the specific characteristics and the pace of change in the respective sectors. The construction sector is characterised by long innovation cycles and generally regarded as not very innovation-intensive. The time horizon suitable for foresight on this sector is thus longer than for most other sectors considered.

This Interim Report is based on a review of available foresight material on the textiles and clothing sector. Together with the corresponding report on the eight other sectors addressed by the SIW project (aeronautics and space, automotive, biotechnology, construction, food and beverage, knowledge-intensive business services, wholesale and retail trade), it serves as background material for a first expert and stakeholder workshop (June 2009). The report concentrates on drivers and innovation themes, but provides already some first findings and thoughts on emerging markets, requirements and future scenarios, i.e. as far as these issues can be derived from the review work. The first workshop aims on the one hand at reviewing the interim findings and on the other at exploring future scenarios of the sector in an interactive mode. The results of this first workshop and some further interviews with experts and stakeholders will then be incorporated in a draft final report that will serve as input to a second foresight workshop (November 2009). This second workshop will focus on the main policy issues that arise from the exploratory scenarios, both within the individual sectors and at their intersection. The final report will bring together in a consistent form the results generated in the different phases of the foresight exercise, i.e. will be based on revised and amended versions of the initial chapters of this interim report and additional chapters dealing with refined scenarios, future requirements and policy issues.
The interim results are presented in six chapters, starting with a situational analysis where the sector stands today to contextualize possible future developments (Chapter 2). Building on this context, Science & Technology (S&T) and demand drivers will be outlined (Chapter 3), as a basis for discussing emerging innovation themes (Chapter 4). These are expected developments resulting from the interaction of supply (technological advances) and demand (societal / customer needs) forces. In this chapter, implications of these innovation themes at firm level will also be addressed. Institutional and structural requirements and implications of the innovation themes for the sector will be highlighted in Chapter 5. This is complemented with first scenario sketches (Chapter 6) and some key questions to be addressed in the remainder of the Sectoral Innovation foresight task (Chapter 7).
2 The current situation of the construction sector in Europe

The construction sector (NACE Section F) had close to 2.7 million enterprises that together generated a combined value added of EUR 433.5 billion in the EU-27 in 2004 and employed 13.2 million persons, equivalent to 8.5 % of the non-financial business economy’s (NACE Sections C to I and K) value added and 10.5 % of its employment (see Table 15.1). The United Kingdom had the largest construction sector in the EU-27 with a 19.0 % share of the EU-27 total in 2004 (see Table 15.2). Spain had the second largest sector in value added terms, with a 17.3 % share, which was close to double its 9.0 % share of value added in the EU-27’s non-financial business economy.


High resource usage

The construction sector is of considerable economic and strategic importance: More than any other sector, construction accounts for use of raw materials and production of wastes. It provides more employment than any other sector. The outputs of the construction sector affect our landscape, our environment, our living and working conditions for generations.

Low R&D

Despite the existence of country-specific differences (Gann, 2001), construction is generally seen to be a low R&D investment sector, and a scarcely dynamic industry. It is characterised by very long cycles and strong cyclical variations in both demand and profits. (Squicciarini and Asikainen, 2008, 5) Projects and undertakings within the construction sector are characterised by a high fragmentation of responsibilities, processes and resources. Typically design, site works, production of materials needed, operation and selling are done by a variety of organisations, with many subcontractors and specialists being involved. This gives large scope to confusion of responsibilities and ambiguous communications.

High fragmentation

The sector itself is also highly fragmented, with a high proportion of very small firms (10 employees or less) and a high proportion of self-employment within these firms. Consequently, key decisions concerning inputs, product and process technologies, which are vital for the various requirements buildings have to fulfill, are made by a high number of often very small firms operating in highly competitive price-based markets. This has implications for their ability to absorb knowledge and information, utilise new technologies and take overall responsibility for the success of the final product or service. (E-CORE Strategy, 2005: 14 and Taskforce on Sustainable Construction, 2007: 10)

In contrast, the construction products and materials sectors are also populated by large multinational firms, with good access to financial markets and a high level of technical competence, often in-house R&D. (BUILD-NOVA Consortium, 2006: 79, see also Table 1) However, for the majority of the sector innovation activities tend to be episodic rather than continuous in nature, with innovation rather happening in client-projects than in research projects. (Squicciarini and Asikainen, 2008: 6)

Highly regulated
The construction sector is highly regulated, in particular energy and environmental regulations and safety regulations. In the case of environmental and energy regulations it is still unclear, if they are likely to enhance innovations, thus increasing productivity and competitiveness, or if they rather hamper competition and distort trade. (Jaffe et al. 1995, cited in Squicciarini and Asikainen, 2008, 9)

Labour intensive and poor image

Despite being very labour-intensive, the construction sector offers poor working conditions. Its safety record is typically second only to mining in terms of probability of injury or death. Safety regulations are essential in the sector, but it still has to be understood how to motivate firms to comply fully with the rules. Due to society’s poor image of the construction sector, the sector is failing to attract the skills and abilities necessary, if it is to adopt new technologies and ways of working and transform its performance. (E-CORE Strategy, 2005: 16 and Squicciarini and Asikainen, 2008: 10)
### Table 1: Categories of Firms in Construction

<table>
<thead>
<tr>
<th>Category</th>
<th>Relative size</th>
<th>Nature of innovation</th>
<th>Innovation drivers</th>
<th>Financing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contractors</td>
<td>Mainly independent SMEs, but maybe also large groups with decentralised affiliates to</td>
<td>Mainly process and methods, mainly incremental innovations, mainly short term problem solving innovations.</td>
<td>Clients driven. Regulation. Safety and productivity.</td>
<td>Most innovations do not require huge sum of money because it is a problem solving approach.</td>
</tr>
<tr>
<td></td>
<td>Specialized trades (plumber, electrician, mason …), which, in most cases, employ less than 10 employees, high proportion of self-employment.</td>
<td>In some cases, these innovations may be further developed. Big contractors also develop service innovation.</td>
<td>Low level of R&amp;D. Know-how of the employees working on the building site is crucial. Manager often plays a key role in the innovation process (especially in (V)SMEs). Strong competition.</td>
<td>When innovations are turned to commercial products, processes or services, funding might become an issue.</td>
</tr>
<tr>
<td></td>
<td>Some international groups but a domination of small and medium sized firms.</td>
<td>Mainly processes, organisational structure, also products.</td>
<td>Clients driven. Regulation. Productivity. Strong competition.</td>
<td>Need for funds can be high when the firm carries out its own R&amp;D. Commercial stages always require to find suitable funding.</td>
</tr>
<tr>
<td>Products manufacturer</td>
<td>Some of them lead their national market but their international market share is limited</td>
<td>Services innovation are complementary and a success factor to differentiate from competitors. Incremental innovations dominate with some examples of radical innovations. Services innovation. Also products innovation in order to better fit with clients demands. Mainly products and processes. Radical innovation is relatively more important here than for other categories of firms.</td>
<td>More or less developed in-house R&amp;D structures according to firm size (expertise and know-how of the manager for small firms).</td>
<td>Groups are quoted on the stock exchange. Access to international funding, receivemost public subsidies.</td>
</tr>
<tr>
<td>Products distributor</td>
<td>Generally local activity (close to local contractors). May be subsidiaries of bid manufacturers.</td>
<td></td>
<td>Clients driven. Regulation. Strong competition.</td>
<td></td>
</tr>
<tr>
<td>Material suppliers</td>
<td>Large international groups in a limited number of domains (steel, glass, …)</td>
<td></td>
<td>Scientific progress. Regulation. Strong competition. In-house R&amp;D laboratory.</td>
<td></td>
</tr>
<tr>
<td>Services providers</td>
<td>Large and small firms. Competition may be national (housing companies) or international (real estate investors, facilities managers)</td>
<td>Mainly service and organisational innovation. Incremental innovation dominates.</td>
<td>In-house project groups, marketing and after-sales departments, customer-relationship management, top-management, co-production with the clients, regulations, imitation of competitors.</td>
<td></td>
</tr>
</tbody>
</table>
3 Drivers of innovation and change – trends and trendbreaks

3.1 Demand-side drivers

Climate change

Climate change constitutes a considerable challenge for the construction sector in several ways:

- Construction outputs are in operation for a long period of time and may, with an increased volatility of climate (storms, floods, extreme temperatures), be subject to more extreme conditions than now.
- Construction has to play a major role in reducing greenhouse gas emissions, as energy use in buildings accounts for around 45 per cent of European greenhouse gas emissions. (E-CORE Strategy: 11)

Demographic change

Demographic change will exert various effects on the construction sector, there will be a need for structures robust for changes:

- Changes in household structure: More households per head of population, households become smaller, in some European countries there has been a trend for single-households for years. This increases the demand for an affordable and flexible housing stock.
- European population is aging. The adaptation of homes and refurbishment of buildings in order to allow people to stay in their familiar environments once they become old and infirm will become a significant feature of the market. (E-CORE Strategy: 11; )

Demographics of the Workforce

- Demographic change will also reduce the flow of younger workers into the workforce. In response, the construction sector might introduce a higher proportion of industrialisation both on- and off-site. (E-CORE Strategy: 11)
- High ratio of migrant labour force, high movement of labour force.
- Recruitment and motivation will be increasingly difficult due to poor image in society, poor safety records, insecure employment and adverse working conditions (disruptive, noisy, dusty and physically exhausting).
Arguments for innovation and change | Arguments against innovation and change
---|---
The demographics of the workforce (e.g. aging workforce, recruitment and retention issues). | Labour is always accessible, whether through retraining, migrant labour or simply by paying more than the competition.
The need for greater output from a smaller workforce. | Alternative methods are too expensive and often perceived as high risk.
The need to improve safety standards and the quality of buildings. | Construction companies are still able to compete and make profits using traditional methods and materials, thus reducing the need for change (e.g. the repair and maintenance sector).
The time to train the increased workforce is longer than the industry has to deliver the increased outputs. | In parts of Europe, land is the restricting factor, not labour.


**Urban redevelopment**

In order to adjust to modern requirements of lower energy consumption, substantial efforts have to be undertaken in order to modify or replace the stock of buildings in Europe. This is especially true for the new member states, where huge populations still live in multi-storey blocks constructed decades ago, which have poor environmental performance and provide inadequate living conditions. Large urban refurbishment, redevelopment and environmental clean-up requirements are going to stimulate markets. (E-CORE Strategy: 11)

**The current financial crisis**

In December 2008, TNO stated in its Building and Construction Forecast for 2008 – 2013 that the Dutch building and construction sector will suffer considerably in the long term from the combination of recession and restrictive borrowing. There will be a drop in demand, particularly for private housing and offices. This diagnosis for the Dutch construction industry is likely to be true for other European countries as well. It has to be expected that although in the years 2008 and 2009 there will be a slowdown in production in the construction sector, due to a time lag it will be mainly the years 2010 and 2011 in which the impact of the credit crisis will be felt most severely. The credit crisis will cause a decline in the permits granted in 2009, especially in the private housing market and office buildings. (TNO, 2008)

However, it seems now that the level of building production remains reasonably intact in terms of infrastructure, major and minor maintenance, renovation, rental accommodation and building for education, healthcare and government. In earlier crises, market and government flexibility has been considerable. Government measures can be expected to help restrain the impact of the credit crisis. (TNO, 2008)

**Public procurement and innovative commissioning**

In general, the professionalisation of clients is a key trend in the building and construction industry. If the client or commissioning party succeeds in detailing objectives involving high qualitative standards and strong incentives to innovate this leads to a shift in responsibility from the commissioner to the contractor/supply chain. This requires informed and competent clients with a detailed strategic agenda. This is a role which may be particularly associated with public clients, but
it actually can also conform to private clients (construction in tourism, hotels, also big industrial firms with various locations. However, the public sector purchases a high share of the construction industry’s output (e.g. over 40 per cent\(^1\), and this figure is growing). Hence, the public sector as a main client of the construction industry may be a key driver to set higher qualitative standards. This leads to higher attention to and the further development of public procurement procedures. They may exert influences on the construction sector in various ways and its size provides an opportunity and a threat: (European Foundation for the Improvement of Living and Working Conditions, 2005: 22 and UK Sector Technology Strategy, 2005: 1)

- higher degree of transparency of the procurement process, fair and transparent competition
- higher qualitative standards of requirements and specifications in public procurement

It is particularly the second issue which may induce substantial innovation in the construction sector. But demand on the public side is scattered - public clients invest in the built environment in the forms of sustainable communities and housing supply, schools, health infrastructures, roads, rail and prisons. Different public bodies, different departments are responsible. A variety of approaches to the deliver the targets is taken across the different public clients. Decision making processes vary, failures, even scandals, in the past limit the perceived scope of action. But, if messages to the market are unclear or clients are undemanding the opportunity to achieve innovation is lost. (UK Sector Technology Strategy, 2005: 1)

**The characteristics of private demand**

The large market for single-family homes is characterised by atomistic demand, most clients purchase individual solutions, they are inexperienced and not aware of innovations and risk-averse. Potential buyers are primarily interested in a high quality-price ratio of their investment and not in whole life cost and flexibility of structures. Important quality aspects are space, location and a sunny garden. All this counteracts eco-innovation in construction. In this area, governmental regulations play an important role to achieve innovations for increased sustainability. (Bossink, 2004: 16)

**Fragmented delivery**

The introduction of a new technology requires cooperation across fragmented decision-making processes and a fragmented supply chain in order to develop skills, change supply chains, invest in installation equipment etc. There are major challenges for initiators of innovation to gain value of their investment rather than succumb to pressures of other members of the supply chain. (UK Sector Technology Strategy, 2005: 7). Hence, for the introduction of new technologies and innovative measures it is necessary to overcome the small and mutually dependent structures which are an integrative part of the sector.

**Discrepancy between owners and users and the change of ownership**

A significant proportion of buildings (residential as well as commercial) are rented to other persons, companies or other organisations after the completion of the buildings. Furthermore, buildings may frequently change owners during their life-time. These features make it difficult for the initial owners to gain rents from their initial investments unless they can incorporate a premium into the sales price. (OECD 2002: 12)

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\(^1\) Taskforce on Sustainable Construction, 2007, 12.
3.2 S&T drivers

**Advanced Manufacturing**

Advanced manufacturing techniques and technologies will be necessary to deliver high quality, globally competitive components for buildings and construction processes at whole life cost which is affordable to public and private clients. Advanced manufacturing techniques and technologies will have to encompass both – i) product and materials development (special and improved properties like fire resistance, insulation, durability, resistance against deformation, corrosion, temperature changes, also better environmental properties like reduced toxicity) and ii) the cost-effective production of these products and materials. (UK sector Technology Strategy: 4)

Considering the development of advanced materials and products, one can speak of material *evolution* on the one hand and material *revolution* on the other. Evolution is the further development and improvement of “classical” materials like steel, cement and glass. Material revolution is the creation of totally new materials like new composites, alloys, new light-weight materials, nano-based materials etc. Also bio-based materials like wood can be technically improved (e.g. for longer durability or better application) and are getting increasing attention in the building industry. Smart materials with integrated ultra-small sensors are already under development, for example to monitor the formation of cracks in bridges. (Butter and Leis, 2009: 1)

<table>
<thead>
<tr>
<th>Development of new/ evolved/adapted materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Development of sustainable, low carbon products (both in terms of components and entrie structures within the built environment)</td>
</tr>
<tr>
<td>✓ Development of products and materials capable of improving the sustainability of the built environment.</td>
</tr>
<tr>
<td>✓ Development of products and materials using recycled/re-used materials.</td>
</tr>
<tr>
<td>✓ Development of products and materials reducing dependency on individual products, e.g. oil, steel etc.</td>
</tr>
<tr>
<td>✓ Development of products and materials robust to climate changes (hotter summer temperatures and wider temperature changes, flooding, wind, earthquakes etc.</td>
</tr>
<tr>
<td>✓ Development of products and materials to enable the development of restricted/ congested sites.</td>
</tr>
<tr>
<td>✓ Development of products and materials robust to security threats</td>
</tr>
<tr>
<td>✓ All the above to support not just new buildings but refurbishment of the existing built environment.</td>
</tr>
</tbody>
</table>

Source: UK Sector Technology Strategy, 2005: 4

**Nanotechnology**

The ability to analyse and modify matter on an increasingly small scale widens the possibilities to develop new materials with specific and tailored characteristics. It is now possible to visualise and manipulate molecules and atomic structures in order to find out properties for improvement. Novel construction materials can result from the application of nanotechnology (e.g. through the use of nano-particles, nano-tubes and nano-fibres), offering new combinations of strength, durability and toughness. Nanotechnology in construction can on the one hand help to equip traditional materials with special properties (concrete – strength, energy storage from day to night, from summer to winter), and on the other hand provide surfaces with new and exciting properties (glass – self-cleaning, self-regulation of transmission of light and heat). (Butter and Leis, 2009: 2)
At the same time there may be impacts of nanotechnology on human health, as it is unclear at this point of time if all types of nanoparticles are degraded in nature or if they accumulate in organisms. It will also have to be part of future research agendas if nanoparticles are emitted from functionalised surfaces in our homes and on our buildings. (Sanden et al., 2008: 2f)

**Future routes for successful application of nanotechnology in the construction sector**

The development of
- understanding of phenomena at nano-scale
- modified nanostructures of traditional bulk materials
- high performance structural materials
- special coatings
- multifunctional materials and components
- new production techniques, tools and controls
- intelligent structures and use of micro/nano sensors
- integrated monitoring and diagnostic systems
- energy saving lighting, fuel cells, communication and computing devices


**New technologies for energy supply and energy efficiency**

This includes the development and incorporation of new energy supply systems including renewables, microgeneration, also the development and application of materials incorporating energy producing components, insulation and design to limit the need for energy supply. Furthermore, effective mechanical and electrical systems (including control mechanisms ensuring effective energy use and appropriate maintenance. (UK Sector Technology Strategy, 2005: 4f)

**Biotechnology**

Biotechnology is able to provide ancient and important building materials like timber or other materials from plants or animals (sheep wool for insulation) with new properties like greater resistance to decay, enhancement of strength and reduced movement in use, greater ability to absorb pollutants, new fibres, new sealants and adhesives, enhanced and controllable growth (enabling natural products to be tailored to specific dimensions). (E-CORE Strategy: 36)

**Living Buildings**

Selection and use of specific bacteria which serve as organic adhesives to form building materials. They may vary the properties of the resulting composites: strength, density, permeability, thermal insulation. Air quality, elimination of pollutants, air purification, control of humidity and heat loss and the release of fragrances could be subject to bacteriological control, using bacteriological sensors.

Source: E-CORE Strategy: 36.
Information and Communication Technology

ICT will continue to influence the construction sector in various ways:

- by embedding ICT in materials or construction products, thereby making them smart. (See also chapter on Smart Buildings below). The adoption of ICT is needed here in order to equip buildings with the flexibility necessary in order to function for different users with varying purposes. (European Foundation for the Improvement of Living and Working Conditions, 2005: 17)

- by integrating ICT in the coordination and organisation of trade (e.g. materials), construction processes and monitoring of materials. ICT is needed to support effective delivery processes (logistics, lean construction, lean production and effective offsite manufacture of components).
  - **E-solutions** will lead to more open procurement,
  - **E-technologies allow more openness and involvement of actors (customers),**
  - **Virtual reality and simulation technologies are able to demonstrate not only the physical aspects of the design, but also the assembly processes. This is crucial for the assessment of constructability (E-CORE Strategy: 30), e.g. the accumulation of waste during different phases of the construction process or inconsistencies and dangers in the construction process. (European Foundation for the Improvement of Living and Working Conditions, 2005: 17)**
  - **RFID (Radio Frequency Identification) needs to be developed to optimise the sustainable use of products (tracking products and their delivery, tracking maintenance and recycling requirements, calculating the embodied energy within a structure or the built environment as a whole. (UK Sector Technology Strategy, 2005: 5)**

Bionics

Bionics as a technological trajectory takes nature as a source of inspiration in order to generate special properties in materials, structures, processes, algorithms, methods, tools, mechanisms and systems. The principles abstracted from nature are transformed into technical solutions made of synthetic materials. Plants, for example can have exemplary characteristics in regard to stability and flexibility and even serve as role model for next generation high-rise buildings. Metallic foams, for example, have similar characteristics as bones and show very favourable characteristics in regard to light-weight, stability, stiffness and absorbality. Also the structures of termites and other animals can serve as models for energy-saving ventilation and cooling systems. (Butter and Leis, 2009: 3) Examples for the design and use of bionics in construction are:

- **Bionic materials:**
  a. Breathing envelopes: Based on the principles and methods abstracted from respiration systems, buildings may be equipped with a breathing surface in order to allow for ventilation in building envelopes, facades. (TU Delft, www.bk.tudelft.nl, 25.3.09)
  b. Light weight materials in construction
• Bionic architecture:
  a. Design of mega-high rise buildings in terms of static properties, using forms, materials and construction principles inspired by nature
  b. Design of functional properties of buildings, e.g. design of ventilation systems inspired from airway systems in insect habitats, or efficient use of artificial energy

4 Emerging innovation themes

Table 2: The Spectrum of Innovation

<table>
<thead>
<tr>
<th>Low level of innovation</th>
<th>Medium level of innovation</th>
<th>High level of innovation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin joint masonry</td>
<td>Manufactured systems</td>
<td>Factory built units</td>
</tr>
<tr>
<td>Design for price</td>
<td>Design for whole life cost</td>
<td>Design for value</td>
</tr>
<tr>
<td>Computer-aided drafting</td>
<td>Computer-aided design</td>
<td>Computer-aided modelling</td>
</tr>
<tr>
<td>Management by objectives</td>
<td>Team work</td>
<td>Matrices of professionals</td>
</tr>
<tr>
<td>Directory procurement</td>
<td>Supplier involvement</td>
<td>Supply chain management</td>
</tr>
<tr>
<td>Multiple quotations</td>
<td>Occasional partnering</td>
<td>Joint ventures</td>
</tr>
<tr>
<td>Power handling</td>
<td>Materials handling plant</td>
<td>Logistics</td>
</tr>
<tr>
<td>Email</td>
<td>Project extranets</td>
<td>Virtual teams</td>
</tr>
</tbody>
</table>


4.1 New products, processes, technological trajectories

Eco-efficient buildings

The market for eco-efficient buildings is populated by a huge variety of concepts with a lack of clear definitions or a common understanding what is exactly meant by them. Eco-efficient buildings include terms like sustainable buildings, green buildings, passive houses, low-impact-buildings, low-energy-buildings, zero-energy buildings (which may entail zero-site-energy, net-zero source energy, net-zero energy costs, or net-zero energy emissions), energy plus buildings etc. (UK Technology Strategy Board 2008, Torcellini, Pless and Deru, 2006: 1) They all refer to a variety of themes, see Table 3 for an overview.

What they all have in common is the general objective of reducing CO2-emissions, although they may vary in the time frame to target the reduction (construction stage, use stage, both) and in the scope of actions taken for the improvement of the environmental characteristics of the buildings. In the construction stage this means to design buildings composed of materials with low embodied energy (low energy for transportation, low energy for manufacturing and building materials etc). It also means to design buildings with low service frequency (i.e. high level of physical durability, easy maintenance of buildings, physically adaptable to change of use). In the use stage, it will increasingly be necessary to improve the energy efficiency of buildings (e.g. thermal insulation, air tightness etc.) and to improve the energy efficiency of appliances (space heating and cooling,
ventilation, hot water etc.). And finally: To maximise the use of renewable energy (active solar heating, passive solar heating, photo voltaics etc.) (OECD, 2002: 20)

To different degrees the above concepts also refer to the minimisation of waste, basically in the construction phase and in the demolition phase. In the construction phase as well as in the demolition phase, this means the reduction of the quantity of materials used in the construction of buildings and the recycling and reuse of surplus materials. However, minimisation of waste is also achieved through characteristics like a high level of physical durability, easy maintenance of buildings, and low barriers to physical adaptability to change of use. (OECD, 2002: 23)

Furthermore, some of the above concepts also incorporate concerns and actions taken in order to protect the occupants’ health and improve employees’ health and productivity. Hence, measures entail the elimination or reduction of sources for indoor toxins and air pollutants, the avoidance of moisture responsible for mold growth, the avoidance of VOCs, formaldehyde and PVC etc. However, indoor pollution is a difficult matter, as there are still some open questions regarding causal relations. (OECD, 2002: 5 and 24)
### Table 3: Themes in the market for eco-efficient buildings

<table>
<thead>
<tr>
<th>Themes</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive solar design</td>
<td>The sun is the prime source of energy. Passive solar design refers to design that uses solar energy to attain thermal and visual comfort. It encompasses a wide range of strategies and options used in buildings to reduce energy consumption and increase occupant comfort. Passive solar design emphasizes architectural design approaches that minimize the demand for energy by measures such as appropriate building siting, efficient envelopes, appropriate fenestration, daylighting design, and thermal mass. The basic intent of a passive design is to allow daylight, heat and airflow into a building whenever beneficial, store and distribute the heat and cool by natural means.</td>
</tr>
<tr>
<td>Renewable energy systems</td>
<td>Renewable energy is used to describe energy flows that occur naturally. Natural sources of energy such as solar, wind, hydro, tidal energy, ocean thermal and hydrogen are all renewable energy sources. The projected shortage of fossil fuels and the environmental degradation associated with their use are the two major reasons that renewable sources of energy sources are attractive.</td>
</tr>
<tr>
<td>Buildings form and construction</td>
<td>The design of a building has a significant impact on the material and energy requirements, both, during the construction and operation phases. The shape of the building, the land area to volume ratio, the orientation of the building, etc., all contribute to a determination of the quantity of material required for construction, and the energy requirements when the building is occupied. Designers need to assess the environmental impact and economics of different forms and designs of buildings to arrive at the optimal solution. Implementing energy-efficient building technologies and efficient construction techniques can reduce construction wastage for the same built-up area of the structure, compared to conventional designs. In terms of energy consumption, it would lead to reduction in cooling, heating and lighting requirements inside the building. Therefore, the main objective is to emphasize sustainability as an integral part of the form and construction of the building.</td>
</tr>
<tr>
<td>Sustainable building materials</td>
<td>The building industry has depended heavily on energy-intensive materials and resources. Building materials contribute to large environmental costs. These costs are incurred in extracting, producing, manufacturing, transporting, installing and recycling these materials. A sustainably managed building material is that which has the minimum possible environmental cost. An overall evaluation of the total energy and environmental impact of the material and its creation process, as well as the long-term efficiency of the material (maintenance and replacement costs) is needed to determine the sustainability of a material. Materials that are more sustainable generally have a lower initial and lifetime environmental impact. A material can be made more sustainable in various ways, including reducing the travel time of transport, reusing materials, selecting materials that have a manufacturing process with a low energy requirement, using recyclable products and so on. Some sustainably managed materials are fly-ash based bricks and blocks, lumber from sustainable forests, etc.</td>
</tr>
<tr>
<td>Water and waste management</td>
<td>Increased demand for water and its limited availability make it essential to have an efficient water management system as well as strategies for efficient water re-use. While water use can be minimized by reducing losses and adopting water efficiency techniques, there is great potential for reducing the overall water requirement by recycling and reuse of water.</td>
</tr>
<tr>
<td>Themes</td>
<td>Description</td>
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<td>------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Health and buildings</td>
<td>Health and buildings are closely linked. We all spend an average of over 90% of our lives in buildings, which can affect our health in many different ways. For instance, mental health can be badly affected in noisy buildings. Buildings can fall on people injuring or killing them. Toxic emissions from finishing materials or mould growth can seriously damage health. Sick building syndrome (SBS) is an example of how important buildings are to the well-being of the ordinary citizen and how widespread health impacts of buildings are. SBS is a recognized condition in which occupants of a building experience mild-to-acute health effects that seem to be linked to the time spent in a building, but no specific illness or cause can be identified.</td>
</tr>
<tr>
<td>Passive and solar assisted cooling</td>
<td>Passive cooling for buildings is mostly relevant to hot climatic zones. The prime intent of passive cooling is to prevent heat (or reduce heat flux) from entering the building or remove heat once it has entered. These concepts use solar energy or other natural cooling sources (radiative cooling, evaporative cooling, natural ventilation, etc.). The applicability of these depends to a large extent on the prevailing climatic conditions, for instance, evaporative cooling is effective in hot and dry climates only. Passive cooling techniques maximize building envelope efficiency by minimizing heat gain from the external environment and by facilitating heat loss to the external environment. Some commonly used passive cooling concepts are: a) evaporative cooling, b) nocturnal radiation cooling, c) passive desiccant cooling, e) earth sheltering / berming, f) earth- cooling.</td>
</tr>
<tr>
<td>Site planning</td>
<td>Site planning is a vital component of any type of building activity and is the first step in efficient utilization of resources available on the site. Site planning for sustainable development focuses on environmentally sound practices through proper zoning of buildings and landscape design. Environmental sustainability includes such issues as protection of existing vegetation on the building site, site disturbances and resource utilization (availability of natural light and ventilation) all of which can be addressed by proper site planning. Site planning is the preliminary step in ensuring efficient habitat design. Sustainable site planning ensures that there is minimum site disturbance, adequate protection and that conservation measures for soil and water are taken. It also ensures that maximum site energy is harnessed, and inter site and intra site transportation is optimized. Water and energy requirements outside the building premises but on the site including water requirements for landscaping, energy required for site lighting play a major role in sustainable site planning.</td>
</tr>
</tbody>
</table>

Smart Buildings

Smart construction or intelligent houses are notions which refer to the automatic adjustment of buildings or components to various external changes, or to the communication of materials, components and systems with each other in order to optimise their use (e.g. sensitive houses, i.e. sensors control lighting, heating, air quality, fire detection, security etc.) (European Foundation for the Improvement of Living and Working Conditions, 2005: 16)

Buildings have to provide various functions and facilities in order to fulfill the needs of the people living in them. A net of sensors and related communication technologies will be able to act independently and efficiently according to specifications and criteria of users: (E-CORE Strategy: 36f)

- More controllable heating, ventilation and air-conditioning systems, with energy being used only when necessary (occupied rooms only), systems that anticipate and respond to users’ needs.
- More effective but less intrusive security systems, capable of making a difference between familiar and unfamiliar users.
- Continuous monitoring of structures and service systems, with stress, corrosion and mechanical performance analysed, automatic diagnosis and report of faults in case of deterioration of performance.
- Advanced detection of fire, with automatic communication and response of protection systems
- Active response systems in seismic regions
- Sensors and communications systems to support health monitoring and provide health care services.

4.2 Organisational change and firm strategies

Lean construction: Integrating the building processes and improving performance

A central approach which may help change the organisation of the construction process, division of labour and management processes is ‘lean’ construction. Key characteristic of this management system is planning at different levels, securing a continuous flow in the construction process by identifying potential barriers, such as whether materials, machinery and labour are available at the time they are needed. For this, all participants at the construction site must be engaged in the planning process. (European Foundation for the Improvement of Living and Working Conditions, 2005: 18)

Important aspects of lean production which will need to be further developed through RTD are: (E-CORE Strategy: 30)

- The assessment of ‘constructability’, i.e. the further development of systems for examining design and assessing their ease of construction.
- 3D modelling systems, now common place in advanced projects, will become more widespread and will have to be further developed to be accessible for a wide range of users, contributing to the integration of the process.
- Just-in-time delivery, as lean production also implies the reduction of uncertainties in the final assembly process. This is achieved through detailed planning in combination with relationships and delivery systems that can provide materials and skills on site at exactly the right time.
Pre-assembling

The prefabrication of construction components is able to speed up the whole process, improve quality, reduce waste and lower the prices of undertakings. The use of industrial robots and automation technology in off-site manufacturing and materials manufacturing is likely to further enhance change in the construction process. However, the introduction of more prefabricated materials and preassembled parts in construction demands extensive coordination between actors collaborating from different preassembling sites. (European Foundation for the Improvement of Living and Working Conditions, 2005: 18)

There are still uncertainties: (E-CORE Strategy: 30)

- Tensions between the improved efficiency and predictability of this approach and the ability to meet the exact needs of individual customers. Maintaining a standard vs. providing great flexibility.
- Acceptability and economics of such systems across Europe will still have to be a matter of exploration.

In Japan, prefabricated housing manufacturers dominate a significant proportion of the private housing market. In some European countries, like the UK government and construction industry advisors show a growing interest in increasing the share of off-site pre-assembling within the private housing sector as a solution to current quality and efficiency problems. (Johnson, 2007: 5) However, the Japanese model presumes that the physical house will be replaced every generation (replacement occurring on average every 26 years) with the mortgage mechanism being based on the site value. Apparently the European housing market shows significantly different characteristics to that of Japan and the scale of prefabrication as it is in the Japanese housing market cannot be replicated in Europe for cultural and market reasons. But with more efficient practices in offsite modern methods of construction, more innovative housing designs and improved supply chain management, social and private housebuilders are increasingly becoming aware of the advantages prefabrication can offer. (Johnson, 2007: 12 and 41f)

5 Institutional and structural requirements and implications

5.1 Skills requirements and the knowledge base

The envisaged changes in the construction sector require a broad range of qualifications (European Foundation for the Improvement of Living and Working Conditions, 2005: 24):

i) Training in the use of new technologies, machinery, processes and materials. This will probably lead to new specialised crafts or further specialisation within existing crafts. As a general trend the number of occupations within the construction process will rise considerably, this is induced by a permanent increase in technological opportunities of the whole sector.
ii) Communication and teamwork skills, etc. Learning in this respect has to be introduced and re-enforced, particularly with new requirements, as the integration of end users and suppliers and the introduction of lean production, where productivity rises with a tight time schedule (just in time etc).
iii) Health and safety issues should be emphasised in order to reduce the amount of accidents in the sector and to further reduce the number of workers leaving the sector after a few years. What structurally hinders the further development of the knowledge base in the construction sector is i) the fact that the construction projects often use shortterm labour contracts. This makes the sector more dynamic and may have a positive effect on the project and the company in the short run. But it leads to the erosion of skills and competences within the sector in the long run. ii) the fact
that there is a high proportion of SMEs in the construction sector. And in most SMEs, the focus on education and training tends to be low, day-to-day tasks and problem solving need all available attention. These smaller companies also find it more difficult to finance training cost. (European Foundation for the Improvement of Living and Working Conditions, 2005: 25)

Latent skill gaps

Employers’ skill requirements are determined by their existing business strategies. While this approach predominates, it will not be able to set the right action in order to cope with future requirements. Latent skill gaps are either hidden to employers or, if known, are not a priority. If construction companies on average were to make better use of technological opportunities, skill gaps would become more apparent as an inhibitor and the pressure of the companies to overcome them would increase. (CITB-ConstructionSkills, 2003: 32.)

A low skills equilibrium

One possible risk thereby is that the sector settles down at a low skills equilibrium: low qualification within the sector prevents the sector from absorbing technical advances available. As long as new technologies are not applied, skill gaps do not become apparent (apart from those due to people leaving the industry). Hence the sector remains in a low skills equilibrium. (CITB-ConstructionSkills, 2003: 32.)
### Table 4: Additional future skills requirements for the workforce

<table>
<thead>
<tr>
<th>Category of profession</th>
<th>Present requirements and trends</th>
<th>Additional future skills requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architects</td>
<td>Will change emphasis from design for form to design for function. They will specify larger and larger units (as opposed to components). Will have to take in greater amounts of information.</td>
<td>Will need a greater understanding of engineering design and the construction process and they will liaise more with the construction team. There will be a merging of roles of architects and construction engineers.</td>
</tr>
<tr>
<td>Designers</td>
<td>Will need to work more closely with clients and the construction team.</td>
<td>Will make more use of information technology to deal with document control and date interchange. Explosion of data will call for better time management. Will need greater communication and facilitation skills. Will have to add process analysis and change management. Additional skills to understand the details operation of the clients' business and the ability to create value. Construction professionals with additional skills to take out cost and adopt lean construction principles. Planning and programme managers with good appreciation of construction methods and additional skills in defining and following programmes to greater detail. In-depth knowledge of construction to bring order to site that is working with no contingencies and to timing plans measured in hours, not days.</td>
</tr>
<tr>
<td>Construction managers</td>
<td>Their core competences revolve around modern management of people, the application of information technology and some technical skills relating to construction methods.</td>
<td>Will have greater and earlier involvement in the design and planning stage to improve the buildability and predictability of defect-free completion. Increase in multi-skilling and polarisation in skill levels. The trades will demand higher skills and the operatives fewer skills. Much of the innovation will deskill fabrication, e.g. removing the skill from joining a water pipe does not remove the need for a plumber to route the piping from supply to sink. Above all, the future requirement is that tradespeople have greater flexibility and are not confined to one discipline.</td>
</tr>
<tr>
<td>Site managers</td>
<td>Lynchpin for construction in the future.</td>
<td></td>
</tr>
<tr>
<td>Trades</td>
<td>Demand for trades will continue to increase with demand for buildings.</td>
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</table>

Source: CITB-ConstructionSkills, 2003, Innovation, Skills and Productivity: 33f
5.2 Institutional change

Regulation and codes for sustainability

At the national level, the construction sector is highly regulated. Especially with respect to materials and the environmental impacts, the formulation, legislation and enforcement of regulations are in the competence of individual states. And, according to the varying constitutional and administrative systems, this responsibility is rather fragmented within the member states. (Taskforce on Sustainable Construction, 2007: 12)

A basic requirement for any regulatory framework is that it must concentrate on targeted performance outputs, including health gains and wellbeing, not on particular technologies in products or processes to implement them. The construction industry must be enabled to find the most appropriate and cost-efficient means of achieving building performances. (Taskforce on Sustainable Construction, 2007: 14)

Complementary to regulation, it may be a valuable approach to create codes for sustainability, e.g. the Code for Sustainable Homes in the UK since 2006 and the label Haute Qualité Environnementale in France, which give indications for industry about the way forward to sustainable homes. In the UK, the code defines six levels of raising the environmental performance standard of new homes, with the aim of zero net carbon emissions after 2016. (Taskforce on Sustainable Construction, 2007: 14) Such codes have i) an information aspect in that they inform industry about desired performances and ii) a motivation aspect in that such a code offers public recognition to innovators, and is thereby more likely to motivate further innovation.

Standardisation

Standardisation is a necessary undertaking in order to consolidate the competitive position of construction companies, which are essentially based locally, on international markets. Standardisation has to involve the following aspects:

- create a common language for testing an declaring the performance of products (there has already been achieved a lot, Taskforce on Sustainable Construction, 2007: 15)
- rationalise the different levels and classes of performances of different products and construction practices in the various member states.
- adoption of Eurocodes, which should replace national codes. There is already a broad consensus towards the establishment of Eurocodes in structural design (safety and security). In the future the scope of these codes should be expanded to comprise also important energy and environmental aspects. (Taskforce on Sustainable Construction, 2007: 15)

Establishment of a European Technological Platform for Construction (ETPC)

In order to achieve an integration and consolidation of the European construction industry a European Technological Platform for Construction was founded in 2004 to cover the following tasks: development of a shared longterm vision by public and private stakeholders concerned with the construction sector, the design of a coherent strategy, a leading role for industry within networks of research and financial communities, public authorities, users and representatives of civil society. (European Foundation for the Improvement of Living and Working Conditions, 2005: 16)
Vision 2030 (ECTP, 2004: 1ff)

- **End-user oriented industry**
- **Improving the competitiveness of European construction and industry at large (Economic dimension)**
- **A vision for sustainable construction (environmental dimension), reducing waste, energy consumption, emissions, increasing technical life expectancy, reparability and recyclability.**
- **Social dimension: Improve health & safety record of construction workers, improve health comfort and safety of European population in enclosed spaces.**

5.3 **Structural change**

*Competition by life-time-performance*

At the initial phase of a construction process, the investment of human, financial and material resources is at its highest. Hence, competition at this crucial stage of the process takes place on the basis of prices alone, rather than a performance/price relationship. Therefore, two factors seriously limit the possibility of innovations in the final constructed process:

1. The relative paucity of performance metrics for buildings and infrastructure and
2. the price-based competition in the initial phase of the construction process.

However, in order to achieve higher levels of sustainability within the construction sector as a whole, it is necessary to compare consumption of resources throughout the whole lifetime of a building or facility. Services and benefits provided throughout their whole existence should be the foundation for design and operating decision of buildings. But the tools and data to inform that perspective have yet to be developed. At present, it is necessary to make a number of assumptions about the longterm functionality, performances and life-cycle cost of a construction asset. (E-CORE Strategy: 29 and 42 and Taskforce on Sustainable Construction, 2007: 12)

In order to develop a life-cycle approach, it will be necessary to stimulate stronger cooperation between contractors and operational and maintenance services, who have the knowledge of real performances of construction assets and their utilities. (Taskforce on Sustainable Construction, 2007: 16)

*The value focus - new service models*

A totally new perspective is to view a constructed output not as a physical object, but as an asset that, over its operational life, will facilitate, and influence the activities associated with it, i.e. concentration, communication, learning, healing, producing, well-being etc. This causes a radical shift in attention from the traditional hand-over period (design, build and leave) to the years beyond. (see Taskforce on Sustainable Construction, 2007: 8 and Bougrain et Carassus, 2003: 8ff)

In this view, which represents a shift in paradigms, the construction industry is not seen as a supplier of a set of outputs, but as a provider of the the most effective longterm support service to its clients. Clients and supply side focus on the value associated with a construction object. (Taskforce on Sustainable Construction, 2007: 8)

Public-private partnerships (PPP) represent a new means to finance, build and manage public buildings and infrastructures. Usually in a PPP process, the public authority negotiates through a
competitive process, a single contract with a private consortium. The private consortium has to provide competences of a client, a bank, a designer, a construction company and a facilities manager. The public authority specifies the funding, the design, the construction and the operation of a building or an infrastructure for ten to forty years. When the contract is achieved, the facility is owned by the public authority. (Carassus, 2005: 1f)

This value focus, i.e. the view of the construction sector as a service provider, takes the contractual forms of i) concessions (traditionally for the construction and operation of motorways and bridges, but also possible for buildings) and ii) multi-year service contracts for public facilities with a guarantee on environmental and economic performance and indoor air conditions. (Taskforce on Sustainable Construction, 2007: 6 and E-CORE Strategy: 8f)

Such a transformation of the construction industry would require knowledge, public-private-partnership models and structures that currently do not exist. It would most probably entail a closer integration of the whole sector in order to achieve the maximum alignment of responsibilities and interests.

The role of the insurance sector

The insurance sector is likely to have a multi-layer role within the market for construction. This has to be considered when trying to achieve changes in the sector:

- Longterm risks and liabilities: some liability regimes discourage different parties to share risk in the event of a problem. Most of the insurance regimes prevent customers from taking an active role in the cooperation since they see the indemnity insurance as their safeguard against failure. (Taskforce on Sustainable Construction, 2007: 10)

- Insurance premiums linked to the adoption of appropriate management procedures and to the performance of construction assets, in particular environmental performance, could help to align interests in the market. (Taskforce on Sustainable Construction, 2007: 17)

- Premiums linked to the adoption of responsible management and to the track record of companies in the construction sector could avoid many conflicts and promote a coherent construction team with shared interests. (Taskforce on Sustainable Construction, 2007: 17)

- Monitoring and enforcement of standards: The insurance industry is a risk mitigating tool for many stakeholders, e.g. in new technologies. Insurers consider where systemic aggregates of risk may arise. They take appropriate action to mitigate those risks and thereby make them known to the public. (Taskforce on Sustainable Construction, 2007: 17 and Lloyd's, 2007: 6)
6 First elements of scenarios

The following sketches of scenarios are drawn from information in existing literature. They are meant to inspire and induce discussion.

Figure 1: First ideas for scenarios

**Business as usual**: First outline, based on the chapter Introduction

This interim report is part of Task 2 (Sectoral Innovation Foresight) of the Europe INNOVA Sectoral Innovation Watch (SIW) project. The aim of the report is to introduce first findings on possible future developments in the sector under study. Particular emphasis is put on the one hand on future changes that are likely to significantly influence the evolution and emergence of innovation activities and associated markets, and on developments that are likely to be of cross-sectoral relevance to innovation on the other. Sectoral innovation foresight thus complements Task 1 of the SIW project, which analyzes current sectoral innovation performance.

The main objectives of Task 2 can be summarised as follows:

- Explore and identify the main drivers of change in the nine sectors. These drivers will be both internal and external to the sectors, with several of them being of a cross-cutting nature.
- Identify and assess key future developments in the nine sectors as well as in terms of cross-cutting developments. The emphasis is put on likely future innovation themes and emerging markets, more specifically also on the requirements and impacts they raise in terms of skills requirements, organisational, institutional and structural changes in the sectors concerned.
- Develop scenario sketches for the sectors under study.
• Highlight key policy issues for the future, with a view to enhancing the innovation performance and competitiveness of firms operating in these sectors.
• Stimulate debate and contribute to the creation of expert networks, based on the participatory elements of this task.

The time horizon of these foresight papers is five to ten years (2015-2020), depending on the specific characteristics and the pace of change in the respective sectors. The construction sector is characterised by long innovation cycles and generally regarded as not very innovation-intensive. The time horizon suitable for foresight on this sector is thus longer than for most other sectors considered.

This Interim Report is based on a review of available foresight material on the textiles and clothing sector. Together with the corresponding report on the eight other sectors addressed by the SIW project (aeronautics and space, automotive, biotechnology, construction, food and beverage, knowledge-intensive business services, wholesale and retail trade), it serves as background material for a first expert and stakeholder workshop (June 2009). The report concentrates on drivers and innovation themes, but provides already some first findings and thoughts on emerging markets, requirements and future scenarios, i.e. as far as these issues can be derived from the review work. The first workshop aims on the one hand at reviewing the interim findings and on the other at exploring future scenarios of the sector in an interactive mode. The results of this first workshop and some further interviews with experts and stakeholders will then be incorporated in a draft final report that will serve as input to a second foresight workshop (November 2009). This second workshop will focus on the main policy issues that arise from the exploratory scenarios, both within the individual sectors and at their intersection. The final report will bring together in a consistent form the results generated in the different phases of the foresight exercise, i.e. will be based on revised and amended versions of the initial chapters of this interim report and additional chapters dealing with refined scenarios, future requirements and policy issues.

The interim results are presented in six chapters, starting with a situational analysis where the sector stands today to contextualize possible future developments (Chapter 2). Building on this context, Science & Technology (S&T) and demand drivers will be outlined (Chapter 3), as a basis for discussing emerging innovation themes (Chapter 4). These are expected developments resulting from the interaction of supply (technological advances) and demand (societal / customer needs) forces. In this chapter, implications of these innovation themes at firm level will also be addressed. Institutional and structural requirements and implications of the innovation themes for the sector will be highlighted in Chapter 5. This is complemented with first scenario sketches (Chapter 6) and some key questions to be addressed in the remainder of the Sectoral Innovation foresight task (Chapter 7).
The current situation of the construction sector in Europe and the trendbreaks in chapter Drivers of innovation and change – trends and trendbreaks. (Based on Baselines- the present characteristics of construction, in: E-CORE Strategy: 14f)

**A vital and responsible industry**: The transition away from price-based competition for a final tangible constructed product to performance-based competition over the life-cycle has worked out well. The industry has access to a broad differentiated knowledge base, with people at all levels able to assess and implement new concepts. There are longterm relationships within supply side as well as between supply and client interests. Lean construction and a network of information and knowledge services. (Based on chapter on top level goals and tools for their integration, in: E-CORE Strategy: 12f and 49)

**An innovative industry fails**: Demand – which adds from public procurement and private demand – is not able to cope with innovative signals from the supply side because of risk aversion, fragmentation and diverging priorities. (Based on information in: UK Sector Technology, Bossink, 2004, Arundel and Kemp, 2009 etc)
An innovative demand fails: Linking the outputs of the industry to needs defined by users and clients requires new tools at many levels to conceptualise and interpret indicators (e.g. performance indicators for environmental requirements throughout life-time). Fails due to a highly fragmented industry which is not able to mobilise competences or share the right knowledge and information within a virtual team. (CITB-ConstructionSkills, 2003)
7 Key Questions

1. Which are the predominant and most disruptive strategies for industrialisation: process innovation, product innovation, off-site production versus on-site production etc.?

2. How are private clients able to drive innovation in the construction industry?
   - Which are mechanisms for client engagement?
   - How can feedback loops for construction performance be developed?
   - Networking between clients, industry and research community

3. Small firms in construction: Is it possible to identify generic preconditions to the successful management of innovation in small firms? Which are the country specific drivers and constraints?

4. Can public authorities act as an actual driver of innovation? (see also chapter 2.1.6 on public procurement) For this, they have to fulfil various fundamental conditions:
   - They have to succeed in detailing objectives involving high qualitative standards and strong incentives to innovate. This requires informed and competent public authorities with a detailed strategic agenda.
   - Preconditions for this are the development of a life-cycle-approach for construction assets and their utilities and the training of public authorities on the legal possibilities and practical issues of how to apply sustainability criteria and life-cycle-cost-methods.

5. The insurance sector seems to play a powerful role in the diffusion of innovations in the construction sector. Does this help to calibrate desired changes in the construction sector?
8 Literature


