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EUROPE INNOVA
Sectoral Innovation Watch

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Construction Sector

Final Sector Report

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Europe INNOVA Sectoral Innovation Watch

Detailed insights into sectoral innovation performance are essential for the development of effective innovation policy at regional, national and European levels. A fundamental question is to what extent and why innovation performance differs across sectors. The second SIW project phase (2008-2010) aims to provide policy-makers and innovation professionals with a better understanding of current sectoral innovation dynamics across Europe

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

Sector Innovation Performance: Carlos Montalvo (TNO)	
Automotive: Michael Ploder (Joanneum Research)	Knowledge Intensive Business Services: Christiane Hipp (BTU-Cottbus)
Biotechnology: Christien Enzing (Technopolis)	Space and Aeronautics: Annelieke van der Giessen (TNO)
Construction: Hannes Toivanen (VTT)	Textiles: Bernhard Dachs (AIT)
Electrical and Optical Equipment: Tijs van den Broek (TNO)	Wholesale and Retail Trade: Luis Rubalcaba (Alcala) / Hans Schaffers (Dialogic)
Food and Drinks: Govert Gijsbers (TNO)	

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

Sector Innovation Foresight: Matthias Weber (Austrian Institute of Technology)	
Automotive: Karl Heinz Leitner (AIT)	Knowledge Intensive Business Services: Bernhard Dachs (AIT)
Biotechnology: Govert Gijsbers (TNO)	Space and Aeronautics: Felix Brandes (TNO)
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Food and Drinks: Govert Gijsbers (TNO)	

Task 3 will **identify and analyse current and potential bottlenecks that influence sectoral innovation performance, paying special attention to the role of markets and regulations.** Specifically, the analysis will cover the importance of the different factors in the propensity of firms to innovate.

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

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

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

Contents

Acknoweldgements

The final sector report for the construction sector builds on the results of various tasks in the Europe INNOVA Sectoral Innovation Watch:

Squicciarini, M. and A.-L. Asikainen (2010) *Sectoral Innovation Performance in the Construction Sector*, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010

Schartinger, D. (2010) *Sectoral Innovation Foresight – Construction Sector*, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Montalvo, C., K. Pihor, J. Hyönen, T. Loikkanen (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Construction Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

H. Grupp†, D. Fornahl, C.A.Tran, J. Stohr, T. Schubert, F. Malerba, Montobbio F., L. Cusmano, E. Bacchiocchi, F. Puzone, (2010) *National Specialisation and Innovation Performance*, Final Report Task 4 Horizontal Report 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, March 2010

Rubalcaba, L, J. Gallego, C. Hipp, and M. Gotsch (2010) *Organisational innovation in Services*, Final Report Task 4, Horizontal Report 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, February 2010

Dachs, B., I. Wanzenböck, M. Weber, J. Hyvönen and H. Toivanen (2011) *Lead Markets*, Final Report Task 4, Horizontal Report 3, for DG Enterprise and Industry, European Commission, March 2011

Montalvo, C., Diaz Lopez F.J., and F. Brandes, (2011) *Potential for eco-innovation in nine sectors of the European economy*, Final Report Task 4, Horizontal Report 4, Europe INNOVA Sectoral Innovation Watch, DG Enterprise and Industry, European Commission, December 2011

Mitusch K. and A. Schimke (2011) *Gazelles – High-Growth Companies*, Final Report Task 4, Horizontal Report 5, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, January 2011

Executive Summary

Economic impact of construction sector

Construction represents a fundamental part of modern economies: it contributes to about 50 per cent of gross fixed capital formation, and represents a major employer of the economy. According to the European Construction Industry Federation construction accounted in 2008 for a total of 3 million enterprises (EU27), the 95 per cent of which with less than 20 workers. Overall the sector employed the 7.6 per cent of total employment (EU27), corresponding to 30% of industrial employment. In construction sector more than half of the total value added is generated by general building and civil engineering activities (58.2%), followed by building installation (22.4%) and building completion (15.1%).

Innovation performance of construction sector

In the European Union the technological advantages in the construction sector seem to concentrate in the EU 15 countries. Compared to the New Member States and the Non EU countries the patent output of the EU 15 countries is very high in this sector. Moreover, this is an area of distinct and persistent European technological advantage at the global level. In technological performance, as measured by the European patent stock, construction sector accounts three per cent between 1978 and 2005. In the specialisation analysis based on patent citation analysis Austria, Portugal, Slovenia and Spain manage well.

According to all indicators of the Fourth Community Innovation Survey (CIS4), firms in the construction sector engage less in R&D and innovation, receive less financial support to innovation, and recur less often to IPR than the firms in the other sectors. The widest gaps can be found in R&D expenditures as a share of turnover, and in the share of firms seeking IPR protection. Overall, the CIS4 based figures argue in favour of the general belief holding construction as a low-productivity low-technology industry, and of a sector generally seen to be underperforming. Despite the evidence above, however, it has to be acknowledged the very much incremental nature of the innovations occurring in this sector. The figures may however look less poor, *first*, if one considers that, due to the complex production process characterising construction, the role of subcontractors as innovators gets easily overlooked. *Second*, the figures based on NACE classifications may give a misleading picture of innovation and R&D in the construction sector, since design and production are not included in the core definition of sector's activities.

Construction and regulation

Construction sector is linked in many ways to public sector through regulation, standardization and environmental aspects, and public sector is also a major client of construction industry. Accordingly also in the promotion of innovation in construction sector various public policy measures like innovation by procurement and by lead market approach play important roles. Moreover the construction sector has various links to many policy areas, such as production and consumption of energy, land-use planning, transportation, etc. Correspondingly the promotion of innovation in construction shall be based on horizontal innovation policy approach covering all relevant policy fields.

Policy agenda

On a basis of scenarios presented in this study the policy toolbox may consist of the following approaches and measures. The first is the need of an innovative infrastructure which is able to connect various technical systems and makes individual business solutions effective. The second is the reduction of risk of disorientation of the business and consumers, improving coordination of business efforts on a macro-level between variety of isolated and competing technological solutions. The third issue is coordination and orientation as basic strategies for public sector. The public sector will be needed to prove leadership and give orientation in setting standards, codes and adapt education. The fourth issue relates to targeted performance outputs. Any regulatory framework must concentrate on targeted performance outputs including health gains and wellbeing, and not on products or processes technologies to implement them. Complementary to regulation, it is a valuable approach to create codes for sustainability. Fifth, standardisation is a necessary undertaking in order to consolidate the competitive position of construction companies. Standardisation creates a common language for testing and declaring the performance of products, it rationalises different levels and classes of performances of products and construction practices in the member states, and adopts Eurocodes which should replace national codes.

Research and development agenda

This report gives support to the following research topics directed towards zero-emission and energy-producing construction (following also suggestion of E2B Association). First, we need to develop new tools and methods for designing and measuring energy efficiency, particularly at district level. Second, R&D will be planned and carried for the design and development – including manufacturing processes- of components for new and retrofitted envelopes. Third, all components and systems need to be designed to ensure that buildings and equipment deliver over the lifetime the energy in use that was expected during the design stage. Fourth, the role of ICT as an enabler of energy efficiency needs to be fully explored and exploited. Fifth, social and behavioural aspects are of importance in construction. It is necessary to develop more accurate and better understanding of the drivers of change in individual demand, appropriate ways to communicate about them, and guidelines to improve individual behaviours and raise awareness. Sixth, pre-normative research is needed towards standardisation of components and systems complying with building codes, electrical normative and grid integration. Seventh, new business models must be developed to take into account clients and user's requirements, the entire supply chain, legal and financial framework, technical aspects, geographical and local features and the whole life cycle.

Apart from R&D for the zero-emission and energy-efficiency goal of construction, R&D in a wide range of other topics is of strategic importance. The first is urban infrastructure - knowledge and research on the behaviour and flows of people, energy and materials in cities shall be integrated in the construction design of cities and their components. The second is efficiency of networks - networked infrastructure systems (highways, railways, waterways, air traffic, utilities, water, sewage, gas, electricity, or fast web access) represent a huge asset of a society. Construction R&D must support interoperability, coordination, integrated information and communication of infrastructure systems, while improving access of users, supply of resources and maintenance. The third issue is efficient and environmentally friendly construction materials supported by environmental performance indicators and rating systems for materials, buildings and infrastructures. Understanding of degradation processes to improve the service life of building materials shall be improved. The fourth issue is the reduction of impact of construction on natural environment (soil sealing, pollution, vibration and noise, etc.).

Skill development agenda

The development of the knowledge base in the construction sector is retarded by the following reasons: first, the construction projects often use short term labour contracts and, second, there is a high proportion of SMEs in this sector that often find it difficult to finance training cost. Key recommendations to influence skill levels are as follows:

The first issue is the provision of incentives to upgrade and better use skills. Aiming at individuals this means that learning accounts and learning vouchers may set incentives for workers, particularly for low-skilled workers, to upgrade skills. These are based on the principle of co-investment by government, individuals and employers. Sector-wide recognition of prior learning is particularly important in a sector with fast-changing employment contracts. Also standards for language skills are needed, as is employing automatic translators where necessary. Aiming at employers the provision of incentives to upgrade and better use skills means *first* that public procurement may enhance skills development if skills requirements are specified in calls for tender. *Second,* tax incentives may stimulate targeted investment in low-skilled workers and also encourage companies to support skills upgrading in their suppliers. *Third,* a union regulation concerning skill requirements should be part of the sector agreement.

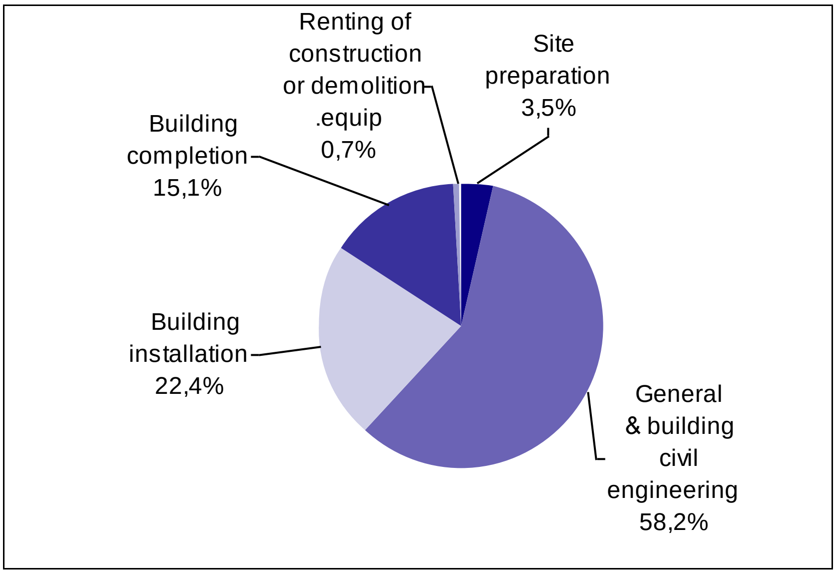
The second issue is to bring the worlds of education, training and work closer together. The implementation of a regional qualification infrastructure may better enable the high share of SMEs to pursue skills upgrading. Outcome-based qualifications and a common language between education/training and the world of work should be developed. The potential of the European qualifications framework as well as the national qualifications frameworks should be communicated and the involvement of all relevant actors, like Public Employment Service, employers and social partners has to be ensured. *The third issue* is to develop the right mix of skills. Educational and training programmes shall be planned and delivered at all levels, including higher education, which incorporate the zero-emission goal in their curricula. The fourth challenging issue is to better anticipate future skill needs, a better labour-market intelligence for developing early-warning and matching systems.

1 Introduction

Construction is a very ancient industry, dating back to the very existence of mankind and human beings' need to get sheltered. Despite being born before the advent of industry as we today conceive it, construction keeps representing a fundamental part of modern economies. Construction contributes to about 50% of gross fixed capital formation, and represents a major employer of the economy. According to FIEC, the European Construction Industry Federation, in the 2008 construction accounted for a total of 3 million enterprises (EU27), the 95% of which with less than 20 workers. Overall the sector employed the 7.6% of total employment (EU27), corresponding to 30% of industrial employment (FIEC, 2009).

Within construction, more than half of the total value added of the sector is generated by general building and civil engineering activities (58.2%), followed by building installation (22.4%) and building completion (15.1%), as shown in figure 1.1.

Figure 1.1 Construction's value added by activity



Source: Eurostat (Structural Business Statistics), 2009

Construction makes massive use of and has a very strong impact on natural resources, with more than 50% of all the materials extracted from the earth being transformed into construction materials and products. These components are then utilised to produce goods characterised by a long life-cycle – of several decades or more - , a slow replacement rate of the building stock, and an even lower rate of demolition. Construction and the built environment are accountable for the largest share of greenhouse gas emissions in terms of energy use, and the sector produces one of the largest waste streams - even though a significant part of it is renewable or re-usable (COM(2007)860-final). Construction is thus a sector facing major environmental challenges, whose sustainability could be improved be means of addressing a set of interrelated factors. Among these there are: environmental innovations for sustainable construction; regulations and standardisation; market structure and the industry supply chain; education; management of costs and risks; and deconstruction, demolition and waste management.

The final sector report of the construction sector in the Europe INNOVA Sectoral Innovation Watch is structured as follows. Chapter 2 presents patterns and performance of sectoral innovation, *first* statistical definition of the sector and sector-specific indicators, *second* characterisation of the sector according to innovation performance, agents for innovative activity, and necessary skills for innovation, and, *third*, a common set of indicators. Chapter 3 considers the carriers and barriers of innovation, *first*, human resources and the role of ICT, *second* the role of universities and other key organisations in innovation, *third* clusters, networks and the role of collaboration in innovation. Chapter 4 is about the sectoral innovation futures and considers, *first*, emerging and future drivers of innovation between S&T and (market) demand, *second*, future scenarios of the sectoral innovation system, *third*, future innovation themes and corresponding linkages with other sectors. Chapter 5 discusses the role of regulation and standardisation in innovation in the construction sector. Chapter 6 considers horizontal issues relevant to innovation in the construction sector, such as environmental sustainability and eco-innovations. Chapter 7 draws conclusions from the analysis and outlines the policy implications in order to improve innovation activities in the construction sector.

2 Patterns and performance of sectoral innovation

2.1 Statistical definition of the sector and sector-specific indicators

2.1.1 Statistical definition of the sector

The activities carried out within the construction sector are accounted for under the heading "Section F" in both NACE[1] revisions 1.1 and 2. NACE Rev. 1.1 classification of economic activities covers construction activities within section F - which is the same as division 45 -, whereas NACE Rev. 2 section F is subdivided into divisions 41, 42, and 43.

Substantial differences also exist with respect to the number of groups and classes contained in the section. From NACE Rev. 1.1 to NACE Rev. 2, the construction sector's number of groups and classes has gone from 5 to 9 and from 17 to 22, respectively. These changes mirror the increased attention that the recently revised classification pays to the details of the production process, and to the different technologies used in the sector. Moreover, whereas in NACE Rev.1.1 groups are divided according to the various stages of the construction process - from site preparation to renting and demolition activities-, NACE Rev. 2 classifies the construction sector according to the outcome obtained.

Table 2.1 shows the divisions and groups composing the construction sector in both NACE Rev. 1.1 and Rev. 2 classifications. As can be seen, in NACE Rev. 2 (right hand side of the table) division 41 covers the complete construction of buildings. Division 42 instead relates to the complete construction of civil engineering works. Finally, division 43 deals with specialised construction activities, if carried out only as a part of the construction process.

The greater number, type and level of details that characterise NACE Rev. 2 vis-à-vis NACE Rev. 1.1 mirror the necessity to better and more comprehensively account for the wide range of activities carried out within the construction sector. Such a necessity is expressly stated in the metadata provided by Eurostat, which highlights a number of activities that could have been included in the section F, but were excluded from it to ensure the general consistency of the classification[2].

[1] The acronym NACE stands for "Nomenclature générale des Activités économiques dans les Communautés Européennes" (i.e. Statistical classification of economic activities in the European Communities). NACE nomenclatures are divided into: i) sections, denoted by a letter, ii) divisions, denoted by 2-digit codes; iii) groups, denoted by 3-digit codes; and iv) classes, characterised by 4-digit codes.
[2] See the metadata provided by the Eurostat web: ec.europa.eu/eurostat.

Table 2.1 Statistical classification of activities in the construction sector

NACE Rev. 1.1 (2002)		NACE Rev. 2 (2008)	
Section F codes		**Section F codes**	
45	Construction	41	Construction of buildings
		41.1	Development of building projects
45.1	Site preparation	41.2	Construction of residential and non-residential buildings
		42	Civil engineering
45.2	Building of complete construction or parts thereof; civil engineering	42.1	Construction of roads and railways
		42.2	Construction of utility projects
45.3	Building installation	42.9	Construction of other civil engineering projects
		43	Specialised construction activities
45.4	Building completion	43.1	Demolition and site preparation
		43.2	Electrical, plumbing and other construction installation activities
45.5	Renting of construction or demolition equipment with operator	43.3	Building completion and finishing
		43.9	Other specialised construction activities

Source: Authors' own elaboration on Eurostat data

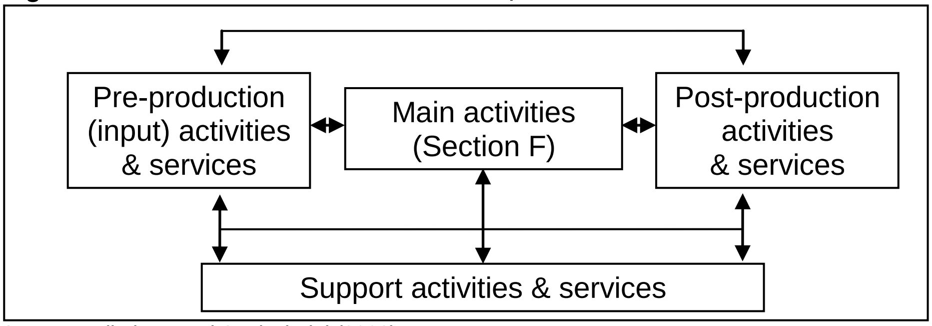
Note**:** NACE Rev. 1.1 and Rev.2 divisions and groups are listed in numerical order. No correspondence is meant among the codes considered.

2.1.2 A new value-chain-based definition of the sector

Despite NACE Rev. 2 attempting a broader classification of construction, many are the activities left outside the definition, and that could instead be part of it. To this end, we have proposed (Asikainen and Squicciarini, 2008) a "wide" classification of the sector, as a complement to the "strict" classification offered by NACE section F. The classification we propose builds on NACE 1.1 and adds to it what we define as "non-core codes". These codes relate to those activities not contemplated in the F section, but that exclusively or preponderantly serve the construction sector, throughout its value chain.

Figure 2.1 summarises the main activities, phases, and components of the construction value-chain. The schematisation proposed centres around construction activities intended as buildings and civil engineering, including soil and water-related constructions (i.e. "main activities", or core activities, in figure 2.1). The flowchart attempts to capture not only the construction value-chain, but also the time sequence in which activities take place, with respect to the time in which the core construction activities are carried out. When saying "main activities" no difference is made with respect to whether the buildings and civil engineering relate to newly-built or renovated constructions, and whether the activities are carried out by a private or public firm, or by a private individual.

Figure 2.1 Construction value chain, based on NACE codes



Source: Asikainen and Squicciarini (2008)

By pre-production activities we mean upstream activities, mainly manufacturing ones, whose output constitutes an input into construction's main activities, as well as those services preceding the actual construction phases. Examples of input activities are the manufacture of construction products like concrete, cement and plaster, bricks, tiles, etc.. These manufacturing activities basically take care of producing all those components and systems - or kits of components - that are used in a permanent way in the construction works (see also PRC, 2006). Traditionally these input suppliers are classified as belonging to industries other than construction, as e.g. chemicals, forest, concrete, etc.. Examples of pre-production services are instead all those architectural and engineering services that precede the actual building construction activities, like geodetic surveying, building design, drafting, and so on.

By post production activities we refer to those downstream activities normally carried out after and in connection to a building or civil engineering work. Among these there are the maintenance of buildings, as well as real estate selling and letting services, and facility management.

Finally, by support activities and services we mean a broad range of production and service activities, from wholesale of construction materials, to renting machinery and equipment, to recycling waste and scrap. In the present taxonomy we consider as support activities also public services like area and urban planning, steering, inspections, certification, market surveillance, research, etc., as well as construction-related finance and insurance, facility management and services.

Table 2.2 illustrates the NACE section, divisions, groups and classes we contemplate within the wider definition proposed. The NACE Rev.1.1-based "wide" classification is shown on the left and side of the table, whereas the corresponding NACE Rev. 2 "wide" classification is shown on the right hand side of it. Under the heading "Section F – Construction – codes" we show the codes contained in section F, under both NACE revisions. The bottom part of the table, the one entitled "non-core codes", instead lists the codes we suggest to add to the core ones in order to obtain a more comprehensive definition of the construction sector.

Throughout the table, activities have been listed following the NACE Rev 1.1 order (on the left hand side), every time showing the corresponding NACE Rev. 2 group/class on the right hand side. Finally, notice that, whenever repeated due to the correspondence NACE Rev. 1.1 – NACE Rev. 2, codes are highlighted in grey.

Table 2.2 The construction sector: a "wide" definition

NACE Rev. 1.1 (2002)*		NACE Rev. 2 (2008)^	
Section F – Construction - codes			
45.1	Site preparation	43.1	Demolition and site preparation
45.2	Building of complete construction or parts thereof; civil engineering	41.2	Construction of residential and non-residential buildings
		42.1	Construction of roads and railways
		42.2	Construction of utility projects
		42.9	Construction of other civil engineering projects
		43.9	Other specialised construction activities
45.3	Building installation	43.2	Electrical, plumbing and other construction installation activities
45.4	Building completion	43.3	Building completion and finishing
		43.9	Other specialised construction activities
45.5	renting of construction or demolition equipment with operator	43.9	Other specialised construction activities
Non-core codes			
14.11	Quarrying of ornamental and building stone	8.11	Quarrying of ornamental and building stone, limestone, gypsum, chalk and slate
		9.90	Support activities for other mining and quarrying
17.54	Manufacture of other textiles n.e.c.	13.96	Manufacture of other technical and industrial textiles
20.20	Manufacture of veneer sheets; manufacture of plywood, laminboard, particle board, fibre board and other panels and boards	16.21	Manufacture of veneer sheets and wood-based panels
20.3	Manufacture of builders' carpentry and joinery	16.22	Manufacture of assembled parquet floor
		16.23	Manufacture of other builders' carpentry and joinery
		41.20	Construction of residential and non-residential buildings
		43.32	Joinery installation
		43.91	Roofing activities
24.30	Manufacture of paints, varnishes and similar coatings, printing ink and mastics	20.30	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
25.23	Manufacture of builders' ware of plastic	41.20	Construction of residential and non-residential buildings
		43.32	Joinery installation
		22.23	Manufacture of builders' ware of plastic
26.14	Manufacture of glass fibres	23.14	Manufacture of glass fibres
26.26	Manufacture of refractory ceramic products	23.20	Manufacture of refractory products
26.30	Manufacture of ceramic tiles and flags	23.31	Manufacture of ceramic tiles and flags
26.4	Manufacture of bricks, tiles and construction products, in baked clay	23.32	Manufacture of bricks, tiles and construction products, in baked clay
26.51	Manufacture of cement	23.51	Manufacture of cement
26.52	Manufacture of lime	23.52	Manufacture of lime and plaster
26.53	Manufacture of plaster		
26.6	Manufacture of articles of concrete, plaster and cement	23.6	Manufacture of articles of concrete, cement and plaster
26.7	Cutting, shaping and finishing of ornamental and building stone	23.7	Cutting, shaping and finishing of stone
28.11	Manufacture of metal structures and parts of structures	25.11	Manufacture of metal structures and parts of structures
		41.20	Construction of residential and non-residential buildings

28.12	Manufacture of builders' carpentry and joinery of metal	25.12	Manufacture of doors and windows of metal
		43.32	Joinery installation
28.22	Manufacture of central heating radiators and boilers	25.21	Manufacture of central heating radiators and boilers
29.52	Manufacture of machinery for mining, quarrying and construction	28.92	Manufacture of machinery for mining, quarrying and construction
		28.99	Manufacture of other special-purpose machinery n.e.c.
29.72	Manufacture of non-electric domestic appliances	27.52	Manufacture of non-electric domestic appliances
		28.21	Manufacture of ovens, furnaces and furnace burners
36.63	Other manufacturing n.e.c.	22.23	Manufacture of builders' ware of plastic
37.20	Recycling of non-metal waste and scrap	38.32	Recovery of sorted materials
45.31	Installation of electrical wiring and fittings	80.20	Security systems service activities
51.53	Wholesale of wood, construction materials and sanitary equipment	46.73	Wholesale of wood, construction materials and sanitary equipment
51.54	Wholesale of hardware, plumbing and heating equipment and supplies	46.74	Wholesale of hardware, plumbing and heating equipment and supplies
70.11	Development and selling of real estate	41.10	Development of building projects
		42	Civil engineering
70.2	Letting of own property	68.2	Renting and operating of own or leased real estate
70.3	Real estate activities on a fee or contract basis	68.31	Real estate agencies
		81.10	Combined facilities support activities
71.32	Renting of construction and civil engineering machinery and equipment	77.32	Renting and leasing of construction and civil engineering machinery and equipment
		77.39	Renting and leasing of other machinery, equipment and tangible goods n.e.c.
74.2	Architectural and engineering activities and related technical consultancy	71	Architectural and engineering activities; technical testing and analysis

Source: Asikainen and Squicciarini (2008)

Legend**:** The left hand side of the table shows NACE Rev 1.1 codes, whereas the right hand side contains NACE Rev. 2 codes. Under the heading "Section F" are listed the groups and classes contained in the official definition of construction sector, whereas under the heading "Non-core codes" are listed the additional groups and classes included in the "wide" definition. Divisions and classes are listed following NACE rev 1.1 order, each time indicating the corresponding NACE Rev.2 group or class. When repeated, due to correspondences, NACE Rev. 1.1 – NACE Rev. 2 codes are highlighted in grey.

The definition of the sector proposed in the present report is in line with the one contained in the COM(2007)860-final about sustainable construction: "[sustainable construction] embraces a number of aspects such as design and management of buildings and constructed assets, choice of materials, building performance as well as interaction with urban and economic development and management" (COM(2007)860-final, p. 4). In both definitions, emphasis is put upon the systemic nature of the construction industry and the need to take into account all the major stakeholders and actors involved in it. In particular, Asikainen and Squicciarini's (2008) definition of construction clearly highlights the very eclectic nature of the industry, a sector whose innovativeness mainly stems from research and innovation activities carried out in other sub-sectors / industries. This is also mirrored by the fact that no construction science exists as such, but many are the science fields - e.g. structural mechanics, building production technologies, building physics, etc. – that any construction project relies upon.

The complexity emanating from the uncertainty related to the tasks carried out, the resources involved, and the environment, as well as their interdependence, conditions the way in which construction firms behave and innovate (Dubois and Gadde, 2002). Moreover, depending on the type of project, the complexity of the supply chain relationships may vary greatly. This happens despite construction projects' phases being generally divided into well-defined and discrete work-packages, which are normally accomplished – sequentially and in a commonly known order - by purposely contracted specialists. The fact that each contractor is ultimately responsible only for its own contribution almost inevitably leads to workflows that face major interruptions, possible conflicts, as well as time and cost over-runs and quality problems (see Barlow, 2000, for a detailed account).

2.2 Characterization of the sector

The construction industry owes its dynamics, performance and innovative behaviour to the very characteristics of the output it produces. Whether directed to the residential, non-residential or infrastructure markets (COM(2007) 860 final), construction output differs in many ways from other manufactured goods. It is generally represented by large and immobile goods, and entails a high degree of complexity and interdependence in terms of number and range of resources and components involved, as well as number and degree of interactions needed[3]. Furthermore, construction output is meant to be more durable - and is usually more expensive - than other manufactured goods, and this may ultimately lead firms to refrain from innovating, and to prefer conservative design and construction techniques. Last but not least, construction activities entail varying degrees of uniqueness and are normally carried out on site, rather than being produced in factories and then transported to the market, as it instead happens in the other industries.

2.2.1 Innovation performance

The figures in tables 2.3 to 2.5 are from Fourth Community Innovation Survey (CIS4)[4]. Table 2.3 shows additional indicators aimed at better illustrating how R&D is conducted in the construction sector. In particular it highlights the type of innovative activities firms are engaged in, and whether they innovate on a continuous or occasional basis. As before, the first column refers to NACE section F; column 2 to non-core construction activities; the third column to all industries, and the fourth column shows the gap construction vis-à-vis all sectors.

[3] Gann (1996) highlights that cars are on average assembled from around 20,000 items, whereas houses might require 200,000 components.

[4] CIS4 covers the years 2002 – 2004. It was carried out in 25 EU Member States, plus Iceland, Norway, Bulgaria, and Romania.

Table 2.3 Share of firms carrying out R&D and innovation, by type of activity (in percentage)[5]

Share of firms:	Construction (1)	Non-core construction (2)	All sectors (3)	Gap (4)
Engaged in intramural R&D	8.52	20.98	23.80	-64.20
Engaged in extramural R&D	3.50	11.82	12.66	-72.35
Acquiring machinery, equipment & software	16.60	29.30	29.84	-44.37
Acquiring other external knowledge	4.04	8.41	9.36	-56.84
Engaged in training	6.88	18.19	19.84	-65.32
Engaged continuously in intramural R&D	40.76	54.76	61.81	-34.06
Engaged occasionally in intramural R&D	59.23	45.24	38.18	55.13

Source: Authors' own compilation on Eurostat data from the Fourth Community Innovation Survey (CIS4)

The most commonly performed R&D and innovation activities take the form of investments in machinery, equipment and software, followed by intramural R&D and training. In general, construction firms engage significantly less in innovation related activities than firms in other sectors do. Interestingly, the figures confirm the very much project base nature of construction activities, with construction firms that perform R&D on an occasional basis more than the firms in other sectors. The fact that the performance of extramural R&D and the acquisition of other external knowledge takes place much less frequently in construction than in other sectors may be explained by considering that "pre-production" (e.g. design) is often fully carried out by specialised partner firms statistically belonging sectors other than construction (see Reichstein, Salter and Gann, 2005; and Asikainen and Squicciarini, 2008, in this respect). Finally, construction firms seem to engage in training much less than other sectors do. This fact indirectly confirms the low skill level of the workforce in the sector, and stresses the necessity of the many regulations that govern the sector in all its aspects, from health and safety, to environmental and energy friendliness. Without such regulations, construction firms would possibly engage even less in training.

Table 2.4 pictures the sources of information for innovation construction firms rely upon. The answer given by the respondent vary between zero, meaning the source has not been used, to 3, implying that the considered source is very important for the respondent.

Table 2.4 Sources of information for innovation

Sources	Construction (1)	Non-core construction (2)	All sectors (3)	Gap (4)
Within the same enterprise / group	2.11	2.31	2.33	-9.64
Suppliers	1.87	1.80	1.82	2.31
Clients and customers	1.37	1.80	1.81	-24.55
Competitors	1.19	1.41	1.45	-17.77
Consultants & private labs / R&D institutes	1.23	1.19	1.23	-0.36
HEIs	0.84	0.91	1.00	-16.27
Government & public R&D institutes	0.59	0.66	0.70	-15.32
Conferences & fairs	1.39	1.50	1.52	-8.45
Scientific publications	1.31	1.32	1.41	-7.21
Professional & industry associations	1.19	1.02	1.08	9.97

Source: Authors' own compilation on Eurostat data from the Fourth Community Innovation Survey (CIS4)

As it could have been expected, suppliers play a very important role for construction firms, as do professional and industry associations. Conversely, customers and competitors prove to be scarcely

[5] The format of table 2. 3 and the type of information contained are the same as those of table 2.4.

important sources of information. Finally, table 2.5 shows the factors hindering innovation in construction. Answers were supplied ranking from zero to 3, implying, respectively, that the firm had not suffered from the factor, and that the hampering factor had high importance.

Table 2.5 Factors hindering innovation

Hampering factors	Construction (1)	Non-core construction (2)	All sectors (3)	Gap (4)
Lack of internal funds	1.46	1.48	1.54	-5.01
Lack of outside funds	1.43	1.34	1.40	2.55
Innovation cost too high	1.61	1.57	1.64	-2.28
Lack of qualified personnel	1.32	1.36	1.29	2.50
Lack of information on technology	1.12	1.20	1.14	-1.85
Lack of information on markets	1.02	1.16	1.13	-9.87
Difficulty in finding cooperation partners	1.05	1.08	1.11	-5.29
Markets dominated by incumbents	1.23	1.25	1.27	-3.16
Uncertain demand for innovation	1.32	1.33	1.37	-3.23
No activity due to prior innovations	0.75	0.60	0.58	28.87
No activity due to no demand for innovations	0.67	0.54	0.52	28.04

Source: Authors' own compilation on Eurostat data from the Fourth Community Innovation Survey (CIS4)

Not surprisingly, it emerges that internal funds and qualified personnel represent problems more difficult to solve in the construction industry than in other sectors. Conversely construction firms feel relatively better off than the firms in the other industries with respect to being informed about technologies and markets. Similarly, they state not to encounter too big problems in finding cooperation partners. Interestingly enough, construction firms argue relatively more strongly than other firms that lack of demand for innovations hampers their innovative activities.

2.2.2 Agents for innovative activity

Construction is a sector characterised by the heterogeneous background of the actors involved, and by a generally conservative attitude. In the EU27, self-employment is quite prevalent in construction, and the industry sees the highest percentage of male workers of all economic sectors (89%). With respect to job tenure and working hours, it emerges that 12%–13% of all workers report just one year or less of service, sign of a sector characterised by a high turnover of human resources. Construction stands out for the high proportion of people working outside the firm's premises, for the high level of workers' exposure to physical risks, and for the percentage of workers using machineries (above 40%). In addition, more than 20% of workers in the construction industry are affected by long working hours (although the sectors is among those in which there is consistently less work at atypical hours). Construction employs a quite important share, i.e. 17%, of non-national workers, which makes of construction the second most important employer of non-nationals, after "other services" (EFILWC, 2007). Many construction trades are well known for their relatively low educational background, and for the fact that learning is neither organised nor widespread. Project experience seldom gets translated into firm know-how, also due to construction firms' little absorptive capacity.

Given the characteristics of the sector's workforce, periodical vocational training, especially training on the job, may help improving the awareness and capacity of workers to recognise innovation opportunities, and their ability to be part and support the innovation process. The importance of on-site vocational training stems from the practitioners' common remark about their inability to remember and/or implement the theoretical concepts learnt during the class lectures. Moreover, a once a year training session - whether safety, environment or practical-activity-related - seldom manages to be absorbed by those who should most benefit from it. Vocational training would not only benefit the less educated part of the workforce, but also the most educated staff, especially the one supervising the on-site work. Supervisors generally have technical backgrounds, but may lack of the organisational and managerial skills needed to enable innovation activities and outcomes. New ideas can thus get lost due to the domination of daily businesses and to unclear competences (Hartmann, 2006).

As Teece (1998) underlines, learning is path-dependent, in that the opportunities for learning are closely related to previous activities and experiences. The fact that too many aspects of the learning environment change simultaneously - as it happens in project-based works – may hinder the ability to learn and to form cognitive structures that facilitate learning. Hence, although the project-basis activity of construction firms should be favourable to the development of new ideas and new solutions, the temporary nature of the network created, time limitations, and the absence of well-structured knowledge transfer mechanisms within the firm might hinder innovation (Dubois and Gadde, 2002). Among the strategies that construction firms may rely upon in order to enhance their core competences and innovative activity there are knowledge-anchoring and relationship building. By knowledge-anchoring it is meant all those knowledge-transferring routines that aim to collect, diffuse and assimilate project-generated knowledge at the firm level. Relationship-building instead refers to the variety of managerial practices and designs aimed to maintain and enhance the client–contractor/supplier collaborations established (Drejer I., Vinding A. L., 2006). The environment in which the firm operates is shaped by actors like suppliers and clients, as well as education providers and research centres, and by industry associations, regulators and government agencies. This environment however changes with time, given the temporary basis of most construction projects, and the likely participation of different group of firms in each project.

In order to enhance the innovativeness of the construction sector, and to improve its productivity, the need arises to implement coherent and coordinated measures boosting simultaneously both the internal and the external environment of the firm. By internal environment we mean the attitude and the ability of both workers and ownership/management to innovate. By external environment we mean customers - whether private or public -, suppliers and partners, as well as the institutional and regulatory frameworks in which the firms operate (see also Hartmann, 2006).

Incentives could be designed in order to enable the transfer of the acquired knowledge within the same firm, i.e. between projects, across firms participating in the same projects (Davies and Brady, 2000, Bayer and Gann, 2007), or even across sectors (Gann, 1996). These incentives could e.g. allow individuals within the firm to take time off the projects to build and integrate the available capabilities, or allow the firm to attract talents and back research activities that would otherwise remain at the level of the single project, and not of the firm as a whole (Acha et al., 2005). Moreover, the incentives-backed creation of dual career structures could encourage capability development at the project level, and help extending that at the firm-level. Knowledge management related to safety through design practices is also essential at the firm level, as well as at the industry level. The dissemination of novel measures, tools, and methods should not be limited to best practices, but extended also to good practices and to generally useful knowledge. This might include experiences and knowledge coming from other sectors, if relevant.

2.2.3 The use of new technologies and ICT

In construction the use, transfer and development of new technologies seem to only marginally improve the efficiency and productivity of the sector. Low is also the use of Information and Communication Technologies (ICT). This might be due to the fact that construction works often involve activities and tasks in which the use of ICT would not bring about much gain in efficiency, as in the case of brick laying for instance. Nevertheless, there indeed exist other activities where the use of ICT might be just as relevant for construction as it is in other industries. Among the most relevant there are: knowledge and project management functions; contacts to clients and suppliers; and design and planning. Information technologies (IT) may in fact have a number of applications from automation, to optimising scheduling, inventory, progress and status tracking, to speeding up the tendering process and improving the success of bids.

In comparison to other sectors, construction falls behind in terms of share of ICT professionals, commonness of enterprise resource planning systems and advanced e-procurement systems, ICT training, and use of e-standards. However, it is almost on par with other sectors when it comes to the frequency of ICT-enabled product and process innovations. In this respect, additional data on innovation in the construction sector can be extracted from the e-Business Survey 2006 (European Commission, 2007(b)). The survey was conducted in connection to the sectoral e-Business W@tch, which collects information on ICT use and e-business. It is the EC’s tool to monitor the adoption, use and impact of various e-business activities in pre-defined sectors[6].

[6] The EU member states included in the survey are: the Czech Republic, Germany, Spain, France, Italy, Hungary, the Netherlands, Poland, Finland and the UK.

Table 2.6 Share of firms (in %) with product or process innovation and share of ICT-enabled innovations in each innovation class

	Product Innovation	ICT-enabled Product Innovation	Process Innovation	ICT-enabled Process Innovation
All firms	17	49	14	67
1-9 employees	20	47	13	65
10-49 employees	13	38	19	57
50-249 employees	23	50	37	67
250+ employees	36	70	49	86
NACE 45.2 firms	14	67	14	52
NACE 45.3 firms	18	43	14	74
Number of observations	754	151	754	171

Source: ICT and e-Business in the construction Industry. ICT Adoption and e-Business Activity in 2006. e-Business W@tch. European Commission (2007(b)).
Categories: NACE 45.2 Complete construction; NACE 45.3 Building installation

As can be seen from table 2.6, product innovations are slightly more common than process innovations. The figures also support the common perception that innovation frequency increases with firm size. However, micro firms (those with less than 10 employees) perform better than the next category in all aspects except process innovation. This can be explained by micro firms consisting not only of self-employed independent entrepreneurs, but also of highly specialised firms, whose expertise, skills and abilities may make them highly innovative.

Overall, and despite their underutilisation in construction, the role of ICT in innovation appears non-negligible. It emerges that half of product and two thirds of process innovations are ICT-enabled. In the NACE category 45.2 (complete construction) firms are on average bigger than those in the NACE category 45.3 (building installation), and firm size and the specific type of activities carried out in the different NACE categories may explain the different innovation types that dominate. ICT-enabled product innovations prevail in the complete construction firms, whereas ICT-enabled process innovations are more common in building installation firms.

2.2.4 Demand side: role of customers and end users

It is meaningful to divide the market for construction output into two separate sub-markets, according to the type of client it is directed to, whether private clients or public customers. Such markets are normally different in both size of the investment and type of product sought, and are characterised by different market structures and levels of competition (number of sellers and buyers) in the market[7]. Households and private customers certainly outnumber firms and public customers as construction clients, but the reverse is true with respect to the monetary value of the average single purchase made. The market in which each type of client operates is also very different. For households, the building type (single house, detached house, apartment, etc.) affects the background of the likely counterpart: bigger firms mostly construct apartment buildings, whereas SMEs dominate the market of single house construction. When planning to build a house, individual households hence face almost perfect competition, as the number of

[7] The market segmentation proposed in the present document is in line with that proposed in the communication COM(2007)860-final, which divides the construction market into: residential (46% for total EU production), non-residential (31%), and infrastructures or civil engineering (23%).

SMEs in the market is large. These construction SMEs, in turn, are normally much smaller than their suppliers - which tend not to disclose detailed information about their internal production strategies – and are too small to influence changes in production methods (Gann, 1996). Consequently, small construction firms do not go further than acting as recipients of technological innovations, which are developed by scale-intensive component manufacturers (Gann et al., 1992). Conversely, when it comes to firms and public clients, the bigger the project, the more likely that a bigger contractor is needed, and the higher the probability that there are partners and sub-contractors involved in the project. Thus, firms and public purchasers face an oligopolistic market structure, but at the same time enjoy a bigger bargaining power, which individual households normally do not have.

In general, any construction project sees the presence of both internal and external customers, the end-customer being generally the one responsible for commissioning and paying the work. Many clients remain often unsatisfied with the typical construction project outcomes (Boyd and Chinyio, 2006). Clients' ability to influence processes and outcomes is likely to vary according to the previous experience accumulated by the buyer. Infrequent purchasers of construction goods and services - having very little incentives and possibilities to become experts in the procurement process -, as well as inexperienced clients, account for the sheer majority of construction works (Barlow, 2000). This is true for both private clients, and public or governmental bodies, although the latter have become increasingly aware and concerned about the influence they can exert on their supplying counterparts. Compared to the construction customer, the car industry customer is more willing to incur the extra costs related to additional/customised features that may boost the customer's public image and life-style, and/or affect his/her safety (e.g. ABS brakes, airbags, etc.). In the car industry homogenous quality is one of the most important competitiveness factors, whereas in the construction sector there still is room for improvement with respect to product integrity and quality standards (Winch 2000).

At present there seems to exist only meagre - if any - interaction and cooperation between the producer and the end-users. Construction innovations are generally not demand driven, since end-users – and private customers in particular - are not integrated in the production process, and are very often unable to request specific devices or to argue about the features of the product they buy (Widèn et al., 2007, Koivu et al., 2001). Private clients, as households, have basically no say in the process, and public sector clients are not necessary well informed about the available possibilities, to the point that construction firms often regard them as "easy clients" (Koivu et al., 2001). Nevertheless, increasingly important in fostering this awareness and knowledge of clients is becoming the role of small construction knowledge-intensive professional service firms. Through enabling a better relationship construction producer - client, they may help firms, increasing their exploitative and explorative capabilities. By exploitative capabilities is meant those resources fostering organisational efficiency, and generating short-term competitive advantage; whereas explorative capabilities are resources geared towards the creation of sustainable competitive advantages (Lu and Sexton, 2006).

2.2.5 Role of public procurement

By public procurement it is meant "the acquisition, whether under formal contract or not, of works, supplies, and services by public bodies at whatever level (local, regional, national, European) and by utilities" (European Commission, 2005, p. 9)[8]. The size, length and extent of the procured project can vary greatly. Traditionally, procurement has referred to public sector led projects where the contractor is responsible for the design of the building work, as well as for all the other aspects of the project. In the tender proposal the contractor would provide the details of each aspect of the work, and the client would bear the risks and costs of implementing it (Winch, 2000).

Public procurement has traditionally taken the form of a "design-build" project or of a "design-bid-build" project. Design-build is a construction project delivery system whereby the design and construction aspects are contracted for with a single entity - known as the design-builder or design-build contractor. This system is generally used to minimise the project risk and to reduce the delivery schedule, since it overlaps the design and construction phases of the project. Conversely, design-bid-build projects, also known as design-tender, are project delivery methods in which the agency or owner contracts with separate entities each phase of the project, i.e. the design phase, the bidding (or tender) phase, and the construction phase.

Competitive tendering is supposed to promote efficiency but, as Cox and Thompson (1997) stress, it only ensures that subcontracting is done at the lowest possible cost level. The tendering system, coupled with the short term perspective characterising construction projects, is often blamed for the problems firms encounter when trying to adopt concurrent engineering practices, and for the difficulty of integrating activities as design and building works (Shammas-Toma et al, 1998). Moreover, given the sequence in which operations happen in open tendering, the tenderer's design affects construction planning, but the reverse is not true. Many are the cases in which the constructor has to build according to specified dimensions, requirements, etc., regardless of the specific and concrete problems encountered. On the other hand though, construction procurement contracts involve fixed specifications and costs, which often raise the likelihood that the contracted party may behave opportunistically. Once the contract is signed, the power relationship contractor-contracted party changes, and the latter tend to exploit their clients by means of putting forward additional claims (Barlow, 2000).

Edler and Georghiou (2007) classify public procurement vis-à-vis innovation according to the target of the contract type and the extensiveness of its impact. "General procurement" refers to public procurement practices in which the innovativeness of the proposals is an important selection/awarding criterion, and in which procurement is centrally planned and executed. "Strategic procurement" is tightly linked to sector policies and aims to enhance innovation in certain markets or technological fields. General and strategic forms of procurement may be complementary to each other, although achieving

[8] In addition to the public procurement concept, there also exists the "procurement for innovation" one, which reflects the "purchase of goods and services that do not yet exist, or need to be improved and hence require research and innovation to meet the specified user needs" (European Commission, 2005, p. 9).

their optimal combination requires an orchestration between the different execution levels and authorities involved. In “direct public procurement” the purchase is solely used by the purchaser/procurer, whereas in “cooperative or catalytic procurement” the benefits also accrue to private/third parties. “Cooperative procurement” involves collaboration between public and private purchasers, so that both may have access to the developed innovative solutions. In “catalytic procurement” the public purchaser is simply an enabler and is not directly involved in the process, nor takes advantage of its results. Typical of catalytic procurement is that, despite of the public purchaser’s role, the success of market entry is in the hands of the private clients. In “pre-commercial procurement” the public purchaser aims to support the finalisation of the development of innovative solutions initiated by suppliers. This type of R&D contract normally covers only a share of the development costs, partly distributes the accrued benefits, but still gives public authorities a chance to influence the development process and to have a say about the foreseen outcome. Finally, “commercial procurement” involves immediately marketable products.

Somewhat departing from its originally (very) rigid roots, modern procurement is nowadays taking the form of more cooperative projects, of public-private partnerships, and even of private sector led projects. These projects cover different phases of the construction process and offer contractors more freedom to use their innovation potential. Typical combinations of different construction phases in procurement calls are design-build-operate-maintain, build-operate-transfer, build-own-operate-transfer, and finance-design-build-operate-maintain plus provide service delivery (see Russell et al., 2006, for further details). The gradual shift from public sector led projects to public-private collaborations and private sector led projects started in the beginning of 1990s. The first major public-private partnerships took place in France and the UK, and initiated a path that was to be followed by almost all countries. The main reason for such a shift may be found in the lack of public financial resources to be allocated to public construction projects. Especially the need for big civil engineering works, like tunnels, bridges, etc, triggered the establishment broader collaborations. In addition, it had become obvious that public sector led projects suffered from weak performance, in terms of low quality, high costs, and too lengthy implementations (Winch, 2000).

Public private partnership has its opponents and supporters. The usual arguments questioning its benefits are offered by those emphasising the length of the procurement process and its high price. Higher total costs are in fact normally arising because of the multi-faceted negotiations taking place during the partnership, and the possibility that legal, financial and technical experts get involved at several points in time during the project. In addition, if project funding is fully arranged by the private partner, it is likely that the financing costs of the project get higher, since private contractors tend to have lower credit ratings than public authorities (Russell et al, 2006). According to the public-private partnership supporters, these potentially additional costs might be compensated by the higher efficiency, stricter budget control, scope of the project, lower expenses, and time and resource saving innovations that the involvement of private actors may generate. Higher efficiency might also stem from market competition, as well as from profit aspirations, both of which could boost innovation. Better coordination between and integration of different project functions may also improve efficiency and support innovation.

The provision of funding for larger public-private partnership projects can hence result in lower financing costs and save public money.

2.2.6 Collaborations, cluster and networks

Construction companies are often structured as project-based organisations rather than as functionally organised ones, and supply clients with custom-designed products and services on a project base (Blindenbach-Driesses and van den Ende, 2006). In project-based production innovation activities are usually conducted in collaboration with other firms, whether clients, suppliers, project partners, etc. (Bayer and Gann, 2007). This complexity leads to innovation activities that are mainly episodic rather than continuous in nature (Bayer and Gann, 2007) - as the CIS4 based evidence offered confirms -, with innovations typically happening more in client-projects than in specific research projects (Gann, 2003). Complexity in construction arises from both uncertainty and interdependence (Gidado, 1996). Uncertainty relates to the resources employed, the environment in which construction takes place and the level of scientific knowledge required. Interdependence refers to the number and type of interactions required between the different parts and actors involved in the workflow. The production process of construction involves a wide and complex multi-technology network of project participants and, despite their different background, they all need to be engaged in the process for R&D and innovation activities to be successful. Moreover, cooperation needs being sustained on a continuous basis to produce breakthroughs and success stories, since temporary or occasional participation in common projects does not seem to serve the innovation purpose (Koivu et al., 2001). Essential is also the integration of end-users and clients into each stage of the innovation process.

2.2.7 R&D collaboration with academia

According to Gann (2001) the flow of ideas and innovations between academia and business seems to be restricted to few established construction firms. Despite the crucial role of experts, only few firms host qualified scientists capable to absorb and apply academic research results. In any case, having the necessary skilled human resources is not a sufficient condition for innovation: technical and research support is also needed. In the construction sector, most firms receive information on the latest developments in their field through media and professional contacts, networks, organizations, etc.. Suitable incentive schemes should therefore be envisaged to address the problem that the scarcity of interactions between academia and business represents. Direct public subsidies might encourage collaboration and innovation. Likewise, investing in the educational, training and life-long learning of the professionals in the sector might increase the absorptive capacity (Cohen and Levinthal, 1989) of construction firms, and their ability and willingness to participate in interdisciplinary collaborations geared toward innovation.

Manley et al. (2001) documents R&D collaboration practices between public-sector research organisations and the construction industry. Their analysis, which focuses on Australia, finds research projects to be concentrated mostly around three broad topics: business and economic issues (23%), construction materials and products (20%), and construction processes (16%). They find that in over half of the cases the research idea is developed within the research organisation, whereas in the remaining cases the ideas comes from external partners, being these either industry or other stakeholders. Generally, the larger the project, the more likely it is to receive external funding, to attract funding from several sources, and to have many stakeholders. Three quarters of the research projects are found to have received external funding, fact that indicates strong interest in R&D on the side of industry. Typical of these projects is the in-kind support obtained from industry associations, training institutions, and firms. In-kind support refers mostly to the provision of data, trade services, business networks and executive time spent on committee work and case studies, and on update and advice on regulations, certifications etc. In-kind support may facilitate network building for researchers, and may enable a broader dissemination of results. Manley et al (2001) find that, despite the rather positive collaboration emerged between public-sector research organisations and construction firms, all the parties involved underline the need to secure more research funds, and to have them over a longer period of time. Public authorities could do this by supporting and motivating private funding efforts, for example by providing tax exemptions. Dissemination of results also remains a central issue in R&D projects, especially outside the collaboration network. Although the most common means to disseminate results appear to be articles, either in scientific or industry journals, what seems to matter in the end is the adoption and implementation of the novel solutions.

2.2.8 Innovation performance and construction

The Sectoral Innovation Watch (SIW) examined sectoral specialisation patterns of the member countries of the European Union (Grupp et al. 2010). The National Sectoral Specialisation Report (NSR) uses a wide range of data sets, including patent and patent citations data for the comparison of technological performance and specialisation patterns across countries, the Community Innovation Survey (CIS) for the evaluation of innovative performance and, finally, a whole range of economic data (e.g. Total Factor Productivity, Value Added, Employment, Imports and Exports) to evaluate the relationship between innovative and economic performance. Construction proved to stand out as an area of distinct and persistent European technological advantage. The following selected findings can be presented in the sector construction.

CIS based innovation performance comparison

In the report on national specialisation, the innovative performance of countries is explored using data from the Community Innovation Survey (CIS). For each country the following innovation success indicators are used: (i) share of turnover due to new products in 2004 and (ii) cost reductions due to process innovations relative to turnover in 2004. Portugal stands for innovation intensity in the construction sector, which goes in line with Portugal’s relative technological advantage. Also Latvia performs quite well. Latvia seems to channel its catch-up process through increased innovative efforts.

Specialisation drives collaboration activities, as it is shown by the focus on co-inventors in European SIW sectors. This is evident not only in the case of biotechnology, space & aeronautics and food & drinks but also in construction where the most collaboration links are between countries which are specialised in these technological fields.

The report shows that the fields of a country's relative technological specialisation do not necessarily stand for relative patent quality, as measured by patent citations. For this reason, the report compares the patent-based index of relative technological advantage with a similarly constructed index that uses patent citations for each country and each SIW sector.

In general, it looks as if the technological advantages in the construction sector are concentrated in the EU 15 countries. Compared to the new Member States and the non EU countries the patent output of the EU 15 countries is very high in this sector. Furthermore, most countries have been specialised in this sector during the whole period of investigation. Especially, Austria is highly specialised in this sector over the whole period. This evidence provides further support to the picture, depicted in previous sections, of European persistent strength in the field of civil engineering. Most of the new Member States are clearly under-specialised in this sector during the whole period of investigation. Exceptions are the Czech Republic, Poland and Slovakia that have gained technological advantages in this sector over the 1990s.

According to the convergence in the technological specialisation, a positive relationship can be observed in most sectors between the specialisation patterns of subsequent periods. So the industry portfolio of the sample countries changes only slowly. Interestingly, at the end of the 1980s and at the beginning of the 1990s only two sectors – biotechnology and construction - show positive and significant correlations. Hence, the hypothesis that the transition dynamics of former socialist economies has implied significant changes in the specialisation patterns of the European countries seems to be confirmed. While considering the technological performance in the construction sector, it can be observed that the technological advantages in this sector are mainly concentrated in the EU 15 countries. Indeed, this is an area of distinct and persistent European technological advantage at the global level.

Patents

Patents can measure the degree of success that is associated with activities in research and development, but they do not measure whether the resulting invention was transformed in a commercially successful innovation. Table 2.7 illustrates the development of the sectoral technological performance between 1978 and 2005.

Table 2.7 Technological performance in selected sectors, 1978-2005

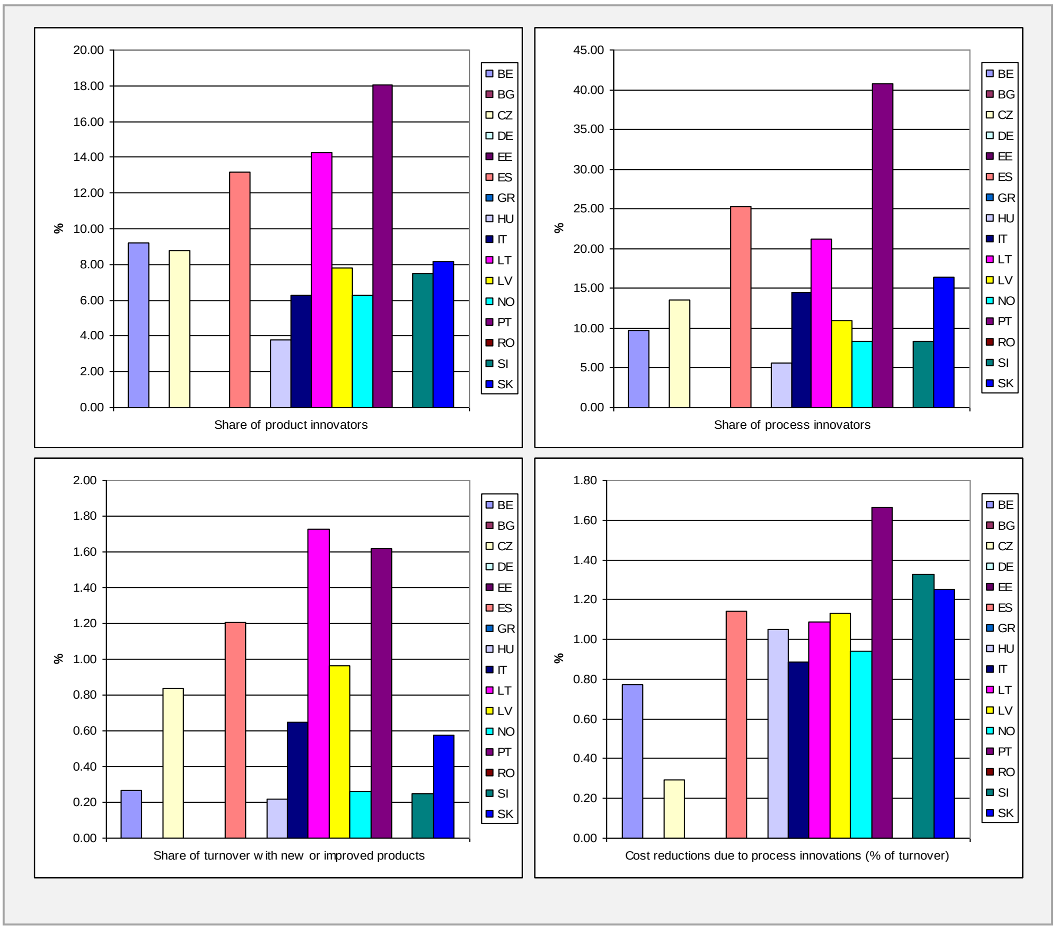
Sector	# patents	share	ranking
Electrical and Optical Equipment	695,239	38.91%	1
Automotive	100,378	5.62%	2
Construction	53,685	3.00%	3
Biotechnology	41,823	2.34%	4
Food & Drink	18,070	1.01%	5
Textiles	9,258	0.52%	6
Space & Aeronautics	7,891	0.44%	7

While the technological activity in the sectors biotechnology, electrical and optical equipment and automotive considerably increases between the end of the 1970s and the end of the 1990s, the patent share in the sectors construction and textiles decreases continuously. The automotive, construction and biotechnology sectors account together for about 10% of the patent stock. About 6% of the patents are held in the automotive sector, 3% in the sector construction and about 2% of the patents are held in biotechnology.

Patent citation

The fields of a country's technological specialisation do not necessarily stand for relative patent quality, as measured by patent citations. E.g. Trajtenberg (1990) explains that patents with many citations have a higher value than those with a low citation rate, as highly cited patents serve as the breeding ground for many subsequent innovations. The patent citations in this analysis refer to the references by other patent. Hence, patents which are cited more frequently have a higher value. The findings are presented in plots (figure 2.2). Countries which have positive or negative values in both specialisation patterns are called +/+ performer or respectively -/-performer. The focus lies on countries which have positive specialisation patterns, but negative Citation Index-values (+/- performer) or the other way around (-/+ performer). The sector of Construction has more +/+ performers. The countries in this group are Austria (which is represented for three times) and Portugal, Slovenia and Spain (which are represented for two times). Notable -/-performers are Japan and India. Japan is in this group for all periods and India for the first and the second period. Outstanding -/+ and +/- performers are just in the latter group. In the second period Romania, Greece and Poland are in this group.

Figure 2.2 **Innovative performance in construction by country**



Top-left: share of product innovators, **top-right**: share of process-innovators, **lower-left**: share of turnover due to new or significantly improved products, **lower-right**: cost-reductions in per cent of turnover due to process innovations

Specialisation and collaboration in innovation activities

Specialisation drives collaboration activities, as it is shown by the focus on co-inventors in European SIW sectors. A much denser network is identified in the construction sector. The key countries in this sector seem to be the same as in many other sectors. The United States, Germany, France and the United Kingdom are strongly linked to each other. The importance of Germany in Construction can also be seen as a gatekeeper for the new Member States to the EU.

For the SIW sectors the findings for all general sectors can be confirmed. Relative technological specialisation advantages can be detected for the construction, the textiles, and the space and aeronautics sectors, which belong to declining technologies. In the construction sector specialised countries tend to cooperate with each other. As in the space & aeronautics sector, new Member States do not play an important role.

2.3 Common set of Indicators

The figures shown in tables 2.7 and 2.4 come from Fourth Community Innovation Survey (CIS4)[9]. Despite the harmonised nature of the questionnaire, the sectors covered by the survey are not the same in each country. Therefore, in CIS4 construction firms-related data are available only for a subset of 11 countries, namely: Belgium, the Czech Republic, Hungary, Italy, Latvia, Lithuania, Norway, Portugal, Slovakia, Slovenia and Spain. Due to the structure of the survey and the presence of filter questions, the numbers shown refer to innovative firms only. In tables 2.3 to 2.8 column (1) shows some innovation indicators for the construction sector; column (2) shows the very same figures for the non-core construction activities; column (3) refers to all economic activities of the countries considered; and column (4) highlights the relative differences (in percentage) existing between construction figures and those of the whole economy[10]. Table 2.8 shows some indicators related to firms' innovation-related expenditures, the reception of public subsidies, and the use of intellectual property rights (IPR).

Table 2.8 Innovation performance in the construction sector (in percentage values)

	Construction (1)	Non-core construction (2)	All sectors (3)	Gap in % (4)
Total innovation expenditures as a percentage of total turnover	0.78	1.94	1.79	-56.42
Intramural and extramural R&D expenditures as a percentage of total turnover	0.15	0.88	1.19	-87.39
Expenditures in machinery and equipment as a percentage of total turnover	0.59	1.44	1.17	-49.57
Expenditure in acquisition of external knowledge as a percentage of total turnover	0.04	0.12	0.12	-66.67
Share of firms receiving public subsidies for innovation	35.07	38.43	42.83	-18.12
Share of firms receiving EU & RTD subsidies for innovation	3.64	7.02	9.30	-60.86
Share of innovators using patents	1.12	6.70	6.30	-82.22
Share of innovators using trademarks	2.35	11.81	10.88	-78.40
Share of innovators using design registrations	0.67	4.93	4.17	-83.93

Source: Authors' own compilation on Eurostat CD rom data from the Fourth Community Innovation Survey (CIS4)

All indicators suggest that firms in the construction sector engage less in R&D and innovation, receive less financial support to innovation, and recur less often to IPR than the firms in the other sectors. The widest gaps can be found in R&D expenditures as a share of turnover, and in the share of firms seeking IPR protection. The latter result is easily explained by the usually very much customised nature of construction works, the consequent difficulty to protect their design, and the impossibility to verify that the same design has not been used by other firms. Table 2.9 shows the share of new goods and services introduced in the market, and the percentage of turnover generated by products, respectively, new to the market and new to the firm.

[9] CIS4 covers the years 2002 – 2004. It was carried out in 25 EU Member States, plus Iceland, Norway, Bulgaria, and Romania.

[10] The gap is calculated by subtracting the EU11 total average from the EU11 construction average, and dividing the difference by the EU11 total average. This gap illustrates the difference in performance in the construction sector in relation to the EU11 all sectors' average. Its formula is Gap= [((1)-(3))/(3)].

Table 2.9 New goods and services, and innovation new to the market and new to the firm

	Construction (1)	**Non-core construction (2)**	**All sectors (3)**	***Gap in % (4)***
Share of firms introducing new or improved goods	4.79	17.38	17.91	-73.26
Share of firms introducing new or improved service	5.94	8.98	11.77	-49.53
Share of turnover from products new to market	0.73	2.20	2.84	-74.30
Share of total turnover from new-to-firm but not new-to-market products	1.91	3.66	4.47	-57.27

Source: Authors' own compilation on Eurostat CD rom data from the Fourth Community Innovation Survey (CIS4)

Similarly to table 2.8, table 2.9 pictures a construction sector that performs significantly worse than the other industries, whereas non-core construction activities perform almost in line with the other sectors.

Overall, the figures above would argue in favour of the general belief holding construction as a low-productivity low-technology industry, and of a sector generally seen to be underperforming (Manley, 2008). Despite the evidence above, however, it has to be acknowledged the very much incremental nature of the innovations occurring in the sectors. These lead to dramatic transformations only over the long term. Examples of the radical transformations happened since 1950 are the changes in materials, the introduction of standardisation and pre-fabrication, the use of information technologies (IT) in both design and construction, as well as the introduction of automation, robotics and the changes in the supply chain management that the sector has experienced (Miozzo and Ivory, 2000).

Creating a stronger innovation culture, aimed at ultimately improving the rate and quality of innovation across the construction value chain, is held to be the possible answer to the problems faced by the sector (Hartmann, 2006). Construction seems to be moving in that direction, and has in recent years performed less poorly than in the past. Moreover, the figures shown look less poor if one considers that, due to the complex production process characterising construction, the role of subcontractors as innovators gets easily overlooked. This may partly explain the low innovation and R&D figures showed by the construction sector in comparison to other sectors (Winch 2003). The figures based on NACE classifications may in fact give a misleading picture of innovation and R&D in the construction sector, since design and production are not included in the core definition of sector's activities. Even in the case of large construction companies the design work (leading to either product or process innovations) is generally subcontracted to smallish but highly specialised architectural and engineering firms, which belong to NACE Rev.1.1 category 74.2 (whereas the construction sector is covered by Rev.1.1 category 45).

As a sector, construction is often compared with the automotive industry, like e.g. Guy and Shell (2002) do. They compare cars and houses along several dimensions and highlight that houses are built to last longer than cars, with houses typically lasting decades, or even hundreds years, whereas cars normally have a less than 20 years life-span. Houses exemplify and represent societal development, prevailing cultural and aesthetic values, whereas cars enjoy a much lower societal value, also due to their shorter life cycle. Houses also enjoy higher psychological importance for individuals than cars do. As an investment, a house is more expensive than a car, but it also is more durable than a car. Cars always need energy to operate, whereas the energy need of houses varies depending on its location and use. Deconstruction of cars constitutes a well-developed industry, whereas deconstruction of buildings is still in its infancy, also because houses are less adapted to disassembly than cars. In any case, as Winch (2003) underlines, the comparison between cars and houses and their respective industries may be highly misleading, also and especially because of the different innovation cycles and dynamics characterising the sectors, and the way final customers perceive the good they buy.

3 Carriers and barriers of innovation

The likelihood that construction firms adopt or generate innovations is affected by firm specific as well as market related factor. On the one hand, firm characteristics as firm size, type of activity, location and managers' quality (including age and education) indeed affect innovation and technology adoption. On the other hand, very important are market-related features as market growth, profit margins, price of financing, risk, intellectual property rights (IPR), market structure, codification patterns, regulations, and type of clients - high-end versus low-end (Blackley and Shepard III). The fragmented structure of the sector contributes to deter diffusion (von Hippel, 1988), as does the complex and network-like structure of the construction production process. As the end-product is the outcome of the coordinated inputs of different sub-contractors the transfer of ideas - and even more the R&D process itself - may become difficult and expensive. In any case, and regardless of firm size, enterprises' success in implementing project-based innovations depends on firms' capabilities, the environment in which they operates, and the characteristics of the innovation itself (Manley, 2008). Firm capabilities include core competences and the methods used to build and exploit them.

Being or getting engaged in R&D and innovation is relatively expensive for construction firms, since the risks related to innovation, also "hidden" innovation (Barrett et al., 2007), are allocated to the producers and not to the users (Widèn et al., 2007). "Hidden" innovations are those that remain undetected by conventional measures, for example project-level innovation activities, organisational, and design innovations (Barrett et al., 2007). In this multi-tech sector successful innovations are often based on hitching and matching several existing technologies, and on implementing systemic innovation, aimed at improving the whole production process (Koivu et al., 2001). Due to the impossibility of producing a test piece, everything has to be done right the first time (MacLeod et al., 1998; Koivu et al., 2001). Moreover, it can be difficult and expensive to test a product that should last for decades and to ex-ante foresee all the changes it might undergo. In addition, since barriers to entry are low in the sector, firms tend to compete in prices, and not even newcomers need to rely on innovations to enter the market. Certification practices, whether related to products or to the firm itself, may also discourage. innovation efforts and investments in small firms, for the additional costs and the delay they imply. Labour unions may also slower the development and implementation of innovations if their approval is needed in order to change the work place or routines (Blackley and Shepard III, 1996)[11].

Project-based production significantly undermines the learning processes essential for innovations and R&D. Although learning in the context of a particular project may indeed take place, it is uncertain whether this information ever becomes available to and accessible from other projects or the firm as a whole (Brady and Davies, 2004). This is true even if certain types of innovations may be project-specific and therefore not repeatable. In addition, it might happen that if project partners do not work together again, they might not be able to exploit the knowledge gained while collaborating. Hence, on the one

[11] Although Clark (1980) and Allen (1984) find that unionised workers are more productive than non unionised ones.

hand, projects represent flexible systems of production, and constitute task-oriented mechanisms enabling the coordination of loose networks of firms (DeFilippi, 2001), and provide opportunities for episodic learning. On the other hand, though, firms working on project-based activities rarely have the opportunity to integrate and further develop the knowledge acquired and to transform it into organisational capabilities (Davies and Brady, 2000; Acha et al., 2005). These features increase the costs of innovation, and lower the ability of firms to fully internalise the long-term benefits that may arise when episodic innovations are transformed into firm-specific – and not only project-specific - competitive advantages. When it comes to project-based firms like construction ones, the success of their innovative-activities seems to importantly depend on: the application of contingency plans; the explicit selection of projects; the support of the senior management; the availability of sufficient experts; and the involvement of product champions (Blindenbach-Driessen and van den Ende, 2006).

It has been noted that the larger and more complex and bespoke the construction work becomes, the more inputs are needed from a variety of sources, and the higher the coordination required (Gann, 1996). The hierarchy of project complexity hence seems to directly relate to the industrial structure of the work: the more the complexity of the work, the higher the project-based and high-technology craft-based nature of the construction activity (Miller et al., 1995). Mirroring these features, there are the differences in the amount of planning, type of materials used, technological solutions envisaged, and degree of complexity attained in “posh” or important buildings and works (from wealthy owners’ houses to landmark buildings like theatres, operas, bridges, etc.) as compared to mass-houses or more low profile constructions. As a matter of fact, projects’ scale may have a huge impact on the likelihood to innovate. Innovations typically become scarcer when moving from large civil infrastructures to industrial or commercial facilities and structures, to utilities and residential projects (Russell et al. 2006).

Construction is, as Crichton underlined already in 1966, characterised by technical interdependence and organisational independence. Moreover, the sector suffers from a “closed shop atmosphere”, i.e. an environment where the rigidity determined by administrative and bureaucratic rules and laws is coupled with the inflexibility of banks, the protectionisms of the professional bodies, and education systems often closely linked to the professional bodies (Pellicer and Victory, 2006). All these characteristics may hinder firms’ ability to systematise and appropriate the lessons learnt and the innovations generated / adopted in previous or parallel works. This is true also with respect to innovative management techniques as, for example, project management. In addition, the intrinsic complexity of construction operations, coupled with the traditional separation of design processes and production, the way contracts are awarded, and the often informal nature of management practices, act as potential barriers to investment in general, and to innovation in particular. These factors have not only hindered large-scale innovations and the dissemination of technological and organisational advances, but also contributed to trigger conflicts among the contracting parties, to cause delays, to lower productivity and quality standards, and to the failure to attract and retain skilled staff (Miozzo and Ivory, 2000).

3.1 People

3.1.1 Knowledge and learning

Construction is a sector characterised by the heterogeneous background of the actors involved, and by a generally conservative attitude. In the EU27, self-employment is quite prevalent in construction, and the industry sees the highest percentage of male workers of all economic sectors (89%). With respect to job tenure and working hours, it emerges that 12%–13% of all workers report just one year or less of service, sign of a sector characterised by a high turnover of human resources. Construction stands out for the high proportion of people working outside the firm's premises, for the high level of workers' exposure to physical risks, and for the percentage of workers using machineries (above 40%). In addition, more than 20% of workers in the construction industry are affected by long working hours (although the sectors is among those in which there is consistently less work at atypical hours). Construction employs a quite important share, i.e. 17%, of non-national workers, which makes of construction the second most important employer of non-nationals, after "other services" (EFILWC, 2007). Many construction trades are well known for their relatively low educational background, and for the fact that learning is neither organised nor widespread. Project experience seldom gets translated into firm know-how, also due to construction firms' little absorptive capacity.

Given the characteristics of the sector's workforce, periodical vocational training, especially training on the job, may help improving the awareness and capacity of workers to recognise innovation opportunities, and their ability to be part and support the innovation process. The importance of on-site vocational training stems from the practitioners' common remark about their inability to remember and/or implement the theoretical concepts learnt during the class lectures. Moreover, a once a year training session - whether safety, environment or practical-activity-related - seldom manages to be absorbed by those who should most benefit from it. Vocational training would not only benefit the less educated part of the workforce, but also the most educated staff, especially the one supervising the on-site work. Supervisors generally have technical backgrounds, but may lack of the organisational and managerial skills needed to enable innovation activities and outcomes. New ideas can thus get lost due to the domination of daily businesses and to unclear competences (Hartmann, 2006).

As Teece (1998) underlines, learning is path-dependent, in that the opportunities for learning are closely related to previous activities and experiences. The fact that too many aspects of the learning environment change simultaneously - as it happens in project-based works – may hinder the ability to learn and to form cognitive structures that facilitate learning. Hence, although the project-basis activity of construction firms should be favourable to the development of new ideas and new solutions, the temporary nature of the network created, time limitations, and the absence of well-structured knowledge transfer mechanisms within the firm might hinder innovation (Dubois and Gadde, 2002). Among the strategies that construction firms may rely upon in order to enhance their core competences and innovative activity there are knowledge-anchoring and relationship building. By knowledge-anchoring it is meant all those knowledge-transferring routines that aim to collect, diffuse and assimilate project-generated knowledge at the firm level. Relationship-building instead refers to the variety of managerial practices and designs aimed to maintain and enhance the client–contractor/supplier collaborations established (Drejer I., Vinding A. L., 2006). The environment in which the firm operates is shaped by actors like suppliers and clients, as well as education providers and research centres, and by industry associations, regulators and government agencies. This environment however changes with time, given the temporary basis of most construction projects, and the likely participation of different group of firms in each project.

In order to enhance the innovativeness of the construction sector, and to improve its productivity, the need arises to implement coherent and coordinated measures boosting simultaneously both the internal and the external environment of the firm. By internal environment we mean the attitude and the ability of both workers and ownership/management to innovate. By external environment we mean customers - whether private or public -, suppliers and partners, as well as the institutional and regulatory frameworks in which the firms operate (see also Hartmann, 2006).

Incentives could be designed in order to enable the transfer of the acquired knowledge within the same firm, i.e. between projects, across firms participating in the same projects (Davies and Brady, 2000, Bayer and Gann, 2007), or even across sectors (Gann, 1996). These incentives could e.g. allow individuals within the firm to take time off the projects to build and integrate the available capabilities, or allow the firm to attract talents and back research activities that would otherwise remain at the level of the single project, and not of the firm as a whole (Acha et al., 2005). Moreover, the incentives-backed creation of dual career structures could encourage capability development at the project level, and help extending that at the firm-level. Knowledge management related to safety through design practices is also essential at the firm level, as well as at the industry level. The dissemination of novel measures, tools, and methods should not be limited to best practices, but extended also to good practices and to generally useful knowledge. This might include experiences and knowledge coming from other sectors, if relevant.

3.1.2 The use of new technologies and ICT

In construction the use, transfer and development of new technologies seem to only marginally improve the efficiency and productivity of the sector (OECD, 1999). Low is also the use of Information and Communication Technologies (ICT). This might be due to the fact that construction works often involve activities and tasks in which the use of ICT would not bring about much gain in efficiency, as in the case of brick laying for instance. Nevertheless, there indeed exist other activities where the use of ICT might be just as relevant for construction as it is in other industries. Among the most relevant there are: knowledge and project management functions; contacts to clients and suppliers; and design and planning. Information technologies (IT) may in fact have a number of applications from automation, to optimising scheduling, inventory, progress and status tracking, to speeding up the tendering process and improving the success of bids.

In comparison to other sectors, construction falls behind in terms of share of ICT professionals, commonness of enterprise resource planning systems and advanced e-procurement systems, ICT training, and use of e-standards. However, it is almost on par with other sectors when it comes to the frequency of ICT-enabled product and process innovations. In this respect, additional data on innovation in the construction sector can be extracted from the e-Business Survey 2006. The survey was conducted in connection to the sectoral e-Business W@tch, which collects information on ICT use and e-business. It is the EC's tool to monitor the adoption, use and impact of various e-business activities in pre-defined sectors[12].

Table 3.1 Share of firms (in %) with product or process innovation and share of ICT-enabled innovations in each innovation class

	Product Innovation	ICT-enabled Product Innovation	Process Innovation	ICT-enabled Process Innovation
All firms	17	49	14	67
1-9 employees	20	47	13	65
10-49 employees	13	38	19	57
50-249 employees	23	50	37	67
250+ employees	36	70	49	86
NACE 45.2 firms	14	67	14	52
NACE 45.3 firms	18	43	14	74
Number of observations	754	151	754	171

Source: ICT and e-Business in the construction Industry. ICT Adoption and e-Business Activity in 2006. e-Busines W@tch. European Commission. 2007.
Categories: NACE 45.2 Complete construction; NACE 45.3 Building installation

As can be seen from table 3.1, product innovations are slightly more common than process innovations. The figures also support the common perception that innovation frequency increases with firm size. However, micro firms (those with less than 10 employees) perform better than the next category in all aspects except process innovation. This can be explained by micro firms consisting not only of self-employed independent entrepreneurs, but also of highly specialised firms, whose expertise, skills and abilities may make them highly innovative.

Overall, and despite their underutilisation in construction, the role of ICT in innovation appears non-negligible. It emerges that half of product and two thirds of process innovations are ICT-enabled. In the NACE category 45.2 (complete construction) firms are on average bigger than those in the NACE category 45.3 (building installation), and firm size and the specific type of activities carried out in the different NACE categories may explain the different innovation types that dominate. ICT-enabled product innovations prevail in the complete construction firms, whereas ICT-enabled process innovations are more common in building installation firms.

[12] The EU member states included in the survey are: the Czech Republic, Germany, Spain, France, Italy, Hungary, the Netherlands, Poland, Finland and the UK.

3.2 Organisations in innovation

Construction companies are often structured as project-based organisations rather than as functionally organised ones, and supply clients with custom-designed products and services on a project base (Blindenbach-Driesses and van den Ende, 2006). In project-based production innovation activities are usually conducted in collaboration with other firms, whether clients, suppliers, project partners, etc. (Bayer and Gann, 2007). This complexity leads to innovation activities that are mainly episodic rather than continuous in nature (Bayer and Gann, 2007) - as the CIS4 based evidence offered confirms -, with innovations typically happening more in client-projects than in specific research projects (Gann, 2003). Complexity in construction arises from both uncertainty and interdependence (Gidado, 1996). Uncertainty relates to the resources employed, the environment in which construction takes place and the level of scientific knowledge required. Interdependence refers to the number and type of interactions required between the different parts and actors involved in the workflow. The production process of construction involves a wide and complex multi-technology network of project participants and, despite their different background, they all need to be engaged in the process for R&D and innovation activities to be successful. Moreover, cooperation needs being sustained on a continuous basis to produce breakthroughs and success stories, since temporary or occasional participation in common projects does not seem to serve the innovation purpose (Koivu et al., 2001). Essential is also the integration of end-users and clients into each stage of the innovation process.

Box 3.1 The construction sector at present

In 2009, the construction sector had close to 3.1 million enterprises, 95 % of which were SMEs with fewer than 20 employees. It employed 14.9 million people, equivalent to 7.1 % of Europe's total employment and 29.1 % of Europe's industrial employment. Germany had the largest construction sector in 2009 in the EU-27 in terms of employees, number of firms and estimated construction investment, followed by Spain and France in each category.

Source: FIEC, 2010

3.2.1 R&D collaborations with academia

According to Gann (2001) the flow of ideas and innovations between academia and business seems to be restricted to few established construction firms. Despite the crucial role of experts, only few firms host qualified scientists capable to absorb and apply academic research results. In any case, having the necessary skilled human resources is not a sufficient condition for innovation: technical and research support is also needed. In the construction sector, most firms receive information on the latest developments in their field through media and professional contacts, networks, organizations, etc.. Suitable incentive schemes should therefore be envisaged to address the problem that the scarcity of interactions between academia and business represents. Direct public subsidies might encourage collaboration and innovation. Likewise, investing in the educational, training and life-long learning of the professionals in the sector might increase the absorptive capacity (Cohen and Levinthal, 1989) of construction firms, and their ability and willingness to participate in interdisciplinary collaborations geared toward innovation.

Manley et al. (2001) documents R&D collaboration practices between public-sector research organisations and the construction industry. Their analysis, which focuses on Australia, finds research projects to be concentrated mostly around three broad topics: business and economic issues (23%), construction materials and products (20%), and construction processes (16%). They find that in over half of the cases the research idea is developed within the research organisation, whereas in the remaining cases the ideas comes from external partners, being these either industry or other stakeholders. Generally, the larger the project, the more likely it is to receive external funding, to attract funding from several sources, and to have many stakeholders. Three quarters of the research projects are found to have received external funding, fact that indicates strong interest in R&D on the side of industry. Typical of these projects is the in-kind support obtained from industry associations, training institutions, and firms. In-kind support refers mostly to the provision of data, trade services, business networks and executive time spent on committee work and case studies, and on update and advice on regulations, certifications etc. In-kind support may facilitate network building for researchers, and may enable a broader dissemination of results. Manley et al (2001) find that, despite the rather positive collaboration emerged between public-sector research organisations and construction firms, all the parties involved underline the need to secure more research funds, and to have them over a longer period of time. Public authorities could do this by supporting and motivating private funding efforts, for example by providing tax exemptions. Dissemination of results also remains a central issue in R&D projects, especially outside the collaboration network. Although the most common means to disseminate results appear to be articles, either in scientific or industry journals, what seems to matter in the end is the adoption and implementation of the novel solutions.

3.2.2 Gazelles in construction sector

High-growth companies, so-called gazelles, are important for economic competitiveness and development, and are increasingly recognised by policy-makers. In Europe INNOVA Innovation Watch, the identification of high growth firms for all firms together is based on CIS IV data (Mitusch and Schimke, 2011). According to the study construction is among the industries with the highest share of gazelles with 45 gazelles. Aside, when we have a look at the general percentage related to industries, the highest share of gazelles are wholesale trade (51) and construction (45).

3.3 Clusters and networks

Construction companies are often structured as project-based organisations rather than as functionally organised ones, and supply clients with custom-designed products and services on a project base (Blindenbach-Driesses and van den Ende, 2006). In project-based production innovation activities are usually conducted in collaboration with other firms, whether clients, suppliers, project partners, etc. (Bayer and Gann, 2007). This complexity leads to innovation activities that are mainly episodic rather than continuous in nature (Bayer and Gann, 2007) - as the CIS4 based evidence offered confirms -, with innovations typically happening more in client-projects than in specific research projects (Gann, 2003).

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4 Sectoral innovation futures

4.1 Emerging and future drivers of innovation in construction sector

In this section drivers of innovation and change process in the construction sector are considered. Drivers can signify both trends and trend-breaking developments, they may be internal to the sector or come from outside the sector. The two main groups of drivers we look at are i) S&T drivers, i.e. major scientific-technological developments of likely relevance to the sector and ii) demand side drivers, i.e. major future developments in terms of consumer preferences and markets.

4.1.1 Demand-side drivers and barriers

Climate change

Climate change constitutes a considerable challenge for the construction sector in several ways: 1) 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. 2) 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, 2005, p. 11). 3) The construction process itself is very resource-intense, the production of cement, steel and glass accounts for a major proportion of greenhouse gas emissions. Hence, climate change as a driver of change in the construction sector is relevant for all segments of the construction market, i.e. all kinds of buildings and infrastructure.

Demographic change

Demographic change will exert various effects on the construction sector. First, changes in household structure are affecting the construction sector: The number of households increase per head of population, households become smaller - in some European countries there has been a trend towards single-households for years. This increases the demand for an affordable and flexible housing stock. Secondly, the age structure of the European population is changing. 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, 2005, p. 11) Thirdly, demographic change also impacts on the need for a functional and high-performing infrastructure, not only infrastructure in relation to the flexible and affordable housing stock, like energy and water supply, but also infrastructure to fulfil increasing needs for individual mobility, information exchange, etc.

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, 2005, p. 11) Needs for urban redevelopment do not merely include buildings, but also changes in urban transport (new urban transport systems, expansion and upgrading of existing urban transport systems), and new requirements for infrastructure to cope with increased urban sprawl.

The economic crisis

Overall, the European building and construction sector is suffering considerably from the combination of recession and restrictive borrowing. According to Euroconstruct[13], construction output in Europe declined 8.8 per cent in 2009, for 2010 a further decline of 4 per cent is expected. This decline is not distributed equally among countries, instead one can roughly distinguish between two groups of countries in which the impacts of the economic crisis differed greatly.

First, countries that had experienced a speculative real estate bubble until 2007, combined with a high level of household debt, were very severely affected by the economic downturn and yet, there are no signs of recovery. Euroconstruct expects Ireland to experience a 51 per cent decline in building activity by 2010, from the 2007 level, 25 per cent in Spain and 18 per cent in Portugal. Other countries in this group are the United Kingdom, and also Eastern European countries like Hungary and Romania. Secondly, in countries which were not in a real estate and housing bubble in 2007, building activity declined more slowly as results from general economic decline and associated cuts in investment. A few countries like Germany, Austria, Sweden and Switzerland are expected to stagnate or experience a small decline in construction activity by end of 2010, whereas Poland is even expecting to increase construction activity. (EFBWW and FIEC, 2010[14])

Similarly, the length and speed of the recovery processes differ in countries. Ireland, Spain and Portugal will stabilise at a deeply depressed level in 2011, whereas CEE countries, dominated by Poland and the Czech Republic, are expected to experienced pronounced growth from 2011. The key drivers for this are new non-residential and infrastructure construction, both benefitting from the EU structural Funds. (Euroconstruct, 2010[15])

[13] Euroconstruct, Press info, 24-25th June 2010, www.euroconstruct.org, last accessed 5th Oct. 2010.
[14] EFBWW-FIEC Joint Appeal; Emerging from the Crisis: Fostering Growth and Jobs for a Sustainable Construction Industry, 29th Jan 2010. www.fiec.org, last accessed 5th Oct. 2010.
[15] Euroconstruct, Press info, 24-25th June 2010, www.euroconstruct.org, last accessed 5th Oct. 2010.

Public procurement and innovative commissioning

In general, the professionalization 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, and also big industrial firms with various locations). This driver applies for all kinds of construction output.

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, 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)

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. This leads to split incentive structures (see table 4.1). 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, p. 12).

Table 4.1 Split incentives for energy investment and saving

Responsibility for energy bills	Landlord	Tenant
Landlord	Incentive to invest	No incentive to save energy
Tenant	No incentive to invest	Incentive to save energy

Source: Taken from World Business Council for Sustainable Development (2009) 20.

Insurances are 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.

Long-term risks and liabilities: Some national liability regimes discourage different parties to share risks 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. This hampers demand for innovation from the customers' side (Taskforce on Sustainable Construction, 2007, p. 10).

Monitoring of risks associated with new technologies: Insurances are also a risk mitigating tool for many stakeholders in new technologies. Insurers consider where systemic aggregates of risk may arise. They take appropriate action to mitigate those risks from an insurers' perspective and thereby make risks more known to the public, which may impact on demand for the use of new technologies in construction (Taskforce on Sustainable Construction, 2007, p. 17). An example is the use of nanotechnology in construction where insurance companies finance research to estimate the associated individual and systemic risks (see e.g. Lloyd's, 2007).

4.1.2 S&T drivers and barriers

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*. The adoption of ICT is needed here in order to equip buildings and infrastructure, like for example, roads, bridges, technical systems, with the flexibility necessary in order to function for different users with varying purposes (EFILWC, 2005, p. 17).
- by integrating ICT in the coordination and organisation of e-commerce/internet 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.
    - *Parametric models, building information modelling (BIM),* allow more openness and involvement of actors (customers) through common data and information instead of document-based exchange of information.
    - *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).

- by using ICT for the coordination of different kinds of infrastructure systems. For water, sewage and energy infrastructure systems, integrated ICT systems may improve communication between users, operators, and between these infrastructure systems, thereby improving supply and mobility of resources. Improved coordination between operators may assure enhanced service with a reduced number of interruptions (ECTP, 2005, p. 20).

New technologies for energy supply and energy efficiency

This includes the development and incorporation of new energy supply systems including renewables, micro generation, 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 are considered new technology trends (including control mechanisms ensuring effective energy use and appropriate maintenance) (UK Technology Strategy Board, 2005, p. 4f).

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 Technology Strategy Board, 2008, p. 4).

Material evolution and revolution

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. Bio-based materials like wood can be also 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 (Schartinger, 2010).

Box 4.1 Development of new materials:

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

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) (Schartinger, 2010).

At the same time, nanotechnology may have impacts 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 become a part of future research agendas whether nanoparticles are emitted from functionalised surfaces in our homes and on our buildings (Sanden et al., 2008: 2f).

Box 4.2 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

Source: E-CORE Strategy: 36. Results from NANOCONEX (2002-2003): Towards the setting up of a network of excellence in nanotechnology in construction applications, European Project (FP5 Competitive and Sustainable Growth).

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, p. 36).

Box 4.3 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, p. 36.

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 with 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 regarding light-weight, stability, stiffness and absorption capacity. Also the structures of termites and other animals can serve as models for energy-saving ventilation and cooling systems (Schartiner, 2010).

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, facade (TU Delft, 2009).
    b. Lightweight 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

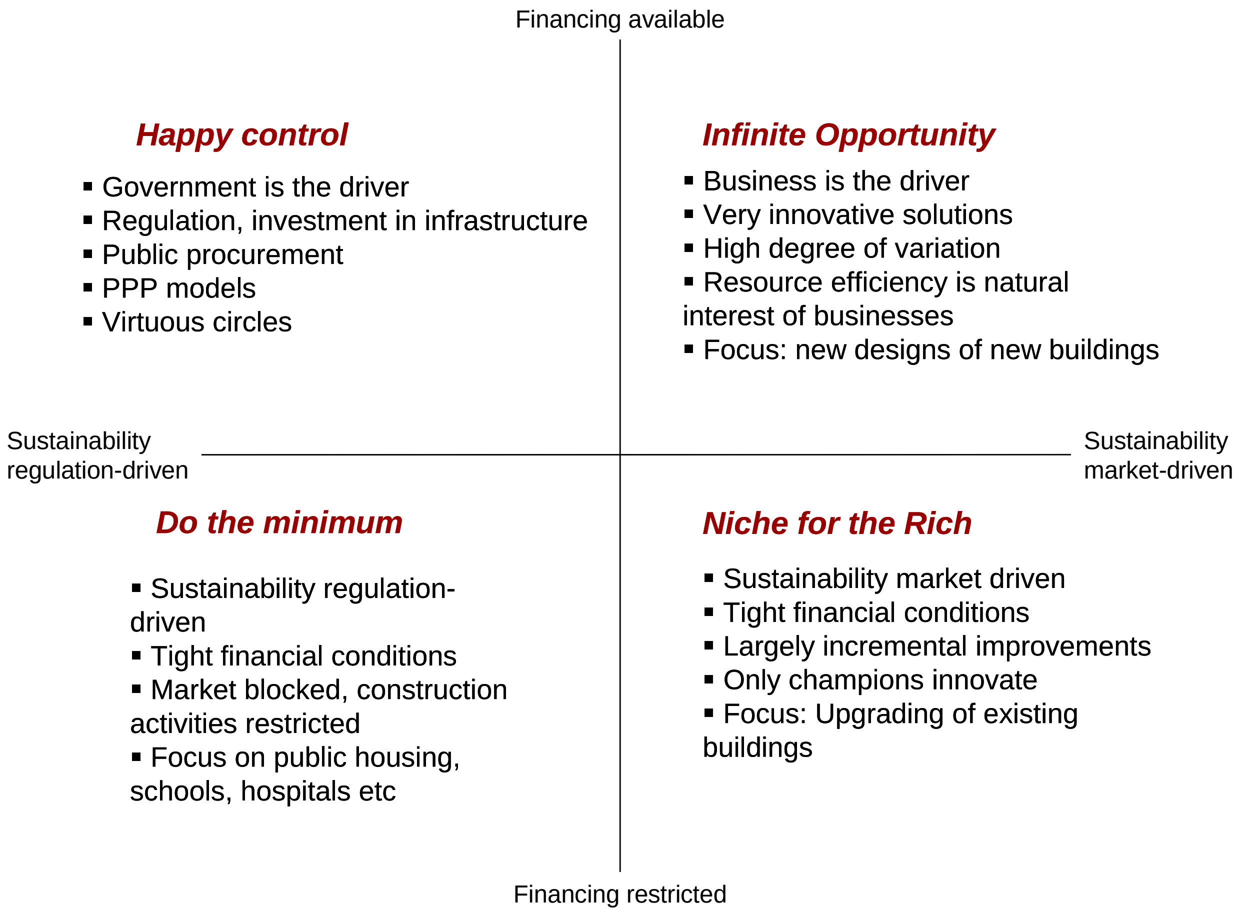
4.2 Sector scenarios

In the first foresight workshop for construction experts identified important drivers for the construction sector in the next 10-15 years according to their own expertise. The scenarios were developed selecting the two most relevant and most uncertain drivers: the conditions for financing on the one hand and sustainability on the other hand.

Concerning the conditions for financing, this was felt to be an issue beyond the end of the present economic crisis. Economic recovery does not automatically guarantee the necessary high level of public and private financial means for i) research and development in relevant technologies, concepts (e.g. radically new concepts of urban transport), materials (new kinds of cement, replacement for cement) etc.), ii) skill enhancement in the construction industry, iii) optimal access to credit (it was the mortgage market that triggered the crisis, access to credit has to be regulated in a way that prevents the long-term and numerous net-indebtedness of private households, and on the other hand may not be too restrictive for the real economy to function).

With respect to sustainability, it was a decision by the experts that the uncertainty was seen in how sustainability is going to be achieved in the construction sector. Is it achieved mainly by the market or mainly by regulation? During the design of the scenarios, it was not doubted that the construction sector will develop towards sustainability on the whole. However, the quality of sustainability differs in the various scenarios.

Figure 4.1 Dimensions for scenarios



Source: 1st experts' foresight workshop, Brussels, June 09.

In general, scenarios are meant to outline qualitatively different directions of how the sector might evolve in the future, based on different sets of assumptions. The description of the individual scenarios focuses on issues which grasp the differences between the scenarios and make the distinction between them more pronounced.

4.2.1 Scenario "Happy control"

Main characteristics

In this scenario the government is the driver and supporter of change. There are sustainable regulations and investments in sustainable infrastructure driven and enforced by the public sector. Publicly financed demonstration projects promote innovative solutions for new buildings, as well as for existing buildings. There are incentive schemes in place to promote these kinds of demonstration projects in the public as well as in the private sector. This generates virtuous circles: As you have more projects of a desirable kind, this leads to economies of scale and generates demand for new know-how and capabilities in workforce.

Opportunities

Public procurement directed towards construction objects with good sustainable performance over the whole life-time may stimulate the market. Economies of scale can be generated through standardised components set to reach environmental targets. The development of sustainable infrastructures with general public access is much more likely.

Publicly funded R&D plays an important role, but also private firms are very active in R&D as the financial means for R&D investments are available. Policy frameworks to increase cooperation between public and private sector enable knowledge spill overs between publicly funded research and the private sector. If it is a policy priority, public-private partnerships (PPP) models replace current purchasing practices, changing the focus from initial prices to value over a life-time. The problems of vocational training and education to avoid shortage of skills can be solved in a coordinated way and not be left to individual firms.

Risks

Policy makers are not "perfectly informed social planners correcting imperfect market signals to guide private decisions towards more desirable outcomes" (Metcalfe and Georghiou, 1998, p. 94). In a world of uncertainty and excess of information, policy makers are unlikely to achieve an optimum, if regulations are too prescriptive.

Regulations towards sustainability may result in conflicts between government and private sector. Government may be experienced as being too prescriptive by the private sector, the government strategy in designing contracts is likely to be segment and differentiate (in contrast to invite performance-based integrated delivery).

Innovation may also be reactive, an answer to regulation. Sub-optimal solutions may arise because businesses stop investing once they conform with regulation. They do not exploit their full potential for innovative solutions and change processes.

Challenges

The public sector has to be coherent, organised, informed and strong. It has to succeed in detailing objectives involving high qualitative standards and strong incentives to innovate. This requires informed and competent public sector authorities with a detailed strategic agenda. Furthermore, financing for incentive schemes and research projects has to be available.

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. This is crucial for construction projects not to be decided on the basis of initial cost, but on the basis of whole-life-performance.

4.2.2 Scenario "Infinite opportunity"

Main Characteristics

This scenario is characterised by a general market growth and simultaneously, by a high demand for green products. Companies are major drivers in radically greening market activities; they are the generators of radical changes in developing alternative business models for sustainable consumption. Businesses invest a lot in R&D; they create a variety of technological solutions and a multitude of new bottom-up business ideas.

Opportunities

Considering sustainable production, businesses themselves are clearly most qualified for establishing radically innovative products, services and inventing related new business models. In their pursuit of efficiency, they can naturally take a role in making production more resource-efficient and in promoting sustainability values in their supply chains. Businesses have proven to be able to contribute significantly to sustainable production via a variety of mechanisms (green innovations, self-regulation, voluntary initiatives like greening their supply chains and eco-design etc.). However, they also have to follow business fundamentals which lead to unsustainable behaviours like externalising cost and the promotion of increased material consumption. [16]

[16] See also Tukker et al, 2008, p. 1220.

In this scenario, businesses invest a lot in R&D as they expect increased demand for their innovative green products, processes and services. These increased R&D efforts may exploit the full set of technological opportunities[17], i.e. the possibilities to incorporate technological advances from a variety of sources into new products, processes and services of the construction sector.

There is a value focus, businesses turn away from merely creating physical objects and abandoning them once they are completed. They now invent new products and service systems, which involve services over the whole life of a constructed object and reduce concentration on the traditional hand-over period (design, build and leave).

Government does not interfere with competencies and technological leadership of the private sector, hence it will define contracts on the basis of performance, i.e. invite integrated design and delivery solutions.

Products and process designs are user focused, beyond the standards of lean processes. User focus in a wide sense means a concerted supply chain, geared towards user preferences.

Risks

There will be a variety of isolated and competing technological solutions, with little or no coordination of business efforts on a macro-level. There will be no integration of technical systems because it all starts from individual technological and business solutions. If the market gets too multi-dimensional, i.e. too scattered, there is a risk of disorientation of consumers.

Although technological opportunities for the construction sector are substantial (see also chapter on S&T drivers), R&D intensity of the construction sector may still remain below expectation because of the lack of a skilled and stable labour force. A skilled and stable labour force enhances the absorptive capacity[18] of firms in the construction sector, and is therefore a prerequisite in order to fully exploit the technological opportunities of a sector.

Challenges

Efficient prices: The crucial characteristic of a well-functioning market is that it should result in prices which correctly reflect cost at all points of the supply chain, as well as the cost of operation and disposal. This imposes several prerequisites on the market, above all the necessity of internalising external cost of emissions. Hence, also in this scenario where businesses are the drivers of change, it is highly

[17] Klevorick et al. (1995) were among the first to provide a concept for technological opportunities of industries and relate this to the R&D intensity of industries. According to this concept, technological opportunity of an industry has three sources: 1. Advances in scientific knowledge and understanding, 2. Technological advances of other industries (inside and outside the vertical chain of production) and 3. Technological advances inside the industry in one period open up new technological opportunities in the next period.

[18] Cohen and Levinthal (1990).

necessary for governments to set framework regulations and incentives in order to guarantee the internalisation of external cost.

Competent clients: Demand for green products, processes and services plays a crucial role in this scenario. Demand of consumers and clients of construction may generate change via their voting power on the market. However, increased demand for green products is only likely if three preconditions apply at the same time: i) motivation /intent, ii) ability and iii) opportunity on part of the consumers.[19] So achieving change through self-organised demand on part of clients places high priorities on information transparency and competency on part of the clients.

4.2.3 Scenario “Do the minimum”

Main characteristics

In this scenario, sustainability is regulation-driven, with a simultaneous lack of financing. Regulations are ambitious and become effective at some point in the future. Because of tight financial situation, there will be no demonstration projects, no incentive schemes and no public investment in infrastructure. Industry is passive, firms need to comply with regulation. But financing for necessary R&D is not available. For the time being, incremental performance improvements with focus on cost are predominant. SMEs collapse, franchising is the business model small business can survive with.

Risks

Investment in construction is often a public measure in order to stimulate markets. Under conditions of financial tightness, the public sector runs the risk of being conservative in its public procurement decisions, focussing on initial cost. The public sector is the dominant investor, but has to keep public demand low. Only essential projects continue. The perceived role of the public sector is that of a business operator, i.e. cost minimisation in the initial investment phase is most important, not cost minimisation over a life-time of a built asset.

There is the danger of a shortage of skills to fulfil regulations, financial means to invest in education of construction workers are far below optimum. Firms are disoriented and uncertain how to address the market.

Because of passivity of industry, sustainability driven by R&D is going to be on a lower trajectory for a long period. Scarce government resources are likely to favour large firms, which makes conditions difficult for SMEs.

Government is in control of infrastructure in this scenario. Due to lack of money no radical innovation is likely.

[19] See also Tukker et al, 2008, p. 1220

Opportunities

Optimise control and use of current stock and processes, saving money, leaning on the existing (not focussing on the value created) are the main opportunities in this scenario.

Challenges

Non-conservative procurement modes are needed especially in such a scenario. Collective R&D, research cooperation between public and private sector, is even more necessary here than in any other scenario.

4.2.4 Scenario "Niche for the rich"

Main characteristics

In this scenario, sustainability is market-driven under tight financial conditions. Most business initiatives aim at incremental improvements, leaving the existing business chains intact. Only leading organisations are the drivers and supporters of change. Because of increasing prices only those who can pay for it can innovate. It is *the rich man's world*, a niche for rich.

Risks

There will be an upgrading of existing buildings, but to minimum levels. There might also be limited research activities from public sector and from champions in the private sector. Risk aversion, fragmentation and diverging priorities most likely prevent a comprehensive reorientation of the market.

Opportunities

Scarcities may lead to radical changes in the construction sector.

Challenges

Innovative financial models, innovative business models will be necessary, otherwise it is an elitist market. If there is no innovation on the financial side, there is no money available and only those who already have the money can afford development. Therefore, in this scenario radically new business models are most necessary.

Table 4.2 Overview of innovation themes in the construction sector

Innovation Theme ▪ **Sub-Innovation Themes**	**Drivers**	**Barriers**	**Market**	**Need for innovation**
Zero-emission/ energy-producing c. ▪ **Eco-efficient construction** ▪ **Energy-producing construction**	Environmental, political and social pressure towards sustainability. The construction sector itself realises that this is a chance to improve its image. Investors exist, e.g. professional users associations.	There is a huge existing building stock, which has to be refurbished. Refurbishment towards eco-efficient and energy-producing construction has to involve many stakeholders (plus transport). This is complex task which makes holistic leadership necessary.	EU could become a lead market. Realisation of innovation theme requires cooperation across sectors (build a new city). Experiences are dispersed in Europe (Need for more holistic leadership)	Technological feasibility has increased (compared to 2 years ago). There is still a huge technological development need (non-marginal efforts necessary, we need new kinds of cement, new kinds of architecture in cities, new kinds of systems approaches.) This is the most comprehensive innovation theme, all others fit in here.
Upgrading of existing buildings	Environmental, political and social pressure towards sustainability. Changing population (age, users, diversity, conversion). Biggest approach to attain sustainable construction.	Dispersed ownership. Availability of investments.	Necessary investments are huge in volume. There are special opportunities for SMEs. It is mainly a local issue, local skills necessary, local competition. Need for strategic choice for specialisation on part of the firms. Opportunities for virtual construction in i) communication with users (user focus) and ii) support of construction workers	New forms of financing necessary. Need for appropriate technologies. How to organise upgrading activities is crucial (buildings are in use). Special skills are necessary (also communication skills).
Smart home technologies	Technological opportunities mainly realised in ICT sectors, not predominantly in construction.	Demand unassertive.	Large firms in electrical and electronics industry invest large sums for further development in this area. Likely applications are ambient assisted living technologies and green smart technologies.	A lot is technologically feasible already.

Source: 2nd experts' foresight workshop, Brussels, December 09.

Innovation Theme ▪ **Sub-Innovation Themes**	**Drivers**	**Barriers**	**Market**	**Need for innovation**
Design and decision systems	End users want to influence design, ask for quality, performance Diffusion of BIM Need for flexibility (purposes vary, technological prerequisites vary etc.).	Lack of skills, competences, aging and decreasing workforce. Education and training not up-to-date.	Europe divided: North and West = drivers, South and East = lag behind, challenge. There are global leaders in Europe.	Need for systemic innovations Open-source innovation Copy-right is changing. Security of data over decades is an issue.
New business models	Drivers are ICT and prefabrication.	Lack of trust in new business models. Public procurement is traditional. Composition of skill level in industry is adverse. Rigidity of insurance: New solutions often cannot be insured.	More of an issue in large firms. SMEs excluded, too risky. Some new business models come from outside the construction sector. Business models for integration/ alliances of old and new specialists, multi-specialists.	Business models have to be different, with a focus on value creation (not cost-cutting), how can we make more money?
Prefabrication	Yields better quality of buildings (“zero defaults”). Feasibility of just-on-time delivery. BIM works as an enabler.	Rise in demand for prefabrication involves change of power from contractor to manufacturer. More qualified clients, risen awareness, better informed	In Europe, large manufacturers, contractors exist. Will there be an impact of Chinese manufacturers? Necessary firm strategies in Europe: Collaboration to develop standards.	Need for connectivity, plug and use, integrated cooling. Develop standards for information exchange, improve connections between BIM and prefabricated components.

Source: 2nd experts’ foresight workshop, Brussels, December 09.

4.3 Future innovation themes and corresponding linkages with other sectors

Innovation themes are new products, processes or services, both final and intermediate, which are specific to the sector. They are those themes where we expect innovation activities to focus on in the next years. The following chapter contains a description of the most prevailing innovation themes in the construction sector for the years to come. Box 4.4 gives an overview of the differing shapes innovation themes can take in the various scenarios.

Box 4.4 Innovation themes in different scenarios

Innovation themes in 'Happy control'

- Zero emission and energy producing construction is a system level innovation and hence needs a system approach. This is more likely in a government driven scenario with financing available.
- The focus in this scenario would be on eco-efficient office buildings and multi-family homes.
- The upgrading of existing buildings needs public incentives, regulation, and public financing. Hence, it is most likely in government-driven scenarios.
- The development of connected technical systems means connecting different energy systems, connecting different heating systems and connections with warm water supply into a generally accessible public infrastructure. This is most likely in a government driven scenario with financing available.
- New public-private-partnership models and structures would most probably entail a closer integration of the whole sector in order to achieve the maximum alignment of responsibilities and interests. They could be favoured in Happy control.
- Greater recycling/re-use of materials (promoted by government)
- Public research for renewable/efficient energy use (financed by government)

Innovation themes in 'infinite opportunity'

- Control and decision support technology, i.e. technologies which help to decide between options in a large variety during the process of construction. In order to fulfil needs they must be able to incorporate a large variety of criteria and be able to comply with different disciplines.
- Integration of design and service delivery, i.e. the use of collaborative work processes and enhanced skills, with integrated data, information and knowledge management from concept phase to maintenance. (CIB White paper, 2009: 1). KIBS (virtual and real) may play an enhanced role here.
- New business models for value capture: In this view, the construction industry is not seen as a supplier of a set of outputs, but as a provider of the most effective long-term support service to its clients. Clients and supply side focus on the value associated with a construction object.
- Product innovations based on new materials: .In a scenario, where sustainability is business –driven and financing for R&D is available, it is likely that sustainable product innovations are also achieved via the development of new materials (material evolution and material revolution**Error! Reference source not found.**).

Innovation themes in 'Do the minimum'

- Innovation themes in this scenario would be informational and organizational in nature, neither government nor businesses have the financing available for comprehensive research activities.
- Codes as a policy instrument (see also chapter Regulations and codes for sustainability in **Error! Reference source not found.**), the creation of codes for sustainability, e.g. the *Code for Sustainable Homes* in the UK since 2006 and the label *Haute Qualité Environnementale* in France, give indications for industry about the way forward to sustainable homes.
- Selection of public sector projects based on life-time-performance could considerably increase the quality of sustainability in this scenario.
- Businesses in this scenario would probably focus their innovation activities on incremental innovations and green marketing measures.
- Businesses are also likely to focus their attention on the further development of lean processes, like (E-CORE Strategy: 30) systems for examining design and their ease of construction, 4-D modelling systems which do not only demonstrate the physical characteristics of a construction but also the assembly processes, or Just-in-time delivery

Innovation themes in 'Niche for the riche'

- As in the previous scenario, businesses in this scenario would probably focus their innovation activities on incremental innovations and green marketing measures (companies want to show to society that they were innovative in this field).

- Businesses are also likely to focus their attention on the further development of lean processes, like (E-CORE Strategy: 30) systems for examining design and their ease of construction, 4-D modelling systems which do not only demonstrate the physical characteristics of a construction but also the assembly processes, or Just-in-time delivery.
- Radical business model innovations are most likely in this scenario. If the money is tight, people start inventing new ways of making money available

Source: 1st and 2nd Europe INNOVA experts' foresight workshop, Brussels, 09.

Zero-emission and energy-producing construction

The feasibility of zero-emission and energy-producing construction has increased radically over the last two years, which is likely to make it a guiding principle in the construction market, increasingly offered by producers and demanded by users of construction, and furthermore enhanced by policy (as in the UK).

Zero-emission construction

The aim of zero-emission and energy-producing construction may on the one hand render other concepts of eco-efficiency in construction obsolete in the near future (for instance passive houses, low-impact-buildings, low-energy-buildings, as these are concepts which entail above-zero emissions). On the other hand, the concept of zero-emission needs sharpening, as it may entail zero-site-energy emissions, net-zero source energy, net-zero energy costs, or net-zero energy emissions etc. (UK Technology Strategy Board 2008, Torcellini et al., 2006, p. 1) 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 be necessary to improve the energy efficiency of buildings 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, p. 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, p. 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 mould growth, the avoidance of volatile organic compounds (VOCs), formaldehyde and PVC etc. However, indoor pollution is a difficult matter, as there are still some open questions regarding causal relations (OECD, 2002, p. 5 and 24).

The markets for eco-efficient buildings: Homes, offices and retail

To understand meaning and consequences of eco-efficiency and to overcome barriers to transformation, it is useful to make a distinction between different functionalities of buildings.

- Residential buildings again consist of two different sub-markets, single-family houses and multi-family houses. Investment decisions are made by private persons, the community, or property investment companies. In both categories of residential buildings, space heating is the main source of energy consumption in Europe (around 70 per cent), followed by domestic hot water, lighting and appliances and cooking (World Business Council for Sustainable Development, 2009, p. 24).
- In office buildings, investment decisions are made by firms, the community, or property investment companies. Space heating, lighting, plug load and cooling account for about 85 per cent of energy consumption (World Business Council for Sustainable Development, 2009, p. 40).
- In retail, investment decisions are made by commercial firms, the community, or property investment companies. In Europe, total retail is responsible for a considerable fraction of energy consumption in the commercial sector, the most energy intense formats being food service and food sales. Retail's main energy uses are space heating, ventilation and air conditioning and lighting (World Business Council for Sustainable Development, 2009, p. 46).

Depending on the sub-market, different technologies may be used, incentive structures and barriers to invest in eco-efficiency vary considerably. Varying ownership structures for different kinds of built assets has an impact on the incentives and barriers to invest in eco-efficiency. For single-family house owners, the lack of easily identifiable energy-efficient solutions relevant to their own specific circumstances is a considerable barrier. Furthermore, they make decisions mostly on the basis of initial cost rather than life-time-performance. The barriers are different in the case of multi-family houses: Here, split incentives play an important role. Financial restraints also play an important role, as residents in multi-family houses often have lower incomes (especially in developed countries) (World Business Council for Sustainable Development, 2009, p. 35). The problem of split incentives also holds true for the office building market – here it is still magnified by a multitude of players (facility managers, property investment companies, etc) who are driven by short term profit considerations and investments. In retail, the striving for growth of sales counteracts reductions in energy consumption. Lighting, which accounts for a significant share of energy consumption, is considered a factor of consumer attraction, also thermal comfort induces an increase in retail sales. Unlike in other types of buildings, in retail energy intensity is higher in new stores than in older ones (World Business Council for Sustainable Development, 2009, p. 47f).

Energy-producing Construction

Buildings provide surfaces which can be utilised as sustainable energy sources (photovoltaic, wind energy). The amount of energy obtained by a distributed network of energy sources may feed into a smart grid. In such a model, the boundaries between users and producers of energy are blurred. This requires new kinds of contracts between producing clients and purchasing suppliers.

Such an increase of diversity may enhance the reliability of an energy system in reducing dependency on a single fuel. However, this requires interoperability at the points of interface between the diverse elements in order to be able to work together cleanly and effectively. Furthermore, it requires deliberate policy decisions, laws and regulations, which create an institutional and contractual framework and technical infrastructure to integrate diverse owners and resources into an energy system (GridWise 2009: 17).

Innovative infrastructure for the connection of technical systems

A precondition for energy-producing construction to be achievable is the provision of an infrastructure to ensure the interoperability of different technical systems like different energy systems, heating systems, water supply. The interoperability of different technical systems means e.g. the seamless end-to-end connectivity of different power sources (power plant, wind craft, solar energy) all the way through the transmission and distribution system to the customers' appliances, which can be heating, hot water, electricity etc.

Interoperability covers several dimensions (GridWise 2009: 3):

- Technical interoperability, i.e. the physical and communications connections between systems (water, energy, etc.),
- Informational interoperability, i.e. the content, meaning and format of data flows,
- Organisation interoperability, i.e. roles and relationships in a broad system, including contracts, intellectual property rights.

The integration of various technical systems into a broad network, the provision of the necessary infrastructures, and the general access to the network are considered as major preconditions for the enhancement of sustainability in the constructed environment. Only if sustainable energy resources may be fed into a generally accessible energy system and be delivered flexibly according to the needs of user appliances, the aim of sustainability may be achieved at all.

Smart home technologies

Smart home technologies, 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. s*ensitive houses*, i.e. sensors control lighting, heating, air quality, fire detection, security etc.) (European Foundation for the Improvement of Living and Working Conditions, 2005, p. 16).

Smart home technologies in buildings are designed to provide various functions and facilities in order to fulfil the needs of the people living in them. A net of sensors and related communication technologies may act independently and efficiently according to specifications and criteria of users (E-CORE Strategy, p. 36f):

I. 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.
II. More effective but less intrusive security systems, capable of making a difference between familiar and unfamiliar users.
III. 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.
IV. Advanced detection of fire, with automatic communication and response of protection systems.
V. Active response systems in seismic regions.
VI. Sensors and communications systems to support health monitoring and provide health care services.

A huge variety of smart home technologies is feasible these days, and a multitude of firms in the electrical, electronics and software sectors invest large sums for further developments in this area. However, what are the advantages of such technologies and who is going to pay for them? It remains an open question, to which degree smart home technologies will actually be part of households in the future.

At the moment, two areas of future applications seem to be likely:

I. Green smart technologies: Technical devices designed to reduce the consumption of energy, automatic and intelligent systems which control heating, ventilation, sun blending, etc. (Wissenschaft im Brennpunkt, 2009, p. 4).
II. Ambient assisted living: Smart technologies to assist people with special needs (old age, chronic illnesses, physical handicaps etc.) to lead a self-determined life in their home environment.

Design and Decision Systems

This involves the change from production information to production “dashboards”, i.e. the use of decision support systems and automated design analysis and approval (CIB White Paper, 2009, p. 3).

Building information modelling (BIM) is an enabler for this. It involves the representation of a design as a multi-dimensional object. This is machine-readable, which makes it possible to check spatial conflicts in a building model automatically. This results in more consistent drawings, more precise cost estimation and bills of material. (Eastman, 2009, p. 1) The process of building information modelling may integrate the dialogue with users and an assessment of constructability of an object, environmental aspects and information for waste management. The need for design and decision systems is radically enhanced by BIM as a variety of requirements and conflicting design aspects are brought forward through by BIM ask for decision and solution. Thus, end users and clients are able to influence the design of buildings.

User driven design means to model and design performance characteristics of buildings or components which reflect current user needs. This requires continuous and intense communication with users in order to explore, investigate and understand user concerns. Examples of relevance for the near future are: Design led by crime reduction, design led by the needs of the aging population and architectural style.

Prefabrication

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).

However, there are still uncertainties associated with this trend (E-CORE, 2005, p. 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 offsite pre-assembling within the private housing sector as a solution to current quality and efficiency problems. (Johnson, 2007, p. 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 house builders are increasingly becoming aware of the advantages prefabrication can offer (Johnson, 2007, p. 12 and 41f).

The value focus - new business 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 (Taskforce on Sustainable Construction, 2007, p. 8, and Bougrain et Carassus, 2003, p. 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 most effective long-term support service to its clients. Clients and supply side focus on the value associated with a construction object (Taskforce on Sustainable Construction, 2007, p. 8).

One example are public-private partnerships (PPP), which 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, p. 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 2005, p. 8f).

Such a transformation of the construction industry would most probably entail a closer integration of the whole sector in order to achieve the maximum alignment of responsibilities and interests. It would require knowledge, public-private-partnership models and structures that currently do exist, but not on a common basis. With the diffusion of certain types of voluntary arrangements for collaboration in the construction sector (e.g. strategic partnering, framework conditions, alliances or construction consortia) it may be possible to establish a longer-term and broader view of the value of a built asset that can be obtained. Especially if the client is a party to the arrangement it is also possible to reconcile client and supply interests. A cultural change in the construction sector implied by the adoption of collaborative ways of working will diffuse only if the involved parties see good prospect of benefitting from them. In fostering diffusion the facilitation of international exchange of experience on such projects, their associated data collection and promotional processes will be crucial (Manchester Business School, 2009, p. 64 and 109).

Insurance premiums can also play a role in fostering cultural change towards the adoption of collaborative ways of working in the construction sector. 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. And insurance 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, p. 17).

4.4 Policy Issues

4.4.1 Policy Issues derived from scenarios

In discussing policy issues in the individual scenarios, there can essential arguments be identified why the public sector plays a pivotal role in each of the scenarios. The consequence is that the public sector has to become active in very basic roles in all scenarios, even in the business driven scenarios, see table 4.3.

Table 4.3 Basic strategies of the public sector in all scenarios

Essential arguments	Basic strategies of the public sector
The public sector is a major client of construction.	Procurement according to criteria of life-time-performance. Make zero-emission and energy-producing construction a standard in public procurement.
Innovative infrastructure is crucial.	Initiate solutions for connection of different technical systems.
Disorientation of business sector and clients through variety of bottom-up solutions.	Coordination and orientation

Source: AIT

The public sector as a major client of construction industry

The public sector purchases a high share of the construction industry’s output (e.g. over 40 per cent , and this number 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. The public sector may exert influences on the construction sector in various ways and its size provides an opportunity and a threat at the same time (European Foundation for the Improvement of Living and Working Conditions, 2005: 22 and UK Sector

Technology Strategy, 2005, p. 1). Mechanisms which allow the public sector to exert influence on the construction sector are:

- A 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. However, demand on the public side is scattered, as 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 and different departments are responsible. A variety of approaches to deliver the targets is taken across the different public clients. Decision making processes vary, and failures 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).

Basic strategy of public sector: Public procurement based on criteria of 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 mostly place on the basis of prices alone, rather than on a performance/price relationship.

Therefore, two factors seriously limit the possibility of innovations in the construction 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.

Hence, there are at least two tasks for the public sector in this area:

1. Develop tools and methods of data analysis to inform on the perspective of life-time-performance. At present, it is necessary to make a number of assumptions about the long-term functionality, performances and life-cycle cost of a construction asset (E-CORE Strategy, p. 29 and 42 and Taskforce on Sustainable Construction, 2007, p. 12).
2. Make decisions about investments on the basis of the life-time performance of construction assets.

This basic strategy by the public sector is not likely to vary in the different scenarios, as the role of the public sector as a major client of construction does not vary in the different scenarios. In the Lead Market Initiative (LMI) on Sustainable Construction by the European Commission, a preparatory action for the implementation of life-cycle-costing was completed at the end of 2009. The establishment of a network between public authorities in charge of procuring sustainable construction is envisaged. (European Commission, 2009, p. 23)

The importance of innovative infrastructure

The development and implementation of an innovative infrastructure which is able to connect various technical systems is crucial for individual business solutions to become effective and not result in a multitude of isolated bottom-up solutions. The development of connected technical systems means connecting different energy systems, connecting different heating systems and connections with warm water supply into a generally accessible public infrastructure. Lack of such an innovative infrastructure connecting different systems will considerably hamper the development of sustainable construction assets.

Basic strategy for public sector: Initiate innovative infrastructure solutions

This public sector strategy may take different forms in the various scenarios – it may range from being an initiator and mediator by setting incentives in research programmes and invite solutions from the business sector (e.g. in the scenarios “Infinite opportunity” or “Niche for the Rich”) to making it part of the public agenda and control negotiation processes (e.g. “Happy control” or “Do the minimum”). However, there is a need for the public sector to initiate the process and in some form take the lead in order to find innovative infrastructure solutions.

Reduce risk of disorientation

Especially in the business-driven scenarios “Infinite opportunity” and “Niche for the rich” there will be the risk of disorientation of the business and consumers caused by the variety of isolated and competing technological solutions, with little or no coordination of business efforts on a macro-level. There will be no integration of technical systems because it all starts from individual technological and business solutions. If the market gets too multi-dimensional, i.e. too scattered, there is a risk of disorientation of consumers.

Basic strategies for public sector: Coordination and orientation

The strategy the public sector chooses to exert this leadership may vary in the different scenarios. It obviously involves a much more comprehensive and active role for the public sector in “Happy control” and “Do the minimum”. However, in the minimum version the public sector will also be needed to prove leadership and give orientation in setting standards, codes and adapt education in the business-driven scenarios, “Infinite opportunity” and “Niche for the rich”.

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. Moreover, according to the varying constitutional and administrative systems, this responsibility is rather fragmented within the member states (Taskforce on Sustainable Construction, 2007, p. 12).

A basic requirement for any regulatory framework is that it must concentrate on targeted performance outputs, including health gains and wellbeing, and 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, p. 14).

Complementary to regulation, it is 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, p. 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, or on international markets. Standardisation has to involve the following aspects:

- create a common language for testing and declaring the performance of products (there has already been achieved a lot, Taskforce on Sustainable Construction, 2007, p. 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. The LMI on Sustainable Construction provides action on widening the scope of Eurocodes (2nd generation) to focus on other design criteria related to sustainability (European Commission, 2009, p. 23 and Taskforce on Sustainable Construction, 2007, p. 15).

4.4.2 Policy issues derived from innovation themes

Innovation themes are new products, processes or services, both final and intermediate, which are specific to the sector. They are those themes where we expect innovation activities to focus on in the next years. Innovation theory emphasizes firms' technological capabilities as a precondition for innovations to happen. Technological capabilities comprise the physical and knowledge capital stock of a firm to develop new products, processes or services (e.g. Baumol 2002). For the development of such a capital stock R&D investments and training and education of the workforce are necessary. Furthermore, especially in the diffusion phase of innovative products, processes and services the (expected) demand from customers is important (e.g. Tukker et al., 2008, Horbach, 2008). Customers may be households, public procurement, other firms and exports. Hence, information of customers (where possible) may also be a useful instrument in order to guarantee that the diffusion of innovations does not fail because of lack of knowledge and understanding. This is especially important for environmental innovations. Demand for environmentally friendly products is dependent on motivation/intent, ability and opportunity and on part of customers (Tukker et al., 2008).

Extensive R&D in a wide range of topics

The realisation that the technological feasibility of zero-emission and energy-producing construction has radically increased over the last two years, raises the probability and expectations of change in the construction sector. Zero-emission and energy-producing construction may therefore be considered as the overarching innovation theme. It is a broad target, many actors and stakeholders are involved. All other innovation themes identified in this report enable or contribute to this one.

In order to achieve such an ambitious goal there also have to be pronounced R&D investments in order for immature innovation themes to develop. Concerning the innovation theme zero-emission and energy-producing construction, the main research focus will be the energy efficiency on building and on district level while improving the quality of life of citizens (See box 4.5).

Box 4.5 Fields of future research directed towards zero-emission and energy-producing construction

Tools and methods

- Tools for designing and measuring energy efficiency are still missing, particularly at district level. Furthermore, going to higher levels of energy efficiency will require more sophisticated tools than those currently used. In order to reach high energy efficiency we need to develop new methods and adapted tools: e.g. overall design processes for renovation of districts or large urban areas, roadmaps, technical and economic models; systemic approaches yielding overall project optimization and ensuring compatibility between technical solutions, etc.

Building envelopes

- R&D will be planned and carried for the design and development – including manufacturing processes- of components for new and retrofitted envelopes, e.g. integration of renewable energies in existing and new envelopes, using thin materials with high insulation capacities for internal insulation, etc.

Systems and equipment

- All components and systems need to be designed to ensure that buildings deliver over the lifetime the energy in use that was expected during the design stage, e.g. integrated PV solutions with increased cost-effectiveness and efficiency; thermal solar: integration and efficiency; small wind turbines, etc.

ICTs for energy management

- The role of ICT as an enabler of energy efficiency needs to be fully explored and exploited. There is a clear need to ensure that ICT enabled solutions will be available, fully deployed and operational.
- In order to enable ICT techniques to reach their full potential, it is necessary to foster research into novel ICT-based solutions and strengthen their deployment, e.g. building automation; smart metering (meters that measure individual energy demand over time); user awareness tools (feedback to users on real time energy consumption in order to change behaviour); interoperability and standards (standardisation for interfaces and communication)

Social and behavioural aspects

- It is necessary to develop more accurate and better understanding of the drivers of change in individual demand and the most appropriate ways to communicate about them. It will also be helpful to develop guidelines for improvement of individual behaviours, to raise awareness and concern. A further issue is to promote change in collective behaviours, and to tackle large groups.

Standardisation

- Pre-normative research towards standardisation of components and systems that shall comply with building codes, electrical normative and grid integration (when applicable). Possible barriers in existing standards and legislation shall be analysed, too.

New business models

- New business models must be developed to take into account clients and user's requirements, the entire supply chain, legal and financial framework, technical aspects, geographical and local features and the whole life cycle.

Source: E2B Association, 2009: 24ff.

Apart from R&D for the zero-emission and energy-efficiency goal of construction, R&D in a wide range of other topics is of strategic importance. See ETCP (2005) for a comprehensive overview of strategic research agenda of the European construction sector.

Box 4.6 Extensive R&D in wide range of other topics related to innovation themes

Urban infrastructure

Knowledge and research on the behaviour and flows of people, energy and materials in cities shall be integrated in the construction design of cities and their components.

Efficiency of networks

Networked infrastructure systems (highways, railways, waterways, air traffic, utilities (water, sewage, gas, electricity), or fast web access) represent a huge asset of a society. Construction R&D shall support the establishment or enhancement of interoperability, coordination, integrated information and communication of infrastructure systems, while improving access of users, supply of resources and maintenance.

Efficient and environmentally friendly construction materials

Development of environmental performance indicators and rating systems for materials, buildings and infrastructures. Increase understanding of degradation processes to improve the service life of building materials.

Reduce impact of construction on natural environment

Increase understanding of impact of construction on soil sealing, pollution, vibration and noise, etc

Widen the knowledge base of the workforce

It is a basic contradiction that the construction sector is on the one hand expected to undergo major structural changes and innovation processes, and should on the other hand accomplish this with a poorly educated workforce on short-term labour contracts. What structurally hinders the further development of the knowledge base in the construction sector is (i) the fact that the construction projects often use short term 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, p. 25).

Current developments from the technological and demand side (see also chapter 3 on Drivers of innovation and change – trends and trend breaks) and envisaged changes in the construction sector require a broad range of qualifications (European Foundation for the Improvement of Living and Working Conditions, 2005, p. 24). These issues will add to the required skill levels in the construction sector.

- 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) Environmental issues, i.e. training in the use of new technologies, machinery, processes and materials directed towards the zero-emission construction goal.
- ii) Communication and teamwork skills. 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.

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-Construction Skills, 2003, p. 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-Construction Skills, 2003, p. 32).

There are several possibilities to influence skill levels in the construction sector, and also to influence the skill levels in the direction of zero-emission and energy-producing construction, as Box 4 illustrates.

Box 4.7 Key recommendations to influence skill levels

Provision of incentives to upgrade and better use skills:

- Aiming at individuals: Learning accounts and learning vouchers may set incentives for workers, particularly for low-skilled workers, to upgrade skills. These are based on the principle of co-investment by government, individuals and employers. Sector-wide recognition of prior learning is particularly important in a sector with fast-changing employment contracts. Furthermore: Set standards for language skills, employ automatic translators where necessary.
- Aiming at employers: i) Public procurement may enhance skills development if skills requirements are specified in calls for tender. ii) Tax incentives may stimulate targeted investment in low-skilled workers, tax incentives may also encourage companies to support skills upgrading in their suppliers. iii) A union regulation concerning skill requirements should be part of the sector agreement

Bring the worlds of education, training and work closer together

- The implementation of a regional qualification infrastructure may better enable the high share of SMEs to pursue skills upgrading.
- Outcome-based qualifications and a common language between education/training and the world of work should be developed. The potential of the European qualifications framework as well as the national qualifications frameworks should be communicated and the involvement of all relevant actors, like Public Employment Service, employers and social partners has to be ensured.

Develop the right mix of skills

- Educational and training programmes shall be planned and delivered at all levels, including higher education, which incorporate the zero-emission goal in their curricula.

Better anticipate future skill needs

- Better labour-market intelligence for developing early-warning and matching systems.

Source: Expert Group on New Skills for New Jobs, 2010.

Table 4.4 Additional future skills requirements for the workforce

Category of profession	Present requirements and trends	Additional future skills requirements
Architects	Will change emphasis from design for form to design for function. They will specify larger and larger units (as opposed to components).	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.
Designers	Will have to take in greater amounts of information. Will need to work more closely with clients and the construction team.	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.
Construction managers	Their core competences revolve around modern management of people, the application of information technology and some technical skills relating to construction methods.	Will have to add process analysis and change management. Additional skills to understand the detailed 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.
Site managers	Lynchpin for construction in the future.	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. Will have greater and earlier involvement in the design and planning stage to improve the buildability and predictability of defect-free completion.
Trades	Demand for trades will continue to increase with demand for buildings.	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 trades people have greater flexibility and are not confined to one discipline.

Source: CITB-Construction Skills, 2003, Innovation, Skills and Productivity p. 33f.

Widen the knowledge base of the construction clients

In order to make informed choices in a complex market with high innovative potential as it is the case with the construction market, clients have to be informed and aware of different variants and consequences of their purchases. However, most private clients on the one hand make the investment of their life-time in purchasing a construction asset, and are at the same time inexperienced, not aware of innovations and are 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.

It may be derived from this that governmental regulations play an important role to achieve innovations for increased sustainability in construction (Bossink, 2004, p. 16). Although this is certainly true, the expansion of knowledge, information and learning on part of the clients may also play a crucial role. The city of Oulu (Finland) may serve as an example here, where private persons must participate in training courses on energy efficiency in buildings in order to get a building permission.

Such measures may be justified as the decision to build and maintain a construction asset does not only cause private cost, but also social cost imposed on society (e.g. CO2-emissions). In order to reduce social cost and enable informed decisions which reduce impact on climate and society, educational and training measures may make a difference.

5 Regulation, innovation and horizontal issues

5.1 Regulation, standardization, and innovation

Innovation in the construction sector is generally characterised by the adoption of new practices and advances in both technological and business processes. Although major innovations do occur in the industry, they rarely imply a major or sudden shift, but rather take the form of (gradual) refinements over a long time frame (Lansley, 1996). These improvements often translate themselves into (the basis for) the numerous norms and standardisation requirements that the firms in the sector have to comply with. This may seem somewhat paradoxical, since innovation is meant to change and replace the incumbent processes and products that are specified in the regulations (Dewick and Miozzo, 2002), but nevertheless is the way in which the construction industry functions. Regulations affect practically every activity and aspect of the construction industry, being this safety, energy, or environment-related. Construction is influenced by a number of regulations that govern products and processes; as well as by planning and environmental regulations governing finished products; and labour market regulations governing the welfare of the workers taking part in the construction work (Dewick and Miozzo, 2002).

Although standardisation and regulations may enable the widespread deployment of novel technologies and processes, the possibly excessively stable system they determine may ultimately hinder innovation. The degree of stability at the core of standardization, which is needed to let improvements get embedded in operational processes, may in fact impinge upon the continuous changes implied by innovation (Edum-Fotwe et al, 2004). This has also been acknowledged by the European Commission in its communication COM(2007)374, where it is explicitly stated that heavy product regulations may hamper the necessary upgrading of industries. If, on the one hand, standards may in fact facilitate the uptake of new technologies and help making the results of R&D reaching their target markets, on the other hand they can stiffen technological change and the convergence of technologies.

5.2 The role of standards and regulations

A vast range of EU Directives and member States regulations and legislations directly and indirectly affect construction. They range from the Equal treatment in Employment and Occupation Directive (78/2000/EC), to the Building Energy Performance Directive (2002/91), to the Waste Framework Directive (2006/12), and to the Construction Product Directive (89/106/EC). In construction, the use of materials is regulated in terms of both specifications of the materials themselves, and of standard test methods aimed to verify the compliance with the specification limits set. Two are the complaints generally put forward in this respect (see, e.g., the discussion in Hooton, 2008). The first is that standards are not responsive to new research findings, and therefore hinder the development and adoption of new materials and construction practices. The second is that (traditionally preferred) prescriptive specifications impinge upon the development of alternative materials and methods, and should hence be substituted by performance based specifications. This move towards using performance-based tests rather than prescriptive requirements has been pursued by, for instance, the Canadian engineering Standards Association (CSA) standard A3000, related to cementitious materials. However, moving from prescriptive to performance-based standards is not easy when the material considered is just one of the ingredients of a more complex construction product, as e.g. binder systems are. Moreover, moving towards performance-based specifications implies assuming that the performances required are actually measurable. Unfortunately, this is not always true, and the absence of reliable, consistent and standardised test procedures can become a major barrier to the adoption of performance standards. This has been the case of, e.g., the European Standard EN197-1, where no commonly agreed test method exists, despite the fact that many countries had in the past relied on some test methods (Hooton, 2008). The cost, time and scarce precision of some tests, coupled with the very often short bid times and necessity to quickly start the work, further hinders the adoption of performance-based standards.

Industry standards, coupled with government regulations, contribute to make of construction a very scarcely innovative sector. In fact, if the existence of joint industry standards simplifies construction works, it nevertheless implies that innovative technical solutions and works procedures cannot be used. Hence, tendering systems favouring standard offerings implicitly act as barriers to innovation and to the pursuit of new solutions (Kadefors, 1995). Given the number and importance of the legislation regulating the construction industry, it becomes of paramount importance to try and evaluate the overall effect of the regulations on the industry’s competitiveness and innovative ability. This would avoid adding unnecessary burdens on the top of the already heavy legislative framework that exists, which is very much fragmented and adapts often too slowly to technological progress and market development.

5.3 Towards sustainable construction industry

Environmental innovations can be defined as the creation or use of production equipment, technologies and procedures, as well as of products and processes that are sustainable, since they optimise the use of energy and natural resources, and minimise the footprint of human activity and/or actively protect the natural environment (Dewick and Miozzo, 2002). Environmental innovations constitute one of the ways through which pursuing the creation of a “sustainable construction” industry. By sustainable construction it is meant the dynamic interaction of developers of new solutions, investors, the construction industry, professional services, industry suppliers and other relevant, committed to achieve sustainable development, taking into consideration environmental, socio-economic and cultural issues (COM(2007)860-final). The concept of sustainable construction relates not only to the impact that construction has on the outside environment, but also the within-the-building one, including the quality of the air, energy consumption, and so on. Despite the introduction of energy consumption standards for houses, and the introduction of more energy-efficient devices, the energy use per household has remained about constant since 1985 (COM(2007)860-final). The need hence arises to further innovate, while at the same time modifying the households' consumption patterns, both through legislation and regulation, and by raising awareness and information sharing.

Dewick and Miozzo (2002) argue that regulations and standardisation would help the effective adoption of innovations, particularly environmental ones. Given the highly fragmented structure of the industry and the project-based nature of construction, they suggest that norms might ensure the participation and collaboration of all the parties involved. Moreover, regulations can ensure the up taking of new environmental technologies, which would otherwise represent a risk for construction firms, also due to lack of information and awareness. Conventional material and processes, thanks to their decade-long use, have in fact proven their reliability against the key factors affecting their field performance, and tend to therefore be preferred by inherently conservative construction firms. It should also be considered that since only very few of (even) the major companies embrace sustainability and corporate social responsibility (Myers, 2005), and since construction firms behave very conservatively (Myers, 2005; Dewick and Miozzo, 2002), environmental regulations may help stimulating innovations. In this respect, Wubben (1999) instead warns about environmental legislation creating a race among major players, at the longer-term expenses of smaller companies, and Demaid and Quintas (2006) warn that formal procedures are not enough to fundamentally change industrial practices.

As Bossink (2002) underlines, industry-wide strategies, including the action of and interaction between public and private agents, and between the supply side and the customers (Rohracher, 2001), are necessary in order to achieve innovations geared towards sustainable and energy-efficient construction. Efforts are also needed to remove the technical barriers that hinder the implementation of sustainable construction. In addition, Matar et al. (2008) emphasise that creating application frameworks integrating sustainability and construction practices at the operational level would facilitate innovation, since the firms in the sector tend to mainly place importance on day-to-day operations (Phua, 2007). In this respect, fundamental is the role of education. At present, the sectors is characterised by a lack of adequate education and skills for innovation uptake.

5.4 Deconstruction and demolition

By deconstruction it is meant the removal of materials from structures, and the systematic and planned disassembly of building materials and components, with the ultimate purpose of maximising reuse and recycling, and to minimise construction and demolition waste at the landfill. Demolition instead refers to the total and fast disassembly or tearing down of a construction or other built structures (Shami, 2006). According to the calculations made by the US Environmental Protection Agency, three quarters of demolition waste could be reused and recycled, for example concrete (Hooton, 2008).

Due to its emphasis on the reutilisation of materials, deconstruction represents an interesting option from an environmental point of view, since it reduces landfill waste, and minimises the use new materials and of the natural resources and energy needed for the production of these materials.

Moreover, compared to demolition, deconstruction minimises the amount of dust released into air, and avoids dumping hazardous materials into nature. This however might come at a cost, since the workers involved in the detection of harmful or toxic materials might be put at risk of exposure, unless they possess the necessary, accurate and up-to-date training related to the optimal handling of such materials. Deconstruction can be partial, targeted or total. Partial deconstruction includes the dismantling of floors, plumbing, doors, windows, etc., but leaves the structure untouched and is therefore followed by demolition. Targeted deconstruction instead refers to the stripping off of structural items, like floor joists, rafters, building assemblies, framing, etc. Finally, in full deconstruction the aim is to salvage as much as possible. This needs extensive planning by specialised professionals, and a careful evaluation of the possible reusability and hazards of the materials contained in the built structure, as well as the necessity to find a suitable storage for all the salvaged material.

Deconstruction and demolition do not exclude each other, but rather constitute complementary opportunities. On the one hand, deconstruction can be more costly than demolition, as it is more labour intensive and time consuming. On the other hand, though, deconstruction may create jobs linked, e.g. to the reuse and recycling of the materials deconstructed. It is generally admitted the cost effectiveness of the deconstruction process needs to be improved. However, the resale of removed recyclable and reusable materials can cover part of these costs. The extent of reuse could be increased by polishing u the image of reused and recycled building materials, by setting up market places for recycled building materials, and also through the use of e-market places. Reuse offers new business opportunities for innovative entrepreneurs who are able to develop different and even unconventional uses for recycled material. Especially the salvage of precious elements and materials might interest a certain clientele. However, the lack of trained personnel, and the uncertainty about the rules and regulations of recycling and reuse may hinder these business opportunities. In this respect, certification and codification may enhance the demand and image of recycled building material.

Design for deconstruction is already part of the design activities, at least in the USA, and should become more and more common everywhere. In design for deconstruction architects or construction engineers pay early on attention not only to the structures, outlook and plan of the building, but also to the renovation needs that the construction might have over its life cycle, and to its final reusability, recyclability and the biodegradability of its materials and structures. This design approach should not be restricted to separate and generally new constructions, but could be more widely applied at all levels, and could also pertain already existing constructions.

5.5 Innovating safety through design

Many are the factors challenging safety in construction. The time and financial pressure exercised by clients willing to speed up the process is a very important one. Important is also the pressure sometimes triggered by the circumstances in which the work is conducted, as it can be the case, for instance, of natural catastrophes, where the aim is to avoid further disasters and emotional human suffering. Construction safety in some countries is also challenged by the relatively high share of migrant workers active in the industry, and by the consequent (linguistic) communication problem that this might trigger (Loosemore and Andonakis, 2007). Moreover, and more generally, the often heterogeneous cultural background of the labour force makes obeisance to rules somewhat volatile, with workers that end up putting themselves and others at risk. Compliance to rules is also hampered by the typical pyramid contracting structure that characterises construction. This makes very hard for both internal and external inspectors to keep track and control the complex network of firms of different size, sub-sector, type, and background often involved in the same project. Auld et al. (2001) investigate the impact of on-site safety inspections on the frequency of work-related injury and death, and find that inspections have no effect on the risk of accident and injury, but do have a positive effect on reducing work-related fatalities.

On the basis of the elements above, it becomes evident why nobody dares questioning the necessity of safety regulations in the Construction sector. However, it still is to be understood how to motivate firms to fully comply with rules, how to best enforce the legislation, and how rules may affect or are affected by innovation. Loosemore and Andonakis (2007) suggest that safety in construction might be enhanced by integrating safety in general training, and by supporting better communication between regulatory authorities and subcontractors. To this end, they propose to have professional on-site safety training, rather than classroom instruction. De Jong et al. (2003) instead, evaluate of the adoption of technological innovations aimed at improving bricklayers' work, and find that more than half of the sector adopted the innovations, making both employers and employees satisfied. Innovations, they found, generated cost/benefit advantages, improved work and health conditions, and ultimately increased productivity.

Concepts like 'designing for construction safety', 'safety through design' and 'prevention through design' all refer to a relatively new approach aimed at improving workers' safety and accident prevention in construction, from the very design phase. In the past, architects, designers and engineers used to put a lot of emphasis on the safety of the end-user or occupant of the construction, whereas rather little attention was paid to workers' safety. The majority of the work accidents in the construction sector used to be caused by improper architectural or organizational solutions, or insufficient planning of the work in the design or in other pre-construction stages. Evidently, then, the earlier in a project attention is paid to safety, the better the safety that can be achieved (Weinstein et al., 2005). One of the first steps in prevention through design is the analysis and assessment of the causalities between possible occupational injuries and design features. Such analyses are then followed by changes in the prevailing practices, by re-organisation of the work environment, and by the possible re-design of tools and equipment that might be needed. In safety through design, attention is to be paid to the whole construction process, to insure that the different measures envisaged are compatible, and to avoid situations where improvement in some phases may cause risks in others.

There is evidence that prevention through design may boost productivity, enhance quality and reduce costs. However, as Gambatese (2008) highlights, there is the need for further cost-related research about the investment needed in preventive measures, for prevention through design to become more common. When prevention through design is not implemented, it is likely that the costs related to the occupational injury risk are transferred downwards in the pyramidal contracting scheme. These costs include injury insurance, healthcare and re-organization of work to prevent accidents. Research on safety through design is one way to support progress in the area. Currently, research challenges include lack of widely accepted methodologies, lack of data and difficulties in accessing data due to confidentiality issues, and poor education and training for safety-related designers.

Improving construction safety through design clearly involves research and development work and innovations. The United Kingdom is a frontrunner in safety and health through design. In the EU, the Council Directive on the implementation of minimum safety and health requirements at temporary or mobile constructions sites (Council Directive 92/57/EEC of 24 June 1992) emphasises overall health and safety issues and the necessity to well plan them ahead. The challenges that can be encountered when promoting safety through design are not only related to legislation, but also to the difficulty of modifying the mind-set and training of architects, construction engineers and designers. In the training and education of designers more attention should be paid to occupational safety and health aspects. Collaborative research with practitioners and scientists could also contribute to the development of tools, guidelines and procedures in line with the safety through design thinking. A clear identification of liabilities concerning work place accidents might also give incentives for designers to do their best to ensure safety at the construction site. Among the factors that prove to affect the safety of the workplace and the attitude towards safety and health issues there are: the dynamics in the work place; the organisational culture; and the workers' attitude towards safety and towards handling machines and tools (Gyekye and Salminen 2007). Designing for safety may imply transferring a considerable amount of work from the building site into factories, since safety aspects are more easily controlled in prefabricated construction. This being the case, demand would shift towards safer building materials and systems, more attention would be paid to ergonomics, and safety measures related to minimum working paces and distances from tools and machineries could be implemented (Toole and Gambatese, 2007).

6 Horizontal issues of construction sector

According to recent figures for the EU 25 (Bilsen, Rademaekers et al. 2009), the construction sector it is the largest industrial employer in the EU. Buildings are one of the products with the longest time-span for usability, usually for several decades and even for more than a century. The length of service life of buildings varies according to many factors including location, materials, construction methods, use and maintenance practices, etc. (OECD 2002). Chapter 6 considers *first* innovation and environmental sustainability in construction sector especially from value chain perspective, and second innovation in construction sector from the perspective of lead markets approach.

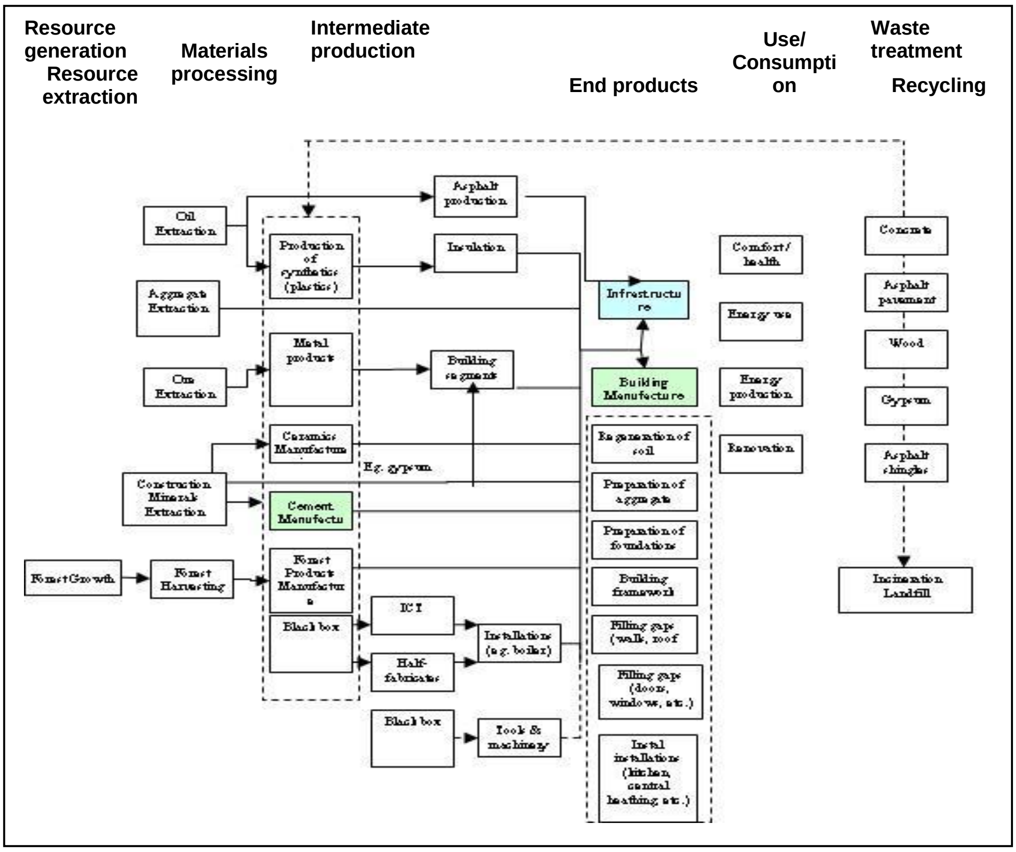
6.1 Environmental sustainability and value chain

The construction process for buildings and infrastructure includes a large number of different steps. The building sector has major impacts not only on economic and social life, but also on the natural and built environment. Various building activities, such as the design, construction, use, refurbishment and demolition of buildings, directly and indirectly affect the environmental performance of the sector (OECD 2002). Inherently, a number of actors are involved in its value chain, from architects, design buffets, material suppliers, maintenance and refurbishment companies, demolition contactors, etc. (figure 6.1).

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

In addition to the amount of materials used also the resource refining, especially the manufacture of cement, has great environmental impact. Industrial Processes is the third largest sector contributing 8 % to total EU-15 GHG emissions in 2007, 27% of which is contributed to cement manufacture (European Environment Agency 2009). Globally the cement industry produces approximately 5% of man-made CO_2; half of this is generated in the production of clinker and 40% while burning fuel. Electricity usage and transportation explain the remaining 10% (Schidler, Sotoudeh et al. 2007).' Total emissions in EU-27 for cement manufacture in 2007 were 107.570 Gg CO_2 equivalents (European Environment Agency 2009). Compared to the manufacture of building materials the environmental impact of the manufacture of building elements and installations is low.

Figure 6.1 Value chain diagram for the construction sector



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

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

During the production process and after the product lifetime a large quantity of waste is generated. The construction industry is accountable for 10-30% of all solid waste globally (Graedel and Howard-Greenville 2005). In Europe, construction and demolition accounts for 40-50% of total waste (Calleja, Delgado et al. 2004). Although a large quantity of this material is potentially recyclable, only concrete is actually recycled at high rates. This is due the relatively high economic value of aggregates and steel (Graedel and Howard-Greenville 2005). Even though one often speaks of down-cycling in these terms, the technical specifications of the recycled material do not add up to the standards of virgin resources (Braungard 2007).

According to results from the APPRICOD project, waste arising from European construction and demolition (C&D) alone amounts to around 180 million tonnes each year. This is over 480 kg per person per year, which makes C&D waste one of the most important waste streams (the commonly accepted European average is 30%). However, only about 28% across the EU-15 is re-used or recycled – the rest is land filled (APPRICOD 2006).

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

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

6.1.1 Identification of eco-innovation opportunities

In the following paragraphs the most important eco-innovation opportunities will be addressed in terms of material extraction, use of building, maintenance, and deconstruction. In this way the following 9 eco-innovation opportunities are described in their sequence of occurrence in the value chain: production of materials (e.g., eco- materials), project design (e.g. passive solar design), construction process (e.g. eco-integrated planning), building in-use (e.g. energy management), deconstruction (e.g. design for easy dismantling). Clearly, the intermediate categories of design, construction (including renovation projects) and use are related to the notion of smart buildings. Smart or intelligent buildings are notions which refer to the automatic adjustment of buildings or components to various external changes. This is also related to enabling the communication of components and systems in order to optimise their use (e.g. sensors control lighting, heating, air quality, fire detection, security etc.)

Table 6.1 Eco-innovation opportunities in the construction sector

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

Eco-innovation	Brief description	Contribution
buildings	terms of energy and materials use is a way to increase its efficiency, often aiming to reduce waste from renovation projects.	Dismantling
Deconstruction	This category includes selecting methods for facilitating the recovering of construction and demolition materials for reuse, recycling or re-processing. Among such materials we account: includes bricks, concrete, masonry, soil, rocks, lumber, paving materials, shingles, glass, plastics, aluminium (including siding), steel, drywall, insulation, asphalt roofing materials, electrical materials, plumbing fixtures, vinyl siding, corrugated cardboard, tree stumps, etc. Examples of deconstruction-related methods include pre-demolition audits, construction and demolition plans, hand-dismantled recovery, etc.	• Eco-park Emmeloord with Dutch BGM Nederland BV as initiator

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

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

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

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

6.1.2 Eco-innovation and regulation in construction sector

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

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

Table 6.2 Correlations between regulation and innovation in construction

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

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

Highly correlated (green)
Moderately correlated (yellow)
No Correlation

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

Box 6.1 Smart building controls in the Netherlands

Smart building controls are an example of innovations that have an effect on the environment. Dutch households making investment to increase energy efficiency are eligible to a subsidy in the cost up to 50% of the total cost of the investment. With the Home Control Box electrical appliances (lights, heating, electronics etc.) can be turned on or off automatically. The system is operated with a control unit with touch screen and through a website. In July 2009, 500 households in Amsterdam were used as a pilot testing of different energy saving services: a website for operating the thermostat and an online "wizard" for collecting data about the energy use of appliances. Main goal of the project is 14% energy and CO2 reduction. The project is an initiative of Dutch energy supplier Nuon, IBM and Cisco. The services are developed by Home Automation Europe in collaboration with Nuon (Home Automation Europe 2009). As a result of the success of the project, local authorities in Amsterdam have commissioned its innovation intermediary “Amsterdam Innovation Motor’ to foster the follow up of this initiative. Cisco has recently announced its contribution to a Euro 1 billion investment (together with IBM, Accenture, and Alliander) to make Amsterdam the first smart grid city. It is expected that the whole of city of Amsterdam will be on smart meters by 2011.

Source: Eco-innovation futures database, TNO

6.2 Impact of innovation on new lead markets

The construction sector is generally regarded as resource- and labour-intensive as well as a low technology sector. Nevertheless, new sector-specific as well as external technological developments (e.g. in ICT, energy, bio- and nanotechnology) may shape the future direction of construction. Technological development will be dominated by the claim for more environmental sustainability in general and sustainable construction methods in particular. Therefore, the sector will face considerable challenges in terms of resource-efficient infrastructure and energy-efficient buildings.

Demand-side drivers in terms of new trends, consumer needs and preferences will additionally change orientation and performance of the sector. The anticipation of global trends is an important driver for the international diffusion of innovation designs. Future demand trends will primarily be related to increasing environmental consciousness, climatic change and global warming as well as the price for energy and the dependence on oil.

The construction sector is characterised by demand from different sources. Not only private demand for residential or office buildings also public infrastructure projects are of particular importance for the market. The public sector is a major client of the construction industry and is expected to boost further development by targeted and criteria-oriented procurement. Moreover, regulatory frameworks, e.g. in terms of quality and environmental standards, have substantial impact on technological direction and sector-specific R&D activities, may induce innovation in the construction sector and shift public and private demand to specific products and services.

New market opportunities for the construction sector arise from the intersection of future technological challenges and demand-side drivers. The following innovation themes (Schartinger, 2010) may direct future innovation activities and create potential for European countries to establish a Lead Market position in the construction industry:

- *Zero-emission and energy-producing construction* with materials of low embodied energy (for e.g. transportation and manufacturing) and energy-efficient applications (e.g. space heating and cooling, hot water) using renewable energy (active solar heating, passive solar heating, photovoltaics, etc.).
- *Innovative infrastructure for the connection of technical systems*: Different technical systems for e.g. energy, heating and water are to be interoperable.
- *Smart home technologies and intelligent houses*: Future applications will be related to green smart technologies, designed to reduce the consumption of energy. New products should provide possibilities to adjust heating and ventilation to external changes and to control them more effectively. Further emerging themes also concern smart security and protection systems in terms of e.g. fire, or sensors. New markets will emerge for applications designed to assist people with special needs (e.g. support by means of health monitoring and individual health care services).
- Increasing use of *decision support systems*, *automated design analysis* and approval as well as *user driven design*, e.g. by means of building information modelling (BIM).
- Increasing usage of *prefabrication* of construction components and the use of industrial robots and automation technology in off-site manufacturing
- *New business models* (in particular public-private partnerships) to finance, build and manage public buildings and infrastructures. In this context the construction sector acts as a service provider for the public sector.

One major challenge in the construction sector is, in particular with respect to sustainable construction, to shift investment criteria from initial costs towards life-time performance and cost. Currently, decisions are mostly based on initial cost for buildings rather than on cost throughout the whole existence of assets. In order to achieve higher demand for sustainable construction, comparisons of maintenance costs and resource consumption throughout the whole life cycle are necessary. Public procurement could take the lead by demanding solutions on the basis of life-time-performance. Consequently, the public sector may act as a lead-user demanding innovative and sustainable applications and construction methods. This, in turn, may foster the development of further innovative solutions and redirect private demand as well. Successful and innovative infrastructure solutions in terms of e.g. particularly low energy consumption can gain high international attention, achieving potential to become a Lead Market in the respective field. Foreign countries and markets, respectively, will subsequently implement specific construction methods in public buildings. The Lead Market will serve as a test bed for the adaption in other markets, enhancing consumer trust in a specific innovation design (demonstration effect).

Compared to other sectors, specialisation patterns in construction are quite even in the EU-15 and most countries are specialized in the related technologies (Grupp et al. 2010). Specialisation in construction technologies is high in Austria, Denmark, Italy and Spain in particular. The leading countries in the EU-12 are the Czech Republic and Poland. Lead markets will more likely evolve in these countries compared to other EU member states.

7 Policy analysis and conclusions

Construction and construction sector are linked in many ways to public sector and public policies through regulation, standardization and environmental aspects, and public sector is also a major client of construction industry. Accordingly also in the promotion of innovation in construction sector various public policy measures like innovation by procurement and by lead market approach play important roles. Moreover the construction sector has various links to many policy areas, such as production and consumption of energy, land-use planning, transportation, etc. Correspondingly the promotion of innovation in construction shall be based on horizontal innovation policy approach covering all relevant policy fields.

Horizontal coordination is important also due to the fact that demand on the public side in construction sector is scattered, as public clients invest in the built environment in the forms of communities and housing supply, schools, health infrastructures, roads, rails, etc. A variety of approaches to deliver the targets is taken across the different public clients. Decision making processes vary and failures 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.

This report discusses two tasks for the public sector, (1) the development of tools and methods of data analysis to inform on the perspective of life-time-performance, and (2) making decisions about investments on the basis of the life-time performance of construction assets (Section 4.5.1). The report envisages the establishment of a network between public authorities in charge of procuring sustainable construction.

Policy agenda

On a basis of scenarios presented in section 4.2 in policy toolbox may consists of the following approaches and measures. The first issue is the development and implementation of an innovative infrastructure. Such an infrastructure is able to connect various technical systems is crucial for individual business solutions to become effective and not result in a multitude of isolated innovative bottom-up solutions in infrastructure. The second issue is the reduction of risk of disorientation. There will be the risk of disorientation of the business and consumers caused by the variety of isolated and competing technological solutions, with little or no coordination of business efforts on a macro-level. The third issue is coordination and orientation as basic strategies for public sector. The public sector will also be needed to prove leadership and give orientation in setting standards, codes and adapt education. The fourth issue relates to targeted performance outputs. Any regulatory framework must concentrate on targeted performance outputs including health gains and wellbeing, and 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. Complementary to regulation, it is a valuable approach to create codes for sustainability. Fifth, standardisation is a necessary undertaking in order to consolidate the competitive position of construction companies, which are essentially based locally, or on international markets. Standardisation involves the following aspects: it creates a common language for testing and declaring the performance of products; it rationalises different levels and classes of performances of different products and construction practices in the various member states; it adopts Eurocodes, which should replace national codes.

Research and development agenda

This report gives support to the following research topics directed towards zero-emission and energy-producing construction (following also suggestion of E2B Association). First, tools and methods for designing and measuring energy efficiency are still missing, particularly at district level. Furthermore, going to higher levels of energy efficiency will require more sophisticated tools than those currently used. In order to reach high energy efficiency we need to develop new methods and adapted tools. Second, R&D will be planned and carried for the design and development – including manufacturing processes - of components for new and retrofitted envelopes. Third, all components and systems need to be designed to ensure that buildings and equipment deliver over the lifetime the energy in use that was expected during the design stage. Fourth, the role of ICT as an enabler of energy efficiency needs to be fully explored and exploited. Fifth, social and behavioural aspects are of special importance in construction. It is necessary to develop more accurate and better understanding of the drivers of change in individual demand and the most appropriate ways to communicate about them. It will also be helpful to develop guidelines for improvement of individual behaviours, to raise awareness and concern. Sixth, pre-normative research towards standardisation of components and systems that shall comply with building codes, electrical normative and grid integration (when applicable). Seventh, new business models must be developed to take into account clients and user's requirements, the entire supply chain, legal and financial framework, technical aspects, geographical and local features and the whole life cycle.

Apart from R&D for the zero-emission and energy-efficiency goal of construction, R&D in a wide range of other topics is of strategic importance. The first issue is urban infrastructure. Knowledge and research on the behaviour and flows of people, energy and materials in cities shall be integrated in the construction design of cities and their components. The second issue is efficiency of networks - networked infrastructure systems (highways, railways, waterways, air traffic, utilities, water, sewage, gas, electricity, or fast web access) represent a huge asset of a society. Construction R&D shall support the establishment or enhancement of interoperability, coordination, integrated information and communication of infrastructure systems, while improving access of users, supply of resources and maintenance. The third issue is related to efficient and environmentally friendly construction materials, supported by environmental performance indicators and rating systems for materials, buildings and infrastructures. Understanding of degradation processes to improve the service life of building materials shall be improved. The fourth issue is the reduction of impact of construction on natural environment. We need to increase our understanding of impact of construction on soil sealing, pollution, vibration and noise, etc.

Skill development agenda

The development of the knowledge base in the construction sector is retarded by the following reasons: *first,* the construction projects often use short term labor contracts, and, *second*, there is a high proportion of SMEs in the construction sector that often find it difficult to finance training cost. Key recommendations to influence skill levels are as follows (see also Box 4.7):

The first issue is the provision of incentives to upgrade and better use skills. Aiming at individuals this means that learning accounts and learning vouchers may set incentives for workers, particularly for low-skilled workers, to upgrade skills. These are based on the principle of co-investment by government, individuals and employers. Sector-wide recognition of prior learning is particularly important in a sector with fast-changing employment contracts. Furthermore: Set standards for language skills, employ automatic translators where necessary. Aiming at employers the provision of incentives to upgrade and better use skills means *first* that public procurement may enhance skills development if skills requirements are specified in calls for tender. *Second,* tax incentives may stimulate targeted investment in low-skilled workers, tax incentives may also encourage companies to support skills upgrading in their suppliers. *Third,* a union regulation concerning skill requirements should be part of the sector agreement.

The second issue is to bring the worlds of education, training and work closer together. The implementation of a regional qualification infrastructure may better enable the high share of SMEs to pursue skills upgrading. Outcome-based qualifications and a common language between education/training and the world of work should be developed. The potential of the European qualifications framework as well as the national qualifications frameworks should be communicated and the involvement of all relevant actors, like Public Employment Service, employers and social partners has to be ensured.

The third issue is to develop the right mix of skills. Educational and training programmes shall be planned and delivered at all levels, including higher education, which incorporate the zero-emission goal in their curricula. The fourth challenging issue is to better anticipate future skill needs, a better labour-market intelligence for developing early-warning and matching systems.

References

Accelerating the Development of the Sustainable Construction Market in Europe, Report of the Taskforce on Sustainable Construction, composed in preparation of the Communication “A Lead Market Initiative for Europe”, COM(2007) 860 final.

Acha V., Gann D. M., Salter A. J., Episodic Innovation: R&D Strategies for Project-Based Environments, Industry and Innovation, Vol. 12 (2), June 2005, pp. 255-281.

Allen S. G., Unionized Construction Workers are More Productive, Quarterly Journal of Economics, Vol. 99(2), May 1984, pp. 251 – 274.

Asikainen A.-L., Squicciarini M., Innovation and the Construction Industry: a “Strict” and a “Wide” Definition of the Sector, mimeo (2008).

Auld M. C., Emery J. C. H, Gordon D. V., McClintock D., The Efficacy of Construction Site Safety Inspections, Journal of Labor Economics, Vol. 19(4), Oct 2001, pp. 900 - 921

Barlow J., Innovation and Learning in Complex Offshore Construction Projects, Research Policy, Vol. 29, 2000, pp. 973 – 989.

Barrett P., Abbott C., Ruddock L., Sexton M., Hidden Innovation in the Construction and Property Sectors, RICS Research Paper Series, Vol. 7(20), Dec 2007.

Baumol, W.J., 2002, The free-market innovation machine – analyzing the growth miracle of capitalism. Princeton University Press, New Jersey.

Bayer S., Gann D., Innovation and the Dynamics of Capability Accumulation in Project-Based Firms, Innovation: Management, Policy & Practice, Vol. 9(3-4), Sep. 2007, pp. 217-234.

Bilsen, V., K. Rademaekers, K. Berden, E. Binda Zane, I. De Voldere, G. Jans, K. Mertens, D. Regeczi, A. Slingenberg, F. Smakman, P. Stouthuysen and A. Unterstaller (2009). Study on the Competitiveness of the EU eco-industry. Final Report – Part 1. Project commissioned by the European Commission - Directorate-General Enterprise & Industry, within the Framework Contract of Sectoral Competitiveness Studies – ENTR/06/054. Brussels, ECORYS, Tecknologisk Institut, Cambridge Econometrics, CES ifo, IDEA consult: 216.

Blackley D.M., Shepard III E.M., The Diffusion of Innovation in Home Building, Journal of Housing Economics, Vol. 5(4), 1996, pp. 303 – 322.

Blindenbach-Driessen F., van den Ende J., Innovation in Project-Based Firms: the Context Dependency of Success Factors, Research Policy, Vol. 35, 2006, pp. 545 - 561

Boyd D., Chinyio E., Understanding the Construction Client, Oxford: Blackwell Publishing, 2006.

Blok, K., L. Geng, D. Harvey, S. Lang, G. Levermore, A. Mongameli Mehlwana, S. Mirasgedis, A. Novikova, J. Rilling and H. Yoshino (2007). Residential and commercial buildings. Climate Change 2007: Mitigation. B. Metz, O. R. Davidson, P. R. Bosch, R. Dave and L. A. Meyer. Cambridge, united Kingdom and New York, NY, USA.

Bossink, 2004, Managing Drivers of Innovation in Construction Networks.Journal of Construction Engineering and Management 130 (3).

Boyd, D. and E. Chinyio (2006), Understanding the Construction Client, September 2006, Wiley-Blackwell.

Bougrain, F. and J. Carassus, 2003, Batiment: de l’innovation de produit à l’innovation de service.Plan Urbanisme Construction Architecture. http://jc-desh.cstb.fr/publications

Brady T., Davies A., Building Project Capabilities: from Exploratory to Exploitative Learning, Organization Studies, Vol. 25(9), 2004, pp. 1601 – 1621.

BREEAM. (2009). "What is BREEAM? The Environmental Assessment Method for Buildings Around The World." BRE Global Ltd. 2009, Available from: http://www.breeam.org/page.jsp?id=66. Retrieved: 10.11.2009

Carassus, J., 2005, Public private partnership: A service innovation.The treasury building case. Paper prepared for symposium of the International Building Council, Helsinki, 2005. http://jc-desh.cstb.fr/publications

CIB, 2009, White Paper on Integrated Design and Delivery Solutions. http://www.cibworld.nl/site/programme/priority_themes/integrated_design_solutions.htm , last accessed May 31st, 2010.

CITB-ConstructionSkills, 2003, Construction Skills Foresight Report 2003. http://www.cskills.org/

Clark K. B., Unionization and Productivity: Micro-Econometric Evidence, Quarterly Journal of Economics, Vol. 95(4), Dec 1980, pp. 613 – 639.

Cohen W. M., Levinthal D. A., Innovation and Learning: the Two Faces of R&D, Economic journal, Vol. 99, Sep. 1989, pp. 569 – 596.

Cox, A. and I. Thompson (1997), Fit for purpose' contractual relations: determining a theoretical framework for construction projects. European Journal of Purchasing and Supply Management 3, 127 - 135.

Crichton C., Interdependence and Uncertainty: a Study of the Building Industry, European Journal of Purchasing and Supply Management, Vol. 6, pp. 207 – 215.

Davies A., Brady T. Organisational Capabilities and Learning in Complex Product Systems: towards Repeatable Solutions, Research Policy, 29, 2000, pp. 931 – 953

DeFilippi R. J., Introduction: Project-Based Learning, reflective Practices and Learning Outcomes, Management Learning, Vol. 32(1), 2001, pp. 5-10

De Jong A. M., Vink P., De Kroon J. C. A., Reasons for Adopting Technological Innovations Reducing Physical Workload in Bricklaying, Ergonomics, Vol. 46(11), 2003, pp. 1091 – 1108

Demaid A., Quintas P., Knowledge across Cultures in the Construction Industry: Sustainability, Innovation and Design, Technovation, Vol. 26, 2006, pp. 603 – 610

Dewick P, Miozzo M., Sustainable Technologies and the Innovation-Regulation Paradox, Futures, Vol. 34, 2002, pp. 823-840

Dick J., Payne D., Regional Sectoral Support: A Review of the Construction Industry, SMEs and Regional Innovation Strategies across Europe, International Journal of Strategic Property Management, Vol. 9, 2005, pp. 55-63

Drejer I., Vinding A. L., Organization, 'Anchoring' of Knowledge, and Innovative Activity in Construction, Construction Management and Economics. 2006 ; vol. 24 (9), 2006, pp. 921-931

Dubois A., Gadde L.-E., Supply Strategy and Network Effects: Purchasing Behaviour in the Construction Industry, European Journal of Purchasing and Supply Management, Vol. 6, 2000, pp. 207 – 215

Dubois A., Gadde L.-E., The Construction Industry as a Loosely Coupled System: Implications for productivity and Innovation, Construction Management and Engineering, Vol. 20, 2002, pp. 621 – 631.

Eastman, C., 2009, Building Information Modelling. What Is BIM? Digital Building Lab, Georgia Tech. http://bim.arch.gatech.edu/ , last accessed April 16th, 2010.

ECTP, 2004, Vision 2030. A working paper by the European Construction Technology Platform.

ECTP, 2005, Strategic Research Agenda for the European Construction Sector. Achieving a sustainable and competitive Construction Sector by 2050. www.ectp.org, last accessed October 5th, 2010.

E-CORE (European Construction Research Network), 2005, E-CORE Strategy for construction RTD. A project by ECCREDI (European Council for Construction Research). http://www.e-core.org/

E2B Association, 2009, European Initiative on Energy Efficient Buildings. Scope and Vision. http://www.e2b-ei.eu/e2bjti_documents.php, last accessed October 5th, 2010.

Edler J., Georghiou L., Public Procurement and Innovation – Resurrecting the Demand Side. Research Policy, Vol. 36, 2007, p. 949-963.

Edum-Fotwe F. T., Gibb A. G. F., Benford-Miller M., Reconciling Construction Innovation and Standardisation on Major Projects, Engineering, Construction and Architectural Management, Vol. 11(5), 2004, pp. 366 – 372

EFBWW-FIEC (2010), Joint Appeal; Emerging from the Crisis: Fostering Growth and Jobs for a Sustainable Construction Industry, 29th Jan 2010. www.fiec.org, last accessed 5th Oct. 2010.

EPA (2000). Building Savings. Strategies for Waste Reduction of Construction and Demolition Debris from Buildings, United States Environmental Protection Agency: 20.

European Commission (2005), Public Procurement for Research and Innovation, Luxembourg: Office for Official Publications of the European Communities, EUR 21793, 2005, 46 pp

Euroconstruct (2010), Press info, 24-25th June 2010, www.euroconstruct.org, last accessed 5th Oct. 2010.

European Commission (2006). ICT and e-Business in the Construction Industry. ICT Adoption and e-Business Activity in 2006. Sector Report no. 7/2006, 2006.

European Commission (2007), Mid-term Review of Industrial Policy. A Contribution to the EU's Growth and Jobs Strategy, COM(2007)374, 2007.

European Commission (2007(a)), Guide on Dealing with Innovative Solutions in Public Procurement. 10 Elements of Good Practice. Commission staff working document. SEC(2007)280, 2007(a).

European Commission (2007(b)), ICT and e-Business in the construction Industry. ICT Adoption and e-Business Activity in 2006. e-Busines W@tch, 2007(b).

European Commission (2007(c)), Accelerating the Development of the Sustainable Construction Market in Europe, Report of the Taskforce on Sustainable Construction, Composed in preparation of the Communication "A Lead Market Initiative for Europe" COM(2007) 860 final, 2007(c).

European Commission (2008), NACE Rev. 2 – Statistical Classification of Economic Activities in the European Community, Luxembourg: Office for Official Publications of the European Communities, 2008, 363 pp

European Commission (2009), Lead Market Initiative for Europe. Mid-term progress report. SEC(2009) 1198 final, Brussels 9.9.2009. http://ec.europa.eu/information_society/newsroom/cf/itemdetail.cfm?item_id=5264, last accessed October 8th, 2010.

European Construction Industry Federation, Construction in Europe. Key Figures | Activity 2008, Brussels: FIEC, June 2009 Edition.

European Council, Council Directive 92/57/EEC of 24 June 1992 on the Implementation of Minimum Safety and Health Requirements at Temporary or Mobile Construction Sites

European Council, Council Directive 2000/78/EC of 27 November 2000 Establishing a General Framework for Equal Treatment in Employment and Occupation.

European Council, Council Directive 89/106/EEC of 21 December 1988 on the Approximation of Laws, Regulations and Administrative Provisions of the Member States Relating to Construction Products

EFILWC (2007), European Foundation for the Improvement of Living and Working Conditions (EFILWC), Fourth European Working Conditions Survey, Luxembourg: Office for Official Publications of the European Communities, 2007

European Parliament and Council, Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the Energy Performance of Buildings

European Parliament and Council, Directive 2006/12/EC of the European Parliament and of the Council of 5 April 2006 on waste (Text with EEA relevance).

Eurostat, 2009, European Business – Facts and Figures, Ch. 16. Construction. http://epp.eurostat.ec.europa.eu/portal/page?_pageid=2293,59872848,2293_68195678&_dad=portal&_schema=PORTAL , last accessed May 26th, 2010.

Evbuomwan N.F.O., Anumba C.J., Towards a Concurrent Model for Design-and-Build Projects, The Structural Engineers, Vol. 74(5), 1996, p. 73-78.

Expert Group on New Skills for New Jobs, 2010, New Skills for New Jobs: Action Now. A report prepared for the European Commission. http://ec.europa.eu/social/main.jsp?catId=568&langId=en, last accessed October 8th, 2010.

FIEC, 2010, Construction in Europe: Key Figures. www.fiec.org, last accessed September 30th, 2010.

Gambatese J.A., Research Issues in Prevention through Design, Journal of Safety Research, Vol. 39, 2008, pp. 153-156

Gann D. M., Construction as a Manufacturing Process? Similarities and Differences between Industrialised Housing and Car Production in Japan, Construction Management and Engineering, Vol. 14, 1996, pp. 437 – 450.

Gann D. M., Putting Academic Ideas into Practice: Technological Progress and the Absorptive Capacity of Construction Organizations, Construction Management and Economics, Vol. 19, 2001, pp. 321 – 330

Gann D. M., Matthews M., Patel P., Simmonds P., Construction R&D, London: IPRA / Department of the Environment, 1992.

Gann D. M., Salter A. J., Innovation in Project-Based, Service-Enhanced Firms: the Construction of Complex Products and Systems, Research Policy, Vol. 29, 2000, pp. 955 – 972

García M. A., Challenges of the Construction Sector in the Global Economy and the Knowledge Society, International Journal of Strategic Property Management, Vol. 9, 2005, pp. 65-77

Gidado K. I., Project Complexity: the Focal Point of Construction Production Planning, Construction Management and Engineering, Vol. 14, 1996, pp. 213 - 225

Gyekye S. A., Salminen S. (2007) Workplace Safety Perceptions and Perceived Organizational Support: Do Supportive Perceptions Influence Safety Perceptions?, International Journal of Occupational Safety and Erogonimics, Vol 13(2), pp.189-200.

GridWise, 2009, Reliability Benefits of Interoperability, Gridwise Architecture Council. www.gridwiseac.org, last accessed Oct.28th, 09

Grupp, H., D. Fornahl, C.A. Tran, J. Stohr, T. Schubert, F. Malerba, F. Montobbio, et al. (2010), *National Specialisation and Innovation Performance*, Final Report Task 4, Horizontal Report 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission

Guy, Bradley, and Shell, Scott. Design for Deconstruction and Materials Reuse, Proceedings of

the CIB Task Group 39—Deconstruction Meeting, CIB Publication 272, 2002,

http://www.cce.ufl.edu/pdf/proceedings.pdf.

Hartmann A., The Context of Innovation Management in Construction, Construction Management and Economics, Vol. 24, 2006, pp. 567 - 578

Home Automation Europe. (2009). "Company homepage." Available from: http://www.homeautomationeurope.com/home.

Hooton R. D., Bridging the Gap between Research and Standards, Cement and Concrete Research, Vol. 38, 2008, pp. 247 - 258

Horbach, J. 2008, Determinants of environmental innovation – new evidence from German panel data sources, Research Policy, Vol. 37 (2008), 163-173.

IPCC (2007) Climate Change 2007: Synthesis Report. Core Writing Team, Pachauri, R.K. and Reisinger, A. (Eds.), IPCC, Geneva, Switzerland. pp 104.

Jaffe A. B., Peterson S. R., Portney P. R., Stavins R. N., Environmental Regulation and the Competitiveness of U.S. Manufacturing: What Does the Evidence Tell Us?, Journal of Economic Literature, Vol. 33(1), Mar. 1995, pp. 132 – 163

Johnson, W., 2007, Lessons from Japan: A comparative study of the market drivers for prefabrication in Japanese and UK private housing development. Report by the Bartlett School of Planning, Faculty of the Built Environment, University College London.

Kadefors A., Institutions in Building Projects: Implications for Flexibility and Change, Scandinavian Journal of Management, Vol 11 (4), 1995, pp. 395 – 408

Kadefors A., Björlingson E., Karlsson A., Procuring Service Innovations: Contractor Selection for Partnering Projects, International Journal of Project Management, Vol. 25, 2007, pp. 375 - 385

Klevorick A.K., R.C. Levinthal, R.R. Nelson, S.G. Winter, 1995, On the sources and significance of interindustry differences in technological opportunities. Research Policy 24(2), 185-205.

Koivu T., Mäntylä K., Loikkanen K., Appel M., Pulakka S., Innovaatiotoiminnan Kehittäminen Rakennus- ja Kiinteistöklusterissa. VTT Rakennus- ja yhdyskuntatekniikka, VTT Research Notes 2103, Espoo, 2001

Lansley P., Innovation: the Role of Research, Education and Practice, in Harlow P., (Ed.) Construction Papers, N. 58, CIOB, Ascot, 1996

Levine, M., D. Ürge-Vorsatz, C. Blok, L. Geng, D. Harvey, S. Lang, G. Levermore, A. Mongameli Mehlwana, S. Mirasgedis, A. Novikova, J. Rilling, H. Yoshino, P. Bertoldi, B. Boardman, M. Brown, S. Joosen, P. Haves, J. Harris and M. Moezzi (2007). Residential and commercial buildings. Climate Change 2007 - Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the IPCC. B. Metz, O. R. Davidson, P. R. Bosch, R. Dave and L. A. Meyer. Cambridge, United Kingdom and New York, NY, USA., Cambridge University Press: 387-446.

Lloyd’s Emerging Risks Team, 2007, Nanotechnology. Recent Developments, risks and opportunities, Lloyd’s Emerging Risks Team Report. http://www.lloyds.com/NR/rdonlyres/B9C7371E-83D4-49DD-8268-5D6C800FBDDF/0/ER_Nanotechnology_Report.pdf

Loosemore M., Andonakis N., Barriers to Implementing OHS Reforms – The experiences of Small Subcontractors in the Australian Construction Industry, International Journal of Project Management, Vol. 25, 2007, pp. 579 – 588

Love P., Gunasekaran A. Concurrent Engineering in the Construction Industry, Concurrent Engineering: Research and Applications, Vol. 5, 1997, p. 155-162.

Lu S.-L., Sexton M. (2006), Innovation in Small Construction knowledge-Intensive Professional Service Firms: a Case Study on an Architectural Practice, Construction Management and Economics, Vol. 24(12), 2006, pp. 1269-1282

MacLeod I.A., Kumar B., McCullough J. (1998), Innovative Design in the Construction Industry, Proceedings of the Institution of Civil Engineers: Civil Engineering, Vol. 126(1), 1998, pp. 31-38

Manley K.J. (2008), Against the Odds: Small firms in Australia Successfully Introducing new Technology on Construction Projects, Research Policy, Vol. 37 (10), 2008, p.1751-1764

Manley K.J., Marceau J., Hampson K.D. (2001), Technology Transfer and the Australian Construction Industry: Exploring the Relationship between Public-Sector Research Providers and the Research Users, Journal of Scientific and Industrial Research, Vol. 60, 2001, pp. 919-928.

Manchester Business School (2009), Study on Voluntary Arrangements for Collaboration in Construction: Final Report. Part 1: Main Report. http://ec.europa.eu/enterprise/sectors/construction/competitiveness/voluntary-arrangements_en.htm , last accessed May 20th, 2009.

Metcalfe and Georghiou (1998), Equilibrium and Evolutionary Foundations of Technology Policy, STI Review, Vol. 22: 75-100.

Matar M. M., Georgy M. E., Ibrahim, M. E. (2008), Sustainable Construction Management: Introduction of the Operational Context Space (OCS), Construction Management and Economics, Vol. 26(3), 2008, pp. 261 – 275

Miller R., Hobday M., L-Demers T., Olleros X. (1995), Innovation in Complex System Industries: the Case of Flight Simulators, Industrial and Corporate Change, Vol. 4 (2), 1995, pp. 363 – 400.

Miozzo M., Ivory C. (2008), Restructuring in the British Construction Industry: Implications of Recent Changes in Project Management and Technology, Technology Analysis and Strategic Management, vol 12 (4), 2008, pp. 513 - 531

Mitusch, K. and A. Schimke (2011) Gazelles – High-Growth Companies, Task 4 Horizontal Report 5, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission

Montalvo, C., P. ten Brink, C. Sartorious, M. Sotoudeh, D. Stromberg, C. Bowyer, M. Fergusson, J. Anderson, F. Sprei, A. Alhback, J. Nassén, R. Nemeskeri, P. Bodo, S. Schilder, F. Heil, G. Angerer, O. Wolf, L. Delgado, M. van Dijk and F. Lippman (2007). Policy pathways to promote eco-innovations (POPA-CTDA) – Scientific summary report. European Sixth Framework Program, Contract no. 502487. Delft, TNO - The Netherlands Organisation for Applied Scientific Research.

Myers D. (2005), A Review of Construction Companies' Attitudes to Sustainability, Construction Management and Economics, Vol. 23(8), 2005, pp. 781 - 785

National Institute for Occupation Safety and Health (NIOSH), www.cdc.gov/niosh/topics/construction/

OECD (2002) Design of Sustainable Building Policies: Scope for Improvement and Barriers, OECD, Paris.

OECD / Eurostat, Oslo Manual. Guidelines for Collecting and Interpreting Technological Innovation Data, Paris: OECD, 2005.

OECD Factbook 2007: Economic, Environmental and Social Statistics, 2007.

OECD Factbook 2009: Economic, Environmental and Social Statistics, 2009.

Pellicer E., Victory R., Implementation of Project Management Principles in Spanish Residential Developments, International Journal of Strategic Property Management, Vol. 10, 2006, pp. 233 – 248.

Phua F. T. T., Does Senior Executives' Perception of Environmental Uncertainty Affect the Strategic Functions of Construction Firms?, International Journal of Project Management, Vol. 25, 2007, pp. 753 – 761

Porter M., Competitive Strategy. New York: Free Press, 1980.

Porter M., van der Linde C., Green and Competitive: Ending the Stalemate, Harvard Business Review, 1995, pp. 120 - 134

PRC B.V., Study to Evaluate the Internal Market and Competitiveness Effects of Council Directive 89/106/EEC (Construction Products Directive, CPD), Final Report, Bodegraven (NL), 28 November 2006

Reichstein T., Salter A. J., Gann D. M., Last Among Equals: a Comparison of Innovation in Construction, Services and Manufacturing in the UK, Construction Management and Economics, Vol. 23(6), 2005, pp. 631 – 644

Rosenberg N., Inside the Black Box: Technology and Economics, Cambridge University Press, Cambridge, 1982

Russell A.D., Tawiah P., De Zoysa S., Project Innovation — a Function of Procurement Mode?, Canadian Journal of Civil Engineering, Vol. 33, (2006), pp. 1519–1537

Samuelson O., The IT-Barometer – A Decade's Development of IT Use in the Swedish Construction sector, Itcon, 13/1, 2008, p. 1 - 19

Sanden, B., S. Molander, M. Hassellöv, H, Fogelberg, 2008, Nanotech in our homes – great opportunities, unknown risk, Sustainability, Vol.3. Schartinger, D. (2010), *Sectoral Innovation Foresight Construction*, Final Report, INNOVA Sectoral Innovation Watch, Vienna.

Schartinger, D. (2010) *Sectoral Innovation Foresight – Construction Sector*, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Schidler, S., M. Sotoudeh, D. Stromberg, U. Fortkamp, J. Norrman, T. Krutzler, H. Frischenslager, I. Schindler, C. Montalvo, R. Kemp and M. Willems (2007). PERFORMANCE TARGETS IN PRODUCTION PROCESSES (PT-PRO), IPTS.

Science, Technology and Industry Outlook. Highlights, Organisation for Economic Development and Cooperation, OECD, Paris, 1999

Shami M. A., Comprehensive Review of Building Deconstruction and Salvage: Deconstruction Benefits and Hurdles, International Journal of Environmental Technology and Management, Vol. 6, 2006, pp.236-291

Shammas-Toma M., Seymour D., Clark L., Obstacles to Implementing Total Quality Management in the UK Construction Industry, Construction Management and Engineering, Vol. 16, 1998, pp. 177 – 192.

Squicciarini, M., A.-L. Asikainen, 2009, Sectoral Innovation Performance in the Construction Sector. Final report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission

Taskforce on Sustainable Construction, 2007, Accelerating the Development of the Sustainable Construction Market in Europe, Report composed in preparation of the Communication “A Lead Market Initiative for Europe”, COM(2007) 860 final.

Teece D. (1998) Capturing Value from Knowledge Assets: the New Economy, Markets for Know-How, and Intangible Assets, California Management Review, Vol. 40 (3), pp. 55 – 79

Toole T. M., Gambatese J.A., The Future of Designing for Construction Safety, Proceedings of the 2007 Construction Research Congress, ASCE, Grand Bahama Island, Bahamas, May 6-8, 2007.

Torcellini, P., S. Pless, M. Deru, and D. Crawley (2006), Zero Energy Buildings: A Critical Look at the Definition, Conference Paper NREL/CP-550-39833, June 2006.

Trajtenberg, M. (1990). A Penny for your Quotes. RAND Journal of Economics, 21, (1990), 172-187.

Tukker, A., S. Emmert, M. Charter, C. Vezzoli, E. Sto, M. Munch Andersen, T. Geerken, U.Tischner, S. Lahlo. 2008, Fostering Change to Sustainable Consumption and Production: An Evidence-Based View. Journal of Cleaner Production 16, 1218-1225.

UK Technology Strategy Board, Low Impact Buildings, Innovation Platform. http://www.innovateuk.org/ourstrategy/innovationplatforms/lowimpactbuilding.ashx

Uihlein, A. and P. Eder (2009). Towards additional policies to improve the environmental performance of buildings.

von Hippel E. The Dominant Role of Users in the Scientific Instrument Innovation Process, Research Policy, Vol. 5, 1976, p. 212-239.

von Hippel E., The Sources of Innovation, Oxford University Press, New York and Oxford, 1988

Weinstein M., Gambatese J., Hecker S., Can Design Improve Construction Safety?: Assessing the Impact of a Collaborative Safety-in-Design Process, Journal of Construction Engineering and Management, Vol. 131(10), Oct. 2005, pp. 1125-1134

Widén K., Hansson B., Diffusion Characteristics of Private Sector Financed Innovation in Sweden, Construction Management and Economics, Vol. 25(5), 2007, pp. 467 - 475

Willis M. A., The Effects of Cyclical Demand on Industry Structure and on the Rate of Technological Change: An International Comparison of the Housebuilding Sectors in the United States, Great Britain and France, UMI Ann Arbor (Mich), 1987

Winch G.M.´, Institutional Reform in British Construction: Partnering and Private Finance, Building Research and Information, Vol. 28 (1), 2000, p.141-155

Winch G. M., How Innovative is Construction? Comparing Aggregated Data on Construction Innovation and Other Sectors - a Case of Apples and Pears, Construction Management and Economics, 2003, Vol. 21(6), pp. 651 - 654

Wissenschaft im Brennpunkt, 2009, Home, smart home. Deutschlandfunk, Sendezeit 26.04.2009, 16:30. http://www.dradio.de/dlf/sendungen/wib/951427/

World Business Council for Sustainable Development, 2009, Energy Efficiency in Buildings. Transforming the Market. www.wbcsd.org, Nov. 2009.

Annex Overview SIW deliverables

Overview of the deliverables from the Europe INNOVA Sectoral Innovation Watch

Deliverables can be downloaded from www.europe-innova.eu

Task 1 Innovation Performance Sectoral Reports

Ploder, M., C. Hartmann, E. Veres, B. Bertram (2010) Sectoral Innovation Performance in the Automotive Sector, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010, revised December 2010

Enzing, C.M. and T. van der Valk (2010) Sectoral Innovation Performance in the Biotechnology Sector, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, November 2010

Squicciarini, M. and A.-L. Asikainen (2010) Sectoral Innovation Performance in the Construction Sector, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010

Broek, van den T. and A. van der Giessen (2010) Sectoral Innovation Performance in the Electrical and Optical Equipment Sector, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010

Leis, M. (2010) Sectoral Innovation Performance in the Food and Drinks Sector, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, March 2010

Gotsch, M., C. Hipp, J. Gallego and L. Rubalcaba (2010) Sectoral Innovation Performance in the Knowledge Intensive Business Services, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010

Giessen, van der A. and M. Poel (2010) Sectoral Innovation Performance in the Space and Aeronautics Sectors, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010, revised April 2011

Dachs, B. and G. Zahradnik (2010) Sectoral Innovation Performance in the Textiles and Clothing Sector, Final Report Task 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, May 2010

Schaffers, H., F. Merino, L. Rubalcaba, E.-J. Velsing and S. Giesecke (2010 Sectoral Innovation Performance in the Wholesale and Retail Trade Sectors, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010

Task 2 Foresight Reports

Leitner, K.-H. (2010) Sectoral Innovation Foresight – Automotive Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Valk, van der T., G. Gijsbers and M. Leis (2010 Sectoral Innovation Foresight – Biotechnology Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Schartinger, D. (2010) Sectoral Innovation Foresight – Construction Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Broek, van den T. and A. van der Giessen (2010 Sectoral Innovation Foresight - Electrical and Optical Equipment Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Leis, M., G. Gijsbers and F. van der Zee (2010) Sectoral Innovation Foresight – Food and Drinks Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Dachs, B. (2010) Sectoral Innovation Foresight – Knowledge Intensive Business Services Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Brandes, F. and M. Poel (2010) Sectoral Innovation Foresight – Space and Aeronautics Sectors, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010, revised April 2011

Zahradnik, G., B, Dachs and M. Weber (2010 Sectoral Innovation Foresight - Textiles and Clothing Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Giesecke, S. and P. Schaper-Rinkel (2010) Sectoral Innovation Foresight - Wholesale and Retail Trade Sector, Final Report Task 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2010

Task 3 Market and Regulatory Factors

Montalvo, c. and O. Koops (2011) Analysis of market and regulatory factors influencing innovation: Sectoral patterns and national differences, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Montalvo, C., K. Pihor and M. Ploder (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Automotive Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Montalvo, C., F. Diaz Lopez, C. Enzing and K. Koman (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Biotechnology Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Montalvo, C., K. Pihor, J. Hyönen, T. Loikkanen (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Construction Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Montalvo, C., K. Pihor and T. van den Broek (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Electrical and Optical Equipment Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Montalvo, C., M. Mayer and F. van der Zee (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Food and Drinks Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Montalvo, C., F. Diaz Lopez, M. Gotsch and C. Hipp (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Knowledge Intensive Business Services Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Montalvo, C., A. van der Giessen and F. Brandes (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Space and Aeronautics Sectors, Final Report Task 3, Europe

INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Montalvo, C., K. Pihor and B. Dachs (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Textiles and Clothing Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Montalvo, C., H. Schaffers and K. Pihor (2011) Analysis of market and regulatory factors influencing sector innovation patterns – Wholesale and Retail Trade Sector, Final Report Task 3, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Task 4 Horizontal Reports

H. Grupp†, D. Fornahl, C.A.Tran, J. Stohr, T. Schubert, F. Malerba, Montobbio F., L. Cusmano, E. Bacchiocchi, F. Puzone, (2010) National Specialisation and Innovation Performance, Final Report Task 4 Horizontal Report 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, March 2010

H. Grupp†, D. Fornahl, C.A.Tran, J. Stohr, T. Schubert, F. Malerba, Montobbio F., L. Cusmano, E. Bacchiocchi, F. Puzone (2010) Appendix to National Specialisation and Innovation Performance, Final Report Task 4 Horizontal Report 1, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, March 2010

Rubalcaba, L, J. Gallego, C. Hipp, and M. Gotsch (2010) Organisational Innovation in Services, Final Report Task 4, Horizontal Report 2, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, February 2010

Dachs, B., I. Wanzenböck, M. Weber, J. Hyvönen and H. Toivanen (2011) Lead Markets, Final Report Task 4, Horizontal Report 3, for DG Enterprise and Industry, European Commission, March 2011

Montalvo, C., Diaz Lopez F.J., and F. Brandes, (2011) Potential for eco-innovation in nine sectors of the European economy, Final Report Task 4, Horizontal Report 4, Europe INNOVA Sectoral Innovation Watch, DG Enterprise and Industry, European Commission, December 2011

Mitusch K. and A. Schimke (2011) Gazelles – High-Growth Companies, Final Report Task 4, Horizontal Report 5, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, January 2011

Task 5 Input and Output Papers

Mitusch, K., C.A. Tran, J. Stohr, F. Montobbio, L. Cusmano and F. Malerba (2010) National Specialisation Report, Input Paper to the workshop ´Tomorrow's innovative industries: Regional and national specialisation patterns and the role of the regional business environment', Task 5, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, May 2010

Mitusch, K, C.A. Tran, F. Montobbio, L. Cusmano and F. Malerba (2010) National Specialisation Report, Output Paper to the workshop ´Tomorrow's innovative industries: Regional and national specialisation patterns and the role of the regional business environment', Task 5, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, June 2010

Rubalcaba L., J. Gallego and Hipp C. (2011) Organisational innovation, service innovation, and the value chain: New trends and policy implications. Input paper for the Workshop on the 25th of January 2011, Task 5, Europe INNOVA Sectoral Innovation Watch, DG Enterprise and Industry, European Commission, January 2011

Rubalcaba, L, J. Gallego, C. Hipp, and M. Gotsch (2011) Organisational innovation, service innovation, and the value chain: New trends and policy implications. Output paper of the Workshop

Services Innovation and Value Chains on the 25th of January 2011, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, February 2011

Mitusch, K. and A. Schimke (2011) Gazelles – High-Growth Companies, Input Paper to the workshop 'Gazelles as drivers for job creation and innovation: How to support hem best?', Task 5, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission January 2011

Mitusch, K. and A. Schimke (2011) Gazelles – High-Growth Companies, Workshop Output Paper 'Gazelles as drivers for job creation and innovation: How to support hem best?', Task 5, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, February 2011

Final Sectoral Reports

Ploder, M. (2011) Sectoral Innovation Watch – Automotive Sector, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Enzing,. C. (2011) Sectoral Innovation Watch – Biotechnology Sector, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Loikkanen, T. and J. Hyvonen (2011) Sectoral Innovation Watch – Construction Sector, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Broek, van den T. and A. van der Giessen (2011) Sectoral Innovation Watch – Electrical and Optical Equipment Sector, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Leis, M. (2011) Sectoral Innovation Watch – Food and Drinks Sector, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Gotsch, M., C. Hipp, J. Gallego and L. Rubalcaba (2011) Sectoral Innovation Watch – Knowledge Intensive Services, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Schaffers, H., L. Rubalcaba, F. Merino, S. Giesecke, P. Schaper-Rinkel, E.-J. Velsing, and C. Montalvo (2011) Sectoral Innovation Watch – Wholesale and Retail Trade Sector, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Giessen, van der A. (2011) Sectoral Innovation Watch – Space and Aeronautics Sectors, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011

Dachs, B., G. Zahradnik and M. Weber (2011) Sectoral Innovation Watch – Textiles and Clothing Sector, Final Sector Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, December 2011

Final Synthesis Report

Montalvo C. and A. van der Giessen (2011) Sectoral Innovation Watch – Synthesis Report, Europe INNOVA Sectoral Innovation Watch, for DG Enterprise and Industry, European Commission, December 2011.