



Aalborg Universitet

AALBORG UNIVERSITY  
DENMARK

**Towards a new role for building materials manufacturers in construction projects**  
*a case study of energy requirements*

Forman, Marianne; Gottlieb, Stefan Christoffer; Haugbølle, Kim

*Published in:*  
Proceedings of the Joint CIB International Conference

*Publication date:*  
2012

*Document Version*  
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

*Citation for published version (APA):*  
Forman, M., Gottlieb, S. C., & Haugbølle, K. (2012). Towards a new role for building materials manufacturers in construction projects: a case study of energy requirements . In N. Thurairajah (Ed.), *Proceedings of the Joint CIB International Conference: Management of Construction: Research to Practice* (pp. 1074-1085). Birmingham School of the Built Environment, Birmingham City University.  
[http://www.bcu.ac.uk/\\_media/misc/hosted/montreal2012/index.html](http://www.bcu.ac.uk/_media/misc/hosted/montreal2012/index.html)

**General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal -

**Take down policy**

If you believe that this document breaches copyright please contact us at [vbn@aub.aau.dk](mailto:vbn@aub.aau.dk) providing details, and we will remove access to the work immediately and investigate your claim.

# Towards a new role for building materials manufacturers in construction projects - a case study of energy requirements

Marianne Forman, maf@sbi.aau.dk

Danish Building Research Institute, Aalborg University

Stefan Christoffer Gottlieb, stg@sbi.aau.dk

Danish Building Research Institute, Aalborg University

Kim Haugbølle, khh@sbi.aau.dk

Danish Building Research Institute, Aalborg University

## Abstract

*To meet the expectations of demanding clients, new project-delivery configurations have been developed. Concurrently, the building sector faces increasing demands from building authorities, most recently in the shape of the new requirements to energy performance as implemented in the Danish Building Regulations. Approaches focusing on performance-based building or new procurement processes such as new forms of collaboration between actors in construction projects and the development of integrated solutions are considered solutions that improve the industry's overall performance. Often building materials manufacturers are perceived, not as part of the construction project, but as suppliers of the construction project and their traditional target groups are architects and consultants. This paper focuses on new types of collaboration between a construction project and building materials manufacturers, where building materials manufacturers are oriented towards clients through direct cooperation, or new types of services aimed at clients. The research investigates the consequences for construction projects and actors. The research is based on qualitative case studies of major manufacturers of building components towards new roles in construction projects. The analysis shows firstly that building materials manufacturers can take on different roles in procurement processes from new ways to collaborate with the client to offering new types of services to the client. Secondly, the analysis shows that building materials manufacturers – in the new role - influence the innovation process. Thirdly, the analysis shows that in order to understand the relationship between regulation and innovation in the construction project, and to identify new ways to promote energy innovation in construction, it is not sufficient to examine the project-based companies' opportunities for innovation, including how they can reclaim the chain, but it is equally important to examine the building materials manufactures' capacity for innovation and how this innovation affects the chain, i.e. a symmetrical analysis.*

**Keywords:** Building performance, Green buildings, Innovation, Procurement, Regulation

## 1. Introduction

Improving building energy performance is perceived as a central part of the solution to climate change. In Denmark, building energy performance has long been in focus, initially prompted by the energy crises in the 1970s and today based on environmental and climate debate. Since then, energy strategies as reflected in the Danish Building Regulations have changed character reflecting differences in the understanding of the problem and possible solutions, who are the relevant actors, how must the phenomenon be defined and governance structure used. Overall, one can describe the evolution as a shift from prescriptive regulation to performance-based regulation.

Regulation affects individual companies and overall delivery system innovation and it is clear, since regulation is part of the institutional context in which companies operate. The question is how regulation affects the respective individual company and innovation in the overall delivery system, including the relationship between companies in the overall delivery system. The building industry is characterised by delivering complex products in complex production systems that often distinguish between project-based companies (architects, consultants and contractors) and industry-based companies that provide building materials and components for the building project (Gann & Salter, 2000).

This paper builds on the hypothesis that the relationship between regulation as a driver of innovation of the materials manufacturers in the construction industry and the importance of innovation for the building project is not sufficiently elucidated. Existing analyses of the regulation's impact on innovation in construction projects is often based on project-based companies and not the suppliers (see e.g. Gann et al. 1998). This results in the focus of analysis often being on how the project-based businesses can require demands directed upstream in the supply system as part of an innovation process. Therefore, there is a lack of knowledge about suppliers' influence and role in the innovation process in the construction project.

This paper addresses first the importance of building regulations as a driver of innovation among building materials manufacturers and second, how this innovation influenced the construction project, i.e. downstream in the delivery system. It is concluded that in order to understand the process of innovation in the building project, it is equally necessary to understand building materials manufacturers influence downstream in the delivery system, as it is to understand the project-based business requirements directed upstream in the delivery system.

## 2. Methods

This paper intends to identify key theoretical and empirical issues that can support further research into energy regulation and innovation in construction. Since energy is a relatively new field compared with other regulatory areas of the Danish Building Code, such as safety and fire conditions, it also contributes to the elucidation of the development and stabilisation processes in the interaction between regulation that drives innovation and the importance of construction. It is assumed that

regulatory initiatives within energy play a significant role in the actors' understandings and interpretations of the relationship between construction and energy, among other things confirmed by a Danish survey on standard-house manufacturers' innovation where innovation in energy appeared as one of the main areas of innovation in recent years. The manufacturers saw the new energy requirements of the regulation as the main reason for innovation within energy. Other important areas of innovation such as design and planning manufacturers stated to be market driven to greater extent (Forman et al., 2011). This does not mean that the study cannot contribute to the more general knowledge about the relationships between regulation as a driver for innovation and innovation in construction and the importance of new forms of procurement and construction management, but the study's particular strength is the knowledge of the implementation of new areas where the building industry as a system is under pressure.

The analysis was conducted as a case study focusing on the shift from descriptive energy regulation to performance-based energy regulation and the shift's influence on the building materials manufacturers' innovation.

In order to describe the evolution of energy regulation in the Danish Building Code, the various building codes were reviewed and additional literature was studied. When reviewing the various initiatives in the Danish Building Code, the development was analysed to identify changes in regulation.

We then turn to a case study describing the interaction between regulation and innovation activities in Rockwool - a large building materials manufacturer. Rockwool A/S has many features in common with other suppliers of materials to the building sector. These are often large companies with their own product-development departments and marketing departments. They supply components to the building sector, and their most important target groups are usually architects, consultants, contractors and DIY people. In this sense, the case is paradigmatic and the experience gained from the case can be generalised concerning other similar manufacturers. To describe the interaction between regulation and innovation activities, documentation from Rockwool's website was used as well as newsletters, articles from the technical press and interviews with employees at Rockwool.

### **3. Theoretical perspectives**

#### **3.1 Construction and innovation**

Buildings are generated by integrating many products and services that together form a complex product system (Gann and Salter 2000). Unlike traditional industry, the dominant mode of production in construction is project based, where a large number of independent companies have to operate in networks with complex interfaces. Gann and Salter (2000) point out that as a consequence innovation, performance and competitiveness depend not only on the individual company, but the interaction across the network between clients, architects, consultants, contractors, building component suppliers and end-users, etc. There are major differences in the conditions of the

individual building projects, and it affects the different actors' ability to plan and execute construction and their ability to be innovative. Conditions that may affect are for example, differences in building type (detached, multi-storey buildings, unique buildings, etc.), differences in the size of the building case (if the building case is new or a renovation project), or differences in the tender forms and the clients position in the project organisation.

Rohracher (2001) suggests that an approach to understanding the opportunities and constraints to innovation in construction is to analyse the building and the actors involved as a socio-technical system, i.e. to analyse dependencies and conditions, but also interests, perspectives and stakeholder interaction. Typical concepts used in analysing socio-technical systems are concepts such as critical issues, technological style and technological momentum. Rohracher (2001) suggests that one can make analyses at two levels: 1) the national and regional level and 2) the project level. In connection with the national / regional innovation system, the interaction is weighted between industry, government and market together with the regulation and education, financial instruments etc. With the project level as a socio-technical system, the focus will be on each construction project. Rohracher (2001) suggests that traditional buildings as technical systems are different from other artefacts such as cars, because there is not in the same way a close technical relationship between all sub-components, which reduces the requirement for close interaction between the actors. Building systems are therefore more loosely coupled systems, being dependent on the interaction between actors (architects, planners, consultants, contractors, building services, etc.) that, when setting up a project, will be wired up to the project until it is over (Dubois and Gadde 2002).

Gann and Salter (2000) identified three types of innovation driver: 1) Demand for radically new types of buildings and structures. 2) Pressure to improve the ways in which projects can be delivered on time, within budget to specified quality. 3) Competition between companies in construction itself, as firms compete in their quest to secure orders and deliver new product and services (Gann and Salter, 2000 pp. 960-961). One of the questions in this paper is how the driver influences materials manufacturers and affects relationships / roles in the construction project.

Gann and Salter (2000) suggest that there is a growing need for new types of services to support the owner and users' use of complex products and systems in relation to for example management and maintenance of building systems. Gann and Salter (2000) further suggests that it is very consistent products and services that create new opportunities for customers in terms of increased performance and increased value. The market is generally very fragmented in relation to different types of products and the production is driven by demands of clients in the individual building projects rather than the result of arms-length market transactions, which typify consumer-goods industries. This distinguishes it from traditional industrial production and turns the procurement / ordering activity into a particular job in construction. One can therefore talk about the need for special services as early as at the procurement stage of construction.

With the current energy demands and future challenges for the construction for climate adaptation, complexity may well increase. It is often necessary to integrate complex products and systems within existing systems to manage products and systems to function in the context that they form part of. Gann and Salter (2000) suggest that the level of technical complexity increases when new generations

of technology must integrate with existing systems. A need arises for new specialisations that can support system integration. The location of the new specialisations can be placed in different parts of companies or between companies; but that it is the project-based companies that are positioning themselves in a role to provide system integration services (Gann and Salter, 2000). In this paper, we indicate that there may be a need to explore the various system integration services that can be developed at different actors.

### 3.2 Regulation as driver for innovation

A distinction is often made between prescriptive approaches and performance-based approaches. Performance-based building is perceived as a shift from the traditional prescriptive approach, where building parts are described, specified and procured, resulting in a building with an implicit set of attributes. The performance-based approach, on the other hand, sets "*...the criteria that define the level of performance required of the building attributes*" (Sexton and Barrett, 2005:143).

Gann et al. (1998) studied the effectiveness of performance-based regulations in creating an environment for product development in construction. They distinguish between four types of innovation that should be taken into account if the purpose of regulation is to promote technological innovation:

1. Product innovation in the materials and components area, which is often a result of R&D activities by manufacturers. Product innovation is mostly limited to changes that improve the individual product without the use of the product requiring changes in other products.
2. Process innovation is the use of new ways to assemble buildings or install components, and this type of innovation is often the result of designers' and builders' efforts to improve the design and construction process.
3. Configurational innovation: when the existing component parts are combined in new ways to improve performance characteristics. This typically arises in the design phase.
4. Systemic innovation: when changes to a component or subsystem causes the need for changes in other parts of the system to be implemented.

They conclude that regulation has to focus on two approaches with respect to innovation in construction, one affecting innovation at the component level and the other affecting innovation at the whole systems level, and they further conclude:

*"The current focus of regulating design and building activities must be able to translate into a system of incentives and certification which encourage a successful flow of ideas between designers and builders responsible for final product development, integration and assembly, and upstream component innovation by materials producers and suppliers."* (Gann et al. 1998, p 293)

What remains is a picture with a clear division of labour between building materials manufacturers and project based companies where building materials manufacturers are assigned a role in relation to type 1 innovations, while the project-based companies are assigned a role in relation to types 2, 3 and 4 for innovation in construction. The question is whether this division reflects the recent experience in Denmark?

### **3.3 Client and users**

There is a growing awareness of clients' and users' role in innovation in construction. This is translated into strategies such as “clients as change agents” and “user-driven innovation”. The specific conditions and opportunities under which the construction industry operates are also important for the clients' and users' role in construction innovation processes.

Project organisation in the construction industry means that for every new construction project, the corresponding actor network is configured anew. At the same time, the project-based production of the building means that there is an ordering activity in each project about making explicit requirements for building process and design criteria for building. This “ordering” activity can be handled by the manufacturing system, the clients or the end-users. There is thus a need for "mediation" between manufacturers, clients and end-users in the design and construction phase, where mediation can take many forms, involve many players and is marked by the interpretation and negotiation processes taking place in and between the actors (Forman et al. 2011).

In order to perform ordering activity, a particular profession, "the client", has emerged, which is supported institutionally through both regulation where the client is assigned responsibilities and duties, and through an organisation of professional clients in the Client Association in Denmark. It is worth noting that despite this professionalisation and institutionalisation of the client's role, there is still a struggle about who best represents the users in a building project. The architects can for example rightly argue that they are the ones who through the design process, interpret and translate user needs. This very loose definition of which actor represents the users in a building project can be taken as an indication that the area is not stabilised. This fact supports the need for a comprehensive exploration of all the mediating mechanisms brought into play between production systems, clients and users.

There is an ongoing discussion within building research about who the "users" are in construction. Many highlight both the different actors in the construction process and the various actors who maintain and use the completed building as potential users. This broad user definition can find its explanation in that the building is composed of many processes that turn the architect into a user of the building materials manufacturer's products in the design process, the craftsman into a user of materials and tools in the execution phase and the end-user into a user of the home (Forman et al. 2011).

As early as 1993, Slaughter (1993) published her study on user innovation among contractors pointing out that contractors were good at innovating in connection with implementation of building

components in the construction process and that a special feature was the solutions provided for the integration of diverse components into a unified whole. At the same time she showed that the innovative solutions that manufacturers chose to include in their product solutions were confined to their own product and not the interfaces between the products. Slaughter wrote that: *"User-builders created most of the innovations in this study; They draw upon their extensive construction experience to create new elements which they then employ. This reservoir of past learning appears to provide opportunities for these users to create innovations which are both inexpensive and rapidly deployed. In addition, these innovations explicitly address problems associated with integrating disparate components into a well-functioning whole unit. In contrast, the innovations commercialized by panel manufacturers only change the product and not its connections to other building components."* (Slaughter, 1993, p 81-82). Slaughter concluded at the time that the building materials manufacturers had the understanding that there was only a very small market for interface innovations. They had a tendency to perceive the interface innovations between different components as specialised applications or customer orders, rather than seeing them as new product development opportunities. This result therefore supports the view of Gann et al. (1998) that building materials manufacturers' innovation is bound to the individual component. The question is whether it still applies.

## **4. Case**

The following case study focuses on the Danish energy regulation as driver for innovation by a building materials manufacturer. First the Danish Building Code is described in terms of energy requirements. Developments resulted in a change from descriptive regulation to performance-based regulation. Then a description of the importance of a major building materials manufacturer's innovation process follows. Finally, it is described how the changes contribute to creating and stabilising a new role for the building materials manufacturers in construction.

### **4.1 Energy regulation and construction in Denmark**

Development in energy regulations in the Danish Building Code can be divided into three strategies, each of which represents a shift in perspective on the relationships between energy and construction. A fourth strategy is visible and involved in the description, since it already exists as a plan and idea for the future relationship between construction and energy, and therefore already serves as driver for innovation among the actors in the construction. The four strategies are based on an understanding of a building as: 1) a building composed of elements with a focus on heat loss, 2) a building that consists of building components and interfaces between building components with a focus on heat loss and line loss, 3) a building as a product with a focus on building energy performance, and 4) a building as part of an energy system focusing on the building's interaction with the energy system. The four strategies are described in the following.

#### **4.1.1 A building composed of elements with a focus on heat loss**

The first Danish Building Code came in 1961 and prior to this regulation of energy did not play a big role (Møller et al., 2011). In the first Building Code, there was a requirement to the U-value of the building parts. "*The U-value is the amount of heat loss in watts by  $m^2$  of the element at a temperature difference of 1 kelvin (or degree Celsius). U-value, the unit  $W/m^2 K$* " (Aggerholm et al. 2007 p. 11) (authors' translation). These requirements for U-values reflected good general practice in newer buildings at the time. With the oil / energy crisis in the 1970s focus on energy increased and in 1977 the requirements to U-values increased with the intention of driving the market (Møller et al. 2011).

In addition to requirements that were directly relevant for manufacturers, in this period requirements were also introduced that were directed at other players in building. In 1982, a requirement was introduced regarding the insulation thickness and how large window areas may be in a building (Jensen et al., 2007), which is likely to have played a special role for architects and consultants in connection with design and engineering processes. In 1997, an energy label was introduced and an energy consultancy scheme for small and large buildings that affect the market for buildings. In spite of criticism, the Danish energy label served as a model for the European energy label, which replaced the two schemes in 2007 (Jensen et al., 2007).

#### **4.1.2 A building that consists of building components and interfaces between building components with a focus on heat loss and line loss**

In 2001, in addition to requirements to U-values a requirement for line loss was introduced to prevent thermal bridges at specific building components. "*Line loss is heat loss through 1 m of the element and measured in  $w / m K$* " (Aggerholm et al. 2007 p. 11 (authors' translation). This meant that the focus of the Building Code changed from focusing solely on the requirements for the individual building elements to dealing with interfaces between building elements, for example doors and windows.

#### **4.1.3 A building as a product with a focus on building energy performance**

In 2006, the Danish Building Code (BR06) introduced a new requirement to the energy performance of buildings based on energy frames, which represents a shift from descriptive regulation to performance-based regulation. The use of energy frames as the main requirements of new construction was a result of the EU Directive on Energy Performance of Buildings (Aggerholm et al. 2007.)

Aggerholm et al. states: "*Energy requirements for new construction are based on the energy frames that cover the building's overall need for additional energy for heating, hot water, cooling, ventilation, and lighting are avoided....*" (Aggerholm et al. 2007 p.11) (authors' translation).

And further:

*"When calculating the energy requirement takes into account the building envelope, building location and orientation, including daylight and outdoor climate, heating and hot water, building heat accumulating properties, possibly ventilation and climate cooling, solar and solar shading, natural ventilation and the designed indoor climate. In determining the energy requirements may also be taken into account e.g. the use of solar thermal, photovoltaics, heat pumps, condensing boilers, district heating, use of heat recovery and cooling with ventilation at night." (Aggerholm et al. 2007 p.12) (authors' translation).*

The total change in BR06 was:

- That an energy calculation has to be provided together with the application for a building permit,
- That new buildings comply with an energy frame provision,
- That specific energy requirements to extensions and larger renovations/refurbishments are complied with,
- That requirements to the tightness of new buildings are complied with,
- That low energy buildings are classified in two classes,
- That new buildings have to be energy labelled before they are taken into use (Aggerholm et al., 2007 p.10).

These requirements are further strengthened in the subsequent changes in the Building Code, most recently with the latest in 2010.

#### **4.1.4 Building as part of an energy system focusing on the building's interaction with the energy system (future)**

The images that characterise tomorrow's ideas and plans for a causal relationship between buildings and energy is based on the concept of a smart grid. Buildings are seen in this perspective as part of an energy system, where buildings are not only energy consuming, but also energy-producing and additional buildings have an active role as flexible units in which energy can be used flexibly and stored. One challenge by using renewable energy etc. is to find solutions to the coupling between energy production and the consumption of energy, because energy is produced when the conditions are present such as wind, solar and also difficult to store, which means that it is optimal to consume energy when it is produced. Key solutions in future ideas and plans are flexible and intelligent solutions based on decentralised buffer systems/storage devices and intelligent control of consumption so that the consumer that only has to take place within a time interval, puts stress on the energy system when it is most appropriate for the energy system ([www.kemin.dk](http://www.kemin.dk)).

## 4.2 Examples of innovation by a Danish building materials manufacturer

Rockwool A/S is a major supplier of materials to the building sector. The company develops, produces and sells insulation products and forms part of the Rockwool Group, which operates globally. Rockwool A/S has its own product-development departments as well as marketing departments. Sales are made through dealers. Due to the shift towards performance-based regulation in the Danish Building Code in 2006 Rockwool focused among other things on the classification of low-energy building and the requirement to the tightness of new buildings. Just before the implementation of the new requirements in the regulation, Rockwool collaborated with an architect and a standard-house manufacturer to develop a low-energy-house to demonstrate how it could be done. They also developed an airtightness programme consisting of different products that can be used in the building process to ensure tightness of a building. The tightness programme was developed to meet the new requirements in BR06.

In 2007, an employee at Rockwool Denmark built a low-energy house for his family. As the employee began to focus on tightness and energy in his building project, the product manager at Rockwool saw a possibility for testing the tightness programme in practice. Furthermore Rockwool saw in the employee's project an opportunity for getting into contact with the users in a new and closer way. By following the project at Rockwool's homepage and describing the process as an ongoing story, they could give some practical instructions concerning the problems that occur when you build and have to integrate considerations of energy performance. This was new for many actors and the homepage received widespread attention. The central actors in the building process were the employees, the suppliers and craftsmen. The employees chose all the suppliers and craftsmen. Concerning Rockwool's development of the homepage, the product manager and employees from the marketing division participated. The product manager was responsible for coordinating the product aspects concerning the homepage, including contact to the suppliers, while the employees from the marketing division were responsible for the rest. At the time of the case study, low-energy buildings were not very common in Denmark. However, to ensure an overview of the complex concept, each of the suppliers was asked to write informatively about the specific problem area at which their product was targeted and the solutions provided by the products. By giving the suppliers space on the homepage, the actor network became visible. By linking the homepages you also link information, and the user needs linked information in a complex system, as a guided way of finding his way around the homepages. As the project was connected with Rockwool, a challenge emerged concerning Rockwool's relations with suppliers in general and how Rockwool could avoid favouring some over others. Rockwool cooperates with many suppliers and usually does not favour one supplier over others. To prevent favouring specific suppliers, the communication of the case has stressed that the selection of suppliers is made by the employee, not Rockwool. At that time Rockwool didn't clarify how this dilemma could be solved in the future about on one hand the wish to participate in projects with other suppliers and on the other hand to treat all suppliers the same. Later Rockwool prepared a list of suppliers whose products met the requirements for low-energy houses. They have limited the list to windows, ventilation, heat-systems and Installations for pre-heating / cooling of the fresh air through soil. Rockwool have developed the list in cooperation with an engineering firm, and suppliers can contact Rockwool if they want to be included at the list. The purpose of the list is to facilitate the development of low-energy and passive houses ([www.Rockwool.dk](http://www.Rockwool.dk))

### **4.3 Towards a new role for building materials manufacturers in the construction project/innovation**

There are three aspects that will be highlighted here. Firstly, Rockwool developed a new marketing method in which the testing of new products, development of new technical building solutions and promotion of the products are integrated processes that take place in a public space on Rockwool's homepage. This new marketing method required a new openness from the company and a redefinition of the kind of experience that it is possible to share with the market. Second, the development of new types of supplier alliances through the development and publication of a "vendor list" at the Rockwool site changed the notion that all suppliers must be "free and independent". Thirdly, Rockwool's product was incorporated in a concept of low-energy houses. The virtual network that links products, information and suppliers can shape the frame for concepts of low-energy houses. It makes it possible not only for the professional construction actors, but also clients and users to relate to the whole and to the individual components. This can be perceived as a new type of service to support the building process.

## **5. Conclusion**

Existing analyses of correlations between performance-based regulation and innovation in the construction project is usually based on project-based companies and focus on how requirements for innovation and new types of products and services can be sent upstream in the supply chain. This paper suggests that performance-based regulation to a great extent influences the building materials manufacturers' innovation and they develop new types of services and products in relation to all types of innovation (component, process, configuration and system). This innovation is important for the construction project both in terms of design, engineering and construction, and the relationships and division of labour between suppliers and the traditional project-based companies (architects, consultants and contractors). To understand the relationship between regulation and innovation in the construction project, and identifying new ways to promote energy innovation in construction, it is not sufficient to examine the project-based companies' opportunities for innovation, including how they can reclaim the chain, but it is equally important to examine the building materials manufactures' capacity for innovation and how this innovation affects the chain, i.e. a symmetrical analysis. This is no less relevant given the challenges that building faces with regard to energy development where the future boundary appears at the system level, requiring the integration of products and services at the system level with even more players and complex problems to be solved and a growing need for packaged product and service deliveries to the users of buildings.

## **6. Acknowledgements**

The authors gratefully acknowledge the financial support of the Danish Agency of Enterprise and Construction to the project "Procuring and Operating Complex Products and Systems in Construction".

## 7. References

Aggerholm, S. & Grau, K. (2007) *Bygningers energibehov: Beregningsvejledning* (SBI-anvisning 213). Hoersholm (DK): Statens Byggeforskningsinstitut.

Dubois, A. & Gadde, L.E. (2002) The Construction Industry as a loosely coupled system: Implications for productivity and innovation, *Construction Management and Economics*, 20, 621-631.

Forman, M., & Haugbølle, K. (2011) The role of clients/end-users in the innovation of detached houses. ARCOM

Forman, M. & Haugbølle, K. (2011) Brugere og innovation I byggeriet, in Juul Kristensen, K and Voxsted, S. (Eds.) *Innovation og Entreprenørskab*, Hans Reitzels Forlag, Copenhagen

Gann, D. M., Wang, Y. & Hawkins, R. (1998) Do regulations encourage innovation? – the case of energy efficiency in housing. *Building Research & Information*, 26(4), 280-296

Gann, D.M. & Salter, A.J. (2000) Innovation in project-based, service-enhanced firms: the construction of complex products and systems. *Research Policy*, 29, 955-972

Jensen, J. O. & Gram-Hansen, K. (2007) Økologisk modernisering af bæredygtigt byggeri – forandringer, potentialer og problemer, in Holm, J., Kjerulf Petersen, L., Læssøe, J., Remmen, A. and Hansen, C.J. (Eds) *Økologisk modernisering på dansk, Brud og bevægelser i miljøindsatsen*, Frydenlund, Denmark

Møller, E.B., de Place Hansen, E.J. & Brandt, E. (2011) Performance and Durability of External Post-Insulation and Added Roof Constructions, *Proceedings of the 12<sup>th</sup>. International Conference on Durability of Building Materials and Components vol. 2 April 2011 Porto.*

Rohracher, H. (2001) Managing Technological Transition to Sustainable Construction of Buildings: A Socio-Technical Perspective, *Technology Analysis and Strategic Management*, 13 (1), 137-150.

Sexton, M, and Barrett P. (2005) Performance-based building and innovation: Balancing client and industry needs, *Building Research and Information*, 33 (2), 142-48

Slaughter, S. (1993) Innovation and learning during implementation: a comparison of user and manufacturer innovations, *Research Policy*, 22, 81-95.

[www.kemin.dk](http://www.kemin.dk)

[www.rockwool.dk](http://www.rockwool.dk)