DRIVING TRANSFORMATIONAL CHANGE IN THE CONSTRUCTION VALUE CHAIN

REACHING THE UNTAPPED POTENTIAL

BPIE

i²₄C INDUSTRIAL INNOVATION FOR COMPETITIVENESS

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FOREWORD

The importance of innovation to the European economy has never been greater. Globalisation, disruptive technologies, emerging business models and growing sustainability concerns are putting unprecedented pressure on European industry to adapt, and innovation is the common thread to the right response to them all.

The economic and social transformation being wrought by these multiple and interconnected pressures also, however, presents an opportunity. By promoting and harnessing innovation, Europe's industrial economy can secure long-term competitive advantage in the race to win the most from the global transition to a radically new economy, whose pace as well as shape is made so much clearer by the Paris climate agreement.

The Industrial Innovation for Competitiveness Initiative has been established to help forge a modern industrial strategy for the EU that has at its heart transformative and massively deployable innovation. Our mission is to strengthen Europe's industrial leadership in the transition to a new global economy, one that is shaped by the decarbonisation imperative and by other megatrends such as digitization, mass customization, servitisation, greater circularity and resource efficiency.

As a starting point, we look at the European economy through a 'human need' or 'end use' lens – focusing on shelter, thermal comfort, nutrition, and mobility, for example – and we consider the complete value chains that meet these needs. Such an approach allows for a full picture of an industrial economic ecosystem, and overcomes some of the conflicts and perverse outcomes that can result from focusing on individual economic sectors and sub-sectors to the detriment of the bigger picture or systemic whole.

The construction value chain is fundamental to any economy, and it deserves particular attention. We are pleased to have worked with the Buildings Performance Institute Europe on this report, which looks closely at the megatrends that are weighing upon the construction value chain, the innovation potential that it contains, and the pools of added-value for stakeholders to tap into.

The report seeks to understand and map out the construction value chain and identify the challenges and transformations facing it. It also sets out the spectrum of innovation opportunities available, and takes a deep-dive into four specific opportunities, to better inform the specific interventions needed to help accelerate the competitiveness and decarbonisation benefits such innovation will bring.

But policy makers also need to be mindful of the likely difficult social consequences of innovation. They will need to act to proactively and sensitively manage the transition, to ensure that the vulnerable are protected from the inevitable side effects of change, and are equipped to contribute to Europe's economic transformation.

Dr Martin Porter – Executive Director, Industrial Innovation for Competitiveness (i24c)
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INTRODUCTION

As the world economy will be transitioning to a fundamentally new paradigm over the next 15 years, shaped by megatrends such as greater urbanisation, disruptive new technologies, socialised communications and globalised value chains, the European industry should plan to succeed to grow through its competitive advantages.

This means having a clear understanding as to where the European industry's current comparative advantages lie, but also:

- To identify where the European industry's competitive advantages could lie in 2020, 2030 and 2050;
- To understand/anticipate how the European industry can maintain its leading position / become a leader in the different markets in light of the global megatrends affecting it, through innovation, including securing its position within global value chains; and
- To discuss the industrial transition pathways.

The construction sector is a key component of Europe's economic growth and its employment sector. In 2011, it was responsible for 7% of the EU GDP and over 11 million people were directly employed in the building sector, which makes it the single largest contributor to EU employment. [1]

Proactively understanding and anticipating the changes that its entire value chain is witnessing is crucial for future jobs and growth in Europe, but it is also fundamental to orienting Europe's future industrial strategy and innovation priorities.

Looking into the construction value chain, particularly within the buildings' segment, this report aims to:

- Identify the global megatrends and innovations that are currently and will in the future impact the construction sector value chain and its stakeholders;
- Assess opportunities for the European industry involved in the construction value chain, - from the design of buildings and the planning of retrofits to the delivery of building services-, to increase its added value, in 2020 and 2030, in EU and global markets; and
- Discuss the innovations and transition pathways that would allow that to happen, including policy changes.

With this report, we ultimately hope to contribute to the current debate on the future of the EU's industrial strategy and related innovation-policy agenda focusing on the construction value chain.

The following sections set the scene of the construction value chain, demonstrate its potential added value and highlight the opportunities for European industrial innovation.

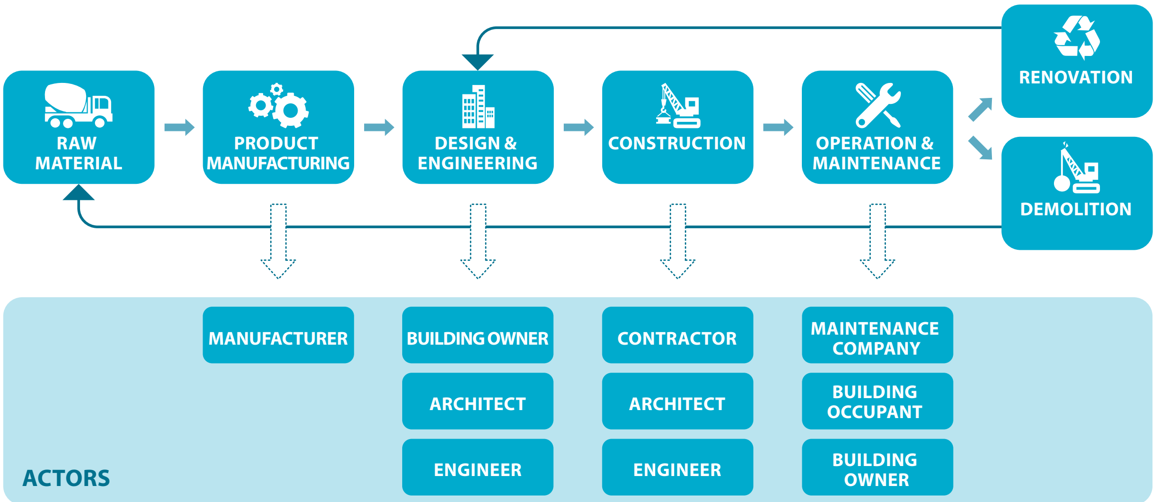
1 MAPPING THE CONSTRUCTION VALUE CHAIN

1.1 THE SUPPLY SIDE AND ITS MANY ACTORS

The construction value chain is complex and involves a number of actors – often uncoordinated and with conflicting interests – including contractors, installers, architects and suppliers as well as producers of material, equipment and energy.

In contrast with other value chains such as the automotive sector, the kind and amount of involved actors vary heavily during a single building process. Actors are selected depending on parameters such as the project scale, planned works and consumer preferences. For example, when retrofitting existing buildings, small-scale contractors or installers often act as "gatekeepers" between suppliers of products and building owners. A high-level overview (see figure below) of the traditional construction sector from a life cycle perspective shows which conventional actors are involved at the different stages such as product manufacturing, design, construction, operation, etc.

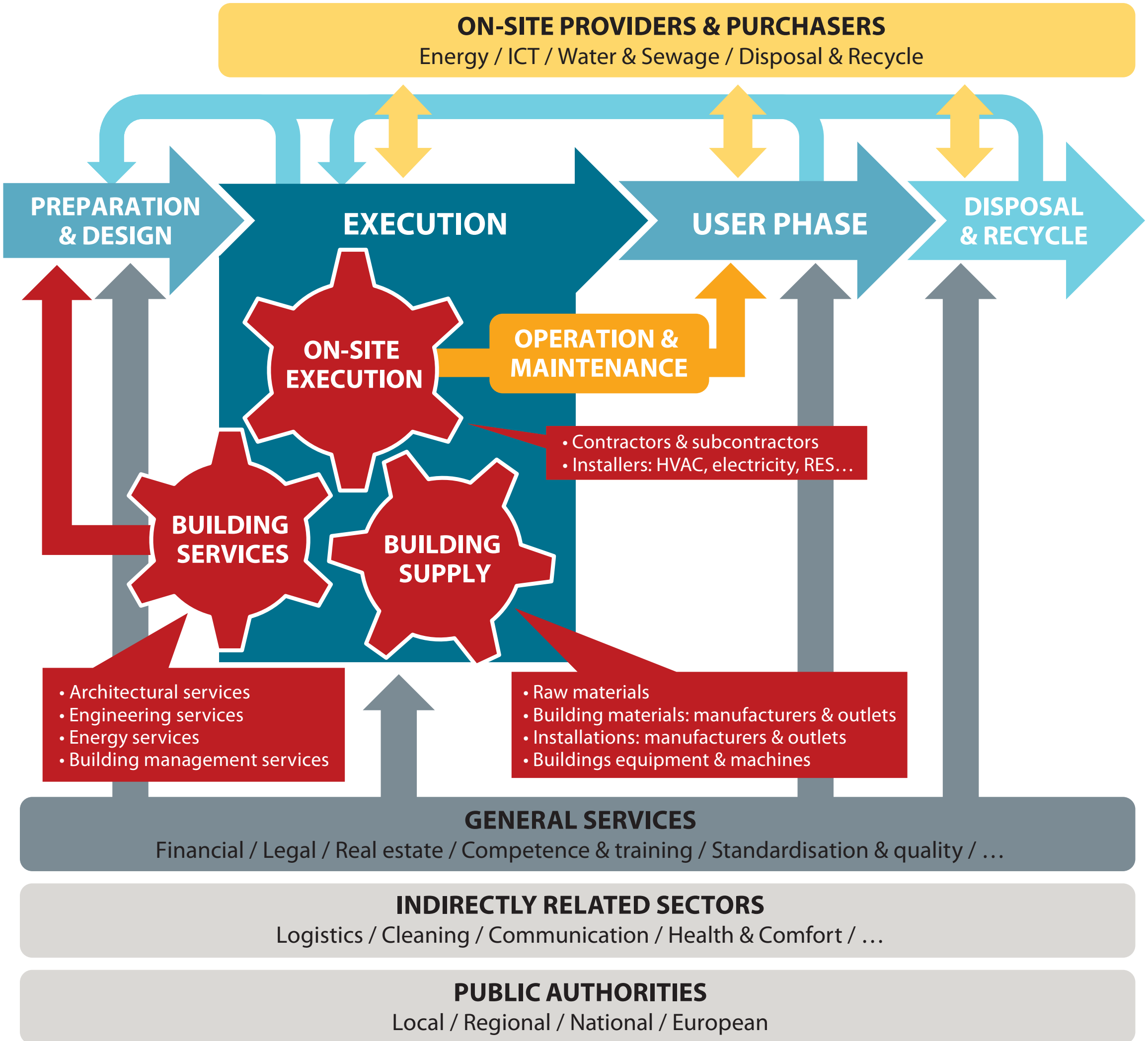
Figure 1: High-level overview of the traditional construction sector (Source: BPIE)



Looking at the construction sector with a 'value chain' perspective allows getting a full picture of this economic sector by identifying all the actors involved in providing value from buildings. This value chain stretches from the supply of raw materials to the final market, thus crossing the borders set by standard classification systems.

The diagram below shows the interactions between actors in the process of value supply– it is much more complex than a linear 'chain'. The activities included in the 'core' construction sector (the gear wheels in figure 2) are thus used here as the starting point to draw the overall value chain.

Figure 2: The building value chain: interactions between actors in the process of value supply (Source: BPIE)



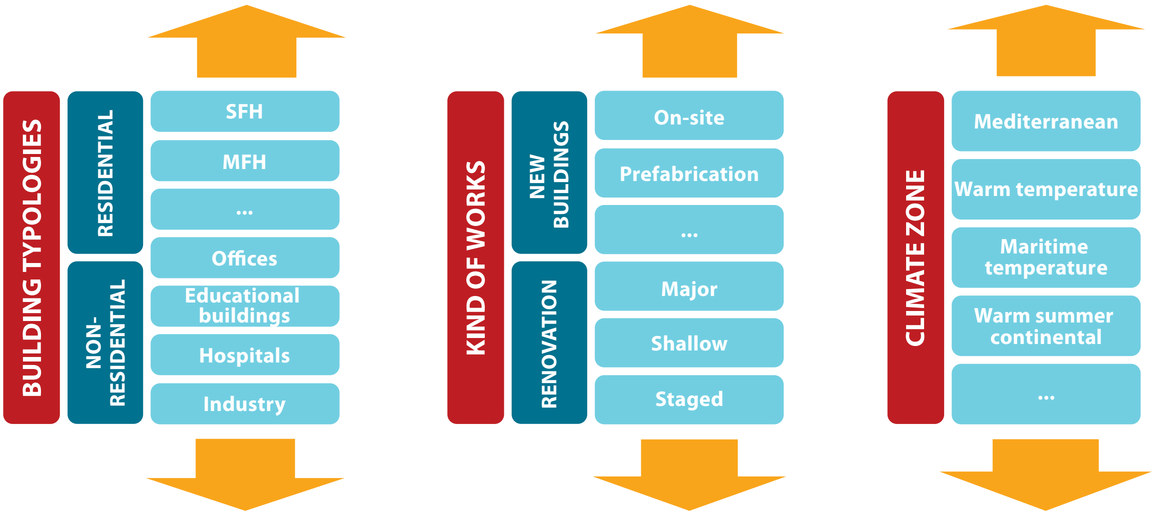
Other (non-construction) actors, such as energy and ICT suppliers, service economies (e.g. financial, real estate, communication and cleaning sectors) are directly or indirectly involved in the construction value chain. Furthermore, local, national and European authorities also have a key role to play, respectively to develop the legal framework, to create incentives and to raise awareness on both the demand and supply sides, steering the construction value chain and therefore the local, national and European economies as well.

1.2 THE EXTREMELY DIVERSIFIED DEMAND SIDE

According to the European Construction Industry Federation, the main activities to be attributed to the European building sector in 2013 were distributed as follows: 31.5% non-residential buildings, 27.5% rehabilitation and maintenance, 20.9% civil engineering and 20.1% building of new houses.

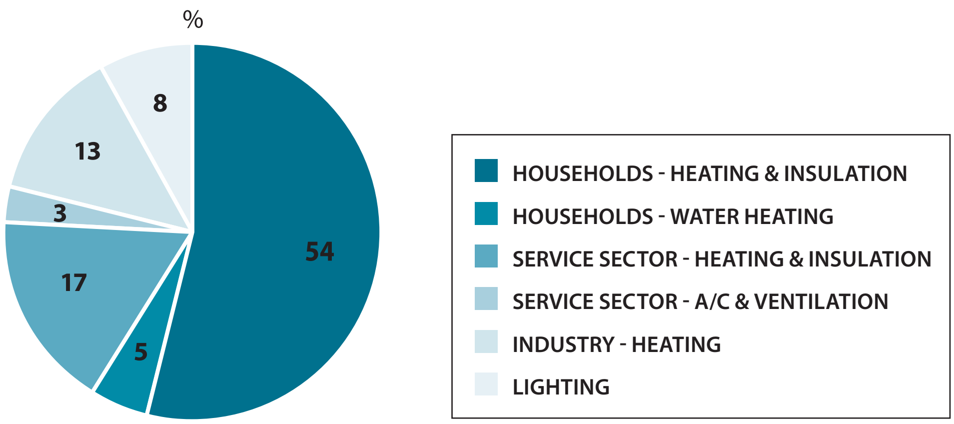
The demand side of the construction value chain is extremely diversified. The segments it can be divided into are: building typologies, users, owners, user status, type of works, construction approach, financing method, energy performance, climate zone, building codes, etc. All these segments allow very detailed sub-classifications.[1]

Figure 3: Three of the many different combinations of segments and sub-segments of the building demand side (Source : BPIE)



As can be seen in figure 4, over half of the energy-saving potential in European buildings lies in the heating and insulation of households, making actors throughout the value chain active in renovation of residential buildings the number one target for GHG emission reduction.

Figure 4: Energy-saving potentials – high EE scenario 2030 (excl. appliances) (Source: Copenhagen Economics [2])

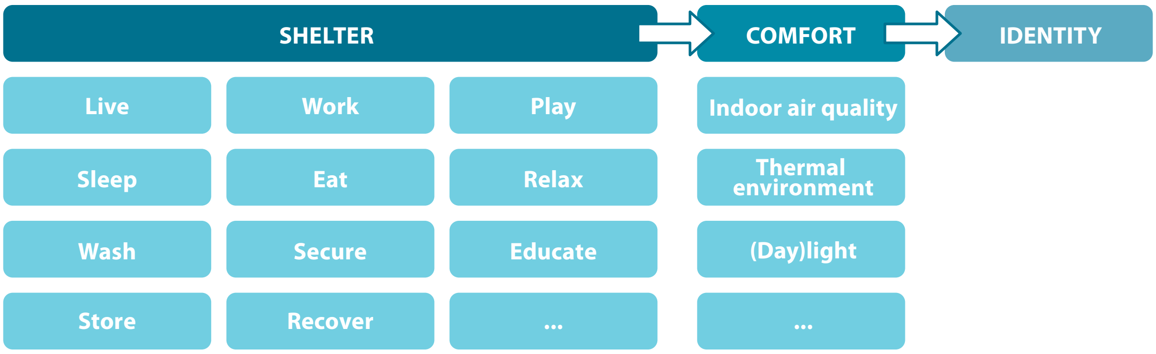


[1] Its complexity could be compared to a slot machine, with a very large set of different combinations of segments and sub-segments.

1.3 END-USE FUNCTIONALITY OF BUILDINGS

Rather than looking at the building as a product per se, exploring its functions and how the different elements and materials provide this function is one of the keys to changing the mind-set of those involved in its construction, servicing, regulation, etc. Taking an end-use functional perspective (thermal comfort, shelter) allows to move one step away from traditional industrial sectors towards changing the way complex multi-sector value chains deliver services to end-use consumers. The service delivered by buildings (and by actors delivering building services) is associated to its end-use functions (figure 5): provide shelter, thermal comfort and identity.

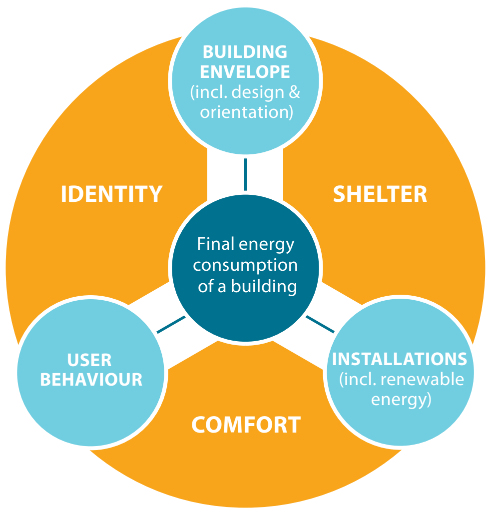
Figure 5: End-use functions provided by buildings (Source: BPIE)



The end-uses are closely related to the final energy consumption of a building. The factors responsible for this final energy consumption are the building envelope's characteristics (incl. design and orientation), the installations (incl. renewable energy) and the user behaviour. These three factors all have a large impact on the building end-use functions such as comfort, performance of work, healthy indoor environment, 'look & feel' of the building, etc.

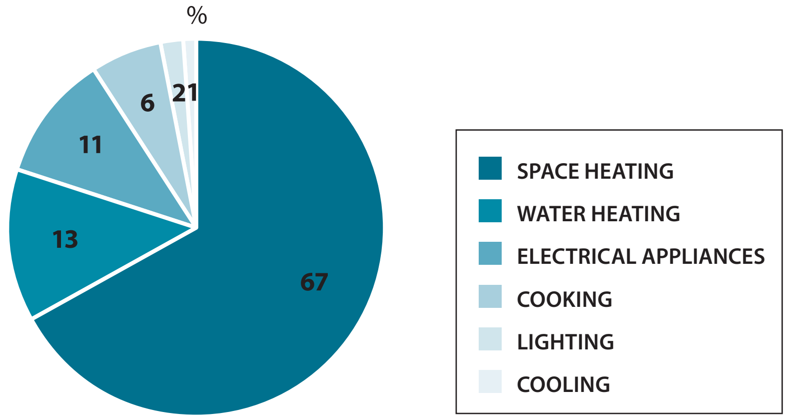
User behaviour is the most unpredictable and precarious factor and it changes over time depending on the occupants' situation and expectations (e.g. higher attendance rate due to changes in the familial situation). However, the better the energy performance of the building (i.e. combination of building envelope and installations), the lower the impact of the user behaviour on the building's final energy demand.

Figure 6: The factors leading to the final energy demand also shape the buildings' end-use function (Source: BPIE)



Space heating, providing thermal comfort, is responsible for almost 70% of the energy consumption in European households (see figure 7).

Figure 7: Breakdown of household energy consumption by end-use in the EU (2012) (Source: Odyssee)



Enhancements in end-use functionalities such as comfort and safety can be a strong demand-pull for innovations in industrial value chains. For example, very often the improvement in comfort is the driving factor for the consumer to invest in energy-saving measures such as (cavity) wall insulation, building automation (as well driven by safety reasons), performant glazing, solar screens, etc.

1.4 THE POTENTIAL ADDED VALUE OF THE CONSTRUCTION VALUE CHAIN

When we describe value chains, we are describing the relationships between all the economic actors who deliver a product or service with a specific value for their end user. This value comes from the benefit the final user gains from this product or service. For a construction, that value can for instance relate to the comfort, peace, aesthetic appeal or status from using a building. The amount of money the final user is prepared and able to pay for this benefit is the amount that the value chain (as a whole) can capture from the value. The delivery and capture of value is the economy's driver.

Value creation and decarbonisation in the construction value chain reinforce each other:

- The value added from specialised construction activities that include renovation work and energy retrofits was €283 billion in 2011, the biggest contribution (66%) to value added in the EU building sector. Such activities contributed most in France (€65 billion, or 24%), followed by Germany (€44 billion) and the UK (€32 billion). They contributed least in Eastern and Central European countries and the Baltic States. Specialised construction activities also made the biggest contribution to employment in the EU building sector, with 7.84 million jobs. [1]
- Value added by activities linked to the building envelope (roofing, walls and floor covering, glazing, etc.) was €166 billion the same year, or 60% of the value added in the EU building sector. In terms of employment, such activities represented 58% of the total employment in the EU building sector, with 6.88 million jobs. [1]

The EU building sector is characterised by a high number of micro-enterprises, mostly operating at the local level. Enterprises with less than nine employees represent 94% of all enterprises active in the sector, while large enterprises represent less than 1%. In 2011, enterprises with less than 50 employees generated 72% of value added in the EU building sector, while those with more than 250 employees generated only 14%.

Buildings are long-term assets expected to remain useful for 50 or more years and 75-90% of those standing today are expected to remain in use until 2050. With low demolition rates (0.1% per year), low renovation rates (1.2% per year) and moves to highly energy-efficient new-builds (1% additions per year), Europe's challenge mainly relates to the energy-efficient renovation and investments in the existing building stock. Moreover, Member States in which the construction of new buildings represented the biggest contribution to the value added were the ones most affected by the financial and economic crisis. [3]

Addressing the challenge – by increasing both depth and rate of energy renovations – creates vast economic opportunities while increasing decarbonisation. A renovation scenario[2] developed in the study "Europe's buildings under the microscope", indicates overall results for 2050 with an investment cost of € 584 billion and a net saving[3] to consumers of € 474 billion. [4]

[2] This is a two-stage renovation scenario with a renovation rate that grows steadily over the next decade to reach a constant rate of around 2.7% and assuming that buildings will be renovated from 2031 onwards a second time.

[3] The net saving is the difference between the present investment and the energy cost saving.

1.5 TRENDS CHALLENGING THE CONSTRUCTION VALUE CHAIN

Megatrends – such as energy availability, demographic changes, the digital and broader technological revolution, and climate change mitigation – affect and challenge the construction value chain.

The table below provides a more detailed summary of the megatrends and drivers of change that are key to understanding the future of the construction value chain's functioning.

Table 1: Summary of the megatrends and drivers of change (Source: BPIE)

MEGATRENDS	DRIVERS OF CHANGE
CLIMATE CHANGE	Legislation and support measures to reduce emissions from buildings
	Environmentally conscious consumers
DEMOGRAPHIC CHANGE	Ageing population
	Increasing number of under-occupied dwellings
	Growing number of small and blended families
	Increasing (awareness for) fuel poverty
	Replacement demand of 60% in the construction sector by 2020 – reduced flow of younger workers in the workforce
DIGITAL AND BROADER TECHNOLOGY REVOLUTION	Advanced automation, 3D printing and industrial processes on- and off-site
	Mass adaptation to smart phone technology and connected devices (Internet of Things)
	Time- and place-independent work
	Non-construction actors enter the construction value chain, e.g. electric vehicles, utilities, ICT, etc.
ECONOMIC CRISIS	Stricter requirements for (mortgage) loans
	Higher caution for investments (in buildings)
	Social polarisation makes it increasingly difficult for vulnerable people to find decent housing at affordable prices
	90% of social housing is in need of (energy) renovation
ENERGY SUPPLY	Legislation and support measures to reduce energy demand from buildings
	Grid parity and widespread adaptation of renewable energy technologies (e.g. solar systems will be at grid parity in up to 80% of the global market within 2 years)
	The energy market is changing (decentralisation, decarbonisation, more complex, open…)
	Electrification of heating & cooling
GLOBALISATION	Unfair competition at the international level due to higher standards of the European construction value chain
	Limited access to international markets – reluctance to open public procurement to European construction companies
RESOURCE AND ENVIRONMENTAL DEPLETION	Legislation and support measures (EU, national and regional levels) to increase resource efficiency
	General awareness of resource and environment depletion, cradle to cradle and local economies

URBAN REDEVELOPMENT	High and increasing degree of urbanisation (>2/3 of the European population)
	Threatened biodiversity and increased risk of both flooding and water scarcity because of urban sprawl and soil sealing
	Non-capital cities in Central and Eastern Europe and old industrial cities in Western Europe facing the threat of economic stagnation or decline
MIGRATION	Migration within the EU
	Immigration to the EU

These drivers of change are leading to multiple implications for the construction value chain, i.e. the practical effects of megatrends and drivers of change on the activities and responsibilities of the construction value chain. The quantity of effects is extensive, therefore only a few representative/crucial ones are listed below:

- Consumers increasingly interested in innovative building technologies;
- Decreasing demand for new and increasing demand for existing properties;
- Increase in non-native-speaking building workforce and building occupants;
- Increase of industrialised and prefabricated building processes;
- Demand for flexible, smaller, lifelong and multi-generational housing typologies;
- Public authorities to lead by example;
- Increasing number of energy suppliers and energy-supply services (e.g. cost-adapted pricing, green energy, comfort services…);
- Increasing potential for district heating;
- Increasing renewable energy production in buildings;
- Increasing risk for black-outs;
- Interaction of buildings with the energy market (demand response, energy storage and energy production);
- Need for affordable renovation techniques;
- Shared use of buildings, especially for office spaces, but also for hotels and residential buildings;
- …

The transition to a low-carbon economy (by 2050) will require a higher-skilled workforce, new business models, different and smarter building archetypes, industrialised construction methods, etc. For the construction sector, this means training experts in the fields of insulation, renewable energy installations, building automation, etc. Integrated business models to deliver one-stop-shop services to the customers need to be set up by the different actors such as architects, energy experts, contractors and installers. In addition to that, strategies to address the skills gap in the sector as well as ways to attract more young people to begin careers in construction and have older people active for longer have to be developed.

In light of the megatrends and the implications for the construction value chain, there are tremendous business opportunities to meet the demand side's expectations:

- Reduce energy use in buildings (i.e. capturing some of the value of the energy saved).
- Supply extra comfort for building occupants (e.g. through building control systems).
- Provide on-site energy production or grid management services.
- Meet citizens' desires to become low-carbon consumers.
- Have industrialised and streamlined renovation services with lower costs and less burden.

2 INDUSTRIAL INNOVATIONS PROVIDE NEW POOLS OF VALUE TO BE CAPTURED BY ACTORS

2.1 INDUSTRIAL INNOVATION OPPORTUNITIES WITHIN THE VALUE CHAIN

Besides the megatrends "disrupting" the construction value chain, there are also multiple potential innovations in the pipeline that provide opportunities for those engaged in capturing new sources of revenue. These various types of potential innovations are related to technology, organisation, marketing, services and products.

The innovations are driven by a few important factors, namely consumer demand/preferences, regulatory signals and manufacturer choice. These drivers are interlinked and influenced by other macro factors such as energy prices as well as resource and infrastructure availability.

For example, given the climate change regulation in Europe, green-construction-related patent filings have tripled in little over a decade, with most dynamic patenting occurring in areas such as HVAC, highly efficient insulation, green lighting and building-related small-scale renewable energy technologies. [5]

These innovations are being undertaken both in the EU (e.g. holistic prefabricated modules for renovation) and outside (e.g. demand response for households in the US). Due to the importance of the construction sector in the European economy and innovation, widely considered as the beacon for the European economy in an increasingly globalised world, innovation in the construction value chain is being highly prioritised, both in European and in local politics.

Assessing this pipeline of innovations, multiple opportunities for the construction value chain arise – driving marginal change (e.g. self-regulating glazing), more fundamental/disruptive change or holistic solutions (e.g. industrialised off-site construction or Internet of Things for smart controls). These innovation opportunities are appearing both upstream (e.g. product innovation of super insulating material) and downstream (e.g. automated monitoring of installation performance) in the value chain.

Table 2 displays various innovation opportunities for the construction value chain with building-related applications, linked to the sources of value and the delivered benefit.

Table 2: Various innovation opportunities for the construction value chain with the building-related application and linked to the sources of value and the delivered added value (Source: BPIE)

INNOVATION OPPORTUNITIES FOR THE CONSTRUCTION VALUE CHAIN	Building envelope	Building installation and interaction with the grid	Holistic approach	Reduction of final energy demand of the building	Additional comfort	Grid stabilisation	Less costly provisions
Product solutions to avoid thermal bridges	v			v	v		v
Resource-efficient buildings or building components	v						v
Smart-building envelop components such as self-regulating glazing, phase change materials…	v			v	v		
Super insulating glazing	v			v	v		
Super insulating materials	v			v	v		
Automated monitoring of the performance of technical installations with feedback to user and or installer		v		v	v		v
Building capacity to insert produced renewable energy in district heating (e.g. solar thermal or electricity through PV and heat pumps)		v				v	v
Building capacity to store (renewable) electricity on building level (batteries, electric vehicles…)		v		v		v	v
Building-integrated PV-technologies		v		v			
Building interaction with the energy market (demand response, energy storage and production) for grid balancing, correcting trading imbalances & opportunistic trading		v				v	v
District heating 'ready' for new buildings and renovations in areas with DH potential (but not yet available)		v		v			v
Services for consumers to use Internet of Things (IoT) devices to extract value from wholesale markets		v				v	v
Business models for integrated approach (one-stop-shop) collective housing renovation			v	v	v		v
Business models for integrated approach (one-stop-shop) single-family housing renovation			v	v	v		v
DBFM contracting for renovation or new buildings			v	v			v
Demountable and recyclable buildings or building components			v				
Financing models for nZEBs and high-energy-performing buildings			v	v			v

INNOVATION OPPORTUNITIES FOR THE CONSTRUCTION VALUE CHAIN	**Building envelope**	**Building installation and interaction with the grid**	**Holistic approach**	**Reduction of final energy demand of the building**	**Additional comfort**	**Grid stabilisation**	**Less costly provisions**
ICT and technological instruments to measure, monitor and analyse existing buildings (sensors, LIDAR 3D-scan, analyse software…)			v				v
ICT instruments to support building services (architects, energy services, engineering…) such as product databases, design and project-planning software			v				v
ICT instruments to support on-site execution (e.g. google glass with lap-over 3D design and reality…)			v				v
ICT training instruments to level up the building actors' competences			v	v			v
Innovative financing models such as ESCOs, crowd funding, cooperative funding for energy renovation in buildings			v	v			v
Business models measuring, demonstrating and communicating the co-benefits of low-energy buildings			v	v	v		
Business models for a collective approach on building renovation (e.g. group purchases, facilitation services…)			v	v	v		v
Off-site construction and modular assembly			v	v	v		v
Performance-guarantee contracting for renovation or new buildings			v	v	v		
Quality frameworks for EE and RES measures and installations			v	v	v		
Real estate platforms for 'future proof' high-energy-performing buildings			v	v			
Business models with the integration of building passports and individual renovation roadmaps			v	v	v		

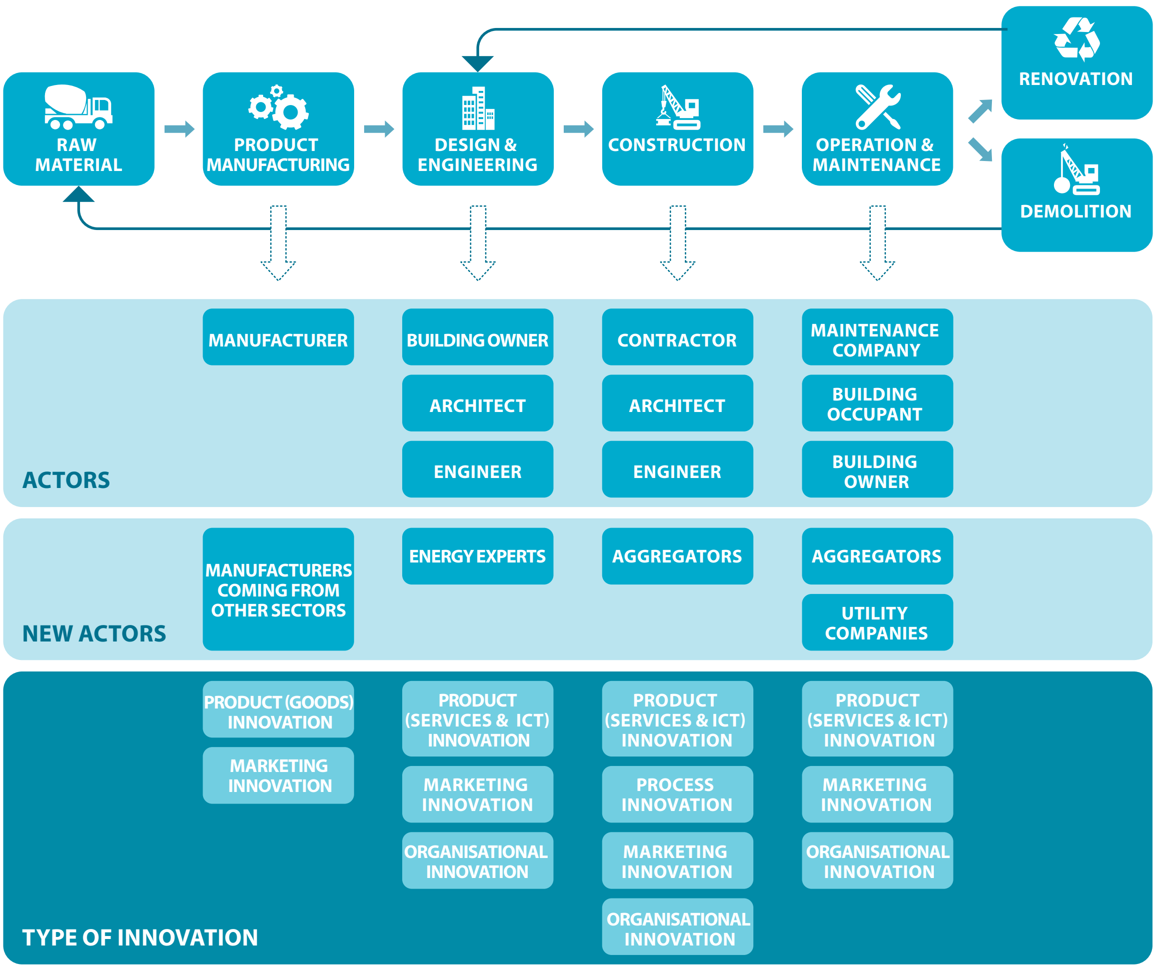
2.2 CURRENT INNOVATION OPPORTUNITIES CHALLENGE TODAY'S PLAYERS IN THE CONSTRUCTION VALUE CHAIN

Building processes are becoming more and more complex, which is why more interaction and collaboration between actors is needed. There are various opportunities to eliminate process and market barriers with organisational innovation leading to new business-models focusing on collaboration between the different building actors, and/or new construction value-chain-related ecosystems. Various types of loose or formal collaboration structures for achieving high-energy-performing buildings are appearing in all countries and the experiences connected to them are setting the scene for further development.

Because of the game-changing environment at the technological, ICT and energy-market levels, new market players are emerging in the construction value chain. Examples include the widely discussed launch of Tesla's Powerwall to stimulate demand-side flexibility and Google entering the home market with Nest thermostat and smoke-alarm.

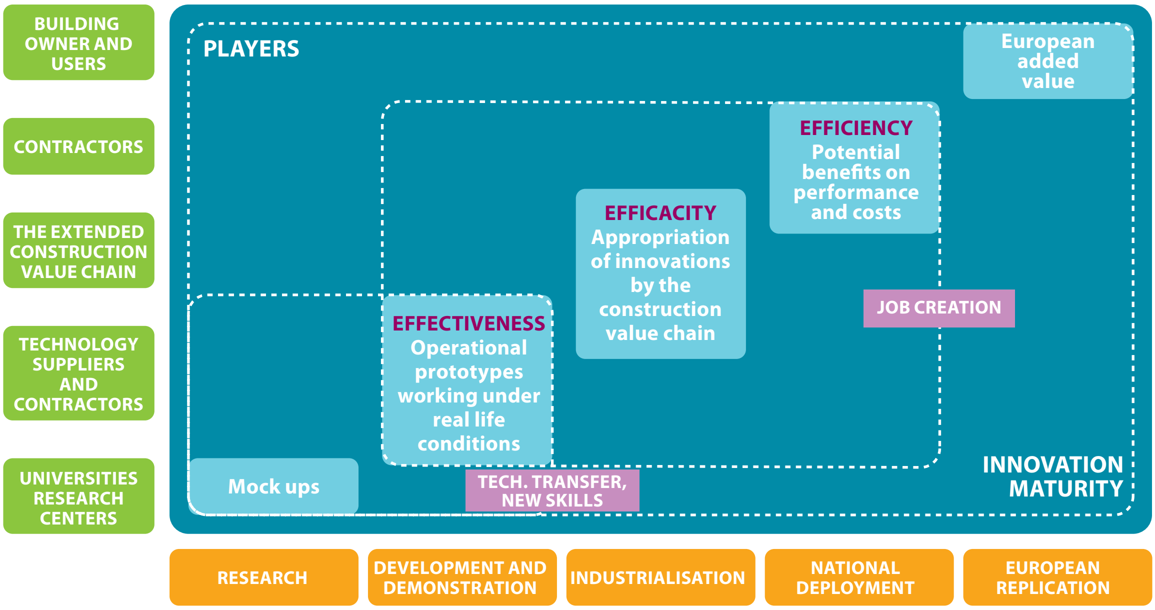
Innovation will occur within companies, but also within ecosystems concentrating on a specific phase in a buildings' life cycle, for example collaboration models between architects, contractors and investors during the construction phase; or building automation for existing households set-up and designed by an installer for a specific family during operation phase. Figure 8 shows the various innovation types (product, service, process, marketing and organisational innovation) according to the building stage and the associated existing and new actors.

Figure 8: Mapping the building process, its actors and the potential innovation (Source: BPIE)



Innovation can foster structural change in the construction sector and a clear added value on a European scale. It is associated with the intended innovation model mobilised along the construction value chain as well as the innovation chain, as illustrated in figure 9.

Figure 9: Intended innovation model and the European added value associated with it (Source: European Construction Technology Platform [6])



The European efficiency-related construction market is expected to double and reach €140 billion by 2020.

2.3 BARRIERS AND CHALLENGES FOR INNOVATION

Industrial innovation in the construction value chain faces different interlinked challenges. These fall into three main groups:

- An uncertain economic and policy outlook that can make it difficult to justify investment in innovation (e.g. missing energy renovation targets for the existing building stock, uncertainty on support measures or the fact that only 50% of the member states have a view on the compliance rates of new buildings with energy performance requirements);
- The need to manage risk inherent to innovation projects because they aim to develop and deploy completely new processes or products; and
- The need to balance collaboration to protect knowledge.

Therefore, the realisation of the innovations quoted in the previous chapter cannot be guaranteed.

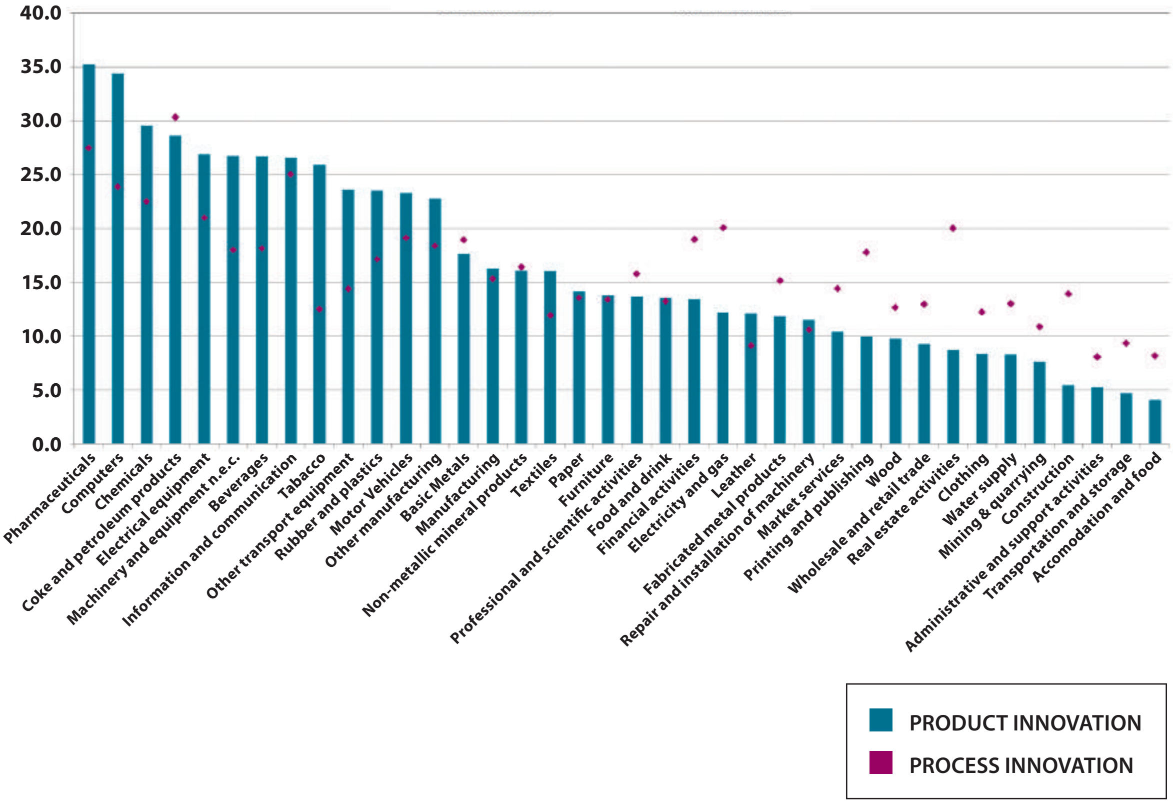
The challenges requiring special attention are the ones associated with deployment. Successful small-scale development and demonstration do not necessarily guarantee large-scale deployment of a given low-carbon technology or solution (e.g. passive housing). Experience has shown that, even when low-carbon technologies prove to be cost-effective under prevailing market conditions, other (non-financial) barriers can stall their uptake and limit private-sector engagement.

The barriers can be overcome and the large-scale deployment boosted through creative approaches, such as capturing and valuing the multiple benefits of technology innovation (e.g. better indoor climate improves working performance), leveraging research on consumer behaviour (e.g. emptying an attic is for some end-users a too high burden to implement roof insulation) and bundling policies. [7]

The relative importance of these challenges depends on the phase within the R&D process in which the technology or process stands. For instance, basic research and laboratory-scale tests tend to be less capital-intensive but they typically involve more uncertainty as the technology principles have not yet been proven during the building execution phase. For example, a vacuum insulation panel can have excellent test reports and proven success in other sectors, but this technology also needs to be resistant to the ecosystem of on-site execution habits. Throughout these initial phases of R&D, cross-sectoral European and/or international collaboration and information-sharing may be critical for a project's success, as they can accelerate the learning process in research and reduce the associated incertitude levels. Low-carbon industrial innovation can face additional challenges, such as the difficulty of penetrating a market dominated by a small number of widely-used process technologies (e.g. super insulating materials undergoing competition of conventional insulation materials). [8]

Compared to others, the construction sector is characterised by a low level of innovation in the downstream. Especially (good) product innovation is scarce, while process innovation is applied more frequently (figure 10). This can be explained by the large number of SMEs, mainly providing services in the 'on-site execution market segment'. Manufacturing firms (such as building material manufacturers) are more orientated than service firms (such as architects and contractors) towards product innovation. Service industries engage rather in process innovation. [9]

Figure 10: Proportion of enterprises that introduced new or improved products (blue bars) and that introduced process innovation (red dots) as percentages of all enterprises in the CIS population (Source European Commission - DG Enterprise and Industry [9])



On the other hand, the demand side is extremely diversified (see section 3.2) but changing likewise because of the global megatrends (described in section 3.5). There is a clear increase in demand for high-energy-performing, flexible, smaller, easy-to-use, lifelong and multi-generational as well as affordable housing concepts. A proactive innovation strategy is required for European actors in the construction value chain to capture that new market, with potential further regulation opening up the markets for innovation as well as greater co-ordination of an ecosystem of players. The transition at the demand side opens as well opportunities for innovations less related to a specific technology, and more to solution or system-led innovations (e.g. building automation).

Without focusing on specific innovation opportunities, enabling measures to stimulate an overall innovative market environment for the construction value chain can be found within – and linked to – different categories:

Governments at European, national, regional and local levels

- Transparent, clear and long-term targets and regulatory approaches (e.g. minimum efficiency standards, building standards and codes);
- Appropriate, transparent, clear and mid- to long-term support measures;
- Public procurement as leading example;
- Pragmatic compliance and control of the works.

Consumers

- In need to be guided with support and facilitation;
- Increased awareness, e.g. information campaigns designed to address risk aversion to new technologies or promote behavioural change.

Financial institutions

- Focus shift from Capital Expenditures (CAPEX) to Operating Expense (OPEX), for example by offering financial products specific to ESCO-services and favour mortgage loans for renovations with higher energy savings;
- Access to capital and risk aversion.

Building-sector federations

- Public-private cross-sectoral frameworks along industrial product value chains;
- Stimulate high-tech and competent building workforce with pragmatic quality schemes;
- Increased prioritisation of service and organisational innovation and energy efficiency investments.

3 FOCUSING ON SPECIFIC INDUSTRIAL INNOVATION OPPORTUNITIES

In order to proceed to a concrete system of solutions directed to stimulating industrial innovation in the construction value chain, it is necessary to focus on specific and clearly defined segments.

Given today's innovations in the construction sector, businesses in the construction value chain see opportunities to reduce the cost of deep energy retrofits and provide new services. Examples of these opportunities are 'energy construction kits' tailored to each construction period, climate zone and building type, 'plug-and-play' manufactured modular components and systems fully integrated with advanced 3D surveying techniques and innovative insulation materials. New technologies enable building-to-building and building-to-grid energy interaction, allowing buildings to become active players in the energy system.

The following construction value chain segments were chosen for deeper investigation to better gauge what the innovation opportunities are and what challenges they bring within the European context. These innovations provide business market opportunities for EU firms along with greenhouse gas emission reductions, which are key to helping Europe meet its decarbonisation goals. Key to the European political agenda, these innovations are also likely to have direct benefits on job creation and growth in Europe. At the same time, potential job losses call for a managed transition.

In each deep dive, the innovation potential and megatrends of each particular segment is indicated along with an overview of what is currently blocking new value creation. The benefits and challenges for the different actors in the value chain are outlined along with measures to enable the transition.

3.1 PREFABRICATED SYSTEMS FOR DEEP ENERGY RETROFITS OF RESIDENTIAL BUILDINGS

3.1.1 Ongoing transition

Off-site industrialisation of the construction of prefabricated building elements for the renovation market represents an enormous opportunity in the construction value chain for new sources of revenue and new prospects of growth, primarily facilitated by the following trends:

- **Increasing focus of governments** on energy renovations;
- **Increasing need for affordable (deep) renovation**[4] techniques with minimal burden for building users;
- **Modernisation of the building sector** through the integration of ICT and automated solutions;
- For new buildings, **improved off-site productivity** combined with **modular assembly on-site**.

[4] The costs of deep energy renovations with a traditional approach are often as high as costs of demolition and new build.

Figure 11: Energiesprong (Energy Leap) project in The Netherlands (Source: Platform 31)

These trends have opened up opportunities in the construction sector. Mainly material manufacturing companies and medium or large contractors are finding new ways to grow their businesses by offering highly innovative and affordable renovation approaches to initiate mass-market uptake of deep energy renovation. A further transition of the industrialised renovation process is required to achieve the long-term transformation targets of the existing building stock for both renovation rate and depth.

"Europe is leading this kind of prefabrication for deep renovation of buildings. [...] In time, there is no question that other regions will also need to have these techniques applied. So, if we can develop these new techniques in Europe now through our innovation and smart development, then this can become an export market in the future." Adrian Joyce, EuroACE

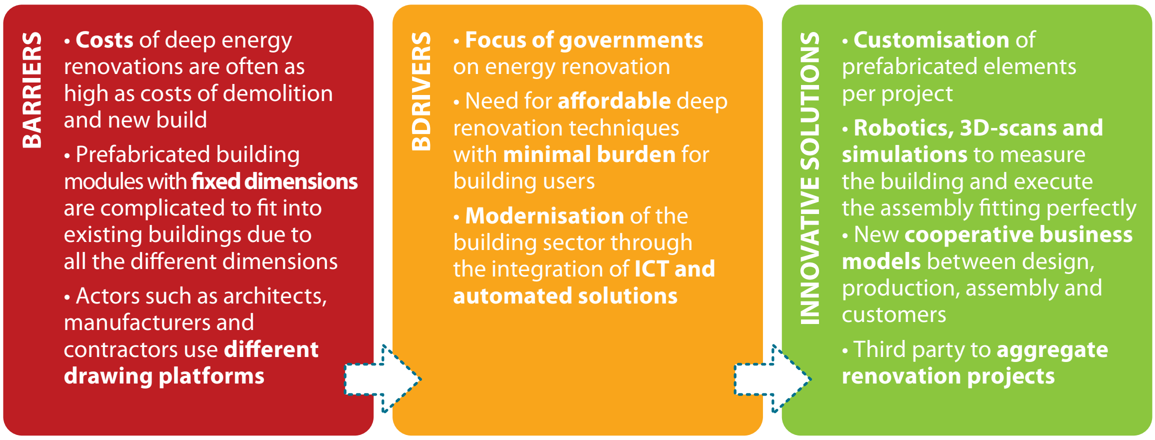
"I've never seen the construction sector change unless it was pushed by regulations. There is a massive inertia in the way the sector is structured and with the way contracts are written. There is a large problem in the demarcation between disciplines that go together in a design team. As a result, there is not enough collaboration." Adrian Joyce, EuroACE

"On one hand, there will be job creation but on the other hand it will also help keep everyone at work much longer." Berri De Jonge, Plegt-Vos

"We have to look differently at standardisation. Prefab used to be standardisation in the sense that you had no choice. It was a fixed module and that was that. [...] We have to look at it like an IT-platform where we have a basis that we can expand with add-ons. These add-ons are the clients' wishes and demands." Berri De Jonge, Plegt-Vos

3.1.2 Innovation potential

Figure 12: Outlining the innovation of 'Prefabricated systems for deep energy retrofits of residential buildings' (Source: BPIE)



The renovation market has an enormous potential for process, marketing and organisational innovation. The key innovation elements to apply successful prefab construction methods for the renovation market are:

- **Customisation of the prefab elements per project**. While the dimensions of the façades are customised to the specific project, prefabrication for renovation means fixed compositions and complete façades.
- The use of innovative technologies such as **robotics, 3D-scans and simulations** to perfectly measure the existing building and execute the assembly that fits almost perfectly to the existing one. Prices for laser scanning and building the detailed model vary from €800-2,500. The larger the project, the lower this cost impact is.
- **New cooperative business models** with guidance and flow of information between design, production, assembly and customers. For example, very often there is a mismatch between the design and manufacturing stages where both architects and prefab manufacturers draw their 3D-model.
- **Aggregating renovation projects** (=organisational innovation) to benefit from economies of scale for 3D-scanning, the facilitation of project management, dissemination, etc. Certain building typologies, such as social housing, apartment blocks and larger offices are more appropriate to be aggregated and renovated in a collective approach.

The industrialised process for **new constructions** is mature all over Europe (e.g. The Netherlands, Italy, The UK, Ireland and Scandinavia). Examples of companies in this field are Sommarnöjen (SE), Riko (SL), Syspro (DE) and Huf Haus (DE). The innovative solutions and competences developed in this area, such as automated production lines, business models, cost optimisation and sales services, are fully mature. The challenge will now be to adapt and transfer these skills and this knowledge to the industrialisation of the renovation market, for there is no mature industrialised approach for energy renovations yet.

There are different possible approaches within the integration of building elements in the prefabricated renovation systems:

- Current best practice in The Netherlands and Switzerland is the prefabrication of complete modules. Companies shifted from producing separate roof and façade modules to holistic building solutions, integrating windows and special techniques such as ventilation and renewable energy systems, in the new building façade.
- In other examples, like the EASEE project, companies develop prefabricated façade insulating panels, optimized in terms of size and geometries as well as in terms of application, structural behaviour, insulating materials and aesthetic options.

3.1.3 Value to capture

The possible value to be captured in this innovation segment is mainly located in the **module manufacturers and installers** and with **home-owners**.

The **industrialisation** of the construction process will lead to **lower costs** for holistic energy renovations. Pilot projects in The Netherlands are showing a potential cost decrease from €130.000 (2010) to €60.000 (2014). These cost reductions are achieved by implementing the following actions:

- Reduced person-hours (labour has always been a bigger cost than materials and equipment);
- Limiting conventional wharf costs significantly since scaffolding, crane, construction site infrastructure, etc. are no longer needed;
- Economy of scale to reuse models and limit the time spent on individual projects;
- Decreased transportation and logistics needs.

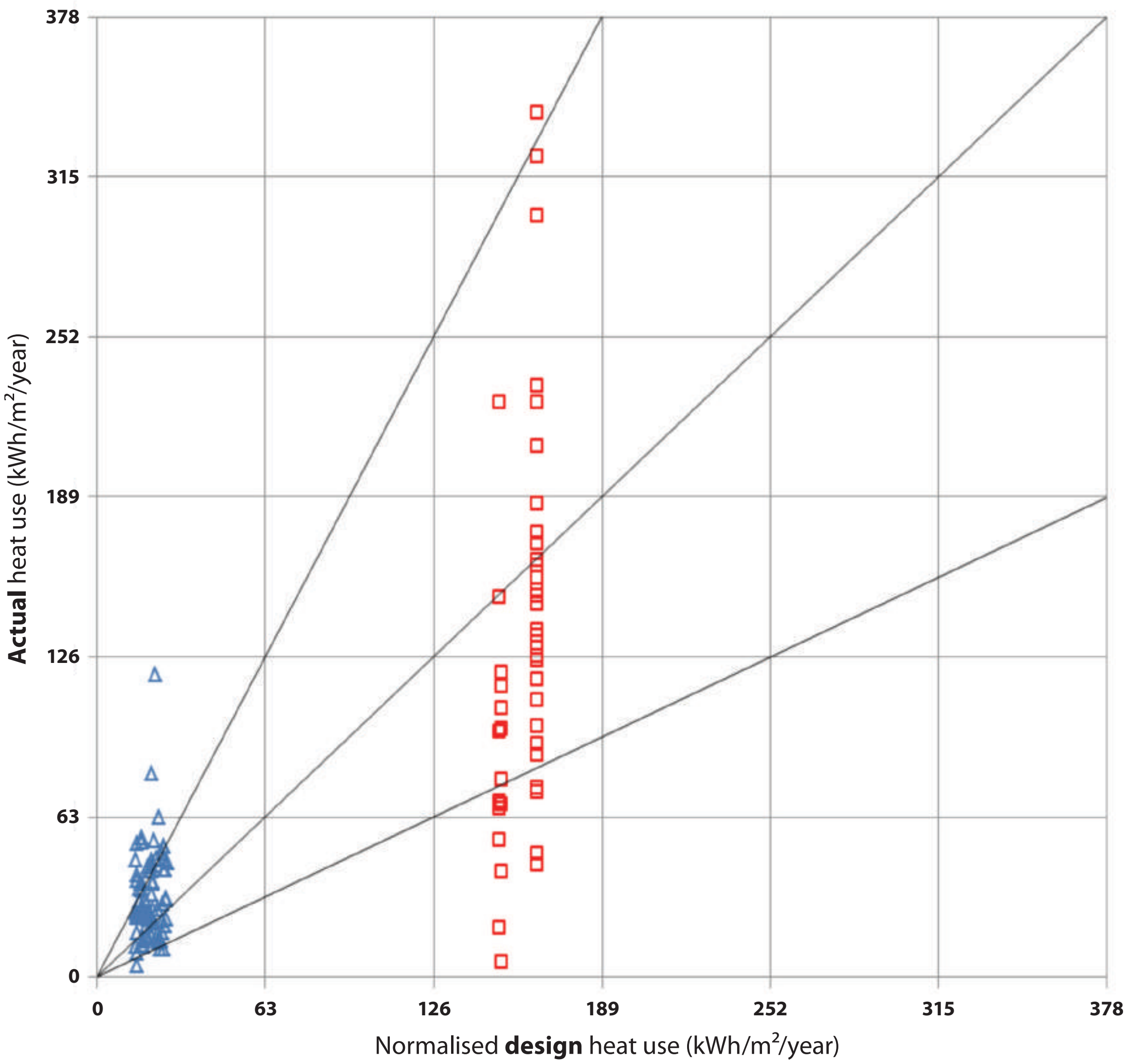
Lower renovation costs, combined with enabling measures, e.g. government incentives for renovation, will lead to **higher renovation rate and depth**. Expert opinions suggest that deep energy renovation equates to a reduction in energy consumption for heating, cooling, ventilation and hot water in a range between 60-90% (0-30% shallow, 30-60% moderate).

The market uptake of affordable industrialised renovation techniques will:

- Drastically decrease energy consumption in buildings;
- Improve the market value, comfort level and indoor air quality of the property for the benefit of the building owner and user;
- Stimulate the circular economy and reduce waste during the building process;
- Increase gender equality employment and keep older workforce longer at work, while also attracting young and more technical employees.[5]

[5] The reason being that the construction process is executed in a safe indoor environment with largely automated production lines, allowing less mobile or strong workforces to enter the sector. The time spent outdoors on the construction site is kept to a minimum.

Figure 13: Actual heat use and designed heat use before (red squares) and after (blue triangles) deep energy renovation, pilot project Venningwijk (BE) (Source: University Ghent)



Today, the renovation rate in the EU is at 1%. If it were to increase to 3%, energy demand in the current building stock could be reduced by 80% by 2050 compared to 2005 levels. Potential revenues for the total construction sector are estimated to amount to around €1,200-1,400 billion/year, which is a boost of ca. €700-800billion/year. If prefabrication modules are counted as material and equipment, which accounts for 25% of the total renovation cost, this still leaves an added value of around €200 billion/year specifically for prefabricated renovation modules.

An example: In Energiesprong (NL), the value of industrialised prefab renovation of 110,000 houses is estimated at €5 billion. This is just a small fraction of the total Dutch value to be captured, and an even smaller one if compared to the whole EU potential.

Experts estimate that per €1 million investment in the construction sector, 17-19 jobs are created. When considering that prefab modules limit labour hours, a job creation of 10-12 jobs per €1 million investment could be foreseen. With a possible growth of €200 billion/year for this particular renovation segment, this could create up to 2 million jobs per year. It is generally considered that the ripple effect of one additional employment in the construction sector leads to 2.5 extra jobs in the overall economy.

Europe is leading the industrialisation of prefabrication materials for deep renovation of buildings. In the years to come, other regions will obviously also need to apply these techniques. European enterprises that successfully achieve market maturity for these new techniques in Europe through innovation and smart development could become leaders in the export market.

Best practices in The Netherlands (Energiesprong, Platform 31) and Switzerland (IEA ECBCS Annex 50) show that aggregated demand, large production capacities and strong marketing campaigns result in large market uptake at lower prices.

The countries with best potential value to capture are characterised by:

- A mature prefab construction market for new constructions;
- An existing building stock in need for renovation;
- The availability of suitable building typologies for an aggregated prefab construction approach, such as (social) housing, apartment blocks and offices.

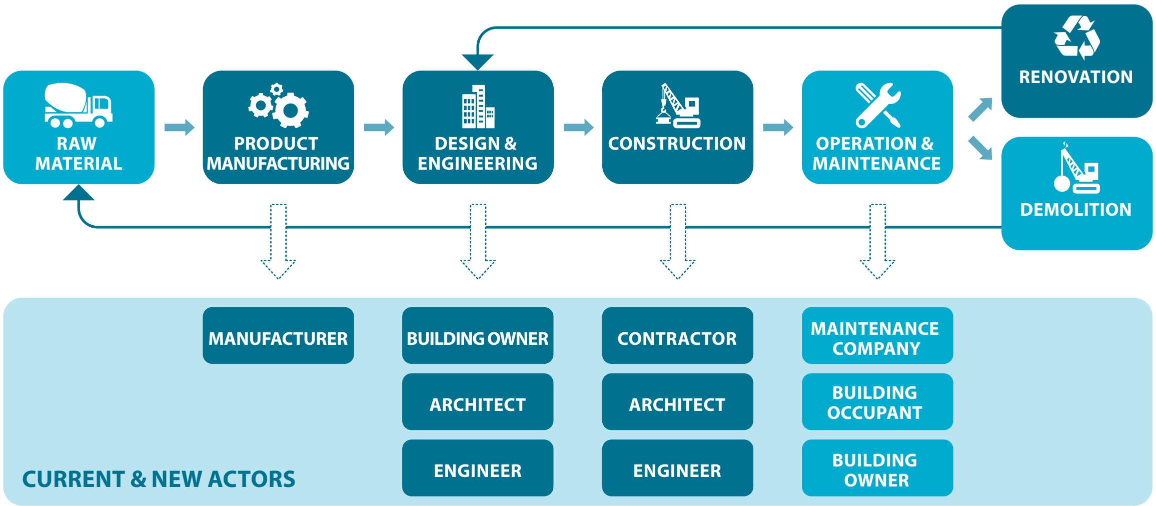
According to these criteria, Sweden, Germany and The Netherlands would be the first markets to target.

Explicit markets to capture value are:

- **Social housing:** In Europe, 90% of social housing is in need of refurbishment, often in poor energy efficiency conditions and with many tenants affected by fuel poverty.
- **DIY-renovation market:** The largest market value to capture in terms of renovation today is still represented by home-owners undertaking (stepwise) renovations by themselves, often missing the comprehensive overview and creating a lock-in effect for future energy-saving measures. To capture value in this target group, an innovative marketing approach is needed.

3.1.4 Impact on existing and new actors entering the value chain

Figure 14: Innovation in the construction value chain – involved actors in prefabricated systems for deep energy retrofits of residential buildings (Source: BPIE)



Since the construction sector is not perceived as an easy, high-profit market, there is little incentive for outside actors to enter the market. However, **shifts within the value chain** itself will occur:

- The numerous micro-enterprises[6] active as on-site workforce will have to reposition themselves to capture value within this market segment. They can do so by:
  - Producing prefab elements themselves;
  - Operating as sub-contractors for on-site assembly;
  - Offering project-management services.
- Manufacturers of prefabricated new buildings could make the shift towards the production of renovation modules.

If this innovation towards industrialised renovation systems were to be **consolidated**, it might lead to the following:

- Actors from building services, such as architects and structural engineers, will provide their services more integrated in the 'one-stop-shop' business models and less as independent actors in the building process. The design and engineering would be fully taken over by the manufacturer core business, primarily with an industrial approach (production line) and less from an individual building perspective.
  Few architects have experience with prefabricated systems for renovations, which is why repositioning is appropriate. Opportunities lie not only in the design of these systems, but also in project management, coordinating the collaboration structure and the contact with customers.
- Municipalities might have to change the way they execute the spatial planning regulation today, for the outside perimeter and the look and feel of renovated buildings might not fall within current regulations.

[6] These are enterprises with less than nine employees, which currently represent 94% of all enterprises active in the sector in Europe.

According to experts, there is **no risk of production leakage outside the EU**: a decrease of involved person-hours gives less incentive to export production to countries with lower labour costs. Moreover, logistics and the accuracy of the product are very important and more reliable and easy to monitor with production nearby.

However, production and assembly will not necessarily take place in the same countries. Dutch manufacturers see opportunities to export ready-to-install prefab systems and work with local contractors abroad for the measurement and assembly.

3.1.5 Enabling measures to unlock the transition

The measures to enable this transition are:

- **Policy regulation and support measures** based on performance (e.g. energy savings per square meter) rather than the quantity for the entire building stock with regular compliance and control mechanisms. There is also a need for a regulation that understands and translates the dynamics of the construction sector, allowing for new contractual relationships within the construction sector, while also paying special attention to not slowing down innovation.
  Plegt-Vos (Dutch prefab manufacturer): *"It would be possible to renovate your house in 3 days but you will have to wait 28 weeks for a permit because the government procedure takes that much time."*
  Main actors to engage with on this topic:
  - European policy makers responsible for buildings and energy;
  - National (or regional) policy makers responsible for buildings and energy;
  - Sector federations representing the different stakeholders in the construction sector.

- **Legislation on urban planning and architecture** should allow **more flexibility** in the expansion of houses due to energy renovation but also concerning their exterior appearance. Materials, glazed surfaces and other parameters can be different from usual ones due to standardisation of the renovation modules.
  Main actors to engage with on this topic:
  - National (or regional) policy makers responsible for relevant cross-thematic environments (e.g. housing, spatial planning, energy);
  - National (or regional) sector federations representing stakeholders from architecture, spatial and urban planning.

- **Support** by (local) governments or other organisations, such as social housing organisations, **in aggregating and mediating with building owners and users**.
  Main actors to engage with on this topic:
  - Local governments such as municipalities (Covenant of Mayors), provinces or district bodies;
  - Social or public service housing organisations, associations or cooperatives[7];
  - End-user alliances or federations.

- The introduction and further implementation of **Building Information Modelling (BIM)** and other standardised protocols. This will harmonise the collaboration between all building actors on matters such as 3D-drawings. BIM implementation and take up is very much country-dependent and has been relatively slow in the construction industry compared to industries such as manufacturing and engineering.
  Main actors to engage with on this topic:
  - EU BIM Working Group of the European Commission;
  - National Building Councils, bringing together all stakeholders of the construction sector;
  - National standards bodies;
  - All levels of governments for public procurement.

[7] Structures, size and typologies of these organisations are country-dependent. More information on how social housing is defined in the different countries of Europe (http://www.housingeurope.eu/page-91/the-observatory).

- An **attractive system and support from banking institutions** for enterprises that want to make these types of investments in innovation of their products or services. After the 2008 crisis and the significantly decreased margins in the construction sector, it is very hard to get bank support for these investments.
  Main actors to engage with on this topic:
  - Financial institutions (and the national federations representing them).
  - European policy makers responsible for finance and economy;
  - National (or regional) policy makers responsible for finance and economy;
  - European and national authorities responsible for support programmes on innovation.

- The calculation of costs and benefits, not only from the financial point of view, but also taking into account the cost to society for higher comfort and better health. Ambitious **energy efficiency renovations** should be approached as a combination of **cost, comfort and health**, where the broader impact on society should also be monetised.
  Main actors to engage with on this topic:
  - European research institutes;
  - European executive agencies responsible for EU support programmes;
  - European policy makers responsible for buildings and energy;
  - National (or regional) policy makers responsible for buildings and energy.

Three main challenges need to be addressed:

- **Renovation or demolition:** prefabricated renovation systems should always be considered alongside the idea of demolition. Renovation is, in some cases, suboptimal in terms of costs, energy savings and quality.
- The holistic application of prefabrication modules (integrating both the building envelope and building techniques) is more complex and often only used in **subsidised demo cases**. It is technically possible but not yet always economically feasible.
- **Transition or consolidation of the workforce**. A different kind of skills is needed for these new processes. The challenge will be to maintain a stable employment rate and use the opportunity to also employ an older workforce in the indoor facilities, for instance. An additional challenge is how to avoid job losses, almost inextricably connected with industrialised processes.

3.1.6 Best practices and pilot projects

Stroomversnelling – "rapids/acceleration"

- **What?** Collaboration between demand- and supply-side actors to realise 110,000 zero-energy renovations at no cost to occupants.
- **Where?** The Netherlands.
- **Stakeholders?** Energiesprong consortium and Platform 31.
- **Target Group?** Home-owners, communities, builders.
- **Type of works?** Whole-house renovation with minimal burden for the occupants (renovation of 4-10 days).
- **Timing?**
  - Prototyping: September 2013-December 2014 (1,000 homes)
  - Industrialization: January 2015-December 2016 (10,000 homes)
  - Scaling up: January 2017-2020 (100,000 homes).
- **More information?**
  - www.stroomversnelling.net
  - www.energiesprong.nl
  - www.stroomversnellingkoopwoningen.nl

Prefabricated systems for low-energy renovation of residential buildings – Annex 50 IEA's energy in buildings and communities programme

- **What?** The development and demonstration of an innovative whole-building-renovation concept for typical European apartment blocks. The concepts are largely based on standardised façade and roof systems suitable for prefabrication. The highly insulated new building envelope includes the integration of a ventilation system. Case studies are taken from six demonstration sites.
- **Participating countries?** Austria, Czech Republic, France, The Netherlands, Portugal, Sweden, Switzerland.
- **Target Group?** Building industry and building designers.
- **Timing?** Completed (2006-2012)
- **More information?** www.ecbcs.org/annexes/annex50.htm

3.2 ADVANCED INSULATION MATERIALS FOR BUILDING ENVELOPES

3.2.1 Ongoing transition

Heating and cooling loads represent the largest building-sector energy end-use. The insulation of the building envelope – the boundary between the conditioned interior of the building and the outdoor environment – can be significantly improved to reduce the energy needed to heat and cool buildings.

Current and future energy performance standards for renovations demand high insulation levels. However, traditional insulation materials cannot always do the job (for example to avoid thermal bridges) and space- or weight[8]-saving insulation solutions are necessary.

New super insulating materials (SIMs), such as vacuum insulation panels (VIP), gas filled panels (GFP) and aerogel based products (ABP) provide promising solutions. They can allow a reduction of insulation thickness by as much as a factor of five. [10]

The conventional insulation market is highly mature and, from a technological perspective, the deployment of traditional insulation has been successful, reaching full maturity in most regions worldwide. However, much more work is needed globally to level up SIMs from the initial market stage to a market uptake. Today they are mostly used in fridges and other appliances, aerospace applications, Formula 1 and industrial applications, but are slowly finding their way into the construction market. Most of these advanced insulation materials were not designed with the construction sector in mind and can therefore not simply be transferred without adaptation. For example, on a traditional construction site, it is difficult to apply SIMs since they do not come with tools or means to install and attach them. They are also to be handled with great care or might lose some of their key features.

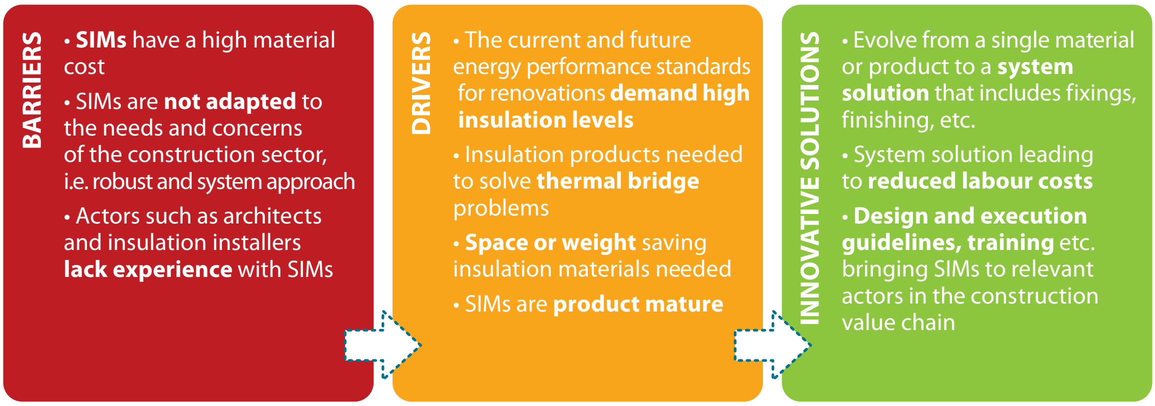
"The products are mature but the market isn't yet." Promat

Figure 15: Belgian production facility of Promat – other facilities in Italy, UK, USA and Japan (Source: Promat)

[8] Existing buildings are constructed with a certain weight taken into account for the structural calculations. Adding a significant extra load might endanger the stability of a building.

3.2.2 Innovation potential

Figure 16: Outlining the innovation of 'Advanced insulation materials for building envelopes' (Source: BPIE)



SIMs have a high material cost and were originally developed for industry applications. To be implemented at a higher scale in the built environment, SIMs should be adapted to the needs and concerns of the construction sector.

Manufacturers need to evolve **from a single material** or product **to a system solution** that includes fixings, finishing, etc. They need to develop **system innovation** customised to the current and future reality of the construction market:

- SIMs should be easy and efficient to install, with all fixings, the attachment structure and the necessary tools to handle them included.
- Price setting: a system solution can lead to SIMs reducing labour costs, especially regarding building renovations (e.g. interior wall insulation in historic buildings). Cost-effectiveness comprises both labour and material cost. With labour costs having the largest impact on the total price, an easy-to-install system could have a significant positive impact on the overall price setting.
- The viability and robustness of the system has to be tested in real-life construction environments and iterations with relevant actors such as architects, contractors and installers are necessary before launching a new product.
- Detailed design and execution guidelines have to be available and customised for the different actors such as architects, contractors and installers EU-wide. During trainings and events, manufacturers can show the benefits and added value of high-performance insulation materials, thus bringing these high-tech materials to the relevant players of the construction value chain.

3.2.3 Value to capture

Approximately 75% of the current European building stock will still be standing in 2050 and the largest part of energy consumption in these buildings is attributed to space heating. Refurbishing existing buildings, both in depth and rate, especially by applying thermal insulation, is one of the most cost-effective methods to reduce energy consumption. Studies show that thermal insulation has the best cost-abatement profile to reduce greenhouse gas emissions. With the adequate systems and a correct market price, SIMs can play a role in every deep energy refurbishment.

Table 3: An assessment of market saturation for high-priority building envelope components (Source: IEA [11])

MARKET MATURITY / SATURATION	ASEAN	Brazil	China	European Union	India	Japan / Korea	Mexico	Middle East	Australia / New Zealand	Russia	South Africa	United States / Canada
Typical insulation	★	●	★	★	●	★	●	★	★	★	●	★
Exterior insulation	●	▲	●	★	●	●	▲	●		▲	▲	★
Advanced insulation (e.g. aerogel, VIPs)				▲		▲				▲	▲	▲

★ MATURE MARKET ● ESTABLISHED MARKET ▲ INITIAL MARKET

Notes: ASEAN = Association of Southeast Asian Nations. Blank cells indicate that there is currently not any market presence or it is so low that it is not known to domestic experts. Some technologies may not be recommended for all climates, such as cool roofs in Russia or highly insulated windows in hot climates. Typical insulation refers to widely available products such as fibreglass and various foams with thermal conductivities higher than 0,02 watts per meter Kelvin (W/mK). VIP = vacuum-insulated panel. See Annex A and Glossary for more detailed descriptions.

The cost of SIMs today is still considerably higher than that of traditional insulation materials. The **average cost difference** for walls with the same thermal resistance is **a factor 10** today[9]. Compared to EPS insulation, payback periods of most investments range from **7 to 15 years** (Alam et al, 2011).

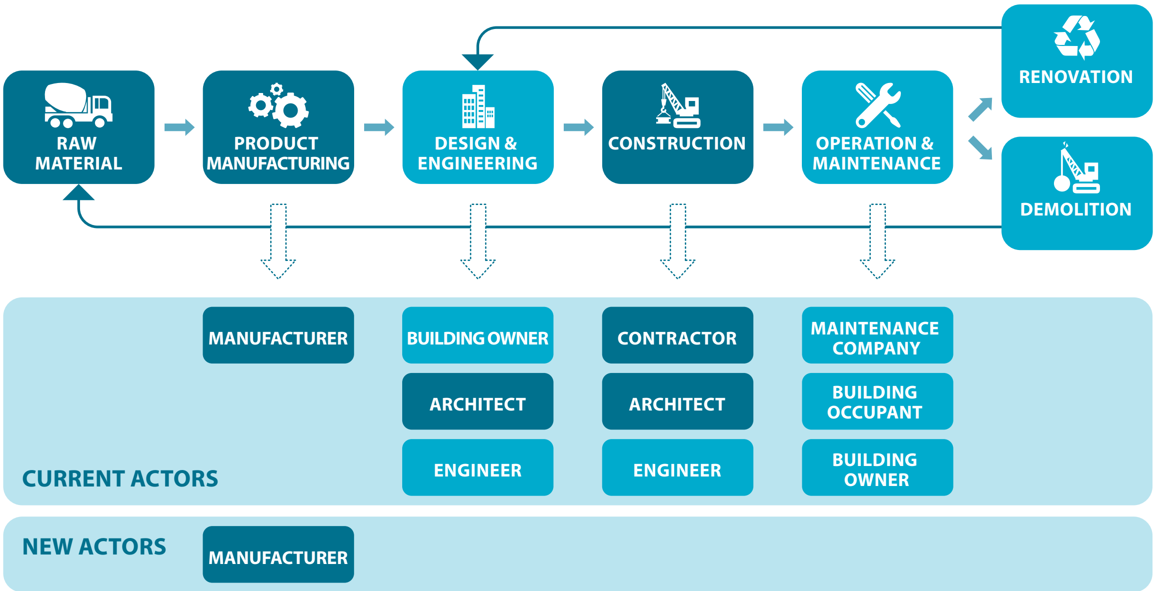
The total market for thermal insulation products in Europe reached **234.6 million m³ in 2014**. This equates to an **approximate market value of €11.5 billion**, of which glass and stone wool insulation together represent 58%. **Until 2019**, the thermal insulation market is poised to **grow at a rate of 2.8% per year.** The growth in Central and Eastern Europe combined is expected to exceed that of Western Europe, where the thermal insulation market is more mature. Interesting current growth has been reported in countries such as Germany, Italy, the United Kingdom and Turkey.

SIMs have a small share in this and will not achieve the same market value as conventional insulation materials. But they have a high market potential in niche areas of the renovation market, such as refurbishments with weight or space limitations or to avoid thermal bridges. Switzerland and Germany seem to be the front-runners in SIMs implementation.

[9] Alotaibi and S. Riffat, "Vacuum insulated panels for sustainable buildings: a review of research and applications", Institute of Sustainable Energy Technology, University of Nottingham, 2013.

3.2.4 Impact on existing and new actors entering the value chain

Figure 17: Innovation in the construction value chain – involved actors in advanced insulation materials for building envelopes (Source: BPIE)



Most of the building services (e.g. architects, energy experts and building management) and on-site workforce (e.g. installers and contractors) have **few or no direct contact or experience with SIMs**. However, it is much more likely that these actors will be trained to handle SIMs, rather than having completely new players enter the market. Within the on-site workforce, it is most likely that existing (sub-)contractors specialised in insulation will be the first to install SIMs. Therefore, these actors, together with architects, must be the primary target interlocutor of SIM manufacturers.

While manufacturers of conventional insulation materials are investing in some R&D regarding advanced insulation materials, their focus remains on **conventional insulation materials**. After all, there is **still a large market value to be captured** within their core business. The current market of traditional insulation materials is still growing, mainly due to increasing legislation on energy efficiency of buildings. Both for new buildings and for the renovation market, there is still room for growth of traditional products.

Manufacturers of industrial and **highly technological insulation materials** for aerospace, machinery, train and container insulation etc. (e.g. Panasonic, BASF and Promat) are interested in **entering the construction market**, attempting to expand their market by selling SIMs. So far, however, they have had **little success** since their products have not (yet) been adapted to the more artisanal nature of today's construction market. Compared to conventional players, they have the disadvantage of not having a wide network in place both with building services and with the on-site workforce.

Product, service and marketing innovations on the SIMs market, leading to more viable solutions for deep energy renovations, could slowly disrupt the conventional insulation market. This might force them to adapt their products and services by lowering prices, increasing marketing efforts, delivering more systematic approaches or focusing on SIMs, too.

3.2.5 Enabling measures to unlock the transition

The measures to enable this transition are:

- **Establishing targets, stricter legislation and support** measures for deep energy renovations. Progress should be tracked, reported and integrated with national energy-policy plans.
  Main actors to engage with on this topic:
  - European policy makers responsible for buildings and energy;
  - National (or regional) policy makers responsible for buildings and energy;
  - Sector federations representing the construction sector different stakeholders.

- The **co-benefits of low-energy buildings**, such as comfort and health, need to be **communicated** in a **better** way to the public and to financial communities, and integrated in policy measures.
  Main actors to engage with on this topic:
  - European research institutes;
  - European executive agencies responsible for EU support programmes;
  - European policy makers responsible for buildings and energy;
  - National (or regional) policy makers responsible for buildings and energy.

- **Integrated and consistent sets of policies**[10] overcoming barriers and promoting advanced materials and technologies that contribute significantly to energy-efficient building envelopes.
  Main actors to engage with on this topic:
  - National (or regional) policy makers responsible for relevant cross-thematic environments (e.g. housing, innovation, energy);
  - National (or regional) sector federations representing the construction sector stakeholders.

- **Trainings, guidelines and quality schemes** to increase the competence level of the on-site workforce and building services. Quality frameworks enforce market trust, leading to an increasing demand and decreasing prices. Consumers should be able to rely on the skills of building professionals and get value for money, which means that a building's equipment should achieve the expected energy performance, comfort level and operational lifetime. Negative experiences might though have an impact on the whole market uptake.
  Main actors to engage with on this topic:
  - Sector federations representing the construction sector stakeholders;
  - European executive agencies responsible for EU support programmes[11];
  - National (or regional) policy makers responsible for buildings, energy and education;
  - European and national certification and standards bodies;
  - Formation centres;
  - Research institutes.

- **Conduct case studies and demonstrations** of added-value high-performance insulation to show overall greater system energy efficiency and monetary effectiveness.
  Main actors to engage with on this topic:
  - Sector federations representing the stakeholders in the construction sector;
  - European and national research institutes;
  - European and national executive agencies responsible for EU support programmes.

- To allow one type of insulation to be compared with another, it is vital to have **accurate test protocols, ratings and performance declarations** for the energy performance of different materials. The performance of insulation types may vary according to types of applications, climate and the ageing process of materials. Therefore, it is best for independent bodies or government agencies to provide unbiased information about product energy performance and appropriate applications and to ensure that appropriate product material certifications are available.

[10] Integrated policies take into consideration the relevant cross-thematic policy environments such as innovation, energy, housing, economy, spatial planning, employment, etc.

[11] The European strategic initiative BUILD UP Skills aims to increase the number of qualified workers across Europe addressing skills in relation to energy efficiency and renewables in all types of buildings.

Main actors to engage with on this topic:

- European and national certification and standards bodies;
- European and national research institutes;
- National (or regional) sector federations representing the construction sector;
- European and national policy makers responsible for building standards.

3.2.6 Best practices and pilot projects

Innovation project almshouse 'de Schipjes'

- **What?** The housing zone called 'De Schipjes' was built in 1908 and consists of twelve almshouses inhabited by persons with a disability and seniors. A methodological approach is being developed to upgrade housing zones' energy in historic centres. To maintain maximum space in limited living areas, super insulating materials (SlimVac) and aerogel plasters are used.
- **Where?** Bruges, Belgium
- **Stakeholders?** Public Centre of Social Welfare De Schakelaar (client), Architecture office Murk Hanssens, University of Leuven, University of Ghent, Engineering Office Boydens, Promat and Viessmann Belgium. Project supported by the Flemish Agency for Innovation by Science and Technology (IWT).
- **Target Group?** Example project for other historic buildings in Flanders and in Europe.
- **Type of works?** Whole-house energy renovation with respect for historical heritage and monitoring user behaviour.
- **Timing?** 2014-2018
- **More information?**
  - www.kennisplatform-renovatie.be/wp-content/uploads/2015/06/5-VanKenhove.pdf
  - www.kennisplatform-renovatie.be

Office building of Frymakoruma

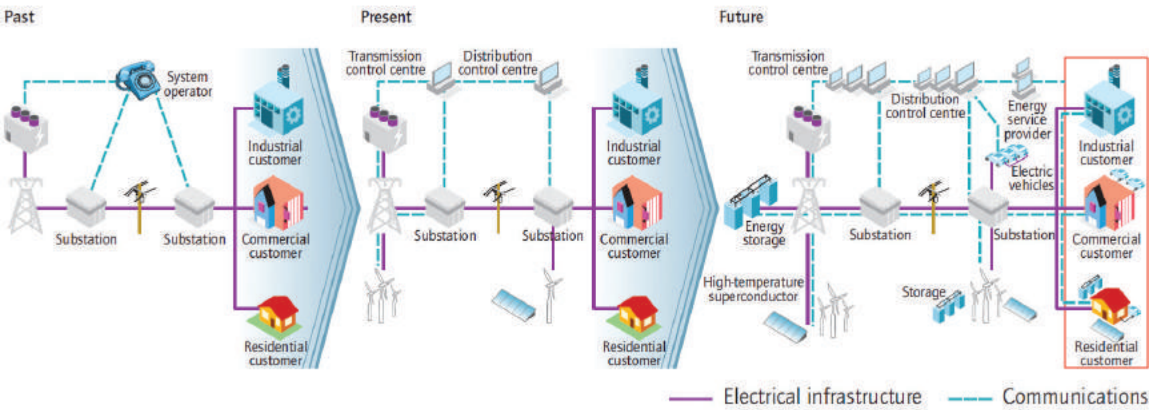
- **What?** An Energy retrofit of a 50-year-old office building with the aim of improving heating and energy efficiency. Reduction of the heating energy consumption from 333.000 kWh/a to calculated 200.000 kWh/a by the façade and window refurbishment.
- **Where?** Switzerland.
- **Stakeholders?** Evonik and Porextherm.
- **Type of works?** In order to achieve the requested objective of a U value of < 0.18 W/m2.K in standard building envelope construction procedures, an extreme renovation of the entire façade structure would have been necessary – meaning that the façade structure would have had to be replaced and all front buildings, the roof, the carpark in front of the building, would also have had to be adapted. Vacuum Insulation Panels were presented as a good alternative to this massive intervention. The intervention was minimally invasive while at the same time allowing for preservation of the existing façade structure. The construction process did not influence the workflow of the office, making this an attractive method.
- **More info?** www.vipa-international.com/case-studies

3.3 BUILDINGS' INTERACTION WITH THE ENERGY SYSTEM

3.3.1 Ongoing transition

The overall electricity market in the EU is transitioning from a centralised, fossil fuel, national system towards a more **decentralised, renewable, interconnected and variable system**, where buildings could become active players.

Figure 18: The smartening of the electricity system is an evolutionary process, not a one-time event[12] (Source: IEA 2011 [12])



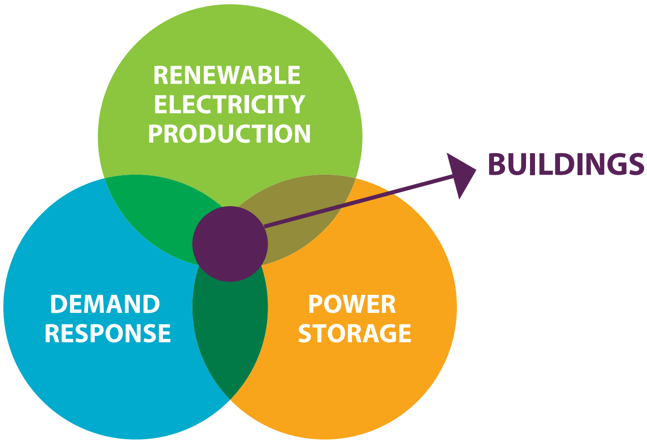
The construction value chain is becoming more and more intertwined with the energy system. The following key trends are changing the interaction between buildings and the energy sector:

- **Imbalance of the power market** because of significant penetration of decentralised – and mostly volatile – renewable energy generation technologies.
- **Power-load growth** due to the transition to electrification of transport and heating.
- **Power storage** in buildings will be viable for a much larger percentage of the market with increasing systemic pressures and pricing that will make it more attractive.
- **Smart appliances** (e.g. the Internet of Things) initiating demand response.

These trends impact the building value chain as they push buildings to take up a more interactive role in the energy system, thus creating **the opportunity for new and tailored services**. Beside the essential demand reduction, buildings increasingly interact with the power market and could take up an important role in power-supply-system stability by providing renewable electricity production, storage and demand response. These three strategies are not only complementary, but even enforce each other.

[12] Note that this figure dates from 2011. It is more realistic to assume that the real present situation is located somewhere between the 'present' and the 'future' from the figure.

Figure 19: Strategies for buildings to interact with the power market (Source: BPIE)



Technology and services will have to evolve to **manage demand in an efficient and responsive manner, as well as integrate storage.** A strong interaction between many different players in the energy market will be necessary.

Thanks to the benefits of experience and scale, **the tipping point for the combination of photovoltaic energy systems and power storage in buildings is expected to be reached in a few years.** In addition, demand-response applications are also suitable for buildings without renewable energy production, since their consumption during peak hours (when electricity is scarce) is mostly higher.

"Depending on how the cost of batteries is evolving in the five coming years, basically all companies (solar players, utilities and new entrants) who want to be active in the residential segment will at some point get into the solar + storage business." SolarPower Europe

"The old idea of fixing a capacity problem with extra cables is not sufficient anymore. We would need more cables than technically possible to solve the problem. […] IT solutions have become so widespread and cheap that this is a much better solution than adding another cable in the ground." Eandis (Belgian DSO)

3.3.2 Innovation potential

Figure 20: Outlining the innovation of 'The buildings' interaction with the energy system' (Source: BPIE)

BARRIERS

- Demand response and power storage are **not yet mature enough for the market**
- **Cost of demand response and power storage** systems
- Customer concerns regarding comfort **decrease, data privacy and user-friendliness**
- Lack of **overall communication protocol** for demand-response components to interact

BDRIVERS

- **Imbalance of the power market** because of significant penetration of decentralised – and mostly volatile – renewable-energy-generation technologies
- **Power-load growth** due to the transition to the electrification of transport and heating systems
- Uptake of **smart appliances** initiating demand response
- The **tipping point for the combination of photovoltaic systems and power storage** in buildings is expected to be reached in a few years

INNOVATIVE SOLUTIONS

- **Third-party business models** aggregating the buildings' interaction with the energy system
- **Communication interface and steering programme** customised to the building occupants needs and wishes
- **Smart controls and household appliances** enabling building occupants to modulate their energy use

Enabled by technology and business-model innovation, buildings can or will become active players in the energy system. As opposed to only using energy from the grid, **they produce, store and supply energy** or help balance the grid with demand management. This role of demand response and flexibility management will ask for the integration of automated steering systems and storage units at the building level. It will also require new business models for the operation and maintenance of buildings and alternatives to the classic contracts buildings have with energy suppliers. This innovation could even extend to include electrification of heat and transport (with electric vehicles serving as power storage system as well) and the needed charging infrastructure, based on an approach that starts from an end-use functional perspective and aims to optimise the energy use to deliver thermal comfort, mobility, shelter and more.

In contrast to various energy-demand reduction measures, demand response and storage can be integrated more easily in existing buildings, but they are not yet at market maturity. The **main issues** preventing market implementation today are:

- The **lack of an overall communication/IT protocol** for all the components of the demand response process to interact properly;
- The **cost and maturity of storage units**, both small and larger scale;
- **Adapted policy and clear responsibility divisions** in all aspects of the demand-response value chain. This will require a close collaboration between the building and energy sectors.

Citizens get easily excited about new technologies, but concerns regarding comfort and data privacy need to form an integral part of the innovation process. Behavioural changes will happen faster if there is societal acceptance. Widespread adaptation of renewable and storage technologies, as well as marketing campaigns, such as the Powerwall campaign by Tesla, largely contribute to this factor.

The construction value chain could empower building occupants by providing the following innovative services or products:

- **Third-party business models** (aggregators, agents or energy service companies – ESCO's) aggregating demand response, storage and on-site power production, as well as monitoring and controlling them, thus saving money for building owners or occupants. They could also provide building technologies through a specific financing model (e.g. leasing). Mass demand response will only happen if these third parties act on behalf of consumers. For this to happen, however, the business case must be viable. Aggregators have to be able to extract enough value – from a pool of resources – in order to have a business case. Therefore, the benefit for the building occupant or manager has to be sufficient to hand over control.
- **A communication interface and steering programme** easy to use for building occupants, limiting their effort to implement demand response themselves.
- **Storage possibilities** facilitating the shift of consumption in time through load shifting and peak savings. These include local storage in buildings as part of their existing heat storage - a potential practically untapped at present, yet with very low costs and short returns on investment.
- **Smart controls and household appliances** enabling building users to temporarily modulate their energy use, without compromising the quality of their process, according to a user's stated preferences, system, load or price signals. As long as there is no variable price signal coming from the grid to activate or deactivate these appliances, there will continue to be a limited use of smart appliances. This is a crucial step in demand response.

3.3.3 Value to capture

In a complex energy environment, a more active role of the existing and future buildings' infrastructure is a key innovation with large value to be captured. Demand response, on-site renewable power production and storage solutions will **lead to uptake of renewables and further decarbonisation**.

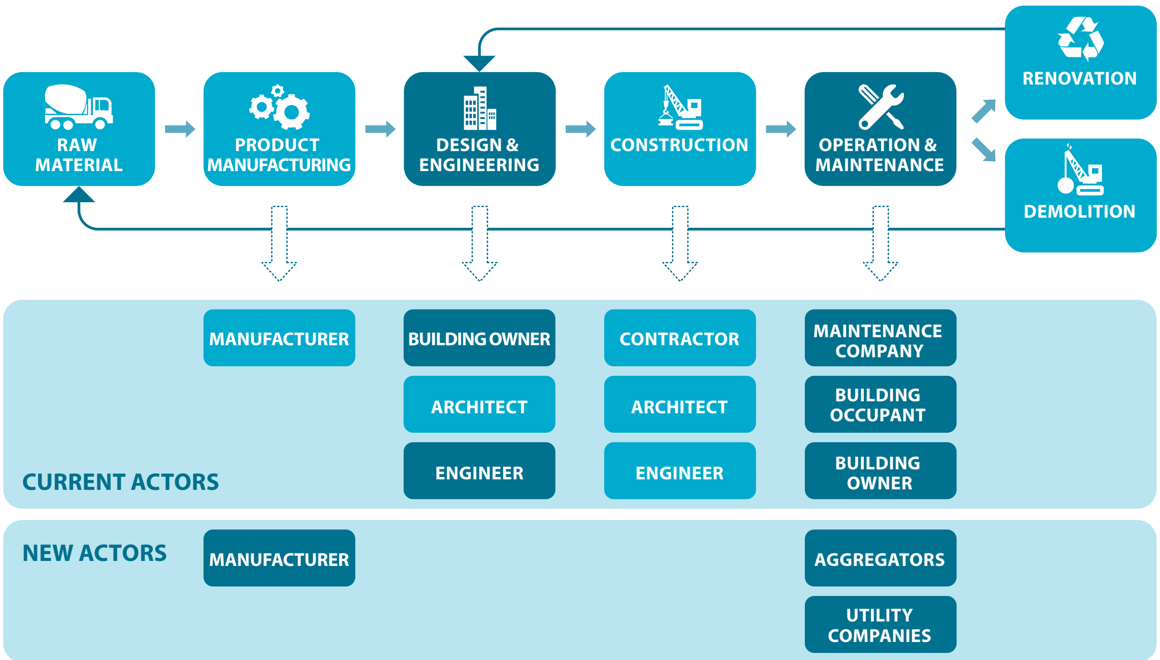
The Rocky Mountain Institute reports that in the US, in the residential sector alone, widespread implementation of demand response can save 10-15% of potential grid costs, and customers can cut their electricity bills by 10-40% with existing rates and technologies.

It is estimated that in 2020 Europe will have about 6,300,000 PV installations on residential buildings, mainly in Germany, the UK, Italy, France, Spain, Belgium and possibly new additional markets. With the tipping point for the combination of PV systems and batteries in Europe to come around 2020, it can be expected that a large share of these buildings with PV systems will install household power storage systems and the necessary applications for demand responsive management.

The uptake of demand response and power storage is coherent with the uptake of related technologies, such as energy management systems, smart meters, smart thermostats, heat pumps and electric vehicles. The integration of electric vehicles in the energy cycle of buildings is advantageous for the energy use of a building and its energy flexibility in the grid.

3.3.4 Impact on existing and new actors entering the value chain

Figure 21: Innovation in the construction value chain – involved actors in buildings interaction with the energy system (Source: BPIE)



Buildings and their smart devices are interacting more and more with the energy market. Both existing building control companies such as Johnson Controls, Siemens, Honeywell and Schneider Electric but also new entrants can offer services relating to demand response for the residential market. New market actors, which originated from the ICT (e.g. Google, Apple), the utility (e.g. E.on, British Gas) and the electric vehicle (e.g. Tesla) value chains, are capturing value across the respective chain and are starting to enter the market.

The EU has a comparative advantage since most of the developments needed in this segment are high-tech innovations. Within the EU there are numerous R&D institutes, subsidy schemes etc. to help develop this specific kind of technology innovation. There is an opportunity for manufacturers of HVAC, monitoring systems and white goods to adapt their products to function in this new technological environment. In contrast to the PV-panel production, which moved to non-EU states, the manufacturers of invertors and power control mechanisms are strongly represented in Europe.

3.3.5 Enabling measures to unlock the transition

The measures to enable this transition are:

- At a political level, a **comprehensive and integrated vision on electrification of heat** (and transport), and more specifically on the integration of demand response, renewable energy production and storage in buildings.
  Main actors to engage with on this topic:
  - European policy makers;
  - National policy makers.

- An **enabling regulatory framework**, which encourages the building's interaction with the energy system.
  Main actors to engage with on this topic:
  - European policy makers responsible for buildings and energy;
  - National (or regional) policy makers responsible for buildings and energy.

- **Aggregators** supporting not only industrial, but as well commercial and residential consumer groups.
  Main actors to engage with on this topic:
  - Private bodies such as private aggregators, utility companies, distribution system operators, new actors, etc. (see section on 'Innovation potential');
  - End-user alliances or federations;
  - Public or non-profit bodies (supported by local government);
  - Housing organisations, associations or cooperatives.

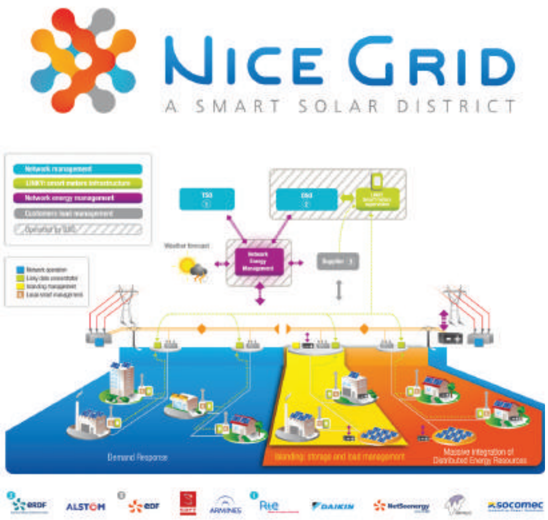
- The **availability of dynamic price signals** for industrial, commercial and residential consumers.
  Main actors to engage with on this topic:
  - Electricity suppliers;
  - Power System Operators;
  - European policy makers responsible for energy;
  - National (or regional) policy makers responsible for energy;
  - National (or regional) energy regulators.

- Smart and user-adapted metering and control systems with a **universal communication protocol**.
  Main actors to engage with on this topic:
  - Large players in the smart metering and control industries;
  - Sector federations representing the smart metering and control industries;
  - Standards bodies.

- **Strategic planning of the grid**, both at transmission and distribution levels: this is a real investment challenge because, under the current paradigm, it is normally the individual generators of supply and the individual users of demand who pay for the grid costs. This does not allow for strategic planning in a transition towards decarbonisation and could thus limit innovation.
  Main actors to engage with on this topic:
  - European policy makers responsible for energy;
  - National, regional and local policy makers responsible for energy;
  - Transmission and distribution system operators;
  - Energy market actors.

3.3.6 Best practices and pilot projects

Nice Grid



- **What?** The first smart 'solar energy district' demonstration project in France to test the operation of a "smart" power grid with enhanced communication and response capabilities, including a high proportion of dispersed solar power sources connected to individual energy storage units. Nice Grid will develop an energy management system that will optimize the balance between power consumption and generation of electricity at district level.
- **Project outcomes?** One of the first conclusions is that battery storage in Europe costs €500-1,000 per kilowatt/hour (KWh), with an extra 30% additional cost. At that level, battery storage would already be economically viable in some parts of Germany and Denmark, both characterised by advanced renewable energy use and retail power rates of around 30 cents per kilowatt/hour (in France, residential power rates are around 17 cents per KWh). At the end of the project, it will be clear how much the cost of batteries would have to decrease to become viable for grid storage.
- **Where?** Municipality of Carros, department of Alpes-Maritimes (near the French Riviera), France.
- **Stakeholders?** Granted funding under France's first Future Investments Program, with private partners such as ERDF, ALSTOM, EDF, SAFT, ARMINES, RTE and DAIKIN.
- **Target Group?** Distribution network owners and operators, electricity producers and consumers.
- **Timing?** January 2012-December 2015.
- **More information?** www.nicegrid.fr

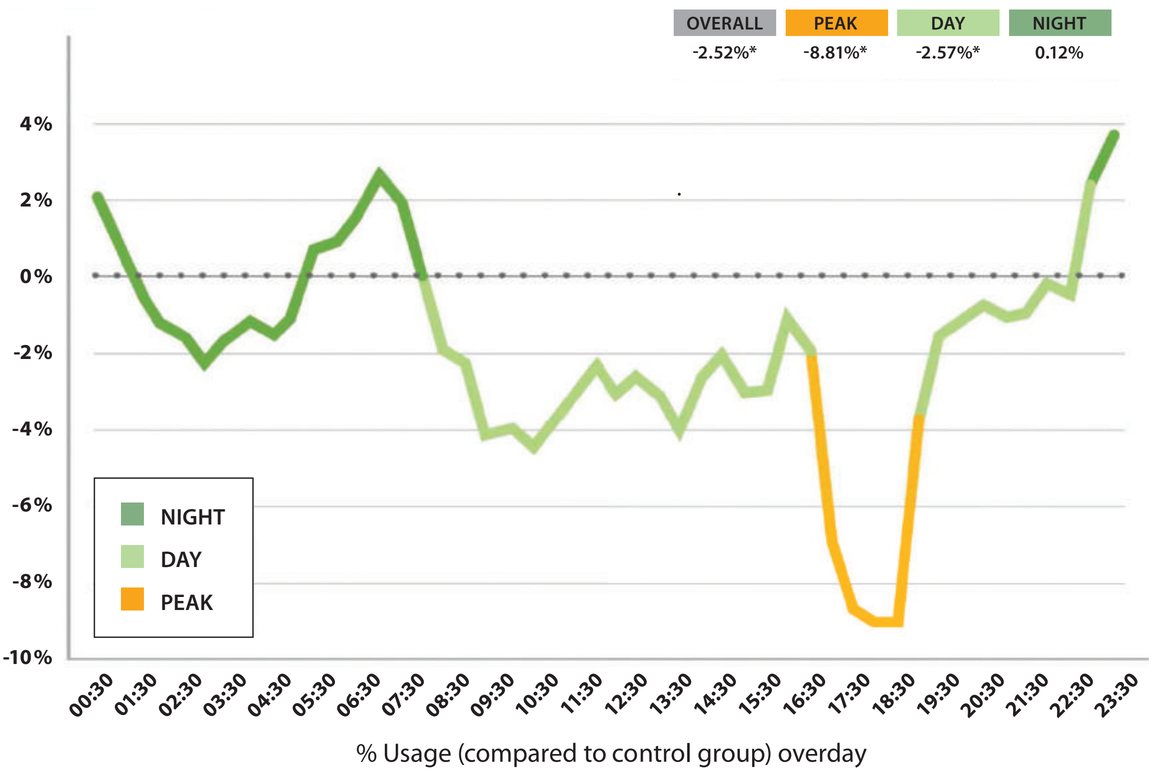
Linear

- **What?** A Flemish Smart Grid project focusing on solutions to match residential electricity consumption with available wind and solar energy, an approach referred to as demand response. Partners from the research and industrial sectors joined forces in close collaboration with the government to develop, implement and evaluate demand response technology.
- **Project outcomes?** Automated demand response with household appliances is technically feasible, but smart-start functionality is needed to avoid user fatigue.
- **Where?** Region of Flanders, Belgium.
- **Stakeholders?** Cooperation between the research institutes of EnergyVille and iMinds. It is financed by the Flemish Government and receives considerable support from Belgacom, Eandis, EDF Luminus, EnergyVille, Fifthplay, Infrax, Laborelec, Miele, Siemens, Telenet and Viessman.
- **Target Group?** In total, 240 families participated, evaluating two different consumer interaction models (variable time of use and automated demand-side management).
- **Timing?** 2009–2014.
- **More information?** www.linear-smartgrid.be

National Smart Metering Programme Ireland

- **What?** Pilot project with a cost-benefit analysis of 12 scenarios for implementing smart metering in Ireland, with an installation of 5,375 smart meters in residential dwellings and 700 in small businesses and commercial enterprises.
- **Project outcomes?** Smart meters in conjunction with time-of-use tariffs and informational aids (e.g. in-home displays, detailed energy statements) deliver an overall reduction consumption of 2.5% and a reduction in consumption at peak times of 8.8%. With regard to consumer information, the participants who had an in-home display were able to reduce their consumption by 3.2% overall and by 11.3% at peak times. If implemented, the roll-out of the smart meters would mean a net present value of €174 million and a 150,000 tons of CO_2 reduction per year.
- **Where?** Ireland.
- **Stakeholders?** Commission for Energy Regulation (CER), Economic and Social Research Institute (ESRI), Sustainable Energy Authority of Ireland (SEAI), Northern Ireland Authority for Utility Regulation (NIAUR) and the Irish Gas and Electricity Industry Participants.
- **Target Group?** Residential buildings, small businesses and commercial enterprises.
- **Timing?** 2009 for a decision on nation-wide roll-out from 2015-2019.
- **More information?**
  - www.iea-isgan.org/?c=5/112/367&uid=1314
  - www.cer.ie/docs/000699/CER14046%20High%20Level%20Design.pdf

Figure 22: Results of the Irish smart meter pilot with consumption reduction by TOU over 24 hours
(Source: International Smart Grid Action Network)



3.4 BUILDING AUTOMATION AND CONTROL TECHNOLOGIES

3.4.1 Ongoing transition

Building Automation (BA) can refer to Building Automated Control Systems (BACS), Building Automation Technologies (BAT) as well as Home and Building Energy Management Systems (HEMS/BEMS) solutions.[13] Today these technologies mainly focus on HVAC systems and they can be applied in varying degrees of integration and sophistication. Detailed analyses have shown that BEMS are among the set of cost-optimal measures that will produce economically viable energy savings [13].

Three main areas of transition can be identified in these different systems:

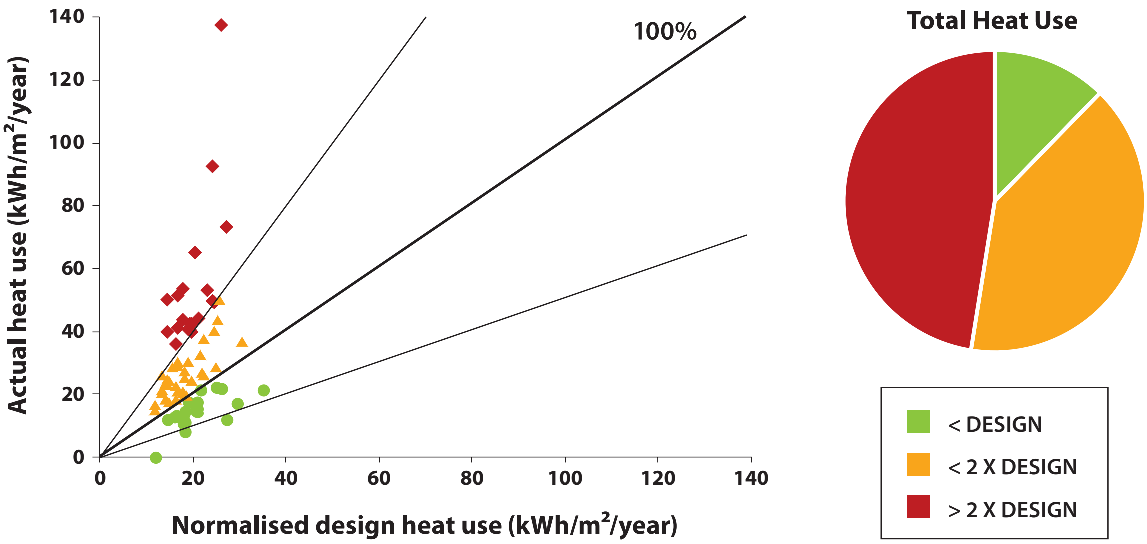
- **Model-based controls[14];**
- **Semantic tagging[15];**
- **Smart building applications.**

All of these changes **focus on dynamic or even self-learning control systems**. Instead of static, predefined parameters for control, the system itself can define and steer the relevant parameters (e.g. optimal temperature, heating time, light lumen, operational-time installations, overheating protection), in a specific moment, and based on occupation, (predicted) inside- and outside temperature and so on. The final energy use in a building is generated through a combination of building envelope characteristics (incl. design and orientation), installations (incl. renewable energy) and user behaviour.

After finalising construction or renovation, the behaviour is adjusted to achieve the expected end-functions of buildings, e.g. turning on the heating/thermostat when cold, opening the windows for ventilation, turning on the air-conditioning if too warm, switching on the lights, etc. Very often, this behaviour leads to the calculated final energy demand (i.e. the building envelope and the installations) and the real measured final energy demand being very different.

Figure 23 clearly shows the difference between the actual and the designed heat use for space and domestic hot water heating of low-energy dwellings and the effect of user behaviour on the final energy demand. One quarter of the dwellings (with highest heat use over design) are responsible for almost 50% of the heat use of the site.

Figure 23: Monitoring designed and actual heat use in dwellings (Source: Ghent University)



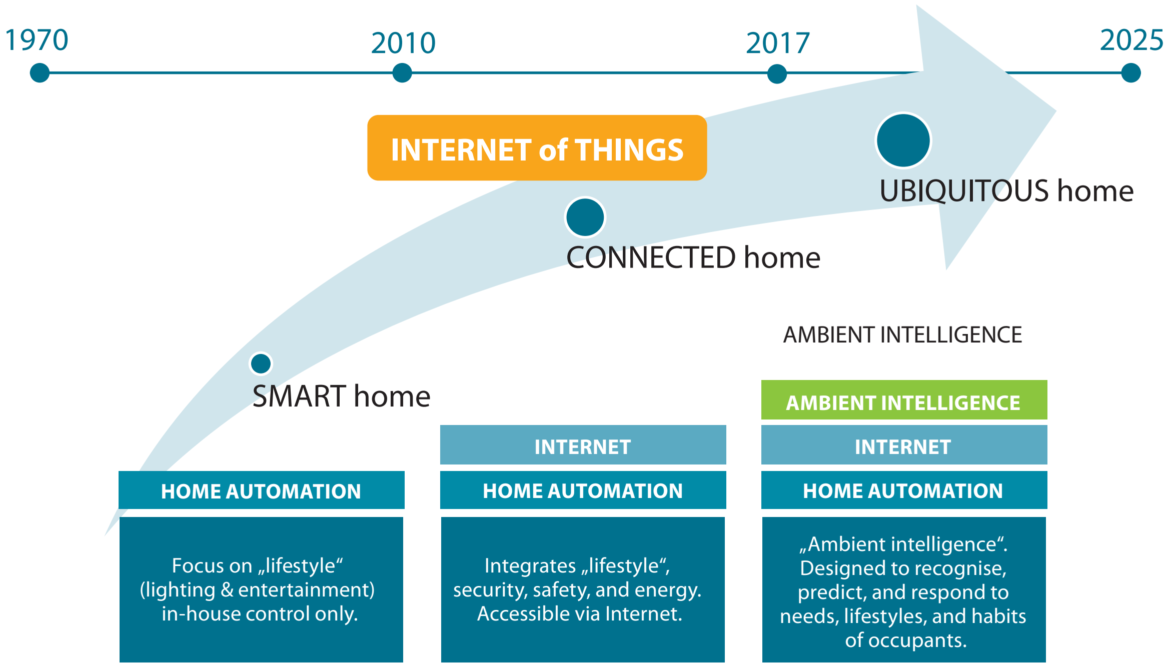
[13] In this document mostly the general terminology Building Automation (BA) is used.

[14] Model-based controls are automated building controls, predicting the necessary behaviour of a building based on the foreseen occupancy, the weather forecast, etc. They look further ahead and adapt the building systems in anticipation of the forecast.

[15] Semantic tagging is the labelling of all components in an entire building's technical system. Naming all these components allows them to be integrated in a system and communicate with each other.

With the ongoing transition towards the "Internet of Things" (figure 24), the market will move to the "Ubiquitous Home"– where sophisticated systems learn user behaviour/lifestyle and respond accordingly.

Figure 24: Evolution of connected and smart homes (Source: BSRIA [14])

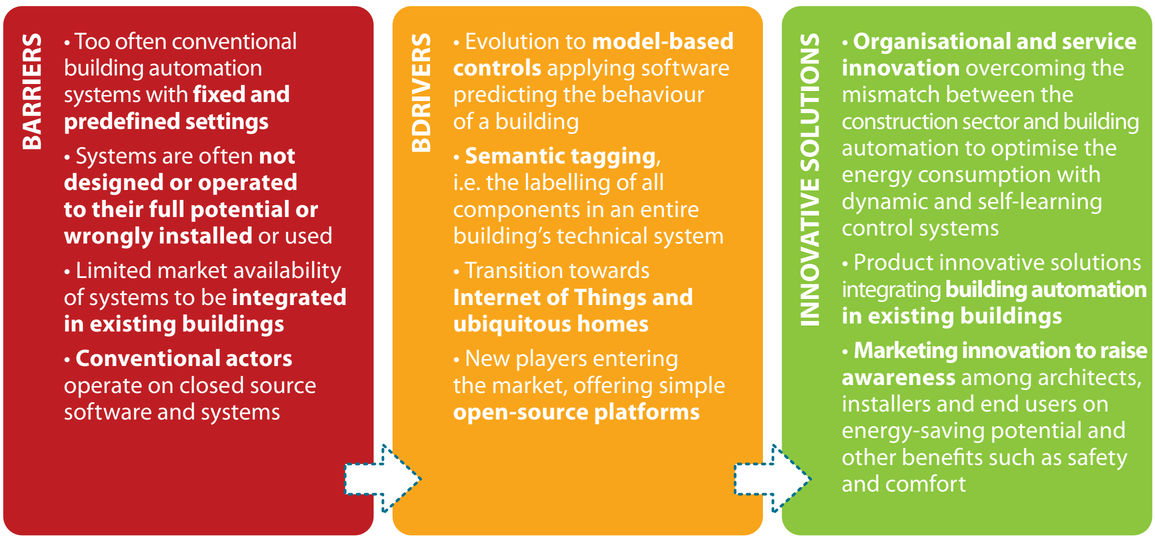


"If we can combine model-predictive control together with self-learning smart applications, then we are almost there." Siemens

"Between 20-30% of the installed systems could be largely improved if they would be combined and people would invest in this combination. Although it's known technology, nothing new, no model prediction, no nothing. It's just a combination of different signals." Siemens

3.4.2 Innovation potential

Figure 25: Outlining the innovation of 'Building automation and control technologies' (Source: BPIE)



In 2013, the BA market was worth more than $20 billion and it has now reached a critical mass from where it seems set to break through to mass market. Yet today BA systems are not yet being used to their full potential to lower energy consumption in buildings. Maximising this potential could provide a **large opportunity** for the construction value chain to **significantly lower building operation costs** and to **create new jobs** for the energy management of buildings.

The innovation potential to achieve full market implementation lies in solutions for the following issues:

- **Organisational and service innovation.** Overcoming the mismatch between the inertia of the construction sector and the complexity of BA systems. A different way of designing a building's HVAC system is required, where it should be considered from the design stage that a balance between energy efficiency and operation efficiency is needed. There is no use in advanced systems if they are not designed or operated to their full potential or if they are wrongly installed or used. All the new BA systems available on the market or under development could easily be used to save energy in buildings by **optimising energy** use, but are very often not used for that purpose (they are more commonly used to monitor system breakdown or malfunction or to measure energy use).
  The market should transform more strongly from the conventional fixed, predefined settings to **self-learning and/or -steering systems** that regulate buildings in a dynamic way. Manufacturers have to skill up installers, energy experts and ICT personnel to achieve the necessary competence levels to correctly design, install and operate systems.
- **Product innovation for existing buildings:** More complex systems are mostly developed from a new buildings perspective, and they are often very difficult to implement in existing buildings. There are integrated systems for existing buildings, but market availability is limited.
- **Marketing innovation:** The largest growth potential lies in marketing innovation to raise awareness among architects, installers and end users on the energy-saving potential and other advantages, such as safety[16] and comfort. Both government organisations and manufacturers of BA have an important role in this process.

3.4.3 Value to capture

BA is cost-effective for essentially all service-sector buildings, regardless of national energy prices, usage and climatic factors, provided it is correctly installed, commissioned and operated. The average net energy savings per installation are about 37% for space heating, water heating and cooling/ventilation, and 25% for lighting. **Currently only about 25% of service-sector buildings have properly installed BA**.

Proper installation[17] and operation of the better types of BA in households will on average save 30% of heating and hot water energy compared to the average default control systems installed in the building stock.

Innovations on different segments of the construction value chain reinforce each other, creating a positive feedback loop: BA is a complement to smart meters and is crucial in the roll-out of the buildings interaction with the energy market (i.e. energy production, storage and demand response).

The Copper Alliance Institute claims that BA has a potential of saving 15-22% of the total energy consumption in European buildings. It is highly cost-effective, with benefits being nine times higher than costs. Even more significant are the contributions towards climate change mitigation. A reduction of 260 to 419 million tons of CO_2 would reduce Europe's emissions from fuel combustion of 8-13% by 2035.

[16] In the US, 90% of consumers indicate security as one of the top reasons to purchase a smart home system.

[17] BA is very complex to install and requires highly skilled monitoring and commissioning to ensure they keep working optimally. Compatible communication protocols between software and hardware remain a problem to ensure a qualitative installation.

Two scenarios are generally presented to capture added value from the BA perspective:

- **The Optimal Scenario**: based on a perfectly functioning construction-market scenario, where all cost-effective energy-saving opportunities are seized, without serious constraints to effective service delivery.
- **The Recommended Scenario:** a more realistic depiction of the potential to deliver additional savings beyond the business-as-usual.

A rough estimation of the possible economic and environmental value potential for both scenarios is listed in table 3 [15].

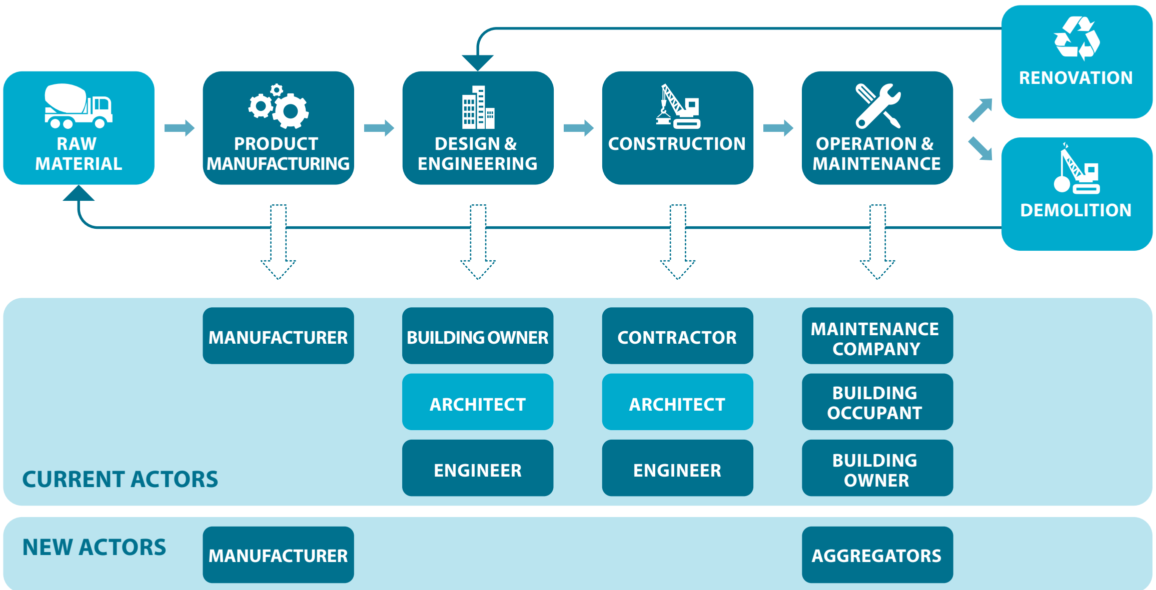
Table 3: Market evolution and environmental impact of BA (Source: Waide Strategic Efficiency)

BA	Job creation	Economic impact	Environmental impact (yearly after peak)	Environmental impact (2013 – 2035)
Optimal scenario	4 million new jobs from 2013 – 2034	Savings = 1.1% of EU GDP Average payback per system = 1.5 year	150 Mtoe 9% of total EU energy consumption	2100 Mtoe 5.9 Gt CO_2eq
Recommended action scenario	(no data available)	Invest = €6.2bn/year Savings = €54bn/year	89 Mtoe 5% of total EU energy consumption	1000 Mtoe 3.4 Gt CO_2eq

In Europe, mainly Germany, Scandinavian countries, the UK and The Netherlands are leading in implementing BA.

3.4.4 Impact on existing and new actors entering the value chain

Figure 26: Innovation in the construction value chain – building automation and control technologies (Source: BPIE)



Innovation in the Building Automation Sector is strongly linked to **innovation and change in the IT and energy sector**. These sectors will strongly impact the technology evolutions of BA.

The US and Japan have strong BA markets, but most product developments for the European market will occur within Europe (mainly Germany, Switzerland, France, the UK and Italy), although many components may be sourced from outside. This is even more the case for BAT, where the technologies tend to be quite specifically geared towards the nature of the HVAC systems used.

The building automation and controls industry is **quite fragmented with many players involved**, but the very large players dominate the market. The top six companies account for about 37% of installed system sales. Because these conventional actors operate on **closed-source** software and systems, more small players are entering the market, offering simple **open-source** HEMS. This allows their products to be implemented more easily in larger buildings.

Some large new actors, like Google NEST and Apple, are entering the market as well focusing on the home side of the market and less on complex building systems. They often have innovative open-source platforms, allowing different applications to run. The interruptive actors could push the larger conventional market players to change their systems and business models. It might also stimulate the necessary change towards more flexible and dynamic systems.

Many of the projected newly created jobs will be for installers and energy experts for whom it will be necessary to establish competence requirements supported by accreditation and certification.

3.4.5 Enabling measures to unlock the transition

The measures to enable this transition are:

Increase the reliability of the savings from BA
Today it is very precarious to organise energy performance contracting (EPC) based on a BA or to calculate return rates based on BAs expected generated energy savings. There is a lack of knowledge about international monitoring standards and because of the many components that the BA controls, it is very complex to estimate and analyse the accurate energy saving of a building. This could be overcome by the following measures:

- **Educating and improving the skills** of the supply chain – focusing on energy engineers or maintenance companies who will operate the systems, on HVAC engineers and installers as well as on building owners.
  Main actors to engage with on this topic:
  - Sector federations representing the stakeholders in the building automation sector;
  - National (or regional) policy makers responsible for buildings, energy and education;
  - European and national certification and standards bodies;
  - Formation centres;
  - Research institutes.

- Strengthening **interoperability between different building installations** like heating, ventilation units, chillers, etc. and a standardization of their communication protocol.
  Main actors to engage with on this topic:
  - European policy makers responsible for eco-design and energy;
  - Large players in the building installation industries;
  - Sector federations representing the building installation industries;
  - Standards bodies;
  - Research institutes.

- Promoting high-quality **continuous commissioning of the full systems** – not just energy audits.
  Main actors to engage with on this topic:
  - National (or regional) public authorities responsible for buildings and energy;
  - Large players in the building automation industries.

- Promoting development **of advanced data-analysis techniques** and routes to market.
  Main actors to engage with on this topic:
  - National (or regional) public authorities responsible for buildings and energy;
  - Large players in the building automation industries;
  - Research institutes.

Increase the adoption of BA

- Raise awareness in the market of the **value proposition**.
  Main actors to engage with on this topic:
  - National (or regional) public authorities responsible for buildings and energy;
  - Large players in the building automation industries.

- Supporting and promoting (further) **uptake of smart grids, demand-side management and on-site renewable energy production**.
  Main actors to engage with on this topic:
  - European policy makers responsible for buildings and energy;
  - National (or regional) policy makers responsible for buildings and energy.

- Push the **implementation of ISO 50001** (energy-management-system standard) in the building sector, which has the potential to stimulate the integration of energy-saving control systems.
  Main actors to engage with on this topic:
  - European policy makers responsible for buildings and energy;
  - National (or regional) policy makers responsible for buildings and energy;
  - European and national standards bodies.

Actions on both aspects are needed to create a virtuous circle, build confidence and drive demand.

3.4.6 Best practices and pilot projects

HOMES - Housing and Buildings Optimised for the Management of Energy and Services

- **What?** Propose operational solutions on a large scale to allow each building to achieve the best energy performance across the entire stock of European buildings, whether new or existing, residential or commercial. Five pilot cases (school, office, collective residential and two hotels) were involved in the project to test in a real situation the developed strategies (i.e. reduce needs, optimise energy supplies and involve behaviour).
- **Project outcomes?**
  At the five pilot cases, energy savings between 25% and 56% were realised. The HOMES-project concluded for the European market with the following projections:
  - Potential savings between 20-60% of a site's total energy bill;
  - Provide a return on investment between 3 and 7 years in the tertiary sector, and between 5 and 15 years in the residential sector;
  - Applied to 230 million European buildings, enabling a significant reduction of final energy demand, i.e. reduced building consumption by 40%, which is 16% of the total energy bill in Europe;
  - Would create about 600,000 direct jobs in Europe over 30 years.
- **Where?** Focus on France and the UK, with roll out opportunity for Europe.
- **Stakeholders?** 13 industry and research partners, launched by Schneider Electric.
- **Timing?** 2008-2013

- **More information?** http://www.eubac.org/cms/upload/newsletter/heatingandcoolingstrategy/Presentation_Homes_Project.pdf and http://www2.schneider-electric.com/documents/press-releases/en/shared/2013/02/20130213_PRG-Cloture-HOMES.pdf

Implementing a Model Predictive Control at 3E's office

- **What?** A demonstration of model predictive control on a hybrid heating system in a Brussels' office building, testing the impact on the control performance in terms of thermal comfort and energy cost. The model predictive control algorithm runs as a software service on top of the existing building energy management system (BEMS). A two-way communication infrastructure with the BEMS allows to read the monitoring data and write the optimised control set points in real-time.
- **Project outcomes?** The model predictive controller provides a similar or better thermal comfort than the reference control while reducing the energy costs by more than 30%. Zone temperature set points are followed more closely, enabling a better use of the heat pumps and an adapted hot water supply temperature.
- **Where?** Medium-sized office building in Brussels, Belgium.
- **Stakeholders?** Granted under the European ITEA2 program funded Enerficiency project, with scientific partner KU Leuven and private partners Thercon, Fixsus and Imtech.
- **Target Group?** Building owners, building asset managers, ESCOs.
- **Timing?** July 2010-July 2015.
- **More information?** http://www.3e.eu/energy-and-buildings-implementing-a-model-predicting-control/

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