European Commission

Business Innovation Observatory

Smart Living

Smart construction products and processes

Case study 17

Enterprise and Industry

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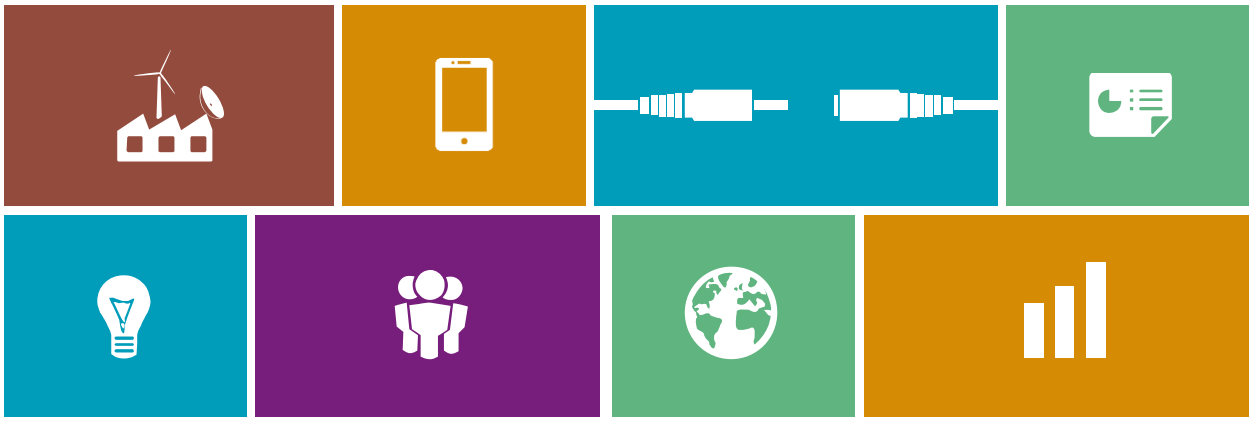


1. Executive summary

Smart Living as a trend involves improved standards in several aspects of day-to-day life, ranging from domiciles, workplaces and the way people are transported within cities. Within the context of construction of buildings, the trend can be identified through the growing existence of innovative, quicker, cheaper and more efficient construction technologies, materials, processes and concepts.

These new technologies provide several benefits: reduced costs; lower carbon emissions for constructing, utilising and decommissioning buildings; multiple functions and added value on the materials utilised on buildings; better attributes, qualities and longevity of buildings and improved quality of life for users.

Companies driving the trend provide solutions related to the following aspects of construction: advanced materials, improved processes, innovative concepts and energy efficiency. This can be illustrated through the technologies offered by the companies showcased in this case study: wireless monitoring of infrastructures; building integrated photovoltaics as a replacement of traditional construction materials; designer mobile homes; a, waste-to-energy technology and the market's most strict green certification of buildings.

A number of drivers have been facilitating the growth of the trend. The economic factor, exacerbated by the economic crisis of the past few years is a strong driver for companies, end users and constructors to adopt the trend. Market demands for better, stronger, smarter and cheaper solutions are another aspect, as well as the environmental agenda, driving possibly the largest share of innovation in the industry. Lastly, regulation across Europe brings new requirements that consequently encourage the development of smart construction.

Some of the elements that drive the trend also work as barriers, such as the economic factor. The price of smart solutions is often more expensive than traditional and mainstream construction methods, products and concepts. The resale value of properties considered smart is also still somewhat uncertain. In an industry characteristically conservative, reputational and slow in adopting innovation, the absorption of smart technologies is also slowed down. Another barrier, particularly for process innovation, is the low qualification of workers and the difficulty to diffuse knowledge and innovation within the industry.

The construction industry and related professions are consistently regulated. Therefore to further support the trend, the adequate regulation can help developing strong framework conditions for the sector. For this policy recommendations have been formulated in the final part of this case study.

The following aspects are at the core of the policy recommendations provided: harmonisation of building regulations and codes for construction materials; improvement on the transposition of the professional qualification directive, particularly for professions such as engineering and architecture; sector policies fostering collaboration with schools, as well as education of the construction market for increased uptake of smarter solutions. Public procurement initiatives to adopt smarter solutions and further financial incentives for SMEs conclude the set of relevant recommendations.

2. Understanding the Smart Living trend – Smart Construction Products and Processes

Smart Living is a trend encompassing advancements that give people the opportunity to benefit from new ways of living. It involves original and innovative solutions aimed at making life more efficient, more controllable, economical, productive, integrated and sustainable. This is a trend that covers all the aspects of day to day life, from domiciles and workplaces to the manner in which people are transported within cities. In short, Smart Living involves improved standards in several aspects of life, whilst striving for efficiency, economy and reduction of the carbon footprint.

The advancement of the Smart Living trend in the specific context of construction of buildings means innovative, quicker, cheaper and more efficient construction materials, products, processes and concepts. These elements allow the development of new types of buildings better adapted to the specifications and needs of its occupants. This means lower costs to run, reduced carbon emissions and better quality and durability.

Examples of innovative elements pervading the construction industry and making it "smart" abound: new materials to be used in all parts of a building are constantly being developed; high tech construction tools such as Building Information Modelling (BIM) and virtualisation are becoming mainstream; evolving building and architectural concepts being mobile homes, energy efficiency, retrofitting, pre-fabricated homes, flexible floor plants, convergence of IT with infrastructure, are just a few examples of new technologies.

In construction of buildings, the following aspects have been presenting innovative improvements:

- **Advanced Construction Materials**, in the form of a myriad of new and cutting edge materials being developed and applied to construction at an increasing scale;
- **Construction Processes**, as streamlined and improved processes, methods, organisational structure and operations. These advancements are paving the way for new ways of constructing buildings, and are strongly dependent on availability of skills in the sector.
- **Innovative Concepts**, meaning new ideas and technologies being applied to solve real life problems. This includes solutions for the construction process (e.g BIM) and new building concepts;
- **Energy Efficiency/Green Construction**, as a regulatory requirement and an increasing market demand. This aspect has become an important driver for innovation within the sector.

In order to identify how the existing framework conditions and policies for supporting the Smart Living trend can be improved, this case study will: define and explore the characteristics of this trend, analyse its socio-economic relevance; use company cases to identify market potential; identify the main drivers and barriers for the uptake of the trend within the marketplace and finally suggest policy recommendations for further development of the trend.

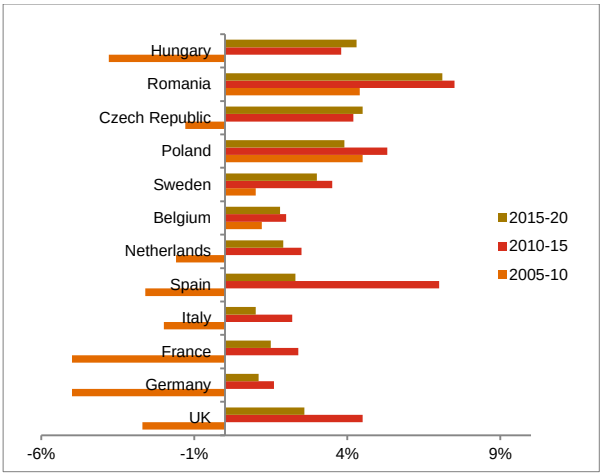
3. Socio-Economic Relevance

3.1. The market potential of smart construction products and processes

Worldwide the construction industry is forecasted to be worth USD 12 trillion by 2020[1]. The share of residential corresponds to 40% of the total market. Global growth of residential construction is expected to be 5.6% between 2010 - 2015 and 4.4% between 2015 - 2020. The growth is expected to be somewhat slower in Europe, especially in the Western bloc. The residential sector currently corresponds to approximately 43% of the total construction output in Europe.

Figure 1 presents the trend for the residential output – including new and refurbishment -in selected countries. According to estimates, up to 60% of the construction output will come from renovation activity in 2013 alone[2]. This trend has been constantly increasing, particularly in the centre of old European cities where space for new construction is rare. Another important factor driving refurbishments is adaptation to stricter regulations on energy efficiency as well as higher energy costs.

Figure 1: Past and Expected Trend in Residential Construction Output between 2010 to 2020 - selected countries. Global Construction 2020



Smart construction is a new and growing trend, increasingly showing evidence of its market potential. However, statistics regarding the specific "smart" part of construction are still difficult to find. Industry players are scattered around several different parts of the construction value chain, and classified in very different fields, making the consolidation of statistics difficult. For example, engineering companies are classified under business services, whilst companies related to the design aspects of construction can be under creative industries.

The industry has some large players which invest heavily in R&D and have the means to drive and originate innovation. However, the construction sector is mainly composed of small businesses, for which it is difficult to diffuse their technological advances. Whilst this can make innovation within the sector slower and not as widespread as possible, still it does not constitute a barrier.

Demographical change is one of the elements driving the trend and increasing its potential. Urban areas are becoming ever more pressurised, crowded and expensive. Ingenious solutions to offer housing for growing populations are required. People want better quality of life and proximity to leisure opportunities and work. This brings new challenges to the industry in developing dwellings flexible enough to cope with the demands of modern life.

Regulatory aspects also strongly affect the industry, with the most evident example being in the context of energy efficiency. New houses have to be increasingly more economical and utilise less resources to be built and function. The onus to comply is not only on constructors, but also on the occupiers who have to endure increasing housing and energy costs. Different building regulations and urban planning requirements also define what can be build and how. In complying with new norms, industry players and clients drive the trend forward.

The **environmental factor** alone has been generating an increasingly large portion of the innovation developed in the context of construction of buildings. Construction and use of buildings is a highly carbon intensive economic sector. The production of cement alone is responsible for 5.0% of global greenhouse gas emissions, whilst heating and electricity use for residential and commercial buildings account for 10.2% and 6.3% of global CO2 emissions respectively.

Aspects in which the environmental factor can be identified range from new ecologically correct materials, to generation of energy on site up to the decommissioning of buildings and the handling of waste. One of the case studies depicted in the following pages, Ennesys, epitomises the smart construction aspect within the field of environmental sustainability.

The **public sector** through public procurement has also a large role to play in strengthening the market potential for innovative construction. Through social housing and public buildings, the scope for experimentation and early adoption of new construction technologies is large. The same demands for quality buildings, better life conditions, energy efficiency and cost reduction that apply to private sector and are relevant for public buildings, if not even more relevant. A European level initiative[3] has been established to encourage and allow public authorities to procure innovative and sustainable construction solutions, demonstrating in practical terms the growing importance of this trend.

Smart construction caters for the needs of **better quality of life**. This can be illustrated by the Tamedia Building, located in Zurich. The structure of the building is made entirely of wood, and the structural parts fit together without the need for glue or screws. This building illustrates several aspects of the trend: the building is carbon neutral, it has utilised material in an innovative way, has a design considering the occupiers wellbeing (light and wood as comfortable elements of the building) and presents a very innovative construction approach. In this method, the wood is non-treated, the pieces of the structure fit together with precision and the building can be dismantled at any time.

An image of the Tamedia building

Source: Tamedia[4]

Another set of examples demonstrating the trend come from the Construction Innovation Forum, promoter of the NOVA Award. The annual prize recognises innovative solutions for the sector, with nominations coming directly from the industry. From the past three years, a number of technology developments in construction have been awarded, mainly in the context of new materials and equipment. Some large constructions also have been represented as construction process innovation, and the last edition of the award also nominated Net Zero Energy buildings, which is one of the case studies depicted in the next pages. Table 1 below illustrates the variety of smart construction aspects that have been nominated for the award.

Table 1: Nominations for the Nova Award from the Construction Innovation Forum

Year	Nomination	Technology
2013	Ground Screw Foundations	A galvanised steel screw that can be put into soil as a foundation for various kinds of construction. It presents an alternative for concrete-free foundations
2013	Thermal Integrity Profiler	Technology utilising the heat generated by curing cement to evaluate the integrity of cast in place concrete foundations. The technology is a system that makes it practical to employ the technology for foundation testing in construction sites
2013	Warm Mix Asphalt	Variety of technologies that allow asphalt mixtures to be produced, transported, placed and compacted at lower temperatures. Less fuel is required for production.
2013	Zero Energy Buildings	Buildings that use no more energy over the course of the year than they produce from on-site renewable sources.
2012	Bubble Filled Concrete Deck	Integration technique of linking air, stell and concrete in a two-way structural slab. This eliminates up to 35% of structural concrete.
2012	Concrete Admixture for moist content	Product that stops moisture from travelling through and out of the concrete surface which helps eliminate flooring failures
2012	Green Asphalt Cold Patch	Environmental friendly cold asphalt that is a direct replacement for traditional cold patch in repairing asphalt pavements
2012	Olmsted Dam Project	Several innovations in the construction project of the dam in Ohio
2012	PCMO for Pavement Repair	Overlay that bonds to asphalt and other types of pavement and increases its lifespan
2011	Brick Paving Machine	Machine that mechanises the laying of brick pavements
2011	Concrete Optmiser	System measures vital information from inside a truck mixer drum and relays it to operators and lab technicians. Improves quality of concrete and the delivery process
2011	Energy Efficient Microturbines	Microturbines capable of producing electric power, heating and cooling in a single integrated system

Source: CIF[5]

To further represent the trend, a set of companies has been selected to be showcased as case studies. Advanced Construction Materials, Innovative Concepts and Energy Efficiency are the aspects of the Smart Construction trend covered by the selected companies. A summary of the companies and their business innovations is presented in the Table 2 below. Further details are provided in the following sub-section.

Table 2: Overview of the company cases referred to in this case study

Company	Location	Business innovation	Signals of success
World Sensing	ES	Wireless structure monitoring technology for maintenance of structures	Private Equity backed, series A investment; several client deployments; international office in the UK; acceleration
Polysolar	UK	Semi-transparent solar panels that can be used for roofing or facades	World's first solar photovoltaic greenhouse; several exhibitions in green summits; extensive media coverage
Coodo	SI	Pre-fabricated modern capsule homes. These customizable units are compact and portable, feature smart monitoring systems, and can be easily made energy self-sufficient	Extensive press coverage; commercial contracts

Ennesys	FR	Energy generation through photobioreactors (flat panels of algae and water)	Extensive press coverage; commercial contracts; investments
International Living Future Institute	US, International	Living Building Challenge is a rigorous program for green certification of buildings that takes in to consideration several aspects of a building to award the recognition.	Extensive press coverage; success cases; awards

3.2. The creation of new markets and jobs

The appearance of a new market with directed demand for smart construction solutions can already be identified through analysis of the case studies depicted and a wider investigation of the sector.

Market demands in the context of construction of buildings are as vast as varied. Urban areas face mounting challenges on price and availability of space aspects, as well as a reduced quality of life. Busy lifestyles also call for solutions that simplify daily life and facilitate the maintenance and management of houses and buildings. Clients commissioning construction projects likewise request better processes and new ways of doing things, such as the so called design and build contracts. Elements like this form together the fabric for a new smart construction market.

The wide spreading of new and smart forms of buildings, construction, urban planning and lifestyles will bring along different challenges for employment in this market. For an industry that corresponds to 10.1% of EU 27 employment in the non-financial business economy[6], this movement is extremely relevant. Higher levels of specialisation and qualification will be increasingly more required to cope with the innovative technologies and processes that will emerge.

When employment in the industry is considered, another closely linked aspect is the economical factor. To keep the level of employment the industry needs to be economically sustainable. The basis for that are the supply of good solutions requested by clients and a healthy market demand. Innovative technologies and processes can increase the quality of the work whilst at the same time improve economies of scale and reduce prices. This, in turn, can bring prosperity to businesses and keep employment levels.

However, the fragmented nature of the industry will still remain. Many aspects of the smart construction trend are driven by niche market players, as illustrated in some of the case studies. Innovation will be driven by small businesses, but higher qualification of the workforce will be the vehicle to diffuse the new technologies generated.

3.3. Bringing smarter construction processes and products to the market

Problem 1 – The operational aspect of construction is often left behind by constructors as a problem for asset owners to deal with. The wireless monitoring of infrastructures would help them running more efficiently.

Innovative solution 1 – Wireless monitoring of infrastructures focused in the construction industry. **World Sensing** is a company based in Barcelona and London that traces its roots to academia. The four founders came together with a vision to commercialise the innovative technology developed through their research.

The technology involves connected sensors attached to the buildings and infrastructures to be monitored. Those sensors can be plugged to a central node, and the node then communicates with a gateway which receives, stores and sends all the information coming from the nodes to a central data repository. Clients can then access the data through a free software application and monitor the status of their infrastructures. This technology can be used for very diverse applications and types of construction.

This is an innovative concept that automates a function traditionally done "manually". Originally this monitoring of structures required inspection by a technician on site, in a costly process that often dealt with remediation rather than a proactive approach to prevent problems.

An image illustrating World Sensor's concept of wireless monitoring for infrastructures

Source: World Sensing

Problem 2 – Generating solar power on a building involves the installation of additional elements to its structure. Until the return on investment is obtained, this can increase costs. In addition, the visual appearance of solar panels is not always attractive and solar specialists have to be called on site to install the technology.

Innovative solution 2 – Building Integrated Photovoltaics (BIPV) provides a replacement of traditional building materials, with the benefit of allowing a building to generate their own energy. BIPVs also cost the same as traditional materials, however with added benefits. This is a fast growing segment of the solar power market. Photovoltaic cells can be directly integrated to the external structure of a building in elements such as walls, roofs and glass.

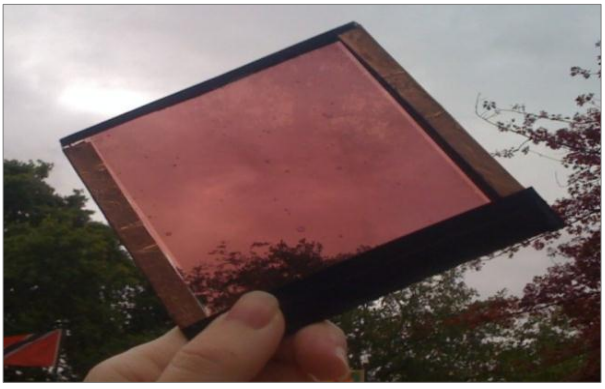
Polysolar presents a pioneering solution to replace standard materials like facades and cladding: semi-transparent PV integrated glass panels. PV glass is a technology that has been developed and is commercialised by a number of vendors. However, these are usually tailor made solutions. In the case of Polysolar, the company is able to provide a lower cost alternative to other PV embedded glasses. Their product is standardised and not bespoke as traditional solutions. In addition, the technology presents a unique transparent material that is embedded in the glass, bringing an energy efficiency of 6-8%, representing a 20% higher yield to similar technologies.

The company has also developed a well-directed approach to business, being founded with an exclusive focus on the building market. For the development of innovation the company often outsources some parts of the process to partners. This helps reducing the costs of prototyping and testing, which are quite high for SMEs. The company's products are also positioned as an alternative to traditional off-the-shelf building materials, including similar price points.

Although technology on the BIPV market has been steadily developing and prices have been decreasing, BIPV is still not regarded as a full substitution to traditional materials. This is attributed to the lower yield of the materials in most commercial applications; the relatively higher cost compared to traditional building materials; aesthetics, given that transparency of solar windows is still limited: the darker the glass, the higher the efficiency of the solar cell.

The innovative nature of the products fits well with the growing BIPV market, set to be worth worldwide US$7.5 billion by 2015 from the US$2.1 billion worth in 2012[7]

Polysolar's semi-transparent solar glass



Source: Polysolar[8]

Problem 3 – Contemporary urban living brings numerous challenges, such as stress, reduced space, limited contact with nature, high costs and a large carbon footprint.

Innovative solution 3 – A mobile home with a design approach. **coodo** originated in 2011 in Slovenia, with a focus on architectural design. Developed by designers, a coodo is a high quality modular home that can be placed in virtually any location, including marinas. The house is configurable, modular and can be moved as many times as desired.

The vision of the founders of the company was to bring to market a new concept of mobile home. This concept includes a house that is beautiful, made up of high quality materials, and is strongly design conscious. The proposition of the house is to solve problems such as lack of space and limited leisure options and contact with nature, issues that people can face when living in urban areas. At a lower cost than a traditional home, it can provide an alternative for a holiday home or even a permanent one, whilst giving users more flexibility on location.

A coodo house is quite modular: there are several units and components available for purchase, including the internal furniture. Bedrooms can be added as a family grows and the houses can be stacked together. A house can also be "installed" (connected to utilities where available) in one day.

According to the company, the market is ready for a concept such as coodo. Market exploratory actions have demonstrated positive feedback with people being interested in the new lifestyle these houses propose. The few negative remarks by potential clients consider the product and concept "too modern".

A coodo house being transported by truck

Source: coodo[9]

Problem 4 – There are a number of challenges and different technologies to generate energy within a building. When focusing on the use of waste and water for the generation of energy, not many solutions proved to be efficient and easy to utilise.

Innovative solution 4 – **Ennesys** has developed a disruptive technology in response to energy and environmental challenges, such as: the need to preserve fresh water resources, scarcity of funds to pay for soaring energy prices and uncertainties affecting conventional energy sources.

The company's waste-to-energy solution involves using natural light to grow algae in closed cultivation tanks (photo bioreactors) placed on buildings roofs or facades. The innovative technology includes a set of systems and techniques to produce energy by treating wastewater with micro-algae cultures, and then converting those in biomass.

Ennesys is the holder of more than 40 patents and its technology obtains a competitive algae growth rate and harvesting that is not currently fulfilled by competitors. Once the algae are grown and harvested, this biomass is converted into vegetable oil or biomass pellets.

Three problems are solved by the technology: wastewater remediation; improvement on a building's thermal insulation; and local renewable energy production with CO2 recycling, without using any valuable ground space.

The company has received wide exposure particularly in its local market of France. Ennesys's technology also represents the smart aspect of construction in its essence, solving several real life problems with one single technology driven solution.

Ennesys photobioreactor tanks

Source: Ennesys[10]

Problem 5 – Buildings, both residential and commercial, are increasingly scrutinised for their green credentials. Market demand and regulation drive this trend. New constructions as well as refurbishments have to comply.

Innovative solution 5 – The environmental and energetic certification **Living Building Challenge**, from the International Living Future Institute, is reputed as the most rigorous program currently available. Only a few buildings in the world have received their full certification, whilst others have received only partial Living Building Challenge certification. The types of certification awarded by the institute are the following:

- Full Certification: buildings achieving this certification receive a Living Building status. They meet strict requirements in the following categories: site, water, energy, health, materials, equity and beauty. There are four typologies for which the certification applies, being renovations, landscapes or infrastructures, buildings and neighbourhoods.
- Petal Recognition: is a partial program certification to projects satisfying the requirements in three categories of the full certification, when at least one of them is water, energy or materials.
- Net Zero Energy: certifies buildings that are able to meet all their heating, cooling and electricity needs from renewable sources available on site.

The market offers a number of other green certifications, very often linked to energy efficiency rather than more holistic aspects of a building. LEED and BREAM, for example, are pioneers and very well-known names within the industry. These certifications are also characteristically tailored to its place of origin, a reflex of the varying building regulations existing in each country.

The innovative element of the Living Building Challenge lies in its widened scope for awarding a green accreditation for a building. It also fits closely with the Smart Living trend since the aim of the label is to encourage the development

of dwellings that are more adapted to a smarter way of living, where values such as quality of life, functionality, sustainability and beauty are regarded as important.

A Living Building Challenge project

Source: Living Future Institute[11]

3.4. Client perspectives and challenges related to the uptake of smart construction technologies

To understand the perspectives and challenges for the uptake of the trend, first it is necessary to know that within the smart construction context there are two types of clients: business to business clients and end users.

Business to business (B2B) clients are the constructors or builders, which will utilise new materials, concepts and techniques to develop the finalised products for end users. In many aspects, they are both generators and clients for many innovations. They not only generate demand for new technologies but also work as catalysts for adoption of these same innovations by the actual end users.

The end users are the building occupiers or people commissioning the construction of their properties (as an user or investor). End users have the power to impact the demand for smart solutions in construction, from the use of new materials to innovative concepts. However, the area in which their impact on uptake of the trend is least felt is the adoption of innovative processes for construction, given this will be managed and utilised mainly by the constructors.

The uptake of the smart construction trend and the underlying technologies still face a number of challenges. From a client perspective – both B2B and end users, challenges for uptake can be understood as the following:

- **Economic challenges**: higher cost of smart construction in relation to traditional; economic crisis slowing down investment; decreasing incentives for the adoption of environmentally friendly solutions for energy generation on site (e.g end of subsidies); uncertain resale value of properties incorporating cutting edge features;

- **Knowledge challenges**: lack of awareness by builders of the new advancements available in the field of construction; low qualification of many industry players which results in poor execution of constructions and added features; reputation of new technologies and market players still unknown; many of the smart technologies are still in their early days; process innovation requires the appropriated skills;

- **Challenges related to the low industrialisation of the sector**: construction projects are characteristically artisanal, built on site and tailor made to the specifications of clients. This makes repeatability difficult as well as development and diffusion of innovation;

- **Risk avoidance challenges**: general risk avoidance is common in the industry. This is related to the large amounts of capital invested and the almost permanent nature of the final products;

- **Challenges related to the impact on employment**: new technologies can improve processes, but as a consequence can reduce the number of people needed to execute something, reducing employment figures. However, the reverse is also true: demand can increase for professionals that are qualified to deal with new technologies and market demands.

Many of the factors listed as barriers for the uptake of the smart construction trend are **economic factors.** The construction of a building requires a large capital investment and takes time to be finalised.. The end products are supposed to last a long time. The return on the investment often takes time to be realised. Therefore, it is more usual for constructors and final customers to require tried and tested solutions.

For many clients and builders, the appealing factor of smart construction is linked to economies that can be achieved in utilising new technologies: new materials, processes and energy efficiency measures can save significant costs. As for innovative concepts, the economical element can still be perceived as a barrier, since the solutions have not yet proved the market worth. This is a common element mentioned by all the companies depicted in this case study: the market still needs to be educated regarding new concepts. Only then wider demand can be generated.

The **knowledge barriers and low industrialisation of the sector are closed linked** challenges for the growth of the trend. The adoption of process innovation, is slowed by the difficulty to diffuse innovation within the industry. New

methods created for a specific project often get lost for use in new assignments, since many of the SMEs have poor knowledge management structures and are pressed for resources. In addition, each project is artisanal, built on site, and tailor made to the specifications of each client, making repeatability difficult. New materials are not adopted also for lack of exposure to them as well as a limited number of showcases. New market players bringing in new products have also yet to establish their reputation on a market where trustworthiness is essential.

The qualification of the workforce in the sector is another barrier. Sector professionals can have a strong role as evangelists for a smart construction approach, but they have to be qualified to do so.

Risk avoidance is another common barrier for the uptake of the trend. This behaviour manifests itself both in the end users as well as in the intermediaries in the value chain. For the constructors, it is difficult to try new technologies that have not yet proofed their value and potential for returns. For end users, with exception of early adopters of innovation, a critical mass of users has to be established in order for the adoption to be widespread in more traditional market segments.

The **impact on employment** can also be seen as a barrier for the increasing uptake of the trend. New materials replacing the traditional ones require new techniques for installation, new qualification and in some cases less people to deal with them. For example, the solution offered by World Sensing for wireless monitoring of infrastructures eliminates the need for technicians to go on site and inspect buildings. This is done by machines.

In the case of BIPV, one single material replaces two different sets of materials that would possibly require two different specialists to install them. Improved processes in general have a focus in reducing costs and time spent on construction, which will consequently reduce number of workforce required on site. However, not all smart processes have as a target reduction of workforce. One example is represented by improved waste management techniques: their added benefit is more associated to the use of less wasteful materials rather than reduction of the workforce to execute the process.

4. Drivers and obstacles

The **main drivers** for the emergence of the smart construction trend can be considered fourfold. The first factor is naturally economical, exacerbated by the economic crisis. Market demands for better, stronger, smarter and cheaper solutions are another aspect. The environmental aspect, which has been driving possibly the largest share of innovation within this industry, is another push for the trend. Finally, regulation across Europe and worldwide brings in new requirements for this industry and increases the market awareness and demand for related solutions.

It is interesting to note that some of the aspects listed above can also function as **barriers for the adoption of the trend**. Regulation and the economic landscape, for example, have this two facet characteristic. Scepticism towards new technologies and weak public support to the trend can also form further obstacles.

4.1. Economic factors

The economic crisis of the past few years added a lot of pressure to the industry. Construction output closely follows fluctuations in GDP, which means that for the past years the output in the EU has been reduced. With less output, market players are driven to either cut costs to keep afloat, or to adapt their offerings to the market demands. Since construction demand is sensitive to price, the offerings have to either be cheaper or strongly differentiated to be adopted. Smart solutions are therefore a mean to relieve the economic pressure faced by the segments of the industry.

"The cost of innovation is very high for SMEs and it is difficult to have the return on what has been invested. So we try to transfer the risk to partners and develop the technology with them." ***– Polysolar***

Access to finance by SMEs is notoriously difficult, and entrepreneurs are more than aware of the fact. Within the construction industry, this situation is aggravated by the fact many of the companies are of micro size, and the industry is not considered innovative enough to attract varied sources of investment both private and public.

For companies working with cutting edge technologies, another obstacle for access to finance is related to the maturity degree of the solutions and the uncertainty of their market demand. This can put some investors off and reduce funds available. Thus, a cycle is generated: the cost of innovation is very high for a SME, and it is difficult for them to obtain a market return. Therefore, companies do not invest in innovation. With less innovation, the growth of the trend is halted, and the sector has reduced exposure. This, in turn, averts investors, and the cycle repeats itself.

The cases depicted demonstrate some different ways in which funds can be raised for SMEs. World Sensing has benefited from the help of incubators and large businesses support, which opened doors for venture capital to be raised. Polysolar, active on the BIPV market, faced more difficulties

to raise funds. The company decided to approach their funding needs through partnerships, outsourcing some of their development process to external partners. coodo, on the other hand, has benefited from the founder's own capital to get off the ground. Ennesys has developed an extremely differentiated technology and through this has been able to raise funds and obtain extensive media coverage. The company is also benefiting from acceleration as a mean to gather further investment.

4.2. Market demands

Smart construction is a trend strongly driven by market demands. As mentioned before, demographic change combined with regulatory pressures, have been creating a new market where smart living plays a key role.

As for the end users, previously mentioned aspects such as new lifestyles and pressure in urban areas have been pushing the market demand for smarter construction. One point that limits the demand for the trend and needs redirection is the reduced number of opportunities to build new dwellings in the centre of increasingly populated cities. However, this brings another face of the trend, which is the market for retrofitting.

Retrofitting of buildings can be a good option of the adoption of smarter technologies. However, market demand for this has to be further encouraged. Retrofit a building is usually costly and disruptive for occupiers, which brings a natural resistance to it. It is also difficult for consumers to perceive the value of these new additions, such as for example insulation on a building: it is not visible and the heating bill will not change dramatically should insulation be improved. Therefore, consumers need to be educated to understand the actual benefits of these new technologies.

Although this is a growing trend with many opportunities to be explored, the market presents still a number of barriers that can be further addressed. The construction industry is traditionally slow in generating and adopting innovation. Companies interviewed describe different reasons for this, from strong reliance in reputation, which takes time to build, and the risk avoidance of both their B2B clients (constructors) and end users.

For World Sensing, for example, a single factor that could most improve the company's market situation would be to obtain a big success story that would influence further adopters. The company founders also mention that their traditional market is very focused on the construction but not on the operational aspect of buildings (asset management), and therefore educating their market to increase adoption will take many years.

Most of the building stock available around Europe is of the "analogic" type. Smart buildings, innovative urban planning and differentiated ways of living are still niche markets, being adopted only by consumers on the edge of this trend. This is a cultural factor that requires a paradigm shift.

In the BIPV market of Polysolar, residential adoption of their technology is driven by regulation and subsidies rather than by customer knowledge of this technology and active choice. In the case of the commercial building sector, adoption is deterred by a risk avoiding behaviour – better to be safe and use established technologies.

4.3. Environmental awareness

Global CO2 emissions generated by the construction and use of buildings are extremely high. Across Europe regulation pushes for increasing reduction in emissions and improved sustainability. Technical advancements presented with this aim have been allowing the materialisation of more economical, practical and energy efficient dwellings. This allows a range of associated benefits, from reduced emissions that impact society as a whole, to better quality of life and responsible decommissioning of constructions and the handling of waste.

Energy efficient technologies, such as onsite energy generation, have been gaining increasing status and exposure in the market. Many governments have also implemented subsidies, so as to increase adoption. However, the return on investment on these technologies often takes a long time to be obtained and the gains in the form of reduced utilities bills are small. These are aspects that slow client uptake and the growth of the trend. However, as a general benefit, buildings with green credentials and certifications tend to obtain higher resale and rental values in relation to their non-certified counterparts.

4.4. Regulation impacting the growth of the European market

The construction industry is heavily regulated and conservative. Examples of regulatory drivers are building norms and standards as well as energy related regulations, such as the directive on the energy efficiency of buildings in Europe. These elements work as drivers for technological and process improvements.

For instance, Polysolar, active in the BIPV market, sees the regulation as one of the drivers for market uptake but at the same time one of the main barriers and sources of expenses for the company. The products offered have to be re-certified on a yearly basis, according to the buildings norms and standards that are also applied to materials and energy generation schemes. Industry standards also play an important role as a driver for adoption of innovation. Products compliant with standards have a type of "quality seal", which can help its market position.

For coodo, regulations can prove a barrier to the company's growth. Their product can be placed in any type of site and does not involve land development. However each different European country has different regulations regarding mobile homes. Whilst some countries treat them as regular houses, others allow more freedom for their installation.

"The market for quality mobile homes could grow faster if regulation was harmonised across Europe." ***– coodo***

4.5. Scepticism towards new technologies and market awareness

The construction industry is traditionally considered slow and conservative in adopting innovation and new technologies. The presence of risk adversity, associated with the need for durable products that are expensive to build, results in this cautious approach. In addition, the industry is very fragmented, with a vast majority of SMEs, and presents low levels of industrialisation. Lack of repeatability in the projects and their artisanal nature, contribute to reducing diffusion of new technologies. Those factors together can hinder the development and adoption of innovation.

"Construction is a very traditional market, slow in absorbing innovation. It is changing a bit, but will still take time. A lot of the changes can be driven by policy." ***— Worldsensing***

The companies interviewed also face issues related to the need to build a reputation and become better known within their market. Their products present solutions to existing problems, but because of the novelty elements of such products, many clients are reluctant in adopting them.

4.6. The need for public support

The companies interviewed and many other SMEs active in this sector have received some form of public support, in the form of incubators, grants, accelerator and of course funds raised. Other aspects representing public support for the trend can be identified in the form of regulation, educational programs, higher market values for smart constructions and buildings, improved urban planning, public procurement and governmental subsidies and grants for companies investing in the sector.

All the companies interviewed obtained some sort of support from either an incubator or accelerator. For them this has been valuable especially in the fund raising aspects as well as in developing correct business practices and a well thought out market approach.

Some of the companies depicted received some funding grants, coming both from private as well as public sector. For the companies, funds coming from the private sector seem to work better in two ways: less administration required for the application as well as value of 100% of the needs covered. In the case of public funds in most cases the amounts raised do not fully cover all the funding needs, and entrepreneurs struggle to find further sources of finance.

To support the spreading of innovative solutions in construction public entities can also develop educational programs to increase awareness of different actors of the construction value chain. As mentioned before the industry is conservative when it comes to innovation and education and knowledge management are actual challenges that pervade the whole value chain. Public entities can develop educational initiatives aimed at builders, manufacturers as well as end users. Public procurement can also be used as a tool for increasing the use of sustainable and innovative construction.

Initiatives with this objective are already in place at European level [12], encouraging adoption of innovative construction processes by public authorities. Public buildings and social housing, for example, are ideal subjects for innovative construction. Public buildings that encompass new technologies work as showcases and demonstrate to wider audiences how these technologies behave beyond the theory and the sales pitch. In addition, directives such as the energy efficiency of buildings push this demand by the public sector even further, since public buildings have to fully comply and implement related innovations.

One case that illustrates public adoption of the trend is the construction of the Thor Heyerdahl College, in Norway[13]. The Vestofold County Council, where the college is based, adopted an interaction model for the construction of the school. This means a partnership was established between the different actors concerned, including contractor, users, and college employees. The contractor participated in the planning of the building and full disclosure of all documents related to the project was granted to all parties. This innovative form of collaboration allowed the delivery of a well-functioning building, delivered on time and on budget and achieving a significant economy of space in terms of built area per student.

Public procurement is a strong tool that can indeed support the adoption of a trend. Increased usage can benefit many market players. However, public procurement is only one of the tools that can be utilised by authorities. Public support comes in many forms and further avenues such as education of the value chain as a whole, support for better integration between industry and academia, as well as access to finance have to be improved, encouraged and supported.

5. Policy recommendations

*"To be more innovative we need more resources and links to the right people. Sometimes academia and work programmes are very far from what the industry needs, so collaboration has to be improved" – **Worldsensing***

The harmonisation of rules and directives governing the construction industry is being addressed by the EU, but efforts for this can be increased. Some leeway has been gained with the development of the Eurocodes. However, many particularities remain in each country, meaning further alignment could especially improve adoption in the private sector. The advantages of compliance on regulations could increase adoption of new materials, innovative building processes, energy efficiency as well as novel concepts in construction.

Whilst the appropriated regulation could encourage the uptake of the trend, **excess of regulation is to be avoided.** Many construction products and technologies have to be certified on a yearly basis (e.g BIPV). Whilst this can bring benefits for end users, for SMEs this is a costly procedure. Another important aspect is the enforcement of regulation by member states. The construction products regulation, which entered into force in 2013, for example, provides a harmonised framework for the provision of construction materials around Europe. However enforcement by all member states is still to be performed and this has to be followed closely.

Policies for **collaboration, integration and training** with engineering, architecture, materials sciences and design schools could benefit the trend. Apprenticeship programs can be started from secondary schools, driving a culture of knowledge and diffusion of innovation for the sector. More alignment between objectives of industry and academia is also needed, as there are dissonances between research efforts and industry needs. Trade associations, schools and sectorial entities should be called out to help design and drive integration programs.

Some actions should address also the **education of the construction market** for the uptake of smarter technologies. This education should be done at the B2B point, with widespread information for builders and contractors, as well as to end users that should demand these new technologies. Much has been done on the energy efficiency aspects, but this could be increased for further and alternative solutions.

The European **rules for professional recognition also need further addressing**. The revised professional qualification directive and associated communications urge member states to review and modernise their rules for regulated professions. This is relevant for smart construction, since engineering and architecture are regulated professions. Addressing barriers linked to these professions and the mobility of qualified workers, could improve employment and diffusion of innovation within the sector.

Public procurement policies to adopt smart solutions provided by SMEs should be extremely beneficial for market players. Construction is a reputational market where success cases are strong advocates for new technologies. Therefore a strong push by local governments for smart construction products and processes in social housing and public buildings should be helpful. Simplification of procurement rules, in favour of SMEs is also relevant.

The new 2014 EU rules on public procurement address some of these aspects. The criterion for the most economically advantageous tender should incentivise the adoption and provision of innovative solutions. The use of self-declarations for bidders should also facilitate the process for SMEs. However the implementation of the new rules by member states has to be closely monitored.

Public financial incentives for SMEs need to be further reinforced. The new Horizon 2020 aims at improving innovation and new technology development, but the process for funding access has to be facilitated. Many of the players in the smart construction sector are small with very limited resources to gather information and follow procedures for the gathering of grants and funds. Easier processes with less administration should be helpful.

Support structures for the benefit of SMEs need to be further encouraged. Incubators, accelerators, demonstrators are elements of this structure. Currently these entities tend to support certain business trends and technologies that are more high profile and gather wider exposure in the media and business circles. The construction industry is considered less attractive and innovative, and this plays against it. Changing the external perception of the industry and improving a support framework specially addressed for this market help to drive the trend forward.

6. Appendix

6.1. Interviews

Company	Interviewee	Position
Polysolar	Hamish Watson	CEO
World Sensing	Ignasi Villajosana	CEO
coodo	Mark Dare Schmiedel	CEO
Ennesys	Pierre Tauzinat	CEO

6.2. Websites

Polysolar	www.polysolar.co.uk
World Sensing	www.worldsensing.com
Coodo	www.coodo.eu
Ennesys	www.ennesys.com
Living Future Institute	www.living-future.org

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