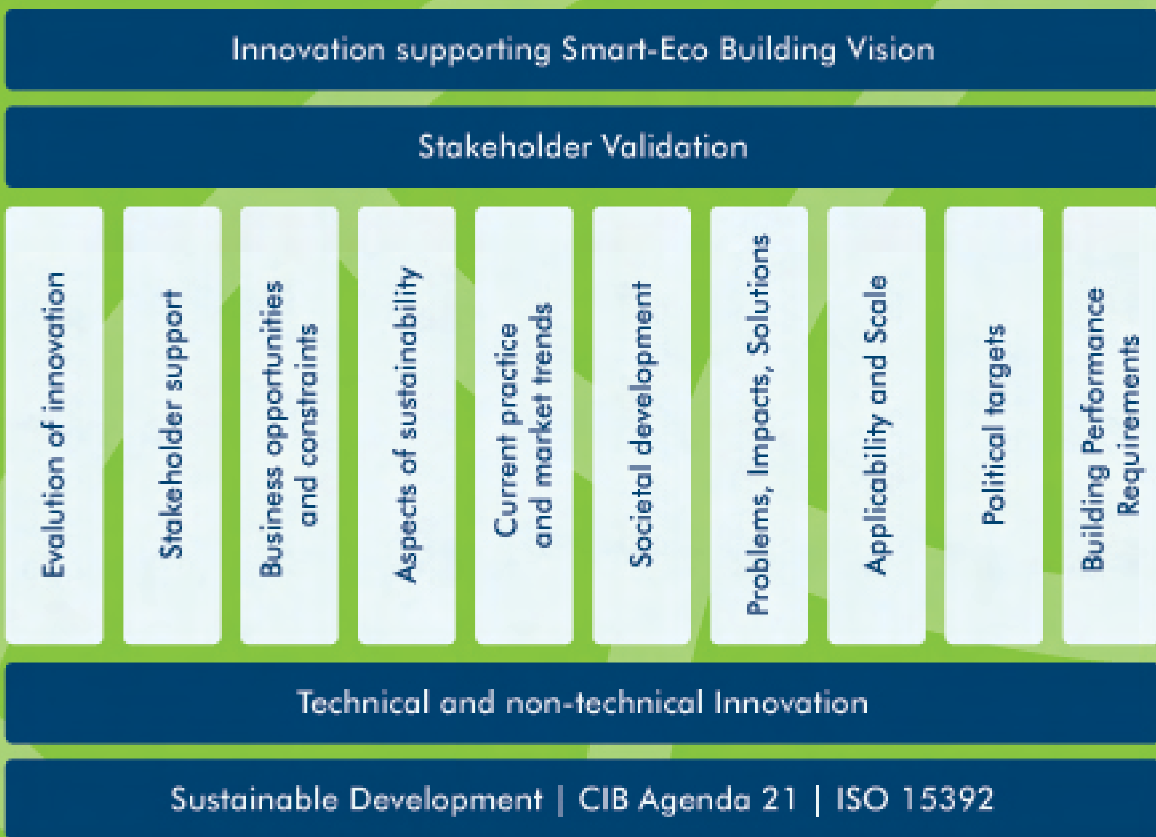

Towards Sustainable and Smart-ECO Buildings

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TOWARDS SUSTAINABLE and SMART-ECO BUILDINGS

Summary Report on the EU-Funded Project Smart-ECO

Sustainable Smart ECO-Buildings in the EU

Contract Number

FP6-2005-TREN4-038699

CONTENTS

The report begins with an explanation of what the Smart-ECO project is and what it sets out to do.

It then considers the relevant information background from which the project drew to define the necessary definition of sustainability aspects for the construction sector. The report also describes in turn the 5 *main problems* and macro–issues which were identified as the actual and future challenges for the construction sector, and considers the *consequences* (impact) of each on human society and on the construction sector, together with the *solutions* that the construction sector might adopt in response.

This summary is based on the much more detailed and densely written reports resulting from the Smart-ECO Project. Of necessity, much of that detail, and many of the illustrated examples, are omitted from this summary.

1.0 What is the SMART ECO project?

The core of the Smart-ECO project is to establish a vision for sustainable European eco-buildings in 2030, giving due consideration to the requirements of all stakeholders' viewpoints and interests. Identifying a vision that is equally idealistic and ambitious while being pragmatic and applicable has been the main challenge. The community of stakeholders, which was involved throughout the project, had to come together around a clear set of priorities in order to derive requirements from the vision.

The SMART-ECO Work Packages relevant to this summary report are described below:

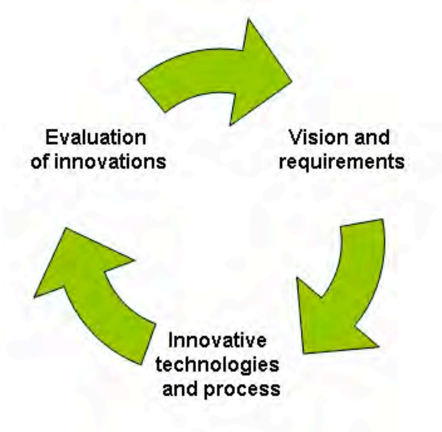
- WP2: Vision & Requirements
  - Develop a vision for sustainable development in building and construction, anchored with stakeholders and applicable for a time horizon 2010 – 2030 & Identify requirements and indicators reflecting the vision.
- WP3: Innovation
  - Identify elements that are providing significant contributions and can be understood as milestones on the route of the building and construction sector to meet the vision of sustainable building.
- WP4: Evaluation
  - Apply the vision as a reference point in order to analyse how the identified elements contribute to the vision.
- WP5: Stakeholders
  - Test and prioritize the issues raised and solutions proposed by the Smart-ECO project

Work Packages WP1 Project Management, WP6 Dissemination, and WP7 Exploitation are not discussed in detail in this report.

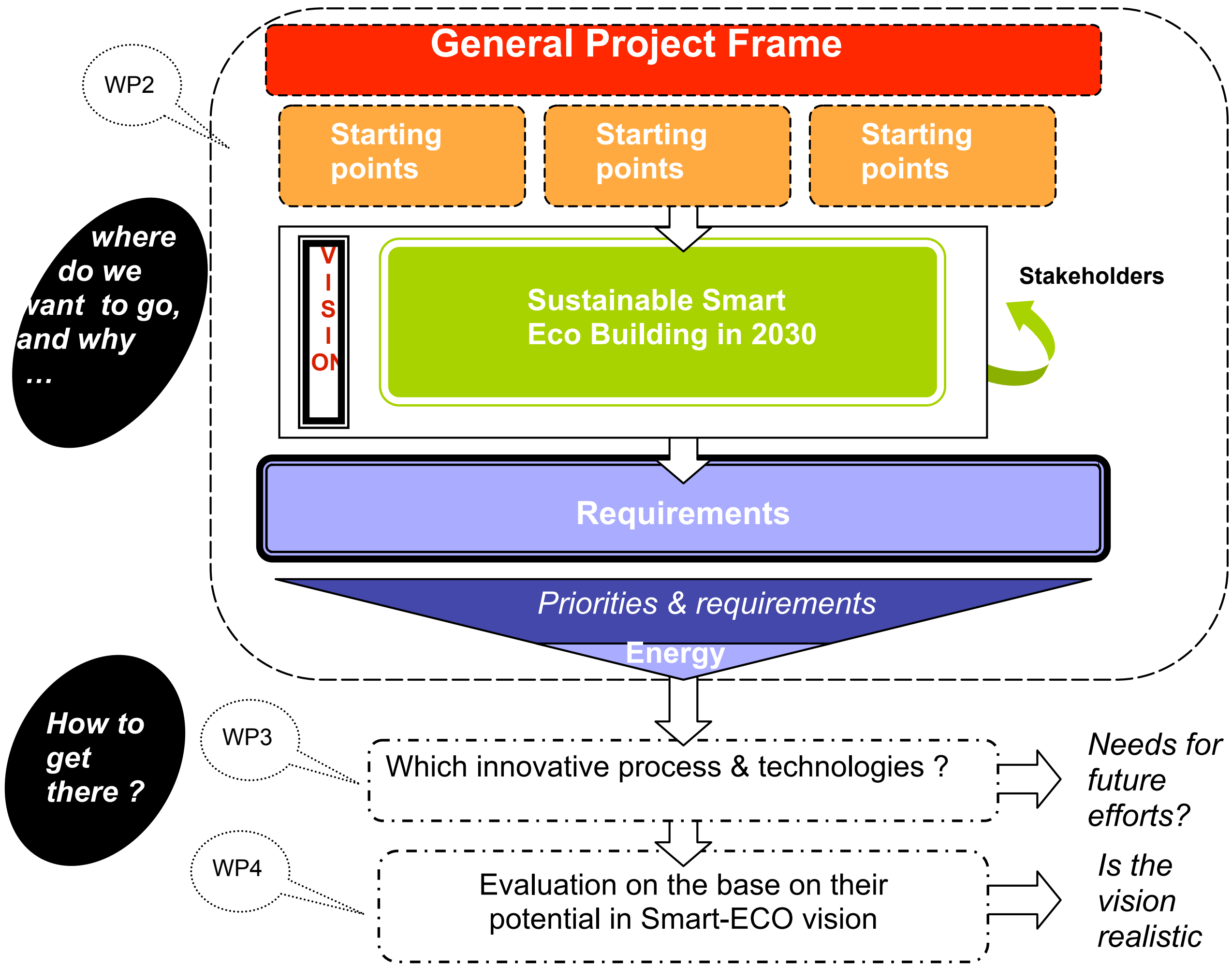
1.1 Methodology to express the vision of a Sustainable Smart-eco Building in 2030

1.1.1 The General Framework of the Smart-Eco project

The vision, as shown previously, is intrinsically tied to the other Work Packages of the Smart Eco project. An iterative process as below is followed.

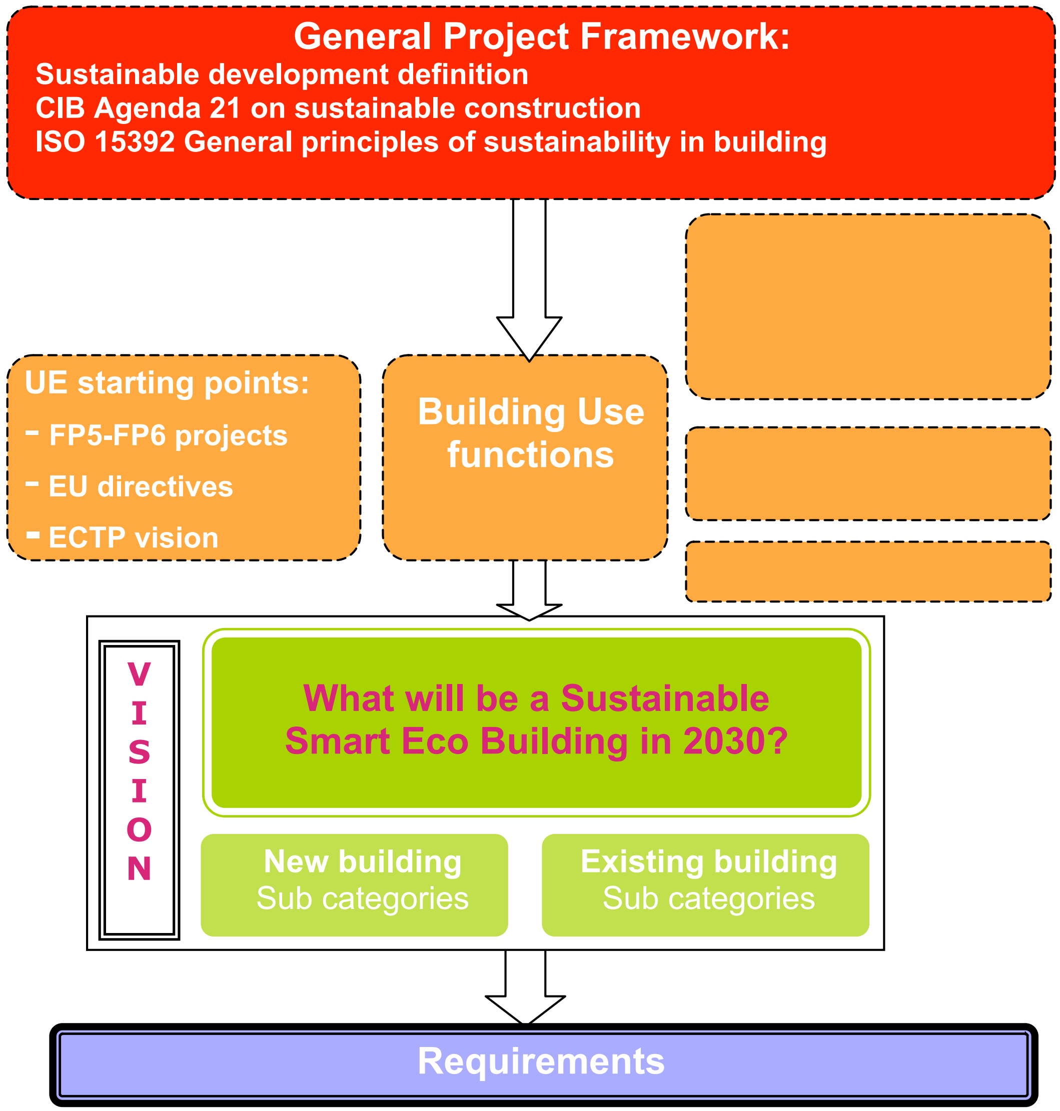


The next figure illustrates the progress of the project: the methodology for feeding information into the iterative process including WP3, Innovation, WP4, Evaluation, and Stakeholder engagement. A panel of stakeholders (researchers, architects, and other decision makers), was set up and has been invited by the Smart-Eco project partners to comment and assist in improving the vision of a sustainable smart-eco building; in this way the results of the project have been grounded with the stakeholder community. The decision was taken to amend the 10 issues of the vision, and to insert those issues into a more communicative and "stand alone" document, enriched with explanations and illustrative examples for each issue.



1.1.2 Development of the vision statement

The next schema illustrates the progress of the project from the general framework to the first steps of the elaboration of the requirements.



The vision was methodically built up by applying a holistic approach based on the full life cycle of the building, and started from the general framework, progress by considering:

- The results of previous European projects
- The use functions of a building
- The EU starting points
- The standardization activities
- Others standard documents

and is expressed as a solution to the macro-issues and their scenarios.

For example, the general framework is aligned to internationally agreed and harmonized basis for the thematic field of "sustainable building", including the Brundtland definition of sustainability, the “CIB Agenda 21 on sustainable construction”, and ISO 15392: “General principles of sustainability in building construction”.

The route chosen to reach the objective has been to take the global reference point expressed in i.e. international standards and agendas and to bring these to the conceptual application context in the European building and construction sector. The global consideration of issues to be included in sustainability assertions, relating to internationally agreed concepts such as for instance life cycle and performance concepts, paired with the tasks and trends in European policy making and the state-of-the-art in building construction was condensed into the draft vision document which was evaluated/intensively discussed by/with the stakeholders.

1.1.3 Stakeholders involvement

In relation to the WP5, stakeholders were consulted over the project, in order to validate and influence the work about the vision. The stakeholders were formally involved and engaged especially in task 2.1 “Establishment of the vision“. The stakeholders were drawn from the wide range of people occupied in the process of construction, from the conception phase to the deconstruction or demolition phase through the operation phase. They also included decision-makers and researchers working in the construction area. Finally, some stakeholders were "external" to the planning process and construction, like investors, insurers, tenants, etc

2.0 The SSE Building as the result of a sustainable construction, into the frame of the Sustainability (General frame from ISO and CEN)

Obviously, the roots of the vision for “Sustainable Smart-Eco Buildings in 2030” lie in the general definition of the sustainability concept and make reference to international standardisation activities.

2.1 Background and definitions of Sustainability

Several definitions of Sustainable Development can be extracted from the literature, but the consensus starting point for the definition of sustainability is: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs", first set out by Mrs Gro Harlem Brundtland, and included in the report “Our Common Future”, [1987].

Since the year 2000, International Standards for sustainable construction have been under development. Now, in 2008, as a result of these efforts, ISO TC 59 on Building Construction has published several standards through its Sub-Committee 17, “Sustainability in Building Construction”. These standards are also the basis of new European Standards currently being drafted by CEN Technical Committee 350 in response to mandate 350 of the Directorate General “Enterprise”, entitled “Sustainability of Construction works”.

2.1.1 General principles of Sustainability in Building Construction

Many initiatives deal with how the construction industry should respond to the sustainable development agenda. In particular ISO 15392 on the "General Principles of Sustainability in Building Construction" identifies:

- ✓ Continual improvement,
- ✓ Equity,
- ✓ Global thinking and local action,
- ✓ Holistic approach,
- ✓ Involvement of interested parties,
- ✓ Long term consideration,
- ✓ Precaution and risk,
- ✓ Responsibility,
- ✓ Transparency.

2.1.2 Building use functions.

The first objective of any construction project is to meet the requirements or needs expressed by the future owner and/or user. The sustainability of a building depends not only on the process of building but also on the final outcome of the process, the finished building or works. Moreover, a building is not only an object that can be sold but it becomes a sum of functions, with hopefully some assurance on the expected performance.

The main use functions of a building works have been identified by CIB Commission W052 “Procurement systems” (1995) as follows:

- ✓ Provide space
- ✓ Provide an indoor climate
- ✓ Provide safety and security
- ✓ Allow the use of goods and tools
- ✓ Control the nearby relationship
- ✓ Take advantage from the site without damaging it
- ✓ Bring meaning (semiology)

2.2 EU-level starting point in terms of research, policies and existing know-how

2.2.1 EU Projects and Networks

The establishment of a vision, which, in terms of sustainable development, meets the European interests concerning innovation, technology, quality of life, etc, cannot be disconnected from its European context. The ‘state of the art’ is the precondition for describing a vision for smart, sustainable Eco-Buildings in the EU. This involves identifying the current status of knowledge within the EU, and relates to the starting point in terms of current policies, targets, technologies, market aspects and mechanisms, R&D projects and their exploitation. It needs to include requirements resulting explicitly, or implicitly from previous R&D projects conducted under the EU FP5 and FP6 programs.

2.2.2 European and National views

A clear picture of the current state of sustainability in construction in Europe, together with the main areas requiring action is needed to establish a realistic vision for SSE Buildings. European countries have focused on different issues: energy, materials, healthy indoor climate, wastes … etc. Even the methodology changes from one country to another: these approaches could be additive, transparent, holistic, or mono-criteria. The driving forces and building categories differ depending on the country. Nevertheless, a general drift is to reduce the sustainability concept to environmental aspects, and then to consider energy aspects or even further to single emissions linked to energy use, like CO2.

Sustainable construction has, nowadays, different approaches and different priorities in the whole of Europe. A more extended analysis is required to give a more accurate map of the actual situation.

Many European countries accept the challenge to save energy and to protect the environment, but this is just the beginning. There is much potential for doing more, not only in new buildings, but also in existing ones.

3.Problems and macro-issues: the actual and future challenges, impacts and potential solutions for the construction sector

The establishment of the vision of what a sustainable building in 2030 needs to be requires assumptions about the main variables of societal and environmental evolution over the next 20 years: namely the evolution of the social, political, economic and environmental concerns. The following scenarios identify the macro-problems, each of which will have some consequences for our environment and more precisely for our built environment. There are possible solutions to those consequences and they are also described.

3.1 Scenario 1 - Limited resources available and distribution (energy resource, material, labour, skills, water, land, finance, etc.)

The basic assumption is the finiteness of the world: particularly the resources (energy resources and material resource) of the world are not infinite.

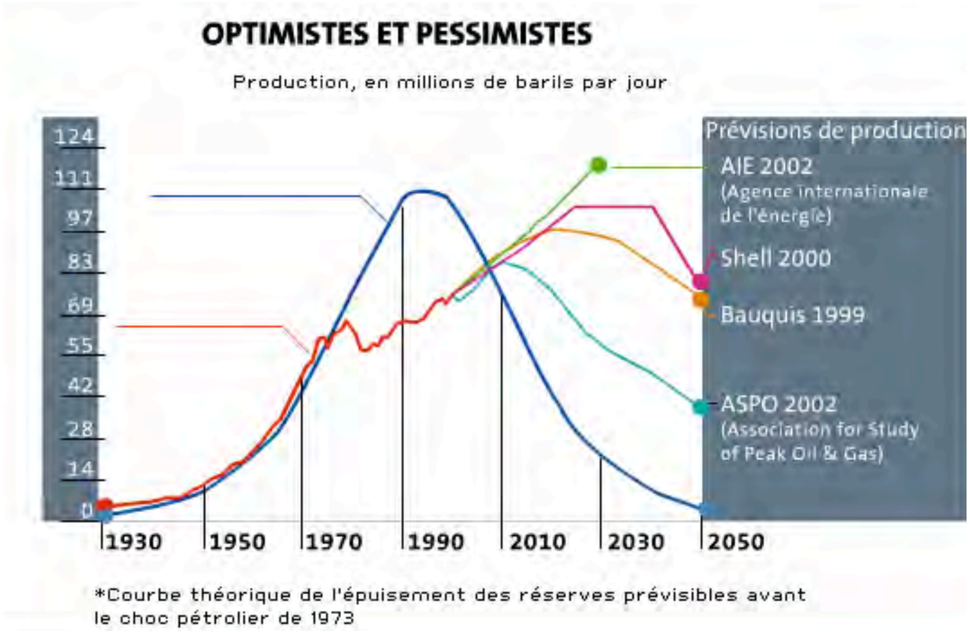


Figure 1 Petrol production forecast; Source: Le Monde Infographie

The same phenomenon is true for raw materials. This is also a major indicator, as construction activities consume more raw materials by weight (as much as 50%) than any other industrial sector. But at the same time retrofitting can be anticipated as the main activity in the construction sector by 2030, with less raw materials consumption (compared to new construction). The main resources addressed are cement, steel, aggregates and oil again for organic materials. Wood is also concerned, and its availability strongly depends on more sustainable growing and exploiting processes. The distribution of other resources, like labour, skills, and money, appears more and more unequal among the population needs.

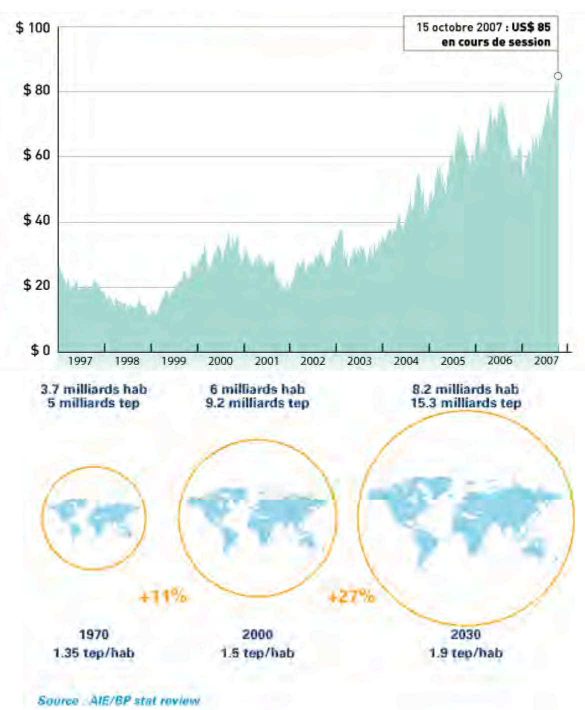


Figure 2: Increasing of the energy demand. Source: IFP (French Petroleum Institute) web site

3.1.1 Consequences of Scenario 1

Limited supply (people and materials)

This can cause rapid changes in prices of food, energy and raw materials and consequent economic limits to the supply of these goods. Now the shortage of people with the right skills to provide the required services or to perform the desired works is becoming a concern.

Interruptions

As technical equipment is increasingly relied on, the dependency on services and infrastructure (particularly for energy) increases. Inadequate distribution networks, especially those lacking adequate back-up systems may lead to interruptions, and shortages in delivery, and significant deficiencies in building performance, ultimately leading to the disruption of building equipment.

Conflict

Conflicts of interests between different stakeholders can also slow the required redevelopment of the building stock, or can significantly delay necessary strengthening of infrastructure.

Higher Cost

Higher cost must inevitably follow if increasing requirements in building lead to increasing demands for volume, space, equipment, energy and material, and if this is coupled with decreasing availability of required resources naturally lead to increasing prices.

Delays

Shortages in resources, both resources and labour, in combination with rising prices, may lead to increasing delays between the decision to build and the execution of the work, as well as delays in essential maintenance.

Efficient operation of buildings

A shortage of resources, whether economic, energetic, material or human, may make efficient (ie optimal) building operation impossible, leading to the disruption of the services provided by the building in question. .

3.1.2 Solutions to Scenario 1

Engaged stakeholders

To establish the agenda of sustainable construction in the building and construction sector, it is necessary that all relevant stakeholders engage according to their respective abilities and include sustainability considerations responsibly into their daily work. This includes their own decisions as well as their acting in their dialogues with suppliers and clients.

Training education

The challenge of sustainable construction creates a large demand for knowledge intensive services. The integration of specific as well as broad and generic know-how of the problems and the solutions related to sustainable construction into decision making processes is a key concern for designers, constructors and users of buildings.

User-friendly solutions

Because a building's overall performance is strongly dependant on the users’ behaviour, users must be enabled to operate innovative solutions in their intended way, otherwise the solutions will not reach their potential. This in turn may lead to inefficiency, non-application, or to early failure.

Building operation logbook

Complete documentation of buildings is a precondition to understand the development of performance over time and to enable taking of corrective or preventive measures.

Enforcing measure

Assuming that not all actors can or are willing to take a pro-active approach, even when sufficient incentives are in place, the combination of incentives to promote pro-activism with carefully chosen enforcing measures will be needed. to ensure to move all actors into the desired direction.

Responsibility
Responsibility is one core element of sustainability. This relates to people's responsibility for their own actions, towards their own as well as to other people's and other generations' concerns. Sustainability itself must be understood as a shared responsibility, to reach significant enhancement, co-operation towards common targets and partnerships are vital.

Peer pressure
Peer pressure, concurrence, market evolution are key elements of a general improvement.

3.2 Scenario 2 - Climate change / environment

The primary ecological concerns are the speed of climate change and the consequential pressure on biodiversity. The built environment accounts for the largest share of greenhouse gas emissions (about 40%) in terms of energy end usage. Our median scenario is based on the most recent report published by the Intergovernmental Panel on Climate Change (IPCC), which suggests that the average temperature of the Earth's atmosphere is set to rise from 1.5 to 6°C by the end of the century.

3.2.1 Consequences of Scenario 2

More cooling load and increasing solar irradiation (gains)
It appears clear that both energy gains and losses are increasing and the spread of conditions in which buildings need to operate appears to be widening. Increasing solar irradiation not only causes thermal gains but also affects the deterioration of building materials.

More water run-off
Climate change is likely to lead to more frequent extreme weather conditions, including heavier rainfalls. These lead to an increased demand in the peak capacity of storm-water run-off systems in order to protect from overflows.

Flood protection needed
The increased water run-off, caused by faster melting of snow and increasing intensity of rainfalls leads to an increasing demand of flood protection. In coastal zones, the combination of increased water run-off with increasing storms and higher sea levels may lead to simultaneous increases in water levels from inland and from the sea.

Impact on materials durability
Increasing solar irradiation not only causes thermal gains but also accelerates the deterioration of building materials. Likewise the changes in relative humidity or the increases in wind-driven rain-water impact on materials or affect details in building designs. Increased temperature related movements and damage to joints or composites are likely. The change of temperature may also encourage biological attack by fungal growth or insects.

Adaptation of existing stock
The adaptation of the existing building stock to changing conditions for building operation may generate a huge demand for renovation and adaptation processes, depending on the nature and speed of changes in climate. There could be a shortage trained people, technologies, and products,l as of economic resources.

Change of buildings performance
Changes in the performance of buildings due to changes in the exposure environment, including partial building failure, may cause significant losses of building efficiency, leading to increasing energy demands,

may lead to sudden disruptions in the economy of building operation, or may even lead to sudden building failures.

Impacts on human health
Projected climate change-related exposures are likely to affect the health of millions of people, particularly those with low adaptive capacity. Buildings may need have their protective role strengthened (against mosquitoes, temperature amplitude, and extreme events, for example).

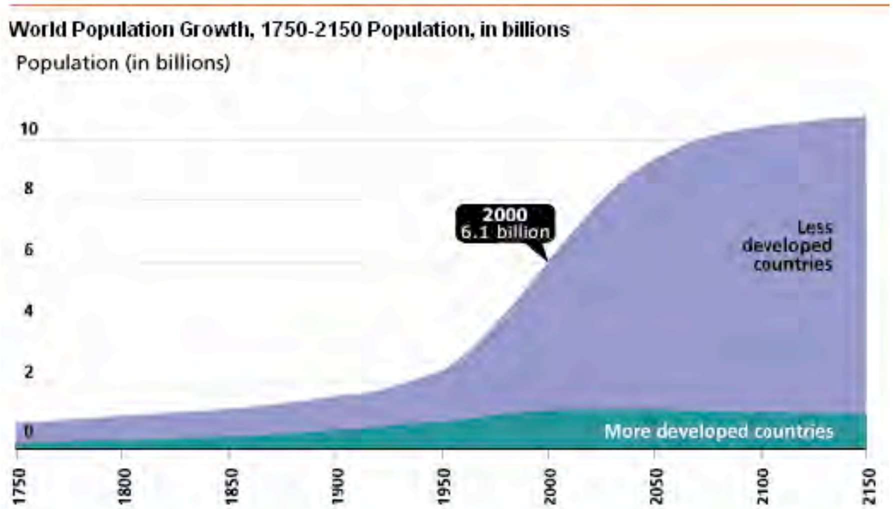
3.2.2 Solutions to Scenario 2

Adaptation to consequences
Buildings have to be designed to be flexible, in order to absorb a wider range of conditions and to increase their resilience against climate actions. The changing conditions could be social, economical or environmental.

Reduce contribution to the problems
Buildings as systems are important factors in the battle to reduce carbon emission and reduce resource demand. The solutions could be technological innovations (e.g. renewable energy systems, etc), methodologies for analysis and assessment (e.g. Life Cycle Assessment), management concepts and tools.

3.3 Scenario 3 - Demography and people movement

There were 6 billion inhabitants on earth in 1999 and there will be 7 billion in 2011 or 2012, with a forecast of 9 billion by 2050.



Source: United Nations, *World Population Prospects, The 1998 Revision*; and estimates by the Population Reference Bureau.

When considering the growth curve, 2030 seems to be the inflexion point. But until that date, the growth rate will remain very high.
A population of 8 billions in 2030 appears as the median scenario.

An historical overview of migratory movements that have occurred for tens of thousands of years and continue to the present day, suggests that major movements will have to occur in the next few decades. Migratory movements could have many origins and factors, for example: the local demography and environment (the search for more and better resources), economic, cultural, or political (the search for freedom from war and conflict, and religious and ideological toleration). These group and individual movements have shaped and structured societies, cultures, technologies and landscapes.

3.3.1 Consequences of Scenario 3

More Buildings
With changes in the demographic structure of societies, the demand for buildings is changing. The demographic distribution as well as the social distribution is changing. These changes usually lead to changing requirements to be met by the buildings, causing the demand for redevelopment, redefinition of functions, replacement, additions or partial deconstruction.

Different Building uses
Changes in demography and in the people using the buildings naturally lead to (slight) changes in the demand for the buildings themselves as well as for the functions provided. The increasing demand for infrastructure and welfare facilities is linked to the ageing population, and the increase of the comfort demand in Europeans countries.

Ageing Population
An ageing population has demands that are significantly different from earlier populations. The adaptation to the demands of elderly, including the functionality, the size, the identity of buildings as well as the possibility to provide the elderly and their decreasing physical strength with the services they need to remain "functional" is an essential task. .

Demand adaptation
Where society and the distribution of "elements of society" change, the demands imposed on the built environment as such, as well as on individual buildings change. Buildings need to be adaptable to these changing demands.

Higher Resource Demand (to build and operate)
The generally increasing economic wealth of people leads to an increasing demand of space and functions provided by the buildings and the building stock. Buildings providing higher levels of functionality are likely to show a higher resource demand, unless a significant increase in efficiency can be achieved.

3.3.2. Solutions to Scenario 3

Solutions to prevent demographic change and people movement are complex and are long-term actions.

More flexibility to absorb wider range of functions and requirements
In order to extend the time that social performances (user's satisfaction) are met, buildings have to be designed to allow internal flexibility.

Make efficient use of existing buildings and space
To reduce land waste, management of land has to be improved. The objective is to improve the flexibility and adaptability of new buildings and land.

High density
To reduce land waste, designer and town planner have to be encouraged to invent compact, mixed-use neighbourhoods. They must create new urban forms that could curb urban sprawl.

Brownfield sites
To reduce land waste, brownfield sites have to be cleaned and reused. The compatibility of land use and building type, taking account of land pollution level must be considered..

Support development of regional centres
To stop urban sprawl and balance the growth of megalopolis and the drain of countryside, regional centres have to be considered and strengthened.

Establish efficient infrastructure within and between metropolitan area
To meet the social need of mobility without encourage car use, infrastructures have to be improved.

3.4 Scenario 4 - People's awareness

Changing individual habitual ways of thinking about environmental and social concerns will be required. The longer that change is delayed, the more difficult it will be. In order not to accentuate the crisis, society will need to decrease its energy and material needs, and to measure accurate needs, in order to find the best balance between the required performance and the energy and material demand. At the individual level, the key issue is the acceptance of modifications to our way of life resulting from this approach.

3.4.1 Consequences of Scenario 4

Inefficiency
Inefficiency has multiple causes:

(1) products and services used are themselves inefficient
(2) efficient products and services are used in an inefficient way
(3) the capacity of products and services is not used
(4) products are regarded in terms of status rather than need, leading to superfluous equipment

The awareness of people, including their sensitivity for own actions and their impact on the local as well as the global environment is a core item of concern.

High Consumption / Waste
High Consumption and Waste: current trends in consumption patterns lead to an increasing demand for energy and material-intensive products and services. This demand in turn causes increased demand in terms of resource extraction, production, process energy, transport, energy in application and ultimately waste handling and treatment. Recycling strategies are an "end of the pipe" approach aiming at reclaiming and reusing resources, but do not reduce the total volume of material and energy turnover.

Lack of know-how
Lack of know-how is directly related to the above problem "inefficiency". Lack of know-how can lead to mis-application of products, to installation and operation mistakes, to deficiencies leading to early replacement, to contradictory product applications (heating and cooling at the same time), to non-useful product application etc.

3.4.2 Solutions to Scenario 4

Reduce demand to reasonable supply levels
The aim is to reduce or optimize existing equipment and building. User behaviour has a huge impact especially when efforts have been made to improve thermal building and equipment performance. For example people have to be encouraged to defer energy load (like washing machine use) to limit peak consumption.

Rely on secure supply sources
Improve diversification and energy resources; independency (regional, local or individual) and reliability in energy supply will increase general supply security.

Create multi-functional environment
A multi-functional environment will , for example, use instrumentation to help people know their consumption and react and change their own behaviour.

Attract people to natural sciences
To make people sensitive to sustainability more could be done by give to them idea of natural sciences, climate change, resources depletion, life cycle assessment, etc.

Attract investment capital to sustainable built environment
A tax system with environmental cost may contribute to raise people awareness.

3.5 Scenario 5 - Lack of coordinated policy making, market distortion

It is not known if national governments in Europe will be in a position to push or regulate the whole economy towards sustainability in order to postpone and lighten the energy and social crises over the next 20 years. Despite the political difficulty of sending such electoral messages, there must be a real political will to initiate some sober trends and national (indeed regional) energy independence. There is some evidence movement in that direction.

European Directives
As a result of a consensus between the European countries, mainly focused on energy performance and reduction of CO_2 emissions, several decisions have been taken recently, each resulting in the formulation or revision of a Directive:
- EPBD
- CPD (revision)
- Energy Services Directive
- Energy using products framework directive

Nations
More than 30 % of the used energy in Europe is accounted for households and the consumption of energy will rise in the next years, because of larger buildings and more residential homes. Furthermore more and more electrical appliances are used. Nevertheless, more than 70 % of the used energy is used for space heating. Governments try to find different solutions to save energy and to make energy saving more attractive to the owner of buildings. They use a range of incentives, persuasion and can ultimately use legal measures to force a response.

3.5.1 Consequences of Scenario 5

Contradictory drivers
Measures applied to encourage various actions may at their extremes act in contradictory ways. Selective descriptive support actions may disregard the over-all performance and the desire to "collect" support may lead to building designs that are optimized not towards their overall performance, but to qualify for the greatest taxation, insurance or subsidy advantage.

Lack of confidence in the market
Lack of confidence in the market reduces incentives for long-term investment. As many of the technologies aiming at increased building efficiency and the use of locally available renewable energy rely on a long-term perspective, a lack of confidence in the market works against their implementation.

Lack of access to sustainable technologies
If the decision-makers do not give the necessary impetus and if the market is waiting for a more favourable time, sustainable technologies which encourage people to use new technological, working and economical methods, will be slow to become accessible.

3.5.2 Solutions to Scenario 5

Harmonized policies with clear common objectives
In order to improve information exchange (e.g. on toxic and environmental data) and to have more efficient results, the community (at the European and the national scale) has the responsibility to harmonize its policies.

Identify drivers and blockers
Decision making process requires public participation.

Establish long-term incentives for stakeholders to act
Enable the construction industry to transform the demand for sustainable development into an opportunity to create and access new markets about efficiency, and performance guarantees.

Enable the market to communicate sustainability performance
Energy performance demonstrations are now rather common. Authorities must engage building owners to communicate about environmental performances and about social and economical aspects.

Push the public sector to act as an example
Authorities must continue to push the public sector because what is the rule for the public sector can become a strong indicator to the private sector.

4.0 Expression of the vision

Sustainable constructions adopt different shapes but are the result of the same approach. Design a sustainable building, imply a holistic approach on the whole life cycle (construction, operation and demolition) in order to reduce environmental impacts and resource depletion, without forgetting the objective to fulfill use functions and be consistent with the general principles of sustainability

New or existing buildings:
The amount of new buildings produced during one year represents a small percentage of the building stock. In Europe the figure is 1%, maybe towards 1,5% in some countries, as a result of the actual efforts for new

social housing construction. This means that in 2030, the stock will include no more that 20 to 30% of new buildings, while 70 to 80 % will be buildings already existing now, and mainly built from 1950 to date. This data indicates the relative importance in the vision of making significant improvements to existing buildings.

Spatial boundaries:
Because a building is strongly dependant to its surrounding plot, the notion of sustainable building must take into account that close environment and its connections to the various networks which contribute to the urban mesh. The vision must be global to European countries without erasing specificities due to climate, cultural habits, etc.

4.1 "The vision of a sustainable smart-eco building in 2030"

A sustainable, smart eco-building (SSE building) results from the practical application, at all phases of the project of the general principles of sustainability set out in ISO 15392:2008.
An SSE building is a new or a renovated building designed as an answer to the needs expressed by the owner and/or future user, for fulfilling its main use functions [CIB W052 "Procurement systems" – 1995]. These are to provide space, an indoor climate and safety and security, to allow the use of goods and tools, to control nearby relationships, take advantage of the site without damaging it, and to bring meaning (semiology). An SSE building contributes to sustainable development when designed and operated to match the appropriate fitness for use, with minimum adverse environmental impacts, while encouraging improvements in economic, social and cultural aspects at local, regional and global levels.

According to local conditions (geography, climate, culture, density, etc.), the physical manifestation of the SSE building may take different shapes. The vision must be timeless to ensure that it remains relevant over time and in different European cultures. All these aspects are part of the overall vision. They may be documented with quantified targets only when defined in detail and for individual categories of buildings.

To obtain a Smart Sustainable Eco Building, it may be necessary to aim beyond most current technical regulations. In particular, Smart Sustainable Eco Buildings need to address the following key considerations:

1. **Apply the general principles of sustainability [ISO 15392:2008]:** these are: Continual improvement, Equity, Global thinking and Local action, Holistic approach, Involvement of interested parties, Long-term consideration, Precaution and risk, Responsibility, Transparency.
2. **Result from the involvement of all interested parties and be designed to meet its occupants' needs individually and collectively.** The occupants' needs must be consistent with collective social ones.
3. **Be completely integrated into the relevant local building, town-planning or environmental–planning schemes and infrastructure.** The building must comply with the local laws applicable to it and connect into the existing services, networks and urban or suburban fabric of its environment.
4. **Be designed or refurbished from a Life Cycle perspective**. The life cycle covers planning, design, construction, operation and maintenance, renovation and end of life. Evaluation of performance at each phase includes taking into consideration all the other phases.
5. **Have its environmental impact minimized over the estimated or remaining service life.** This takes into consideration regional and global requirements, resource consumption (energy, material, and water) and waste and emissions (to air, water and soil) reduction.
6. **Deliver economic value over time.** To assess economic value over time requires a life cycle cost approach, taking account of future costs of operation, maintenance, refurbishment and disposal.
7. **Provide social and cultural value over time and for all.** A Smart sustainable Eco-building must provide a sense of place for its occupants (permanent or occasional), and be seen as a mean of work status improvement for the workers. A SSE building should relate to the local environment and wider regional culture. Moreover, a SSE building is one of the key points for the social affordability.
8. **Be healthy, comfortable, safe and accessible for all.** Health criteria include indoor air quality and comfort criteria include acoustic, thermal visual and olfactory comfort. Full access allows every one, to use the facilities of the building. A Smart sustainable Eco-building must allow safe working

conditions to the workers during the construction and the service life. “For all” means for permanent and occasional, private and professional occupants.

9. **Be designed to be user-friendly, simple and cost effective in operation, with measurable technical and environmental performances over time.** A manual describing the operation and maintenance of the building must be available for both operators and occupants.

10. **Be designed or refurbished to be adaptable throughout the service life, with an end-of-life strategy.** The building allows adaptation to changing performance and functionality requirements, in accordance with new environmental constraints, and taking into account particular regional requirements.

Requirements, derived from this vision, will illustrate in full detail the meaning of each part of the vision.

5.0 Requirements

While the vision describes general expectations, the next step is to establish requirements implementing this vision and expressing it more precisely, considering the demands of sustainable performances.

The vision for 2030 expresses its ambitions when its content is associated with tangible requirements and quantifiable targets.

These are no longer requirements in terms of means (e.g. in terms of type of used equipments) or restricted to users' specifications, but actually performance requirements, based on environmental, economic, social and health and comfort aspects. Obviously, a sustainable building is a building whose technical performance must be seen as an answer to a social demand, the user needs. The designers' and builders' role is to suggest technical solutions to meet the programme, but always considering the impacts of the technical choices on the three aspects of sustainability: environmental, economic and social/cultural. They are free to design the building and to choose equipment (in consistency with the social demand) provided that performance goals are reached. These expected performances must be measured or calculated, at the final handing over or during its exploitation, according to indicators or characteristics at the building scale. These requirements are the skeleton of the project requirements of brief.

These requirements are the practical and concrete expression of the vision and make reference to the actual and future challenges for the construction sector, which are described on the extended vision document. In this document the purpose is not to quantify the expected performance: consequently, the requirements are expressed as directive sentences. A sustainable building is the one for which the relevant questions addressing all the stages of its life cycle have been raised at the initial stage by the owner, and answered through the technical and process choices described in the brief.

The next pages will present the full tables including requirements derived from the vision, classified into:

- topics of requirement
- preoccupations/concerns

5.1 From the vision to the requirements

The ten points of the Vision cover different aspects that can be distinguished and identified as 4 distinct categories of requirements: environmental, social, economical and health and comfort aspects. In fact, to follow one specification of the vision, many requirements need to be expressed and reached. The following table expresses relations between the vision and the four categories of requirements.

	Vision	Topics of requirments	Thematic
1	Apply the general principles of sustainability;		
2	Result from the involvement of all interested parties and be designed to meet its occupants' needs individually and collectively;	Social attractiveness, Users satisfaction	Social
3	Be completely integrated into the relevant local building, town-planning or environmental–planning schemes and infrastructure;	Ressources, Users satisfaction	Environment, Social
4	Be designed or refurbished from a Life Cycle perspective;	Life cycle approach, Cost performance and economic assessment, Users satisfaction, Climatic change	Environment, Economic, Social
5	Have its environmental impact minimized over the estimated or remaining service life;	Life cycle approach, Ressources, Air, Climatic change, Water & soil, Waste	Environment
6	Deliver economic value over time ;	Cost performance and economic assessment, Economic attractiveness	Economic
7	Provide social and cultural value over time and for all;	Full access, Social attractiveness, Users satisfaction, Social accessibility	Social
8	Be healthy, comfortable, safe and accessible for all ;	Indoor Air Quality, Acoustic comfort, Thermal comfort, Olfactory comfort, Visual comfort, Internal comfort, Water quality, Social attractiveness, Full access	Health & Comfort
9	Be designed or refurbished to be user-friendly, simple and cost effective in operation, with measurable technical and environmental performances over time;	Economic attractiveness, Users satisfaction	Economic, Social
10	Be designed or refurbished to be adaptable throughout its service life, with an end-of-life strategy;	Cost performance and economic assessment, Economic attractiveness, Users satisfaction	Economic, Social

5.2 Environmental requirements

Requirement general Topics	Preoccupations		Requirements
Life cycle approach			Indicators applied to measure performance must reppresent full life cycle
Ressources	Consumption of energy resources	energy	Reduce energy consumption
		except energy	Reduce material consumption
	Land use		Reduce land use. Is integrated into town planning
	Water consuption	drinking water	Reduce water consumption
		non drinking water	
	Biodiversity	gene biodiversity conservation	Reduce impact on biodiversity
		Species conservation	
		Ecosystem conservation	
Air	Atmospheric acidification		Reduce contribution to air pollution
	Formation of photochemical ozone		
	Air pollution		
Climatic change	Climatic Change		Reduce contribution to climatic change
	Adaptation to climate change		Adapt to environmental changes
Water & Soil	Soil & Water pollution	Eco-toxicity terrestrial	Reduce impact on biodiversity
		Eco-toxicité aquatic	
		Eutrophication	
Waste	Eliminated solid waste	Non hazardous	Reduce waste production
		hazardous	
		radioactive waste	
		inert waste	

A SSE Building is not designed to reach only the reception requirements but be designed or refurbished from all the Life Cycle perspective. The life cycle covers planning, design, construction, operation and maintenance, renovation and end of life. Evaluation of performance at each phase includes taking into consideration all the other phases.

A SSE building has not only few energy focuses efficient systems or its carbon emission lightly reduced but it has all its environmental impact minimized over the estimated or remaining service life and takes a major role into the carbon emission reduction battle. This takes into consideration regional and global requirements, resource consumption (energy, material, and water) and waste and emissions (to air, water and soil) reduction. The ultimate vision requirement would be a SSE building which has the combination of: zero energy, zero net resource use and zero impact.

5.3 Requirements for the economy

General topic of requirement	Preoccupation	Requirements derived from the vision
Cost performance and economic assessment	Life cycle cost performance	Be economically efficient before the use stage
		Be economically efficient on the use stage
		Be economically efficient on the end of life stage
Economic attractiveness	Adaptability	Be adapt to change in use
		Be adapte to change in fuctions
		Be adapte to new legislation
	Efficient support for activity	Be functionnal

A SSE Building does not only provide a large profit margin to the investor but at contrary deliver economic value over time. To assess economic value over time requires a life cycle cost approach, taking account of future costs of operation, maintenance, refurbishment and disposal.

A SSE building is economically efficient before the use stage. It is mean that the analysis must include the cost of the land on which the building stands, the costs of products incorporated into the smart sustainable building, the costs of construction -excluding products- and the costs of professional fees and other payments associated with the building during the before use phase.

But a SSE building is also economically efficient in the use stage. This efficiently concerns the cost linked to : operation and maintenance, operational energy and water use, refurbishment, rent, taxes, regulatory costs, incomes, grants and other liabilities

A SSE building is economically efficient at the end of life stage. The end of life costs is associated with the removal of the building and clearance of the site ready for further use

A SSE building is adapted to change in use. The design, the structure of the building, the HVAC design, the location of structural elements, of building systems, of fire separations, are design with the consideration of a future possible of change. Moreover it is possible to change the energy/heat supply and to upgrade the building automation/management system.

5.4 Social requirements

General topic of requirement	Preoccupation	Requirements
Full access	Disabled friendly living space	Allow flexible usages for every one (physical, mental or sensorial handicap)
	Age-based living space	Be adaptable of the living space
Social attractiveness	Life quality (comfort & security)	Be connected to the urban mesh. Integrated, multimodal transport plan. Optimise people flow and crowd circulation.
		Have a visual quality
		Be adaptable of the cultural background (Religion, social environment)
		Have a cultural value: Respect of cultural heritage and indentification
		Allows access to knowledge, culture, etc. Allows access to leisures and sportive activities
	Safety, Security & Privacy	Allows inhabitant to have the feeling to be safe (use fonction)
		Avoid danger for users (domestic danger : sliding, etc.)and workers (safe working conditions).
		Occupants are free to manage their relations with the neighbourhood
Users satisfaction	Satisfaction of the user	Adapted to the present and futures owners requirements
		Be user-friendly
		Have a cultural value: Patrimonial approach
	Satisfaction of the local residents	Local residents are satisfatied with the building presence. Loadings on and benefits for neighbourhood.
		Promote governance : communication and participation.
Social accessibility	Social accessibility	Have a responsability in the social mixity plan. Promote solidarity and integration.
		Inhabitant can afford to pay the services charges

A SSE Building is not so sophisticated than nobody is able to use it properly and its performances are catastrophic but be designed to be user-friendly, simple and cost effective in operation, with measurable technical and environmental performances over time. A manual describing the operation and maintenance of the building must be available for both operators and occupants

5.5 Requirements about health and comfort

General topic of requirement	Preoccupation		Requirements derived from the vision
Indoor Air Quality	General interior air quality		Be healthy for its occupants. Minimise indoor air polluants. Reduce equipement and material contribution to interior air pollution. Control fresh air renewal. Minimise radiative pollution
	VOC & Formaldehyde		
	Fungi & bacterial growth		
	Radioactive emissions		
	Fibres & particules Emissions from		
	Presence of allergenic matters		
Acoustic comfort	Noise from outside		Be comfortable for its occupants. Reduce nuisances and elimination of unwanted frequencies. Minimise noise pollution and vibration. Noise from equipment, neighbourough and facilities.
	Noise within the building		
	Acoustic quality of room		
Thermal comfort	Ambient temperature		Be comfortable for its occupants. Reduce thermal deperditions.
	Use of Inertia		
	Level of humidity		
	Air movment		
Olfactory comfort	Odour nuisance from the neighbourhood		Be comfortable for its occupants. clean compartment air
	Materials odours		
Visual comfort	User comfort	Natural luminosity on the building	Be comfortable for its occupants. Reduce incomfort layout, dazzle, dark room, etc. Optimise daylight usage.
		Artificial light	
	Neighbourough comfort		
Internal comfort	Dust	anti-static properties of the materials used	Minimize allergenic potential
		anti-static environment created by the facilities	
	Magnetic field		Have limited magnetic field inside
Water quality	general water quality in internal water supply		Have safe water supply

6.0 Conclusion to the vision

An ultimate vision (the zero energy, zero impact, zero net resource use, high-value outstanding performance building) would have been more provocative, but it was decided instead to have a non-target vision, a consensual and timeless vision. Obviously, this vision is strongly attached to a structure of requirements that give substance to the vision. Requirements need ambitious but achievable targets to assist the political focus especially on the “zero carbon” subject. Moreover, targets must be dynamic to accommodate the variables in the scenarios underlying the establishment of the vision, like carbon target values evolution, energy prices, etc.

7.0 Innovative Technical solutions

7.1 Definition of Innovation

Innovation is a new way of doing something and may be incremental or radical. As radical innovation is difficult to foresee, this report focuses on incremental innovation. Further, an innovation must lead to increasing value, where the value relates back to the requirements. When dealing with innovation supporting sustainability, these requirements necessarily include those listed below. Meanwhile, innovation is context-dependent. An approach successfully applied in a different industrial sector, now being transferred to building construction would be an innovation, even though the concept itself may be well known. Additionally, the transfer of an approach from one region to another may be innovative, even where the transferred technology would not ordinarily be regarded that way.

The performance requirements included in the vision have shown that a Smart-ECO building should:

- reduce use of resources (land, water, materials and energy)
- reduce contribution to climate change as well as reduce adverse environmental impacts in general (emission to air, water, soil, impacts on flora and fauna, generation of waste, pollution)
- be adaptable (to changes in use conditions and environmental conditions)
- meet occupants’ needs and provide comfort (indoor air quality, acoustic, thermal, visual, olfactory, water quality)
- deliver economic value over time
- be integrated with the natural and built environment.

These requirements are the practical and concrete expression of the vision and make reference to the current and future challenges for the construction sector.

Innovations will play an integral part in meeting these requirements. Technological innovation plays a critical role but just as important are changes in the wider political, institutional, and cultural environment that enable technologies to be exploited and provide incentives for their deployment.
Areas of innovation to be considered include technologies, materials, design or evaluation tools, processes, policies and financial tools. Innovation is considered at different scales: micro (product, service and process), meso (sector, supply chain, region and system) and macro (economy-wide).

8.0 Outline of technologies identified

Energy saving:

Heating and cooling:

- Thermal insulation
- Cladding materials
- Glazing
- Thermal storage in the building fabric
- Natural ventilation for comfort and overheating control
- Control systems

Lighting:

- Natural lighting
- Artificial lighting

Energy generation and distribution, especially from renewable sources

Areas for innovation: buildings

Areas for innovation: non-building

Areas for innovation: integrated generation

8.1 Energy Saving

Overview

The key opinions expressed by stakeholders were that:

- the potential of existing technologies is not being fully utilised. Improving existing technologies or developing new is important but the focus needs to be on implementation and integration of existing technologies
- passive design measures is the area of innovation with the highest impact potential
- insulation, passive solar design and passive cooling are the best energy saving technologies, followed by lighting and innovative materials
- buildings should be automated using existing technologies to reduce consumption, integrate systems and inform users so they adapt their behaviour.

The stakeholder views were used as a starting point, to identify areas of innovation with the greatest potential to impact Smart-ECO buildings in the period 2010-2030.

Understanding the problems

The operation of building services such as space and water heating, ventilation and lighting consume energy which cause carbon dioxide emissions amounting to 46% of the total (27% from housing).

Energy demands in dwellings are dependent on climate. European climates are determined not only by latitude or altitude but by proximity to the ocean or inland seas. For example, although much of Europe lies in the northern latitudes, the relatively warm seas that border the continent give most of central and western Europe a temperate climate, with mild winters and summers. In the Mediterranean area, the summer months usually are hot and dry; almost all rainfall in this area occurs in the winter. With such variation within Europe, commonality in design is difficult and it is crucial that buildings are designed to utilise site conditions with a thorough understanding of the constraints.

Eurocodes provide a common approach to design of buildings and are recognized by the member states of the European Economic Area to serve as a framework for drawing up harmonized technical specifications for construction products and a means for demonstrating compliance with the building regulations and various construction directives. The main directives of interest here are the Energy Performance of Buildings Directive (2002/91), and the Construction Product Directive (89/106/EC).

Apart from designing higher quality, site specific buildings to prevent energy loss, the challenge to energy saving is changing consumer behaviour and habit. Using less is about first understanding how much we use and then knowing what changes in use make a significant difference.

Working towards solutions

Reducing the energy requirements in buildings (mainly those for heating, cooling and lighting) emphasises the role of the building envelope (opaque and transparent) as a filter between the controlled conditions indoors and the ambient outside. The improvement of the building fabric's performances is at the basis of any climate-conscious design approach.

The basic principles of very low energy (or passive) houses are very good fabric insulation, air-tightness, exploitation of solar radiation and internal gains and controlled ventilation with heat recovery (depending on climate – this is necessary in Central and Northern Europe, and even in Northern Italy).

Climate-conscious, energy-efficient design requires the adoption of a number of coordinated strategies, with conflicting requirements potentially arising between heating and cooling seasons. Innovation lies not just in products and components themselves, but also in the way they are combined and coordinated.

8.1.1 Heating and cooling

8.1.1.1 Thermal insulation

To reduce the environmental impact on the built environment, it is essential to consider further development of the efficiency of thermal insulation materials, noting that:

- insulation has a great potential for reducing CO_2 emissions
- energy conserved through insulation use outweighs the energy used in its manufacture. Only when a building achieves a low energy standard does the energy embodied in the insulating materials become significant
- the durability of insulation affects its performance e.g. settlement, physical degradation, vapour permeability and air movement.

Note that insulation only provides reduction of heat loss through the building fabric. Equally important is the energy lost through ventilation and glazing (hence the need for integrated design).

When selecting an insulation material, priority should be given to performance in the construction context. Very few insulation materials are capable of performing all functions. For example, sheep wool is perfectly suitable for ventilated wall construction but not in unventilated cavities.

Life cycle data is available for some products but often newer products have not had their claims verified by third party research. This should be considered when assessing information provided by the manufacturer. Not until all products have undergone LCA's will accurate comparisons be possible.

8.1.1.2 Cladding materials

Recent developments in materials and manufacturing processes are delivering solutions that have the potential to transform the building from being a net burden on the environment to being an active producer of energy and even an environmental filter.

Advancements in nanotechnology and surface science is opening up new possibilities to improve performances of traditional construction materials, or to discover new ones. The past decade has seen a remarkable revolution in our understanding and mimicking of natural processes at a chemical, physical and atomic structural level[1]. This is translating to innovative cladding products that make buildings more interactive with the surrounding environment and easier to maintain.

Progress in self-cleaning surfaces is significant and is based on three alternative strategies[2]:

- Easy physical removal of dirt through superhydrophilic films of water which thoroughly wet the surface
- Prevention of residual dirt adhesion with superhydrophobic surfaces where water droplets readily roll off a surface, collecting dust particles on the way
- Removal of organic or biological surface films by photocatalytic oxidation.

The first two strategies are already applied in commercial products such as glass and coatings (e.g. external render and textiles) that can be cleaned by the simple action of rainwater. The photocatalytic effects of TiO_2 coatings have been applied into a wide range of paints, glazes and cements. Besides being self-cleaning

[1] (Turney, 2009)
[2] (Turney, 2009)

(TiO_2 has superhydrophilic properties), nanoparticulate titanium dioxide is a potent catalyst under near-UV radiation and can thus be used for the control of airborne pollutants. In the future, the use of TiO_2 coatings may find feasible applications for the control of odour in indoor environments provided there is sufficient UV light intensity.

Recent laboratory developments in thermocromic VO_2 coatings could form the basis for thermally responsive materials. Vanadium dioxide undergoes a marked change in optical transmittance and reflectivity in the IR region, associated with an insulator-to-metal phase transition: in principle, such coatings would absorb IR radiation until they reach the transition temperature, and then become strongly reflecting.

Buildings can also contribute to the definition of the microclimate surrounding the construction itself. Until now, most buildings have contributed to the urban heat island effect, raising the ambient temperatures as a consequence of heat absorption on external surfaces and its release to the outdoor air.

Two examples of how buildings can minimise their negative contribution are:

- Cool roofs and paving materials which can deliver high solar reflectance (the ability to reflect the visible, infrared and ultraviolet wavelengths of the sun, reducing heat transfer to the building) and high thermal emission (the ability to release a large percentage of absorbed, or non-reflected, solar energy) which reduces the heat build-up on external surfaces contributing to UHI.

- Green roofs which are vegetated roof covers with growing media and plants taking the place of bare membrane, gravel ballast, shingles or tiles. A vegetated surface remains at a lower temperature and may include a water retention system to add to the benefit by evaporation from the wet soil.

These examples show how buildings can become elements that improve the surrounding environment, contributing to the reduction of air pollution, the mitigation of ambient temperatures and the production of energy.

8.1.1.3 Glazing

Low-energy, low-carbon construction concepts call for improved efficiency of the glazed parts of the envelope. These should allow for:

- passive solar gain during the heating season,

- reduction of heat losses and avoiding overheating in summer.

Heat transfer by conduction and convection should be reduced by means of:

- improved U-values for glazing and frames,

The control of solar radiation entering the building can be obtained through

- shading or

- materials with variable transparency.

8.1.1.4 Thermal storage in the building fabric

The thermal capacity of a building (the amount of heat that can be stored in its elements) defines its dynamic thermal behaviour, that is, how quickly it heats up or cools down when boundary conditions change.

While in traditional buildings, mass is used to reduce the inbound heat flow through thermal lag and decrement, the levels of thermal insulation required by European regulations shifts the emphasis onto the surfaces that exchange heat with the indoor environment. Thermal storage surfaces can:

- absorb heat due to solar radiation and internal gains in summer, thus reducing overheating of indoor air, or

- absorb heat in winter, releasing it during the night or when the heating system is switched off.

While thermal mass is able to stabilise indoor temperatures, reducing peak loads on systems, these surfaces are also instrumental in defining user comfort, as a perceived comfortable (??) temperature is defined by both air and surface temperatures. Thus a warm surface will increase comfort in winter, while a cool surface will be beneficial in summer provided heat can be removed during the night with ventilation.

The relationship among climate, insulation levels, thermal mass, relative dimensions of glazed parts, and so on is specific to each building and the correct assessment of comfort levels requires dynamic energy simulation tools case by case. Buildings with thermal mass can save cooling energy in summer and often appear to be more robust to misuse by the user.

Thermal storage can be realised either with traditional massive materials or with innovative solutions such as PCM (phase change materials). It is also possible to artificially activate thermal masses through the inclusion of radiant systems in slabs and walls.

8.1.1.5 Natural ventilation for comfort and overheating control

Natural ventilation has three quite different functions with relative benefits:

- to supply fresh air in winter for health,
- energy conservation, and
- to provide cooling in summer for comfort.

As energy conservation issues imply that new buildings are airtight and refurbished ones have reduced leakage rates, air change is still needed for the well-being of users. Thus, the required amount of fresh air should be supplied by controlled ventilation systems that in winter are also able to recover heat from stale air.

The challenge is how to deliver the required air change rate while reducing energy consumption from fans and pumps.

When ambient temperatures are mild, natural ventilation can be exploited to dissipate excess heat from the building and to improve comfort. The feeling of comfort improves with open windows and air movement; under natural ventilation conditions, users can still feel comfortable at higher temperatures than in sealed buildings.

In some seasons, natural ventilation can thus reduce if not replace the use of HVAC systems during the day. Moreover, it can be beneficial during the night, when it can be used to cool down the components of the building if temperature variations between day and night are large enough.

Building design strategies and components that foster natural ventilation should be implemented in new and refurbished buildings. Often, it is possible to exploit natural phenomena such as wind forces and stack effect to activate air flows in buildings through carefully placed vents, passive wind cowls and solar chimneys.

At a larger scale, atria can also be used to temper climate. Atria exploit direct solar gain in winter and allow for abundant ventilation and shading in summer.

Natural ventilation alone may not always be sufficient to deliver the expected air change rates and indoor air quality (especially in large buildings with high occupancy rates), or it may not even be beneficial if ambient temperatures are too high.

It may then be necessary to develop hybrid approaches, allowing for the use of natural ventilation when ambient conditions allow, and of mechanical heating / cooling in peak periods of the year, when temperatures outdoors are not comfortable or when natural drivers of ventilation are too weak.

In temperate climates that may experience extreme hot or cold conditions, it is fundamental to allow for the use of natural ventilation when ambient conditions allow and mechanical heating or cooling in peak periods of the year, when temperatures outdoors are not comfortable or when natural drivers of ventilation are too weak. There are multiple motivations for the interest in hybrid ventilation:

- The likelihood of a positive response by occupants and a positive impact on productivity
- Reduced environmental impact
- Increased robustness and/or flexibility & adaptability
- Commercial factors (the prospect of lower investment costs and/or operation costs).

For many years mechanical and natural ventilation systems have developed separately. However, for both systems the focus in their development has been to minimize energy consumption while maintaining a comfortable and healthy indoor environment. The next step in this process is the development of ventilation concepts that utilise and combine the best features of each system to create a new type of ventilation system – Hybrid Ventilation.

Hybrid ventilation is based on a different design philosophy and expectations about its performance cannot be the same as for mechanical ventilation. Energy performance targets and comfort requirements must be different. Cost comparisons between hybrid and mechanical systems should be done on a life-cycle cost basis rather than simply on an initial capital cost basis, because of the different design approach, and hence the different balance between initial, running, maintenance and disposal costs.

Buildings with hybrid ventilation often include other sustainable technologies e.g. daylighting, passive and natural cooling and passive solar heating. For these buildings, energy optimization requires an integrated approach in the design of the building and its passive and mechanical systems, allowing for the smooth switch between passive and active ventilation, or even the combination of the two (e.g. active supply, passive extract).

8.1.1.6. Control systems

Mechanical systems have been designed in the past to supply cheap energy to buildings with a very inefficient envelope; today, design is moving towards closer integration of high-performance building fabric and very efficient, small-size mechanical systems. This approach exploits the passive performances of the building, leaving to systems the role of refining indoor comfort conditions (thermal, air quality and lighting) through an efficient use of energy.

As the amount of energy required to operate buildings will decrease significantly between 2010 and 2030 and energy prices are very likely to rise, it will be more and more important to manage it efficiently (e.g., avoiding waste and over-use of systems). One identified challenge, however, is that buildings with highly insulated envelopes are often more sensitive to misuse by users. The correct use of ventilation and shading systems are crucial if buildings are to behave as expected.

Building automation is becoming a crucial element to deliver buildings that live up to expectations and provide indoor comfort with an optimised use of energy. A Building Management System (BMS) is a computer-based control system installed in buildings that controls and monitors the building's mechanical and electrical equipment.

A BMS is most common in large buildings. Its core function is to manage the environment within the building and, in most cases, to control:

- temperature,
- carbon dioxide levels, and
- humidity

A BMS can also have the crucial role of controlling solar shading systems in order to optimise heating and cooling loads.

Smart BMSs allow for significant energy savings both in new and existing buildings and avoid over-use of energy. Although until now BMSs were common in large commercial buildings, smaller systems suitable for households are available under the broad definition of "home automation" systems.

Building automation systems have the advantage of making the idea of the "smart building" practicable where a building can react to constantly changing conditions and situations caused by environment and occupants. A BMS takes over the regulating and controlling functions related both to provision of energy inside the building and to the manipulation of the envelope. While this has the potential to deliver considerable efficiency, it is necessary to underline that extensive automation involves considerable risks, such as:

- vulnerability to technical system or component failures,
- higher building costs,
- avoiding the consequences of our own inappropriate behaviour,
- our growing dependency on newer technical systems and also on manufacture and maintenance firms (Herzog, 2008).

Moreover, research about adaptive comfort shows that users are more comfortable if they can define their own environment, for example opening a window. This is already translating in buildings where the envelope, far from being sealed, can be opened to activate natural ventilation when this is effective. Such hybrid buildings, that can work both with mechanical systems and passive natural ventilation, should become more common but pose additional challenges to BMS designers because of the more complex heat exchange mechanisms and the potential misuse by the occupants.

Smart-ECO buildings will require the right balance between automation and grid integration with the flexibility and resilience provided by overall sound building design (good insulation, effective shading and thermal storage capacity, as described in the relevant paragraphs of this report)..

8.1.2. Lighting

8.1.2.1. Natural lighting and shading

Good daylight levels are essential for comfort of users and for this reason regulations and standards in Europe require either minimum daylight levels or dimensions of windows relating to size of rooms, or maximum distances of workplaces from windows. Good levels of natural lighting inside the building not only saves electricity for artificial lighting but reduces the related internal gains.

The issue of natural lighting needs to be gauged against the ingress of solar energy that may be beneficial in terms of winter heating but may also lead to glare (especially in workplaces) and to summer overheating, especially in buildings with high internal gains such as offices and schools.

As summer temperatures rise throughout Europe, the control of solar radiation becomes crucial for homes; this is not only in Southern countries where traditional architecture has always been facing this problem.

It is thus necessary to spread the use of effective shading systems that control heat gain and glare (adjustable systems allow for precise control in different conditions) while letting natural light in for visual comfort. Solutions range from glazing-integrated shading to complex, adjustable systems that rely on indirect reflections to spread light in rooms. This sort of shading can be very useful also in refurbishment operations, when lighting levels need to be improved.

Shading systems may also be an effective surface for energy generation (e.g., PV panels or vacuum tubes). Other building-integrated solutions include light shelves, which are architectural elements allowing daylight to penetrate deep into a building, also in existing buildings.

Natural light is even more desirable in difficult conditions such as deep-plan buildings and urban canyons. Solutions that allow transportation of light deep into the building can be adopted such as light pipes (tubes with highly reflective coating), glass fibres, or heliostats (horizontal or vertical). These are also suitable to improve natural lighting levels in existing buildings.

8.1.2.2. Artificial lighting

One of the strategies to reduce energy consumption is the improvement of technologies for artificial lighting. The progressive discouragement of incandescent bulbs from EU and the US in the past few years is already creating a radical shift to energy-saving products such as the compact fluorescent lamps.

Light-emitting diode (LED) devices can deliver very high efficiency over very long life spans. A 13W LED lamp produces 450 to 650 lumens, which is equivalent to a standard 40 watt incandescent bulb. A standard 40W incandescent bulb has an expected life of 1,000 hours, while an LED can continue to operate with reduced efficiency for more than 50 times that lifespan.
Organic light –emitting diodes (OLEDs) are also the subject of intense research as they do not require the complex fabrication methods that current LEDs need and are thus expected to be cheaper on the market (Turney, 2009).

Significant savings can also be obtained if artificial lighting systems are used, during the day, as a complement to natural light entering the rooms. Instead of having lights on or off only, simple controls (daylighting sensors and dimmers) can ensure that overall lighting does not exceed the required level for the specific task, thus avoiding over-use of artificial light (Ferrari & Bonomi, 2009).

8.2. Energy generation and distribution, especially from renewable sources

Overview

This section considers renewable generation in urban areas both at building and district levels highlighting barriers and areas of innovation for renewable technologies.

The direction of this section has been shaped by stakeholder input in the Smart-ECO project including direct survey of industry experts and findings from interactive workshops.

On the topic of renewable energy generation, the key opinions expressed by stakeholders were:

- No European-wide renewable solution. Systems need to be designed to suit local conditions focussing on multiple sources at building and district level.
- The potential of existing technologies is not being fully utilised. Both improving existing and developing new technologies is important but the focus should be on implementation and integration of existing technologies.
- The most important issues to help improve innovation are applied R&D and exchange of know how. This is considered a higher priority than policies and market measures.
- Existing buildings pose the greatest challenge and priority should be given to residential buildings and offices.
- Renewable energy technologies are the primary aspect towards the creation of Smart Eco solutions (in particular solar thermal, earth energy and co-generation).

Using the stakeholder views as a starting point, this section aims to identify areas of innovation with the greatest potential to impact Smart-ECO buildings in the period 2010-2030.

Understanding the problems

In the European Union, buildings use almost half of all consumed energy. Sources of energy used in buildings vary significantly based on economic development as shown below, where electricity and natural gas are dominant inputs in OECD countries and developing countries use a higher proportion from renewable and waste sources.

As people gravitate towards urban living environments, the total energy consumption of high density cities is also increasing. In addition, it is estimated that at least 90% of buildings today will still be standing in 2030 hence the main challenge in the next 20 years will be to improve the existing building stock.

Notwithstanding the potential to increase energy generation at building level, it is often assumed that the solution is to create energy autonomous buildings (buildings that generate and store on site all energy needed, even selling excess energy to the grid). This vision is far more problematic than it may appear. Energy autonomy is possible for some new small to medium residential dwellings in low density areas. For buildings in medium to high density areas, potential renewable generation falls significantly short of consumption. This is mainly due to a lack of usable area, physical constraints of other buildings, limitations of existing building and the low efficiency of generation. The last of these can and will be improved in the future but renewable generation is still constrained by intermittent supply and a lack of congruence between supply and demand.

8.2.1 Areas for Innovation: Buildings

While it is unlikely that all existing and new buildings can be energy autonomous, innovation should focus on improving the efficiency of technologies to minimise the reliance on external energy supply.

The split of renewable energy generated by buildings and local grid will depend on each building location, use, age, mass and fabric/structure. Existing buildings will heavily rely on off-site renewable technologies and imported renewable fuel while new buildings will have a larger opportunity to maximize the use of on-site generation and become exporters to the grid where possible.

Based on the efficiency (power production per unit of land used), the key renewable source on which to focus innovation for buildings is the sun, using some of the following technologies:.

Traditional photovoltaic (PV) cells are widely used. PV innovation must now focus on improving efficiency to enable a greater quantity of energy to be generated from the relatively small amount of roof space on buildings. Multiple junction solar cells are considered to be one approach of third generation solar cells aiming to substantially increase efficiency following the widely used single junction devices such as crystalline silicon and thin film cells. By using multiple junctions with several band gaps, different portions of the solar spectrum may be converted by each junction at a greater efficiency.

Building integrated photovoltaic (BIPV) systems are photovoltaic materials that are used to replace conventional building materials in parts of the building envelope such as the roof, skylights, or facades. They are increasingly being incorporated into the construction of new buildings as a principal or ancillary source of electrical power, although existing buildings may be retrofitted with BIPV modules as well.

The advantage of integrated photovoltaics over more common non-integrated systems is that the initial cost can be offset by reducing the amount spent on building materials and labour that would normally be used to construct the part of the building that the BIPV modules replace. In addition, since BIPV are an integral part of the design, they generally blend in better and are more aesthetically appealing than other solar options.

Transparent PV modules allow for integration in glazed facades without limiting the views out.
Up to now, BIPV have been based on slightly modified standard PV modules, but research is under way to provide the market with better and more appealing products (International Energy Agency, 2009).

8.2.2 Areas for Innovation: Non-building

Due to limited surface area available at building level, renewable energy generation needs to be supported with urban scale infrastructure. To achieve this, urban planning has to incorporate smart infrastructure and recognise the surface area needed to accommodate renewable generation to meet urban demand.

Local (or distributed) energy generation encompasses a suite of zero and low emission technologies which aim to:

- reduce reliance on a centralised energy supply,
- reduce emissions and improve energy use efficiency.

Local energy generation involves relatively small capacity (<30MW) units typically sited close to the point of consumption.

Solar technology boasts more than a century of R&D and is an inexhaustible resource. This source shows the greatest potential for large scale solutions in the period 2010-2030.

Concentrating solar power typically uses mirrors to catch the sunlight and redirect it towards a single point. The USA were the first to install commercial CSP plants in the 1980s while Europe's first plant went online in Spain in late 2008 with two more sections under construction by Andasol. Each section is expected to produce a 50MW plant using 200ha of land. Plants generally require:

- level ground (less than 1% slope)
- high solar irradiation
- on-site water
- established electric transmission capacity for distribution.

While trough technology is reasonably mature, innovation has seen increases in efficiency with the introduction of tracking modules used to rotate panels to follow the path of the sun which increases direct light and therefore create more electricity. The estimated performance improvements are 20% for 1-axis and 35% for 2-axis systems[3].
While concentrating solar power has many established or developing applications, two significant areas for innovation are:

[3] "PV Plants with Trackers", abengoasolar.com

- integration with storage and
- improvement in efficiency to reduce land needed.

8.2.3 Areas for Innovation: Integrated Generation

To maximize renewable energy generation, it is important to consider the integration of each building with its surrounding environment and district capability. This relies on:

- significant innovation in the approach to planning building works,
- monitoring through smart grids and
- energy storage.

To increase uptake of Integrated Generation the following issues need to be addressed:

- Regulations on the use of on-site and district generation and the interaction between companies in different segments of the energy generation industry;
- Holistic town planning strategies to allow sufficient land for sustainable energy generation for new developments
- All major new developments should establish or connect to a local renewable grid, district heating and district cooling where appropriate
- Tools to assess the capacity of local industry to meet demand and increase the attractiveness of community scale energy industry
- Increasing awareness of the benefits of an integrated approach
- Carbon costs across industry and consumer groups

Smart grids

Smart grids are being developed to combat the challenge of intermittent energy supply and reducing peak requirements by regulating use. At an infrastructure level, sensors fitted to power lines will enable utilities to operate systems more efficiently and reliably and predict transmission problems earlier. With peak demand lower, utilities would no longer need as much back-up capacity. More intelligence in the grid would also help integrate renewable sources of electricity. Added intelligence would also make it simpler to deal with the imminent and very considerable demand from electric cars. Car batteries could be used to feed electricity back into the grid if needed, and so act as a vast electricity storage system.

At a consumer level, one of the problems of traditional electricity grids is a lack of transparency whereby consumers do not have the means to know how much they are using in real time, and therefore do not have the opportunity to adapt their behaviour to suit supply.

Smart meters track electricity use in real time and form a data connection with providers. While commonly used in industry, the benefit of smart meters is now reaching a wider audience including residential consumers. The next generation of smart meter is integrated with smart thermostats and home appliances giving people more control over how much electricity they are consuming through awareness and automation. As electricity prices rise (and in some cases are charged depending on system load), a home display means consumers can time their usage to be cost effective and also select the source of their electricity.

To facilitate a model “energy internet”, the following need to be addressed:

- Sensors and digital relays installed on power lines will enable utilities to operate systems with greater efficiency and reliability.
- Large scale roll out of smart meters to establish the two-way data connection between consumer and utility company. Italy, for example, has deployed 30 million costumer smart meters in five years.
- Efficient management of intermittent renewable energy systems (RES).
- Compatible system components to encourage interoperability of devices

To increase uptake the following issues need to be addressed (note similarity to 8.2.3):

- Regulations on the use of on-site and district generation and the interaction between companies in different segments of the energy generation industry;
- Holistic town planning strategies to allow sufficient land for sustainable energy generation for new developments
- All major new developments should establish or connect to a local renewable grid, district heating and district cooling where appropriate
- Tools to assess the capacity of local industry to meet demand and increase the attractiveness of community scale energy industry
- Increasing awareness of the benefits of an integrated approach
- Carbon costs across industry and consumer groups

Energy storage

A fundamental challenge to sustainable energy is the irregular supply of the sources. A major restriction to this market is the ability to store energy during peak generation to use during peak need, because the two peaks seldom coincide.

Energy storage is emerging as a major target for innovation in sustainable energy as it is a clear barrier to large scale renewable generation. Several technologies are being developed but, like energy generation, it is unlikely there will be one solve-all solution. Technologies include large-scale batteries, heat transfer fluids such as molten salts for solar thermal storage and compressed air energy storage.

Energy can be stored either at the plant or at the end user. An example of the impact of innovation in storage at the plant is at Andasol's solar thermal power plant. It uses a molten salt storage facility (60% sodium nitrate and 40% potassium nitrate) to absorb part of the heat produced during the day and a turbine to produce electricity from this heat during the evening or overcast weather. This process almost doubles the number of operational hours at the plant per year[4].

Seasonal thermal storage systems are designed to retain heat deposited during the hot summer months for use during colder winter weather. The heat is typically captured using solar collectors, although other energy sources are sometime used separately or in parallel.

Seasonal (or "annualized") thermal storage can be divided into three broad categories:

- Low-temperature systems use the soil adjoining the building as a low-temperature seasonal heat store, drawing upon the stored heat for space heating
- Warm-temperature inter-seasonal heat stores use soil to store heat but employ active mechanisms of solar collection in summer to heat thermal banks in advance of the heating season
- High-temperature seasonal heat stores are an extension of the building's HVAC and water heating systems. Water is normally the storage medium and is stored in tanks at temperatures that can approach boiling point.

In all cases, very effective above-ground insulation of the building structure is required to minimize heat-loss, and hence the amount of heat that needs to be stored and used for space heating.

Despite the differences in design, low-temperature systems tend to offer simple and relatively inexpensive implementation which is less vulnerable to equipment failure. They do, however, require the site of the building or neighbourhood to be clear of the water table, bedrock and existing buildings and are limited to temperate (or warmer) climate zones and to space heating only. High-temperature systems share the same vulnerabilities as conventional space and water heating systems due to their 'active' mechanical and electrical components, as well as the advantage of enabling greater control. They can also be employed in colder climates.

Hydrogen as an energy currency, carrier and storage medium may be a key component of the solution to problems of global warming, poor air quality and dwindling reserves of liquid hydrocarbon fuels. Hydrogen is a flexible storage medium and can be generated by the electrolysis of water. It is particularly advantageous if an electrolyser may be simply and efficiently coupled to a source of renewable electrical energy (Clarke et al., 2009). Use of hydrogen as a source of renewable energy is in its infancy but there have been proposals and experiments to use hydrogen as the intermediary between the solar source and the electricity (and heat) used because it can be stored readily. Works are ongoing to produce hydrogen via thermally generated steam, at temperature capable of splitting water, in its solar catalytic hydrogen generator.

[4] "Andasol 1 Goes Into Operation", renewableenergyworld.com dated 6 November 2008

9.0 Building construction and operation

Overview

This section considers innovations in the areas of the production of building materials and construction activities.

The direction of this section was shaped by stakeholder input in the Smart-ECO project including direct survey of industry experts and findings from interactive workshops.

Stakeholders stated that construction is not as critical as design and operation activities in the creation of the Smart Eco vision although innovations in materials production would reduce waste, progressing sustainability performance throughout the supply chain.

Using the stakeholder views as a starting point, this section aims to identify areas of innovation with the greatest potential to impact the construction of Smart-ECO buildings in the period 2010-2030.

Understanding the problems

The construction industry is one of the most resource-intensive and environmentally damaging industries. The total flow of construction materials into the global economy every year equates to some 3 billion tons. Their production and processing impacts heavily on the environment and causes air pollution, toxic runoff into watercourses and loss of biodiversity and agricultural land. A large portion of construction waste ends up in landfill without any form of recovery or reuse.

Design and construction markets currently face many drivers for increased project performance and sustainability, including new materials of construction, new building designs involving greater complexity and requiring increased quality, shorter schedules, and increased financial pressure. Increased integration and innovation, both fostered by more effective application of information technology, are important means to respond to these challenges. Effective integration of design and construction for improved project performance requires shared knowledge of design processes and products, construction processes, and the constraints faced by both. Construction methods and technologies for the medium-term future will need to fulfil an ever growing set of requirements and will need to deliver the flexibility of application required by adaptation to new uses and climate change.

9.1 Working towards solutions

This section illustrates some of the innovations that are currently contributing towards the creation of a sustainable and efficient construction industry. For the purpose of this section the word construction includes three main activities:

- Material sourcing and manufacture of components or systems
- Site Assembly and Logistics (transport, handling, delivery and storage of materials and products)
- Demolition and recycling

Depending on the material, component or system considered, each of the above stages have different impacts on energy and water use, waste and use of by-products, recycling opportunities, resource depletion, human toxicity and pollution of soil, water or air.

9.2 Material sourcing and manufacture of components or systems

Material sourcing and manufacture of components are often the most resource intensive phases of the construction process and generally have an energy or carbon footprint larger than site works, demolition & recycling activities.

In the UK the carbon emissions associated with running buildings are currently four to five times greater than the emission generated from material sourcing and manufacture. However with more buildings constructed to high operational efficiency standards, the impact of material sourcing and manufacture in the LCA is becoming even more significant.

A key parameter used to identify the energy required to manufacture and supply materials or services is embodied energy. Embodied carbon dioxide is defined as the CO2 emitted during these processes. The CO2 emissions associated with the energy used in the manufacture and supply of materials may vary depending on the energy source and manufacturing processes involved. For example any material that uses electricity in its manufacturing process will have an embodied CO2 that is dependent on the fuel mix for the electricity supply. Electricity in France has much lower carbon intensity than UK electricity due to large nuclear power capacity in France compare to the UK's higher reliance on fossil fuels. Therefore the same material manufactured in France and the UK could have different embodied CO2 values.

One of the biggest challenges during the design and material selection process is finding the embodied energy and carbon of materials. Concrete can be pre-cast or in situ and contains a number of constituents (cement, aggregate, water, sand, admixtures) in an infinite variation of ratios and type and amount of steel reinforcement. Accessible, reliable and objective data source are critical to assess the impact of a particular design, manufacturing or construction decision on energy and water use, waste and use of by-products, recycling opportunities, resource depletion, human toxicity and pollution of soil, water or air. The sustainable energy research team (SERT) at the University of Bath (UK) has published an Inventory of Carbon and Energy (ICE), which has been adopted by many designers and government agencies to provide fast and simple evaluations of embodied energy and carbon.

There are case studies which illustrate an innovative approach to the reduction of embodied carbon for a building and a new city development during the design process using a combination of data availability, life cycle assessment analysis and supporting tools.

Innovations need to help the transition from a system predicated on resource extraction-manufacture-use-dispose, to one based on life cycle principles, cradle to cradle manufacture and construction. ndard practice.

The Smart-ECO project found examples that illustrate the opportunities for technical improvements within the construction industry and the importance of environmental assessment methods and tools to help tracking the origins of all raw materials, components or systems throughout the supply-chain and to select sustainable technologies and methods from the initial stages of the project lifecycle.

Many organizations are now recognizing the importance of managing their supply chains in a more sustainable way. This is driven by corporate or political targets, such as cutting carbon emissions, reducing waste to landfill or by costs related to energy consumption or landfill use. Other reasons could be risk mitigation and reputation.

Notwithstanding the drivers, innovative sustainable procurement and tendering processes give an additional opportunity to embed sustainable actions into construction work. Practical measures including whole life value in proposals, demonstration of how suppliers and contractors can include sustainability within their business processes, how contractors can plan for conservation of resources throughout the design, procurement of suppliers, and into construction works, have the potential to reduce the environmental and carbon footprint of a project.

9.3 Site Assembly and Logistics

There are a number of enabling operations, which can play a significant role in the effective delivery of a construction project. One of these is logistics (defined as transport, handling, delivery and storage) . Often considered a backroom function, logistics can be overlooked in terms of its contribution to the broad improvement and sustainability agenda. Studies have shown that innovation in logistics can significantly reduce waste and transport carbon emissions.

In the case of construction projects, freight vehicles play an integral role in the transportation of equipment, the delivery of materials and the removal of waste. Yet, despite its importance, freight transport also has less positive effects on urban areas and the environment in general. Safety is also an issue, with high number of people killed or seriously injured involved in collisions with goods vehicles.
By managing deliveries to construction sites more effectively, and reducing the number of journeys required, the efficiency of freight in construction activities can be improved helping to cut costs for both freight operators and their clients.

The Smart-ECO project found cases that illustrate where innovative processes and tools helped improve logistics and reduced the environmental impact of construction activities.

As the deconstruction sector grows, more companies are developing the required skills to undertake efficient building deconstruction and more designers are learning how to incorporate deconstruction criteria into their plans of work.
One important policy driver could be the inclusion of deconstruction criteria into green building assessment methods. Again the question of measuring deconstruction arises but some suggested criteria include:

- excluding Portland-cement based grouts and mortars for masonry,
- the labeling of structural materials,
- fixings that can be disassembled
- specifying minimum percentages of reclaimed building elements by weight.

Ultimately, it may be necessary to significantly change the regulatory environment within which businesses operate to engender sufficient levels of material reuse. CIRIA notes,
"Perhaps the most important conclusion is that the reuse of building materials and elements is much more likely to occur if construction firms retain ownership of their buildings until their end of life, or manufacturers retain ownership of their products – or at least are responsible for them – until their ultimate dismantling and recycling of the constituent materials."

10.0 Meeting future requirements

10.1 Climate change and adaptation need

Awareness of climate change and the contribution of buildings to energy use, resource consumptions and CO_2 emissions is widespread. Climate change policy has developed around two themes: mitigation and adaptation. Mitigation is tackling the causes of climate change through reduction of greenhouse gas emissions; adaptation is adjusting to the physical impacts of climate change, by reducing vulnerability and finding opportunity. Mitigation and adaptation should not be viewed as alternatives. Adaptation will be needed to deal with the unavoidable impacts of climate change even with mitigation. In the longer term, adaptation is likely to be insufficient to manage the most serious impacts of climate change should mitigation efforts fail[5]. Expected changes to central Europe, for example, include increase in average temperature, more heat waves and droughts in summer, milder, wetter winters, more winter storms and more frequent extreme conditions throughout the year[6].

The building sector has a considerable potential for positive change both in mitigation and adaptation strategies, to become more efficient in terms of resource use and environmental impact. Considering the effects of climate change, building practices will have to change to ensure buildings continue to fulfill their functions throughout their life cycle.

A Smart-Eco building can be realized through a combination of proven and commercialized technologies and innovative improvements.

[5] (ARUP, 2009; Stern N., 2006)
[6] (Werner, Chemella-Emrich, 2009)

Climate factor	Climate effects	Affected building functions and components	Adaptation need	Priority
Temperature	Increase in summer, longer periods of heat	External envelope: external walls, roof, windows	Comfortable, healthy indoor climate achieved through: thermal insulation, amount of glazing, solar protection	High
		Building services	Ventilation, air conditioning	
Precipitation	Increase in heavy rain (pelting rain, >40mm/24h)	External envelope: roof, external walls, components in contact with ground, base area, cellars	Preventing penetration of water and damp: waterproof seal, drainage	High
	Increase in heavy hailstorms	External envelope: roof, facade, windows	Impact resistance, breaking strength	Locally and regionally high
	Short-term increase in damp snow masses	External envelope: roof	Snow load strength	Regionally high in the coming decade
	Changes in groundwater conditions	Components in the ground: foundations, cellars	Stability	Generally low
			Waterproof deal	Possibly high in special conditions
Wind	Increase in strong winter storms	External envelope: roof, external installations (satellite dishes, blinds, pergolas), facade cladding	Wind-resistance of roofs and external installations in part also wind-resistance of facades	Medium to high
	Local tornados			Medium to high
Humidity	Increase in damp, mild winters	Damp sensitive components	Structural protection or surface protection	Tends to be low at present
		Wooden structures, historic building fabric		Potentially high
Sunshine hours	Summer radiation	Light-sensitive components and building materials in outer envelope	Light- and UV-resistance	Low

Climate change in Central Europe: expected effects, priority and adaptation strategies (Werner p., Chmella-Emrich E., 2009).

1 The challenge to achieving sustainable buildings and reduced climate change impact is usually not a lack of access to technical solutions but a lack of uptake by building sector stakeholders. This challenge must be tackled through policy, finance and education.

10.2 Adaptable and flexible design for future needs

Changes characterizing our society include an ageing population, urban migration, our lifestyle and work. These often make traditional building approaches obsolete.

The existing building stock cannot totally satisfy the changed needs and new projects ask for careful valuations and new operating tools. To face the change, a feasible solution is to introduce in an architectural project the requisite of flexibility: i.e. to realize adaptive buildings, or buildings that can modify their characteristics according to changing boundary conditions.

A design based on the adaptability and flexibility concept makes it possible to continue using the building even if needs have changed: this is the “loose fit, long life” concept, that aims at the maximum reuse of the structural components of the building (structural frames and floor slab embody, on average, 50% of the grey energy of a building; Hegger, Fuchs, Stark, Zeumer, 2008).

The following points illustrate the strategies for adaptive/flexible buildings.

- Structural efficiency of buildings can be increased by using frames, braced in a proper way, usually in steel or wood. The embodied energy of such solutions is lower than massive brick/concrete or concrete frames and this also allows to save money and materials for foundations. Steel or wood frame structures can be reused/recycled in the future.
- Fixed parts like staircases, balconies, ramps, can be located outside the inhabited box. If this is made in a steel/wood frame system, it will allow a great flexibility in the interior transformation which could be obtained during the service life cycle of the building. Using internal lightweight walls, flexibility and transformation can be easily obtained without using too much energy for the necessary works.
- Adaptable internal fit out (modular / movable walls and finishes, modular services). Walls with fittings and mobile walls allow for simple and 'soft' changes in the internal fit-out of spaces according to changes in uses ad habits. In the long term, modular services, with smart plug-ins, could help the internal flexibility.
- Flexible façade technology that allows for change in use (e.g. offices vs. housing). Façade elements are designed and conceived with the same level of flexibility as the interior walls. Outdoor spaces could be integrated in the interior spaces (e.g. balcony could change into loggia). A right evaluation of changes in natural lighting, fire safety, noise reduction, solar gains, thermal insulation is needed in order to guarantee always high levels of comfort.

10.3 Resource depletion and building strategies

Increasing scarcity and the consumption of fertile land and natural resources is a significant global problem.

The use of building materials should be reduced considerably as a means of resource efficiency. In order that materials remain available permanently, open materials chain, especially those for non renewable raw materials, must be closed wherever possible. Actually, the strategies to use materials efficiently and to integrate building materials in closed cycles are being applied sporadically. The updated Construction Product Directive (CPD) in the future will demand proof of the environmental impact of building materials in accordance with the life cycle assessments.

The extension of materials life-cycle could be obtained by promoting the extension of life expectancy in buildings, i.e. by means of conversion/transformation of existing buildings instead of new construction. As explained in a previous chapter, the largest part of the embodied energy is in the load-bearing structure. The refurbishment of existing building enable further use of load-bearing structure and a great potential for resource and energy savings.

In a flexible or adaptive building, growing usage expectations and correspondingly better internal fitting-out mean that long-lasting components are not fully exploited. In such cases the design should take into account renewal processes and, if feasible, secondary uses for components and materials.

The design of buildings has always been a complex matter, not least because life cycles are extremely long and it is difficult to predict what will happen in decades. Today, this challenge is made even more compelling because climate change is accelerating and we may find ourselves in 2030 with a very different world from the one we have known in the last century.

Buildings constructed today will very probably be still in use when fossil fuels will be no longer available and should be ready to be retrofitted for other forms of energy supply. Buildings should invest more on the “passive” behaviour rather than on “eco-bling” technologies applied for greenwashing purposes (Liddell, 2008).

Flexibility and adaptability of buildings (not limited to internal fit-out, but including the external envelope) seems to be a crucial point if our buildings are to face uncertain conditions of climate and use.

On the other hand, escalating costs for materials (due to scarcity of resources) and maintenance (due to increased stress on the building as a consequence of climate change) may push in the direction of self-healing structures and materials, involving nanotechnologies and surface science (Turney, 2009).

Buildings will very likely become (the trend is already underway) more and more akin to organisms, with feedback loops controlling its behaviour, managing energy flows efficiently, changing the functionality of the envelope according to external conditions and comfort requirements from the users (Turney, 2009). Whether this will happen through innovative materials, “smart” control systems or a combination of both, the psychological effect of these far-fetching ideas on the occupants should not be underestimated, and a degree of control (and responsibility) should be left to the users, as pointed out in paragraph 3.1.1.6.

11. The Smart-ECO Stakeholder process

11. 1 Setting up Smart-ECO Stakeholder Group

At the start of the Smart-ECO project, it was necessary to establish a group of stakeholders, and to develop a plan to involve the Stakeholders in the project in order to achieve the project goals. The primary objective here was that stakeholders’ priorities and concerns, from all viewpoints, were to be gathered and then used in carrying out the technical details of the Smart-ECO work programme. The work was started by focussing on the type of stakeholders that were felt to be needed, and included, within the Stakeholder Group. In doing this the following categories of stakeholders were felt to be needed;

1. Technical experts in all the areas of technology needed in the construction sector, to comprise researchers, engineers, scientists, etc, all with vested interest in developing innovations for a sustainable construction sector.
2. Industrialists involved in manufacturing and commercialising products for construction.
3. Developers involved in real estate development and planning of large construction sites.
4. Material specialists to support the variety of materials needed in construction.
5. Architects involved in design of green and eco-friendly buildings in particular.
6. Builders, ranging from house builders to construction companies involved in building large commercial structures.
7. Occupants of various disciplines, to give feedback from a general viewpoint on the acceptability of various innovations being considered for adoption.
8. Educationalists involved in training and education of different types of Stakeholders in the construction sector.
9. Authorities ranging from government bodies to professional organisations and associations involved in developing policy and having activities related to the construction areas.
   All the project partners were invited to contribute their personal contacts in these areas, and a list of over 238 persons was created. From these contacts 66 stakeholders from the following countries: UK(9), Italy(12), Turkey(1), Belgium(1), France(6), Sweden(5), Greece(3), Estonia(10), Netherlands(1), Romania(1), Germany(3), Portugal(1), Finland(1), Spain(2), Hong Kong(1), USA(2), Brazil(1), South Africa(1), Japan(2), Pakistan(1), Canada(1), Australia(1) accepted to join the Stakeholder Group.

11.2 Smart-ECO questionnaires

In total, 3 questionnaires have been formulated and distributed to the Stakeholder group. These were as follows:

- Questionnaire 1 – related to Workpackage 2, focussing on formulating the vision for Smart-ECO.
- Questionnaire 2 – related to Workpackage 3, focusing on the innovations needed to realise the Smart-ECO vision.
- Questionnaire 3 – related to Workpackages 4 and 5, focussing on developing the evaluation methods to realise the sustainable construction vision and the potential market for sustainable construction products.

The questionnaires contained an executive summary of the work carried out within the project and a range of questions formulated to obtain the views of the stakeholders. For most of the questions a statement was made and a 5-point scale was used to assessing agreement /disagreement with the statement made, as follows:

- 0: Strongly disagree
- 1: Disagree
- 2: Neutral
- 3: Agree
- 4: Strongly agree

In addition, there were questions for assessing and ranking the most important issues as well as opportunities for comment by way of feedback. The details of the questionnaires are presented next.

11.2.1 Smart-ECO Vision: Questionnaire 1

In order to determine whether the suggestions being made by the Smart-ECO Consortium had a proper grounding, a short executive summary of the draft vision being formulated was produced together with questionnaires to determine the viewpoints of the Stakeholder Group members on different aspects being considered within the vision. The questions also related to the relative importance of different aspects that were being considered within the vision.

11.2.1.1 Data Analysis from Questionnaire 1 (Q1)

A total of 58 Q1 questionnaires were completed (44 stakeholders and 14 partners) and the top 8 ranked issues of the stakeholders and the project partners agree very closely. The overall result from Q1 indicates that the issues (in ranked order) that should be included in the Vision are as follows:

1. Lifecycle of building
2. Minimum energy consumption
3. Monitoring of building
4. Building user manuals
5. Building adaptability
6. Local issues
7. Dismantling building phase
8. Setting up building phase

The detailed responses for the questions are presented next.
Question 1: It is important to ensure that the SMART-ECO vision is obtained via wide consultation and consensus rather than consulting a few elitist stakeholders (average of responses: 3.2).

Question 2: Using the back-casting approach is important in formulating a reliable and robust “Vision” document (average of responses: 3).

Question 3: The general principles of sustainability set out in ISO 15392:2008 are acceptable for basing the Vision (average of responses: 2.7).

Question 4: An SS-E building could be a new or a renovated building without any difference of approach. (average of responses: 1.8).

Question 5: The main use functions of SS-E buildings as expressed by CIB WO52 Procurement systems”: 1995 are acceptable for formulating the SMART-ECO Vision document (average of responses: 2.4).

Question 6: From the detailed issues stated in the Initial SMART-ECO Executive summary, please indicate your level of agreement/ disagreement on the importance of each issue:

- Question 6a: SS-Es should result from a collective decision (average of responses: 3.1).
- Question 6b: SS-Es should be designed from a life cycle perspective (average of responses: 3.6).
- Question 6c: SS-Es should be erected in acceptable setting up conditions (average of responses: 2.8).
- Question 6d: SS-Es should sustain their use functions with minimised energy consumptions (average of responses: 3.5).
- Question 6e: SS-Es provide monitored and traceable technical and environmental performances (average of responses:) 3.4.
- Question 6f: SS-Es should come with user and operation manuals (average of responses: 3.4).
- Question 6g: SS-Es should allow the insertion into local networks and urban life (average of responses: 3.2).
- Question 6h: SS-Es should permit and ensure refurbishing, retrofitting and adaptation, etc, for different uses (average of responses: 3.2).
- Question 6i: SS-Es should facilitate dismantling (average of responses: 3.1).

11.2.2 Innovations to realise the Smart-ECO Vision: Questionnaire 2

The second Smart-ECO Questionnaire (Q2), related to how the Smart-ECO Vision produced could be realised. The technical team within the Consortium have considered a variety of innovations, both technical and non-technical, and the work for Q2 involved gathering the views of the Stakeholder Group and making sure the proposals being suggested were properly grounded within the built sector community represented by the experts in the Stakeholder group. As for Questionnaire 1, a summary of the innovations was formulated together with a set of questions that requested the views and priorities of the stakeholder members.

11.2.2.1 Data Analysis from Questionnaire 2 (Q2)

A total of 51 Q2 questionnaires were completed (37 stakeholders and 14 partners) and again the responses from the stakeholders and the project partners for the various rankings of the key issues agree very closely. The detailed responses for the questions are presented next.

Question 1: There is added value of EU level action to promote innovative technologies. (average of responses: 3.3).

Question 2: Taking into account public and private sector initiatives, the current economic downturn will slow down the deployment of innovations (average of responses: 2.2).

Question 3: The most important issues to help improve innovation through international cooperation are (select max 3 from following: Applied research & demonstration actions; Exchange of know how; Technology transfer; Basic research; Stimulate global market; Global codes and standards; Regulatory aspects; Intellectual property rights; and Others (please specify)).

The ranked responses are as follows:

1. Applied R&D
2. Exchange of know how
3. Technology transfer
4. Global codes and standards
5. Stimulate global market
6. Regulatory aspects
7. Intellectual property rights

8. Basic research

Question 5: TECHNOLOGY PUSH or DEMAND PULL is needed to promote innovation. Which is the most able to accelerate the pathway to the market?
The ratio of “Technology push” to “Demand pull” of the responses is 19:36 with some persons voting for both.

Question 6: Smart-ECO buildings could be achieved with technologies currently available in the market (average of responses: 2.7).

Question 7: Types of buildings (new and existing) where Smart-ECO building are likely to have the higher impact are the following (select max 2 from Residential; Offices; Retail / Shops; Hospitals; Warehouses; Stations/ Airports; or Others (please specify)).

The ranked responses are as follows:

1. Residential buildings
2. Offices
3. Retail/shops
4. Hospitals
5. Stations/airports
6. Warehouses
7. Schools

Question 8: The stages of the building life cycle process where innovations are likely to be most effective are (select max 2):

- Innovations affecting the way buildings are designed
- Innovations affecting the way buildings are constructed
- Innovations affecting the way buildings are refurbished
- Innovations affecting the way buildings are operated
- Innovations affecting the way buildings are demolished or dismantled

The ranked responses are as follows:

1. Design stage
2. Operational stage
3. Refurbishment stage
4. Construction phase
5. Demolition stage

Question 9: The areas where innovation has the higher potential to impact Smart-ECO buildings are (select max 3 from Education; Policies; Finance and incentives; Communications; Management and processes; Passive design measures; New materials; Renewable energy generation; Water conservation; Operation; Recycling; or Others (please specify)).

The ranked responses are as follows:

1. Renewable energy generation
2. Passive design measures
3. Operation of building
4. Finance and incentives
5. New materials
6. Management and processes
7. Education
8. Policies
9. Recycling
10. Communications
11. Water conservation

Question 10: Innovations adaptable to the refurbishment of existing buildings are more important than innovations for new buildings in the period 2010-2030 (average of responses: 2.6).

Question 11: Applying integrated design procedures (close cooperation among architects, engineers, consultants, etc.) is important to achieve the Smart-Eco Vision objectives (average of responses: 3.6).

Question 12: The energy saving and efficient technologies with high potentials to impact Smart-ECO buildings are (please rank from 1 to 7 on potential impact where 1=high, 7=low) from the list: Insulation; Passive cooling; Lighting; Passive solar; Orientation; Innovative materials; Water conservation and storage; or Others (please specify).

The ranked responses are as follows:

1. Insulation
2. Passive cooling
3. Passive solar
4. Lighting
5. Orientation
6. Innovative material
7. Water conservation and storage

Question 13: The renewable technologies with high potentials to impact Smart-ECO buildings are (max 3 from Wind related technologies; Solar thermal; Photovoltaics; Earth energy; Biomass; Cogeneration (CHP); Fuel cells; or Others (please specify)).

The ranked responses are as follows:

1. Solar thermal
2. Co-generation
3. Earth energy
4. PVs
5. Biomass
6. Wind related technologies
7. Fuel cells

Question 14: Energy generation related innovations should focus on (select max 2):

- Improving large power plant efficiency
- Increase energy generated at building level
- Develop more local / district plants
- Increase large-scale renewable power generation

The ranked responses are as follows:

1. Increased energy generated at building level
2. Increased large scale renewable power generation
3. More local power plants
4. Improved power plant efficiency

Question 15: The most important ‘Operation’ to help improve innovation are (select max 3 from Building management systems; Air quality control sensors; Waste management plan; Intelligent lighting; Daylight dependent control systems; Robustness to user behaviour; Automation or controls for energy saving; Post occupancy monitoring; or Others (please specify)).

The ranked responses are as follows:

1. Building management systems
2. Automation for energy saving
3. Robustness to user behaviour
4. Post occupancy monitoring
5. Waste management plan
6. Intelligent lighting
7. Air quality control
8. Daylight dependent control systems

11.2.3 Evaluating the Smart-ECO Innovations: Questionnaire 3

The third and final Smart-ECO Questionnaire (Q3), is related to how the Smart-ECO innovations identified in Workpackage 3 can be evaluated to assess success. The technical team within the Consortium have considered a variety of metrics and viewpoints, and the work for Q3 involved gathering the views of the Stakeholder Group and making sure the proposals being suggested were again properly grounded within the built sector community represented by the experts in the Stakeholder Group. For Questionnaire 3, a summary of the first two questionnaires was formulated together with a set of questions that requested the views and priorities of the stakeholder members. The questions for Q3 are as follows:

1. In order to perform holistic evaluations of the innovative technologies, the main viewpoints that need to be considered from WPs 2 and 3 are stated below; please rank in order of priority (1: highest; 2 next highest, etc) from the list: Technical performance; Economic; Sustainable; Social.
2. The main issues to be included in the regional pre-conditions for performing the evaluations, in ranked order, are: (Choose from the list: Climatic conditions; Local building regs; Local policies; Geographical features; and Other (specify)).
3. The main issues to be included in performing technical evaluations of the innovations, in ranked order, are: (Choose from the list: Requirements met?; Robustness; Reliability; Maintainability; and Other (specify)).
4. The main issues to be included in performing economic evaluations of the innovations, in ranked order, are: (Choose from the list: Set up costs; Operational costs; Cost-benefit; Service length; and Other (specify)).

For questions 5 – 8 please assess the potential contribution that the top innovations identified in Q2 could make to the various issues that are important to the Vision as determined by Q1. To do this please enter a number between 0 – 5 in each box, where 0 indicates no potential contribution, and 5 indicates maximal contribution. The boxes which are shaded are felt to be no applicable for the innovation under question. However if you feel that some contribution could be made with respect to that issue, feel free to enter a number between 0 – 5.

5. Please assess the potential impact of the most important energy saving innovations identified in Q2.

Vision "issue" (Q2)	Min energy	Monitoring	Local issues	User manuals	Adaptability	Life cycle	Setting up	Dismantling
(Assessment criteria)	Reduces energy	Increases awareness	Regional conditions	Easy to use	Adaptable	Easily reuseable	Ease to set up	Ease to dismantle
1. Insulation								
2. Passive Cooling								
3. Passive solar								
4. Lighting								
5. Orientation								
1st other?...................								
2nd other?...................								

6. Please assess the innovations which are felt to have the highest potential impact as identified in Q2.

Vision "issue" (Q2)	Min energy	Monitoring	Local issues	User manuals	Adaptability	Life cycle	Setting up	Dismantling
(Assessment criteria)	Reduces energy	Increases awareness	Regional conditions	Easy to use	Adaptable	Easily	Ease to	Ease to
1. Renewable energy								
2. Passive measures								
3. Operation								
4. Finance incentives								
5. New materials								
1st other?...................								
2nd other?...................								

7. Please assess the potential impact of the most important renewable energy innovations identified in Q2.

Vision "issue" (Q2)	Min energy	Monitoring	Local issues	User manuals	Adaptability	Life cycle	Setting up	Dismantling
(Assessment criteria)	Reduces energy	Increases awareness	Regional conditions	Easy to use	Adaptable	Easily reuseable	Ease to set up	Ease to dismantle
1. Solar thermal								
2. Co-generation								
3. Earth energy								
4. Photovoltaics								
5. Biomass								
1st other?..................								
2nd other?..................								

8. Please assess the potential impact of the most important operational aspect innovations identified in Q2.

Vision "issue" (Q2)	Min energy	Monitoring	Local issues	User manuals	Adaptability	Life cycle	Setting up	Dismantling
(Assessment criteria)	Reduces energy	Increases awareness	Regional conditions	Easy to use	Adaptable	Easily reuseable	Ease to set up	Ease to dismantle
1. Building management sys								
2. Automation								
3. Robustness to users								
4. Monitoring								
5. Waste management								
1st other?..................								
2nd other?..................								

For questions 9-12 please assess the potential contribution that the top innovations identified in Q2 could make to the key decision criteria identified in WP4. To do this please enter a number between 0 – 5 in each box, where 0 indicates no potential contribution, and 5 indicates maximal contribution.

9. Please assess the most important energy saving innovations identified in Q2 with respect to the WP4 criteria.

Assessment criteria	How effective is it?	Does it have large potential?	How sustainable is it?	How cost effective is it?	How easy is it to implement?
1. Insulation					
2. Passive Cooling					
3. Passive solar					
4. Lighting					
5. Orientation					
1st other?..................					
2nd other?..................					

10. Please assess the innovations having the highest potential impact identified in Q2 with respect to the WP4 criteria.

Assessment criteria	How effective is it?	Does it have large potential?	How sustainable is it?	How cost effective is it?	How easy is it to implement?
1. Renewable energy					
2. Passive measures					
3. Operation					
4. Finance incentives					
5. New materials					
1st other?..................					
2nd other?..................					

11. Please assess the most important renewable energy innovations identified in Q2 with respect to the WP4 criteria.

Assessment criteria	How effective is it?	Does it have large potential?	How sustainable is it?	How cost effective is it?	How easy is it to implement?
1. Solar thermal					
2. Co-generation					
3. Earth energy					
4. Photovoltaics					
5. Biomass					
1st other?..................					
2nd other?..................					

12. Please assess the most important operational innovations identified in Q2 with respect to the WP4 criteria.

Assessment criteria	How effective is it?	Does it have large potential?	How sustainable is it?	How cost effective is it?	How easy is it to implement?
1. Building management system					
2. Automation					
3. Robustness to users					
4. Monitoring					
5. Waste management					
1st other?..................					
2nd other?..................					

13. What are important issues related to the validation of implementing the innovations within Smart-Eco buildings?

For questions 14-15 estimate the market perspective for the innovations considered and the likely take up rates at the EU level (in percentage) within the built sector over various timescales.

14. From all the best energy innovations identified in Q2 estimate the market perspective for the timescales requested.

	Likely product?	Take up % by 2015	Take up % by 2020	Take up % by 2025	Take up % by 2030
1. Insulation					
2. Passive Cooling					
3. Passive solar					
4. Lighting					
5. Orientation					
1st other?..................					
2nd other?..................					

15. From all the renewable energy innovations from Q2 estimate the market perspective for the timescales requested.

	Likely product?	Take up % by 2015	Take up % by 2020	Take up % by 2025	Take up % by 2030
1. Solar thermal					
2. Co-generation					
3. Earth energy					
4. Photovoltaics					
5. Biomass					
1st other?..................					
2nd other?..................					

The Questionnaire 3 has only recently been formulated and responses are being collected from the Stakeholder Group members and the Smart-ECO partners.

11.3 Conclusions of Stakeholder process

The section has presented the work carried out within the WP5 Workpackage of the Smart-ECO project to set up and engage with the built sector stakeholders. A large number of experts (238) from a range of areas were contacted and invited to participate with the Smart-ECO project to formulate the Vision, identify the innovations and evaluate the proposed solutions that have been identified within the project. Of these contacts 66 agreed to join the Smart-Eco project and have assisted in the project by providing responses and comments to specially produced questionnaires. In addition, some stakeholders have attended Smart-ECO meetings and events and provided detailed input on various tasks of the project.

This section has presented the details of the responses that have been gathered from the Stakeholder Group and which have helped the partners to finalise and rank the various aspects in the Smart-ECO Vision, the innovations which have potential to contribute to this vision and how the solution identified should be evaluated.

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- participation in local and international CIB conferences, symposia and seminars
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TG66	Energy and the Built Environment
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TG76	Recognising Innovation in Construction
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TG78	Informality and Emergence in Construction
TG79	Building Regulations and Control in the Face of Climate Change
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W018	Timber Structures
W023	Wall Structures
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W070	Facilities Management and Maintenance
W077	Indoor Climate
W078	Information Technology for Construction
W080	Prediction of Service Life of Building Materials and Components
W083	Roofing Materials and Systems
W084	Building Comfortable Environments for All
W086	Building Pathology
W089	Building Research and Education
W092	Procurement Systems
W096	Architectural Management
W098	Intelligent & Responsive Buildings
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- Performance Criteria of Buildings for Health and Comfort (CIB 292)
- Performance Based Building 1st International State-of-the-Art Report (CIB 291)
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- Condition Assessment of Roofs (CIB 289)
- Proceedings from the 3rd International Postgraduate Research Conference in the Built and Human Environment
- Proceedings of the 5th International Conference on Performance-Based Codes and Fire Safety Design Methods
- Proceedings of the 29th International Symposium on Water Supply and Drainage for Buildings
- Agenda 21 for Sustainable Development in Developing Countries

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- Agenda 21 for Sustainable Construction
- Agenda 21 for Sustainable Construction in Developing Countries
- The Construction Sector System Approach: An International Framework (CIB 293)
- Red Man, Green Man: A Review of the Use of Performance Indicators for Urban Sustainability (CIB 286a)
- Benchmarking of Labour-Intensive Construction Activities: Lean Construction and Fundamental Principles of Working Management (CIB 276)
- Guide and Bibliography to Service Life and Durability Research for Buildings and Components (CIB 295)
- Performance-Based Building Regulatory Systems (CIB 299)
- Design for Deconstruction and Materials Reuse (CIB 272)
- Value Through Design (CIB 280)

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