> **Systemic Approach (for new buildings):** integral concepts, consisting of building and system technologies (e.g. roofing and facade systems for high envelope/plants integration) making up neutral/energy-positive buildings are needed, with good quality of the indoor environment and high reproducibility, making optimal use of local energy opportunities and boundary conditions. Simulation tools taking into account ancillary phenomena for a high accuracy in building physical predictions are also required. Within this systemic approach it is worthwhile considering also the growing need to design and build for adaptability to climate change. Furthermore systemic approaches are needed in terms of well-designed cooperating parts (system packages) of installation and systems, to be able to use Building Information Models (BIMs) successfully and in relation to standardisation as well as diagnosis of materials and systems in a coherent way. Architectural aspects are essential in order to utilise thermal masses and still design buildings of high aesthetic quality that people like to live and work in. Design best-in-class processes and construction methods are also needed.

3.2.3 Energy-efficient districts/communities

As far as "districts/communities" are concerned, six research challenges are described below:

> **District and urban design:** there is a need for the development of new decision support tools for eco-district design choices in line with the GOLD paradigm (Globally Optimised Locally Designed), including relevant aspects such as the integration with the transportation infrastructure and smart grids, to name a few. In this framework, innovative approaches in district design are needed to study and to introduce climate adaptation and mitigation. Breakthroughs are searched for in the development of innovative methodologies, tools and solutions for continuous district commissioning.

> **Systems and equipment for energy production at district level[20] :** solutions are needed for achieving 20% coverage of built environment energy demand by renewable (thermal and electrical) energy production at district level (10-15 GJ/capita of district population). This has to come along with new methods of predicting one day ahead the renewable energy production at a resolution of 15 minutes. As far as energy production at district level is concerned, new methodologies are also needed to link district systems and smart (heat/cold and power) grids, exploiting for instance the potential of low-temperature district heating systems based on renewable energy.

> **Systems and equipment for energy use at district level:** energy-conversion hub/router concepts are needed, enabling maximum renewable energy usage from decentralised (electrical, thermal) production by combination of storage and energy-conversion techniques in one district demand-supply station which is fully integrated with the smart grid. Such solutions should prevent a loss of energy efficiency of approximately 15-20%, as is typically encountered at system level (with respect to total potential at component level).

20. All values were related to energy produced by district systems, thus excluding energy produced by buildings or outside the district borders such as wind farms and off-shore wind

At a system level, efficient management of boosted water pumps for global energy reduction in water supply and distribution is extremely important at district level, including their possible reversible use for effective energy harvesting. Integration of advanced efficient urban lighting, including new preventive maintenance procedures is needed. Breakthroughs are searched for in the development of efficient transportation infrastructures at district and urban level to minimise energy use and fuel consumption, addressing both hybrid and fully electric vehicles as well as future hydrogen-based mobility systems;

- **Storage of energy: thermal, electrical or other (chemical, hydrogen, mechanical, others):** specific solutions are needed, enabling storage of renewable thermal energy at district level (5-10 GJ/capita of district population), with respect to the current situation where normally no thermal energy is stored in district systems. Innovative solutions are needed as far as storage of renewable electric energy is concerned at district level (2-4 GJ/capita), with respect to current average electric energy stored by district systems: 0 GJ/capita in the district. Seasonal storage of energy should be tackled considering also any effect on the sub-soil (specifically in the case of thermal energy). This is especially relevant for densely populated areas where there is a lack of surface area. Novel approaches are needed for the development of innovative methodologies for using bio-gas as storage medium and energy carrier within districts, combined with effective waste management strategies at community level;

- **Interaction (integration) between buildings, grid, heat networks, etc.:** innovative methodologies for the bi-directional connection between storage systems, smart grids, buildings and vehicles/mobility systems are needed jointly with methodologies for the bi-directional connection between grids and utilities networks, in line with the SET plan. The interconnection between water and energy is a key challenge; wastewater collection has potential to improve energy recovery. Integral on-demand conversion of energy carriers between different forms requires specific research actions. New methods for real-time energy demand-supply management are required jointly with innovative approaches for building-to-grid integration without power quality pollution. In this framework, new technologies and approaches are needed to enable effective Building-to-Building interaction as in an energy market. Energy efficiency interoperability of buildings with other domains (transportation, energy grids, etc.) has to be achieved. Methodologies and tools for CO_2 as well as certification procedures at district level are required;

- **Retrofitting:** Identification of building groups by period and energy performance has to be performed. The use of green areas in urban retrofitting planning requires specific solutions to be developed; new research efforts need to be deployed for the energy-efficient retrofitting of historical districts. Cost-effective integration of emerging technologies to improve the return on investment within an holistic life cycle perspective are needed.

3.2.4 Horizontal technological aspects

As far as "Horizontal technological aspects" are concerned, thirteen research challenges are described below:

- **Envelope and components (for new or existing buildings):** Thermal insulation materials, and in general the envelope of the buildings, are most important contributors to the decrease of energy demand in the building. Improvements of thermal properties of materials have a strong impact in the energy demand of the buildings. This could be reached by adding coatings, nanotechnologies, raw materials, other additives, etc. Furthermore, new or adapted products and techniques are needed to increase energy efficiency of transparent envelope parts. New integrated approaches to fill the gap between theory and practice are needed in the training process of workmanship, including emerging technologies like virtual or augmented reality. New modelling and simulation approaches are needed to take into account the overall physics and behaviour of the envelope when planning its refurbishment (e.g. air-tightness, thermal bridges, insulation, thermal losses, shading).

- **Systems and equipment for energy use (for new or existing buildings):** new flexible and efficient equipment is needed along with advanced technologies for heating, cooling, lighting, ventilation, etc. There is a need for hybrid, integrated systems for heating and ventilation with improved price/performance ratio. Heat pump technology still needs further developments to target higher performances, low cost and small size. Integration of advanced lighting like (O)LEDs with sensors and actuators as well as with suitable intelligent power electronics and control systems is necessary, interfacing with energy management systems and local energy generation by renewable sources. Development of passive systems is needed that will enable replacement of conventional ventilation and cooling systems, often used on many office and residential buildings. Power electronics needs further development for its cost-effective integration in systems and equipment. Energy efficiency enhancement is sought by applying new concepts of heating and/or cooling sources, including sustainable and economically viable use of emerging energy carriers such as hydrogen. Innovations are also sought to enhance performance of existing thermal distribution systems, including new approaches which go beyond the state of the art. Other energy users, such as lighting systems, need to be more intelligent in their interaction with the surroundings, in such a way that lighting will be applied only when needed, and in the most efficient and meaningful way (linked to health, comfort and productivity).

- **Systems and equipment for energy production (for new or existing buildings):** improvements in the integration of PV in the external façade are needed, for instance PV integrated on the surface of the building materials or building materials such as roofs replaced by PV modules. Efficient power electronics and system integration methods are needed for leveraged efficiency improvements in renewable energy systems. New concepts for ventilated façades are sought with integrated systems for energy production. Innovative integration of solar thermal systems is needed for building heating and cooling (e.g. absorption technologies). Innovative Geothermal solutions are needed with heating and cooling integration for residential or commercial sectors. Breakthroughs are required in efficient integration of hydrogen and RES technologies in buildings, in particular fuel cells. Intelligent power electronics need further development for use within PV inverters or converters/generators for wind turbines as well as their overall integration in complex energy production systems at building and district scale. New solutions for waste heat recovery need to be devised (e.g. heat recovery from computing data centres in large office buildings). Overall emphasis should be put on building integration and minimal operation and service costs.

> **Storage of energy, thermal or electrical:** new flexible systems for energy storage are needed which take into account different working conditions (e.g. different climate, different seasons) and storage methods (e.g. ground storage). Innovative methods are needed for the storage of energy, that enable a higher thermal energy density of 1-2 GJ/m^3, and respect of the current thermal energy storage density, equal to 0.2 GJ/m^3. In particular, new solutions enabling seasonal storage of renewable thermal energy integrated at building level are needed, having as a target 15-30 kWh/m^2 of building area per annum. Innovative solutions are needed, decreasing energy loss during storage to less than 10%, having in mind that current thermal losses during storage are approximately 50%. Innovative solutions are needed, enabling storage of renewable electric energy produced locally at building level, e.g. in plug-in hybrids at 1 GJ/household, and respect of current average electric energy stored by district systems: 0 GJ/household. There is a need to focus on (spatially) distributed storage for heat and electricity..

> **Quality indoor environment (including comfort and health):** energy efficient buildings require effective insulation and air tightness of the envelope; mechanical ventilation is therefore needed, combined with air cleaning and air quality control techniques. Exchange of indoor air with fresh air from outside, although limited, should be based on counter-current thermal exchangers to reduce the heating power. New solutions are needed which consider energy efficiency, indoor air quality, comfort as well as the reproduction potential simultaneously: breakthroughs are needed which address the potential of energy efficiency to realise healthy and comfortable indoor environments, with high reproducibility while guaranteeing full accessibility (i.e. novel concepts for door thresholds). This may involve also lighting as well as natural rooms' illumination through light guides. The expected result is an increase in user performance (e.g. productivity or learning capabilities), which is a function of indoor quality, comfort and health, sound, to name a few.

> **Design - Integration of new solutions:** in order to facilitate the energy retrofitting of buildings and the design of new buildings considering energy performance criteria, a data repository with optimal technical interventions should be defined, including daylight and climate aspects, return of investments, HVAC, system configurations, retrofitting solutions. A European-wide data ware-house of possible interventions and their effect in real buildings (including their occupants) can improve dramatically the quality and cost-effective retrofitting of buildings in Europe. Development of model based ICT applications is needed, enabling information sharing through neutral platforms without re-entry. Theoretical engineering models (for virtual simulation, and with standardised set tests to compare virtual models) should be compared with rules and norms to achieve benchmarking of pilots so as to validate the models. Breakthroughs are needed concerning object oriented design with embedded parametric engineering. Novel ICT tools that ensure the integral use by all building / district stakeholders of a unique evolving set of building data from inception and design, to construction, operation & maintenance, refurbishing and demolition need to be developed. Assessment, simulation and visualization techniques are needed to support decision making, removing gaps between prediction and reality (e.g. thermal simulation of buildings). Usage of model based horizontal platforms needs the integration of local existing platforms and simulation tools. This integration for European-wide solutions needs the involvement of country-specific attributes regarding not only construction solutions but also to the construction process itself. Reliable life cycle cost calculation methodologies and benchmarks are needed, including investment, maintenance and energy aspects. New methods and tools are required to have good communication through information-sharing among different stakeholders on projects, using tools such as the Building Information Model (BIM). Development of methodologies and support tools

allowing a simplified building monitoring and building performance analysis are searched for. This would allow a drastic reduction of required data input and a simplified assessment. A standardised methodology for European countries would mean a more comprehensive approach to building assessment. Architectural aspects and aesthetics should be considered in their contribution towards optimal energy use.

> **Automation and control:** new methods and procedures are needed to integrate ICT tools (e.g. low-cost vision systems, building information models, embedded wireless devices, new user interfaces, new processing algorithms, etc) into construction processes while maintenance operations are essential for energy efficiency, productivity and security. Service oriented architectures are needed to introduce building and district automation and control systems. Service platforms should be developed to host various software sub-systems for monitoring, control, automation. Further efforts should be spent in the development of web based control platforms that will allow the user to monitor and immediately act on the installation from a remote location with the use of portable devices (e.g. cell phones, laptops). Monitoring should be connected with data-mining modules to support tracking and performance evaluation in interactive environments. Interoperability standards, protocols and interfaces for wired and wireless communication need to be addressed and developed. Integration of real-time with design/operation information (static information) as well as gateways to connect with external services and interfaces with stakeholders are needed. The increasing complexity of buildings makes it necessary to analyse the usability and efficiency of the new solutions jointly with reliability aspects, robustness and maintainability. Mobile productivity tools that allow on-site access and monitoring of the building performance data will be needed to maintain and diagnose a built environment bearing an increased complexity in systems and their integration. These tools will help to support new models for performance-based service contracts.

> **Industrialisation and mass customisation:** the need for cost-effective solutions in the energy retrofitting of buildings makes it necessary to have industrialised solutions and products, capable of being adapted to the final conditions of the building (size, finishing, etc). Configuration design, intelligent E-catalogues, Logistics, Templates need to be developed. In building energy retrofitting, an industrialised solution is characterised by a lower execution time needed. This low actuation time implies that the activity (domestic, commercial, business) of the existing building will be interrupted for a short period of time.

> **Life Cycle Analysis (LCA):** life-cycle methodologies are needed and the LCA approach "from design to reconstruction" has to be accepted as the only approach by evaluation of long term complex quality of buildings and its urban neighbourhood, taking into account aspects such as the adaptation to future climate change. Development of materials, products and processes requires the build up of environmental databases, as well

as development and verification of EPDs (Environmental Product Declarations). There is a need to develop solutions to provide verified environmental information and tools for architects and engineers when designing new buildings and renovating existing ones. Reduction of embedded energy/Deconstruction is needed as resource depletion, waste generation and emissions associated with extraction and production of building materials are major issues that need to be addressed to make the construction sector more sustainable. Embodied CO_2 can account for between 10% and 30% of building life-cycle carbon footprint. In addition, waste generated in the construction sector is among the most significant waste streams in many European countries. Finally, natural resources are becoming scarce and the current extraction rates need to be reduced. The need of a Europe-wide common standard has to be addressed, in order to ensure the development of a common basis of understanding for all architects and producers of new sustainable products in Europe that enables a successful implementation of sustainable criteria in the erection/deconstruction of new buildings as well as in the refurbishment of existing ones.

> **Energy Management Systems:** from the energy management point of view, one of the main weaknesses of the current Building Energy Management Systems (BEMS) is that they operate according to predefined energy control strategies. Current operation algorithms are based on conventional control approaches, which are not able to learn from previous operations and to forecast the impact in the building behaviour of the control orders. This results in a loss of overall energy efficiency of 10-15% at system level. Automation and self-adaptation are needed to adapt to the changing operation conditions of the buildings, including building/grid energy balancing. BEMS are needed which implement holistic approaches, going beyond current technology which manages every energy related systems (HVAC, lighting, local generation, etc.) as fully decoupled systems, resulting in a loss of efficiency of at most 5%. The BEMS will be able to support and give feedback to the building users on how the energy is being spent, providing advice for a more efficient energy use. New strategies for monitoring, protocols, service platforms, standards as well as ambient intelligence and intuitive user interfaces are needed, which are developed fully understanding/working with users.

> **Labelling and Standardisation:** a holistic approach for an efficient labelling system of sustainable buildings is needed, in order to give reliable measurement and comparable results. There is a need for integration and definition of standard protocols to make it possible to analyse energy behaviour on the same terms in all EU countries, better understanding energy aspects from building experts to end-users. The standardisation is strongly focusing on energy performance of buildings, but products and systems on physical characterisation. Between both there is a gap which must be covered with research activities, in order to develop accurate standardisation methodologies that reflect what physically happens in buildings, both new and existing, including cultural heritage.

> **Materials: Embodied energy and Multi-functionality:** embodied energy in materials represent a relatively high percentage of energy throughout the life cycle of buildings, especially when increasing the level of energy performance in operation. New approaches combining novel processes, sensors and material science are needed to minimise the embodied energy of main construction materials such as cement, concrete, glass, steel, ceramics, etc. Development of new multifunctional materials is needed, having a low embedded energy and also higher thermal and acoustic properties (embodied energy is often proportional to mass), overcoming scarcity of renewable materials. It is becoming more apparent that the next technological frontiers will be opened not through a better understanding and application of a particular material, but rather by understanding and optimising material com-

binations and their synergistic function, hence blurring the distinction between a material and a functional device comprised of distinct materials. Future research will be strongly focused on the final performance properties and less on the individual material performance. New technology routes to integrate waste in the production cycle (recycling) of materials are needed.

> **Diagnosis and predictive maintenance (continuous commissioning):** in order to guarantee energy-efficient performance throughout the life cycle, new solutions are needed for automated or continuous commissioning including diagnosing faulty economic operation, diagnosing uncalibrated or malfunctioning sensors, diagnosing uncalibrated or malfunctioning valves, dampers, or actuators, diagnosing faulty or improper ventilation control strategies, diagnosing malfunctioning economizers and dampers as well as identifying improper set-point settings. As far as new buildings are concerned, these new solutions should perform checkout and functional tests, collect data used for performance verification and retain completed functional test sheets. As far as existing buildings are concerned, new solutions are sought to perform functional tests, collect monitored data and retain functional test and monitoring data results to confirm initial findings. These solutions should operate within districts for the maintenance of district energy infrastructure. In this framework, the design and development of integrated networks of sensors and actuators, and their related embedded devices, is a key challenge for energy efficient buildings and districts.

3.2.5 Horizontal organisational aspects

As far as "Horizontal organisational aspects" are concerned, five research challenges are described below:

> **Relationship between user and energy:** at present the energy use in buildings with equal building and system characteristics can differ by a factor of 4, primarily due to user behaviour. A different meteorological, policy and cultural background leads to different solutions for buildings. However, some basic principles for better energy-efficiency can be adapted and disseminated to end users and policy makers alike. The first consideration should be to understand how people behave, and the reasons for their behaviour, so that the technology can be designed to work with people's normal behaviour. Reliable knowledge of the relationship of energy efficiency versus wellbeing (e.g. comfort, ...) needs to be created (and possibly quantified through specific indicators), taking into account the behaviour of the users. There is a need to develop new knowledge on how to effectively realise change of attitude and behaviours for the end-users, using intrinsic user motivations, education and information exchange. This new knowledge needs to be translated into smart equipment and active systems for improving energy efficiency according to evolutionary and self-adapting paradigms in Expert Systems. It is necessary to develop a new framework for Knowledge Sharing able

to benefit from continuous advances in Technology Enhanced Learning. Different dissemination levels for experts, students, end-users are required. Technologies (e.g. user-adaptive controls) to enable provision of wellbeing rather than temperature or light, for instance, are searched for. Demonstration houses for both new (plus-energy) and existing buildings (refurbishment) needs to be deployed. Effective user awareness generation for (district) energy systems is highly needed. Systems and interfaces for user awareness are needed to develop sensitivity of any stakeholder about impact of energy consumption (cost, CO_2…). The overall focus should be on enabling the user to live and operate within the built environment in an energy efficient way with minimised integral living expenses.

> **Value Chain and SMEs focus:** construction processes are carried out in the EU alongside largely different patterns, involving a large number of players, usually not interconnected along the different stages of the construction process. More than 90% of these players are SMEs. There is a need to build up a seamless value chain which makes use of latest ICT solutions and is "SME-friendly". This requires an EU wide approach to develop tools and methodologies that will not be restricted by any particular workflow and collaboration pattern. It is necessary to develop concepts and tools for process integration along the construction value chain, with a special consideration of energy issues, by engaging actors in energy supply, storage, and use, as well as to provide the SMEs with tools that would assist them in developing a clear view, in differentiating and optimising the value they deliver along the full value chain of their operations. The build-up of the value chain can be favoured by the launch of Europe-wide Trade shows and business to business events.

> **Geoclustering:** greatly varying meteorological, policy and cultural variances across the EU, as well as traditional and long established practices, create a complex everyday operational framework that, by definition, needs to be understood, addressed and optimised at EU level. Modelling of largely differing regional profiles across the EU is needed, as regards processes, materials and technologies in use to create a solid horizontal data infrastructure, for the use of other EU wide services and tools in energy and construction, including national key performance indicators (KPI) and best practices/available technologies ready to use. Structured information at the European level on typology, volume energy status, etc of the existing building stock is lacking. Buildings vs. Districts data modelling is needed, including the development of multi Spatial Geographic Design tool. Implementation of a Semantic 4D model to support energy efficiency analysis of traditional materials/techniques and sustainable analysis of innovative ones is needed. New simulation and prediction tools for an open and remotely accessible dynamic geo-database would allow common EU standards and parameters to be defined.

> **Knowledge transfer:** there is a need to encourage the transfer of good practices, technologies and methodologies, including cross-sectorial cooperation, the set up of a communication infrastructure and the organization of a number of coaching events. New tools which are cost effective, fast and easy to use have to be developed to overcome actual barriers (cultural, linguistic,..). A number of activities needs to be developed and applied, such as spreading the information, training and providing an infrastructure of Experimental Buildings that incorporate cutting-edge technologies in the field of Energy in buildings to achieve coordination between the EU and national/regional levels. The integration of new solutions and existing networks at EU level is the key. Energy audits and clear improvement scenarios should be considered in the overall framework as key to the success of knowledge transfer.

> **Business models, organisational and financial models, including Energy Service Companies (ESCOs):** development of innovative business models and organizational paradigms (dedicated particularly to SMEs) is needed, including the marketing of energy positive buildings and their demonstration. For instance, regional flagship projects like schools or residential homes could be addressed. Common energy tool sets at the EU level are needed, taking into account country specific issues: energy, Best Available Technologies (BATs), structured information on typology, volume, energy status, etc. of the existing building stock. Performance based contracts and the shift towards life-cycle-performance based business is needed, including risk/value distribution across the value chain. This requires an early involvement of stakeholders and the introduction of the role of system integrators. Alternative business models using life-cycle costing and/or total cost of ownership at building or even district level are needed. Synergies with on-going initiatives should be established by mapping the relationship between relevant programmes and actions at national and regional level among European Member States. This applies to innovative financing and business models and private and public incentive schemes to encourage main-streaming of solutions at district scale or greater, including policy approaches such as the use of voluntary Codes as well as regulations.

4.0 ASSOCIATED INVESTMENTS AND QUANTIFIED EXPECTED IMPACT

As better detailed in the "E2B Impact Assessment" documen[t21], industry considers that an average investment of around **€ 73 billion per year**, during the period from now until 2020, will be necessary in order to achieve the 165 Mtoe[22] reduction and the 50 Mtoe contribution from renewable energies, making a total accumulated investment from 2009 to 2020 of about **€ 870 billion**. The investment involved in much more efficient and clean technologies would be about 17 – 25 % of the associated investment; this means a yearly associated investment between € 12 and 18 billion. These figures would represent between 1 and 1.5% of the total outcome of the building sector that is about € 1,200 billion annually[23]. Additionally, the joint action of the construction industry would lead to a relevant cost reduction of around 10-15% of the above stated investment. This would mean (taking the average) a reduction of around € 1.5-2.25 billion/year. Therefore, **each Euro spent in the implementation of the proposed long term programme will save costs of at least 8-9 Euros**.

In this framework, investments for Research and Development associated to the implementation of the proposed long term strategy can be estimated in roughly 3 to 5% of the global investments, although a precise quantification is difficult to make. Focusing on the 5 key research areas highlighted in Figure 3, we can estimate that:

> 40% of the investments and associated funding should be dedicated to **"Refurbishment to transform existing buildings into Energy-efficient Buildings"**;
> 15% of the investments and associated funding should be dedicated to **"Neutral/Energy-positive new buildings"**;
> 15% of the investments and associated funding should be dedicated to **"Energy-efficient districts/ communities"**;
> 25% of the investments and associated funding should be dedicated to **"Horizontal technological aspects"**;
> 5% of the investments and associated funding should be dedicated to **"Horizontal organisational aspects"**.

The above mentioned breakdown of the investments/funding can be further distinguished in research and demonstration activities, being the latter inclusive of both demonstration work at a reduced scale to validate research results as well as larger scale validation work to prove the applicability of technologies closer to the market, once the fundamental and applied research activities demonstrated the technological and economical viability. In this framework the following can be tentatively highlighted for the longer term strategy:

> within the research area **"Refurbishment to transform existing buildings into Energy-efficient Buildings"**, 40% of the investments and associated funding should be dedicated to Research activities, the remaining 60% to demonstration work;
> within the research area **"Neutral/Energy positive new buildings"**, 40% of the investments and associated funding should be dedicated to Research activities, the remaining 60% to demonstration work;
> within the research area **"Energy-efficient district/ communities"**, 40% of the investments and associated funding should be dedicated to Research activities, the remaining 60% to demonstration work;
> within the research area **"Horizontal technological aspects"**, 80% of the investments and associated funding should be dedicated to Research activities, the remaining 20% to demonstration work;
> within the research area **"Horizontal organisational aspects"**, most of the investments and associated funding should be dedicated to Support and Coordination activities.

21. E2B Impact Assessment, Version 2, February 2009
22. The tonne of oil equivalent (toe) is a unit of energy: the amount of energy released by burning one tonne of crude oil, approximately 42 GJ.
23. Euroconstruct 2007

This preliminary allocation of resources foresees that **a higher research share of investments and associated funding needs to be devoted in the shorter term** to develop the enabling science and technology. As a result of these investments, impact is expected at different levels. From the analysis presented in Chapter 2, the overall goal for an energy-neutral built environment in 2050 implies that the following targets[24] need to be reached:

- Integration of large scale renewable energy on district level (excluding building integrated renewable energy) to approximately 20 % of current total primary energy usage in the built environment;
- Uptake of net energy positive new buildings from 2015 with full market penetration in 2025 at the latest;
- Adoption of 80% primary energy-reduction refurbishment packages;
- Integration of HVAC systems which can reduce the primary energy usage for heating and cooling by a factor 2 from 2020 onwards;
- Reduction in energy usage by household appliances of approximately 2% per year from 2015 onwards.

More details on the expected impact are provided in Appendix 2 and 3.

24. In all cases when energy targets are mentioned, they refer to primary energy required for both building related measures (such as HVAC) and user related measures (such as domestic appliances).

5.0 DEFINITION OF A MULTI-ANNUAL ROADMAP

Based on the research challenges described in Chapter 3, the main research focus of the multi-annual Roadmap for the years 2011-13 will be to speed-up research on key technologies and development of a competitive industry in the construction sector with a focus on energy-efficient processes, products and services.

In order to achieve this impact, research until 2013 will mainly focus on "Reducing the energy use in buildings and its negative impacts on environment" (Step 1 as defined in Chapter 2), while at the same time launching in parallel the development of those enabling technologies and knowledge needed for a long term impact associated with the further two Steps of the industry strategy.

The "Strategy towards 2050" is indeed at the core of our Roadmap and it is therefore implicitly embedded within the dynamic nature of the multi-annual Roadmap, requiring a continuous update based on feedback and results from the different waves of research and demonstration projects to be launched.

A **quali-quantitative assessment** of the research challenges has been made at AIAG level for the definition of research priorities for the period 2011-2013. The analysis has been made considering the relevance of each challenge towards the reduction of energy consumption in the built environment and the associated decrease in greenhouse gas emissions as well as the expected impact when addressing the challenge itself, as better defined in Chapter 2.2.

The analysis has been performed on all the challenges as described in Chapter 3.2. The folllowing set of **thirteen challenges has been considered of high priority** within the framework of the EeB PPP initiative:

- Envelope (for existing buildings);
- Systems and Equipments for energy use (for existing buildings);
- Interaction (integration) between buildings, grid, heat network, etc;
- Systems and Equipments for energy use (horizontal research challenge);
- Systemic Approach (for existing buildings);
- Knowledge transfer;
- Relationship between User and Energy;
- Retrofitting (for districts/communities)
- Envelope and components;
- Design – Integration of new solutions;
- Systemic Approach (for new buildings);
- Energy Management Systems;
- Labelling and standardization.

They will be referred to in the following of the document as **Priorities**. The order of these thirteen priorities does not reflect any specific ranking. The analysis also highlighted several other logical links between the overall set of Priorities and other research challenges within the framework of the EeB PPP. These connections are highly relevant for the definition of future calls for proposals by the European Commission as they identify the multi-disciplinary aspects and allow the key challenges to be tackled from a broader perspective, where technological and non-technological issues are jointly addressed. These related research challenges include:

- "Materials: embodied energy and multi-functionality", logically linked to the priorities "Envelope (for existing buildings)" and "Envelope and components";
- "Storage of energy at district level: thermal, electrical or other (chemical, hydrogen, mechanical, others)", logically linked to the priority "Interaction (integration) between buildings, grid, heat network, etc.";
- "District and urban design", logically linked to the priority "Interaction (integration) between buildings, grid, heat network, etc.";

- “Systems and Equipment for energy production”, logically linked to the priorities “Interaction (integration) between buildings, grid, heat network, etc.” and “Systems and Equipment for energy use (horizontal research challenge)”;
- “Storage of energy”, logically linked to the priorities “Interaction (integration) between buildings, grid, heat network, etc.” and “Systems and Equipment for energy use (horizontal research challenge)”;
- “Value Chain and SMEs focus”, logically linked to the priorities “Knowledge transfer” and “Labelling and standardisation”;
- “Energy Management Systems”, closely linked to the priority “Relationship between User and Energy”;
- “Geo-clustering”, closely linked to the priorities “Relationship between User and Energy” and “Systemic Approach (both for new and existing buildings)”;
- “Solutions for Cultural Heritage (including diagnostics)”, logically linked to the priority “Retrofitting (for districts/communities)”;
- “Quality indoor environment”, logically linked to the priorities “Envelope and components” and “Systemic Approach (both for new and existing buildings)”;
- “Automation & control”, logically linked to the priorities “Design – Integration of new solutions” and “Energy Management Systems”;
- “Diagnosis and predictive maintenance (continuous commissioning)”, logically linked to the priorities “Design – Integration of new solutions” and “Energy Management Systems”;
- “Life Cycle Analysis (LCA)”, logically linked to the priority “Labelling and standardization”;
- “Business models, organisational and financial models (including ESCOs)”, logically linked to the priority “Labelling and standardization”.

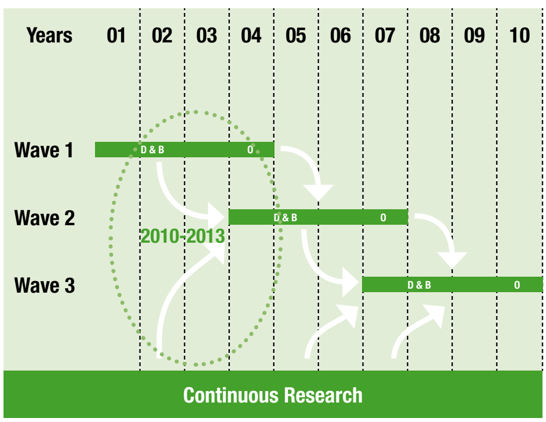
Most of the Priorities **support multidisciplinary collaborative and integrated research projects** on technologies, methods and concepts that are clearly oriented towards industrial application, involving all the stakeholders in the value and innovation chain, from basic research to technology demonstration.

Large-scale demonstration projects are also expected, where not only the components performance is a key to success, but also the way the building industry will install, and people accept these components. The projects have to be visible and made with public-private partnerships approaches as often as possible. These projects should be understood as organised testing in the field of new concepts and ideas in a specific domain, with a very accurate follow-up. **The demonstration actions will integrate and demonstrate innovative technologies (not yet commercial)** in their last phase of development that have not been implemented in an industrial scale demonstrator. Project findings are expected to transfer to production within five years after the conclusion of the project, thus leveraging the expected impacts.

Some of the research priorities associated with Horizontal organisational aspects **would gain from a set of Coordination and Support Actions** to pave the way towards effective and large-scale impact.

The overall scenario until 2013 matches with the first wave of the long term strategy presented in Chapter 2, as shown in Figure 6 below.

Figure 6 - The positioning of the multi-annual Roadmap (2011-13) within the longer term “wave action” strategy



In this framework the research priorities for 2011-2013 have been plotted against time and activities proposed. The overall result is shown in Table 1 below:

Table 1: Proposed Roadmap for 2011-2013

	2011	2012	2013
Research	> Envelope (components) for existing buildings, with a link to materials (multifunctionality and embodied energy) > Systems and Equipments for energy use for existing buildings (focus on space heating and hot domestic water) > Envelope and retrofitting > Design – Integration of new solutions, fostering ICT technologies > Systemic approach (link to Quality of the Indoor Environment)	> Interaction (integration) between buildings, grid, heat network... > Systems and Equipments for energy use (including production and storage) > Relationship between User and Energy, leveraging on ICT tools > Systemic Approach, for existing buildings (including integration of Renewables) > Energy Management Systems	> Systems and Equipments for energy use > Retrofitting (at district level) (including cost effective integration of emerging technologies) > Envelope and components, enabled by latest advances in multifunctional materials and nanotechnology > Design – Integration of new solutions, focus on assessment, simulation and visualization techniques to support decision making, removing gaps between prediction and reality. > High efficiency retrofitting of buildings (including systems and equipment, ICTs,....) > Novel approaches in automation and control > Envelope (components) for existing buildings, with links to cultural heritage > Labelling and standardisation
Demonstration	> Envelope and Systems and Equipment for energy use	> Cost effective zero energy new buildings in districts > Envelope, Systems and Equipments for energy use for existing buildings	> Retrofitting (at district level) > Interaction (integration) between buildings, grid, heat network... > Large scale demonstration including new technologies (Envelope components, Systems and Equipments, ICTs…) and new business models
Coordination and Support Actions	> Coordinated actions for systemic approaches in Europe (Geo-clustering) > Relationship between User and Energy > Labelling and standardization (focus on LCA)	> Labelling and standardization (including business models, impact assessment,...) > Knowledge transfer (including value chain and SMEs)	

6.0 INTERNATIONAL COOPERATION

Several initiatives are being undertaken worldwide in the field of Energy-efficient Buildings. For a successful implementation and take-up of future results it is highly important to establish close links with those initiatives and benefit from benchmarking and mutual cooperation in areas which can lead to a win-win situation.

For instance in USA a globally visible and widely used standard, LEED, exists. They have valuable experience on standardisation issues, scientific approaches, related business models, etc. Similar opportunities can be identified in Russia, China, Japan and Canada, to name a few. An international effort would require pilot projects and joint initiatives to be established, building on common challenges and specific case studies.

Appendix

Appendix 1

Coordinated Call on Energy-efficient Buildings published in the Work Programme 2010

TOPICS COVERED BY THE NMP THEME

EeB.NMP.2010-1	New nanotechnology-based high performance insulation systems for energy efficiency
EeB.NMP.2010-2	New technologies for energy efficiency at district level

TOPICS COVERED BY THE ICT THEME

EeB.ICT.2010.10-2	ICT for energy-efficient buildings and spaces of public use

TOPICS COVERED BY THE ENVIRONMENT THEME

EeB.ENV.2010.3.2.4-1	Compatible solutions for improving the energy efficiency of historic buildings in urban areas

TOPICS COVERED BY THE ENERGY THEME

EeB.ENERGY.2010.8.1-2	Demonstration of Energy Efficiency through Retrofitting of Buildings

Appendix 2

Expected socio-economic impacts and relevance to policy objectives

In the following the main impacts expected are summarised; measurable targets and performance indicators are provided on the E2BA website (www.e2b-ei.eu), including expected jobs creation.

The implementation of the Roadmap will help to reduce the potential associated investment

As mentioned, the accomplishment of the long term objectives set in the Roadmap will contribute to reducing the potential associated investment (about € 70 billion/year) needed by the construction sector to accomplish the 20/20/20 mandate:

- Reducing the timeframe to accomplish the 20/20/20 mandate;
- Because of technological advances promoted by the Research programme;
- Because of a better use of the capital, reducing the financial pressure.

The legislative instruments expect to mobilize about 50% of necessary associated investment. The industry and E2BA members consider that the implementation of the proposed long term strategy on energy efficient buildings will have an induced investment effect:

- directly: via the organisations involved in E2BA;
- and indirectly: via the promotion of green products and practices associated to the entire supply and value chain of the building sector.

Contribution to the objectives of the SET Plan:

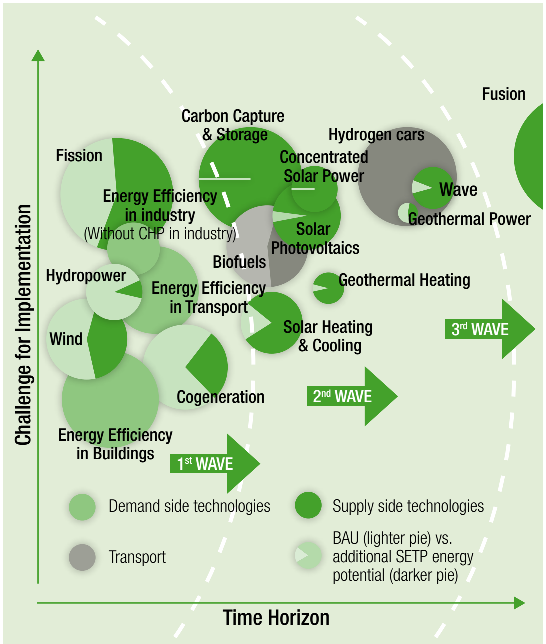
The implementation of the Roadmap will introduce important changes in the way of thinking, in the joint approaches and methodologies for implementing research and development, in the new approaches to face the market in full respect of competition and in the joint way that many different industries together are going to afford the policy challenges defined by the spring 2007 European Council and reinforced in the European Council of 11th and 12th December 2008. In more details the following impact at the level of the SET-Plan is expected from the implementation of the Roadmap:

> Overcome structural weaknesses of the energy innovation system:
- Correct European, National and Regional market failure,
- Networking of the dominant companies involved,
- Mobilise financial resources,
- Contribute to increase public funding for research on energy,
- Concentrate sub-critical capacities in order to create critical mass for producing results,
- Improve the international cooperation with the industrial and developing countries to jointly tackle climate change and global challenges,
- Strength en the European institutional framework in order to help to change the innovation system on energy,
- Reinforce the European shared vision about innovation on energy,
- Build a strong coalition and partnership on energy efficiency.

> Help Europe to lead the world in energy technologies:
- Reinforcement of the international cooperation,
- Fair application of the competition rules,
- Cooperation among Member States at all levels: market, research, etc., reinforcing the internal market for energy technologies and for the buildings construction sector.

The implementation of the multi-annual Roadmap will have a direct impact on the Energy Technologies which have their application domain in buildings, as showed in the Technology Map of the SET-Plan (see Figure below).

Technology Map of the SET-Plan, 2007



The focused effort put in Energy Efficiency in Buildings (Lower left corner of the figure) through the proposed Roadmap will reduce the time horizon of other technologies involved also in buildings, such as Cogeneration, Solar Heating and Cooling, Solar Photovoltaic and Geothermal Heating, to name a few, due to a demand driven approach. The long term strategy would involve a collaboration with the industrial initiatives (Smart grids, Solar, Wind,…) identified within the SET-Plan in order to ensure collaboration and avoid overlapping of activities. This is particularly relevant considering the synergies and coherence with the “Smart Cities” initiative.

The implementation of the strategy will accelerate the process to accomplish with the 20/20/20 mandate of the Council

The implementation of the proposed strategy will contribute to accelerate the process to accomplish the mandate of the Council by:

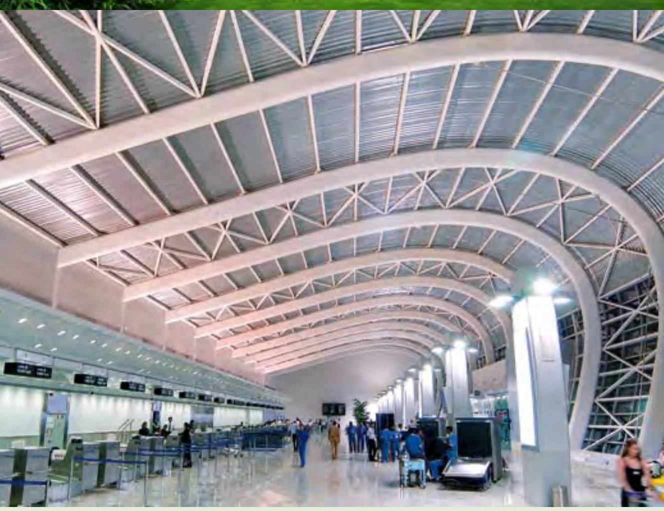
- Developing a long term and sustained programme that will result in higher quality research;
- Leveraging the investment in EeB RTD activities from the private and public sector;
- Reducing the time to market by 5 years of innovative and cost-effective solutions of energy efficient buildings and districts, and therefore providing the market with better and more appropriate solutions. Accelerating and increasing the RTD effort for RES in buildings;
- Improving the competitiveness of the European industry by developing high quality products and processes;
- Introducing good and green practices into the corporate values of the industry. Starting from the industry members of E2BA that represent the entire supply and value chain of Europe, and to the rest of the building sector through demonstration, training and dissemination actions;
- Creating a new consciousness on energy efficiency in buildings in the Public Sector by integrating in the long term strategy public agencies such as social housing promoters;
- Helping to change the citizens' behaviour and organisations close to them with dissemination actions showing the social benefits and therefore boosting the market.

The achievement of the targets will create a new consciousness in the public sector about the new routes to follow

The Roadmap foresees actions towards a deeper involvement of the Public Sector through the participation of Public Agencies as Social Housing Promoters with the objective of taking into account the requirements and concerns of the public sector in the building sector. New links will be established among the public sector, the industry and the research organisations through the participation in research and demonstration projects. Indeed, the Roadmap foresees the establishment of new frameworks to strengthen best practices in green procurement and generating new and appropriate business models on energy-efficient buildings.



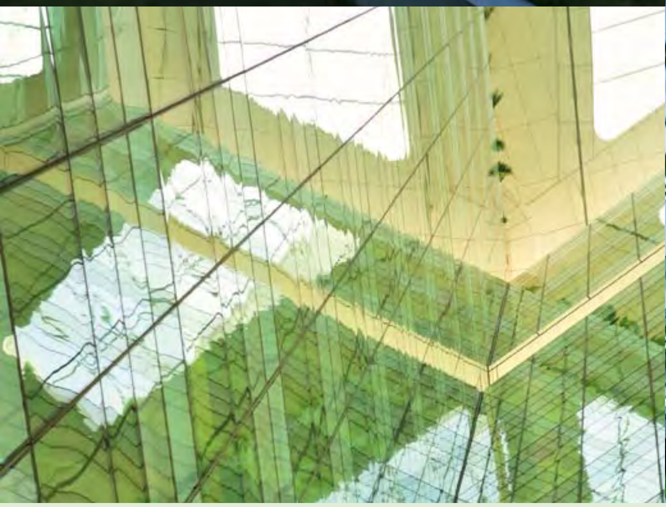











European Commission

EUR 24283 – Energy-efficient Buildings PPP
Multi-annual Roadmap and longer term strategy

Luxembourg: Publications Office of the European Union

2010 — 48 + 4 pp. — 17.6 x 25 cm

ISBN 978-92-79-15228-3
doi: 10.2777/10074

Price (excluding VAT) in Luxembourg: EUR

Acknowledgements:
Special thanks are expressed for their contributions to all industry-related members of the Ad-hoc Industrial Advisory Group of the "Energy-efficient Buildings" Public-Private Partnership, to all those who participated in the public consultation to the wider community of stakeholders, and to the Commission officials (particularly from the FP7 Themes NMP, ICT, Energy and Environment) who took part in the discussion sessions during the elaboration of this document. The collaboration of Christophe Lesniak and Bingen Urquijo Garay in the preparation of this booklet is also acknowledged.

J.L. Vallés, Head of Unit RTD.G2 "New generation of products"

How to obtain EU publications

Publications for sale:

- via EU Bookshop (http://bookshop.europa.eu);
- from your bookseller by quoting the title, publisher and/or ISBN number;
- by contacting one of our sales agents directly.
  You can obtain their contact details on the Internet (http://bookshop.europa.eu)
  or by sending a fax to +352 2929-42758.

Free publications:

- via EU Bookshop (http://bookshop.europa.eu);
- at the European Commission's representations or delegations.
  You can obtain their contact details on the Internet (http://ec.europa.eu)
  or by sending a fax to +352 2929-42758.

The construction sector accounts nowadays for around 30 million jobs in the EU. Buildings also represent 40% of energy use and 33% of greenhouse gas emissions in Europe.

The European Economic Recovery Plan, launched a year ago to address the current crisis, includes a new Research Public-Private Partnership (PPP) aimed at developing building and district concepts having the potential to reduce energy use.

The "Energy-efficient Buildings" (EeB) initiative is a € 1 billion programme in which the European Commission and industry will support research on sustainable technologies for the EU construction sector. The aim is to develop energy-efficient materials and systems for new and renovated buildings which can help to radically reduce their energy consumption and CO_2 emissions. In these Research Priorities for the Definition of a multi-annual Roadmap and Longer Term Strategy for the EeB PPP, besides the horizontal aspects, three major challenges have been identified: (i) Refurbishment to transform existing buildings into energy-efficient buildings, (ii) Neutral or energy-positive new buildings and (iii) Energy-efficient districts and communities.

The public-private efforts to support research in these areas will contribute to a successful European strategy for industrial growth in a greener economy.

KI-NA-24283-EN-C

Publications Office

ISBN 978-92-79-15228-3

9 789279 152283