Multi-stakeholder, Cross-sectorial, Collaborative long term Research and Innovation Road Map to overcome Technological and Non-technological barriers towards more energy-efficient buildings and districts

Deliverable D3.2: Roadmap

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<th>Project Title:</th>
<th>Multi-stakeholder, Cross-sectorial, Collaborative long term Research and Innovation Road Map to overcome Technological and Non-technological barriers towards more energy-efficient buildings and districts</th>
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<td>01-05-2011</td>
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Guidance for reading and contribution

This document attempts to build a draft roadmap, based on contributions received from Building Up experts, either as comments to the preliminary working documents or during the BUILDING UP workshops.

It was agreed to focus the roadmap on cross-platform collaboration areas in research, development and innovation in the field of NMP, with the aim of contributing to enhance cross-sectorial cooperation of European organisation in the energy efficiency for the built environment.

The executive summary gives you a full picture of the roadmap, while the different chapters focus on roadmap details.

*The key contribution required from ETP experts is to check the overall document, but in particular the parts highlighted in yellow. Your feedback on those will be collected during the next Building Up Expert Panel Meeting.*
Executive Summary

The present document constitutes Deliverable D3.2 in the framework of the BUILDING UP project titled “Multi-stakeholder, Cross-sectorial, Collaborative long term Research and Innovation Road Map to overcome Technological and Non-technological barriers towards more energy-efficient buildings and districts” (Project Acronym: BUILDING UP; Contract No.: NMP4-CA-2010-267024).

The document is the result of activities performed within the framework of WP3 “Definition of a cross-platforms long term research and innovation roadmap”, and more specifically of Task 3.2 “Definition of a long term Research and Innovation Roadmap”. The document aims to present the Draft Roadmap focused on a set of cross-platform areas preliminary identified in D3.2.

The Deliverable has been drafted by E2BA and DAPP, supervised by the Coordinator and with the collaboration of the involved European Technology Platforms (ETPs) and Building Up Stakeholders.

The involved ETPs are:

- ECTP : European Construction Technology Platform
- E2BA : Energy Efficient Buildings Association
- ESTEP : European Steel Technology Platform
- EUMAT : European Technology Platform for Advanced Engineering Materials and Technologies
- FOREST-BASED PLATFORM : Forest Based Sector Technology Platform
- RHC : Renewable Heating and Cooling Platform
- SUSCHEM : Sustainable Chemistry ETP
- TEXTILES ETP: European Technology Platform for the Future of Textiles and Clothing

Moreover, a community of Building Up stakeholders contributed to the Roadmap through the Building Up Website (online surveys, posts etc.). They are listed in Appendix 1.

The overall objectives of the Building Up Industrial and Research Roadmap are:

- To outline and detail cross-sectorial NMP research and innovation targets up to 2020 and beyond, in order to improve the energy efficiency in built environment;
- To obtain such goal with a cross-ETP roadmapping activity, involving the Building Up network through large public consultations and debates.

Building Up long term vision is well aligned with the E2BA “2020 Research & Innovation Roadmap” which aims at driving the creation of an innovative high tech energy efficiency industry where the entire value chain will produce advanced systems, solutions and high value services for intelligent and sustainable buildings and districts.

This vision meets the 2020 targets with the overarching goal to support both Climate and Energy policies set at European level for the full decarbonization by 2050 of the European economy. This requires preparing new market conditions where building owners are ready to invest into an affordable built environment having lower energy demand and lower GHG emission footprints over their whole life cycle, while improving optimal indoor air-quality and comfort.
Whilst it is based on a long term vision (up to 2050), the Building Up Roadmap focuses their main targets in the short-medium term (up to 2020), with some suggested actions for longer term (beyond 2020).

In this framework, the Building Up Roadmap includes:

- **8 Cross-Platform (CP) collaboration areas** in research and innovation in the NMP field, i.e. areas considered (1) of interest by several ETPs involved in the roadmapping, (2) with high impact for the energy efficiency in the built environment. These are:
  - CP1. Performance Based Approach for building components, including sustainable design, Life Cycle Analysis;
  - CP2. Multi-material composites;
  - CP3. Healthy indoor environment (including air quality, ventilation, lighting, acoustic performance);
  - CP4. Electricity generation and storage materials and systems (e.g. storage systems including building integrated energy technologies);
  - CP5. Thermal generation and storage materials and systems (e.g. storage systems including building integrated energy technologies);
  - CP6. Advanced thermal insulation construction materials for new buildings and existing buildings (e.g. aerogel, nanofoams, vacuum insulation panels);
  - CP7. Building materials recyclability and re-use of components;
  - CP8. Renewable resource-based products to substitute non-renewable based products.

- A set of **cross-cutting targets** with considerations on broad non technological issues.

- The **overall social, environmental and economic impact**, adding specific examples on **target markets** and **expected benefits** of the proposed actions for each cross-platform areas. These are the following:

The following two figures summarise the Roadmap cross platform collaboration areas and the Building Up Roadmap structure for each CP. The latter figure includes logos of ETPs and EU initiatives that are mainly involved in Building Up roadmapping activities.
Figure 1 – Overview of the Building Up Roadmap

Cross-Platform Research and Innovation Areas

State of the Art  Detailed Targets & Priorities up to 2020  Considerations beyond 2020

Economic and Social Impact
Markets, Applications, Target End-Users

Figure 2 – Structure of the Cross-Platform areas & involvement of ETPs and associations
The following figures report 2020 targets and priorities for each identified cross-platform area.

**Figure 3 – Targets and priorities for CP1. Performance Based Approach for building components, including sustainable design, Life Cycle Analysis**
Figure 4 – Targets and priorities for CP2. Multi-material composites

Figure 5 – Targets and priorities for CP3. Healthy indoor environment (including air quality, ventilation, lighting, acoustic performance)
Figure 6 – Targets and priorities for CP4. Electricity generation and storage materials and systems (e.g. storage systems including building integrated energy technologies).

Figure 7 – Targets and priorities for CP5. Thermal generation and storage materials and systems (e.g. storage systems including building integrated energy technologies).
Figure 8 – Targets and priorities for CP6. Advanced thermal insulation construction materials for new buildings and existing buildings (e.g. aerogel, nanofoams, vacuum insulation panels)

Figure 9 – Targets and priorities for CP7. Building materials recyclability and reuse of components
Figure 10 – Targets and priorities for CP8. Renewable resource-based products to substitute non-renewable based products

In the following table, **technologies and target applications** are listed for each cross-platform area.

**Table 1– Technologies and Target Applications for each CP area**

<table>
<thead>
<tr>
<th>CP AREA</th>
<th>TECHNOLOGY</th>
<th>TARGET APPLICATION</th>
</tr>
</thead>
</table>
| CP1 - Performance Based Approach for building components, including sustainable design, Life Cycle Analysis | Eco-construction techniques | Any scale of Construction:  
- Residential;  
- Non-residential (e.g. offices);  
- Public facilities (e.g. schools, hospitals);  
- Commercial (e.g. shops);  
- Industrial (light and heavy)  
- Infrastructures (e.g. bridge). |
| CP2 - Multi-material composites | Multi-material composites | Composites for exterior design include:  
- columns  
- pediments  
- domes  
- cornices |
| CP3 - Healthy indoor environment (including air quality, ventilation, lighting) | Energy Efficient Equipments (including HVAC, lighting, acoustic performance, etc.) | The following buildings and construction sites:  
- Residential;  
- Non-residential (e.g. offices);  
- Public facilities (e.g. schools, hospitals);  
- Commercial (e.g. shops);  
- Industrial (light and heavy);  
- Outdoor sites. |
| CP4 - Electric generation and storage materials and systems | Electric generation materials | Entire skin of the building, including building envelop (e.g. roofing, sunshading, glazing, architectural fabrics). |
| CP5 – Thermal generation and storage materials and systems | Solar Thermal Energy | Domestic hot water & space heating  
- One/two/multi-family homes  
- Hotels, hospitals, residential homes, etc.  
- District heating systems  
- Multifunctional façades |

1 http://205.254.135.7/todayinenergy/detail.cfm?id=4310
<table>
<thead>
<tr>
<th>Biomass</th>
<th>- PV-Thermal (PV-T) hybrid collectors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Process heat</strong></td>
</tr>
<tr>
<td></td>
<td>- Low up to 100C</td>
</tr>
<tr>
<td></td>
<td>- Medium up to 250C</td>
</tr>
<tr>
<td></td>
<td>- Solar assisted cooling and refrigeration</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Small burners</th>
<th>- Pellets stove</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- Wood chip boiler</td>
</tr>
<tr>
<td></td>
<td>- Log wood stove/boiler</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>District heating &amp; cooling and process heat</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Heat only or combined heat and power</em></td>
</tr>
<tr>
<td>- Pellets boiler</td>
</tr>
<tr>
<td>- Wood chips boiler</td>
</tr>
<tr>
<td>- Waste &amp; agricultural feedstock boiler</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geothermal: Shallow GT (Geothermal HP, Underground thermal storage)</th>
<th>- DHW, space heating &amp; cooling</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- process heat</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geothermal: Deep GT (&gt;400m) (Direct heat use, Comb heat &amp; power)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- District heating</td>
</tr>
<tr>
<td>- Agriculture and industrial processes</td>
</tr>
<tr>
<td>- Balneology Cooling</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Cross Cutting Technologies - District heating and cooling (DHC)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- District heating</td>
</tr>
<tr>
<td>- District cooling</td>
</tr>
<tr>
<td>- DH&amp;C with seasonal storage</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Cross Cutting Technologies - Thermal energy storage</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Water storage</td>
</tr>
<tr>
<td>- PCM</td>
</tr>
<tr>
<td>- Thermo chemical</td>
</tr>
<tr>
<td>- Underground storage (UTES)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Cross Cutting Technologies - Hybrid systems and heat pumps</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>- Innovative system design</td>
</tr>
<tr>
<td>- Ground, water and air heat pumps</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Cross Cutting Technologies – Energy Distribution</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>The entire building skin could be used for capture and the building elements – such as floors – could be used for storage</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CP6 - Advanced thermal insulation construction materials for new</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation construction materials:</td>
</tr>
<tr>
<td>- Wool</td>
</tr>
<tr>
<td>• Wall insulation:</td>
</tr>
<tr>
<td>- External walls</td>
</tr>
<tr>
<td>- Internal walls (including</td>
</tr>
<tr>
<td>buildings and existing buildings</td>
</tr>
<tr>
<td>----------------------------------</td>
</tr>
<tr>
<td>Plastic foams</td>
</tr>
<tr>
<td>Expanded polystyrene</td>
</tr>
<tr>
<td>Extruded polystyrene</td>
</tr>
<tr>
<td>Polyurethane foams</td>
</tr>
<tr>
<td>Other plastic foams</td>
</tr>
<tr>
<td>Fiberglass and foamglass</td>
</tr>
<tr>
<td>Other insulation materials</td>
</tr>
<tr>
<td>curtain walls)</td>
</tr>
<tr>
<td>Roof insulation:</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Floor insulation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CP7 - Building materials recyclability and re-use of components</th>
<th>Construction materials and components' waste</th>
<th>All kind of load bearing structures, such for example:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>- bridges and major infrastructures;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- houses and buildings;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moreover, traditionally waste may be re-used in:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- construction of roads and road foundations;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- sports grounds;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- noise protection walls;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- earth banks ;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- landscape construction;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- as aggregates in the concrete and stone production.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Finally, steel can be re-used in building components and also recycled.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CP8 - Renewable resource-based products to substitute non-renewable based products</th>
<th>Renewable resource-based products</th>
<th>- All kind of wood products: walls, roofs, etc.;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>- All kind of clay products: bricks etc.;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Insulating products in general.</td>
</tr>
</tbody>
</table>

A few set of non technological cross-cutting targets, i.e. issues that address broad challenges going beyond the specific area of each cross-platform. The following table reports the identified targets. More cross-cutting targets may be added.
**Table 2— Cross-Cutting Targets**

<table>
<thead>
<tr>
<th>Title of the Target</th>
<th>Description</th>
</tr>
</thead>
</table>
| Approach of EU wide improvement of building stock                                 | The approach consists of different parts:  
  • Extend the warranty for new buildings to 15 years by regulation. This already will force construction companies and building owners to invest into sustainable buildings.  
  • Set a standard for the sustainability of buildings, this includes a recycling quota for all materials, the need to describe and define the materials used in all individual buildings in a repeatable way, define the way materials have to be recycled (as much as possible cradle-to-cradle).  
  • Install a tax system that produces a profit for low emission buildings, like with cars, and that provides significant benefit for maintenance work.  
  • Install a best practice platform where companies can learn about maintenance approaches and recycling possibilities. |
| Smart housing management                                                           | As we have the smart phone and TVs, we may have a “smart house”, with the following features:  
  • it is up to date in terms of energy efficiency (runs itself efficiently by switching on and off different appliances as fit);  
  • it takes care of its residence by monitoring the healthcare and able to communicate to the relevant bodies. This is important with the aging population and the strain on the healthcare  
  • once it detects the possibility of fire, it deals with it by cooling the area or switching off other areas such as electricity and also contact the fire brigade without the intervention of humans. |
| Clustering Activities on Energy management (harvesting/generation/storage) in building of the future | Energy management/storage/harvesting/generation solutions will be investigated in different and separated projects consortia and it will be suitable to put in place an overall platform/network who will manage the different breakthroughs in this area and study how to manage in global point of view these alternative energies (smart grid, domotic, software embedded...) |

Regarding the **expected impact**, Building Up project will **promote the European knowledge in the built environment** and **boost the industrial competitiveness** of the construction sector and the inter-connected sectors.
The project is well aligned with E2BA Roadmap priorities to complement the EU pathways in supporting energy savings in buildings and districts and preparing the building sector (technology manufacturers, construction companies and energy utilities) to be in line with the 2050 decarbonisation goals for the European Economy.

Moreover, the project will contribute to the priorities in the upcoming “Horizon 2020” specifically regarding Industrial leadership (“technologies enabling Energy-efficient buildings”) and Societal Challenges such as “Health, demographic change and wellbeing; Secure, clean and efficient energy; Climate action, resource efficiency and raw materials”.

Each Cross-Platform areas will have an impact on several markets which have been identified with the help of ETPs experts. The table below summarizes the target markets and expected benefit identified for each of the Cross-Platform areas.

### Table 3 – Target Markets, Expected Benefit and reference Cross-Platform Areas

<table>
<thead>
<tr>
<th>TARGET MARKET</th>
<th>REFERENCE CROSS-PLATFORM AREAS</th>
<th>EXPECTED BENEFIT</th>
</tr>
</thead>
</table>
| Construction industry (including eco-construction, green, recycled building materials and renewable source-based building materials) | CP1 – Performance Based Approach for building components, including sustainable design, Life Cycle Analysis  
CP7 - Building materials recyclability and re-use of components  
CP8 - Renewable resource-based products to substitute non-renewable based products | The development and release of target products/applications/services described in CP1, CP7 and CP8 would increase the technological competitiveness of EU industry and would involve a wide range of SMEs from different sectors (including Steel, Wood & Paper and Chemical sectors) as suppliers of materials and components.  
In particular CP7 and CP8 products will help towards addressing the Societal Challenges “Climate action, resource efficiency and raw materials”, re-using the construction waste and increasing the usage of recyclable and sustainable products.  
This “eco” added value will increase with time and give European companies a quality advantage to other countries. The percentage of ecological products will depend on the market situation but as seen in Germany with the passive house standard it can increase in short time from some percentages to 30%.  
To be detailed if needed. |
| Composite materials market | CP2 - Multi-material composites | CP2 target technologies and products will highly contribute to address the Social challenge “Climate action, resource efficiency” because they will contribute to buildings with low embodied energy |

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### Deliverable D3.1

<table>
<thead>
<tr>
<th>Market/Technology Area</th>
<th>Description</th>
<th>Additional Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>the “Comfort” market:</strong></td>
<td>- Analytical equipment and human physiological diagnostic; - Acoustic and Thermal comfort, including HVAC, Lighting</td>
<td>One of the main and radical advantages of CP3 approach and developed technology/solutions is that it actually gives feedback of the indoor air quality and its implications to human health, not just by using theoretical estimations without any true feedback of their relevance. This approach will give HVAC-system and lighting systems development totally new insight and performance characteristics. Details on more benefits for HVAC systems and lighting might be added.</td>
</tr>
<tr>
<td><strong>Photovoltaics, and electricity storage for buildings</strong></td>
<td>CP4 - Electric generation and storage materials and systems</td>
<td>CP4 target technologies and products will highly contribute to Societal Challenge “Secure, clean and efficient energy” with solutions for efficient and sustainable electric energy generation, storage and distribution system. To be detailed if needed.</td>
</tr>
<tr>
<td><strong>Thermal generation and storage material and systems</strong></td>
<td>CP5 - Thermal generation and storage materials and systems</td>
<td>CP5 target technologies and products will highly contribute to Societal Challenge “Secure, clean and efficient energy” with solutions for efficient and sustainable thermal energy generation, storage and distribution system. To be detailed if needed.</td>
</tr>
<tr>
<td><strong>Insulation construction materials</strong></td>
<td>CP6 - Advanced thermal insulation construction materials for new buildings and existing buildings</td>
<td>CP6 target technologies and products will highly contribute to Societal Challenge “Climate action, resource efficiency and raw materials”. Future advantages of improved insulation materials will be: 1. better insulation at same thickness: important for space restricted applications like cavity wall, refrigerated transport, .. 2. thinner insulation layers at same U-value: this is important for architectural aesthetics, less material (energy) bound in the insulation, reduced transport volume. Durable and well performing new insulation materials will replace existing insulation; hence the market share will shift; construction market is very conservative and adoption times of &gt;8yrs have to be expected. This area will also increase the involvement in the construction sectors of industries and SMEs from different sectors (including Steel, Wood &amp; Paper and...</td>
</tr>
</tbody>
</table>
In the impact chapter, a brief overview is given for each of the target market identified.

An estimation of distribution of costs among the cross-platform areas will be included after the Expert Panel Workshop.

The Roadmap will be released at the end of July and validated through a validation meeting in September-October 2012 (Deliverable D4.4).
Glossary

TO BE COMPLETED by DAPP and E2BA in the final version of the document.
1 Scope, objective and methodology of the roadmap

1.1 Overall scope and objectives

The Building Up project aims to create an effective coordination of ETPs and major initiatives whose Strategic Research Agendas and activities address energy efficiency in the built environment from an NMP perspective.

In this framework, the overall objectives of the Building Up Industrial and Research Roadmap are:

- To outline and detail cross-sectorial NMP research and innovation targets up to 2020 and beyond, in order to improve the energy efficiency in built environment;
- To obtain such goal through a cross-ETP roadmapping activity, involving the Building Up network and large public consultations and debates.

1.2 Roadmapping methodology

The Building Up roadmapping process is described in the image below.

![Diagram of the Building Up Roadmapping Process]

**Figure 11 – The Building Up Roadmapping Process**

The roadmapping process may be divided in the following steps:

2. **PLANNING and DESK RESEARCH**: The first step was aimed at organise the roadmapping activity and the flow of information as well as the definition of the background knowledge. This step was performed based on:
   a. Careful planning of aims, methods and deadlines;
   b. Integration and further development of available desk research (ETP Strategic Research Agendas, National and European policy documents, research reports etc.) with contributions from supporting ETPs and associations.
c. Identification of ETP experts to be involved into workshops and of a large network of stakeholders to be invited to online surveys.

3. ROADMAP DEVELOPMENT:
   a. Identification of cross-platform research and innovation areas, i.e. areas considered (1) of interest by several ETPs involved in the roadmapping, (2) with high impact for the energy efficiency in the built environment;
   b. Development of each cross-platform area, through expert workshop and web surveys.

4. PLAN PREPARATION:
   a. **ROADMAP RELEASE** (shown in this deliverable D3.2): integration of all cross-platform areas in a overall roadmap scheme. Identification of non-technological cross-cutting actions.
   b. **WIDE VALIDATION of the ROADMAP**: the roadmap will be validated through consultation with Advisory Board and other stakeholders.

5. DISSEMINATION & FOLLOW-UP:
   a. **DISSEMINATION**: The Roadmap will be disseminated through ETP large networks. Particular care will be taken that the main results of the roadmap will be integrated into the E2BA roadmap, to be publicly presented in July during the PPP-Info day. The Building Up Roadmap will be also disseminated through a final meeting.
   b. **FOLLOW-UP**: In order to keep the Building Up Roadmap live and effective, periodic revisions of the roadmaps are needed after the final release, beyond the completion of the funded project. Continuous incorporation of changes in roadmap, taking into account latest developments in research and innovation, are suggested.

1.3 ETPs and Stakeholders involved in Building Up Roadmap

The Deliverable has been developed by E2BA and DAPP, supervised by the Coordinator and with the collaboration of the involved European Technology Platforms (ETPs) and Building Up Stakeholders. The involved ETPs are:

- ECTP : European Construction Technology Platform
- E2BA : Energy Efficient Buildings Association
- ESTEP : European Steel Technology Platform
- EUMAT : European Technology Platform for Advanced Engineering Materials and Technologies
- FOREST-BASED PLATFORM : Forest Based Sector Technology Platform
- RHC : Renewable Heating and Cooling Platform
- SUSCHEM : Sustainable Chemistry ETP
- TEXTILES ETP:

Moreover, a community of Building Up stakeholders contributed to the Roadmap through the Building Up Website (online surveys, posts etc.). They are listed in Appendix 1.
2 Building Up vision

Building Up will pave the way towards the development of radically new products and services enabled by NMP technologies while ensuring that all the necessary bottlenecks and gaps at technological, non-technological and programme level are properly addressed. Enhanced sustainability, competitiveness and employment are key socio-economic challenges for a knowledge based and “eco-innovative” society in the 21st century.

The collaboration framework pioneered in Building Up will be an effective demonstrator to draw guidelines and policy recommendations for the engagement of the public and private sectors in the area of Energy Efficient buildings, preparing the ground for any future implementation beyond 2013 through relevant European and National public and private (industrial) research initiatives, fully in line with the “wave action” used in the ongoing E2BA multiannual roadmap.

![Diagram of multiannual roadmaps within the longer term “wave action” strategy](image)

*Figure ...: The positioning of the multiannual roadmaps within the longer term “wave action” strategy*

*Source: E2BA Roadmap 2010-2013*

**Building Up long term vision** is well aligned with the E2BA “2020 Research & Innovation Roadmap” which aims at driving the creation of an innovative high-tech energy efficiency industry where the entire value chain will produce advanced systems, solutions and high value services for intelligent and sustainable buildings and districts. This vision meets the 2020 targets with the overarching goal to support both Climate and Energy policies set at European level for the full decarbonization by 2050 of the European economy. This requires preparing new market conditions where building owners are ready to invest into an affordable built environment having lower energy demand and lower GHG emission footprints over their whole life cycle, while improving optimal indoor air-quality and comfort.

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3 Roadmap overview: focus on cross-platform (CP) research and innovation areas

3.1 Roadmap overview

Whilst is based on a long term vision (up to 2050), the Building Up Roadmap focuses their main targets in the short-medium term (up to 2020), with some suggested actions for longer term (beyond 2020).

In this framework, the Building Up Roadmap includes:

- **8 Cross-Platform (CP) collaboration areas** in research and innovation, i.e. areas considered (1) of interest by several ETPs involved in the roadamapping, (2) with high impact for the energy efficiency in the built environment. These are the following:
  
  - CP1. Performance Based Approach for building components, including sustainable design, Life Cycle Analysis;
  - CP2. Multi-material composites;
  - CP3. Healthy indoor environment (including air quality, ventilation, lighting, acoustic performance);
  - CP4. Electricity generation and storage materials and systems (e.g. storage systems including building integrated energy technologies);
  - CP5. Thermal generation and storage materials and systems (e.g. storage systems including building integrated energy technologies);
  - CP6. Advanced thermal insulation construction materials for new buildings and existing buildings (e.g. aerogel, nanofoams, vacuum insulation panels);
  - CP7. Building materials recyclability and re-use of components;
  - CP8. Renewable resource-based products to substitute non-renewable based products.

- **A set of cross-cutting targets** with consideration on broad non technological issues.

- The overall social, environmental and economic impact, adding specific examples on target markets and expected benefits of the proposed actions for each cross-platform areas.

The figure below reports an overview of the Building Up Roadmap.
For each cross Platform area, the following items are detailed:

- **State of the art** in terms of technological and non technological aspects
- **Detailed Targets for 2020** and corresponding **Priorities**, highlighting the interests of different ETPs;
- **Target applications and end-users.**
- **Considerations beyond 2020** including draft long term targets.

The following figure shows the structure of each platform area, including logos of ETPs and EU initiatives that showed interest in them and in Building Up roadmapping activities during experts’ workshops, ETP meetings, Advisory Board meetings and through online consultations.
Figure 13 – Structure of the Cross-Platform areas & involvement of ETPs and associations
4 CP1 - Performance Based Approach for building components, including sustainable design, Life Cycle Analysis

The cross-platform area CP1, entitled “Performance Based Approach for building components, including sustainable design, Life Cycle Analysis” contains different targets and priorities towards 2020. A scheme of this cross-ETP research and innovation area is described in the figure below.

![Scheme of CP1 targets and priorities](image)

**Figure 14 – Scheme of CP1 targets and priorities**

4.1 Current situation (State of the Art)

It is known that improving the energy performance of buildings is critical for achieving 2050 decarbonisation goals. Therefore, major efforts are needed in order to contribute to rethink the approach about the main activities that concern a building: materials manufacturing, construction, use and maintenance, and end of life.

The Life-Cycle Stages of a building are described below:

- **Materials Manufacturing**: Removal of raw materials from earth, transportation of materials to the manufacturing locations, manufacture of finished or
intermediate materials, building product fabrication, and packaging and distribution of building products;

- **Construction:** All activities relating to the actual building project construction;

- **Use and Maintenance:** Building operation including energy consumption, water usage, environmental waste generation, repair and replacement of building assemblies and systems, and transport and equipment use for repair and replacement;

- **End of Life:** Includes energy consumed and waste produced due to building demolition and disposal of materials to landfills, and transport of waste materials. Recycling and reuse activities related to demolition waste also can be included and have a “negative impact.”

All these phases need to be checked and designed with specific tools which must take into account the sustainability of the building and the energy consumption, in order to reduce the environmental impacts.

**State of the Art in Technology/Research:** Public funding facilitated several projects focusing on the individual and holistic performance. However, the sustainability in the whole life cycle of the product (including the construction process) is still less in focus modern building, this is increasingly important since the production phase today can account for equal emissions of e.g. CO2 as the usage phase. Today Life Cycle Assessment (LCA) tools analyze the environmental impact of buildings and support decisions to reduce these impacts: there are many disparate standards about energy efficiency (LEED, Energy Star etc.) that have started to incorporate Life Cycle Assessment.

### 4.2 Targets by 2020

The following targets were considered:

1. All building components have to meet an eco-design approach (including LCA) covering the whole chain of the building life: material production, construction, use, recycling;
2. In order to control every loss of energy and monitor energy consumptions, it will be necessary to guarantee higher building physics performance (e.g. acoustic, vibration, etc…).

### 4.3 Research and Innovation Priorities

The targets previously mentioned need to be strongly linked with specific priorities, in order to fill the gap between the current situation and the desired future condition. A scheme of those connections is described in the figure below.

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5 AIA Guide to Building life cycle assessment in practice; Georgia Institute of Technology 2010
4.3.1 Research and Innovation Priorities by Target

**Target 1** includes the following priorities:

- ✓ Agreement on common understanding (boundaries) and handing back to national standards;
- ✓ Common methodology based on existing Life Cycle Analysis /LCA studies and standards;
- ✓ Systemic approach for all energy usages (energy, water…) taking into account their mutual interaction;
- ✓ Link with future Ecodesign UE directive;
- ✓ Design tools for optimization of sustainability of buildings and building components (embedding LCA etc.);
- ✓ Building design tools for architects allowing for real time building eco-design.

In order to reach the implementation of a common eco design approach and energy-saving oriented standard (**Target 1**) the following platform suggestions are explained in the tables below.
**ESTEP**

- Adoption of designing innovation processes, including all aspects of life-cycle design.
- Environment Product Declaration (E.P.D.)'s of all components and solutions should be considered as a mandatory requirement for buildings. It can be an added value information for designers: it would be good to have a tool that once you pick a product in the design phase, the tool will tell you its E.P.D. value and contribution.
- Modeling and simulation, evaluating the performance of nano-enabled materials.
- Service-life design methods for multi-material composites; interaction of various materials to degradations and ageing models in various environmental and loading conditions.

**SUSCHEM**

- Raising public awareness and dissemination of Life Cycle Analysis techniques for the building sector, paying attention in not to disclose intellectual property during LCA processes.
- The combination of different building materials to obtain a cost-optimum solution and the measurement of actual building performance will be important versus just only data from the material suppliers.

**EUMAT**

- Deep analysis of the mechanisms that influence the durability of the different properties of construction materials, products and components, including improved Life Cycle Analysis (LCA) tools and reliable, fast and robust ageing models.
- Development of processes to generate improved durability, including reliable test methods and inspection procedures.
- Focus on emerging market of bio based materials, or resources that are renewable in less than 10 years, low in embodied energy, carbon neutral and/or biodegradable. Research is needed on potential gains in terms of embodied energy compared to conventional materials and on LCA of bio-based materials.
- Development of prototypes of new products and systems, and identification of more transparent and dedicated LCA methodology.
4.4 Target Applications

Target applications for each technology are listed in the following table.

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>TARGET APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eco-construction techniques</td>
<td>Any scale of Construction:</td>
</tr>
<tr>
<td></td>
<td>- Residential;</td>
</tr>
<tr>
<td></td>
<td>- Non-residential (e.g. offices);</td>
</tr>
<tr>
<td></td>
<td>- Public facilities (e.g. schools, hospitals);</td>
</tr>
<tr>
<td></td>
<td>- Commercial (e.g. shops);</td>
</tr>
<tr>
<td></td>
<td>- Industrial (light and heavy)</td>
</tr>
<tr>
<td></td>
<td>- Infrastructures (e.g. bridge).</td>
</tr>
</tbody>
</table>

4.5 Considerations beyond 2020

It is necessary to consider buildings as complete systems rather than sums of components: performance-based approach must be a recognized as driving factor all over Europe, assuming that existing best practices become the standard (both in new construction AND renovation) after a certain transition time.

The large majority (>85%) of building products should obtain EPD (Environmental Product Declarations) compliant with CEN TC 350 (Sustainability of Construction Works) by 2030, at the same time increasing the use of embodied energy calculations and LCA in product manufacturing.

It would be desirable to have a sort of “speaking” components: those elements must have indicators built into them to point out their status, their effective functioning and the availability to modify several parameters.
5 CP2 - Multi-material composites

The cross-platform area CP2, entitled “Multi-material composites” contains several targets and priorities towards 2020. A scheme of this cross-ETP research and innovation area is described in the figure below.

![Scheme of CP2 targets and priorities](image_url)

**Figure 16 – Scheme of CP2 targets and priorities**

5.1 Current situation (State of the Art)

**State of the Art in Technology/Research:** Almost all construction materials are nowadays multi-material composites. We use concrete with admixtures and additives. We use plastics with different additions of other materials for performance enhancement. Plasters and renders are likewise stabilized, plasticized and strengthened by organic, inorganic and metallic additions. The steel-based solutions comprise steel-concrete composite structures (beams, columns, floors, heavy walls) and sandwich panels with cores made of various materials. The basic design methods are standardized based on intensive research. New applications need usually experimental involvement. Nano-technologies used for improved coatings. Therefore we can state that there are no construction materials existent that are not multimaterial mixtures. Even semi natural products like cellulose fibres, used for heat insulation, have anti bacteria additions in order to increase their durability. However, if we talk about multimaterial composites we should separate the meaning into two categories: formulations and "combination". In formulations you can find a dominant phase, e.g. aggregates in concrete, while two or materials coexist in comparable fractions in
combinations/composites. These combinations/composites have normally a different scale than formulations and clearly separated functions for each “partner” material.

State of the Art in non technical aspects (standards, commercialization, regulation): There is a need of services to support recycling of building components & materials (link with CP7).

5.2 Targets by 2020

Energy savings can be achieved through several leading actions regarding materials, waste processes and advanced composites, summarised in the following targets:

1) Providing multifunctional materials from multi-material composites in order to be resource and energy efficient, with low embodied energy and carbon;
2) Increasing the reuse of the building waste into recycled composites;
3) Developing composites consisting of renewable source matrix and fibre materials.

5.3 Research and Innovation Priorities

Targets previously mentioned need to be closely related to specific priorities, in order to fill the gap between the current situation and the desired future condition. A scheme of those connections is described in the figure below.

![Figure 17 – Link between CP2 targets and priorities](image-url)
Research and Innovation Priorities by Target

In order to reach Target 1 is necessary to advance towards different main concerns, both technological and process-related issues:

- Low-cost processing technologies for materials;
- New production processes for fibres - easy application methods;
- Bio-mimetic technologies: need for better understanding of surface interaction on nano-scale; Multi-scale modelling from atom to system; development of Chemical coupling agents and binders.

The platforms proposed several actions to reach Target 1, which are described in the table below:

<table>
<thead>
<tr>
<th>ESTEP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combinations of high-strength materials and multifunctional materials, contribution to lightweight solutions: e.g. sandwich panels with improved long-term performance.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SUSCHEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nanocomposite materials with competitive mechanical properties (mainly structural) compared to steel.</td>
</tr>
<tr>
<td>Formulation of thermoplastics for composites used in construction &amp; performance evaluation with respect to concrete.</td>
</tr>
<tr>
<td>Low embedded energy concrete with high mechanical properties and obtained at low temperature.</td>
</tr>
<tr>
<td>Performance-oriented development.</td>
</tr>
<tr>
<td>Self-healing materials (plastic composites, concrete and coatings), that will reduce maintenance costs, producing measurable benefits for the building owner.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TEXTILES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use of advanced textiles as reinforcement materials for next generation building composites.</td>
</tr>
<tr>
<td>Advanced (top)coatings for building composites.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>EUMAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable biotic materials are low in embodied energy, and have a favourable carbon footprint. These are particularly applicable to insulation materials.</td>
</tr>
<tr>
<td>Bio-based polymers, in particular bio-based resins, allow wood composites, hybrid composites and fibre insulations.</td>
</tr>
</tbody>
</table>

In order to reach Target 2 it would be valuable to go towards the following priority:

- Set up waste collection, separation and reaction techniques in order to increase the reuse of the building waste into recycled composites

The platforms suggested several actions to hit Target 2 which are described in the table below:
Target 3 could be achievable through advancing in research and development activities about the next priority:

- To improve technical properties (e.g., fire resistance) for organic materials

The platforms proposed several actions to reach Target 3 which are described in the table below:

### SUSCHEM
- Bio-based non-toxic flame retardants.

### FOREST TECHNOLOGY Platform
- There is a strong interest in increasing the amount of renewable materials in multi-material composites. Also highly interesting to increase the amount of renewable biomass in all other construction materials. In both cases this will contribute to lower energy use and CO2 emissions.

#### 5.4 Target Applications

Target applications for each technology are listed in the following table.

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>TARGET APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-material composites</td>
<td>Composites for exterior design include:</td>
</tr>
<tr>
<td></td>
<td>- columns</td>
</tr>
<tr>
<td></td>
<td>- pediments</td>
</tr>
<tr>
<td></td>
<td>- domes</td>
</tr>
<tr>
<td></td>
<td>- cornices</td>
</tr>
<tr>
<td></td>
<td>- formworks</td>
</tr>
<tr>
<td></td>
<td>Interior Composite applications include:</td>
</tr>
<tr>
<td></td>
<td>- walls</td>
</tr>
<tr>
<td></td>
<td>- floors</td>
</tr>
<tr>
<td></td>
<td>- building envelop</td>
</tr>
</tbody>
</table>

Table 5– Technologies, Target Applications and End-Users for CP2
- panels
- blinds
- sanitary-ware
- functional items (letter boxes, meter boxes)
- decorative items
- window profiles

5.5 Considerations beyond 2020

The results from implementing those technologies and processes will be buildings that cost less to operate and are worth more to their occupants: so it would be good if construction companies and industrial partner could be able to reuse all building waste into recycled composite materials; **FOREST TECHNOLOGY PLATFORM** suggest to set up waste collection, separation and reaction innovative techniques in order to support the overall recyclability of construction & demolition materials.

Another crucial target would be to provide intelligent materials that can be connected and disconnected by needs, that react on their environment according to different situations, materials that "know" each other and organize accordingly (e.g. nano glues for different types of molecular surfaces etc): this goal can be achieved through the development of advanced technologies such as molecular construction, that could support the spread of those intelligent materials.
6 CP3 - Healthy indoor environment (including air quality, ventilation, lighting)

The cross-platform area CP3, entitled “Healthy indoor environment” includes different targets and priorities towards 2020. A scheme of this cross-ETP research and innovation area is described in the figure below.

Figure 18 – Scheme of CP3 targets and priorities

6.1 Current situation (State of the Art)

State of the Art in Technology/Research: “Indoor Environmental Quality” refers to the quality of the air in an office or other building environments. While research has shown that some respiratory symptoms and illnesses can be associated with damp buildings, it is still unclear what measurements of indoor contaminants show that workers are at risk for disease⁶. Despite uncertainty about what to measure and how to interpret what is measured, research shows that building-related symptoms are associated with building characteristics, including dampness, cleanliness, and ventilation characteristics. But indoor environments are highly complex and building occupants may be exposed to a variety of contaminants (in the form of gases and particles):

⁶ The National Institute for Occupational Safety and Health (NIOSH), http://www.cdc.gov/niosh/topics/indoorenv/
- Professional activities (ex. office machines, cleaning products, hospitals, paints, dried washing shops, hair-cut shops, cooking, carpets and furnishings, cigarette smoke, …)
- Outdoor pollutants (road traffic, professional activities vectorization, unfavourable weather …)
- Construction materials pollution release (paints, coating, wood treatment, plastic equipments, carpets, curtains…)

Other factors such as indoor temperatures, relative humidity, and ventilation levels can also affect how individuals respond to the indoor environment.

The topic “indoor environment” was reinvented recently. After years of discussions about limitation of certain compounds it was realized that an added value is based on the actual “feeling” of people working and living in spaces. The feeling issue is not strictly related to these limits. It is rather dependent on soft criteria like artificial lighting, architectural design, heating and ventilation concepts. For example, steel product manufacturers and suppliers of whole-building solutions have a range of tools to model and simulate indoor air quality including technologies and materials that influence on the human health. However, the current practices focus mainly almost solely on individual building materials and their emissions, which is mandatory to ensure product safety. As the emissions from building materials represent only a part, and sometimes even an insignificant part, the scope of research needs to be extended to overall performance of buildings. Needs for major reductions in the energy consumption of buildings create other needs to ensure the healthy and comfortable indoor environment quality (IEQ).

High-tech products to reduce energy consumption from heating and air-conditioning in buildings have been developed by the glass industry, in order to improve also the general indoor environment. Three of the most famous glazing solutions are Low-Emissivity, highly insulating glass and solar control glass.

State of the Art in non technical aspects (standards, commercialization, regulation): Since Ecolabel is being released at the end of 2012, regulations for indoor/outdoor air environment have to be studied in order to adapt with the technology evolution. Indeed the EC Joint Research Centre’s Institute for Prospective Technological Studies (JRC-IPTS) in cooperation with the Circe consortium for the European Commission's Directorate General for the Environment is currently carrying out a pilot study on developing an EU Ecolabel and Green Public Procurement (GPP) criteria for buildings7. Among the documents released by this study it is worth mentioning the minutes8 from “Second meeting on development of GPP criteria for Office building” in which a set of criteria for indoor quality and well-being are identified, namely: Visual comfort, Separate rooms for printers and office equipment, Exclusion of certain materials and Minimum ventilation rates. Even if discussions about these criteria are focused only on office buildings and development are still ongoing, it is important to notice that CEN is now developing the TC351 standard for IAQ based on emissions from construction materials that will be mandatory in future.

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8 http://susproc.jrc.ec.europa.eu/buildings/docs/GPP%20draft%20minutes%20201202012.pdf
6.2 Targets by 2020

To achieve a healthy indoor environment, the following targets have been identified:

1) Tools for planning and instruments for measuring Indoor Environmental Quality are available and well validated
2) Highly energy efficient and financially affordable glazing and glazed components are available to reduce air-conditioning use and CO2 production, to improve safety and security, to improve fire resistance. These achievements will lead to an overall improvement of comfort levels in buildings and houses, including historical buildings.
3) Active functions are integrated into the building:
4) Acoustics materials/systems;
5) Energy Monitoring and Controlling (EMC) systems;
6) Lighting systems
7) All used materials have limited emissions of indoor air pollutants and ventilation rates are in accordance with European standards

6.3 Research and Innovation Priorities

The targets previously mentioned need to be strongly linked with specific priorities, in order to fill the gap between the current situation and the desired future condition. A scheme of those connections is described in the figure below.

![Figure 19 – Link between CP3 Targets and priorities](image)
6.3.1 Research and Innovation Priorities by Target

In order to reach Target 1 is necessary to advance and work on different main concerns, both technological and process-related issues:

- To create and validate new and accurate Indoor Environmental Quality (IEQ) assessment and planning tools for building structures and materials in Energy Efficient buildings (e.g. sustainable labels). Example: New quality control procedure of Indoor Air Quality (IAQ) during the manufacture and use of buildings.
- Better understanding of volatile organic compounds (VOC) emittance and control of harmful components. Better control over acoustics; Better control over moisture. Example: Multifunctional measurements for evaluating indoor environment.
- Provide empirical and reliable epidemiological data on correlation between building structures, materials, indoor environment quality and human health, desirable level of microorganisms etc. This may include User behaviour studies about inhabitants feeling comfortable
- Improved aesthetic room concepts

The platforms proposed several actions to reach Target 1 which are described in the table below:

<table>
<thead>
<tr>
<th>ESTEP</th>
<th>SUSCHEM</th>
<th>RHC Platform</th>
</tr>
</thead>
</table>
| • Controlling indoor-environment by design (e.g. removal of thermal bridges; promotion of dry technologies to reduce moisture and water from structures). Smart building technologies and continuous monitoring in use. | • Buildings materials and building performance analysis. Evaluation of factors with respect to health and toxicology of compounds for which information is lacking but are commonly emitted from materials  
  • Materials allowing control over key parameters of comfort and health inside buildings: acoustics control, humidity control, temperature control, perhaps even electromagnetic field shielding and light control. Ideally these should be building-integrated and where attractive available as layers on the interior building surface (e.g. allowing lighting surfaces, humidity control surfaces, sound deadening surfaces).  
  • Building energy rating certification could be a lever to improve energy efficiency and economical targets, generating a set of shared standard UE regulations in term of definitions and environmental specifications, that each national system must comply with could be a great help. | • Creating and validating a risk assessment and planning tool for HVAC systems, materials and structures in EE buildings in terms of their impact on IAQ&IEQ |
In order to reach **Target 2** is necessary to advance and work on different main concerns, both technological and process-related issues:

- Improvement of Low-E insulating glazing, low-E coatings, vacuum glazings and aerogel for reduced U value. Improvement of electrochromic, thermochromic or photochromic properties for G value control;
- Combination with many other features for multifunctional glazing, such as thermal insulation, self-cleaning, noise reduction, decorative glass, enhanced safety and security, solar control, low-maintenance.

The platforms proposed several actions to reach **Target 2** which are described in the table below:

<table>
<thead>
<tr>
<th>SUSCHEM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lambda 0,03 W/m²K</strong> insulative performance of windows including their window frames at economically viable cost levels.</td>
</tr>
<tr>
<td>Promote this technology to manage UV radiation window cutoff (photochromism) to avoid/limit air conditioning running to compensate. Photochromism versus Electrochromism takes the advantage to work without any power supply. To control the cost, promote not only windows replacement but smart films technologies (plastic films) to add on the windows on existing buildings.</td>
</tr>
<tr>
<td>PHOTOCATALYTIC windows with self-cleaning and air-purification properties, including improvement in efficiency in visible light range</td>
</tr>
</tbody>
</table>

In order to reach **Target 3** is necessary to advance and work on different main concerns, both technological and process-related issues:

- Efficient, comfortable indoor lighting (Flexible Lighting based on LEDs - Development of LED integrated coated textiles )
- Materials/systems with integrated failure warning

The platforms proposed several actions to reach **Target 3** which are described in the table below:

<table>
<thead>
<tr>
<th>SUSCHEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air filters consisting of advanced (non-woven?) textiles combined with active coatings such as microbe-killing Ag or TiO₂ nanoparticles; offering high air flow at low mechanical ventilation power consumption, reduced cleaning or replacement intervals of such filters.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TEXTILE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalytic materials have to be promoted to be also integrated in air conditioning system or in stand-alone application (as air cleaner device). Some setups are under development in startup companies but still suffer of many drawbacks: Catalytic performance</td>
</tr>
</tbody>
</table>
In order to reach Target 4 is necessary to advance and work on different main concerns, both technological and process-related issues:

- Reducing the Volatile Organic Compound (VOC) content of building materials (in the production phase).

### 6.4 Target Applications

Target applications for each technology are listed in the following table:

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>TARGET APPLICATION</th>
</tr>
</thead>
</table>
| Energy Efficient Equipments (including HVAC, lighting, acoustic performance, integrated systems etc.) | The following buildings and construction sites:  
- Residential;  
- Non-residential (e.g. offices);  
- Public facilities (e.g. schools, hospitals);  
- Commercial (e.g. shops);  
- Industrial (light and heavy);  
- Outdoor sites. |

### 6.5 Considerations beyond 2020

Indoor Environmental Quality represents one of the most critical issues for the development of more energy efficient buildings and districts, because it consists of many parameters representing the interface between users and buildings. The complexity of elements related with IEQ is also apparent when considering the different initiatives related with parameters, standards and rules aiming at regulating this area. Therefore among longer term targets it has been highlighted the need for providing more stable and constant conditions for the indoor environment of a building. This may be achieved through:

- Optimum balance between HVAC and insulation
- Implementation of Phase Change Materials to buffer variation in external conditions.
- Bringing more natural light inside the buildings

Moreover there will be the need of a wider application of new glazing materials in public and private buildings including historical buildings, in order to improve day lighting, that measuring smart windows to redirect light around within rooms in order to reduce the need for artificial lighting.

Another example of future improvement could be the use of advanced chemical products, like thermoplastic polymethyl methacrylate, that makes a valuable contribution to energy saving. PMMA transmits more light than conventional glass and the use of multi-skin sheets in greenhouses offer an ideal energy balance. Their good heat insulation means that less energy is required than with conventional glazing, thus cutting costs and CO2 emissions.
7 CP4 - Electric generation and storage materials and systems

7.1 Current situation (State of the Art)

The cross-platform area CP4, entitled “Electric generation and storage materials and systems” contains several targets and priorities towards 2020. A scheme of this cross-ETP research and innovation area is described in the figure below.

![Figure 20 – Scheme of CP4 targets and priorities](image)

**Figure 20 – Scheme of CP4 targets and priorities**

**State of the Art in Technology/Research:**

Electricity generation could be implemented through several devices: photovoltaic systems and small wind turbine are current technologies for building installation.

Photovoltaic systems use solar panels to convert sunlight into electricity: their effectiveness changes over the year with a certain regularity, because generating power from renewable energy sources is subject to extreme fluctuations and cannot be controlled since the period during which power is generated (when the sun is shining) only coincides by chance with power consumption. Already, today, not all the green energy generated can be fed into the grid all the time. In order to overcome this physical and technological barrier it is necessary to improve in storage systems and
innovative batteries, also because increased electricity consumptions and reduced availability of fossil fuels will lead in next years to a global increased energy needs.\(^9\)

Small wind turbines could be one of the most adaptable, flexible and easy to use technologies for generating sustainable and cheap electricity. Currently Small Wind Turbine (SWT) is still an unsafe technology, because their efficiency is strictly correlated to wind conditions and altitude installation. Those devices consume more electricity than they deliver\(^10\) when they are installed in urban environments at sub-optimal heights (<15mt) and do not provide sufficient payback, in contrast with previous assumption AWEA stated that SWT are a valuable solution if installed minimum 15 meters above buildings\(^11\).

Materials are key enablers in all PhotoVoltaic systems. (…) The materials supply chain needs to be able to supply sufficient quantities of the required elements, and thus, cost effective recycling solutions should be developed along with standardised performance testing. Reliability/ageing test protocols needs to be developed to provide confidence (and so bankability) for PV devices employing newly developed materials in a wide range of operating conditions (from Europe to Sunbelt environments).

**Electricity storage**

Electricity energy storage technologies are important for improving the efficiency of electrical energy utilisation. The primary aims of developing and deploying electricity storage technologies is their potential to generate an “electricity reserve”, the benefits of which include:

- **Stabilisation of the energy market:** Areas that could see improvement with the wider application of energy storage are increased diversification and security of supply;

- **Stabilisation of the transmission and distribution grid:** A consequence of this is that energy management can potentially reduce the need for reserve fossil fuel plants. Power quality applications can assist in smoothing out faults and other short term disruptions and perturbations, reducing the requirement for ‘spinning reserve’ in the system.

- **Optimisation of intermittent renewables, particularly wind:** Linkage between intermittent sources of energy and associated storage - for example during the night or other periods of low demand - could reduce the vulnerability to supply shortages by providing a means to store excess energy, and then release it during periods of high demand. Improvements in this field will enable intermittent sources to command a higher price for the energy produced by making it more dispatchable.\(^12\)

Today, most storage technologies are too costly and exhibit inadequate technical performances for a wide-spread deployment and integration at system scale.

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\(^9\) State-of-the-art electricity storage systems, Deutsche Bank Research, 2012

\(^10\) http://www.theoildrum.com/node/6954


\(^12\) Outlook Of Energy Storage Technologies; UE Parliament - Policy Department Economic and Scientific Policy; 2007
7.2 Targets by 2020

The construction of low-energy ‘passive’ or even ‘zero-energy’ houses promises to cut energy use dramatically: in this framework the following targets were identified:

1) building system and components need to be optimized (cost and energy) and their performance evaluated correctly. Tools for modelling new energy generating system performances need to be designed and developed.

2) Energy savings could be achieved only through the availability of new technologies and systems for electric energy storage and electric generation.

7.3 Research and Innovation Priorities

Targets previously mentioned need to be strictly linked with specific priorities, with the aim of associating detailed matters required for filling the gap between actual situation and future condition.

A scheme of those connections is described in the figure below.

![Figure 21 – Link between CP4 targets and priorities](image_url)

**Figure 21 – Link between CP4 targets and priorities**

7.3.1 Research and Innovation Priorities by Target

In order to reach Target 1 it will be necessary to adopt new testing procedures, identification of new performances for new or existing materials (e.g. with reference
also to adaptive performances); it would be useful to provide holistic, intelligent & predictive energy control systems that could manage a sustainable building.

The following platforms suggest reaching those targets through the actions described in the tables below.

**ESTEP**

- Building components that are capable to capture & store energy
- Smart control system that can balance the three activities (capture, storage and distribution)

**TEXTILES**

- Incorporation of electronic/sensor functions into building composites materials
- Integration of energy storage systems into building composites materials

**EUMAT**

- **Energy generation** - 1. Layer CdTe <1,5μm / CIGS <1,0 μm; Wider total layer band gaps than current (e.g. TFPV 1,7-1,8 eV; multi junction 2,2 eV); Elimination of all toxic substances in PV devices; Non indium containing TCOs with adequate performance; Low Silver / silver free metallisation. The combined effect of all improvements should lead to a reduction by 50% of the LCOE by 2020 and >65% by 2030 compared with 2011;
- 2. Typical PV module efficiencies (crystaline Si- 18-23%; thin film Si- 13-14%; other thin films- 10-18%; HCPV 40-50%);
- **Electricity storage** - Li-ion battery performance improvements to 180-350 Wh/kg - 350-800 Wh/L

The widespread availability of new technologies and systems (e.g. building integrated PV) is strictly needed (Target 2), in order to produce energy to be stored in either batteries or hydrogen through electrolysis. The stored electricity can be used in household appliances or for electric vehicles. Stored hydrogen can also be transformed back to electricity or used directly in fuel cell electric vehicles. The system involves integration of PV (also in the infrastructures at large), smart meters/grids, battery technology, electrolysis and fuel cells, transparent electric active windows; also smart grid solutions could be necessary to fully enable distributed energy generation. Demand response solutions will be crucial to fully exploit energy production at local level; also with the wide market distribution of fuel cells devices for static applications.

The following platforms suggest reaching those targets through the actions described in the tables below.

**ESTEP**

- Implementation of Sandwich panels & entire building envelope; Pilot and demonstration buildings
- Smart components that work intelligently and remotely with the smart grid
7.4 Target Applications and End-Users

Target applications and end-users for each technology are listed in the following table:

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>TARGET APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric generation materials</td>
<td>Entire skin of the building, including building envelop (e.g roofing, sun-shading, glazing, architectural fabrics).</td>
</tr>
<tr>
<td>Storage technologies</td>
<td>Various types of existing or potential storage technologies are adapted for different uses. All storage technologies are designed to respond to changes in the demand for electricity, but on varying timescales. Demand fluctuations on shorter timescales—sub-hourly, from a few minutes down to fractions of a second—require rapidly-responding technologies like flywheels, super-capacitors, or a variety of batteries, which are often of smaller capacity.¹³</td>
</tr>
</tbody>
</table>

7.5 Considerations beyond 2020

Buildings could play an active role in energy saving with the possibility to produce electricity with PV systems. Buildings will also have the capability to store energy

¹³ http://205.254.135.7/todayinenergy/detail.cfm?id=4310
(batteries, fuel cell etc..) in time periods with low energy demand, and to release this energy again in periods with a high energy need and thereby lead to a reduction of the total energy demand.

A further development and a wider application of new energy generating and storage system will be highly recommended, specifically a integration on urban scale.

A driving priority could be the expansion of smart building envelopes capable of adapting their energy generation and storage to external condition, with automatic weather stations that provide inputs in order to self-regulate several parameters.

**ESTEP** suggests investing in solution & tools capable to transform buildings into mini power stations capable of producing energy and consider whole urban areas, i.e. urban planning level.

**EUMAT** suggests the development of technologies with the following improved characteristics:

- *Electricity generation* - Typical module efficiencies (crystalline Si- >30%; thin film Si- >16%; other thin films- 16->21%; HCPV 50-60%);

- *Electricity storage* - Li-ion improvement to >350 Wh/kg and >800 Wh/L.
8 CP5 - Thermal generation and storage materials and systems

The cross-platform area CP5, entitled “Thermal generation and storage materials and systems” includes different targets and priorities towards 2020. A scheme of this cross-ETP research and innovation area is described in the figure below.

![Figure 22 – Scheme of CP5 targets and priorities](image)

8.1 Current situation (State of the Art)

*Thermal generation became a main concern in order to save energy:* many innovative devices like cogeneration and trigeneration systems are entering step by step into the mass market.

*The storage of energy efficiently converted into the required form is also a current day challenge for scientists.*

Energy storage not only reduces the difference between supply and demand but also improves the performance and reliability of energy systems, playing a valuable role in conserving the energy. It leads to saving fuels and makes systems more cost effective by reducing the waste of energy and capital costs. Thermal energy storage can be collected as a change in internal energy of a material as sensible heat, latent heat and thermochemical or a combination of these ones.\(^\text{14}\)

State of the Art in Technology/Research: The vast majority of the thermal energy used in buildings is currently produced through the combustion of fossil fuels such as oil, gas and coal, with an impressive environmental impact in terms of greenhouse gas emissions. A variety of renewable heating and cooling technologies exist which can be integrated into the built environment. Directive 2009/28/EC on the promotion of the use of energy generation from renewable sources classifies the following technologies:

- Solar Thermal;
- Biomass;
- Geothermal and Aerothermal Heat Pumps.

These technologies can be combined in highly efficient hybrid heating (and/or cooling) systems.

Thermal energy storage solutions can be classified according the temperature level of stored thermal energy (heat storage; cool storage), the time length of stored thermal energy (short term; long term), and the status of energy storage material (sensible heat storage; latent heat storage; thermochemical heat storage).

Sensible heat storage systems (e.g. hot and chilled water) and some latent heat stores (e.g. ice storage) are mature technologies. However, developments in advanced PCM and thermochemical materials are opening up possibilities for new applications, such as PCMs embedded in building materials used for bricks, wall boards or flooring. Phase Change Materials (PCMs) respond to slight changes in temperature meaning that they are good at buffering changes in temperature close to the temperature at which they change phase. Using ice storage, chiller capacity can be generally reduced by 50% or more thanks to the reduction in the electrical peak loads. Hybrid systems are also possible, for instance plastic PCM modules can be put into a tank where the heat-transfer fluid (usually water) melts or solidifies the PCM. This hybrid system has a higher storage density than that of water, but less than a pure PCM system. The development of thermochemical materials and technologies is still at an early stage.\(^\text{15}\)

State of the art of solar thermal technology

Current key applications of solar thermal technologies:

- Domestic hot water preparation for single- and multi-family houses with typical solar fractions between 40 – 80% (meaning the energy of sunlight meets these shares of demand for this use);
- Space heating of single and multiple family houses with typical solar fractions between 15 – 30%;
- Hot water preparation in the hotel and tertiary sector.

In some European countries, such as Austria, Denmark, Germany and Sweden, solar-assisted district heating systems are already well established. In recent years the number of solar thermal systems for cooling and air conditioning and industrial process heat has increased considerably, while there is a big untapped potential in new applications such as sea water desalination and water treatment.

\(^{15}\) Atul Sharma, V.V. Tyagi, C.R. Chen, D. Buddhi; Review on thermal energy storage with phase change materials and applications; Devi Ahilya University 2010
The increase in the installations of solar thermal combined-systems, providing both domestic hot water and space-heating, is a very promising development enabling greater use of the solar resource. 100% solar-heated buildings (Active Solar Buildings) have already been demonstrated in Central European climates (both detached houses and multi-family buildings). These buildings need very good thermal insulation, space for a large collector area and for a heat store.

State of the art of biomass technology

Technology for providing bioheat to households, commerce and industry is available, reliable and efficient but has to compete against well-established systems based on fossil fuels. Bioenergy can provide both low-temperature heat and steam, and high temperature heat suitable for industrial processes.

Small-scale heating systems fired with wood logs, chips or pellets offer good ease of use, low operating costs and are replacing oil heating in many European regions. Biomass district heating is of growing importance in Scandinavia, Austria, and other countries where demand for heat by the residential / service sector is high.

Methane production by fermentation is an alternative route suitable for wet raw materials. Biogas can be burned directly in a boiler for heat or in an engine for cogeneration, while upgraded biogas (methane) can additionally be injected into the natural gas grid or as vehicle fuel.

State of the art of geothermal technology

By definition, geothermal energy is the energy stored as heat beneath the earth’s surface. Currently, besides electricity production, geothermal energy is used for district heating and cooling, and to heat and cool single buildings or groups of buildings (offices, shops, houses, schools, greenhouses, swimming pools). At low temperature (up to 25°C) a number of innovative applications of geothermal energy have been developed based on the relatively stable groundwater and ground temperatures found at depths of up to 400 m. Typically, but not necessarily, heat pumps are used to raise the temperature to the level required by the hot water, heating or cooling end-use. In certain conditions and configurations, this system can be used to change ground temperatures artificially, in order to use the ground as heat or cold storage. UTES (Underground Thermal Energy Storage) represents a growing market for combined heating and cooling systems mainly for commercial and institutional buildings.

In new construction, shallow geothermal energy (geothermal heat pumps) has already achieved a market share of about 20% in some countries. Most low-temperature energy demand is found in existing houses, and these can be supplied by geothermal district heating systems.

State of the Art in non technical aspects (standards, commercialization, regulation):

The RES Directive (28/2009/EC) is not yet effectively and fully implemented in all Member States. Binding energy efficiency targets and renewable energy obligations in both new and existing buildings are essential. In addition, “electricity-only” generation from biomass should be discouraged, with regulation providing an incentive for cogeneration.

Measures to enforce EU-wide CEN standards, certification and quality labels for renewable heating and cooling equipment and systems are therefore required.
A comprehensive framework for the certification and accreditation of installers should be put in place in order to ensure quality standards are met and customers are kept satisfied. This will in turn spur further market deployment.

Specifically for bio-energy, an increased focus is needed on the sustainability of the whole chain from biomass production and supply to conversion and use, leading to a unified, transparent EU bio-energy market.

New business models for daily and seasonal storage need to be developed. The expected growth of UTES in Europe requires a clear legal status and policy. Although improvements are still desirable, in general the legal framework for borehole thermal energy storage is fairly well developed in Europe. The use of groundwater for energy storage is generally poorly regulated and in some countries there are significant barriers to it. Labelling or certification standards for thermal energy storage have not been developed yet. They are necessary to evaluate and compare new storage materials, products, and systems as they will become available on the market.16

8.2 Targets by 2020

The following targets to be achieved by 2020 were identified:

1) Research, development and demonstration activities should proceed in order to obtain a total building integration (e.g. in plaster, windows, tiles, etc.) of energy generation and storage systems. It is also essential for a high mass market implementation to increase aesthetics and integration flexibility, efficiency, cost, quality insurance, plug and play development, and support market implementation of plug and play hybrid solutions for sustainable heating and cooling systems;

2) It is critical to make available new technologies, systems and processes for thermal energy storage and heating management, including enhanced control and automation (Target 2). Finally a further development of advanced nanotechnology application for total building integration will be needed.

8.3 Research and Innovation Priorities

Targets previously mentioned need to be strictly linked with specific priorities, with the aim of associating detailed matters required for filling the gap between actual situation and future condition. A scheme of those connections is described in the following figure.

8.3.1 Research and Innovation Priorities by Target

In order to reach Target 1 is necessary to advance and working on different main concerns, both technological and modelling topics:

- Need for modeling behavior and properties of building integrated thermal technology. (e.g. Development of flexible high efficiency solar thermal collectors);
- Validation of thermal energy generation through advanced modeling tools.

The following platforms suggest reaching those targets through the actions described in the tables below.

**ESTEP**
- Adoption of energy efficiency tools, in order to fully validate solar thermal (and not only) technologies
- District heating system may be a solution for thermal needs : utility companies could sells directly thermal energy like a commodity

**SUSCHEM**
- To concentrate on the development of smart sensors for building integration: those sensors should be resilient, low cost and should monitor different kind of parameters (energy storage, production systems and energy use)
• Storage materials should be able to generate long term profit for building owners.

**RHC**

- **Biomass technology**: to increase system efficiency and reduce emissions (e.g. particulate emissions) from stoves, boilers and Combined Heat & Power (CHP) plants from micro to large scale
- Development of high efficient biomass conversion systems to trigeneration (heating, cooling and power) and the advancements in material sciences that will allow the reduction of costs for condensing biomass boiler technologies whilst maintaining the reliability of operation and life time of the condensation heat exchangers.
- **Geothermal technology**: to integrate geothermal energy in standard housing systems
- To develop Heating & Cooling networks integrating ground source heat pumps and Underground Thermal Energy Storage (UTES)
- Geothermal Heat Pumps: Decreasing installation cost, increasing of Seasonal Performance Factor (SPF), optimisation of the system integration (ground heat source / heat pump/ distribution), and support of activities towards a decrease of overall energy demand in buildings.
- Geothermal Heat Pumps: Decreasing installation cost, increasing of Seasonal Performance Factor (SPF), optimisation of the system integration (ground heat source / heat pump/ distribution), and support of activities towards a decrease of overall energy demand in buildings.
- **Solar thermal technology**: to adopt more efficient ways to use conventional collector materials (metals, glass, insulation), especially with a view to developing multifunctional building components, which also act as an element of the building envelope and a solar collector.
- Evolution in the optical properties of collector components, in particular, a more systematic use of optical films to enhance heat/light transmission in glass covers and to reduce this transmission during excessive exposure; and the use of colours in absorbers or covers to achieve more flexible integration concepts

New technologies deployment is a key passage to make thermal storage a more efficient solution: to meet Target 2 it is necessary to work on another priority regarding the exploration of the potential demand side management opportunities associated with the storage of energy in the thermal mass of buildings in district heating systems. The idea here is that there may be possibilities to store heat in some building types (e.g. public big facility) during periods of low energy demand which can then be used in other areas of the system during periods of high energy demand. The following platform suggest to reach the goal through the actions showed in the tables below.

**ESTEP**

- To work towards different solutions for various energy-sources, e.g. soil heat through eco-pile and uptake in advanced components and systems
PCMs are substances with a high heat of fusion which, melting and solidifying at a certain temperature, are capable of storing and releasing large amounts of energy. Heat is absorbed or released when the material changes from solid to liquid and vice versa; thus, PCMs are classified as latent heat storage elements. Two kinds of heat storage systems have to be supported in the short-medium term:

- daily storage (to capture heat for the day and release the night);
- seasonal storage (capture heat summer times and control the release in winter).

Fundamental R&D activities need to be performed into ultra-high enthalpy transition materials, that can be used to replace present Phase Change Materials which shave off the peaks of day-to-night temperature cycles. Similar R&D should be performed on materials that allow for ultra-high efficiency of heat-to-cold processes of heat energy storage. Evolution of the Regulations and certification level will push and promote material discovery for heat storage (batteries, heat...) to fix next step of challenges (in analogy with automotive environmental cleanup evolution).

**RHC**

- **Thermal energy storage:** to reduce costs and improve the ability to efficiently shift energy demand over days, weeks or seasons
- R & D on advanced sensible heat storage, PCM, sorption and thermochemical

Improving the properties of TES materials is important, in particular concerning their stability and the number of charging and discharging cycles they can withstand. The durability of new systems and their constituent parts must also be accurately quantified in order to estimate their long-term performance.

Research focused on the integration and optimisation of heat/cold stores with renewable energy technologies. A “system-level perspective” is needed, taking into account the heat demand patterns of all consumers connected to the system, as well as the interaction with the building envelope and the energy networks.

**EUMAT**

- To promote R&D actions on solid ceramic particles, high temperature Phase Change Materials, graphite, high temperature concrete; furthermore, it should be developed studies on thermo-chemical energy storage materials and on high temperature materials.

- Enabling of smart technologies to be easily integrated with the building envelope: driven for the need for better insulated zero-carbon buildings, a new generation of actively controlled components should replace conventional materials. These smart devices must respond to seasonal variations in temperature and solar radiation, in order to continuously provide a healthy environment for occupants.

8.4 Target Applications and End-users

Target applications and end-users for each technology are listed in the following table:

Table 8 – Technologies, Target Applications and End-Users for CP5

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>TARGET APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar Thermal Energy</td>
<td><strong>Domestic hot water &amp; space heating</strong></td>
</tr>
<tr>
<td></td>
<td>- One/two/multi-family homes</td>
</tr>
<tr>
<td></td>
<td>- Hotels, hospitals, residential homes, etc.</td>
</tr>
<tr>
<td></td>
<td>- District heating systems</td>
</tr>
<tr>
<td></td>
<td>- Multifunctional façades</td>
</tr>
<tr>
<td></td>
<td>- PV-Thermal (PV-T) hybrid collectors</td>
</tr>
<tr>
<td></td>
<td><strong>Process heat</strong></td>
</tr>
<tr>
<td></td>
<td>- Low up to 100C</td>
</tr>
<tr>
<td></td>
<td>- Medium up to 250C</td>
</tr>
<tr>
<td></td>
<td>- Solar assisted cooling and refrigeration</td>
</tr>
<tr>
<td>Biomass (Solid biomass, Bio fuels / biogas)</td>
<td><strong>Small burners</strong></td>
</tr>
<tr>
<td></td>
<td>- Pellets stove</td>
</tr>
<tr>
<td></td>
<td>- Wood chip boiler</td>
</tr>
<tr>
<td></td>
<td>- Log wood stove/boiler</td>
</tr>
<tr>
<td></td>
<td><strong>District heating &amp; cooling and process heat</strong></td>
</tr>
<tr>
<td></td>
<td><em>Heat only or combined heat and power</em></td>
</tr>
<tr>
<td></td>
<td>- Pellets boiler</td>
</tr>
<tr>
<td></td>
<td>- Wood chips boiler</td>
</tr>
<tr>
<td></td>
<td>- Waste &amp; agricultural feedstock boiler</td>
</tr>
<tr>
<td>Geothermal: Shallow GT</td>
<td>- DHW, space heating &amp; cooling</td>
</tr>
<tr>
<td>(Geothermal HP, Underground thermal storage)</td>
<td>- process heat</td>
</tr>
<tr>
<td>Geothermal: Deep GT (&gt;400m)</td>
<td>- District heating</td>
</tr>
<tr>
<td>(Direct heat use, Comb heat &amp; power)</td>
<td>- Agriculture and industrial processes</td>
</tr>
<tr>
<td></td>
<td>- Balneology Cooling</td>
</tr>
<tr>
<td>Cross Cutting Technologies -</td>
<td>- District heating</td>
</tr>
<tr>
<td>District heating and cooling (DHC)</td>
<td>- District cooling</td>
</tr>
<tr>
<td></td>
<td>- DH&amp;C with seasonal storage</td>
</tr>
<tr>
<td>Cross Cutting</td>
<td>- Water storage</td>
</tr>
</tbody>
</table>
| Technologies - Thermal energy storage | - PCM  
|                                       | - Thermo chemical  
|                                       | - Underground storage (UTES) |
| Cross Cutting Technologies - Hybrid systems and heat pumps | - Innovative system design  
|                                                          | - Ground, water and air heat pumps |
| Cross Cutting Technologies – Energy Distribution | The entire building skin could be used for capture and the building elements – such as floors – could be used for storage |

### 8.5 Considerations beyond 2020

Wider applications of new cost efficient and durable solutions (applicable also on urban scale) for thermal energy generation and storage will be achieved, enhancing the ability to efficiently shift energy demand and facilitating the integration of Renewable Energy Sources.

Renewable energy technologies for heating and cooling should be designed on the assumption that buildings and industrial processes will be more energy efficient. Solar thermal, biomass and heat pump technologies will achieve a significant costs reduction and relative performance improvement.

Wider application of advanced solar thermal technology in buildings will help to spread also hydrogen technology, helping an innovative implementation of grid integration; hydrogen will be produced with renewable sources, stored, and with air taken from the atmosphere will produce the heat needed to warm the building, through a catalyser that allows hydrogen and oxygen to combine in a molecule of water, simultaneously releasing heat.\(^{18}\)

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\(^{18}\) [www.solaritaly.enea.it/Documentazione/Calore\%20ad\%20alta\%20temperatura\%20dal\%20sole.pdf](http://www.solaritaly.enea.it/Documentazione/Calore%20ad%20alta%20temperatura%20dal%20sole.pdf)
9 CP6 - Advanced thermal insulation construction materials for new buildings and existing buildings

The cross-platform area CP6, entitled “Advanced thermal insulation construction materials for new buildings and existing buildings” includes several targets and priorities towards 2020. A scheme of this cross-ETP research and innovation area is described in the figure below.

![Figure 24 – Scheme of CP6 targets and priorities](image)

9.1 Current situation (State of the Art)

Measures to improve insulation materials, in order to reduce the heating/cooling demand in buildings, represent a significant part of the potential of the Construction Sector to highly contribute to meet EU objectives in terms of energy efficiency and reduction of CO₂ emissions. Currently available methods are largely based on non-renewable resources as well as consuming a large amount of energy and causing air pollution during production and disposal. A less resource-consuming substitute is needed which is both more ecological and provides other positive aspects of sustainability.

State of the Art in Technology/Research: New technologies were developed, (e.g. organic nano-structured materials), older technologies improved (e.g. aerogels and
vacuum insulations), and new material combinations placed successfully in the demanding markets. However, the increasing insulation demands caused also new problems, such as algae growth on north orientated facades, increased fire loads and significantly increased difficulties on construction sites.

**State of the Art in non technical aspects (standards, commercialization, regulation):** Increased stricter national regulations led to a significant improvement in research and performance of new insulation materials.

### 9.2 Targets by 2020

The reduction of the overall energy consumption in the building sector requires a significant decrease in energy consumption in buildings, particularly in existing ones. As energy-efficiency standards for buildings become further severe, using a traditional insulation material often means having to accept gradually more thick layers of insulation in walls, floors, and roofs. This matter consumes valuable floor space in new construction. In refurbishment project, valuable aesthetic and functional compromises are often required to retrofit more insulation on the inside or outside of the building envelope.

In this framework, the following targets to be reached by 2020 were identified:

1) availability of insulation materials with innovative characteristics e.g. highly enhanced properties ($\lambda < 0.03$ W/m2K, fire safety, improved durability, low cost, recyclability) especially for retrofitting;

2) availability components with very high insulated materials (used especially in retrofitting operations).

### 9.3 Research and Innovation Priorities

As read in previous paragraph a better improvement in insulation material goes through several steps: a continuous technology development, an economic analysis of cost/benefits of the new material and integration with existent structures and work methods.

So it is necessary to consider several priorities to reach goals: in the figure below a scheme of the links between targets and priorities is showed.
9.3.1 Research and Innovation Priorities by Target

A cost-effective improved material with prominent properties (Target 1) can be obtained through working on the following topics:

- Development of new cost-effective energy efficient insulating materials from renewable sources or waste materials;
- Optimization of materials with active properties (e.g. Semi permeable insulation membranes, pigments with a certain absorption reflection spectrum that changes at different conditions);
- Evolution of materials with $\lambda < 0.03$ W/m2K based on nanofoams or silica aerogels, capable to both retain and reflect heat from inside or outside, integrate other functions (e.g. fire safety) with solutions for both new buildings and for energetic improvement of existing ones.

The following platforms suggest reaching those targets through the actions described in the tables below.

**SUSCHEM**

- Further advance of suitable processes for nanofoams manufacturing and application
- The improvement of processes to produce modular, easy to assemble/disassemble and fully recyclable insulating systems may be
useful for new buildings, while the improvement of thin layer insulating coatings and paintings could be functional for the refurbishment of existing buildings

**TEXTILES**

- to develop advanced insulation materials (i.e. ecological, lightweight, cost-efficient, multifunctional)
- To be detailed

**FOREST TECHNOLOGY PLATFORM**

- Developing new insulation products based on cellulose and nanocellulose fibres: they are a green, efficient, non-toxic, affordable thermal alternative to be considered in future refurbishment for existing buildings and for the construction of new buildings.

The availability of components with advanced insulation properties, such as prefab materials (Target 2) is a driving factor that can be pursued by:

- Identification of the environmental tradeoffs between using insulation and sophisticated building techniques to control indoor climate in buildings with energy using heating / cooling and ventilation systems;
- Integration of insulated materials in traditional products for large application (plaster, bricks, etc.); innovative solution for retrofit, e.g. internal insulation; thermal insulation, with good vapour permeability;
- Improved material combinations in a layered and structured facade construction, IR absorption and reflection on demand in combination with insulation and switchable U-values;
- Cost-effective analysis on pilot test demonstration in public / administrative buildings;
- Cost-effective large volume manufacturing.

The following platforms propose to reach those targets through the actions described in the tables below.

**ESTEP**

- To develop self insulating components, i.e. without need for insulation layer/material, in order to save money and installation costs

**SUSCHEM**

- To integrate additional breakthrough advantages (e.g. fire safety, self cleaning, reduced time for construction), in parallel with demonstrating cost effectiveness and performance (feasibility of zero emission potential) in public / administrative buildings
- To create conditions for a quick and quantifiable recovery of invested capital through energetic gains
TEXTILES

- Development of advanced, multifunctional insulation materials based on non-woven
- Integration of insulation and energy harvesting/storage systems

EUMAT

- Analyzing and developing new materials combining structural properties and/or thermal resistance/inertia and/or lightweight structures
- Foamglass, nano-foams, foam insulation with addition of storage capacity: basic research for material optimization and applied research to investigate material integration in new constructive solutions (e.g. breaking cold bridges, combination between reinforcement and insulating material, constructive strength for heavy and pulling loads). Also thermal properties (mainly resistance and inertia) of structural/lightweight materials should increase of 30% with respect to current best performers: a 20 % specific reduction of embodied energy in production should be pursued.

FOREST TECHNOLOGY PLATFORM

- To concentrate major efforts on promoting industrially manufactured prefab components for building envelope retrofitting: for example prefabricated light-weight systems for envelope energy efficiency retrofitting with integration of insulation and technical installation of retrofit systems.
- The use of prefabricated systems and sustainable raw materials can help in drastically reducing energy demand, performing a reduction of heat loss in a building, and at the same time lowering the embodied energy.

9.4 Target Applications

Target applications for each technology are listed in the following table:

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>TARGET APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation construction materials:</td>
<td>Wall insulation:</td>
</tr>
<tr>
<td>• Wool</td>
<td>o External walls</td>
</tr>
<tr>
<td>o Rockwool</td>
<td>o Internal walls (including curtain walls)</td>
</tr>
<tr>
<td>o Glasswool</td>
<td>o Cavity walls</td>
</tr>
<tr>
<td>• Plastic foams</td>
<td>• Roof insulation:</td>
</tr>
<tr>
<td>o Expanded polystyrene</td>
<td>o Flat roofs</td>
</tr>
<tr>
<td>o Extruded polystyrene</td>
<td>o Pitched roofs</td>
</tr>
<tr>
<td>o Polyurethane foams</td>
<td>• Floor insulation</td>
</tr>
<tr>
<td>o Other plastic foams</td>
<td></td>
</tr>
<tr>
<td>• Fiberglass (and foam glass)</td>
<td></td>
</tr>
<tr>
<td>• Other insulation materials</td>
<td></td>
</tr>
</tbody>
</table>
9.5 Considerations beyond 2020

The possible introduction of new housing models & spaces for next standard design in Europe is quite desirable: the improvement of the energy efficiency of buildings, through an advanced thermal insulation, could be a major benefit to the energy saving potential as well as a valuable action to the reduction of the total CO$_2$ emissions from buildings.

**ESTEP** hopes for the implementation of active insulation material that is capable to work in both directions - cold & heat barrier – in order to achieve the aim of new efficient buildings;

**EUMAT** propose to make an effort in developing super insulation properties of cost-effective materials to minimize building Operational Energy/Carbon. Maximization of insulation/storage properties by at least 60% with respect to current best-performer building materials (e.g. thermal conductivity $< 0.001 \text{ W m}^{-1}\text{K}^{-1}$) with 50% cost reduction (including installation and maintenance cost) by 2050.
10 CP7 - Building materials recyclability and re-use of components

The cross-platform area CP7, named “Building materials recyclability and re-use of components” includes several targets and priorities towards 2020. A scheme of this cross-ETP research and innovation area is showed in the figure below.

Figure 26 – Scheme of CP7 targets and priorities

10.1 Current situation (State of the Art)

Existing building practices focuses mainly on the act of construction: at this time a little thought is given to the full life cycle of a building, both in a functional and environmental sense. Nowadays there’s fortunately a big interest in improving the sustainability of structures: reuse and recycling of the main components of residential and commercial buildings appear to be making continuous progress. The benefits of reuse and recycling of waste streams from building construction and demolition include diversion of waste materials from land fill sites and reduced depletion of natural resources. Both of these benefits contribute to sustainable development within building industry. Anyway there several barriers, both economical and technical, which are difficult to overcome: one of the main barrier to deconstruction process is that buildings are not designed to facilitate it. Most of them are constructed in a manner that does not allow for disassembly as a simple reversal process.¹⁹

¹⁹ Developing Guidelines For Designing For Deconstruction – Crowther – Queensland University of Technology, Brisbane Australia - 2000
Otherwise economic barriers include the need for rapid demolition and clearing of the site, the cost of separating the material to be recycled from contaminating materials and the relative economic advantage of disposal versus recycling. These issues and the role of the market are a driver for increased reuse and recycling of construction and demolition waste.

**State of the Art in Technology/Research:** The heavy fraction of demolition and construction waste streams is today 98% recyclable into granulates that can be applied in road construction and even to some extent in concrete. Overall, there is 95% recycling technologically possible but this should be cost-effective. For some materials a recycling approach seems to be impossible and ecological not suitable, e.g. plasticizers in concrete. The cradle to cradle approach seems to be possible but difficult, e.g. for plastics. Deconstruction is also not an art but rather a more complex job. Documentation of building materials components is not sufficient.

**State of the Art in non technical aspects (standards, commercialization, regulation):** The current situation is different among European countries. National codes and regulations try to push the subject but the quotas of recycling materials of individual materials and products differ a lot. There is a need for services to support recycling and re-use of building components & materials.

10.2 Targets by 2020
The following targets to be achieved by 2020 were identified:

1) **A reduction of the amount of down-cycling, considering cost and energy issues is required.** In fact, the quality of materials changes in a relevant way when it is recycled: not all products can be made into qualitatively equal products when they are recycled. Down-cycling process also reduces the number of times a product can be recycled: this is a particular problem with elements, like building components that are obliged to maintain high structural and high quality properties.

2) **Further implementation of recycling and re-use of materials and techniques in construction is needed.** In fact, minimizing the use of energy is a central task in a sustainable building, also reducing the use of natural resources and maximizing the recycling potential are other important tasks to take into consideration into the design phase.

3) **It is necessary to establish a standardized deconstruction processes and guidelines for existing buildings in order to provide useful tools for stakeholders.** Demolition of building structures produces enormous amounts of materials that in most countries results in a significant waste stream.

10.3 Research and Innovation Priorities

Improved recycling practices that utilize reused materials instead of virgin materials would significantly improve the environmental performance of the building sector, but it will be essential to follow several priorities to achieve those targets. In the figure below a scheme of the link between targets and priorities is showed.
10.3.1 Research and Innovation Priorities by Target

An improvement in reducing the amount of down-cycling can be done (Target 1) through putting efforts on the following topics:

- Development of solutions to recycle and re-use the light part of construction materials, including thermal recycling; Increase the uptake by the manufacturing chain;
- Research about the recyclability of different types of demolition products;
- Adoption of a clear description and documentation of materials used in buildings, comparable to automotive industry.

The following platforms propose to reach those targets through the actions described in the tables below.

**ESTEP**

- to put a lot of effort in analyzing and understanding the business model for re-use, in order to clarify the economical sustainability and technical feasibility of a different approach.
- to make a deep analysis on demolishing technologies for multi-material solutions and the development of modular systems and their connections for easy demolishing.
- To develop tool that can measure the amount of recycling/reuse and
give us an LCA value. The tool should be smart enough to account and credit the content of re-use in a design

**SUSCHEM**

- Need for studying high added value, sustainable solutions to recycle or otherwise process the light fraction of demolition and construction waste streams;
- Switchable adhesives allowing disassembly of adhesive bonded structures / assemblies
- Added-value construction products by using recyclable construction and demolition (RCD) materials: stony and other fractions
- Green cement/concrete development with less energy waste and less production costs

**TEXTILES**

- mono-component approach for building materials, Ecodesign methodology for recyclable building materials

**EUMAT**

- further consideration of Design for Destruction (DfD) (see LCA targets).
  The Waste Framework Directive specifies a 70% target by 2020. A 90% target by 2030 is considered achievable.

**FOREST TECHNOLOGY PLATFORM**

- The potential for and benefits from energy recyclability of renewable resources should be considered;
- Bio-based renewable building materials and components;
- Light-weight volumetric modular construction for improved reusability of buildings

The adoption of suited guidelines and processes for deconstruction and recycling/reusing materials (Target 2) are achievable through the following enabling factor:

- Better adhesives and other methods allowing disassembly of bonded structures / assemblies;
- Optimization of recyclability properties of materials for new buildings;
- Building concepts with high fraction of material replacement where needed; clear separation of functionality layers in buildings;
- Building concepts with very low resource input: low emissions recycling options.

The following platforms propose to reach those targets through the actions described in the tables below.

**ESTEP**

- To work for the implementation of unique deconstruction guidelines that could help in improving deconstruction processes according
standardized practices;

**SUSCHEM**

- To use more often switchable adhesives, that allow to disassembly of adhesive bonded structures
- Introduction of added-value construction products by using recyclable construction and demolition (RCD) materials, like stony and other fractions would be valuable

**TEXTILES**

- to promote recycling instead of downcycling, because the resulting product of downcycling is often of lesser quality

**FOREST TECHNOLOGY PLATFORM**

- A further development of biobased renewable building materials and components: some of the major factors that could influence the demand for bio-based products will be a limited availability and increased cost of fossil resources vs. renewable bio-based resources, also the policy development, in particular climate change mitigation, sustainable production and consumption
- A changing consumer demand based on the awareness of the need to ensure sustainable production and consumption.

There is a shared need to perform a wide adoption of deconstruction guidelines for existing buildings, because there’s a lack of knowledge among construction companies and designers, and also the structures itself often presents a lack of information about constituent materials (Target 3):

- Specific training to companies and end users in order to improve recycling and re-using skills and techniques;
- Information management and traceability (e.g. database of recyclable components and materials).

The following platforms propose to reach those targets through the actions described in the tables below.

**ESTEP**

- The implementation of demolishing technologies for multimaterial solutions, and the development of modular systems and their connections for an easy demolishing process;

**FOREST TECHNOLOGY PLATFORM**

- To raise the use of light-weight volumetric modular constructions in order to facilitate a better improved reusability of buildings.
10.4 Target Applications

Target applications for each technology are listed in the following table:

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>TARGET APPLICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction materials and components’ waste</td>
<td>All kind of load bearing structures, such for example:</td>
</tr>
<tr>
<td></td>
<td>- bridges and major infrastructures;</td>
</tr>
<tr>
<td></td>
<td>- houses and buildings;</td>
</tr>
<tr>
<td></td>
<td>Moreover, traditionally waste may be re-used in:</td>
</tr>
<tr>
<td></td>
<td>- construction of roads and road foundations;</td>
</tr>
<tr>
<td></td>
<td>- sports grounds;</td>
</tr>
<tr>
<td></td>
<td>- noise protection walls;</td>
</tr>
<tr>
<td></td>
<td>- earth banks;</td>
</tr>
<tr>
<td></td>
<td>- landscape construction;</td>
</tr>
<tr>
<td></td>
<td>- as aggregates in the concrete and stone production.</td>
</tr>
<tr>
<td></td>
<td>Finally, steel can be re-used in building components and also recycled.</td>
</tr>
</tbody>
</table>

10.5 Considerations beyond 2020

Less use of natural resources would be a wide adopted solution: a reduced use of imported goods will make home grown materials more valued. Timber and other plants such as hemp, flax and reeds will become increasingly important for use as building materials and in textile manufacture. The economic and environmental benefits derived from ecosystems, for example in water retention and purification, will be recognised, and opportunities for re-naturalising land to capitalise on this should be sought.

**EUMAT** believes that a possible mandatory requirement of 90% recycling of demolition wastes could be a leading factor to reduce the usage of natural resources.
11 CP8 - Renewable resource-based products to substitute non-renewable based products

The cross-platform area CP8, entitled “Renewable resource-based products to substitute non-renewable based products” takes account of several targets and priorities towards 2020 and a consideration about long term actions. A scheme of this cross-ETP research and innovation area is described in the figure below.

![Figure 28 – Scheme of CP8 targets and priorities](image)

11.1 Current situation (State of the Art)

A renewable resource is something “that is grown, naturally replenished, or cleansed, at a rate which exceeds depletion of the usable supply of that resource.” The length of time needed to replace a renewable resource can vary greatly depending upon the resource: for example, it can take 30-100 years for a tree to mature while bamboo can be harvested in as little as 7 years. Rapidly renewable resources are defined as those that can be replaced within 10 years. Bamboo, linoleum, and cork are just a few of the more common examples of rapidly renewable resources.

The key point for building’s sustainability is based on a more efficient and responsible use of resources. It is necessary to start including renewable and recyclable materials instead of petroleum based products in the construction value chain. The development of biomaterials is crucial to support industries in closing material loops. Advances have
been made in developing biodegradable foams, resins from vegetable oils, and biopolymers for making plastics.\textsuperscript{20}

**State of the Art in Technology/Research:** Non-renewable construction materials such as mineral or fossil based materials today dominate the market. Materials based on renewable resources are primarily wood or natural fibre based, the use of which are currently slowly increasing. The increasing interest can be attributed to the renewability as such but also to the fact that they act as carbon sinks and reduce the CO\textsubscript{2} in the atmosphere. An additional benefit is also the fact that at the end-of-life of the building or product, energy recycling is an efficient alternative for renewable resources. The potential in the building industry for further renewable resource-based materials is huge, as construction and sheathing materials and insulation, but also as bio-based adhesives and surface treatments and as bio-energy.

**State of the Art in non technical aspects (standards, commercialization and regulation):** Up to date, there are no economic incentives for choosing materials that result in lower CO\textsubscript{2} emissions in the production phase of a building. There is also a lack of suitable standards (covering such areas as the determination of bio-based content and environmental impact) was identified as a factor hindering market uptake both by consumers and in public procurement. Two standardisation mandates were issued: in 2008 as a direct result of the LMI action plan:
- Mandate 52/2008 for the programming of standards for all types of bio-based products
- Mandate 53/2008 for the rapid elaboration of pre-standards for bio-lubricants and Biopolymers.

The LMI aim was to develop Technical Specifications as an interim measure and convert these into full European Standards (ENs) subsequently.

11.2 Targets by 2020

The following targets were identified:

1) Availability of renewable (bio-based) construction materials and systems as alternatives to fossil and mineral based products for sheathings as well as advanced insulation products with improved performance and cost-effectiveness;
2) Accessibility of bio-based treatments such as paints, adhesives and modifications for high performance renewable products.

11.3 Research and Innovation Priorities

Targets previously mentioned need to be strictly linked with specific priorities, with the aim of associating detailed matters required for filling the gap between actual situation and future condition.

A scheme of those connections is described in the figure below.

\textsuperscript{20} Bio-Materials in the Construction Industry - B.VanderHeyden - University of Florida
11.3.1 Research and Innovation Priorities by Target

A cost-effective improved material with advanced properties (Target 1) can be implemented through working on the following issues:

- Creation of new value chains considering the complete life cycle (possibility of re-using etc.);
- Optimization of natural fibres for insulation in order to ensure durability;
- Advanced research on biotechnology and new bio-based materials such as plastics for barriers, pipes etc and foams for insulation;

The following platforms propose to reach those targets through the actions described in the tables below.

**SUSCHEM**

- To invest on bioplastics based on wood as renewable feedstock, combined with possible breeding of optimal tree species to offer optimum feedstock for such processes. For example ‘liquid cellulose’ is today used to produce viscose
- Use of materials reinforced by wood based renewable fibres delivering a 100% renewable feedstock composite
- Improvement of sandwich structures combining steel sheet with bioplastic core materials could be helpful, also with the introduction of
a wood combined with bioplastics as sandwich structures or using the bio-based resin for coating of such wooden structures

- R&D activities should be performed to acquire information on several topics: about the disassembly of multimaterial structures allowing their high-end recycling or reuse, about surface chemistry R&D on interfaces between the different materials (steel-bioplastic, wood-bioplastic); about bio-based flame retardants for use as additives in polymeric materials; about eco-friendly Biocides for the protection of bio-based products.

**EUMAT**

- To lower the use of non-renewable resources (e.g. fossil energy carriers) by increasing recycled content (e.g. use of paper fibres) up to 90% (currently quite high), shifting towards renewable resources (e.g. bio-based materials, being low in embodied energy, renewable and/or biodegradable).
- To increase recycling potential for products with non renewable elements could be useful to achieve the target.
- To increase efficiency and lowering environmental impacts of production processes

**FOREST TECHNOLOGY PLATFORM**

- To insert in the building value chain forest (and agriculture) based industries as suppliers of raw materials and products for the construction materials industry
- Need to agree on methodology and system boundaries so the benefits of the renewable resources will be included

### 11.4 Target Applications

Target applications for each technology are listed in the following table:

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>TARGET APPLICATION</th>
</tr>
</thead>
</table>
| Renewable resource-based products | - All kind of wood products: walls, roofs, etc.;  
- All kind of clay products: bricks etc.;  
- Insulating products in general. |

### 11.5 Considerations beyond 2020

Design feasibility of economically and competitive buildings made of renewable resources are needed: in fact, in next year non-renewable resources will gradually substitute renewable resources up in order to achieve a zero-emission status for new buildings.

Wood-based construction materials will be widely used, helping the built environment to highly contribute to reduction of 80% of CO\textsubscript{2} by 2050, extending the carbon storage role of forests by providing a further storage period in products and at the same time replacing other (energy or carbon intensive) construction materials. For example,
replacing cement or steel with a cubic meter of wood would result in saving about 1.1 tonnes of CO2 emissions. New wood construction techniques allow for solutions not seen before. At the end of their service life, wood products are reused or recycled, before being used as a carbon neutral fuel.\textsuperscript{21}

\textsuperscript{21} The Forest Fibre Industry: 2050 Roadmap to a low-carbon bio-economy; CEPI
12 Non technological cross-cutting targets

A few set of non technological cross-cutting targets, i.e. issues that address broad challenges going beyond the specific area of each cross-platform.

The following table reports the identified targets. **More cross-cutting targets may be added.**

### Table 12– Cross-Cutting Non-technological Targets

<table>
<thead>
<tr>
<th>Title of the Target</th>
<th>Description</th>
</tr>
</thead>
</table>
| Approach of EU wide improvement of building stock | The approach consists of different parts:  
• Extend the warranty for new buildings to 15 years by regulation. This already will force construction companies and building owner to invest into sustainable buildings.  
• Set a standard for the sustainability of buildings, this includes a recycling quota for all materials, the need to describe and define the materials used in all individual buildings in a repeatable way, define the way materials have to be recycled (as much as possible cradle-to-cradle).  
• Install a tax system that produces a profit for low emission buildings, like with cars, and that provides significant benefit for maintenance work.  
• Install a best practise platform where companies can learn about maintenance approaches and recycling possibilities. |
| Smart housing management | As we have the smart phone and TVs, we may have a “smart house”, with the following features:  
• it is up to date in terms of energy efficiency (runs itself efficiently by switching on and off different appliances as fit);  
• it takes care of its residence by monitoring the healthcare and able to communicate to the relevant bodies. This is important with the aging population and the strain on the health care  
• once it detects the possibility of fire, it deals with it by cooling the area or switching off other areas such as electricity and also contact the fire brigade without the intervention of humans. |
| Clustering Activities on Energy management (harvesting/generation/storage) in building of the future | Energy management/storage/harvesting/generation solutions will be investigated in different and separated projects consortia and it will be suitable to put in place an overall platform/network who will manage the different |
breakthroughs in this area and study how to manage in global point of view these alternative energies (smart grid, domotic, software embedded...)
13 Expected Impact

13.1 Overall Economic, Social and Environmental Impact

The construction market accounts for 6 to 10% of EU’s GDP (depending on the source) and with at least 2.9 million companies (around 15 million operatives or 7% of EU workforce), it is the biggest industrial employer in the EU.

The built environment is responsible for 42% of total EU final energy consumption and produces about 35% of all greenhouse gas emissions. More than 50% of all materials extracted from earth are transformed into construction materials and products.22 Moreover, the world population is over 6 billion people and is projected to increase by 50% to 9 billion people by 2050. As the population grows, so will our energy requirements. Finally, the expected improvement in the standard of living in the emerging economies will again lead to a higher energy demand.23

Key Figures of the construction in Europe24:

- Estimated construction investment (EU 27 - 2009) : 1.173 billion €
- 9,9 % of GDP
- 51,4 % of Gross fixed Capital Formation
- 3 million enterprises (EU 27), of which
  - 95% are SMEs with fewer than 20 and
  - 93% with fewer than 10 operatives
- 14,9 million operatives:
  - 7,1 % of Europe’s total employment
  - 29,1 % of industrial employment
- 44,6 million workers in the EU depend, directly or indirectly, on the construction sector

The figures above show how construction activities are of major importance for the European economy and the environment in general. Meeting the environmental sustainability criteria and contributing to the competitiveness of the EU economy by making it more energy and resource efficient are the key challenges the sector has to face today and in the future.

The construction market focusing on the building sector is divided into two big market segments: residential and non-residential. Besides, an important distinction exists between the construction of new buildings and the refurbishment of existing ones. The latter representing a huge market potential both domestically and internationally. Furthermore SMEs are at the core of this two market segments, representing the majority of enterprises mainly working at national and local level.

Developments in the construction sector, further than bringing positive outcomes to the all value chain, including both basic manufacturing and supply of construction materials

22 http://ec.europa.eu/enterprise/newsroom/cf/_getdocument.cfm?doc_id=5417
23 Energy technology perspective - Scenarios & Strategies to 2050; IEA 2008
24 http://www.fiec.eu/
and several knowledge-intensive private/public services, also have a significant indirect impact on the growth in other sectors of the economy. The figure below shows the number of people employed in the construction sector (including infrastructure) by MS in 2006.

![Graph showing the number of people employed in the construction sector by Member State in 2006.](image)

**Figure 30 – Total number of people employed in the construction sector by Member State in 2006 (Source: Eurostat)**

**Building Up** project will promote the European knowledge in the built environment and boost the industrial competitiveness of the construction sector and the interconnected sectors.

The project is well aligned with E2BA Roadmap priorities to complement the EU pathways in supporting energy savings in buildings and districts and preparing the building sector (technology manufacturers, construction companies and energy utilities) to be in line with the [2050 decarbonisation goals](http://ec.europa.eu/energy/energy2020/roadmap/doc/com_2011_8852_en.pdf) for the European Economy.

Moreover, the project will contribute to the priorities in the upcoming “Horizon 2020” specifically regarding Industrial leadership (“Technologies enabling Energy-efficient buildings”) and Societal Challenges such as “Health, demographic change and wellbeing; Secure, clean and efficient energy; Climate action, resource efficiency and raw materials”.

### 13.2 Example of target stakeholders and end-users

The target stakeholders and end-users of the technologies and products to be developed through Building Up roadmap may be summarized as follows:

- Civil engineers, architects and designers, including interior designers;

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- Building contractors, dealers, wholesalers and building workforce;
- Wood & paper industries, chemical industry, steel industry and suppliers of raw and advanced materials and components;
- Integrators of building components and systems;
- Public Authorities, building inspectors and consultants (e.g. for air quality testing systems);
- Building owners, tenants;
- Occupants of residential, public, commercial and industrial buildings in urban and rural areas;
- Civil Society at large.

13.3 Example of target markets addressed by the CPs

Each Cross-Platform areas will have an impact on several markets which have been identified with the help of ETPs experts.

The table below summarizes the target markets and expected benefit identified for each of the Cross-Platform areas.

<table>
<thead>
<tr>
<th>TARGET MARKET</th>
<th>REFERENCE CROSS-PLATFORM AREAS</th>
<th>EXPECTED BENEFIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Construction industry (including eco-construction, green, recycled building materials and renewable source-based building materials)</td>
<td></td>
<td>The development and release of target products/applications/services described in CP1, CP7 and CP8 would increase the technological competitiveness of EU industry and would involve a wide range of SMEs from different sectors (including Steel, Wood &amp; Paper and Chemical sectors) as suppliers of materials and components. In particular CP7 and CP8 products will help towards addressing the Societal Challenges “Climate action, resource efficiency and raw materials”, re-using the construction waste and increasing the usage of recyclable and sustainable products. This “eco” added value will increase with time and give European companies a quality advantage to other countries. The percentage of ecological products will depend on the market situation but as seen in Germany with the passive house standard it can increase in short time from some percentages to 30%.</td>
</tr>
<tr>
<td>Composite materials</td>
<td>CP2 - Multi-material composites</td>
<td>CP2 target technologies and products will highly contribute to address the Social challenge “Climate</td>
</tr>
</tbody>
</table>
## Deliverable D3.1

### Market

<table>
<thead>
<tr>
<th>Deliverable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CP3 - Healthy indoor environment</td>
<td>One of the main and radical advantages of CP3 approach and developed technology/solutions is that it actually gives feedback of the indoor air quality and its implications to human health, not just by using theoretical estimations without any true feedback of their relevance. This approach will give HVAC-system and lighting systems development totally new insight and performance characteristics. <strong>Details on more benefits for HVAC systems and lighting might be added.</strong></td>
</tr>
<tr>
<td>CP4 - Electric generation and storage materials and systems</td>
<td>CP4 target technologies and products will highly contribute to Societal Challenge “Secure, clean and efficient energy” with solutions for efficient and sustainable electric energy generation, storage and distribution system. <strong>To be detailed if needed.</strong></td>
</tr>
<tr>
<td>CP5 - Thermal generation and storage materials and systems</td>
<td>CP5 target technologies and products will highly contribute to Societal Challenge “Secure, clean and efficient energy” with solutions for efficient and sustainable thermal energy generation, storage and distribution system. <strong>To be detailed if needed.</strong></td>
</tr>
</tbody>
</table>
| CP6 - Advanced thermal insulation construction materials for new buildings and existing buildings | CP6 target technologies and products will highly contribute to Societal Challenge “Climate action, resource efficiency and raw materials”. Future advantages of improved insulation materials will be:  
  3. **better insulation at same thickness:** important for space restricted applications like cavity wall, refrigerated transport, ..  
  4. **thinner insulation layers at same U-value:** this is important for architectural aesthetics, less material (energy) bound in the insulation, reduced transport volume. Durable and well performing new insulation materials will replace existing insulation; hence the market share will shift; construction market is very conservative and adoption times of >8yrs have to be expected. This area will also increase the involvement in the construction sectors of industries and SMEs from |
different sectors (including Steel, Wood & Paper and Chemical sectors) as suppliers of materials and components.

A brief overview is given for each of the target market identified.

13.3.1 Construction industry (including eco-construction and green building materials)

More than 50% of all materials extracted from earth are transformed into construction materials and products. Eco-construction focuses specifically on the sustainable dimension by reducing the natural resource requirements (energy, but also water and land) and the overall environmental impact of buildings. In principle, eco-construction starts with design and ends with demolition and recycling. Life-cycle assessment encompasses the assessment of raw material production, manufacture, distribution, use and disposal including all transportation. Eco-construction also requires a high degree of integration in architecture, design, construction, and building systems and materials. Potentially huge market potential lies in retrofitting the existing building stock according to modern standards.\(^{27}\)

The market for building information modeling (BIM) software and services is still nascent, but evolving rapidly. Some EU governments are taking steps to implement BIM: for example, in the UK, the government has a dedicated minister pushing BIM in public projects. In fact, BIM software and processes have evolved to allow new ways of collaboration, work sharing, and virtual design capabilities that serve to reduce costs for building owners and add visibility to the overall design and construction process. With this added visibility and upfront understanding of a project’s detailed characteristics, building owners and operators are realizing that the lifecycle costs of a building can be significantly reduced.\(^{28}\)

The recycling quota for construction and demolition waste is on average to be increased significantly: for example a 70% increase in recycling of mineral waste is targeted for 2020 in the 25 EU. In construction the readiness to recycle differs remarkably in Europe and depending on the materials (mineral waste, polymer, composite or metal-based waste). Altogether approximately two thirds of the waste are produced in the fields of construction, demolition, mining and extraction of stones and earths. This waste consists predominantly of mineral waste. Thus it is the aim to produce high-quality construction products of construction waste in the sense of a closed cycle.\(^{29}\)

13.3.2 Composite materials market

Global composite materials market (fibers, resins, etc.) is expected to reach $19 Billion in 2011\(^{30}\). The global construction industry represents several trillion dollars. Given the size of the market and its prospects for further expansion, the construction

\(^{27}\)http://ec.europa.eu/enterprise/newsroom/cf/_getdocument.cfm?doc_id=5417


industry represents an attractive opportunity for OEMs, material suppliers and component suppliers.

Figure 31 – Worldwide market in tons of composite materials. Total market: 4.6 million tons. (Source: Owens Corning\(^{31}\))

13.3.3 “The Comfort” Market

The Comfort market is a complex market that may market include: (1) analytical equipments and human physiological diagnostics; (2) acoustics and thermal comfort, including HVAC systems and (3) lighting systems.

13.3.3.1 Analytical equipments and human physiological diagnostics

One of the main challenges in indoor air today is the very limited building indoor air “testing” system: currently we rely mainly on theoretical estimation of indoor air quality based on individual product testing, performed just after products came from the production line. However, the indoor air harmful and healthy components arise from diverse sources outside the original construction materials throughout the lifetime of the building. Consequently, to ensure truly healthy indoor air and environment it is mandatory to start developing meaningful testing and measurements of actual in-situ indoor air and its implications to human health.

Air quality consulting and testing services were estimated to be around $2.7 billion in 2011 in US, with an estimated 10% AAGR over the next 5-year period. Environmental services, including mold remediation, asbestos abatement, and radon mitigation reached around $2.9 billion in US n 2011.

Currently, the end-use markets with the biggest potential for applications of IAQ (indoor air quality) equipment and services include residential dwellings, commercial buildings, schools, and health care facilities. The commercial segment was the largest market for IAQ equipment and services, accounting for 26% of the market in 2005, followed by schools (22%), residences (19%), and health care facilities (17%).\(^{32}\)

13.3.3.2 Acoustic and Thermal Comfort, including HVAC

In today’s competitive economy, worker productivity is critical to success. A great deal of new technology is devoted to improving productivity, but one of the simplest and most obvious factors is often overlooked – noise. According to the American Society of

\(^{31}\) http://www.compositesconsultants.com/Other/Economics%20of%20Composites.pdf
\(^{32}\) http://www.bccresearch.com/report/ENV003B.html
Interior Designers (ASID), Washington, D.C., an industry-sponsored study showed that more than 80 percent of the workers surveyed believed they would be more productive if their workspaces were quieter. Their belief was confirmed: When noise was reduced, productivity measurably improved. Moreover, acoustic comfort is fundamental also in residential buildings and public facilities such as schools, hospitals, hotels, where a quiet environment is required for the comfort and health of the inhabitants, clients, children or patients. Governments are tightening up legislation on noise pollution and local residents are being more vociferous in seeking a quieter environment.

Wiring, telecommunications, traffic patterns, even air delivery routes are all clearly visible on blueprints or engineering plans. Acoustical issues and potential problem areas are not that easy to see. The planning stage is the best time to consider these problems and address them cost-effectively. For example, it is fairly economical to design an air-handling system to minimize unwanted noise, but once the space is built, options are much more limited and solutions more costly.

No clear economic data were found on the market related to noise control and acoustic comfort management but it is clear that this activity relates to different applications, that goes beyond HVAC systems. Examples of applications of markets for acoustic comfort management within the building industry are: buildings in general (from design to construction, use and demolition), acoustic ceilings and wall absorber systems, flooring.

Regarding the thermal comfort, for decades, surveys of building occupants have shown their biggest complaint about their workplace is the lack of a comfortable thermal environment. More recent surveys of office building occupants confirm that this long-standing complaint is unchanging. A recent survey shows occupants consider the two most important elements in a workspace to be thermal comfort and air quality. The same survey shows that lack of occupant control and lack of adequate comfort constitute the two largest complaints occupants have about their buildings.33 The market of thermal comfort includes smart design of buildings and building components, efficient insulation and ventilation systems. One of the main pillar of thermal comfort is an efficient HVAC system.

The worldwide HVAC equipment market is estimated to be 150 billion€ per year, with Europe accounting for more than 50 billion€ per year, including HVAC cleaning services. Global demand for HVAC equipment is projected to rise over 6% a year through 2014 to more than US$88 billion, according to the latest ‘World HVAC Equipment’ report from Bharat Book Bureau. Approximately 40% of the global market is covered by HVAC for commercial buildings, where cooling equipments will continue to outpace heating equipments. Demand will benefit from recovery in the key US market, which will rebound from dismal levels in 2009. Demand in the Asia/Pacific region will also outpace the global average, increasing 6.6% a year through 2014. China will be the fastest-growing national market, and comprise the largest share of global demand growth through 2014. Above-average growth will also occur in India due to solid gains in the number of households and rising per capita incomes.34

Heating, Ventilation, and Air Conditioning (HVAC) systems represent almost 33% of the energy use in commercial facilities (14% space heating, 10% space cooling and 9% ventilation). In this framework, the European Multi-Annual Roadmap and Longer Term Strategy, released in the framework of the Energy-Efficient Buildings Public Private

33 http://automatedbuildings.com/news/jul00/articles/hartman/hrtmn.htm
Partnership initiative, set as a priority target to reduce the primary energy usage for heating and cooling by a factor 2 from 2020 onwards.

The global lighting market is expected to have revenues of around EUR 110 billion in 2020, with 6 percent and 3 percent p.a. growth from 2010 - 16 and 2016 - 20, respectively, based on McKinsey’s Global Lighting Market Model.

![Global lighting product market trend](Source: McKinsey’s Global Lighting Market Model)

**Figure 32 – Worldwide market for lighting (Source: McKinsey’s Global Lighting Market Model)**

### 13.3.3.3 Lighting

General lighting is the dominant market, with total market revenues of approximately EUR 52 billion in 2010, which represents close to a 75 percent share of the total lighting market. This is expected to rise to some EUR 88 billion by 2020 – approximately 80 percent of the total lighting market. The general lighting market has two key drivers. The strong growth in construction investment in emerging countries is one. The second is the greater penetration of higher priced light source technology, including LED, which raises the average price of lighting products. The next generation of technology, OLED (Organic Light Emitting Diode), could be a really technological breakthrough in this business area with two main features: a very low energy consumption and a great adaptability (flexible display etc.). One of the main issues of this emerging technology is to reinvent the lighting management into building because this device can be used also for flexible and flat surface. Therefore, new ways of integration of such solutions should be found, in order to improve the energy efficient of the building.

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35 Lighting the way: Perspectives on the global lighting market. McKinsey & Company
13.3.4 Photovoltaics, and electricity storage for buildings

With almost 22 GW of grid connected PV installations in 2011, Europe has increased its cumulative capacity base by over 50% compared to 2010. Figure below shows how the 2011 market was shaped, distinguishing among ground mounted, commercial and industrial rooftop, and residential applications. Overall a very large share of the market in Europe is concentrated in the commercial rooftop segment; this trend will continue, based on the foreseen evolution of the legal framework.  

Building-integrated photovoltaics (BIPV) currently make up a small but noticeable part of the world PV market. The global market was valued at 1,201 megawatts in 2010 and is expected to increase at a 56% compound annual growth rate (CAGR) to reach a capacity of 11,392 megawatts in 2015. BIPV roofing is the largest near- and mid-term market segment. The global market for BIPV capacity in the roofing sector was 404 megawatts in 2010 and is expected to reach 3,197 megawatts in 2015, a compound annual growth rate (CAGR) of 51%. The market for architectural fabrics may be very large and expanding, but the rate of adoption of BIPV elements will be slow for a period of time. This sector had a capacity of .2 megawatts in 2010 but is expected to increase at a 670% compound annual growth rate (CAGR) to reach a capacity of 5,439 megawatts in 2015.37

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The total global utility-scale electricity storage (UES) market is valued at nearly $4 billion in 2010 and is expected to reach $18.5 billion by 2015, at a 5-year compound annual growth rate (CAGR) of 36.6%. Total UES market volume is lead by the Asian/Australian market, which will surpass $7 billion annually by 2015, an increase over the 2010 value of $2.7 billion, reflecting a 5-year compound annual growth rate (CAGR) of 21.7%. The most significant jump in UES markets is expected in the North American market, which is anticipated to leap from a 2010 market size of $272 million to more than $6 billion by 2015, at a compound annual growth rate (CAGR) of 86.2%.  

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13.3.5 Thermal generation and storage material and systems

Every year, almost 50% of the total energy consumed in Europe is used for the generation of thermal energy for either domestic or industrial purposes. In residential buildings, approximately 80% of the energy used is required for space heating & cooling and sanitary hot water. In this context thermal generation and storage systems based on renewable sources appear promising to address energy needs while overcoming current resource challenges. From a commercial point of view, in a global market, the main competitive strength of the European Renewable Heating & Cooling industry is the high quality of its products.

In 2010, the European solar thermal market totalled 2 586 MWth (3 694 940 m²) of newly installed capacity, decreasing by an estimated 13% in comparison with 2009. Although it is the first time in over 10 years that the market has declined in two successive years, it still remains above the 2007 level. The effects of the 2008/2009 financial crisis are still being felt with very low renovation rates and collapse of new build developments, preventing the solar thermal sector from taking full advantage of the European trend towards more demanding standards for the energy performance of buildings.39

Key facts:
MARKET 2010 (EU-27 + Switzerland):
- Newly Installed: 3.7 Mio m² / 2.6 GWth;
- Total installed: 34 Mio m² / 24 GWth;
- Heat produced: 1.5 Mtoe / 17 TWh.

The biomass heat market share in Europe should rise from 11% in 2007 to about 25% in 2020, even considering the reduction in heat demand. In 2007, about 35 Mtoe of biomass have been used for grid independent supply of energy to households and services within EU-27, which make it the dominant application for bioenergy, and more largely for renewable energy in general in Europe.40

Key facts:
MARKET 2010 (EU-27):
- Newly Installed: 16.9 GWth;
- Total installed: 393 GWth;
- Heat produced: 61 Mtoe / 712 TWh.

Currently geothermal energy sources provide about 24 GWhth for heating and cooling in the EU, equivalent to 2.1 Mtoe per year, whereby geothermal Heat Pump systems contribute to the largest part. In the EU 27, the installed capacity in 2020 will amount to around 50 GWth installed corresponding to a contribution of more than 10 Mtoe.41

Key facts:
MARKET 2010 (EU-27):
- Newly Installed: 2.7 GWth;
- Total installed (with GSHP): 15 GWth;
- Heat produced: 2.8 Mtoe / 33 TWh.

40 Strategic Research Priorities for Biomass Technology, RHC Platform
41 Strategic Research Priorities for Geothermal Technology, RHC Platform
13.3.6 Insulation construction materials

Insulation is an integral part of the overall design of buildings. Global demand for insulation materials as a whole is expected to expand by 3.8% annually to reach €29 billion by 2012: the demand may be segmented in foamed plastics, mineral wool, fibreglass and other types of materials (see figure below)\(^\text{42}\).

![Figure 37 - Global market segmentation for insulation construction materials (Source: ObservatoryNANO)](image)

Coherently, recent studies report that the worldwide demand for building insulation is expected to increase an average of 5% per year through 2014 to nearly 23 billion square meters of R-1 value. In this framework more than 40% of all new global insulation demand between 2009 and 2014 will occur in the Asia/Pacific region. Insulation consumption in the region is forecast to increase almost 6% annually due to advances in process manufacturing, appliance shipments, and residential and nonresidential building construction. China alone will account for 29% of all new global insulation demand between 2009 and 2014 \(^\text{43}\).

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14 Funding of the CP areas: expected cost

DAPP: Here we may want to give % on the expected cost for each CP and for cross-cutting actions. For example CP2 may require a larger percentage of funds with respect to CP3. This topic will be discussed during the workshop, in the afternoon session.
15 Conclusion

The current document was the result of activities performed within the framework of WP3 “Definition of a cross-platforms long term research and innovation roadmap“, and more specifically of Task 3.2 “Definition of a long term Research and Innovation Roadmap“.

The Roadmap will be validated through a validation meeting in September-October 2012 ((Deliverable D4.4).

To be extended if needed by– DAPP & E2BA
Appendix I – List of Contributors

The list of contributors will be included in the final version of the Roadmap.