# Increased use of wood in urban areas
# - WOOD/BE/BETTER

## 1. Relevance relative to the call for proposals

The consortium responds to the call by establishing an interdisciplinary group of architects, engineers, wood technologists and mycologists. They will help to increase the urban use of wood by defining the building categories and typologies that will be in great demand in future city regions. The team will then clarify the potential for large-scale application of wood-based solutions in these buildings.

Focus will be put on construction systems and envelope designs that are safe, robust, adaptable and easily integrated into architecture of a high and sustainable quality. Use of wood should be linked to visions of a better urban future.

Key knowledge needs are defined, and will be subject to interdisciplinary research in work packages and Ph.D. dissertations. Dissemination is inherent in the broad organization of the project, and will be followed up by scientific publication and initiatives aimed at users in education systems, forest owners associations, industries, housing businesses and cooperative building associations.

The BIONÆR program asks for integrated perspectives on bioeconomic value-chains and resource cycles since both the systems for production, systems for processing and end use needs to be understood. To facilitate this, the present project is coordinated with the UMB / NFLI initiative for sustainable and optimal resource utilization. Fig. 1 illustrates main themes and integrated value chains in the two research projects.

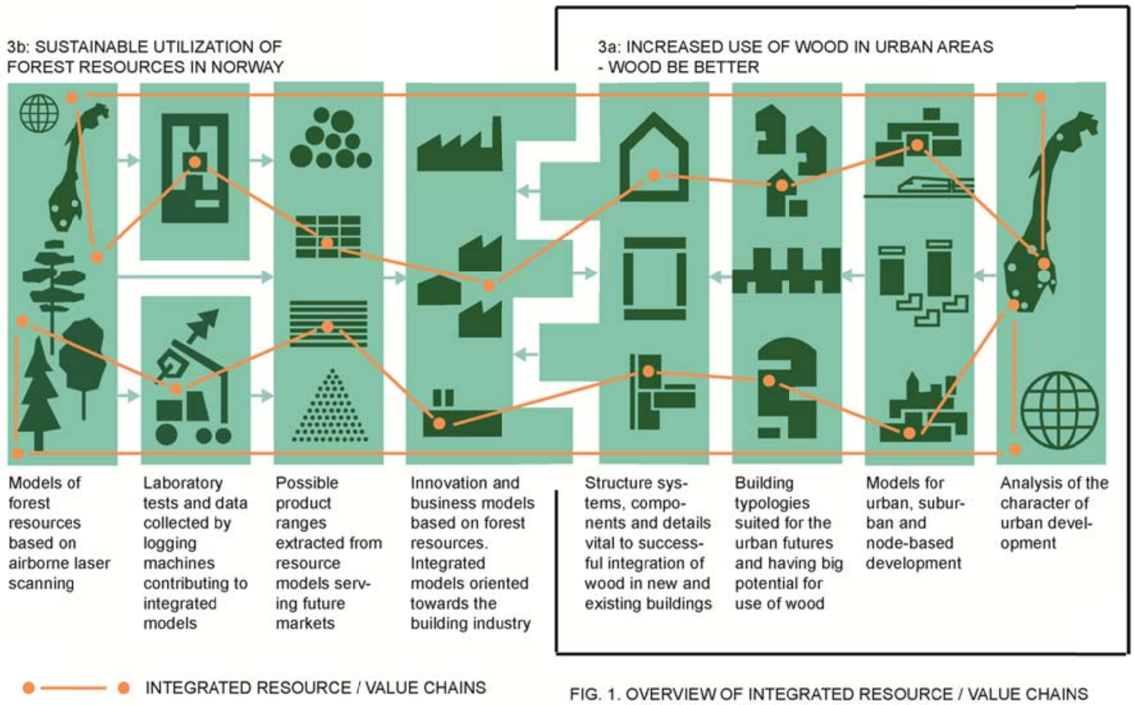


FIG. 1. OVERVIEW OF INTEGRATED RESOURCE / VALUE CHAINS BRIDGING BIONÆR PROJECT BORDERS

# 2. Aspects relating to the research project

## 2.1. Background and status of knowledge

### Urban applications of wood in a global, climatic perspective

Increased use of wood in the building industry is positive from a carbon sequestration point of view. The effect will increase with more efficient use and increased use of local wood resources. Since wooden products store carbon until they are burned or decomposed, a prolonged service life and reduced maintenance is of great importance for the total environmental- and climate impact. The building sector represents some of the most important material transformations in the society. Hence, the utilisation of renewable resources in buildings, especially materials that store carbon, will play a significant role in the sequestration of carbon.

Heavier rainfall, hurricanes, duration of floods, rise in sea level and extreme weather incidents are likely to increase due to global warming (IPCC 2007). This will certainly affect building environments and increase the proportion of buildings with moisture problems (EPA 2008, Mattson 2007, WHO 2009). The environmental effect of activities in the forest-based value-chain is analysed in the on-going Norwegian KlimaTre (ClimateWood) project. The present project will implement the results from KlimaTre and utilize the information and methodology in design. The building sector requires huge material transformations. Wood buildings of a high technical and architectural quality will maintain their value and store carbon for a long time.

### Urban growth patterns, the demand for buildings and the potential for use of wood

(Related to work packages 1, 2 and 5)

The accelerating movement of domestic population and immigrants into the Norwegian city regions is well documented in official statistics and prognoses. By 2040, a recent and dramatic forecast of 310,00 new inhabitants in the Oslo region shows that housing will play a major part in urban development (Oslo kommune 2012).

The urbanizing areas, both globally and in Norway, are typically located in mild coastal zones that are exposed to wind, humidity and driving rain (UN-Habitat 2009). These factors are enforced by climate changes, raising the risk of rot in constructions (Kvande et al. 2012). This requires a better understanding of the building physics of wood-based solutions.

Models and principles for sustainable urban growth in Europe and North America implies that densification and refurbishment of city centers, suburbs and regional transportation nodes must take place, but with solutions adapted to the different urban situations.

A growing number of architectural competitions, pilot projects and large-scale developments show solutions that are relevant to these project types. Norwegian examples are Brøset in Trondheim, the Future Built projects in Drammen and Oslo and the Norwegian Wood projects in Stavanger. They show that high-density urban patterns with building structures in two to eight storeys are optimal in a large variety of project types. They are suitable for housing as well as commercial, cultural and public functions.

Most importantly, these building types may also be easily adapted to wood constructions. Development of massive timber elements has been seminal. New Norwegian building codes for universal access will lead to water-based fire control systems in most multi-storey buildings. This will expand the field for wood-based solutions. In ”Trebyen Växjö”,Sweden, relevant projects have been built. European studies indicate that similarities in national technology development and market penetration will give the Norwegian solutions international relevance (Jonsson 2009). Cooperation, especially with Sweden and the UK/Ireland, should be mutually beneficial. The presence of many climate zones in Norway is an advantage related to international cooperation and marketing of skills and products.

Detailed studies of life cycles and climate gas emissions in entire buildings have generated knowledge about the volume and weight of the different building subsystems. Many more materials are put into the floor slabs, partitioning walls and building envelope than into columns, beams and frames. Well-integrated wood-based systems are needed to achieve a significant increase in the use of wood in urban areas. Emphasizes have to be put on integration of wood research into the development of safe, robust, adaptable solutions, which should be tested systematically as platforms for architectural design of urban quarters and individual buildings for varied functions. A holistic, architectural and system-oriented approach will not overlap, but interact in a productive way with on-going research, innovation programs and regional initiatives for pilot projects.

Available knowledge and products need to be integrated in principal, holistic solutions that are simple and reliable in relation to fire protection and sound insulation. They must offer platforms for differentiated architectural exploration and systematic studies of technological improvements. Studies within these themes will not overlap, but interact in a productive way with on-going research, innovation programs and regional initiatives for pilot projects. Convincing, wood-based architectural solutions for whole buildings and areas are needed to expand the acceptance of wood as an urban building material.

Interdisciplinary interaction is required both in research and in education to achieve a rapid spreading of knowledge to all participants in design and construction processes. Key decision points for choice of materials must be defined within the design processes. Information needed for innovation in integrated value chains must be extracted from the research. Information with relevant content and format should be defined and developed to support wood alternatives.

### Marketing

(Related to work package 5)
Any change in building practice will be implemented through specifiers (architects and engineers) as well as the contractors that construct the buildings. Accordingly, it is critical to have an in-depth understanding of their knowledge and perceptions of wood as a building material. Basic principles of marketing dictate that knowledge of customer needs is an essential starting point for any product development or product adoption process (Hansen and Juslin 2011). Clarification of the potential for large-scale application of wood-based solutions in future urban buildings must come directly from the marketplace.

Previous studies show that harmony of visual surfaces is correlated with preference (Broman 2000). Nyrud et al (2008) found homogeneous visual appearance to be preferred by consumers. Høibø and Nyrud (2010) found in a study on decking that homogeneity is influenced both by wood properties and treatment, and concluded that producers of decking should maintain a focus on high quality materials, but also focus on producing products with an unstained appearance which will give a more harmonic appearance.

Since harmony is of importance, it is expected that quality of a single board is important, but more important is how the material functions in a building element such as a façade. We believe it is critical to obtain more in-depth information regarding consumer preferences of different building elements. It is valuable to know more about how consumers perceive and prefer building elements and façades that architects consider to be aesthetically good. It is also important to apply this methodology not only on visual perception but also more principle and fundamental aspects of quality in buildings.

## Wood in the structure systems of future urban buildings

(Related to work package 3)

In order to increase the use of wood in urban buildings it is important to develop integrated systems linking the architectural expression with the structural function. Connections of components of timber building systems are among the major challenges since they are complex and time consuming to install. It is also difficult to obtain sufficient rigidity in such systems. The recent development of sophisticated, self-tapping screws will facilitate assembly and calculation of structural systems in wood (Echavarria 2007, Lie 2011, Buene 2009). The benefits are a more direct transfer of forces and increased stiffness due axially loaded screws instead of bending of bolts, dowels and fittings (Blass et al. 2006). Eurocode 5, Timber Engineering has limited rules when it comes to axially loaded screws. Such screws in combination with perpendicularly mounted screws might give sufficient strength and stiffness in frame corners. Screws are also hidden in the timber, and therefore considerably more fire resistant than fitting-solutions. Screws may also be used in conjunction with reinforcement of holes in the wood, and where stress occurs across the fiber direction. Sound propagation and acoustic comfort in massive wood constructions are dependent on rigid connections. In this way, also the sound properties of the building system are affected by the connections

The performance of structural connections does not only depend on the fastener, but also on the wood. The variability of wood properties has been investigated extensively during the last decades. Models describing knot properties (Colin & Houllier 1991, Mäkinen & Colin 1998, Maguire et al. 1999, Moberg 2000), density (Wilhelmsson et al. 2002, Molteberg & Høibø 2007) and heartwood content (Flæte & Høibø 2009) have been developed. Models describing variation in mechanical properties are being developed in the ongoing Norwegian project Tresterk (The Research Council of Norway, project number 208085/I10). The models provide a basis for more accurate sorting wood, and selection of wood with better specifications. Studies on variation of mechanical properties have also been conducted in European projects, for instance Combigrade (Hanhijärvi et al 2005, Hanhijärvi & Ranta-Maunus 2008) and Gradewood (Ranta-Maunus 2009).

Even though a lot of studies have been carried out on wood property variation, there is a need for more research about the effects of wood properties, like density and moisture content, on calculations of connections. Analytic tools for calculation of nodes, based on the different types of screws and the wood properties, is necessary for increased use of wood in frame constructions made of solid wood or laminated wood. This is also important for building systems using massive wood. Today the knowledge is limited. New knowledge about how normal and shear stresses are transferred in nodes with a combination of axial screws and perpendicular screws is needed.

## Wood in the envelopes of future urban buildings

(Related to work package 4)

Redefined wood architecture in new urban contexts, new classes of buildings and code regimes, in addition to new climatic situations, places new requirements on the building envelope. Documentation of the performance is decisive for the innovative use of wood in the building envelope. The large variation in different wood properties is a challenge when estimating service life. An interdisciplinary approach, which combines knowledge on wood properties, biological deterioration and microclimatic effects, is required to target the main challenges associated with wood exposed outdoors.

Fungal deterioration of wood affects both the users' perception of wood as a building material, and the service life and environmental effect of the wooden material. Several reviews on fungal-influencing factors have been made (Zabel & Morrell 1992, Eaton & Hale 1993, Adan 1994, Brischke et al. 2006, Gobakken 2009). However, there are surprisingly few published results from durability tests, which are usable and directly linked to the service life of the material or component in question (Brischke et al. 2012a, b). A detailed understanding of the influencing factors and interactions involved is essential when working with the service life prediction of wooden components in buildings. Prediction models based on micro-climatic data and controlled indoor experiments for the occurrence of spore germination and fungal growth of various materials have been developed (Adan 1994, Sedelbauer 2002, Viitanen 1997, Ritschkoff et al. 2000, Hukka and Viitanen 1999). Gobakken and Lebow (2009) and Gobakken et al. (2010 a, b) took this a step further and modelled fungal growth and aesthetic service life for wood outdoors exposed based on climatic parameters, wood properties and treatment. Another promising approach is the dose-response method that calculates the service life based on climatic data and decay rate (Brischke and Rapp 2008, Brischke et al. 2008). In addition, a major effort has been put into research on climate exposure of building materials the last 15-20 years. Several new methods have been developed, e.g. Computational Fluid Dynamics (CFD) coupled with Heat and Moisture simulations (HAM) (Saneiejad et al. 2011, Kyllingstad et al. 2010, Nore 2009). This has enabled detailed and accurate simulations of microclimates on building facades, which are crucial for understanding the mechanisms of deterioration of building materials.

In contrast to the fragmentary base of available data and modelling approaches, there is an imminent need for service life related durability records (Brischke et al. 2012a, b). There are several reasons why: 1) material-inherent resistance needs to be implemented in service life planning, 2) reliable documentation and predictability of wooden material serve as the competitive edge related to competing materials, and 3) input to Life Cycle Assessment (LCA) studies are strongly requested. Some of these issues are dealt with by a World Wide Durability Database initiative from Brischke et al. (2012b), an ongoing report quantifying service life of wooden products in Norway (Gobakken et al. in prep.) in the ClimateWood (KlimaTre) project, and by past projects Woodexter (2007-2010) and WoodBuild (2009-2013). This project introduces a strong coupling between advanced micro-climatic simulations and service life modelling of wooden building materials, which is new and will enable the development of a combined simulation and prediction model for building envelopes. Furthermore, this will give architects and planners a customized tool that supports the development of new building topologies with the innovative use of wood with a high degree of predictability of the aesthetic appearance and durability.

## 2.2. Approaches, hypotheses and choice of method

The project will consider the following issues and hypotheses:

- Two- to eight-story buildings, located in urban structures with high density, will be a major category of new buildings in urbanizing regions in Norway and Northern Europe. Multi-family residential buildings will be the most important project type.
- Robust, adaptable and integrated systems must be developed to facilitate large-scale urban application of wood. These must support development of buildings with a high and lasting architectural and technical quality.
- Interdisciplinary research and teaching must be established to develop the holistic solutions requested by architects and engineers.
- Detailed studies of constructions and building envelopes will support the development of robust and adaptable systems that are relevant to the integrated design.
- Cooperation with a network of merited architects´ offices and the other industrial partners will be essential in defining relevant research tasks, project examples and details vital to the architectural quality of buildings. A major challenge will be to utilize methods both from architecture, engineering, wood science and marketing.

The following working packages will be included:

**Working package 1 (WP 1) - Urbanisation, sustainable buildings and utilisation of wood (AHO)**

The character of urbanisation (WP 1.1). To illustrate the character of urban development, it is necessary to use a concrete and relevant example. Oslo is a natural choice for the consortium, since it shares many features with other cities in Norway and Europe.

The analysis may and should be fairly rough, and based on available data. This means population statistics and prognoses, surveys of housing preferences and planning documents developed by the municipalities. Combined with relevant models for area development, these data may form the basis for a simple forecast of the distribution of building categories. The aim is to present this big picture in a map of the Oslo region.

The important building categories (WP 1.2). Research will be focused on three main categories of buildings that will be present in the urbanising regions: a) 1-2 story buildings, b) 3-4 story buildings, and c) 5-8 story buildings. This division reflects significant thresholds in building code requirements. Priority will be given to b) and c), but high-density examples of two story buildings also need further exploration.

For each category, integrated and wood-based solutions for constructions and building envelopes will be described in a principal and diagrammatic way. The wood volumes and weights will be quantified. The challenges related to fire and sound requirements must be handled. Vertical communication and HVAC systems should also be included. This collection of integrated systems solutions will serve as a state of the art description and as reference projects for timber constructions in the important urban building categories. It will combine information from diverse sources into transparent, structured and quantified examples.

Interdisciplinary analysis of main building categories (WP 1.3). The principal solutions will be subject to systematic, interdisciplinary analysis. Here, the network of experienced and innovative practicing architects will play an important role. The architectural adaptability of the solutions will be challenged. Suitability for housing will be given priority, but also the potential for accommodation of mixed functions in an urban setting. Together with the structural engineers and wood technologists, the architects must discuss if the present solutions are optimal. Stronger wood may reduce the need for laminated constructions. New screw-based joints may replace complex steel reinforcements. Envelope details vital to the overall architectural appearance of the building will be pointed out. Application of an integrated model combining microclimatic simulations and performance of wood materials will create a new interdisciplinary foundation for design.

The comprehensive analysis of the three main building categories will define a set of questions, problems and possibilities for further study. These must be communicated up and down the value chains and will be presented for systematic architectural exploration in master level studio courses at AHO. A Ph.D. student will be working on this WP, and the supervisor group will be from AHO and other participating institutions. This WP will have close coordination with WP 2, and also connections to WP 4 and 5.

**Working package 2 (WP 2) – Design-based research (AHO)**

Preparing for use of AHO master courses as laboratories for systematic architectural exploration (2.1).

The themes for further study formulated in the interdisciplinary analysis of the main building categories will be explored by using master level studio courses at AHO as laboratories. This must be prepared by careful descriptions of different boundary conditions for the design tasks. Some of the students will be asked to utilize wood-based solutions as far as possible, whereas others must seek optimal combinations of wood and other materials. Parallel exploration of alternative strategies for wood constructions will be tested. Different principles for envelope design and envelope detailing are to be studied and exemplified. Urban dimensions, for example the suitability of different construction systems and architectural typologies to high-density applications, will be addressed. The documentation of the projects will be standardized, and calculations of volumes and weights of materials and subsystems will be included. Prepared in this way, the studio courses will produce a series of integrated designs that will explore the effects of wood application on the functional, technical and architectural quality of whole buildings and areas. This is not possible in ordinary research projects because it will be too expensive or too slow. It also represents a type of architectural research that utilizes the core competence of architects. This is to structure and transform large amounts of data and complex sets of requirements into integrated architectural solutions.

The interdisciplinary team of researchers must supervise the execution of the design tasks. This means that the students will have access to competence beyond that of ordinary studio courses at AHO. It should be underlined that regular expenses associated with the studio courses will not be covered by the research project.

<u>Analyzing the results from the studio laboratories (2.2).</u>
The master students´ projects (typically 12-15 per term) will be subject to interdisciplinary critique and analysis, similar to the ones carried out on the reference building examples. These discussions will clarify and document the architectural solutions and implications of the questions formulated in WP 1.

In addition to the systematic evaluation of qualities, the research team will extract and systemize the data submitted on quantities of materials distributed on different wood types and other product categories. This will enable analyses of the connection between different integrated architectural solutions and the quantities and qualities of wood involved. This information may be used in the big picture of the city region to indicate the accumulated effect of strategies for increased use of wood in urban buildings.

The aim will be to arrange two project-related studio courses per year. This means that problems and solutions that are explored in the first studios may be reformulated in later courses. It also implies that successive versions of the solutions and design tools from WP 3 (constructions) and WP4 (building envelope) may be tested during the research project period. The master studio projects will be presented in the form of exhibitions aimed at the professions, the wood- and building industries, the property developers, the governmental bodies and the public.

**Working package 3 (WP 3) - Constructive solutions and material requirements for important building types (IMT)**

WP3 will develop practical solutions and calculation tools for joining wooden components of frame-based and module-based building systems. The building typologies, which will be addressed in WP 3 are defined in WP 1 and 2. The methods to be used are laboratory tests on component and system level. UMB has recently developed a method for non-contact detection to record displacement field during load testing of timber structures. This equipment registers displacement fields and local offsets even after the cracks and fractures occur. Such equipment is important in studies of stress and strain in connections with a combination of axial and perpendicular screws.

Rigid and fire protected solutions will be achieved by using newly developed self-tapping screws. The benefits are a more direct transfer of forces and increased stiffness due axially loaded screws instead of bending of the bolts, dowels and fittings. The stress-strain relationships in such systems will be studied for combination of different screws and materials with different properties. We will validate numerical computations and use both methods as a basis for a practical design tool in the form of tables and engineering considerations.

The main part of the work will be performed as a Ph.D. study with joint supervision from UMB and AHO. The knowledge produced in the project allows for wider application of timber based building systems. The production process of such systems can be rationalized and the applications of timber structures can be expanded. This will increase the competitiveness of timber compared to steel and concrete. This WP will have close links to WP 2 and 5.

**Working package 4 (WP 4) – Wood in building envelopes (NFLI)**

A wooden façade functions as a building envelope, protecting the load-bearing structure from the environment, and serving as an important aesthetic design element. Every wooden façade is unique, and several factors will be decisive for its durability and visual appearance. The aim of WP 4 is to enable construction of wooden urban building envelopes with long lasting and predictable quality, where the architectonical innovation will be supported by optimal choice of material, details and wood protection.

The theoretical approach will be to combine the latest models predicting climate exposure on buildings (Kyllingstad et al. 2010, Saneinejad et al. 2011) and with the deterioration models (Gobakken & Lebow 2009, Gobakken et al. 2010 a, b, Brischke & Rapp 2008, Brischke et al. 2008) to predict service life. A combined model will be made that simulates and predicts future service life in urban wooden architecture, and enables knowledge-based decisions regarding design and material selection. This interdisciplinary approach is new, not only in Norway, but also internationally.

Field tests and laboratory experiments will be performed for verification and further development of the new combined prediction and simulation model. The tests will include studies of exposed building details with a high risk of biological deterioration. The next step will be full-scale studies on different architectural building topologies. The models will be translated into customized tools for architects, contractors, developers and engineers. This will enable an optimal utilization of wooden materials, based on design level, durability, accessibility, climatic exposure and environmental impact.

This is an interdisciplinary approach, combining knowledge about climate effects and service life prediction in order to make new models and customized user-tools. A Ph.D. student will be working on this WP, and the supervisor group will be from UMB-IMT, UMB-INA, NFLI and AHO. This WP will have close links to WP 1, 2 and 5.

**Working package 5 (WP 5) - Wood knowledge in design and building processes, value chains and marketing (AHO)**

a) Wood knowledge in design and building processes

It is vital that updated and reliable information about wood-based products and solutions is available during the planning, construction, use and reuse of buildings. Recent descriptions and examples of interdisciplinary processes related to sustainable design will be adapted, and focus will be on the perspective of wood use. Both strategic and more detailed decisions regarding choice of materials will be defined. In this project, special attention will be given to the role and requirements of architects. Therefore, a network of associated architects` offices will contribute to the description of knowledge needs and information format in the different phases of the design process. The other industrial partners and the collaborating research institutions will ensure that the information needs of all groups involved will be mapped.

The research and presentation of the results in work packages 1-4 will be adapted to this model of the building processes and its information requirements. These information requirements will overlap and interact with information directed at the value chains.

b) Wood knowledge transferred through the value chains

An integrated value chain perspective is required in the call, and is illustrated in figure 1. The work packages covers themes reaching from the building component level to the regional and urban scale in wood applications. All subtasks will be expected to deliver information relevant to forestry and timber resource production. The main focus should be on applications where large quantities of wood materials will be utilized. On the other hand, materials with specific properties may enable effective and high quality solutions leading to higher prices. The value chain perspective will complement the building process perspective in the dissemination of research results.

c) Marketing and preference studies

Studies that reveal consumer preferences are relevant for the market and the manufacturers. They are also relevant for architects and other decision makers involved in building design- and construction processes.

The building process and value chain descriptions will point out the main users of information and products inside the industries and in their markets. Market research methodology may contribute to a better understanding of the culture and the priorities in the groups involved. Groups involved in the study will be immigrants that must be accommodated in the growing Norwegian cities and a control group of random Oslo citizens.

The idea is to study what kind of houses the two groups prefers, regarding size, use of different materials such as wood, and price levels. Further, consumer perception on different wood design elements will be studied together with consumer preference studies. Some of the design elements researched will be put into whole facades to study how they function as parts in a certain façade. The design element will be the wood material itself, but also how the wood material functions together with other materials in a certain building element. The consumer quantitative perception study will be conducted using a survey.

## 2.3. The project plan, project management, organisation and cooperation

The consortium is interdisciplinary and covers all the competence needed to reach the objectives of this project. The established link between urbanism and architecture at AHO, the interdisciplinary expertise situated at the campus in Ås, the international research partners, professional architects and involvement from the forest sector will ensure that the objectives within the projects are fulfilled.

The project will utilise national expertise mainly through the consortium and associated partners. In addition expertise and network-building promotion will be sought through meetings, workshops, and by participation in national and international conferences. A part of the budget will be allocated to international cooperation in order to get a broader insight to the challenge of increased use of wood in urban buildings. The allocation of money will support travel expenses and participation in joint peer-reviewed papers.

An account of the planned project implementation is given in Figure 2. The project will be carried out through work packages and sub-tasks.

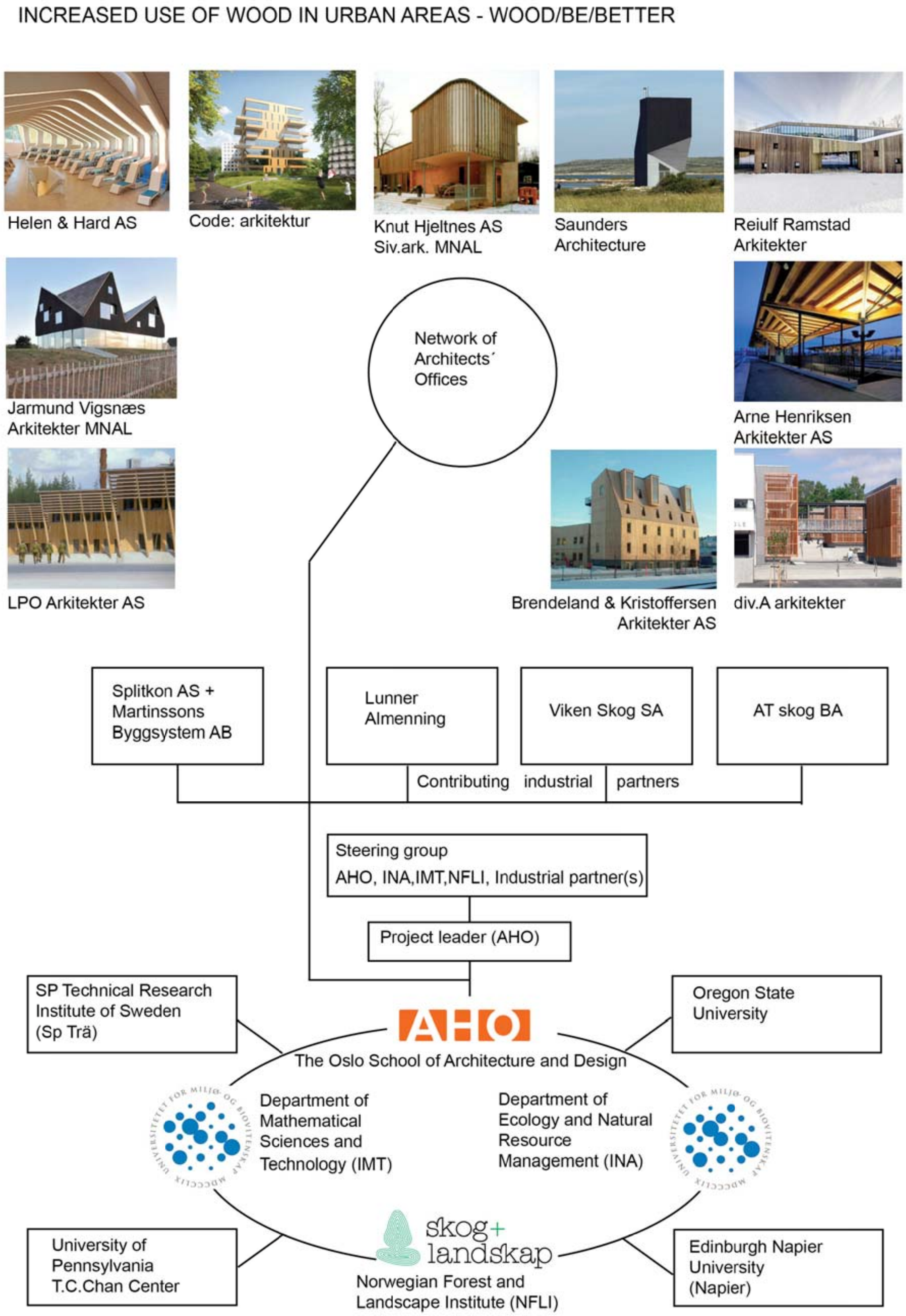


**FIG. 2.** Project organization

This project also includes industry-oriented research because the aim is to promote large volumes of wood, with the right quality. This will provide increased profit for the industry, but also create a demand for more diverse products. Communication and input from the industry is crucial throughout the whole project period.

The major participating partners have lengthy and documented experience with supervision of Ph.D. students. The three Ph.D. students involved in this project will be closely integrated into the project. The WPs in this project will cooperate closely which is essential to secure the workflow needed to fulfil the aim of the project. Hence, the framework is already in place for ensuring that the candidates complete the programme.

A steering group will be established with representatives from the national participants, including architects, forest sector and wood science. If the NFLI/UMB initiative on call 3b receives funding, 1-3 joint reference group members will be included.

Project meetings will be arranged twice a year for presentation of results, progress reports and coordination. The project meetings will be important arenas for development of the interdisciplinary aspects in the project.

Overview of the overall expertise, infrastructure and other resources from the applicant institutions:
Norwegian partners:

- The Oslo School of Architecture and Design (AHO). Expertise: Urbanism, architecture, building technology and design. Infrastructure: Construction hall and series of specialized and well equipped workshops for production of architectural models (incl. CNC milling and rapid prototyping). Other resources: student resources.
- The Norwegian University of Life Sciences, Department of Mathematical Sciences and Technology (IMT). Expertise: Climate impact, building physics, load-bearing structures in wood, joints. Infrastructure: Well-equipped laboratory for strength measurements of wood and timber structures. Other resources: student resources.
- The Norwegian University of Life Sciences, Department of Ecology and Natural Resource Management (INA). Expertise: Wood anatomy and properties, modelling of wood properties. Infrastructure: Well-equipped laboratory for strengths measurements of wood and timber structures. Other resources: areas for field studies of wood durability. Student resources.
- Norwegian Forest and Landscape Institute (NFLI). Expertise: Service life prediction of wood and wooden products, biological deterioration of wood, wood protection, fire protection. Infrastructure: Well-equipped laboratories for wood technology, wood chemistry and mycology. Other resources: areas for field studies of wood durability.

International partner:

- SP Technical Research Institute of Sweden (SP Trä). Expertise: Timber engineering, wood based materials, wood adhesive bonding, timber strength grading. Infrastructure: complementary wood technological equipment.
- Edinburgh Napier University (Napier). Expertise: leading UK architect and wood technology research organisation concerned with research into timber and material derived from forest biomass. Infrastructure: Well-equipped technological labs and studios. Other resources: student resources.
- T.C.Chan Center at the University of Pennsylvania, School of design, Department of Architecture. Expertise: Environmental design, sustainability studies and rating systems, thermal & air flow simulations, lighting simulations. Infrastructure: Augmented Reality (AR) studio. At T.C. Chan Center at Tsinghua University: Climate chambers controlling a wide range of thermal conditions and indoor air characteristics.

- Oregon State University (OSU), Department of Wood Science and Engineering. Expertise: Organizational innovation, environmental marketing, corporate responsibility.

National contributing partners:

- A group of ten leading Norwegian architectural firms. Expertise: All are widely internationally published and exhibited. They have received a series of prestigious national and international awards. All have comprehensive experience in the use of wood in architecture of a high quality, and in a wide variety of buildings and constructions: Helen & Hard AS, Jarmund Vigsnæs, Arkitekter MNAL, Code: arkitektur, Reiulf Ramstad Arkitekter, div.A arkitekter, LPO arkitekter AS, Saunders Architecture, Knut Hjeltnes AS Sivilarkitekter MNAL, Arne Henriksen Arkitekter AS, Brendeland & Kristoffersen Arkitekter AS,
- Lunner Almenning (LA). Expertise: Management of forest and community-owned common land. Property development with focus on sustainability and the use of wood in urban projects.
- Viken Skog SA (Viken). Expertise: Forest owners association with the aim to ensure long-time profits through sustainable resource management.
- Splitkon AS + Martinsons. Expertise: Wood-based constructions and building systems.

## 2.4. Budget

The project plan and accompanying cost for this large-scale interdisciplinary project is presented in Table 1.

**Table 1**. Project plan with working packages (WP) and sub tasks, cost, responsible partner plus participating partner(s), location of PhD students and estimation of peer review papers (P. rev.). Cost in 1000 NOK.

| WP No. | Working packages and sub tasks | Cost | Responsible partner | Participating partners | PhD + P. rev. |
|---|---|---|---|---|---|
| 1 | Urbanisation, sustainable buildings and utilisation of wood | | AHO | | AHO |
| 1.1 | - Urban development patterns in Norway – international perspectives | 850 | AHO | Napier | 1 |
| 1.2 | - Important building categories and typologies | 2000 | AHO | IMT | 1-2 |
| 1.3 | - Potential for large-scale application of urban timber buildings | 2000 | AHO | IMT, INA, NFLI | 4-5 |
| 2 | Design based research | | AHO | | |
| 2.1 | - Critical analysis of contemporary examples of urban wooden architecture | 875 | AHO | Napier, Penn. | 1 |
| 2.2 | - Preparing for use of AHO master courses as laboratories for systematic architectural exploration | 975 | AHO | IMT, INA, NFLI, Penn. | 2 |
| 3 | - Constructive solutions and material requirements for important building types | | IMT | | IMT |
| 3.1 | - Laboratory tests on strategically important component and system levels | 2080 | IMT | AHO, INA, SP Trä, Napier | 2 |
| 3.2 | - Develop practical solutions and calculation tools for joining wooden components of frame-based and module based building systems | 2080 | IMT | AHO, INA, SP Trä | 2 |
| 4 | Wood based climate envelopes in urban architecture | | NFLI | | INA |
| 4.1 | - Develop a combined prediction and simulation model | 2105 | INA | AHO, IMT, NFLI | 1 |
| 4.2 | - Field tests and laboratory experiments for development and verification of a combined model | 1875 | NFLI | AHO, IMT, INA, Napier | 2 |
| 4.3 | - Perform full scale studies for development and verification of a combined model | 1550 | IMT | AHO, INA, NFLI | 2 |
| 4.4 | - Develop customised tools for specifiers for optimal utilization of wood | 1475 | NFLI | AHO, IMT, INA | 1 |
| 5 | Integration of wood competence in interdisciplinary project processes | | AHO | | |
| 5.1 | - Implementation of customised architect tools | 650 | AHO | IMT; INA; NFLI | |
| 5.2 | - Develop communication throughout the value chain | 690 | INA | AHO, IMT, NFLI | |
| 5.3 | - Marketing and user preferences | 1150 | NFLI | AHO, IMT, INA, OSU | 2 |
| | Administration and coordination | 750 | AHO | IMT, INA, NFLI | |

The Research Council of Norway will supply 20 million NOK for a four year-period. A grant of 800,000 from Skogtiltaksfondet will be put forward by AT Skog, Viken Skog SA and Lunner Almenning. In addition Lunner Almenning will contribute 400 000 in-cash.

# 3. Key perspectives and compliance with strategic documents

## 3.1. Compliance with strategic documents

The main aims of the project align very well with the Strategy 2020 formulated for the Oslo School of Architecture and Design. Research, especially of an interdisciplinary character and in international networks will be given priority. Focus will be put on interaction between research and teaching. The AHO strategy is followed up by the Strategic plan 2015 for The Institute of Architecture. The recently established Research Centre for Architecture and Tectonics will carry out research on the relationships between climate, materials, constructions and architecture. The present project fits well within this framework. Two new professorships focusing on housing strengthen the Institute in this field, which is also central to the Wood Be Better project.

## 3.2. Relevance and benefit to society

The Arkitektur.nå action plan for architecture was presented by the Ministry of culture in 2009. It focuses on sustainability and gives priority to further development of Norwegian expertise in wood architecture. The Government white paper "Buildings for a better society" emphasizes research on sustainable buildings of high quality, and stresses the utilization of wood in buildings. This project will provide knowledge about use of wood in urban building and enable architects and constructors to develop high-quality buildings with long and predictable service life. The society will also benefit from the knowledge acquired by the participating Master- and PhD-students, as well as the group of practitioner architects who are part of the project.

### 3.3. Environmental impact

Increased use of wood as a substitute for more energy consuming building materials is one of many means to reduce environmental impact and climate change. A wood construction serves as a carbon sink during its service life, and it can be recycled into other wooden products before it eventually is deteriorates or is used as energy. Increasing the service life of wooden buildings and creating designs that are valued and worth keeping for generations are therefore means to reduce the emission of $CO_2$ due to a reduction in transport and production processes, and increased carbon sequestered in the timber products. The project will help the European woodworking and building construction industries to utilize renewable, non-toxic raw materials for the production of durable and sustainable wood products and buildings. No negative environmental effects of the projects have been identified.

### 3.4. Ethical perspectives

This project will not involve any experiments, new innovations or other aspects raising specific negative ethical questions.

### 3.5. Gender issues (Recruitment of women, gender balance and gender perspectives)

Taken into account the bias in availability of female students within several of these research areas, the gender balance in this project is well in order. In the core group of researchers, the gender balance will be five male researchers to two female researchers, of whom one of the females coordinator at NFLI. By their participation in this project, Dr. Lone Ross Gobakken and Dr. Gry Alfredsen will get the credentials and experience needed to qualify as senior researchers. Recruitment of Ph.D. students will be in accordance with the Norwegian rules regarding gender balance.

# 4. Dissemination and communication of results

## 4.1 Dissemination plan

In addition to the planned scholarly and popular science dissemination described in the grant-application, results from the project will be communicated as follows:

- Involvement of architect students in the project,
- annual meetings as well as in a concluding meeting in 2016,
- two work-shops each year gathering architects, Ph.D.-students and the representatives from forestry and forest industries,
- acquired knowledge will continuously be disseminated to students at the two Universities,
- the reference group will also be an important arena for communication of results,
- web page and newspapers.

## 4.2 Communication with users

Special to this project is the broad contact to users in architecture represented by the network of ten architectural offices. It will strengthen the discussion on qualities in entire buildings and whole urban areas achieved through the increased use of wood. Communication through drawings and models (analogue and digital) is a core skill within architecture, and this will be utilized in exhibitions and conferences aiming at people in the industries, politicians and the general public as end-users. The interdisciplinary research process and the interaction between research and teaching imply that broad user communication is embedded in the execution of the project.

# *5. Additional information specifically requested in the call for proposals*

There are no specific requests for this call.

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