Life City - A Climate-Conscious Concept for Smart and Sustainable Built Environment

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Abstract. Residential construction and land use planning are changing in many countries around the world. There is a clear need for comprehensive, energy-efficient, cost-effective and CO_2-neutral concepts meeting the latest energy and climate policy goals. This opens up new opportunities for the industry. Northern Finland has strong expertise in the field of wooden architecture and wood construction industry. By combining the existing high-tech expertise of enterprises, and strengthening the cooperation between SMEs, new value networks with significant international business potential can be created.

This paper presents the Life City -concept, a holistic approach for smart and sustainable built environment, which is being created in the ongoing Life City -project. The concept consists of energy-efficient and modern wooden buildings in CO_2-neutral neighborhoods and includes decentralized energy infrastructure with multiple renewable energy sources and smart networks. Life City -concept is a comprehensive export concept that adapts to the local climate conditions, but also considers the social needs of different communities.

Other targets of the Life City -project include enhancing the export business knowledge and technical prerequisites of the collaborating SME companies. In cooperation with the companies, the project aims to develop new design, manufacturing and construction methods that enable improving the cost-effectiveness, environmental impact, energy-economy, microclimate and other living comfort issues of wooden buildings in different climate zones, taking also the climate change and resiliency issues into account.

Preliminary project results show that the wood construction industry in Finland is not quite ready for exporting holistic concepts such as the Life City -concept, as more product development, knowledge and resources for export are needed. This finding applies especially to SME companies in the industry.

Keywords: Sustainable Smart Cities, Smart Energy Solutions, Wooden-town Planning, Modern Wood Construction.

1 Introduction

Northern Ostrobothnia and the surrounding areas in Northern Finland have strong expertise in the field of wooden architecture and wooden construction industry. However, the development of small-scale industry into international business should be promoted through research and innovations. Also, the residential construction and land use planning are changing in Finland and in many foreign countries and this will open up new opportunities for the industry.

In urban and regional construction areas, there is a clear need for a comprehensive concept, which is energy-efficient and cost effective as well as CO_2-neutral, and which meets the latest energy and climate policy goals. By combining the existing high-tech knowhow of enterprises in Northern Finland, and strengthening the cooperation between SMEs, it is possible to create new value networks that have new business potential. This could also create new enterprises and jobs in the wood product and biomass processing value chain.

1.1 Life City -Project

Life City -project (2015-17) is a research and development project mainly funded by the European Regional Development Fund, coordinated by VTT Technical Research Centre of Finland Ltd, and implemented in cooperation with the University of Oulu, and collaborating companies. The main objective of the project is to develop the Life City -concept, but also to provide knowledge for collaborating companies about sustainable city planning based on modern energy-efficient wooden buildings, and decentralized energy infrastructure with the integration of multiple renewable energy sources and smart networks.

Other objectives include enhancing the export business knowledge and technical prerequisites of the collaborating SME companies mainly in northern Finland. In cooperation with the collaborating companies, the project aims to study and develop new design, manufacturing and construction methods with which it is possible to improve cost-effectiveness, environmental impact, energy-economy, microclimate and other living comfort issues of wooden buildings in different climate zones, taking also the issues of climate change and resiliency into account. These methods include 3D building information modeling integrated more efficiently with manufacturing automation systems (CAD-CAM), and the development of the overall production management process “from forest to cities”.

As a result, the project aims to create a CO_2-neutral concept for built environment, consisting of modern wooden buildings in smart and sustainable neighborhoods. Life City is an export concept that adapts to the local climate conditions, but in addition to technical matters also considers the social needs of different communities. It includes both public services (community centers, kindergartens, schools, health centers) and residential buildings (multi-storey apartments - and single-family houses).

Life City as a concept bases on the recent theories on sustainable buildings and communities, and ecologically designed cities with smart functions included. The following chapter briefly describes some of the theories and concepts.

2 Review on the Theories Behind Life City

2.1 Sustainable Communities and EcoCities

The definition of sustainability has been almost the same for the last 200 – 300 years. However, the subject matter and geographical scope of application have increased during that time. The modern concept of sustainability has three dimensions: economic, social, and ecological. A worldwide implementation is implied repeatedly. The ultimate question is how to reconcile conflicting interests. [1]

An EcoCity is essentially seen as a community that has high ecological quality, but at the same time, it is technologically advanced. This is a kind of town that has not yet been realized anywhere in the world. The attempts to build an EcoCity so far base on optimization of different sectors or technologies, and thus they compromise between the high-level targets and present level of design. However, there is not just one EcoCity concept but a variety of possibilities that need to be adjusted so as to fit the local context, local culture and local economic realities. This is the way to achieve a possible solution with regard to the local resources, but at the same time meet the high goals set for an EcoCity. High-tech solutions are one way to the EcoCity, but they are not the only goal. [2] [3]

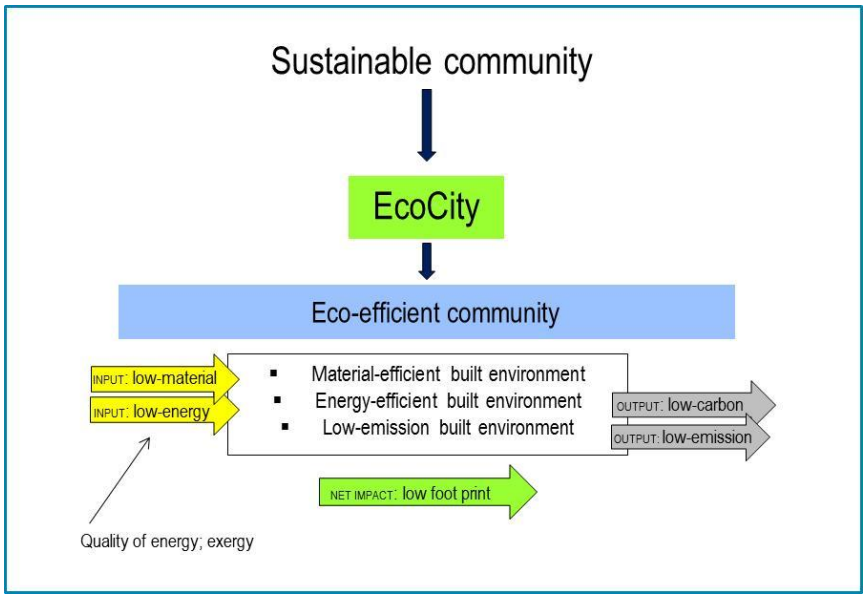

Fig. 1. The key elements of eco-efficiency are material- and energy-efficiency and low environmental emissions [3].

An EcoCity is a city built of the principles of living within the means of the environment. The ultimate goal of most EcoCities is to eliminate all carbon waste, to produce energy entirely through renewable sources, and to incorporate the environment into the city; however, EcoCities also have the intentions of stimulating economic growth, reducing poverty, organizing cities to have higher population densities, and therefore higher efficiency, and improving health. [4]

The economic structure of the proposed EcoCity area lays on new services, enhanced local culture, agriculture, and tourism. During the recent years, work possibilities have reduced because of closing down of activities that harm the environment. The feasibility study suggests activities that improve the economic performance of the whole area. [3]

VTT's EcoCities approach was developed to respond to the abovementioned challenges in collaboration with local partners, and can be summarized as follows:

- Best combination of technologies and services that form sustainable solutions providing the users and inhabitants a high quality of life and indoor and outdoor comfort
- Applicable EcoCity solutions depend on local conditions and need to be customized to socioeconomic realities
- There is not one solution that fits all, but a number of possibilities that need to be studied to find the right solution for each case
- Requires knowledge of local traditions, perceptions, available materials and competent partners

2.2 Smart Cities

There is no single definition for sustainable smart built environment, or *smart cities*. Smart city as a holistic concept is quite controversial and under debate. Something that is smart for some people or stakeholders might be unnecessary or even adverse for others. These are often political questions. However, there are some established definitions on the subject.

A city can be defined *smart* when investments in human and social capital and traditional (e.g. transport) and modern (e.g. ICT) communication infrastructure fuel sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory action and engagement. [5]

Smart cities can be identified (and ranked) along six main characteristics or dimensions:

- Economy
- Mobility
- Environment
- People
- Living
- Governance

These six axes connect with traditional regional and neoclassical theories of urban growth and development. In particular, the axes are based on theories of regional competitiveness, transport and ICT economics, natural resources, human and social capital, quality of life, and participation of citizens in the governance of cities. [5].

Smart cities combine diverse technologies to reduce their environmental impact and offer citizens better lives. This is not, however, simply a technical challenge. Organisational change in governments and in the society is just as essential. Making a city smart is therefore a very multidisciplinary challenge, bringing together city officials, innovative suppliers, national and EU policymakers, academics and civil society. [6]

3 Life City Concept

3.1 Basis for the Concept Development

The idea in the beginning of the Life City -concept was to create a Finnish-Japanese network of experts who could design an ecological smart city concept for tsunami-damaged areas in Japan, after the great East Japan earthquake disaster in 2011. Rebuilding in the area was ineffectively organized; solutions were temporary and energy consuming. Part of the area is still today unbuilt as the reconstruction is delayed. There was a serious need to develop the area, which was regressive even before the disaster. Communities need to solve reconstruction problems, authorities and business life need innovative solutions, which can act as a driver for sustainable development.

In the first stage, it was necessary to strengthen the existing relations and co-operation with Japanese and Finnish companies, and local authorities to find possibilities to design a concept for smart and eco-efficient district, and possibly even realize concrete pilot projects. If successful, this could open new markets for Finnish building industry that focuses on ecological solutions.

Life City -concept is an inspiring and healthy way of life. It intends to give an opportunity to live ecological and healthy life easily and without making difficult and complicated choices continuously. In large-scale it also gives the model for the idea that economic growth and eco-efficiency is possible at the same time.

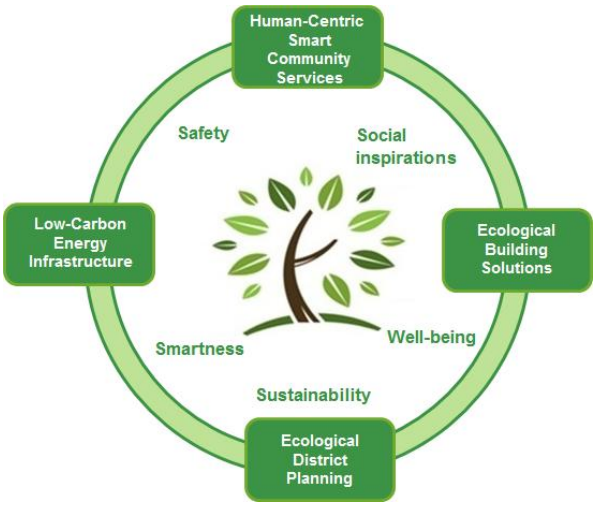

Fig. 2. Life City concept's value propositions and technical development areas.

Figure 2 presents the *corner stones* of the Life City -concept. Technical development areas include ecological district planning, low-carbon energy infrastructure, ecological building solutions and human-centric smart community services. With these technical developments, the target is to increase sustainability, smartness, safety, wellbeing and social inspirations in Life City communities.

3.2 Livable City with Ecological Buildings and Smart Solutions

Buildings are an essential element of a sustainable smart city infrastructure, and naturally in Life City -concept also. Buildings connect closely to their environment; also inside the building different components are interacting. In the future buildings will have an active role in the seamless communications and services. An intelligent building integrates technology and processes to create a facility that is greener, safer, more comfortable and productive for its occupants. It also needs to be operationally efficient for its owners. Advanced technology – combined with improved processes for design, construction and operations – provides a superior indoor environment that improves occupant comfort and productivity while reducing energy consumption and emissions. It is evidently very important to verify the holistic performance of the building for technical performance but also for user experience.

Considering the material and building technology, the concept is based on modular construction units made of massive wood products (i.e. logs or CLT), which are cost-effectively prefabricated in factories. This also guarantees a secure and continuous dry chain. Solar panels, IoT sensors, modern HVAC equipment and other smart solutions can be installed already in the factory, or they can be preinstalled in separate units. Complete modular units are transferred to the construction site, where different sized

buildings can be compiled from *plug-and-play* units. The method is speeding up the construction site process significantly, which produces cost saving and secures that the structures stay dry.

The concept bases on sustainable construction methods utilizing wood as much as possible, because massive wood construction has proven to be the best solution for adverse climate conditions, adding resiliency, and can be applied in all climate areas.

Life cycle thinking is another key element in the concept. The design of a *Life City* includes comprehensive life-cycle evaluations, assessments and optimized life-cycle costs, combined with performance monitoring of buildings and infrastructure. VTT has developed tools and methods for extensive monitoring that are ready to be used in Life City area developments.

Life City is an export concept that adapts to the local climate conditions, but also considers the social needs of different communities. It includes both public services (community centers, kindergartens, schools, health centers) and residential buildings (multi-storey apartments - and single-family houses). To ensure the involvement of the people at stake, different working- and design methods have been discussed during the project. These methods give citizens and other stakeholders the opportunity to take part in the development process (co-creation with e.g. charrette method). A summarized description of the overall vision and development process of the concept is presented below in Figure 3.

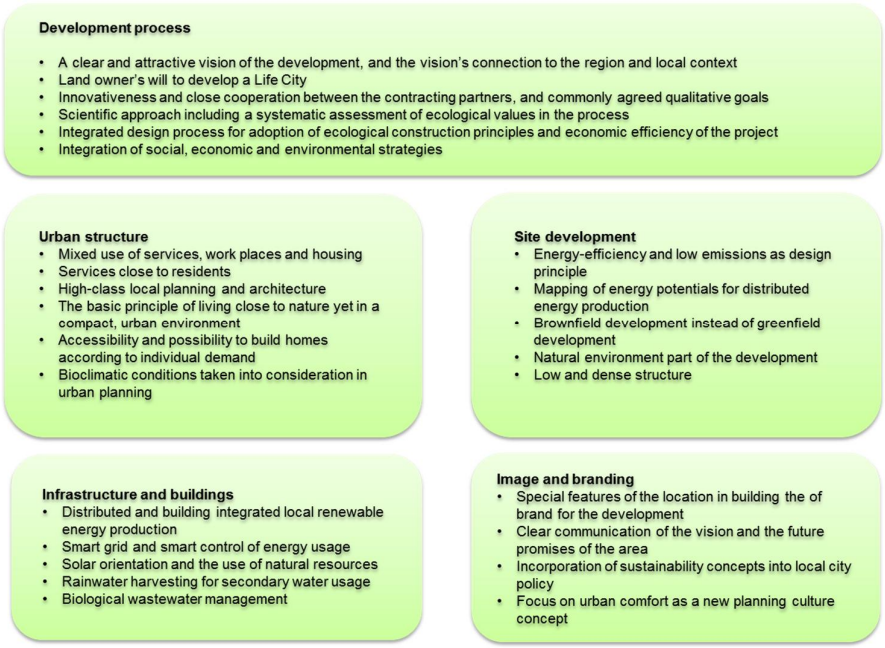

Fig. 3. Overall vision and development process of the Life City concept.

3.3 Developing Modern Techniques for Wood Product Manufacturing

Several operators in the field of wood product manufacturing industry have a challenge to find enough skilled designers to use their own products and design tools. In addition, the processes do not allow the full utilization of the products. Late and incomplete plans will cause production errors, downtime and extra waste of time.

3D-model design and Building Information Modeling (BIM) have been found to give invariable cost savings in complex projects. In particular, the savings are realized in the decrease in errors. Benefits of 3D BIM stand out when value added rises (e.g. engineered wood products) and specialty products are used.

The aim is to create - in cooperation with the participating companies - a common concept, which utilizes the strengths of all participants. The conceptualization is developed for an actual construction project, and it combines the strengths of each company, their products and expertise. The aim is to provide a cost-effective and high-quality product package, which primarily concentrates on the production possibilities of a wooden multi-storey building. An important aim is to assure the suitability also for the overseas market.

The process of BIM-based implementation for wooden multi-storey buildings. The objective is to define the needed processes for designing, ordering, manufacturing and executing the wooden multi-storey building and an exemplary schedule. The concept does not only consider the "technical" performance, but aims to create a guideline for how to order, design, manufacture and build, combined into a genuine and controlled package.

In the construction of wooden multi-storey buildings, the advanced planning is emphasized more than in traditional construction, because the products are made with dimensional accuracy and customized for the specific entity. The planning material needs to be ready earlier and it needs to be more detailed than in traditional construction. There cannot be even a single plan, which says that the measures will be revised on site. This causes requirements for BIM, not only for the content but also for the schedule and process.

There is also a new working phase in production planning, where the responsibility interfaces and roles are not completely established in the field. As a pre-specified process, all the interest groups from the customer to designers and suppliers are able to allocate the right production and working time, and are capable of setting the price correctly. Therefore, extra redesigning is avoided and significant schedule benefits in wood construction are realized.

The content of implementation. The needed technical data and project organization for building the wooden multi-storey building are defined. The required decision-making points are presented as a schedule frame connected to designed contents. An important task is a BIM study, which defines the BIM requirements of the wooden multi-storey building in a general level. This study particularly expresses needs about the contents of the adequate and efficient design made in different stages. In addition to

design, the role of the collision detection and quality control is viewed as a part of the process. The study does not take a stand between different software programs, but it defines which properties are needed to the implementation in different stages. The study produces different road maps for the overall process, which could be developed to a *ready-to-use* concept for wooden multi-storey buildings in the international level.

In addition to the frame, the goal is also to provide expertise in the design and procurement process, as well as the opportunity to create new business models to subscribe to implementation. The results of the BIM study are:

- Presentation of the design process for a typical project (tools, schedules, created material, responsibilities)
- The definition of the BIM requirements of the wooden multi-storey buildings
- Process description for the entire project, from design, production and construction.

4 Export Knowledge and Skills

One of the main objectives of the Life City -project was to provide market information and knowledge about export business for the companies involved in the project. Life City -concept is designed to be an export product in which the involved companies participate to the process by including their own products and expertise to the concept. The comprehensive export product should be developed together by effective and close co-operation.

Life City -project's one work package concentrated on collecting needed market information by doing market research, creating contacts with several partners in selected countries and making a questionnaire for Finnish SME companies in wood industry sector. This information helps the companies to develop their own export business and products. It also gives the researchers important information about the current situation of The Finnish wood industry and the direction where it should be developed in the future.

The market research was focused on wood product and wood construction markets in Japan, Germany, Sweden and Norway. It mainly examined lumber and massive wood products such as log and CLT structures.

A web-based questionnaire was sent to 150 Finnish SME companies in the field of wood products, manufacturing of massive wood elements, and wooden house construction. The response rate was 14 per cent. Of these respondents, most have had more than 10 years of experience in wood industry and all have less than 250 employees. The export business of the companies is mainly targeted to Europe and Japan and concentrated in building timber products, including log and CLT.

Most of these respondents wanted to increase their export business and those who did not, were lacking the suitable products for that. However, all of the respondents were missing resources for exporting. The biggest need was for skilled sales, marketing and exportation specialist and time. Knowledge of the foreign economic development, political atmosphere, procedures and products of the competitor countries were biggest

barriers for exportation. In addition, products and process needed to be developed. Development for the degree of processing, delivery cycle, route network automation, product specialization and variation depending on the export country were seen as important.

Previous projects for developing export in wood construction area were not found very effective as they are now. Some of the respondents required projects to be built around their business and less concentrated on building networks. However, at the same time, more than half of the respondents appreciated the development of co-operation and networking between companies. The tight economic situation in Finland has sharpen the competition and complicated co-operating and real networking. Respondents felt that training the export sales experts, cutting down the bureaucracy of the financing the exportation, developing the co-operation networks for small businesses and establishing the professional contact person in target countries create the base of the good export business.

Public financial support for wood product export was mostly highly appreciated; especially export start-up support to small businesses for projects and training.

In general, there is a lot of talk about wood product export and developing export businesses, but the opinion about developing and boosting first the wood construction inside Finland was strongly emphasized in the responds for the questionnaire as well as putting efforts in further processing of wood products.

5 Conclusions

The Life City -concept is not a quick solution for single buildings, but a comprehensive development method for districts, areas, blocks, quarters, neighborhoods or entire cities, according to the needs of the community. The extent, methods and applications are customized as the concept adapts to the local climate, culture, buildings codes, and other conditions in different countries around the world. It contains the pre-planning, design work and alternative suggestions for building structures, materials and energy systems, performance monitoring and even traffic arrangements, adding resiliency to the built environment towards adverse climate events. The solutions aim to increase ecological way of living that is also affordable, comfortable and healthy.

The research results so far show that the wood product and construction industry in Finland is not quite ready for exporting holistic concepts of this magnitude, as it needs more product development and knowledge, and most of all resources for export. This finding applies especially to SME companies in the industry. There is a need in Finland to develop co-operation inside the wood industry and between supporting industries. Export business needs more experience and training, and a clear orientation to meet the customers' needs. The biggest concerns in companies are:

- Lack of resources for export
- Products are not suitable for exporting
- Lack of skilled sales, marketing and exportation specialist and time
- Not enough knowledge about the foreign economic development, political atmosphere, procedures and products of the competitor countries

- Undeveloped export process: for the degree of processing, delivery cycle, route network automation, product specialization and variation depending on the export country
- Tight economic situation, which makes cooperation and networking complex
- Bureaucracy of the exportation financing

One concrete project result is the process description of BIM-based implementation for wooden multi-storey buildings. The development work produces guidelines and knowledge on the needed processes for designing, ordering, manufacturing and constructing wooden multi-storey buildings. The results of the BIM study include at least:

- Presentation of the design process for a typical project (tools, schedules, created materials, responsibilities)
- The definition of the BIM requirements of the wooden multi-storey buildings
- Process description for the entire project, from design, production and construction.

As a summary, the project was challenging from the start. It was realized during the course of the project, that it is quite impossible to reach all the ambitious targets, and this type of comprehensive concept is never completely ready. The concept clearly needs to be developed further in future projects. The next step could be the realization of a concrete pilot project in which the products and expertise of participating Finnish companies could be utilized together in co-operation with local stakeholders.

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