Project **CEC5**: Demonstration of energy efficiency and utilisation of renewable energy sources through public buildings **3sCE412P3**

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**Investment Summary 4.1**

**Floor Module 3 - LifeCycle Tower One**
Fährergasse 17b, 6850 Dornbirn, AUSTRIA

WORK PACKATE OUTPUT 4.4.2
Prepared by:
Peter Steurer, Regionalentwicklung Vorarlberg eGen
### Investment Summary 4.1

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1 PROJECT TITLE & PA/ INV. TITLE (AS LISTED IN AF)

CEC5: Investment 4.1: Establishment of one floor module of the LifeCycle Tower One

2 PP NAME & NUMBER

Regionalentwicklung Vorarlberg eGen, LP

3 OUTPUT NAME & NUMBER/ RELATED INV. NO., IF APPLICABLE

Output 4.4.2: Demonstration Building LP, Investment 4.1

4 THE OWNERSHIP OF THE INVESTMENT

The Floor Module 3 of the LifeCycle Tower One is owned by Regionalentwicklung Vorarlberg eGen

5 PLACE/ ADDRESS/ AREA OF PA/ INV. IMPLEMENTATION

Address
LifeCycle Tower One
Färbergasse 17b, 6850 Dornbirn
Vorarlberg / AUSTRIA

Contents and Objectives

In the "LifeCycle Tower One Demonstration Building", where the Regionalentwicklung Vorarlberg eGen owns the third floor, the objective was set to implement the know-how gained from forerunner project studies in form of a demonstration project with eight floors in timber hybrid construction. This was also planned to provide the opportunity for the functionality of the building concept to be tested under real conditions and to set an international milestone for the development of resource-efficient, sustainable building.

Results

For the first time in Austria, it was possible to construct a building up to the official high-rise building limit using wood as the basic construction material. The building system was tested in reality for its usability and brought to wider public attention. The demonstration building shows the great potential of timber as construction material, including for large buildings. Just as much interest has been received from international industry specialists as from the general public.
Prospects / Suggestions for future research

The demonstration building will serve as a reference project for marketing the building system internationally. All components have been designed in a way they can be internationalised and modified in order to meet the requirements and regulations in different countries. Various new-build projects are being planned and built by the builder CREE GmbH based on the principles of the timber construction system used for the demonstration building.

The concept offers huge opportunities for changing our lifestyles: as an example for "green building", the LifeCycle Tower system can make a significant contribution to the environmental and resource-friendly reformation of our living spaces. As a result, the concept can bring about a clear improvement of our quality of life, in particular in urban areas. Individually configurable, a LifeCycle Tower can be fine-tuned to suit the precise needs of its occupants and the circumstances of its location.

6 DURATION OF PA/ INV. IMPLEMENTATION

- Building Permit 26.04.2011
- October 2011 - March 2012: The reinforced concrete core was manufactured at the construction area in Dornbirn.
- March 2012: Within two weeks (8 working days), the specific timber-hybrid-modules of the demonstration project were installed to a completed shell
- November 2012: first floors of the building were officially opened
- November 2012 – June 2013: Interior works of floor module 3 took place.
- Opening of floor module 3: 20.06.2013

7 COSTS RELATED TO PA/ INV. (IF OVERALL COSTS ARE HIGHER THAN CONTRIBUTION FROM CE, THE REMAINING FUNDS SHOULD BE ALSO MENTIONED)

Out of total costs of 4.7 Mio Euro for the whole building, 787.400 Euro belong the floor module 3, where 300.000 EUR are covered by ERDF via the CEC5 project. From this allocation proportionately the fundamental construction with the innovative wood/concrete hybrid system, including windows and façade and energy efficiency and renewable source measures were financed. This include all the building facilities: electric primary installation, ventilation, heating connected to the district woodchip heating, due to less need of hot water no solar panels were mounted, daylight optimized light and blind steering. The PV-plant on the roof was financed outside the project.

8 ACTIVITIES CARRIED OUT

Planning and approval

The planning stage aimed at receiving the building permit for the demonstration project. Here, planning workshops were conducted with all lots. The future scalability of the developed detailed
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Technical solutions and the application on further buildings were emphasized as well as achieving the planning permission.

Real fire tests of the ceiling components were conducted in order to reinforce theoretical knowledge with real test results. This and the close cooperation with the Fire Prevention Agency Vorarlberg finally led to the official authorisation of the demonstration project. What is worldwide unique is the fact that the supporting parts of the timber construction were not encapsulated, not even in the top floor. They therefore remain visible.

Previous research activity and an intense examination on all issues that are relevant to receive official authorisation, especially fire protection, took place. Thanks to the work done, the approval stage could be completed with positive decision at the 26th of April 2011.

**Planning operation and test stand**

The goal of this project stage was the tendering and placing of the building and delivery services including the planning on producing, transportation and installation of the timber construction parts respectively the prefabricated composite timber/concrete parts as well as the façade elements. The crucial challenge of this work package was to define details for the execution of a construction system exactly that has so far only existed as theoretical design and development. Therefore, it was decided to conduct a 1:1 trial. The findings obtained were included into the tendering documents as regulations regarding the construction process, the quality assurance and delivery issues.

Three essential construction details were examined:

1. **Joints between pillars and ceiling:** What was important was the joint of the laminated wood pillars and the hybrid ceiling components at the mounting points. The sealing and moulding of the joints, the measurement of the base plates and the relocation of the pillars were analysed.

2. **Sealing of the joint between hybrid ceilings.** Within the scope of this series of tests, the joint between the hybrid ceilings was tested. Here, four different alternatives to seal the joints were examined. The joint needs to be sealed in order to ensure that no grout flows through the joint during the moulding process. This would lead to a pollution of the laminated wood pillars on the bottom of the hybrid-ceiling element.

3. **Fitting of the angle brackets at the reinforced concrete wall.** In this test, only one alternative has been examined, since it emerged to be the most plausible solution during the planning process. This could be confirmed in the test. The angle brackets made of steel were welded at pre-installed welding bases, which serve as support for the hybrid-ceiling elements.

Within the working preparation for the demonstration building, special attention was paid to the choice of appropriate subcontractors. Besides professional criteria, special criteria for sustainability for...
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subcontractors” were developed and both technical and ecological and social requirements were defined.

Pre-fabrication of the system components

The manufactured system components based on timber can be divided into the following building component groups: the façade elements, which are delivered fully insulated including the windows; the hybrid- and ceiling elements with laminated wood pillars and concrete layer and the laminated wood pillars for the vertical load deflection.

Façade elements:

A façade element consists of pre-assembled laminated wood (BSH)-pillars, pre-assembled frame components, concrete-bonded laminated wood chip boards for outside planking and OSB-plates (oriented strand board) for inside planking.

After the fabrication of the timber frame, first the mineral insulation is brought in, after that the outside planking is added. Then, the BSH-pillars are joined with the system façade. The last step is the installation of the windows. The façade elements are stored temporarily at the construction site until they are used.

Hybrid ceiling elements

By the hybrid construction of the timber and concrete joint ribbed slap, the use of material is significantly optimized. The elements have a size of 2.7 per 8.1 metres and consist of a layer of reinforced concrete as pressure plate, which also serves as noise and fire protection. Composite lumber bars (size 24x28cm) are the beams.

The first step in the fabrication process is the preparation of the BSH-pillars that are integrated in the ceiling later. Those are furnished with joint screws and cut outs for diverting shear forces. The prepared BSH-pillars are put into a shuttering table, and then concrete is poured into them. After the curing of the concrete the ceiling plate is taken out of the shuttering table and stored in the plant temporarily. Only when the hybrid ceiling elements are needed at the construction site, they are transported there.

Laminated wood pillars

All pillars have a unique cross-section (24x24cm) and are equipped with steel bolts at the head which join the modules. As double pillars, they each take up one ceiling element at the module from the façade surface.

The pre-fabrication of the system components was conducted primarily in the production sites of the craftsmen according to the principals of industrial pre-fabrication.
4.4.2, LifeCycle Tower One CEC5, 3sCE412P3
Dornbirn, Vorarlberg/AUSTRIA

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Construction

Between October 2011 and March 2012, the reinforced concrete core was fabricated at the construction site in Dornbirn first. It serves for the bracing of the construction and in contrast to the timber pillars that are constructed as pin-ended column, the reinforced concrete core is able to absorb shear forces. In the completed building, the core includes the stairwell and the elevator shaft. Due to fire protection, they have to consist of non-flammable material. The bearings at which the pre-fabricated components will be installed later are also fixed to the core.

The composite timber-concrete slab is the actual key which makes it possible to build upwards. This ripped slab helps to consequently separate each floor by a non-flammable layer. In a steel formwork of 8.1 per 2.7 metres, the timber beams are inserted. The gaps in between are formed and concreted in a casting process. Due to the high pre-fabrication level, the construction process is crucially simplified. The ceiling elements can be pre-fabricated more detailed. No time for hardening is needed at the construction site and for relocation one ceiling elements, craftsmen need only five minutes. At the end of each working stage, the recently accomplished floor and therefore the humidity sensitive interior wood surface is protected from weather influence. The dry construction makes it possible to begin with the interior construction right after installing a section of the building.

Another advantage is the low construction height of the composite slap. The concrete layer measures eight centimetres and installation modules like lighting, ventilation, heating and cooling system as well as sprinkler are integrated into the progress bar. They are pre-fabricated and are simply put between the laminated beams. The rooms have neither pillars nor walls and together with the integrated installation module, this leads to a high flexibility and therefore sustainability of the concept. A LCT-building can adopt to changing usage requirements easily.

The shear coupling between concrete and laminated beams is not manufactured by complicated connectors but by screws and “Schubkerven”. Furthermore, a window lintel made of concrete contributes significantly to the transmission of the enormous forces from the façade pillars.
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The end-wood of the double pillars directly stands on top of the concrete; the joining bolt is poured in the prefabricated module on the construction site. This window lintel facilitates the separation of the construction of each floor also in the layer of the pillars, which is necessary due to fire protection reasons. By this, adding the loads from the ceiling into the pillar is possible without stressing a timber construction part transverse to the fibre. Following the force vectors, the pillars are finished according to the actual static requirements.

Installation process: Threading of façade and ceiling elements
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Threading of the ceiling plates on the BSH pillars

Detail of the junction between ceiling plates and BSH-pillars from above

The next element is lifted into position with an integrated BSH-pillar

Grouting at the bottom of the BSH-pillars

The summit of the construction process was reached in March 2012. Within two weeks, the specific timber-hybrid-modules of the demonstration project were installed to a completed brick shell at the construction site in an impressive way: the construction time only lasted eight days; no more than five workers were needed. Within this time, about 800 experts from different departments visited the construction site to get an idea of this single occasion.

Day 1
Day 2
Day 3
Day 4
Day 5
Day 6
Day 7
Day 8

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The system components could be installed hitch-free at the construction site in Dornbirn thanks to both the precise planning and pre-fabrication and the perfect cooperation of all parties involved. This was a central milestone for the general research within the topic of „large-volume construction with timber“.

9 TECHNICAL SPECIFICATION, IF RELATED TO PA/ INV.

Acoustic research

The thematic field of the acoustic insulation was a big challenge since it was not clear how the acoustic would influence such a hybrid construction.

An essential focus of the research was the examination of the hybrid ceiling element concerning the acoustic within the room acoustic and footstep sound. Detailed acoustic calculations were not possible in the beginning, since existing calculation models and norms have not taken timber hybrid solutions like the LCT system into account so far. 5 different floor compositions were developed and their acoustics simulated:
The theoretic simulations showed that only one of the developed superstructures corresponded to the legal requirements. This superstructure is an acoustic optimized raised floor system. Finally, this system was used, also due to the high flexibility of installation.

The measurements executed in the completed object showed much better results than the measurements simulated before. The legal requirements could be met easily.

**Acoustic examination inside the LCT ONE in the 6th floor**

With this appliance, the impact noise was measured. The appliance hammers on the ground. One floor below, there is a sound level meter. With this appliance, the airborne noise was measured. The appliance makes „noise“. One floor below, there is a sound level meter.

**Long-term deformation of timber**

The long-term deformation of the timber hybrid ceilings was hard to estimate in the beginning since the creeping of concrete is hard to calculate. Creeping designates the deformation rise of the concrete.
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over time with a constant tension. It is a characteristic of concrete, which is expressed especially when there is compressive load and volume reduction. Therefore, a measurement of the sag of the timber hybrid ceiling elements was conducted in the LCT ONE.

The engineering office of MKP has undertaken a prognosis about the deformation behaviour in advance.

The theoretical calculation predicted worse results than those, which were manifested in the real building. This can be ascribed to the difficult calculation of the creeping itself.

<table>
<thead>
<tr>
<th>Holz-Beton-Verbunddecke</th>
<th>Max. Ausnutzung</th>
<th>Verformung T=0</th>
<th>Verformung T=∞</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RO</td>
<td>g [mm]</td>
<td>ges [mm]</td>
</tr>
<tr>
<td>24D/280 GL28c</td>
<td>0,91</td>
<td>5,7</td>
<td>6,5</td>
</tr>
</tbody>
</table>

The long-term deformation and the influence of the development of the single floors had priority within the measuring process. In each floor, two ceiling elements were measured.

The measuring points P1, P4, P5 and P8 helped to control the height level of the bearings. The measuring points P2 and P6 represented the actual sag.

Quality of the room air

Measuring the room air took place in two chosen rooms of the LCT ONE. Subject of the investigation were volatile organic compounds (VOC) and formaldehyde.

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Measuring the room air quality is essential for the security and health of building users. They should be able to work with optimal room air quality. The room air is measured by a black box that is put into the room for a few hours. Then, the VOC concentration is read off.

In addition to that, the concentration of formaldehyde was analysed, since formaldehyde is considered to cause cancer. Prior to the measurement, there was the apprehension that the concentration of formaldehyde would be high due to the amount of timber used. Timber has a relative high concentration of formaldehyde but it is highly controversial, if „natural formaldehyde“ has also harmful effects. Anyway, by the measurement inside the LCT ONE we could prove that we are far below the limit value.

Austrian directives for room air assessment. With a value of 250 and below, the room air is considered to be completely non-dangerous.

With a room air concentration of 0.06mg/m³ and less, the room air is considered to be non-dangerous according to the Austrian directive.

Air tightness
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A high air tightness of the building is an essential factor to avoid energy losses. At the same time, ventilation is essential for a guaranteed supply of fresh air.

There are two different forms of energy loss:

- Transmission heat loss (Heat/energy that is lost through walls or windows, for example)
- Ventilation loss (Heat/energy that is lost due to ventilation)

With the LCT ONE it was made possible to minimise the energy loss by ventilation as much as possible. By a heat exchange system, the heat of the „consumed“ air that is drowned off is emitted and handed back to the fresh air.

Due to a high number of pre-fabricated elements that the LCT is composed of, the building is also equipped with many joints which can be a critical point concerning the air-tightness. With a „Blower Door Test“, it was proven that the air tightness in the LCT ONE is excellent and the heat loss small.

Two measurements were conducted: the first measurement took place inside the brick shell in order to identify possible system errors (i.e. not airtight closed joints) and correct those errors if necessary.

The second measurement took place after the completion of the building. Here, the results also proved the success of the LCT construction.

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**Illumination measurement**

Using daylight as much as possible saves electrical energy for artificial lighting. Furthermore, the composition of daylight plays an essential role for the wellbeing of the users of a building.

The daylight measurement was conducted in the 7th floor with dull weather. The measurement inside the building resulted in an average value of 342 Lux, the measurement in the outside resulted in an average of 10.475 Lux. The obtained daylight factor of 3.3% is an outstanding result which is shown in the table below. These are the target values:

<table>
<thead>
<tr>
<th>Daylight factor</th>
<th>Evaluation</th>
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<tbody>
<tr>
<td>1</td>
<td>&gt; 2% Very good</td>
</tr>
<tr>
<td>2</td>
<td>1.5 % Medium</td>
</tr>
<tr>
<td>3</td>
<td>1 % Low</td>
</tr>
<tr>
<td>4</td>
<td>&lt; 1 % No evaluation</td>
</tr>
</tbody>
</table>
The optimal light use control is conducted by a light management system at the LCT ONE which is called LUXMATE LITENET. This system unites complex system characteristics like an optimal use of daylight, attendance sensors, and the integration of emergency light and pre-defined room profiles. A mere optimized use of daylight can save up to 75% of lighting energy.

A daylight measure bottom on the roof of the building continuously measures the incident light. It ensures that only as much artificial light is added that is needed for an optimal lighting solution. The blinds control is also integrated to the light management system. With the automated operation, the blinds adjust to prevalent lighting conditions and solar radiation by changing their position and their slat angle. Therefore, shielded visibility conditions and thermal sun protection are given.

LUXMATE LITENET – a consistent system all over the building.

**Subjective workplace quality**

Timber does not only provide for an incomparable living and working climate, it can also promote health. Scientists from the institute for non-invasive diagnosis at the research centre JOANNEUM RESEARCH in Weiz researched in a school for one year and came to the conclusion that the heart beat is more tranquil and due to a lower stress level, the heart is protected from overstressing. The heart and circulatory system are less strained in a room made of natural wood, while the vegetative process of generation increases. This means that wooden rooms improve the overall wellbeing – and even lift the mood. Comparative tests have proven that people are more open and more communicative after a longer stay in rooms made of wood than people who have not spent time there.
Regional development: (Franz Rüf, manager of regional development Vorarlberg)

„Our task as the Regional Development of Vorarlberg is to promote regional economic cycles. The wood for our office building had short transport routes and was processed and installed by regional companies.”

„Due to the versatile application of our office that can be used for seminars, single-user workstations, a workshop etc., a flexible arrangement of the rooms was a key priority for us. Since the Cree system does not need bearing walls inside the floor space, we have a maximum of free space.”

„If our organisational structure develops further, we can adjust the arrangement of the rooms in the Cree building easily, fast and cost-effectively.”

„Our office building is regarded as being a lighthouse project for sustainable building.”

10 CONTRIBUTION TO PROJECT/ WORK PACKAGE OBJECTIVES

Overall the LCT One demonstrates energy efficient and sustainable qualities through a pilot building that proofs the feasibility of an elaborated concept.

The LCT One and the demonstration buildings in the other countries were examined with a model assessment CESBA (a common generic assessment tool, which allows regional contextualisation) to visualize a transnational comparability (2.4.5 Model assessments). The buildings and these actions then contribute to the development of CESBA (3.3.4 Feasibility study of certification process). All experience result in the CESBA Guide (2.4.4) and the CESBA wiki (www.cesba.eu). The building and its exhibition (2.2.6) attract many stakeholders e.g. architects, designers, potential investors and public representatives. The LCT One serves as a good practice for the broad public to experience energy efficiency in combination with a new quality of housing.

11 IMPACT/ RESULTS/ EXPERIENCE (HOW MANY TARGET GROUPS/ STAKEHOLDERS WERE REACHED)

By building the prototype LCT ONE, it was proven that the concept of primary building with timber up until the high-rise building limit is feasible today. Simultaneously, other benefits of the system for large-volume timber construction could be demonstrated: The resource and energy efficiency is high; further advantages that could be proven by the implementation of the building are an industrialized building processing and batch fabrication. Based on the prototype (LCT One), they can be presented to the general public.

The „proof of concept” with the LifeCycle Tower One is an important milestone for the further development of the constructing company „Cree GmbH”.

The actual level of development approves the technical feasibility of a high-rise building with the developed construction method. Of course, the approvability of further projects depends from respective local conditions and local regulations. Still, the demonstration project LifeCycle Tower is an essential basis for future constructions that use the LCT system. For achieving approvability for even higher buildings, a sequential increase of the maximal legitimate design height is strived. The gained
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experiences, e.g. approvals, fire protection concepts, assessments and tests will accumulate with an on-going number of projects. For administrative bodies, they can serve as a basis for discussion for approvability for following classes of buildings.

Since the opening of floor module 3, 1949 people from all over Europe where guided through the building and its exhibitions. These people represent roughly 85 different public entities and 75 various private entities and service providers.

In the construction schedule, the modular construction system more than fulfilled the expectations concerning functionality and timing. The present stage of usage has yielded new important results already:

- The long-term deformation of timber is no problem
- The prototype already has a noise level that is distinctly lower than the legal requirements and further optimization is possible,
- The room air quality in the completed building is extremely good.
- For the interior structure, there is further potential for optimization, for example by a more intense modularization of the building technology.

12 TRANSNATIONAL ADDED VALUE - HOW PA/ INV. CONTRIBUTED TO OTHER PAS/ INV. IMPLEMENTED BY THE PROJECT

The one floor module 3 which is co-financed by the CEC5 project/CE is open to the public. There is an exhibition showing the project, the CESBA building assessment methodology as well as other demonstration buildings being constructed within the CEC5 project by other PPs focusing on the transnational dimension of cooperation in the field of energy efficient construction. The is open to the general public as well as various interested stakeholders e.g. architects, designers, potential investors.

On the ground floor and the first two floors exhibitions in the LifeCycle Hub are presenting energy efficient building construction approaches and technologies applied during the construction of the LifeCycle Tower One. This is financed outside the CEC5 project.

By the end of 2013 the number of visitors is supposed to reach the figure of 5000 thus, promotion, knowledge sharing and visibility is ensured. There has been a significant replication effect already achieved as based on the successfully implemented pilot demonstration building already a new building for Illwerke Zentrum Montafon (IZM) at Vandans, Vorarlberg was finalized recently.

13 HOW SUSTAINABILITY OF PA/ INV. IS ENSURED

Sustainability is ensured by the quality of the building, the products, the location, the owners and the exhibition area (LifeCycle Hub) and their partners to show the latest state of technologies of energy efficiency and renewable energy sources. Regionalentwicklung Vorarlberg eGen uses the floor module 3 as an exhibition space, seminar area and office working space for their members (64 municipalities and 11 expert organisations so far) and will be in charge of the maintenance and further promotion of the demonstration building.

14 PICTURES.
This project is implemented through the CENTRAL EUROPE Programme co-financed by the ERDF.
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