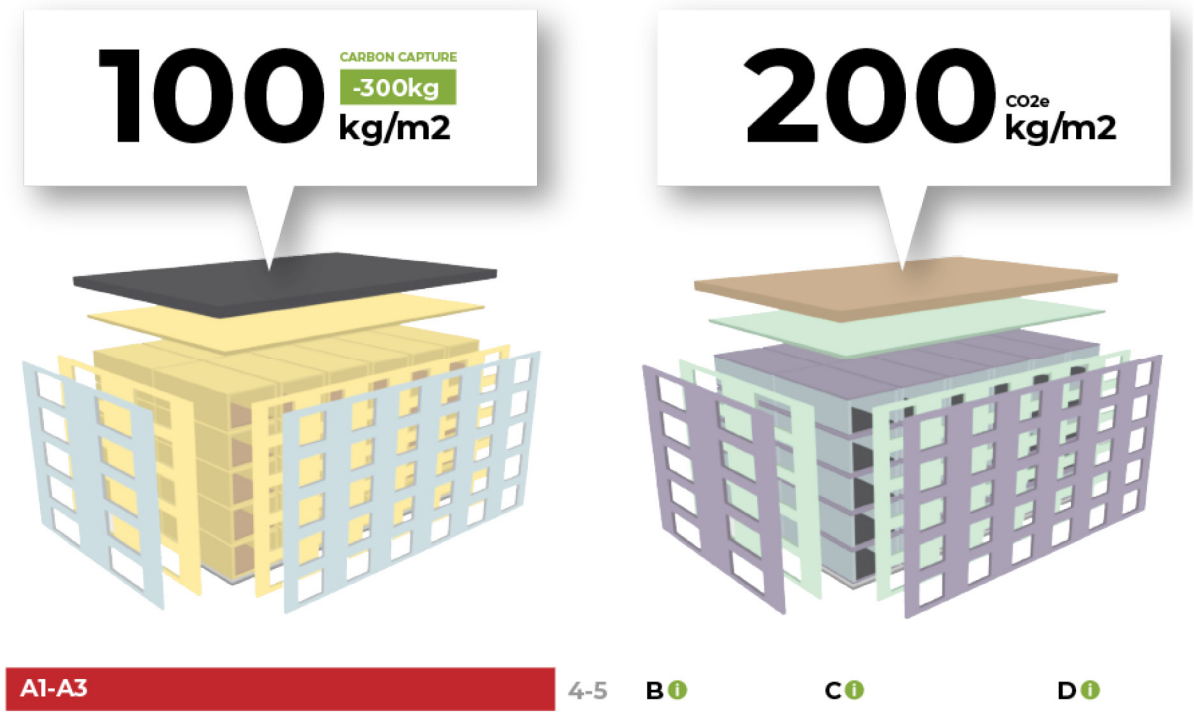

JOKOTAI

Material Impact Screener

www.jokotai.oopeaa.com
www.oopeaa.com

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Support

Ympäristöministeriö
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Helsinki, 15.10.2020

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1.Tiivistelmä

Hankkeen tuloksena on luotu verkkopohjainen työkalu, JOKOTAI Material Impact Screener, jonka avulla on mahdollista tarkastella rakennushankkeen rakenteellisten ja materiaalivalintoihin liittyvien ratkaisujen vaikutuksia kestävyyden näkökulmasta jo heti suunnittelun alkuvaiheessa. Työkalu havainnollistaa eri ratkaisuvaihtoehtojen keskimääräisen kuormituksen helposti hahmotettavissa olevassa visuaalisessa muodossa. Se tekee mahdolliseksi kestävyyden näkökulman ymmärtämisen ja jakamiseen kaikkien rakennushankkeen päätöksentekoon osallistuvien tahojen kesken. Se avaa mahdollisuuden keskusteluun, jonka avulla kestävyyden näkökulma voidaan ottaa huomioon suunnittelun ratkaisuja ohjaavana ja informoivana tekijänä jo heti suunnitteluprosessin alkuvaiheessa.

Työkalun tarkoituksena on mahdollistaa eri ratkaisuvaihtoehtojen arvioiminen kestävyyden ja ympäristökuormituksen näkökulmasta jo ennen keskeisten rakenteellisiin ja materiaalivalintoihin liittyvien päätösten tekoa. Se tarjoaa uudenlaisen työkalun, jonka avulla ratkaisuja voidaan arvioida ja vertailla kestävyyden näkökulmasta jo ennen kuin varsinaiseen elinkaarianalyysiin tarvittavat päätökset rakennushankkeen osalta on tehty. Verkkopohjainen työkalu pohjautuu avoimen datan periaatteisiin ja taustalla olevien laskelmien läpinäkyvyyteen. Tämän läpinäkyvyyden puuttuminen on tunnistettu puutteeksi LCA arvioinneissa. Työkalun kehittämisessä on kiinnitetty erityistä huomiota käyttöliittymän suunnitteluun ja käytön sujuvuutta edistävien seikkojen hiomiseen.

Hankkeen aikana työkalun luomisessa keskityttiin ekologisen kestävyyden mittareihin: rakentamisen tuottamat hiilidioksidipäästöt (embodied energy), rakennuksen käytön energiantarve (operative energy) ja rakennuksen hiilidioksidikuormitus sen koko elinkaaren aikana (overall life cycle). Työkalun jatkokehittämisessä on mahdollista laajentaa työkalua tuomalla myös kustannusvaikutusten ja sosiaalisen (cost) kestävyyden (quality of life) näkökulmat osaksi arviointia.

Hankkeen päätavoitteena oli verkkopohjaisen arviointityökalun kehittäminen eri ratkaisujen kestävyyden ja kuormituksen arvioimiseen rakennushankkeen suunnittelun alkuvaiheessa helposti ymmärrettävällä ja visuaalisesti havainnollistavalla tavalla. Työkalun luomisen yhteydessä on työkalun varhaisen testauksen (alpha) avulla lisäksi kartoitettu muutamien, rakennusprojektissa eri rooleja edustavien tahojen (arkkitehti, rakennuttaja, tilaaja) kanssa heille merkityksellisen datan syvyyttä ja määrää suhtessa päätöksentekoon: Mikä (kestävän kehitykseen liittyvä) tieto on alkuvaiheessa mielekästä ja kuinka tarkkaa sen pitää olla. Tämä on tuottanut arvokkaan katsauksen päätöksenteon kriteereistä, itse työkalusta riippumatta.

Rakentamisen ympäristökuormitus ja työkalun merkitys

Rakentaminen on tuottaa nykyisellään yli 40% hiilidioksidipäästöistä, joten puun käytön lisääminen rakentamisessa voi merkittävästi auttaa edistämään ilmastotavoitteiden toteutumista paitsi rakennuskantaan sitoutuvan hiilen kasvun myötä myös rakentamisen koko elinkaaren ekotehokkuuden kautta. Arkkitehtitoimistona OOPEAA:lla on paljon kokemusta sekä puun käytöstä rakentamisessa että myös uusien CLT:n mahdollisuuksia hyödyntävien ratkaisujen kehittämisessä. Puurakentamisen suunnittelijana OOPEAA on tunnistanut tarpeen työkalulle, joka mahdollistaa rakennuksen ympäristökuormituksen suuntaa-antavan arvioimisen jo heti suunnittelun alkuvaiheessa siten että rakennushankkeen kestävyyteen liittyvistä tekijöistä on mahdollista keskustella hankkeen

päätöksen tekoon osallistuvien eri tahojen kanssa hankkeen keskeisiä suuntaviivoja määrittäviä ratkaisuja informoivana ja ohjaavana tekijänä. Nykyisten tarjolla olevien LCA-analyysin työkalujen avulla hankkeen elinkaarikestävyyden arvioiminen on mahdollista vasta kun suunnittelu on edennyt jo varsin pitkälle, koska varsinaisen elinkaarikestävyyslaskelman tekeminen edellyttää sitä, että valinnat materiaalien, rakenteellisten ratkaisujen ja julkisivun osalta on jo tehty. Kestävyyden näkökulman tuominen osaksi suunnittelua jo heti hankkeen alkuvaiheessa avaa mahdollisuuden kehittää ja laajentaa ymmärrystä puun käytön mahdollisuuksista kestävän rakentamisen materiaalina. Se toimii myös päätöksenteon tukena eri vaihtoehtojen kestävyyttä arvioitaessa. Varhaisen arvioinnin työkaluna JOKOTAI Material Impact Screener palvelee paitsi suunnittelijoita, myös päättäjiä ja rahoittajia.

JOKOTAI Material Impact Screener tarjoaa olemassa olevista LCA-työkaluista merkittävällä tavalla poikkeavan visuaalisen ja helposti ymmärrettävää informaatiota tuottavan työkalun, joka soveltuu suunnittelun ja rakentamisen ratkaisuihin liittyvän päätöksenteon varhaisen vaiheen tarpeisiin. Työkalu tarjoaa mahdollisuuden tarkastella rakentamisen eri ratkaisuvaihtoehtojen ekologista kestävyyttä ja ympäristökuormitusta jo rakennushankkeen suunnittelun alkuvaiheessa. Sen avulla on mahdollista hahmottaa puurakentamisen edut elinkaarikestävyyden näkökulmasta jo rakennushankkeen varhaisessa vaiheessa ja hyödyntää sen avaamaa ymmärrystä päätöksenteossa. Helpon käytettävyytensä ja selkeän, visuaalisen informaation esitysmuotonsa ansiosta työkalu toimii sekä suunnittelun että kommunikaation välineenä ja edesauttaa puurakentamisen etujen laajemman ymmärtämyksen syntymistä.

Hankkeen toteutus ja tulokset

Työkalun kehittämisvaiheessa tehtiin aktiivista yhteistyötä paitsi eri maissa toimivien, kestävyyden näkökulman keskeisen merkityksen tiedostavien arkkitehtitoimistojen kanssa myös muiden rakentamisen alan toimijoiden kanssa. Hankkeeseen kutsuttiin mukaan valikoitu joukko testikäyttäjiä, jotka edustavat mahdollisimman monipuolisesti rakentamiseen ja suunnittelun kenttää. Hankkeen aikana järjestettiin sarja testikäyttäjien työpajoja, joiden yhteydessä työkalun toimivuutta saatiin arvokasta tietoa työkalun jatkojalostamiseksi vastaamaan käyttäjien tarpeita mahdollisimman hyvin. Hankkeen tuloksena syntyi avoin verkkopohjainen rakennushankkeen eri ratkaisuvaihtoehtojen kestävyyden visualisoinnin työkalu, joka mahdollistaa kestävyyden arvioinnin tuomisen osaksi rakentamiseen liittyvää päätöksentekoa jo hankkeen alkuvaiheessa. Avoimen datan periaatteisiin ja taustalla olevien laskelmien läpinäkyvyyteen perustuva työkalu kehittyy sitä toimivammaksi mitä enemmän sitä käytetään, sillä käyttäjät voivat täydentää sitä käytön myötä. Hankkeen tulosten esittelemiseksi tullaan järjestämään avoin verkkopohjainen seminaari, jossa hankkeen kehittämiseen osallistuneet testikäyttäjät kertovat kokemuksistaan ja avaavat myös laajemmin kestävyyden merkitystä oman työnsä näkökulmasta. Kiinnostuneet osallistujat tutustutetaan työkaluun ja tarjotaan heille mahdollisuus osallistua käyttäjinä sen jatkokehittämiseen. Seminaarin yhteydessä kehittämishankkeen anti koostetaan myös julkaisun muotoon.

Hankkeen päättyessä työkalun beta-versio avataan avoimeen käyttöön. Työkalun käyttöönottoa tukemaan on tuotettu perehdytysmateriaali verkkoon ja syksyn aikana tehdään viestintäkampanja, jonka tavoitteena on tuoda työkalu mahdollisimman laajan käyttäjäkunnan tietoisuuteen ja saavutettavaksi. Laajapohjainen yhteistyö kunkin erikoisalan parhaiden osaajien kanssa on keskeinen lähtökohta OOPEAA:n toiminnassa. Yhteistyön ja eri osapuolten välisen vuoropuhelun kautta avautuu uusia näkökulmia ja syntyy uusia ajatuksia, joiden myötä ratkaisut hioutuvat ja kehittyvät. Tämän hankkeen yhteydessä on kansainvälisen ja monialaisen yhteistyön myötä avautunut mahdollisuus paitsi toimivan työkalun kehittämiseen rakentamisen eri ratkaisuvaihtoehtojen kestävyyden arviointiin jo rakennushankkeen suunnittelun varhaisessa vaiheessa, myös puurakentamisen kehittämiseen ja

edistämiseen liittyvään vuorovaikutteiseen jakamiseen ja oppimiseen eri tahojen kesken.

Hankkeen toteuttavana tahona on toiminut OOPEAA ja hankkeen vastuullisena johtajana Anssi Lassila. Hankkeen ympärille on muodostettu ydin tiimi, joka koostuu OOPEAA:n toimiston omasta tiimistä ja sen tueksi hankkeeseen alihankintana kiinnitetystä ohjelmoinnista vastaavasta henkilöstä ja käyttöliittymäsuunnittelusta vastaavasta henkilöstä. OOPEAA:n tiimin vetäjänä on toiminut Katharina Heidkamp. Työkalun ohjelmoinnista on vastannut insinööri Lucas Toh ja sen käyttöliittymäsuunnittelusta Tuomo Tammenpää. Ohjelmointityöhön on lisäksi osallistunut Daniel Blackburn. Hankkeen viestinnällisten toimenpiteiden toteuttamisesta on vastannut erillinen viestinnän tiimi, joka on toiminut tiiviissä yhteistyössä hankkeen suunnittelutiimin kanssa hankkeen alusta lähtien.

Hankkeen oli määrä päättyä kesäkuun loppuun mennessä 2020, mutta Korona-pandemiaan liittyvien syiden johdosta suunnitelmat menivät osin uusiksi kevään 2020 osalta, minkä vuoksi anoimme ja saimme hankkeelle jatkoaikaa 30.9.2020 saakka. Alun perin Helsingissä toteutettavaksi suunnitellun kansainvälisen seminaarin sijaan hakkeen tuloksena syntyneen työkalun lanseeraamiseksi järjestetään verkkoympäristössä paneelikeskustelu, johon on kutsuttu osallistujia sekä Pohjoismaista että muualta maailmasta.

2. Background and Goals

The Environmental Impact of the Building Industry

Since the discovery of fossil fuels followed by the industrial revolution, human activities on earth are estimated to have caused approximately 1.0°C of global warming above pre-industrial levels. Between 2030 and 2050 global warming is likely to reach 1.5°C or more, if it continues to increase at the current rate.[1] Climate change in the 21st Century is projected to have severe consequences for the environment and human health world-wide.[2] The urgency to take action becomes clear in the special report on global warming of 1.5°C, published by the intergovernmental panel on climate change (IPCC), which states that by 2030 all sectors world-wide need to undergo a dramatic change of direction towards a more sustainable and responsible use of resources in order to limit global warming to a maximum of 1.5°C. [1]

Hereby the building sector plays an important role. Currently it is the most resource intensive sector globally. In Europe buildings are responsible for 35% of greenhouse gas emissions, 42% of final energy consumption, 50% of extracted raw materials and 30% of generated waste. [3] The immense need for resources and the production of waste and emissions by the building sector imposes an enormous pressure on the environment. Therefore, architects carry an important responsibility in lowering the environmental impact of their projects. But in order to create buildings with a smaller environmental footprint, architects need to be able to understand all inputs (energy, resources) and outputs (emissions, waste) that are caused by their design decisions.

1 Allen, M.R., et al. (2018) Framing and Context. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C
2 Füssel, H. -M. et al. (2017) Climate change, impacts and vulnerability in Europe 2016 – An indicator based report
3 Dimova, S. and Gervasio H. (2018) Model for Life Cycle Assessment (LCA) of buildings, Publications Office of the European Union

A Building's Life Cycle Phases

Assessing environmental sustainability of buildings requires taking a look at the whole building life cycle - from material extraction to demolition. Life Cycle Assessment (LCA) used as a method to quantify the environmental impacts of buildings can give a valuable insight into all processes related to the construction, use and deconstruction of a building. It models the buildinǵs technical life cycle and documents energy and material flows throughout the building's lifetime, while assessing the associated environmental burdens. The building's life cycle is divided into five stages which need to be dealt with: The production stage, construction process stage, use stage, the end-of-life stage and benefits and loads beyond the system boundary. The methodology of life cycle assessment is based on the international standards ISO 14040 and ISO 14044. In Europe LCA is included in the European standards on sustainable construction and further specified in the standards EN 15643 series, EN 15978 and EN 15804.

A Compass for Direction in the Quest for More Responsible Building Practices

As architects, we are stakeholders in the processes that shape our built environment. In order to take seriously our responsibility in that, we at OOPEAA felt the need to better understand the impact that our choices of material have on the sustainability of a building project. Instead of merely relying on instinct and common beliefs, we wanted to create a tool that would help us deepen our knowledge about the impact of materials through an analysis of verified and reliable data. We wanted to be able to compare the impact of alternative material choices before nailing down our decisions regarding the materials to be used in a new project under design.

Currently, there are plenty of tools available to assess the sustainability of a building over its full life cycle. However, those tools are mainly intended for conducting an analysis of a building project once all the crucial decisions have already been made and the design process has already reached quite an advanced stage. In practical terms, that means that at that stage one can no longer go back and start over the design with a different material. To complement the existing Life Cycle Assessment tools, we felt the need for a tool that would be quick and easy to use at an early stage of the design process when it is still possible to re-evaluate and change our choices regarding materials to be used.

Additionally, we wanted a tool that would make it possible for us to communicate about the impact of the material choices in a clear and comprehensible manner not only among members of our own team but also with clients, developers and public officials in charge of building permits. Finally, we also wanted to share the tool with others internationally and use it as a platform for discussion about sustainable practices beyond our Nordic experience in Finland.

Early Phase Impact Screener

Currently the method of Life Cycle Assessment (LCA) is mainly used at the end of a building´s design phase or for certification purposes, due to the level of detail needed to perform a full LCA. To complement this, a tool is needed that enables architects to understand and communicate the initial impact of structural and material choices already in the early design phase. Important decisions such as building volume as well as the structural and facade materials to be used are usually made in the beginning of the project. These early decisions, however, have a big effect on the long-term sustainability of the end result.

With the JOKOTAI tool, OOPEAA has created a material impact screener that enables quick drafting and visualization of a preliminary design for assessing the initial impact of material and structural choices at an early stage of the design and decision-making process. To underscore the intent of providing a tool that allows us to make comparisons between alternative material choices, we decided to name the tool JOKOTAI. It is based on the Finnish words “joko – tai” that means “either – or”. To emphasize the nature of the tool as a quick evaluation tool to be used at an early stage of the design process to screen alternative options, we included the further specification “Material Impact Screener” in the name. JOKOTAI is based on the screening method of environmental impacts conducted according to the EeB Guide (Operational Guidance for Life Cycle Assessment Studies of the Energy Efficient Buildings Initiative, European Commission Research & Innovation Environment).

3. Project Team and Work Process

The JOKOTAI Material Impact Screener tool is realized under the leadership of OOPEAA in collaboration with a small team of experts. It has been carried out with the support of a grant awarded by the Ministry of Environment in Finland. The grant is part of the Growth and Development from Wood Program.

The core team of the development project for the JOKOTAI tool is composed of a small group of OOPEAA staff working in collaboration with a programmer, a 3D specialist, a user interface designer and a person in charge of communications and dissemination. Anssi Lassila acts as the director for the development group, and Katharina Heidkamp is in charge of the research work at OOPEAA. Lucas Toh has been in charge of the programming for the tool working in collaboration with Daniel Blackburn who has shared his special expertise with the team. Tuomo

Tammenpää has been in charge of the user interface design. The aspects of communication, dissemination and international collaboration have been an integral part of the development process from its inception. A small international group of test users including architecture offices in the Nordic countries, Europe and the United States as well as Japan has provided an important sounding board and valuable feedback for the project during the various stages of the iterative development process.

Learning from Collaboration

As architects, the OOPEAA team is in a special position to create a tool to address the needs of architects. The journey of collaboration with programmers and user interface designers to create a web-based assessment tool has been an interesting and rewarding one, and it has given all of the parties involved a great opportunity to learn from each other. Having been chosen as one of the projects in the Growth and Development from Wood Program by the Ministry of Environment, Finland has given a meaningful framework to connect the project with. It has also provided valuable financial support that has made it possible to focus on research work.

The partnership with Obayashi, a Japanese construction company, has further enriched the process and broadened our perspective beyond the European experience. It has made us aware of the fact that the way in which data regarding the impact of materials on the environment is collected and made available varies greatly from country to country. This makes it sometimes challenging to compare the data from one place with that of the data from another. It also highlights the need for transparency regarding both the sources of data used as well as the method of calculation applied. Therefore, transparency has been one of the key guiding principles in creating the JOKOTAI tool.

Description of Work

An iterative process that can be roughly divided into two phases according to the nature of the development work performed. In the first phase focus was on background research and early development of the tool. In the second phase the tool was developed further and fine-tuned in response to the experience of testing and feedback from test users.

As the core team was composed of a small group of international collaborators based in different geographical locations, a practice of making efficient use of electronic platforms of communication was established early on. The core team had regular weekly meetings over Skype, and once a month there was a meeting for which the entire team would gather together for a workshop in the same physical location. For quick and efficient internal communication among the members of the group, Slack was used and for keeping track of the progress of tasks Trello was used. Due to the international nature of the team, the language of communication for the project was English.

Research and Early Development Phase 11.15.2018 – 30.9.2019

In the research and early development phase, the scope of work and the focus of the tool were defined on the basis of a thorough evaluation of the already existing life cycle assessment tools that provide a complete analysis of the entire cycle of a building's life from the material extraction to the demolition of a building. An analysis of a selection

of already completed OOPEAA projects such as Puukuokka, Pihapetäjä and Jätkäsaari and a project in the early design phase, Porvoo, was performed to test several existing LCA tools.

On the basis of the testing and evaluation of the existing tools for performing a full life cycle analysis of a building project, three aspects were identified as key focus points in developing a tool for the early assessment on the impact of structural and material choices on a building's environmental impact:

1. The need for a quick assessment tool that can be used in the early design phases

The concept of the life cycle assessment of buildings is a great support in identifying the processes and building parts that contribute significantly to the environmental performance of a building. However, typically the assessment is quite complex and time consuming to perform and requires a level of detail that can only be achieved after a project's completion. This means that the knowledge acquired as a result of performing a life cycle analysis is not available to be used to inform the decision-making process during the early design phases.

2. A visual tool that presents environmental impacts in a comprehensible manner

Architecture is a profession with a very visual approach. However, the presentation of environmental data in the current LCA tools is often a based on numeric tables and pie charts with no apparent visual connection to the designed building. In order to emphasize the connection between the building's design and i.e. the choice of materials and their environmental impact, a strong visual representation is needed. In addition to the need for a visual tool that can be used within the architecture office, a visually oriented tool is needed also to enable architects to communicate about environmental impacts of a new building project with engineers, clients and public officials in charge of building permits.

3. A tool that presents information about environmental impacts in a transparent manner

Evaluating the environmental sustainability of building materials requires transparent communication of all impacts related to their production, service life, and afterlife from the producer. Environmental product declarations (EPDs) are supposed to provide that information. However, currently only a fraction of the building materials produced in Europe include a complete EPD. In addition, the current LCA tools often lack the transparency of calculation methods and EPD sources. In order to make it possible for us to be fully aware of all impacts related to materials, EPDs need to become an essential and verified element of material trade and LCA tools need to provide transparently their sources.

After defining the need for a visual and transparent early stage life cycle assessment tool, a range of possible inputs and outputs of the tool were considered and evaluated. The initial idea was to create a tool that would provide a combination of a 3D sketching application and a complete life cycle assessment. However, during the development process it became clear, that in order to offer a tool that can efficiently be used to inform the design process at a stage in which it is still possible to alter the material and structural choices, the focus of the tool needs to be directed more towards the early design phase of a building. In order to emphasize the nature of the tool as an early stage screening tool, it was decided that it is best to limit the building design to an abstract volume only. Further, to highlight the part of the building design process in which an architect has the most pertinent influence, the building materials, it was decided to focus only on phase A1-3 (Material extraction, transportation and production) of the life cycle assessment. The phase A1-3 is the second largest contributor to the carbon footprint of a building, with only the operative energy consumption having a bigger impact. Finally, the decision was made to enable a comparison of only two alternative building options at a time. This further served the intention of making this a tool to compare the environmental impacts of building materials.

The research and early development phase also included a series of visits to various architecture offices in the Nordic countries to present the idea of an early design material screener and to get their feedback. The visits proved to be extremely valuable because they made the urgent need for a transparent and visual assessment tool very clear.

As part of the initial phase of the development process of the tool, the following steps were conducted:

- Research and testing of optimal software architecture (front-end and backend), including selection of front-end framework, selection of backend server setup and UI-package.
- Development of data models (input and output) and calculation engine.
- Testing of calculation engine and data validity.
- Development and testing of UX (User Experience) concepts.
- Setup and configuration of Cloud-server.
- Research and integration of external packages for data visualization and design modelling.

During the first part of the development of the tool, the software architecture and server solutions were finalized, as well as the development of the data models and the research of external packages. The calculation engine and UX-concepts were developed through an ongoing development process and finetuned in response to findings from user-testing and internal research on calculation principles.

Development, Testing and Fine-tuning Phase 1.10.2019 – 30.9.2020

In the project development phase, the inputs and outputs of the tool were determined and specified. Due to the shift from a flexible 3D drawing application to a more simplified 3D volume, all parameters that define the building's volume and material mass had to be determined according to recommendations for maximum width, length, story height, number of stories, internal load-bearing layout density, construction types, and opening percentage.

In the second part of the project, the focus of the tool development was on optimizing the data flow and the calculation engine. Later, when user-testing was conducted, the focus shifted to integrating the knowledge learned from the testing, including adapting the UX-concepts and data structures. Based on the information gathered during the initial phase of the project, where the specifications for the application were defined, the development towards a production build was initialized. Due to the non-standardized nature of the application, most of the components within both the frontend and backend required significant customization in order to perform the required task.

For the second phase of the project, the team focused on preparing the stack for user testing and the production setup. In accordance with the specifications of the development team and test user feedback, the user interface and functionality were developed to meet the highly customized demands for the appearance and functionality of the tool. This included the customized styling of the web-application, implementing navigation, templating and assets, as well as the interface logic. This was developed through several development cycles, in dialogue with the development team, in order to reach a satisfactory user experience and features.

To prepare for test-users and public launch, a production server was set up and configured for the application. This

included setting up a CI/CD pipeline for development- and production environments, integration to OOPEAAs existing website and implementing security and routing on the server. In this development and test use stage, the server configuration was set to handle both the web-application and the database layer of the application. Due to the customized nature of a calculation tool, a significant amount of time was spent on developing the database-layer logic, which includes the handling of different scenarios and performing the calculation.

For data storage, the backend configuration has been set up to fit the needs of the web-application. This includes developing the user management system, content management system, database layer and logic, and configuring the REST API. In order to conform to the specifications of web-application, the data structures have been refined in the database, while the REST API has been configured to deliver the data.

A big part of the work in the second development phase was the preparation of information for 29 building materials that were selected for inclusion in the tool in its first iteration. Seven building parts were defined: foundation, vertical and horizontal structural elements, insulation, façade, floor and roof material. For each of the seven building parts, a range of commonly used building materials was selected. The collection of information for each material included a comparison of multiple European EPDs to identify the median EPD for the tool. In addition to the numerical information based on the EPD, each material was analyzed on its expected service life, the environmental pros and cons, the production process, and the recycling potential in the EU. Furthermore, each material has a detailed breakdown of its volume / surface area in the building, its individual impact and the EPD source link provided in the info box that was decided to be included in the tool. To visualize the information provided regarding the materials, an illustration was created for each aspect. That resulted in the development of 116 illustrations for 29 materials.

Contents of the user interface, 3D visualization and construction types of the building and calculation methodology (Phase A1-3 of LCA) were developed in close collaboration between the research team, the graphic designer, the programmers and the people responsible for the communicative aspects of the tool. In order to transparently show our approach, sources and calculation methodology in a transparent manner, a “research” information page was created to explain each element of the tool in detail. For presenting the environmental impact of different parts of the building in a visual manner, three result categories were defined: resource types, building parts and building materials. Each of the categories identify the most contributing resource, building part or material for the two alternative building options. In the final result page, a comparison of the total environmental impact of both of the alternative building options visualizes the amount of CO2 emissions or primary energy that can be saved by choosing the more sustainable option. In addition, the potential amount of carbon storage provided is also indicated in the results as a separate piece of information.

Finally, the partnership with Obayashi, a Japanese construction company, helped to further enrich the process and broaden our perspective beyond the European experience in the life cycle assessment of buildings. It made us aware of the fact that the way in which data regarding the impact of materials on the environment is collected and made available varies greatly from country to country. This made it sometimes challenging to compare the data from one place with that of the data from another. It also highlighted the need for transparency of both the sources of data used as well as the method of calculation applied. We hope that in the future, material production companies would be obliged to provide a complete dataset about the environmental impact of their material which is then checked and verified by independent parties.

4. Results

Due to the unexpected situation with the Covid-19 pandemic, the schedule of testing and finetuning phase of the tool in 2020 was slightly delayed and there was also a need to adjust the plans regarding the arrangements for the launch of the tool for sharing it with the public. An extension of the run of the project was requested so as to move the concluding of it from the initially planned time of the end of June 2020 to the end of September 2020, and permission for the extension of time was granted. In lieu of the original plan of organizing an international workshop and a launch seminar in Helsinki in June 2020, an online seminar will be arranged in the fall of 2020 in order to share the tool with the wider public. In all other respects, the project was carried out and realized as planned.

A Screening Tool for Comparing Alternative Choices of Material

OOPEAA JOKOTAI is a tool for screening the environmental impact of structural and material choices on the sustainability of a building project. The tool enables architects to quickly sketch the building volume of a preliminary design and compare the environmental impact of alternative material choices to support the early decision-making process. The intention is not to create a tool for providing a complete life cycle assessment. Instead, the goal is to create a web-based visualizing tool to be used in the early stages of design prior to having made decisions that at a later stage will make it possible to perform a full life cycle analysis. The tool is a user friendly, web-based platform that enables communication and visualizes sustainability issues in a comprehensible manner. The calculation method and sources are made visible to support the learning process and to provide full transparency.

To underscore the intent of providing a tool that allows us to make comparisons between alternative material choices, we decided to name the tool JOKOTAI. It is based on the Finnish words “joko – tai” that means “either – or”. To emphasize the nature of the tool as a quick evaluation tool to be used at an early stage of the design process to screen alternative options, we included the further specification “Material Impact Screener” in the name.

Application

JOKOTAI allows architects to get an overview of the environmental impact of structural and material choices during the early design stages and to use the tool to discuss and evaluate design options within the team. At the same time, the tool can be a valuable support in the communication with technical planners and clients. It provides a detailed breakdown of environmental impacts caused by structural and material choices, which can be utilized in conversations with technical planners. It visualizes these impacts in a comprehensible manner to also support communication of sustainability issues with clients. That way JOKOTAI does not only function as a calculation tool for environmental impacts, but also supports a continuous learning process that promotes awareness of key issues regarding sustainable building design.

Scope

A building’s environmental impact can be divided into embodied and operative emissions. Embodied emissions include all processes before and after the occupation of a building, while operative emissions cover the energy and water consumption during occupation time. Since the global oil crisis in the 1970s, significant efforts have been

made to reduce the operative energy consumption of buildings. As a result, the operational energy consumption of new and refurbished buildings has decreased considerably.[1] Therefore, reducing the embodied energy of buildings will be an important part of mitigating the environmental impact of the building sector in the future.

Within embodied energy, the production phase (A1-3) often accounts for the biggest share of total embodied energy.[2] It is based on independently verified and registered EPDs that communicate transparent and comparable information about the environmental impact of products and does not depend on external influences in terms of service life of materials or end-of-life scenarios. The production phase is the one in which the architect has the most pertinent influence in determining choices that impact the sustainability of a building. JOKOTAI focuses on the impact of material and structural choices in this phase (A1-3), while also giving useful information regarding the potential impact of choices later on in a building's lifespan.

1 Gantner, J. et al (2015) EeB Guide Guidance Document - Part B: Buildings - Operational guidance for Life Cycle Assessment studies of the Energy Efficiency Building Initiative

2 Lavagna et al. (2018), Benchmarks for environmental impact of housing in Europe: Definition of archetypes and LCA of the residential building stock

Overview of the Functionalities of the Tool

JOKOTAI is not based on an existing BIM program. Instead it is a web-based application that supports the architect in the early phases of the design by offering a quick 3D volume draft and impact assessment tool. The assessment can be made in four steps. First a 3D volume of the estimated design is created by defining the width, depth and height of the building, the internal structural density, the construction type and the opening percentage. Afterwards materials for the main building parts can be selected. In the comparison view the environmental impacts of structural and material choices of the designed building are displayed in the environmental indicators global warming potential (GWP) and primary energy from non-renewable resources (PENRT). Material alternatives can be tested and compared with the original design by applying them to an identical copy of the building. A detailed breakdown of the results informs about the most contributing building parts, resources types and materials, while giving additional information about the production flow and recycling potential of building materials.

Impact Comparison and Material Information

The user interface is divided into three sections, each serving different purposes. The top bar functions as a call for action during the 3D modeling phase, which guides the user through the design process. Later on the results of the environmental impacts are displayed in the top bar. The 3D model, located in the center, is visualized in a pre-defined color code, representing the resource type of the selected material. The bar at the bottom provides additional information regarding the current action as well as material and result specifications.

In addition to the calculated environmental impacts caused by the extraction and production of building materials (Phase A1-3), the JOKOTAI tool provides information about the expected service life of materials, their environmental pros and cons, the production process and their recycling potential, including the most common pathway of recycling in Europe at the moment. The current version of the JOKOTAI tool includes information for 29 different building materials in the categories structure, foundation, insulation, facade, floor and roof material.

To support the aim of making decisions based on a fuller understanding of the impact that our choice of building materials has on the environment, we also felt the need to provide information about the environmental harm

caused by some of the commonly used building materials. Therefore, we have chosen to complement the calculation results provided by the JOKOTAI tool by graphical information about the environmental burdens, the expected service life and the recyclability of a material.

Environmental Product Declarations as Sources of Data

Evaluating the environmental sustainability of building materials requires transparent communication of all impacts related to their production, service life and afterlife from the producer. However, currently only a fraction of the building materials produced in Europe include a complete environmental product declaration (EPD). And, depending on the location, in some parts of the world information about environmental impacts of materials might not be required at all. That needs to change in order to make it possible for us to be fully aware of all impacts related to the extraction of valuable resources and emissions and waste caused during production and at the end of a product's service life.

Focus on the Most Resource Intensive Parts of a Building's Life Cycle

The current version of the JOKOTAI Material Impact Screener is only the very first iteration of the tool. In this first version it is possible to analyze the impact of alternative material choices in the case of singular buildings. In this first development round of the tool, we decided to focus on the phase that, after the consumption of operative energy, is the most resource intensive part of a building's life cycle, that from the extraction of raw material to the production of the building materials used (LCA phases A1-3). This is also the phase in which the architect has the most pertinent influence in determining choices that impact the sustainability of a building.

5. Impact of the Project

The JOKOTAI Material Impact Screener enables a direct comparison between building materials in the early stages of the design for a building project. Based on the material's environmental product declarations (EPDs), the materials can be compared in two environmental indicators: the 'global warming potential' (GWP) and the 'primary energy from non-renewable resources' (PENRT). Currently, conventional construction often consists of highly processed materials with complex compositions. Despite the price advantages and comparable energy efficiency during occupation, these materials often have a high demand of energy during production and considerable environmental impacts. This, however, is typically not taken into account in the current building practices. The JOKOTAI tool allows architects and planners to screen the environmental implications of their design choices at the beginning of their design project, which, we hope, might result in a change of direction towards using more renewable, low processed and overall more sustainable building materials.

Therefore, the positive impact of the tool would be an increased awareness of the environmental impacts that occur during the production of various building materials, the knowledge about sustainable alternatives to conventional materials, and a learning process in terms of the life expectancy, production process and recycling potential of materials. In order to provide an educational aspect intended to support the formation of such an increased awareness of the environmental impacts of various building materials, the tool includes material info boxes with information on the qualities of 29 different materials. In the future, it is possible to add more materials to the selection of alternative materials included in the material library of the tool.

A possible risk of a potentially negative impact could be the 'screening' character of the tool, which was only possible to achieve by selecting just one EPD for each building material. That might result in a generalization of materials, despite the fact that the environmental impact of the same product can be very different depending on its source. A factory that uses renewable energy, is efficient in its use of materials, and can avoid long transport distances can produce functionally comparable products with considerably less emissions than a factory that relies on fossil energy and has not yet optimized its production and raw material acquisition processes. However, that issue was addressed in the process of the development of the tool by comparing multiple EPDs of the same product from various European manufacturers and choosing an EPD for the tool that best represented the average environmental impact of the product. Moreover, in order to make the source of the EPD data transparent, we have decided to include a link to the source in the tool so that it is easily accessible to the users.

Special attention has been devoted to making the tool as transparent as possible to the user. In addition to providing a link to the source of the EPD data used, also the calculation of the global warming potential (GWP) and the primary energy from non-renewable resources (PENRT) has been made visible in the tool.

6. Communications and Dissemination

The idea of providing a tool for facilitating communication regarding the environmental impact of the structural and material choices of a building project is at the core of the concept of the JOKOTAI tool. In addition to creating a visually oriented tool for making it possible for architects and builders to communicate with clients and decision makers about the impact of alternative choices at an early stage of the design process, and to providing an educational tool offering information on the environmental impact of different materials, we also hope to be able to provide a platform for discussion and debate among architects and designers globally on questions related to sustainable and responsible building practices. Therefore, the aspects of communication, dissemination and international collaboration have been an integral part of the development process of the tool from its inception.

The primary target groups for the tool are practitioners involved in the building design and construction related activities. Therefore, the publicity efforts are primarily focused on reaching out to professionals in the field. The strategy has been to build publicity in stages, starting with establishing a dialogue with a relatively small group of test users, and then gradually broadening out to wider audiences as the tool takes shape and is ready for sharing with users. Eventually, the plan is to share the tool as broadly as possible and to invite users from a variety of different backgrounds. In line with the intention of providing a tool that is intended to facilitate communication between different parties in the early stages of design, it was deliberately decided to offer it as an open source tool in order to make it easily accessible and usable for people.

We want to make the case for a collaborative effort among architects to discuss together current issues in the field of sustainable design. JOKOTAI is planned as a starting point, with the potential to adapt to the needs of designers by enabling a lively exchange of thoughts and comments on the tool and its usability. At the same time, it provides a platform for ecological building case study projects of different architectural firms to inspire and encourage a low embodied carbon design. Dialogue and exchange with a diverse group of international test users during the different stages of the development process has provided a good foundation for a continued discussion on the topic. The small group of test users has included architecture offices and other agents involved in the building and construction field with various levels of prior knowledge on sustainable building practices, from experts with a high level of experience in the area to practitioners with an awakening interest in the subject matter. The group of test users covers a broad range including offices from the Nordic countries and from Europe as well as the United States and Japan.

During the development process, early information about the upcoming tool has been shared on select platforms including the Holtzbau Conference in Augsburg, Germany in February 2020, just prior to the Korona pandemic putting travel and international events on hold. The tool has already attracted plenty of interest with a few early peak presentations of it published in magazines such as the Swiss publication ModulArt (https://www.modulart.ch/cleveres-tool-jokotai-von-oopeaa/) and the October issue of the Singapore based SLIA magazine under the title Reboot. The project has also been presented in the news section of the OOPEAA home page (https://oopeaa.com/oopeaa-is-embarking-on-a-research-and-development-project-to-create-a-life-cycle-visualizer/ and https://oopeaa.com/japanese-company-obayashi-is-joining-as-partner-in-the-oopeaa-initiated-life-cycle-visualizer-project/) and in the social media networks of OOPEAA with a reach of about 14 000 followers in December 2019. A more detailed presentation of the project under development has also been published in the Research section of the OOPEAA home page (https://oopeaa.com/tool-for-evaluating-sustainability/).

In order to share the JOKOTAI tool with a wider audience and to invite others to join in the discussion already started with the small group of test users, the plan is to launch the tool in the fall of 2020 by making use of the social media channels of OOPEAA as well as by reaching out to select online media publishers and discussion leaders. In lieu of the original plan to organize a seminar event in Helsinki with invited experts from different parts of the world to come to share their thinking on the topic of sustainable practices in the field of architecture and building, an online event will be organized. Further, we plan to actively participate in international conferences to present the tool in the coming year.

7. The Validity, Durability and Applicability of the Results

The JOKOTAI Material Impact Screener is based on the 'Screening' principle of the EeB Guide Guidance Document – Part B: Buildings – Operational guidance for Life Cycle Assessment studies of the Energy Efficiency Building Initiative. Due to its rough, screening character, the developed 3D sketch and calculated results of environmental impacts during the production phase (phase A1-3) of a life cycle assessment, need to viewed as an early guidance in the decision-making process about structural and material choices and not as a precise calculation of the environmental impacts of a specific building project. Anyhow, the transparent character of the tool enables the download of the chosen EPD and an insight in the predefined material thickness, the total volume, surface area or weight of a material and the calculated environmental impact in two environmental indicators. As intended, this makes the tool a rough, early stage assessment tool with a lower degree of precision and functionality compared to a tool performing a full LCA. Yet, despite its rough character suitable for a screening tool, the JOKOTAI tool provides full transparency of the calculation methodology and EPD sources to enable a fact-based analysis of the credibility of the tool.

In order to make it easy to maintain the tool and keep the information used as a basis for the calculations, we have designed it in such a way as to make it possible to update the EPD information over time. We have also made a point of clearly indicating the validity period of the given EPDs used. Moreover, it is also possible to add new materials as needed.

In the future a tool such as the JOKOTAI Material Impact Screener could be an important element in the decision-making process in response to the sustainability demands of a new building project. Political support in terms of a mandatory screening of the embodied environmental impacts and municipal benchmarks for new building projects would promote the use of wood-based or other sustainable materials over conventional building materials.

The results of the JOKOTAI Material Impact Screener are not only useful in the decision-making process about building materials in an architecture office, but also enable a dialogue with clients, engineers and public officials in charge of building permits. Hereby, the tool can be used as a support in comparing different structural and material options of a building project or in referring to the sustainability of material choices in terms of their life expectancy or recycling potential. Due to its ease of use and the clear, visual presentation of information, the tool serves as a base for discussion for different stakeholders in the decision-making process of a new building project.

We have deliberately wanted to make this first version of the JOKOTAI Material Impact Screener tool an open source tool as a reflection of our intention to make it easily accessible and usable for people. We believe that by allowing people to have free access to the tool, we can promote its use. Furthermore, we have intentionally designed the tool in such a manner that it is at once easy to use, simple to read, and yet also provides a rich layer of information for those interested in digging a bit deeper into the information offered by the tool. That way, it functions also as an educational tool that allows people to learn more about the interdependencies between materials and their impact on the environment.

8. Budget

The research and development project for creating the JOKOTAI Material Impact Screener was supported by a grant from the Ministry of Environment as part of the Growth and Development from Wood program. In principle, the project was realized according the initial budget outline presented in the application for the grant. Due to the Korona pandemic, however, it was not possible to organize a launch seminar with international experts invited to share their experience and thinking on the topic of sustainable building practices in Helsinki as originally planned. Instead, a launch seminar will be conducted as an online event. This meant that some of the funds originally allocated for covering expenses related to the launch seminar planned to take place in Helsinki became available to be assigned for investing additional resources on fine tuning the tool on the bases of feedback gathered from the test users. This reallocation was discussed with representatives of the Ministry of Environment who grant permission for it.

9. Plans for Further Development

The current iteration of the JOKOTAI Material Impact Screener offers a good foundation for further development and a rich potential for various alternative possible ways of extending of the scope of the tool. During the two-year development program in 2018 - 2020, the tool has developed from the rough idea of quickly assessing and visualizing environmental impacts of preliminary design decisions to a functional 3D sketching and environmental impact assessment and comparison tool. It is our intention to continue to develop the tool further and make it possible to analyze larger complexes of several buildings or entire blocks in the context of a specific location. We also intend to extend the analysis to address the full scope of a building's life span. However, we intend to keep the tool focused on the needs of the very early sketching stage of the design process. This tool is intended to provide a compass for direction, not a roadmap with specific instructions.

The field of life cycle assessment is broad and a tool that enables the integration of life cycle based thinking in the design process can improve the environmental sustainability of a project dramatically. That is why we envision further development of JOKOTAI to make it even more applicable in different design scenarios.

Urban Scale

In the further development of the JOKOTAI tool, it would be possible to widen the scope from screening the environmental impacts of a single building to evaluating a combination of several buildings or even whole neighborhoods in their existing context. Nowadays a majority of the projects that architects are working with are done within the context of existing cities. Due to the ongoing global urbanization, the pressure on cities to densify and extend is increasing, which makes cities a significant contributor and therefore a focal point in the discussion about the environmental impact of the building industry. The work of an architect often combines working within a city that draws from the rich layers of existing structures while also putting the focus on the future of the growing city as a socially sustainable place to live and work. Therefore, an aim of the JOKOTAI II tool would be to widen the scope of assessment to the urban scale while placing the project to be evaluated in the context of its existing urban fabric.

By implementing a map interface, the building masses could be placed their urban context. That way local aspects such as the density of the urban fabric, size and materiality of the neighboring buildings as well as the existing structures on site could be taken into account when screening the environmental sustainability of a new project with the JOKOTAI II tool. Understanding the potential of whole neighborhoods being utilized as carbon storages could be one of the outputs of an assessment in the urban scale.

Existing Buildings

Construction and demolition waste in Europe accounts for around 800 million tons each year. The recovery rate of construction materials varies greatly between member states. However, in average only 50% of construction and demolition waste is being recycled in Europe.[1] The EU set a target to achieve a recycling rate of 70% across all member states by 2020, according to the new waste framework directive. [1] However, with a recycling rate of 70%, 240 million tons of construction and demolition waste would still end up being landfilled. That not only causes waste, but also results in the loss of valuable raw materials. Currently the lack of confidence in the quality of construction and demolition waste, the uncertainty about potential health risks and missing waste management and recycling infrastructures, prevent the development in the use of reclaimed construction materials.

Circular economy needs to become an integral part in the design of our built environment and architects carry an important responsibility in providing concepts for the reuse of existing buildings, recycling of materials or design for disassembly. And while a complete demolition and new construction is the more profitable option at the moment, the environmental impacts are severe. The JOKOTAI II tool could provide a screening option of existing structures, their potential for reuse and recycling or the environmental consequences and waste production in the case of demolition. It would visualize the fact that existing buildings are a valuable source of existing resources and a powerful method to save emissions in the construction process, while the impacts of demolition become an essential consideration in the early design phases.

1 European Commission (2016) EU Construction & Demolition Waste Management Protocol

Localization

Currently the EPD data for the JOKOTAI tool is based on average values of materials or specific building products in the European context. To increase the use of the tool worldwide, different EPD data sets could be created that cover each the range of a certain region in the world. By choosing the project´s location in the beginning of the assessment, a localized database would be selected automatically.

Screening the Complete Life Cycle

The first version of the JOKOTAI tool is focused on the initial embodied energy phases A1-3 (extraction, production and transportation of building materials), which have a significant impact on the final environmental footprint of a building. However, additional information regarding the operative energy demand, emissions and energy during construction processes, maintenance and demolition could be added to the assessment tool to give further insights into the full life cycle.

- Construction phase: How do different building materials effect the construction emissions, demand for energy and waste production? What are the effects of prefabrication in comparison to on-site construction?
- Maintenance phase: What are the most durable building materials? Which building materials produce a significant amount of waste during the building's lifetime due to their low recycling potential?
- Use phase: What effect do renewable energy systems have on the energy efficiency of a building compared to the material extraction, processing and maintenance demand of those systems?
- End-of-life phase: What are the materials with the highest reuse or recycling potential? How big is the share of demolition emissions in the complete life cycle?

Sustainability Network

JOKOTAI was created with the intention to enable architects to evaluate and understand the environmental impacts of their design choices at an early stage and to communicate them in a visual manner within their team or to third parties. Reducing embodied carbon emissions and embodied energy in buildings will be a key strategy in mitigating the environmental impact of the building industry in the future. Architects need to be aware of their immense responsibility especially in the choice of building materials at the beginning of the design process. However, there is not only one solution to a more environmentally sustainable and responsible approach. That is why we want to make the case for a collaborative effort among architects to discuss together current issues in the field of sustainable design. JOKOTAI is planned as a starting point, with the potential to adapt to the needs of designers by enabling a lively exchange of thoughts and comments on the tool and its usability. At the same time, it provides a platform for ecological building case study projects of different architectural firms to inspire and encourage a low embodied carbon design.

Possibilities for Further Development for JOKOTAI II

VISION 1 MULTIPLE BUILDINGS - BLOCK DESIGN

- While the current, first version of the JOKOTAI tool focuses on singular building, JOKOTAI II could enable to create a housing block with multiple buildings.

VISION 2 URBAN SCALE - NEIGHBORHOOD DESIGN

- The aim of the JOKOTAI II tool could be to widen the scope of assessment to the urban scale while placing the project to be evaluated in the context of its existing urban fabric.

VISION 3 EXISTING BUILDINGS - REUSE, RECYCLING AND DEMOLITION

- The JOKOTAI II tool could provide a screening option of existing structures, their potential for reuse and recycling or the environmental consequences and waste production in the case of demolition.

VISION 4 LOCALIZED EPDS - MULTIPLE DATASETS

- To increase the use of the tool world- wide, different EPD data sets could be created for JOKOTAI II that cover each the range of a certain region in the world.

VISION 5 COMPLETE LCA - CONSTRUCTION, OPERATION, DEMOLITION

- In JOKOTAI II all life cycle phases including the energy demand, emissions and energy during construction processes, maintenance and demolition could be part of the assessment to give further insights into the full life cycle.

10. Conclusion

The JOKOTAI Material Impact Screener tool is realized under the leadership of OOPEAA in collaboration with a small team of experts. It has been carried out with the support of a grant awarded by the Ministry of Environment in Finland. The grant is part of the Growth and Development from Wood Program. Having been chosen as one of the projects in the Growth and Development from Wood Program by the Ministry of Environment, Finland has given us a meaningful framework to connect the project with. It has also provided us valuable financial support that has made it possible for us to focus on research work.

During the two-year development program in 2018 - 2020, the tool has developed from the rough idea of quickly assessing and visualizing environmental impacts of preliminary design decisions to a functional 3D sketching and environmental impact assessment and comparison tool. It is our intention to continue to develop the tool further and make it possible to analyze larger complexes of several buildings or entire blocks in the context of a specific location. We also intend to extend the analysis to address the full scope of a building's life span.

The experience of creating the JOKOTAI tool has taught us that the process of developing a new tool as well as that of further expanding its scope are at once inspiring as well as labor intensive processes that are best addressed as a collaborative effort with a small and devoted team of experts who are willing to learn from each other and to explore new possibilities and try out new ways of doing things. While we see several interesting alternative paths for the further development of the tool, we know that they cannot all be tackled at once, and that for each one of them a considerable amount of resources and time will be needed.