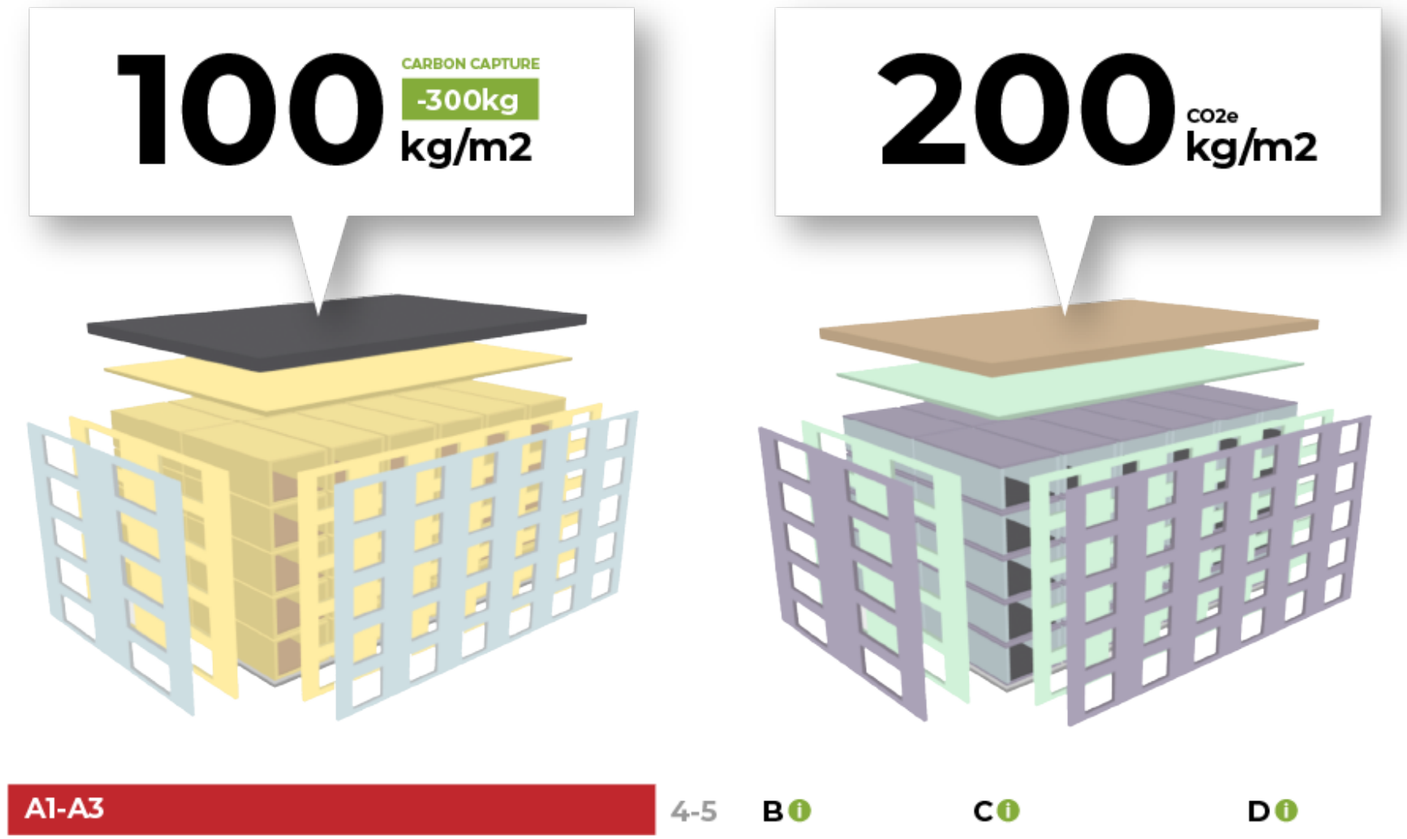

FINAL REPORT

JOKOTAI

Material Impact Screener

30.09.2020

OOPEAA RESEARCH

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INTRODUCTION

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.

35%
of total greenhouse gas emissions

42%
of total final energy consumption

50%
of extracted raw materials

30%
of total generated waste

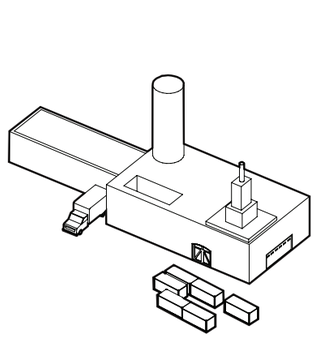
1 Allen, M.R., et al. (2018) Framing and Context. In: Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C
2 Füssel, H. -M. et al. (2017) Climate change, impacts and vulnerability in Europe 2016 - An indicator based report
3 Dimova, S. and Gervasio H. (2018) Model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

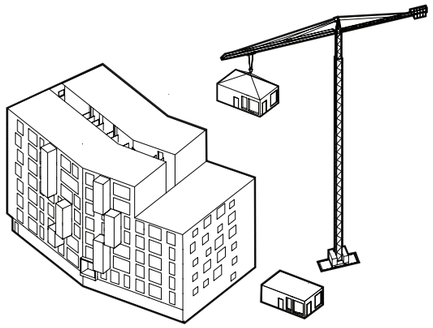
INTRODUCTION

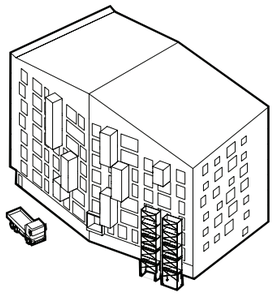
A Building’s Life Cycle Phases

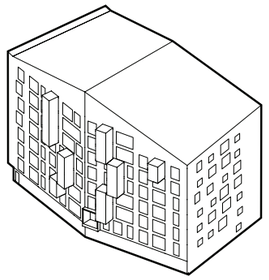
Assessing environmental sustainability of buildings requires taking a look at the whole building life cycle - from material extraction to demolition. Life Cycle Assessment (LCA) used as a method to quantify the environmental impacts of buildings can give a valuable insight into all processes related to the construction, use and deconstruction of a building. It models the building´s 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. [1]

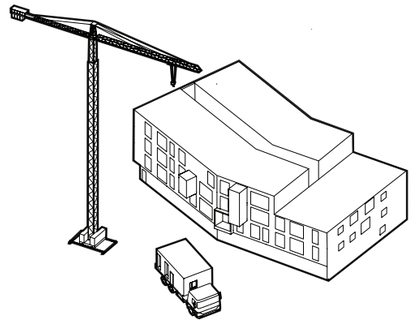
1 Gantner, J. et al (2015) EeB Guide Guidance Document - Part B: Buildings - Operational guidance for Life Cycle Assessment studies of the Energy Efficiency Building Initiative











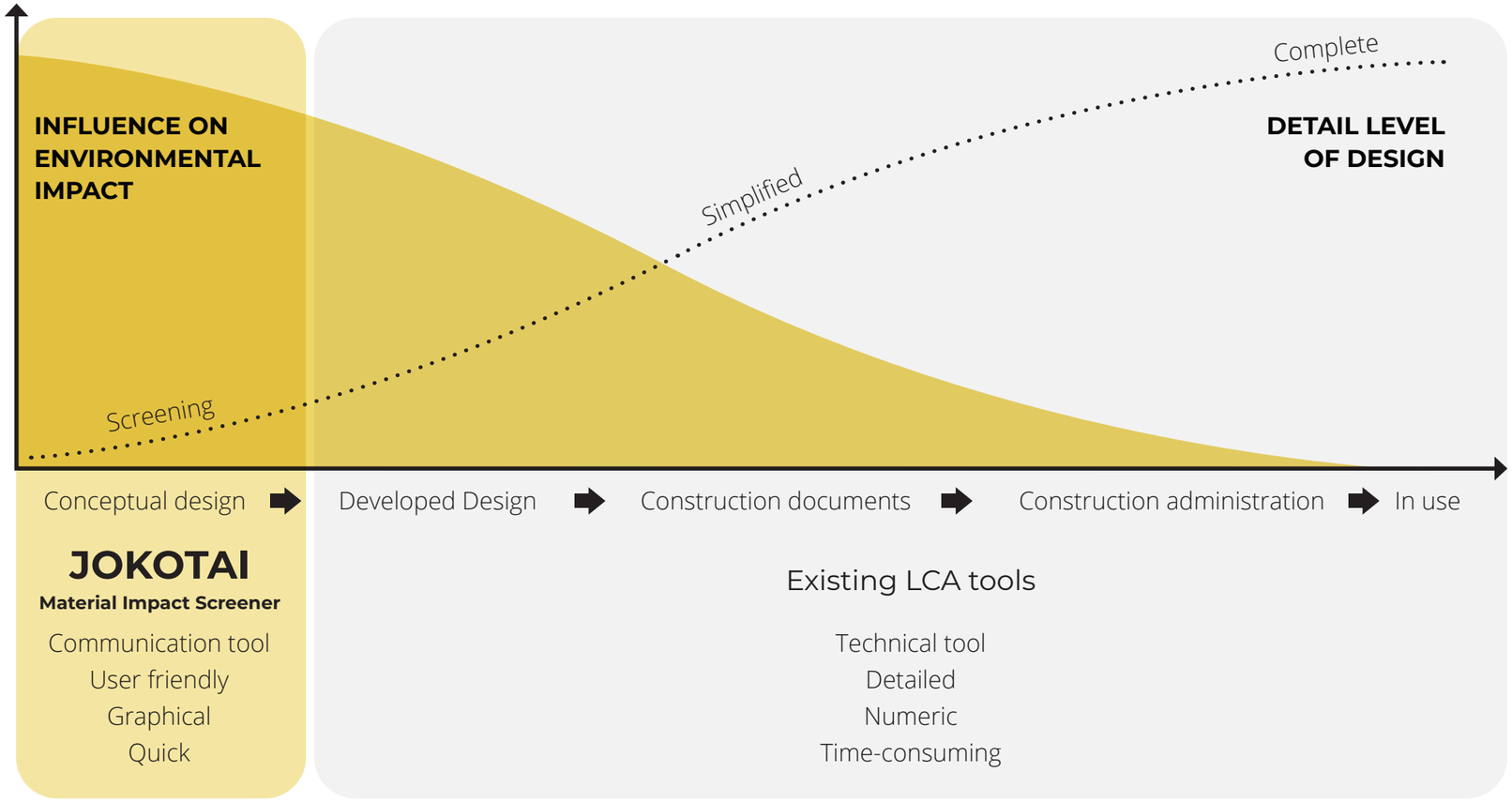
A1-3 **PRODUCTION**	A4-5 **CONSTRUCTION**	B1-6 **MAINTENANCE**	B6-7 **USE**	C1-4 **END-OF-LIFE**
A1 Extraction of raw materials	**A4** Transport	**B1** Commissioning	**B6** Operational energy use	**C1** Dismantling, demolition
A2 Transport	**A5** Construction, Assembly	**B2** Maintenance	**B7** Operational water use	**C2** Transport
A3 Production		**B3** Repair		**C3** Waste recycling
		B4 Replacement		**C4** Disposal
		B5 Refurbishment		

INTRODUCTION

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.

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).



PART 1. JOKOTAI

PART 1: JOKOTAI

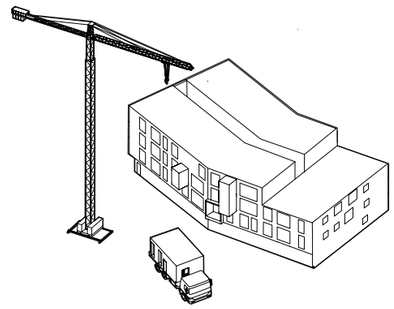
Scope

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.

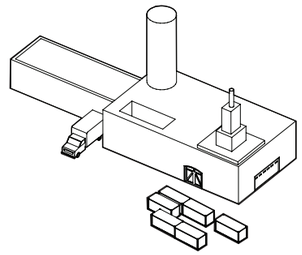
Within embodied energy, the production phase (A1-3) often accounts for the biggest share of total embodied energy. [2] It is based on independently verified and registered EPDs that communicate transparent and comparable information about the environmental impact of products and does not depend on external 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

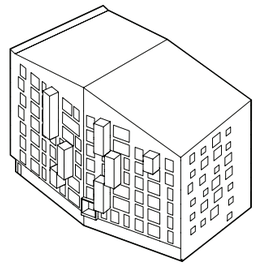
2 Lavagna et al. (2018), Benchmarks for environmental impact of housing in Europe: Definition of archetypes and LCA of the residential building stock



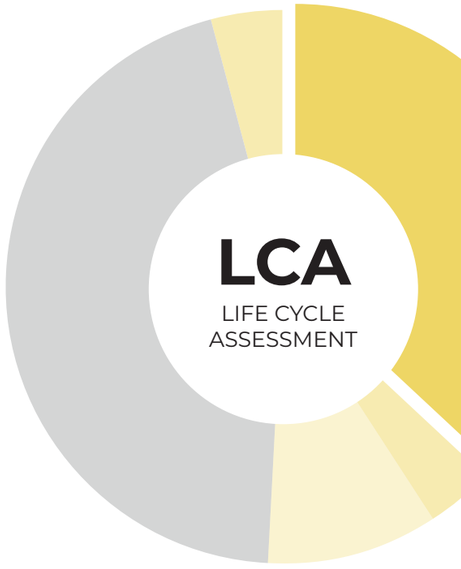
C1-4 **END-OF-LIFE**

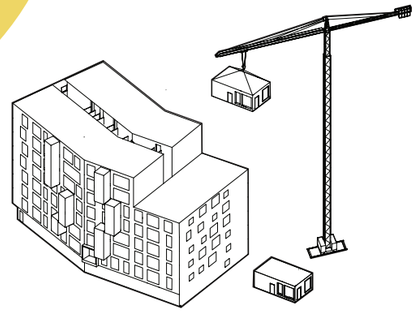


A1-3 **PRODUCTION**

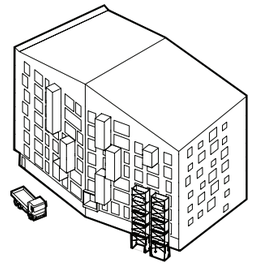


B6-7 **USE**





A4-5 **CONSTRUCTION**



B1-6 **MAINTENANCE**

Embodied Energy

Operative Energy

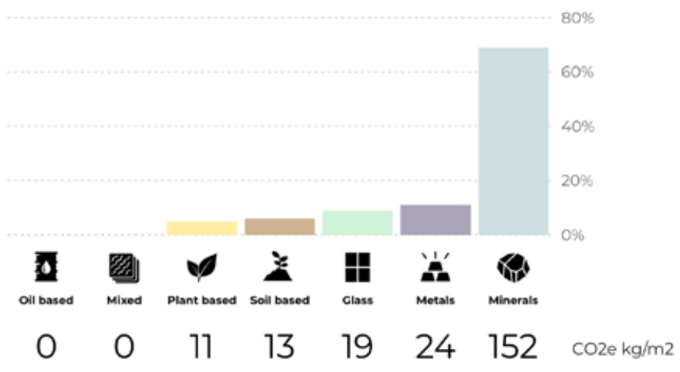
PART 1: JOKOTAI

Intention

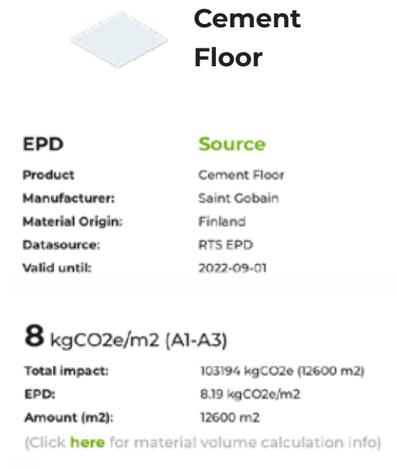
OOPEAA JOKOTAI is a tool for screening the environmental impact of structural and material choices on the sustainability of a building project. The tool enables architects to quickly sketch the building volume of a preliminary design and compare the environmental impact of alternative material choices 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.

Quick
User-friendly, web-based, intuitive

Communication
Visual, comprehensible



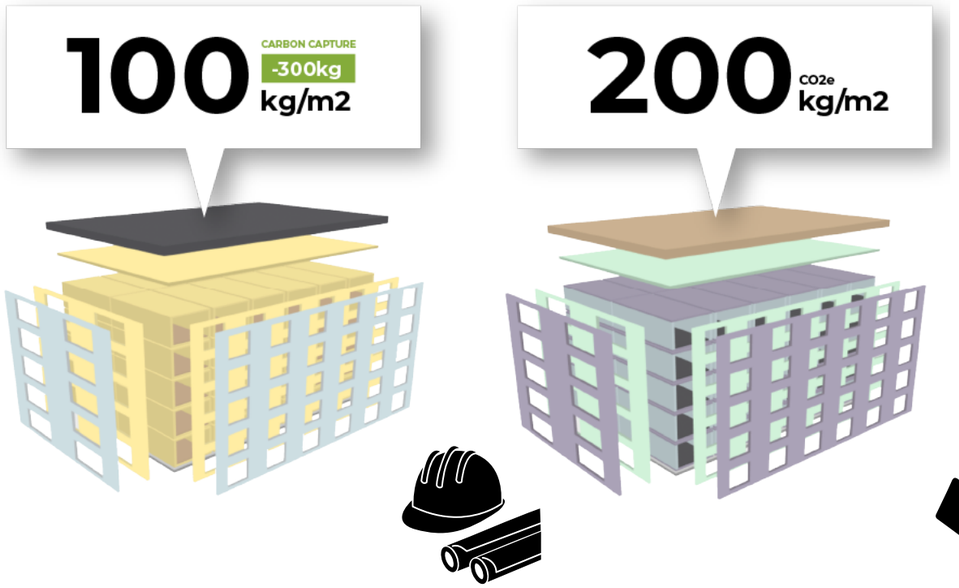
Transparent
EPD source links



PART 1: JOKOTAI

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 visualises 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.



Communication with

ARCHITECTS

Internal communication and evaluation of design and material choices

Communication with

TECHNICAL PLANNERS

Communication about ecological structural and material solutions

Communication with

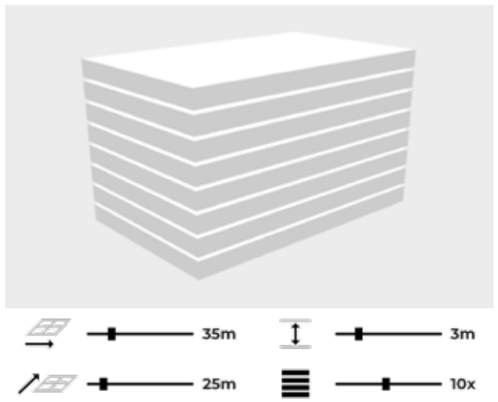
CLIENT

Communication about environmental impact of design and material choices

PART 1: JOKOTAI

Overview

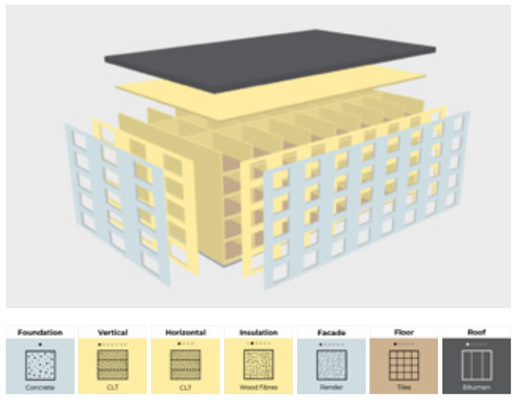
JOKOTAI is not based on an existing BIM program. Instead it is a web-based application that supports the architect in the early phases of the design by offering a quick 3D volume draft and impact assessment tool. The assessment can be made in four steps. First a 3D volume of the estimated design is created 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.



STEP 1

CREATE A QUICK 3D MODEL

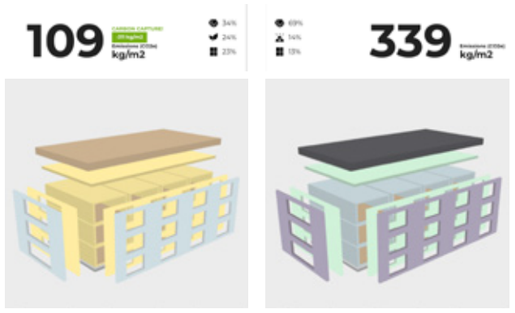
Define the building volume:
Width and depth of the building
Amount of storeys and story height
Internal structural density
Construction type
Opening percentage



STEP 2

SELECT MATERIALS

Material selection for:
Foundation
Vertical and horizontal structure
Insulation
Facade
Floor
Roof

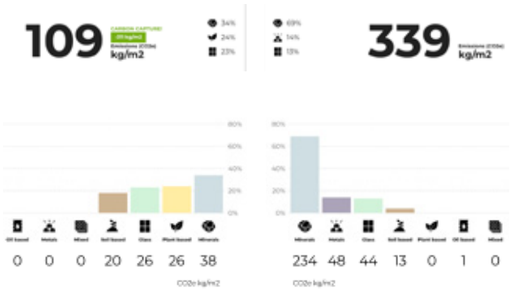


STEP 3

COMPARE IMPACTS

Environmental indicators:
Global Warming Potential (kgCO2e)
Primary energy from non-renewable energy sources (MJ)

Comparison:
Expected service life
Environmental pros and cons
Production process
Recycling potential
Calculation methodology, EPDs



STEP 4

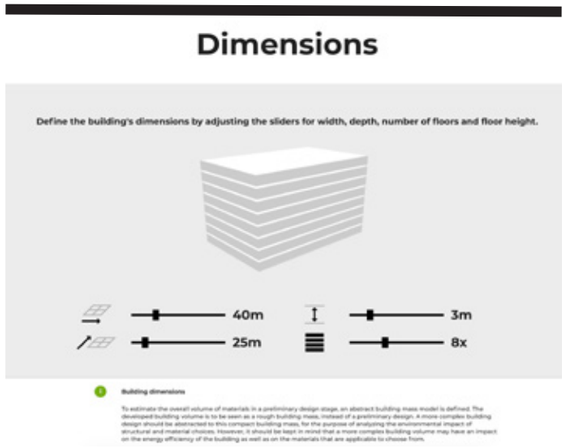
ANALYZE RESULTS

Result breakdown:
Most contributing building parts
Most contributing resources types
Most contributing materials

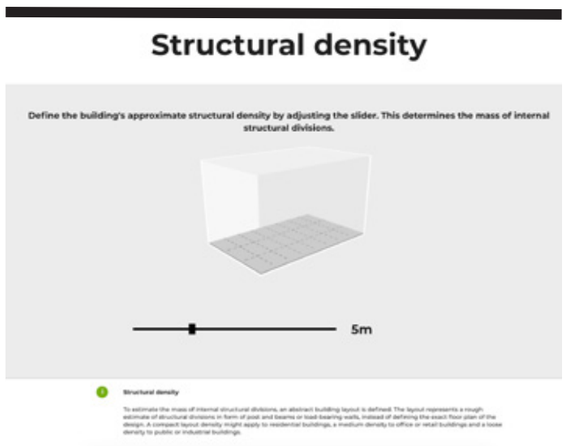
PART 1: JOKOTAI

Building Set-Up

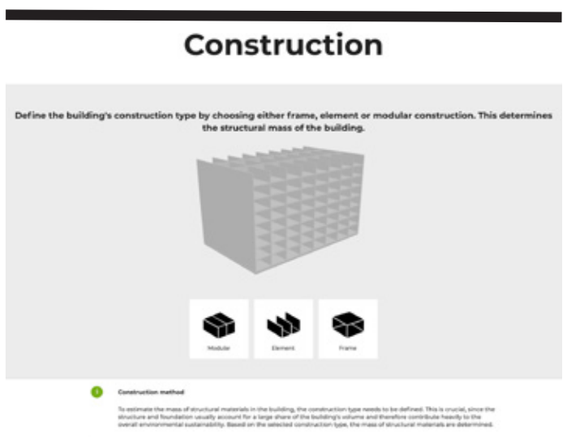
To estimate the overall volume of materials in a preliminary design stage, an abstract building mass model is defined. The developed building volume is to be seen as a rough building mass, instead of a preliminary design. The user can define the building's volume by adjusting the sliders under the interactive 3D model. Adjustments can be made for the building's width, depth, story height, number of stories, internal load-bearing wall or frame density, construction type (modular, element or frame construction) and opening percentage.



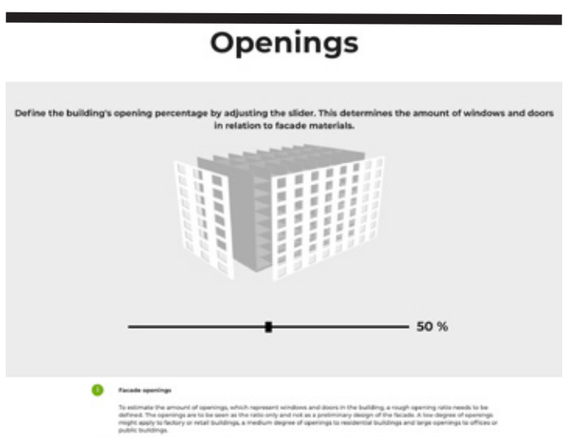
STEP 1
DIMENSIONS



STEP 2
STRUCTURAL DENSITY



STEP 3
CONSTRUCTION

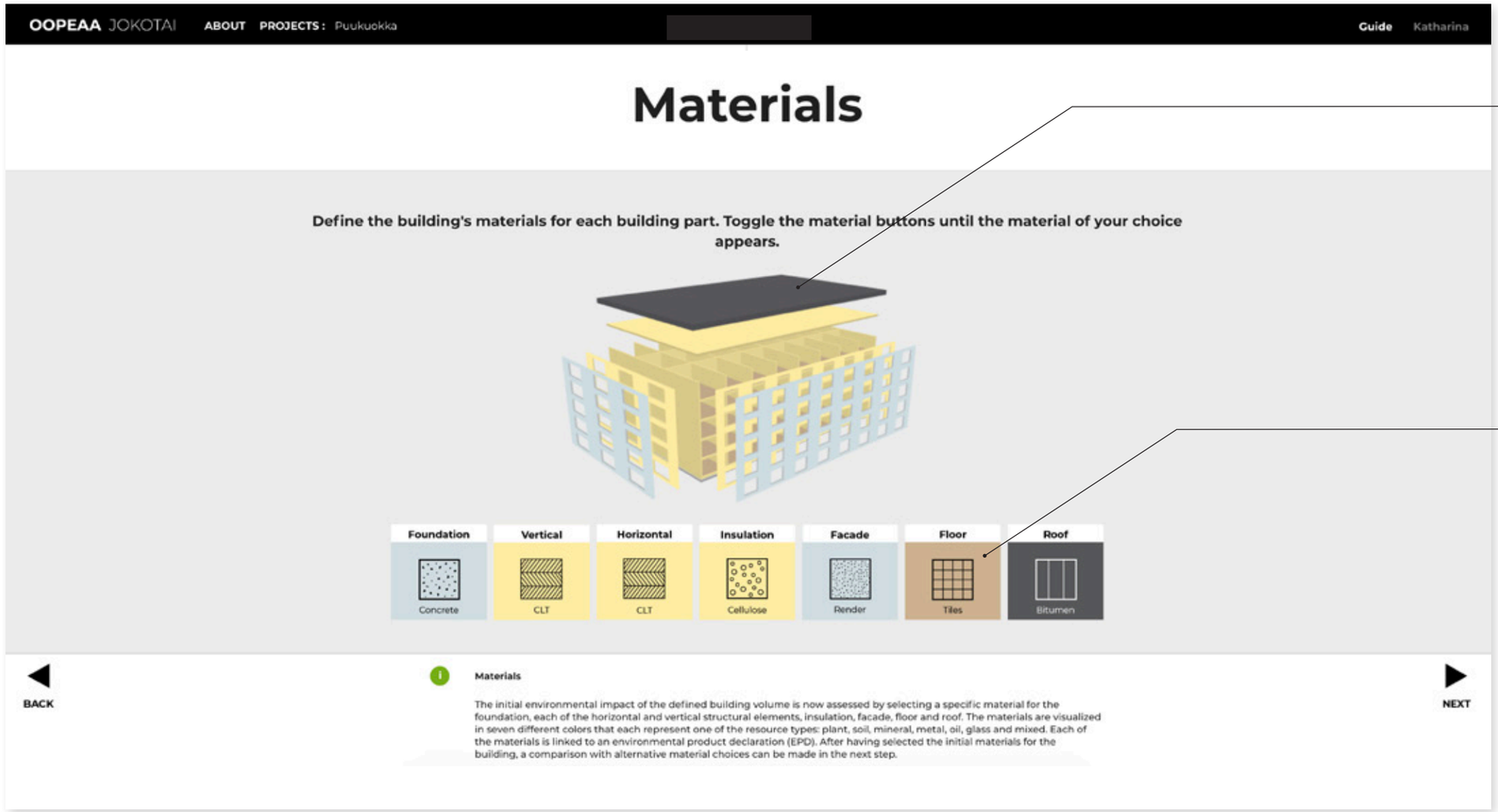


STEP 4
OPENINGS

PART 1: JOKOTAI

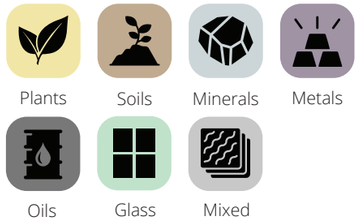
Material Selection

The initial environmental impact of the defined building volume is now assessed by selecting a specific material for the foundation, each of the horizontal and vertical structural elements, insulation, facade, floor and roof. The materials are visualized in a color code of seven different colors that each represent one of the resource types: plant, soil, mineral, metal, oil, glass and mixed. Each of the materials is linked to an environmental product declaration (EPD). After having selected the initial materials for the building, a comparison with alternative material choices can be made in the next step.



Color Code

Materials in the 3D model are visualized according to their resource type category:



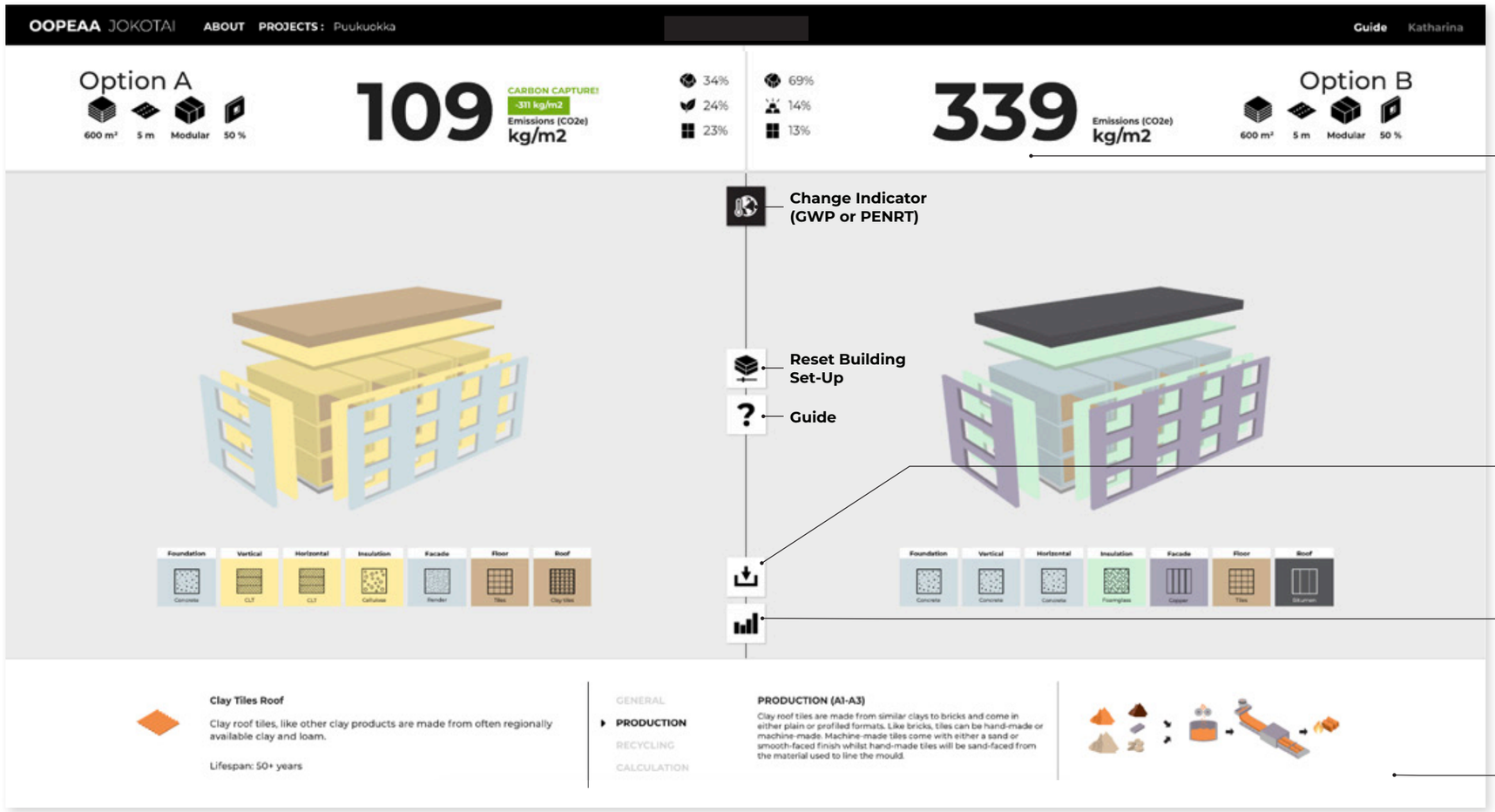
Building Materials

Each of the 29 materials that can be selected in the tool is represented by a European based environmental product declaration (EPD). The EPDs were selected with a focus on covering a wide range of common building materials from different European countries. In order to use EPDs that represent the average environmental impact of a product and avoid large aberrations, the EPD selection is based on a comparison of multiple EPDs of the same product from different manufacturers, after which the median EPD was chosen for the JOKOTAI tool.

PART 1: JOKOTAI

Comparison View

The user interface is divided into three sections, each serving different purposes. The top bar reveals the results of the environmental impact comparison in two indicator categories of the two building options. 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 about the sustainability of building materials, the EPD source and result breakdown for each material.



Results

In the comparison view the top bar shows a preview of the initial environmental impact value per square meter in the selected indicator category (Global Warming Potential or Primary Energy).

69% 14% 13% The illustration in the center gives a preview of the most contributing resource types in each building option.

Save Project

User accounts and project libraries enable each user to save building comparisons in order to access them again at a later time.

Results

A detailed breakdown of the most contributing building parts, resource types and materials can be found here.

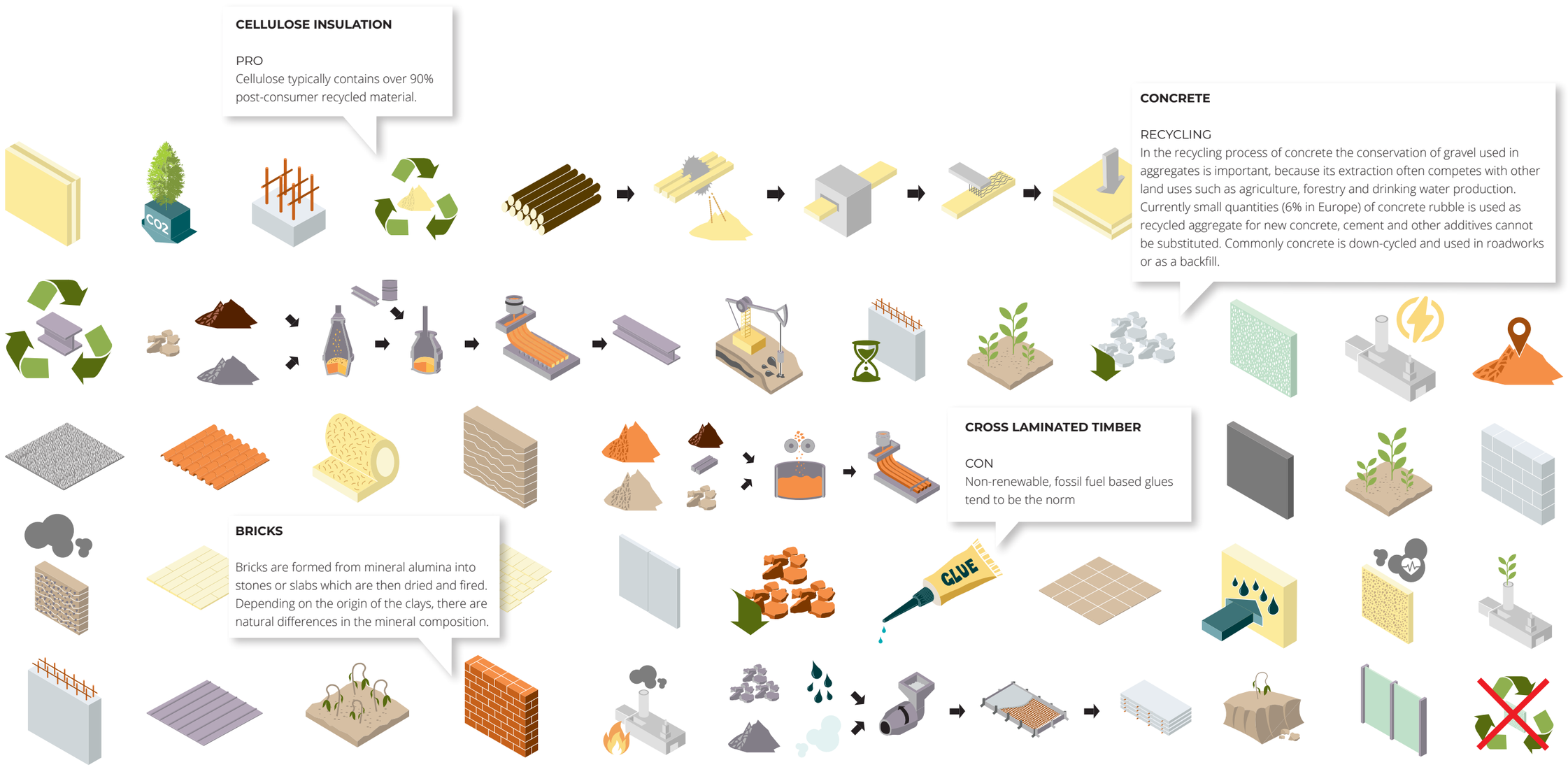
Info Boxes

The material infoboxes provide additional information regarding the sustainability of building materials and EPD sources.

PART 1: JOKOTAI

Material information

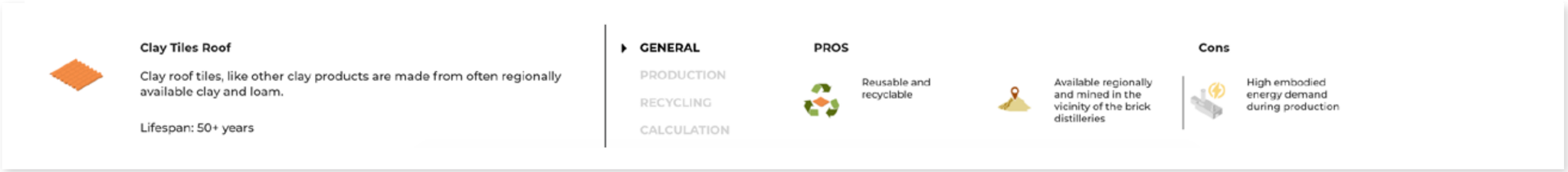
In addition to the calculated environmental impacts caused by the extraction and production of building materials (Phase A1-3), the JOKOTAI tool provides information about the expected service life of materials, their environmental pros and cons, the production process and their recycling potential, 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.

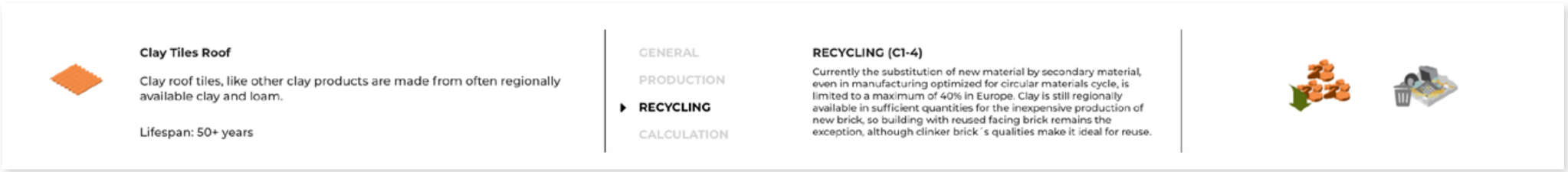


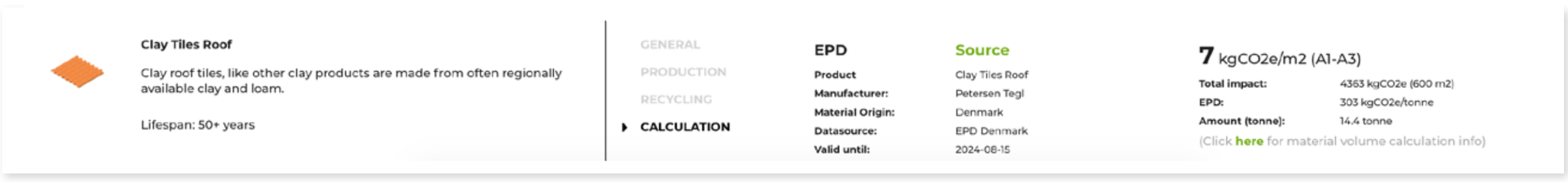
PART 1: JOKOTAI

Material Info Boxes

For each building material additional information is provided beyond the environmental impact that occurs during the production phase (A1-3). The material info boxes have fours subcategories: General information (expected service life and environmental pros and cons), Production (Production process and possible environmental concerns during the process), Recycling (Recycling potential and current recycling infrastructure in Europe) and Calculation (EPD source link and result breakdown).



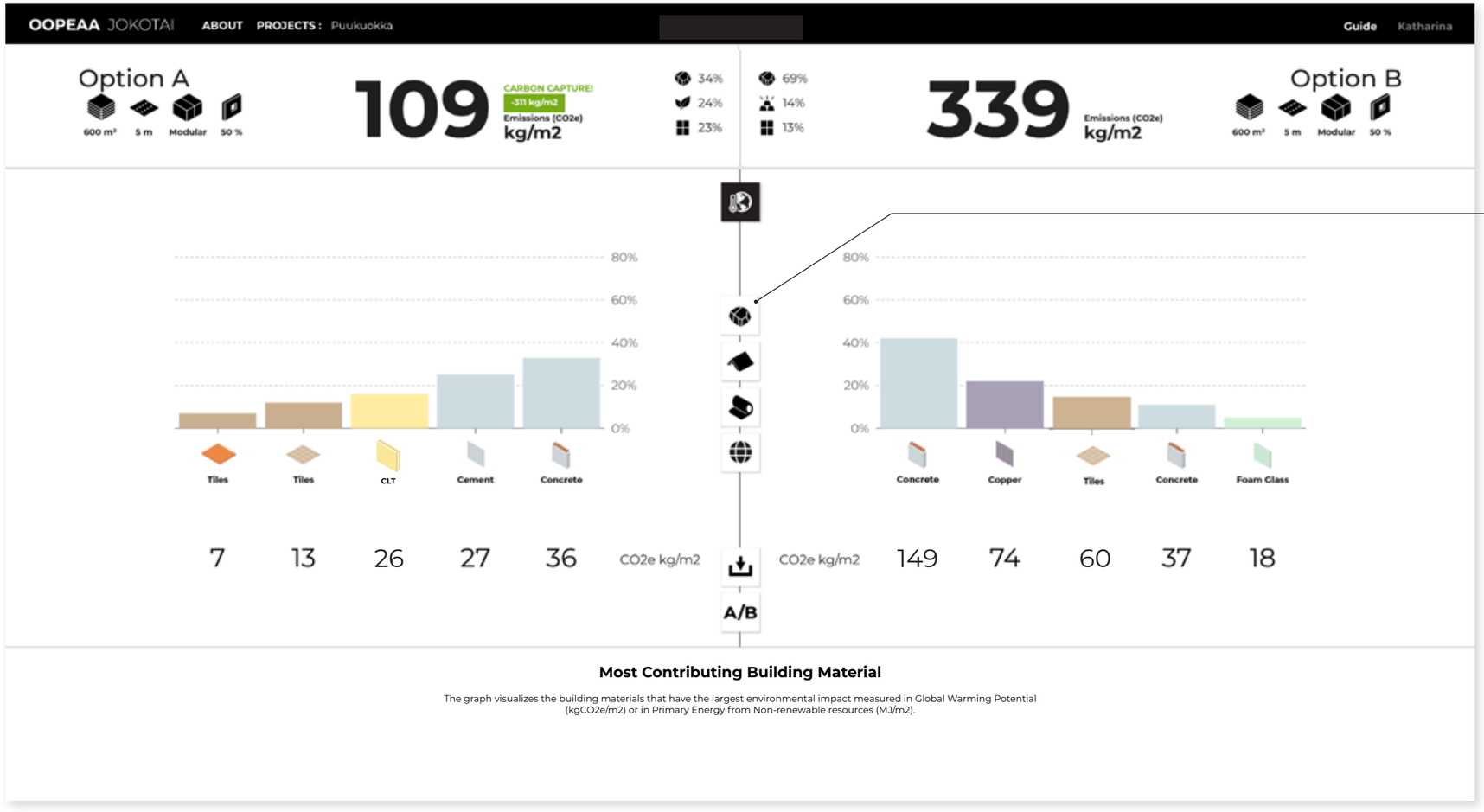




PART 1: JOKOTAI

Result Breakdown

In the result breakdown view the environmental impact of both building options are presented in three result categories: Most contributing resource type, most contributing building part and most contributing building material. Each of the graphs is visualized in the color code of the resource types and is organized in order to place the most contributing element in the center of the view. The results can be viewed in the indicator categories GWP or PENRT.



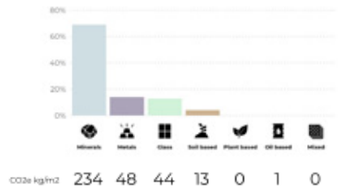
Most Contributing Building Material

The graph visualizes the building materials that have the largest environmental impact measured in Global Warming Potential (kgCO2e/m2) or in Primary Energy from Non-renewable resources (MJ/m2).

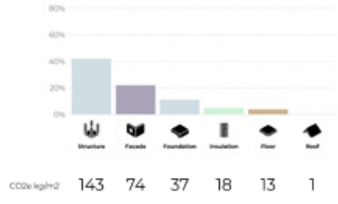
Other Result Categories

The results are presented in three result categories and the indicator can be switched between GWP and PENRT.

Most Contributing Resource Type



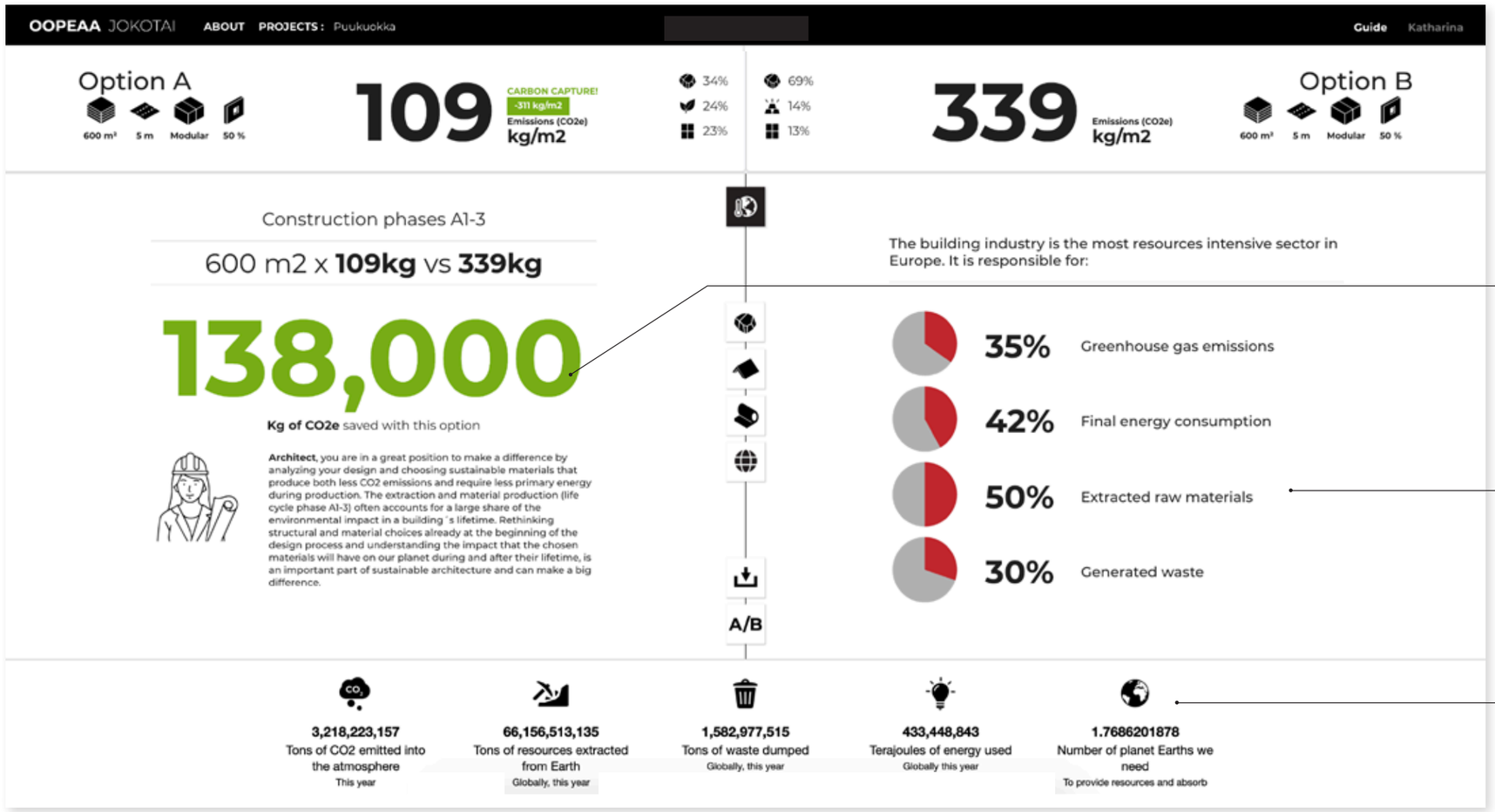
Most Contributing Building Part



PART 1: JOKOTAI

Total Impact

The final screen of the tool visualized the total amount of emissions or primary energy that can be saved when choosing the building option with the lower environmental impact. Hereby the environmental impact is presented in the total amount instead of dividing the value per square meter. The last page is meant to appeal to the designers responsibility to make a difference by analyzing the design and choosing sustainable materials that produce both less CO2 emissions and require less primary energy during production.



How much can be saved?

Depending on which of the building options resulted in having the lower environmental impact the positive difference is placed under the favorable option. The difference is shown in the total amount of saved emissions or primary energy.

Impact Building Industry

Currently the building sector 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.

The World Counts

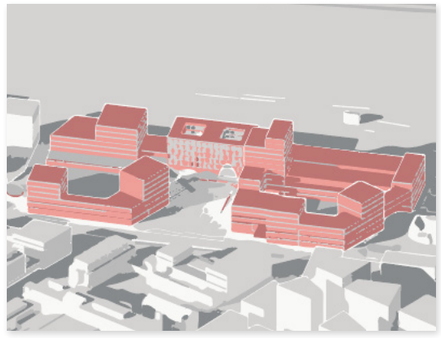
The World Counts is a platform visualizing a life-count of global challenges such as the amount of CO2 emissions emitted to the atmosphere. It has been created with the hope that it may contribute to an awakening and promote a change of direction of common practices.

PART 2. JOKOTAI Future Development

PART 2: JOKOTAI FUTURE DEVELOPMENT

Overview

JOKOTAI tool stage 1 is realized under the leadership of OOPEAA and 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. During the two year program, the tool has developed from the rough idea of quickly assessing and visualizing environmental impacts of preliminary design decision to a functional 3D modeling and environmental impact assessment and comparison tool. 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.

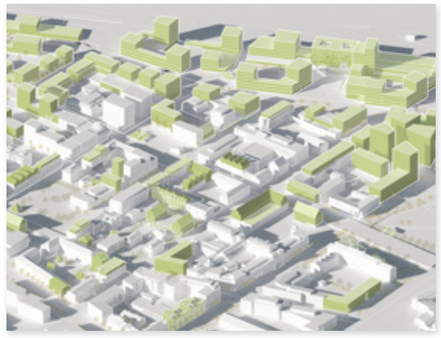


VISION 1

MULTIPLE BUILDINGS

BLOCK DESIGN

While JOKOTAI I 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

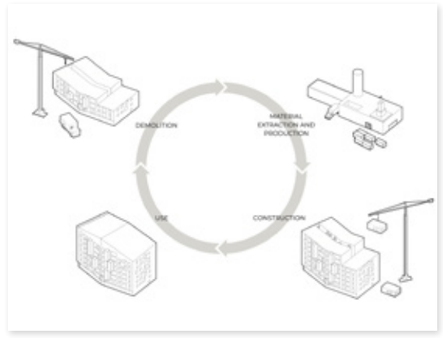
The JOKOTAI II tool could provide a screening option of existing structures, their potential for reuse and recycling or the environmental consequences and waste production in the case of demolition.

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

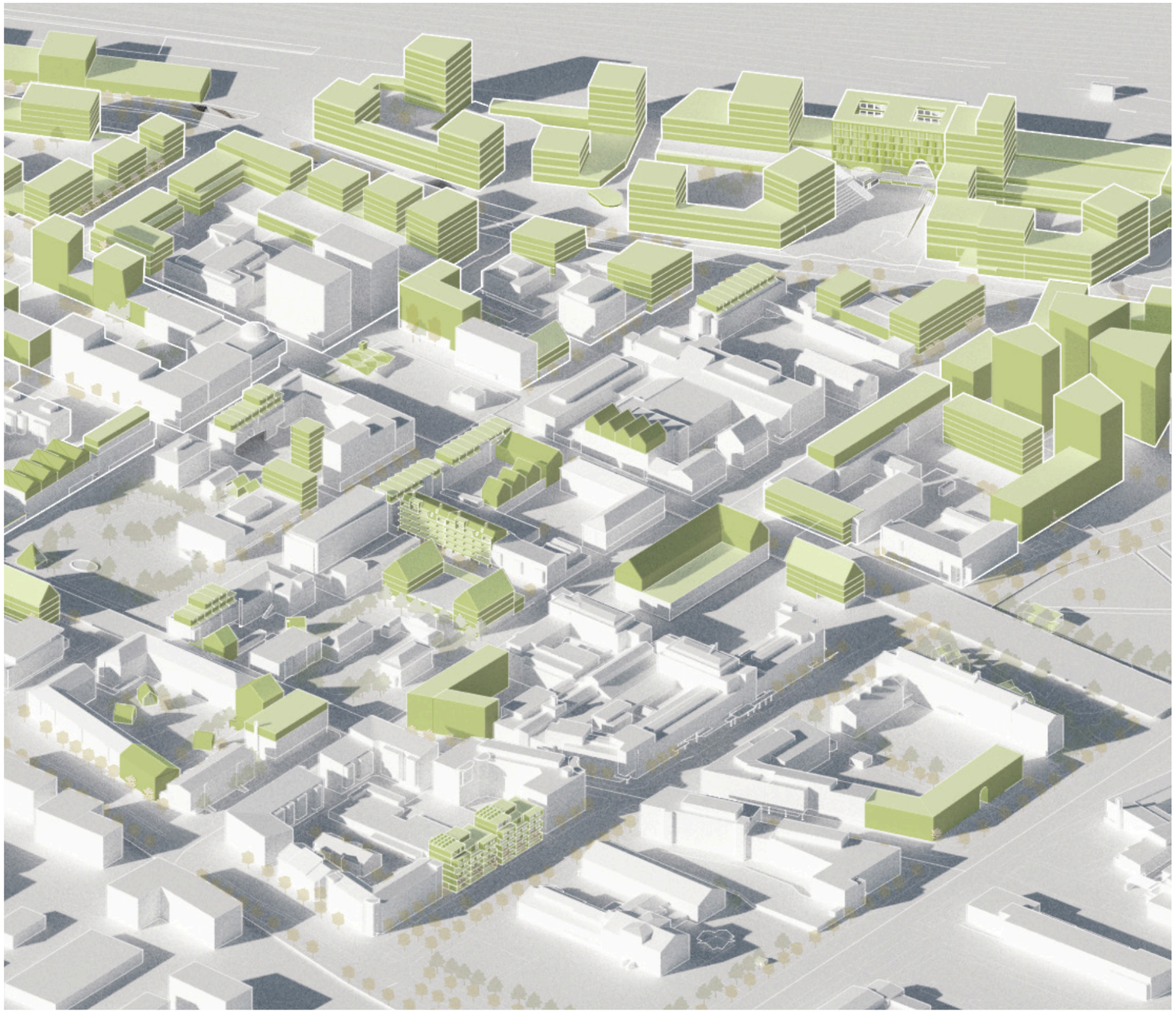
In JOKOTAI II all life cycle phases including the energy demand, emissions and energy during construction processes, maintenance and demolition could be part of the assessment to give further insights into the full life cycle.

PART 2: JOKOTAI FUTURE DEVELOPMENT

Urban scale

JOKOTAI II aims 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 the aim of the JOKOTAI II tool is 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.



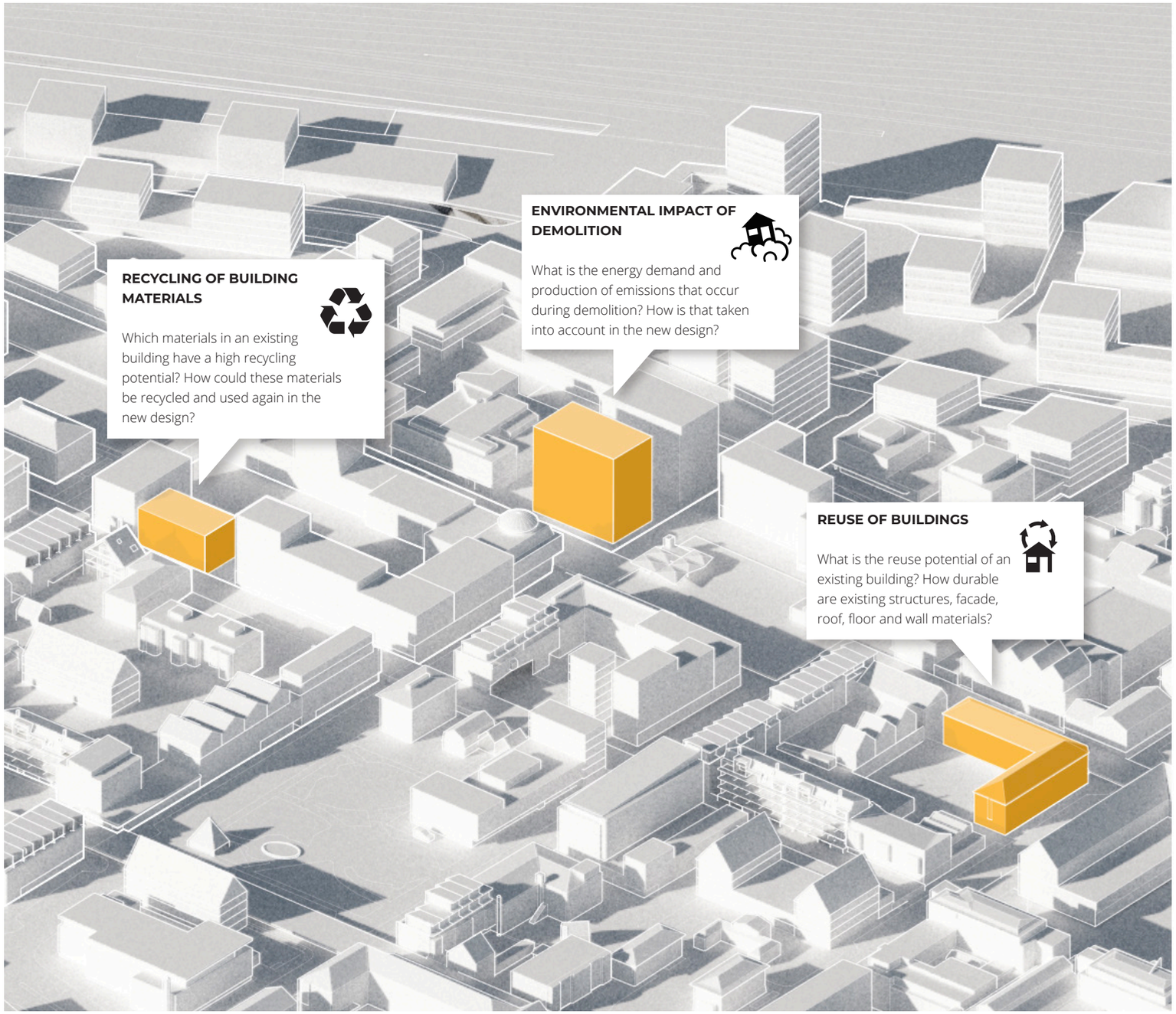
PART 2: JOKOTAI FUTURE DEVELOPMENT

Existing Buildings

Construction and demolition waste in Europe accounts for around 800 million tonnes 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 tonnes 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 visualise 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.

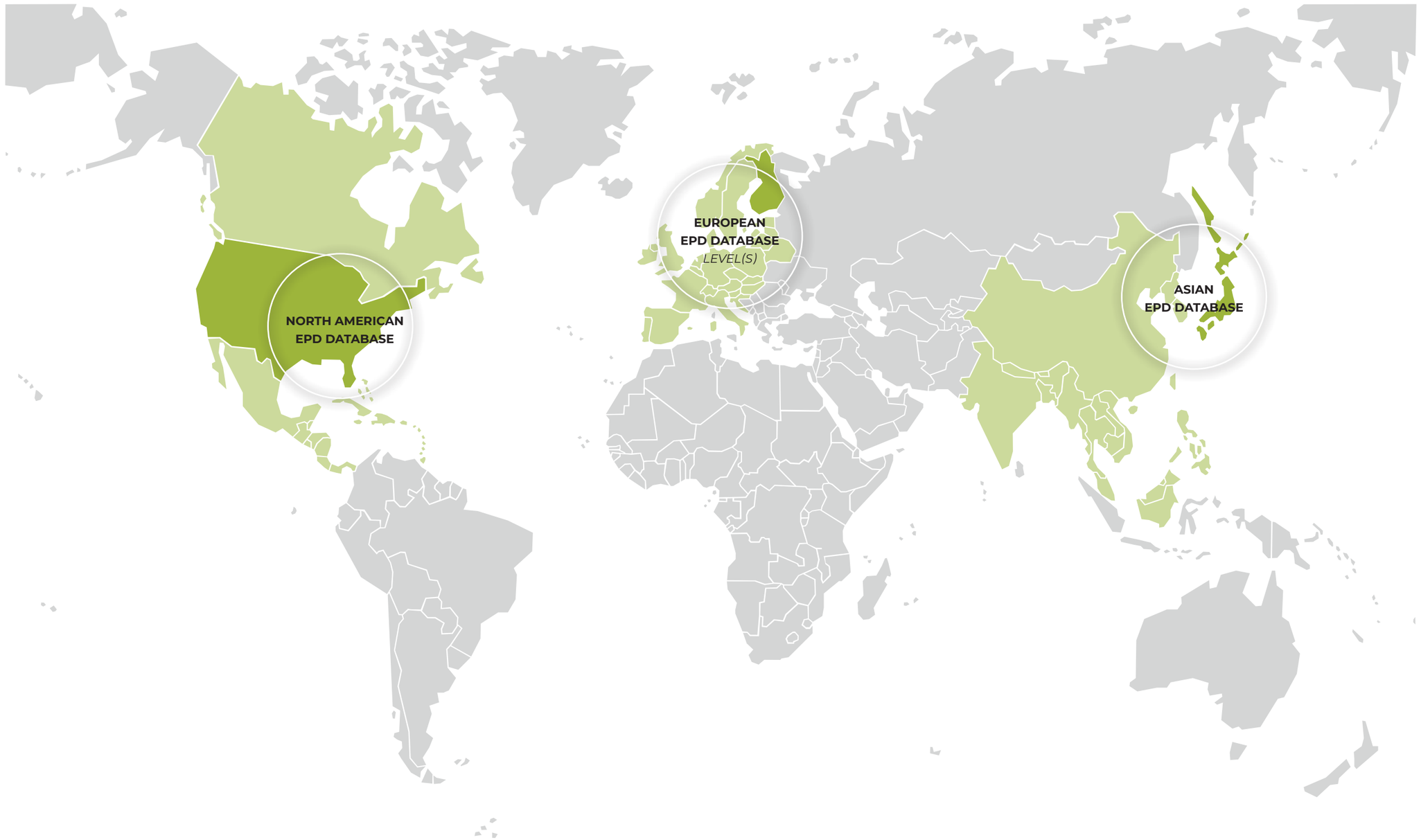
1 European Commission (2016) EU Construction & Demolition Waste Management Protocol



PART 2: JOKOTAI FUTURE DEVELOPMENT

Localisation

Currently the EPD data for JOKOTAI I is based on average values of materials or specific building products in the European context. To increase the use of the tool word-wide, 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.



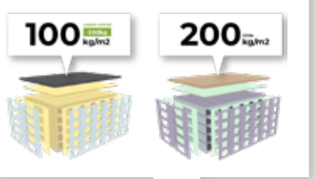
PART 2: JOKOTAI FUTURE DEVELOPMENT

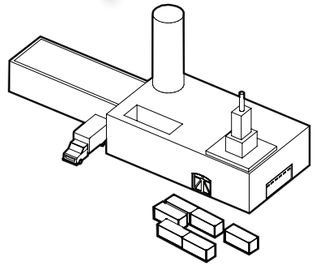
Screening the complete life cycle

JOKOTAI I focuses on the initial embodied energy phases A1-3 (Extraction, production and transportation), 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.

JOKOTAI FUTURE DEVELOPMENT

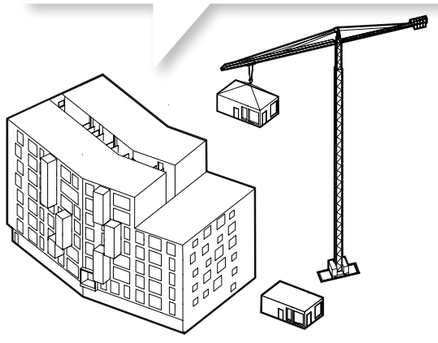
JOKOTAI





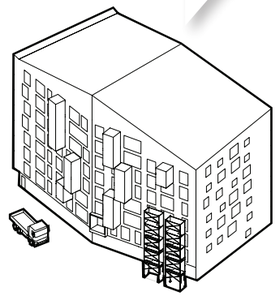
CONSTRUCTION PHASE

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?



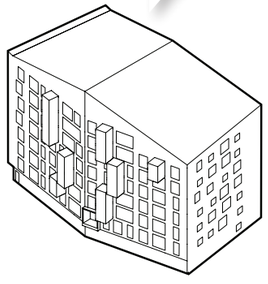
MAINTENANCE PHASE

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?



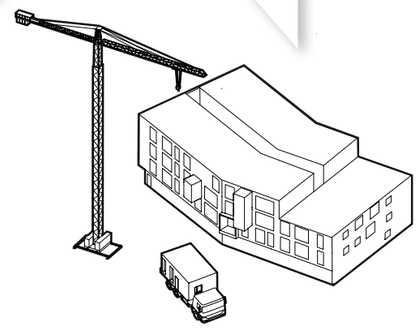
USE PHASE

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?



A1-3 **PRODUCTION**	A4-5 **CONSTRUCTION**	B1-6 **MAINTENANCE**	B6-7 **USE**	C1-4 **END-OF-LIFE**
A1 Extraction of raw materials	**A4** Transport	**B1** Commissioning	**B6** Operational energy use	**C1** Dismantling, demolition
A2 Transport	**A5** Construction, Assembly	**B2** Maintenance	**B7** Operational water use	**C2** Transport
A3 Production		**B3** Repair		**C3** Waste recycling
		B4 Replacement		**C4** Disposal
		B5 Refurbishment		

PART 2: JOKOTAI FUTURE DEVELOPMENT

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.