DigiConCyc

Energy-efficient automated production technology for energy-efficient modular sustainable lightweight buildings

Institut für Strukturleichtbau und Energieeffizienz GgmbH
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Project Consortium

- Project Titel: „Energy-efficient automated production technology for energy-efficient modular sustainable lightweight buildings“

- Project executiv organisation: PtJ, Forschungszentrum Jülich GmbH

- Duration: November 2022 – Oktober 2025

- Partners:

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
aufgrund eines Beschlusses des Deutschen Bundestages

Projektträger Jülich
Forschungszentrum Jülich

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Institut für Werkzeugmaschinen und Produktionsprozesse (IWP)

TECHNISCHE UNIVERSITÄT DRESDEN
Professur für Werkzeugmaschinenentwicklung und adaptive Steuerungen

Universität Stuttgart
Institut für Leichtbau Entwerfen und Konstruieren

ISE
Institut für Strukturleichtbau und Energieeffizienz gGmbH

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LF-Elektro GmbH

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Agenda

1. Introduction
2. Motivation and objectives
3. Approach
4. Status of work

Introduction

- Development of an innovative manufacturing technology for modular, energy-efficient lightweight residential buildings based on modules with the aim of reducing greenhouse gas emissions in production and operation
- structural deficits of such lightweight buildings especially low heat storage capacity, low thermal insulation and lack of sound insulation can be overcome by using appropriate innovative materials
- Architecturally appealing designs of modular buildings

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2. Motivation and objectives

- The use of lightweight construction in the form of container construction can achieve the following advantages over conventional solid construction:
  - 20 to 30 % lower total costs
  - High degree of prefabrication and the associated short assembly times
  - sustainable and resource-saving through lightweight construction and the use of recycled and recyclable materials
  - Use of materials that are harmless to building biology
  - sophisticated architectural design
  - Inadmissibility to damage for construction defects (no building moisture/drywall)
  - Compliance with the EnEV and DGNB guidelines

2. Motivation and objectives

- Development of mass-market CAD/CAM-supported manufacturing technologies based on **innovative sheet metal processing and forming technology** as well as process engineering **transfer of this technology to lightweight space modules**
- Development of **robot-assisted technologies for the automation of component production and assembly** (forming processes, welding processes, assembly processes, etc.) for the industrial prefabrication of modular buildings
- Development of **automatable connection technologies for the laying of cable harnesses** for the electrical supply and electronics of the room modules
- Manufacturing and assembly technology for the introduction of universal interfaces for electrical/electronic media and media supply
- Development of **robot-assisted assembly technologies for lightweight climate solutions** that can **be integrated into the automated production and assembly process** of the room modules

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2. Motivation and objectives

- **Material flow optimization** (inclusion of recycling solutions and recyclates)
- Development of **architectural concepts for energy-efficient modular buildings depending on regional construction methods and the climate zone** as well as taking into account district solutions
- Achieving a **flexibilization of the manufacturing and assembly technologies** of modular buildings depending on the type of use of the buildings (e.g. equipment)
- Establishment of a **virtual twin as a central development and demonstrator platform**

3. Approach

- Drafts
- Virtual Twin
- Preliminary tests
- Demonstrator

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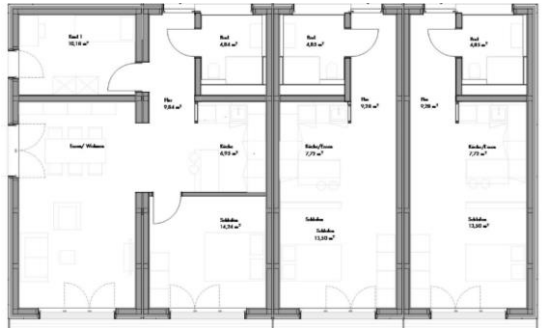
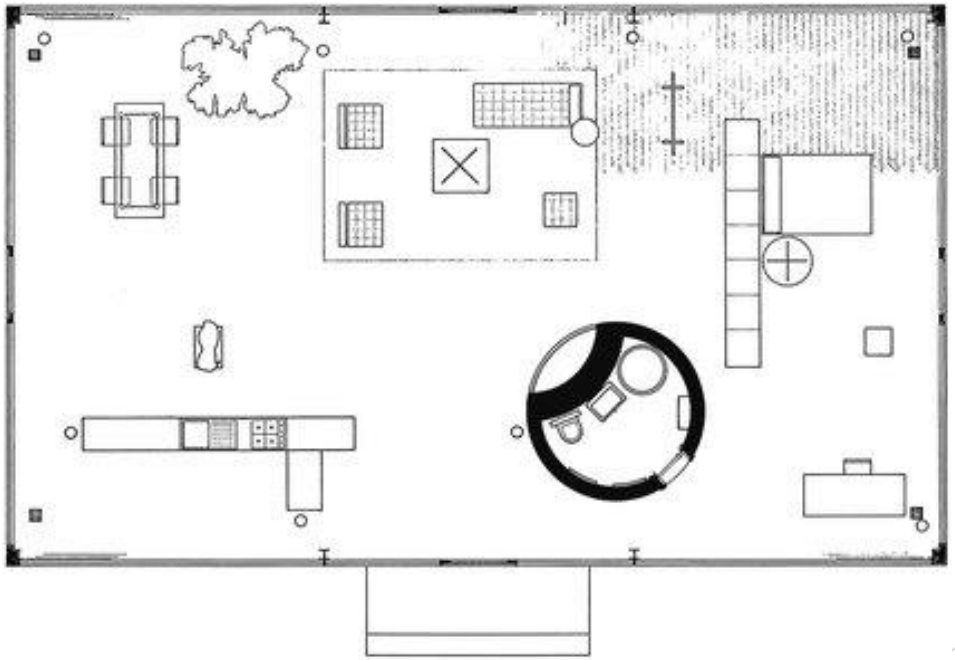
4. Status of work – Drafts & Design





- What distinguishes sustainable, customizable, minimalist and flexible architecture?
- No fixed room divisions due to the container construction

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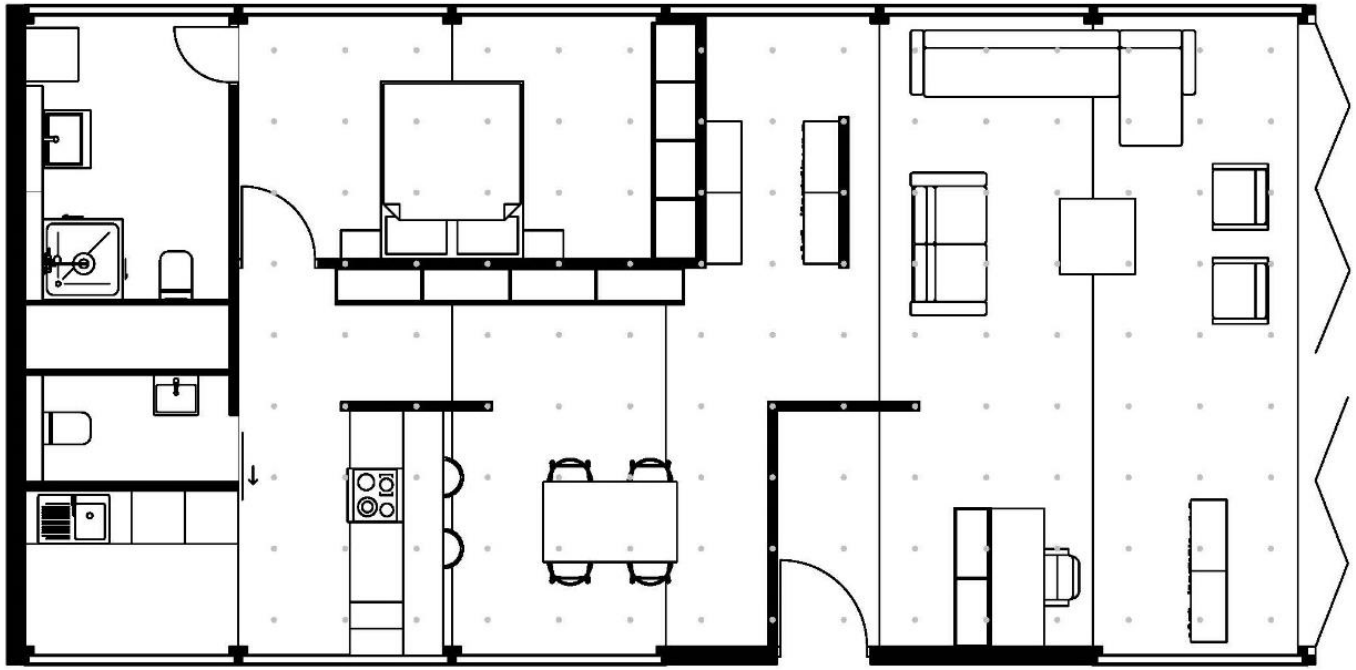
4. Status of work – Drafts & Design

- Designs for various building typologies of the University of Stuttgart – Institute for Lightweight Construction, Constructing and Design (ILEK):



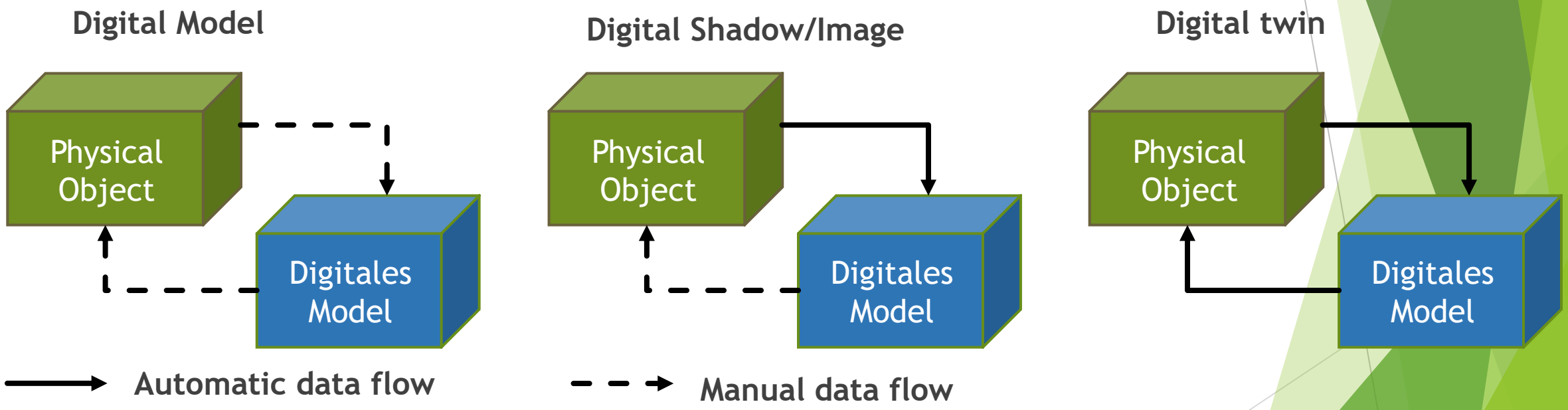
- Example of a single-family house with 100 m² of living space
- Flexible interior design thanks to non-load-bearing walls that can be relocated by the users

4. Status of work – Drafts & Design

- Designs for several building classes and locations are created
- Single-storey and two-storey designs
- Multi-family buildings, office buildings, dormitories

4. Status of work – Virtual Twin

- Digital twin as a term widely used in business and research
- Interpretation of the term nevertheless not uniform
- The core idea is always the digital representation of an object/process



4. Status of work – Virtual Twin

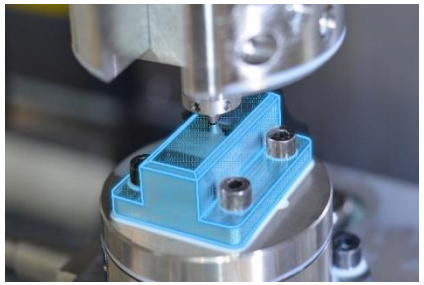
<u>End-to-end data integration</u>
Bundling and integration of e.g. Design, planning, meta and simulation data

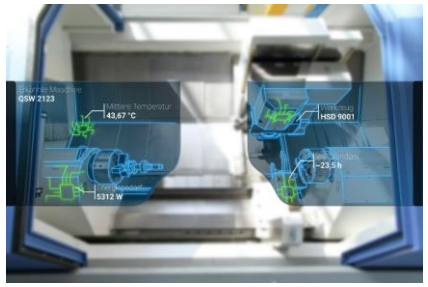
+

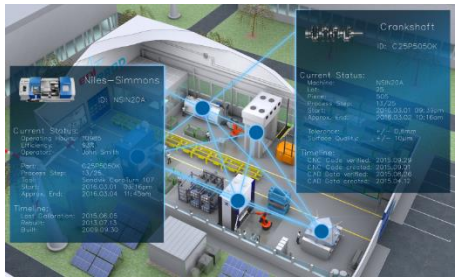
<u>Real data management</u>
Collecting, evaluating, and reproducing real data from the product, machine, and process

Virtual Twin	Virtual Twin Produkt	Virtual Twin Process / Machine	Virtual Twin Factory / Process Chain

- Visualization of the data
- Localization on a 3D geometry
- Multi-directional linking
- Situational and user rightst







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4. Status of work – Virtual Twin

Chemnitz

Unity Client

Interpolation between data pairs to smooth animation

Subscription on start

VPN

Subscribed axis data

Dresden

Robots with OPCUA server

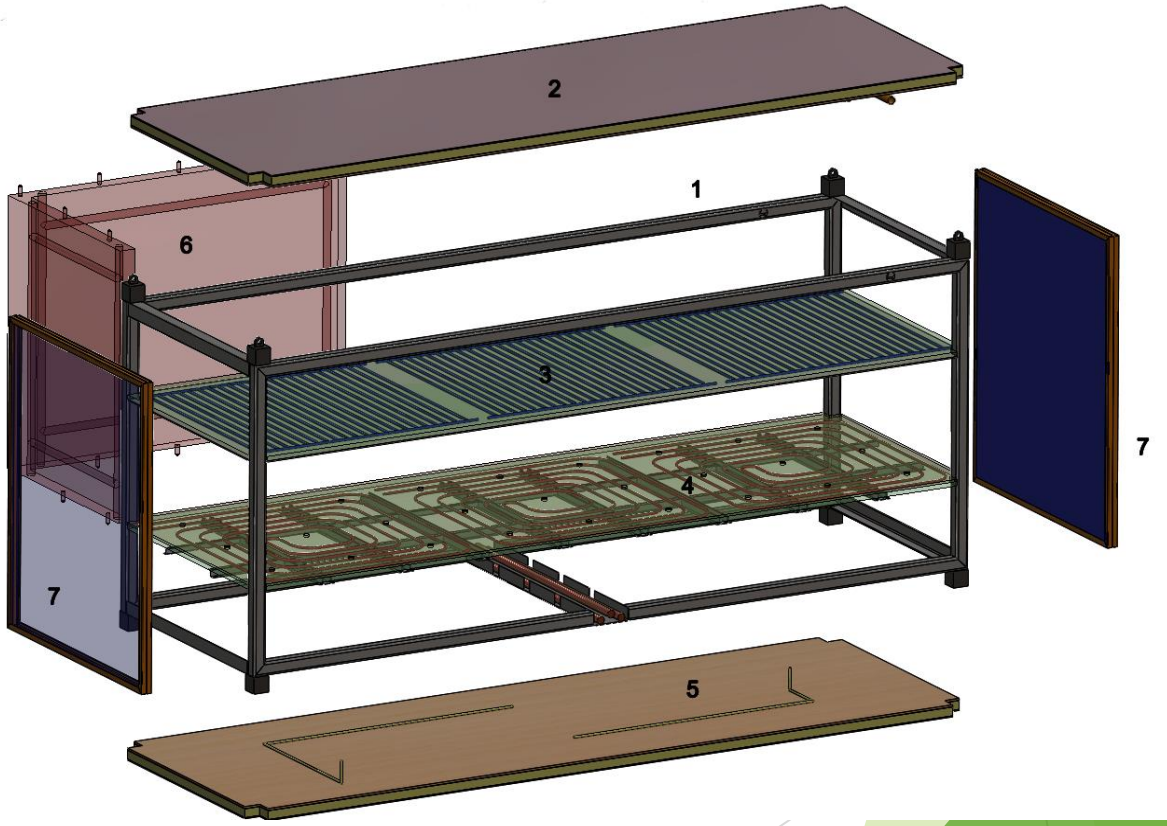
Movement data is synchronized with server

Advantages of virtual Twin in Production Systems:

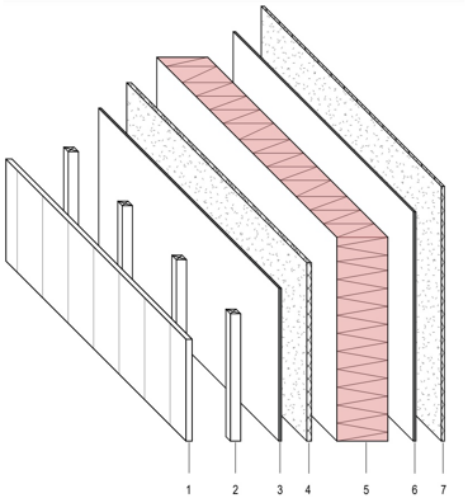
- Comprehensive Monitoring of production processes
- Virtual commissioning to reduce development time
- Allows for quick testing of new processes and technologies
- Maintenance support and fast fault recovery

4. Status of work - Room module

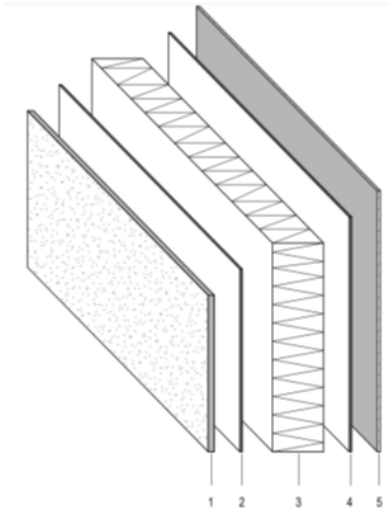
- The room module as the starting point for the modular lightweight building
- The basis is a container-skeleton construction as a steel frame (1)
- Wall (6, 7), floor (3, 4 ,5) and ceiling (2) elements are manufactured in parallel and then joined together to form a unit



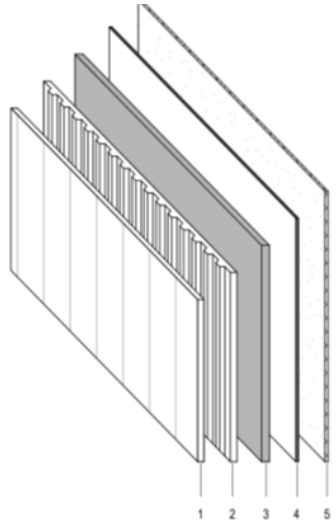
4. Status of work - Surface Elements



Materialschicht	Dicke	Wärmeleitfähigkeit λ
Holzverkleidung Lärche (1)	24*mm*	-
Unterkonstruktion: Lärche (4%)/Hinterlüftung (2)	40*mm*	-
Dampfbremse (3)	-	-
OSB-Platte (4)	18*mm*	$0,130 W/(mK)$
Dämmstoff (5):		
a) Holz	190*mm*	$0,044 W/(mK)$
b) Mineralwolle	170*mm*	$0,040 W/(mK)$
c) Jute	170*mm*	$0,040 W/(mK)$

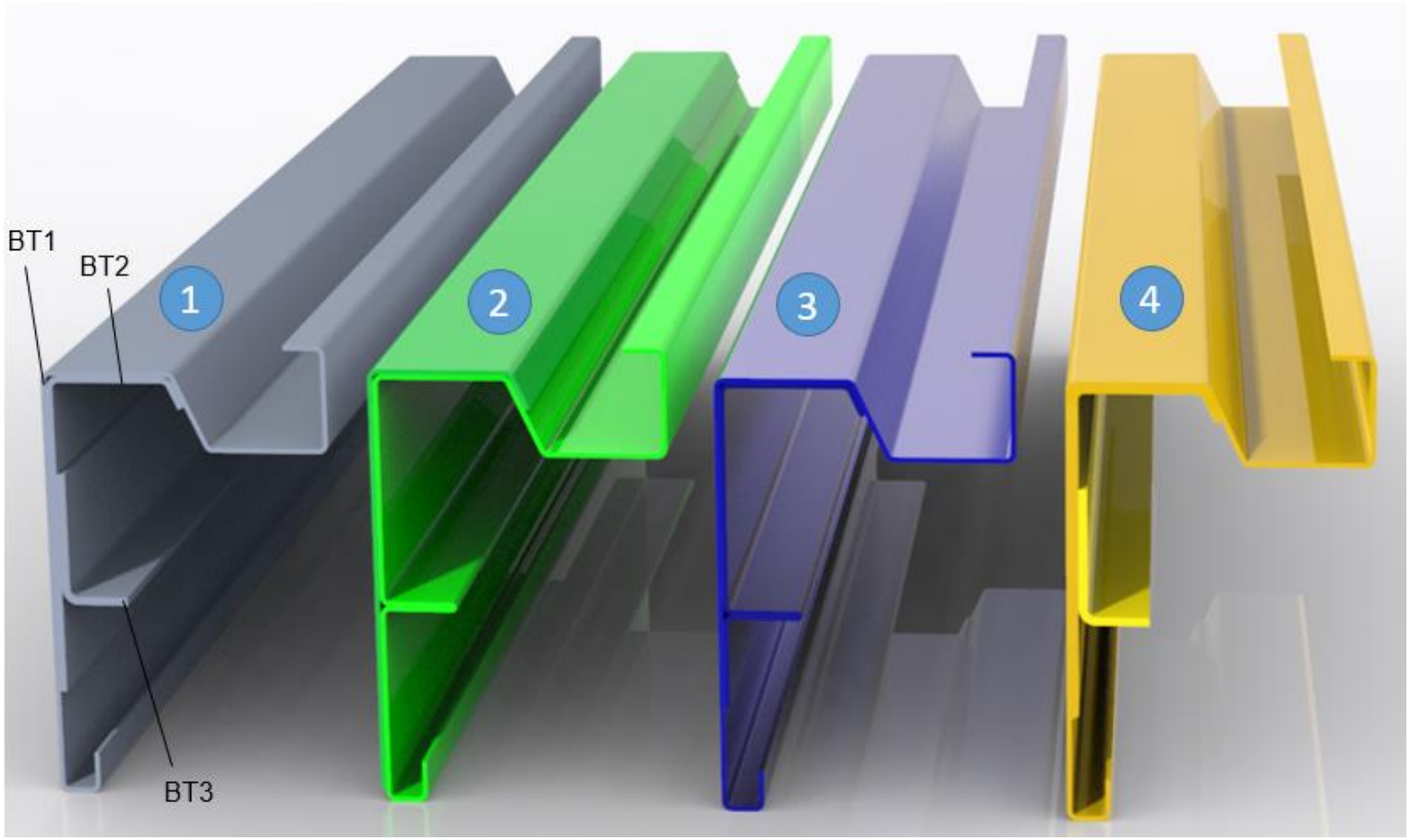


Materialschicht	Dicke	Wärmeleitfähigkeit λ
Kalkzementputz (1)	24*mm*	$0,890 W/(mK)$
Dampsbremse (2)	-	-
Mineraldämmplatte (3)	200*mm*	$0,045 W/(mK)$
Dampfsperre (4)	-	-
Gipsfaserplatte (5)	12*mm*	$0,350 W/(mK)$



Materialschicht	Dicke	Wärmeleitfähigkeit λ
Lärche (1)	10*mm*	$0,890 W/(mK)$
Trapezblech	20*mm*	$10,000 W/(mK)$
Mineralwolle (2)		$0,040 W/(mK)$
Vakuum-Isolations-Paneel (3)	30*mm*	$0,007 W/(mK)$
Dampfsperre (4)	-	-
OSB-Platte (5)	12*mm*	$0,130 W/(mK)$

4. Status of work – Profile Optimization



- Development of manufacturing solutions to be able to produce structural, functional and cladding components with classic punching and bending machines
- Optimization of the profile geometry to implement the Profiles into the automated Manufacturing process

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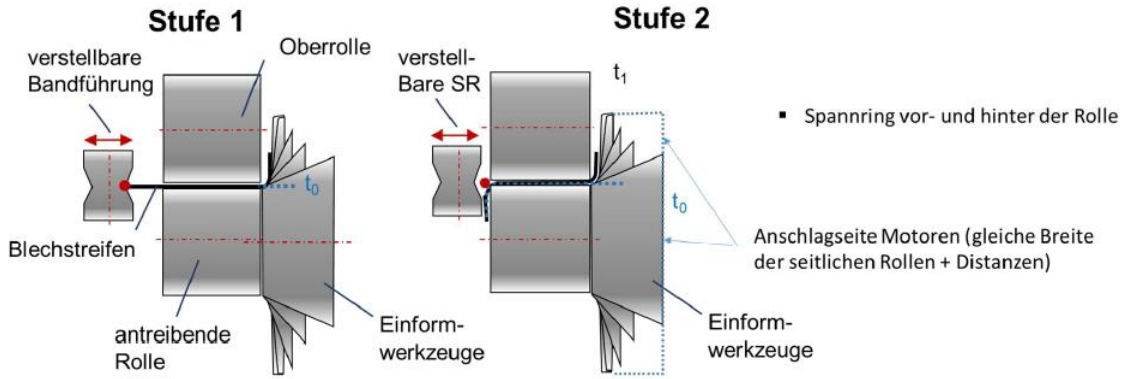
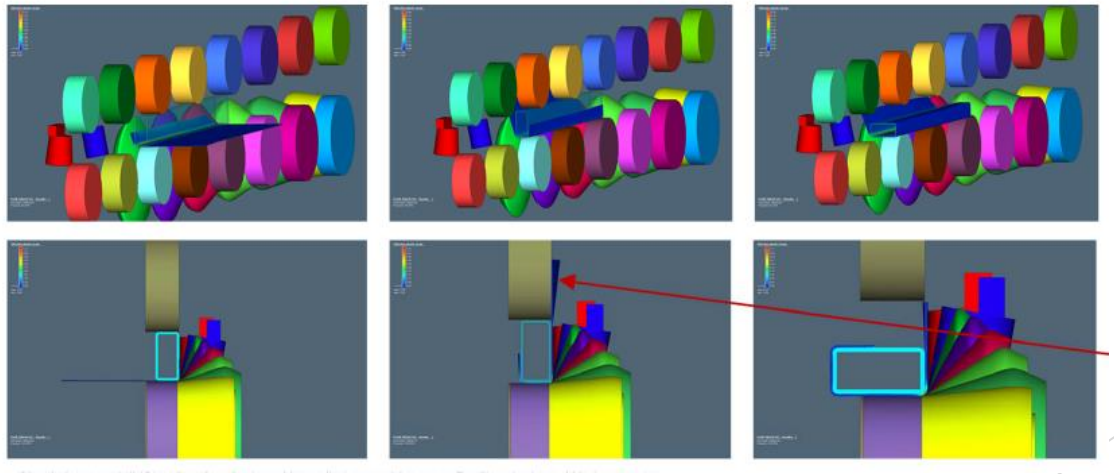
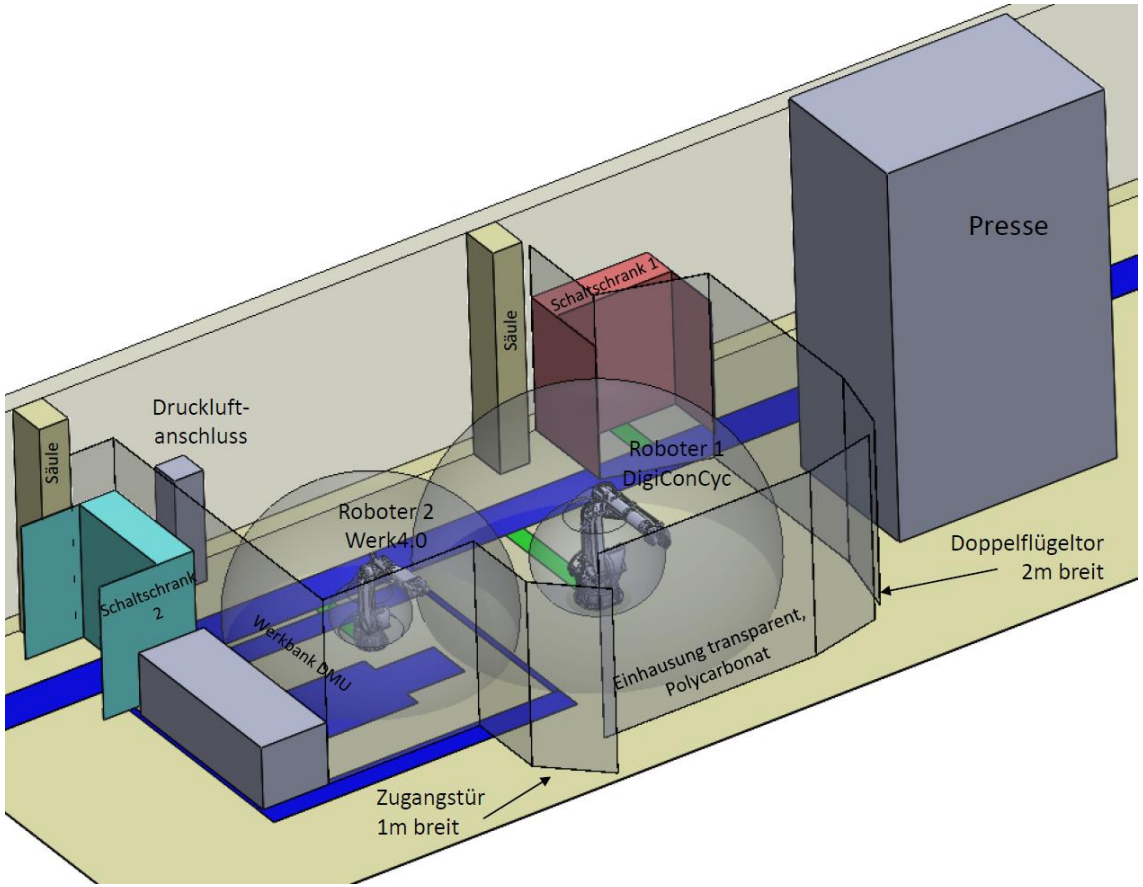
4. Status of work – Profile Optimization



- Simulation of roll forming for simple profile cross-sections
- Simulation Model for a Rectangular Profile
- Be aware of conflicts with tools
- Designing profile and semi-finished products to size according to the welding process



4. Status of work – Manufacturing Technology

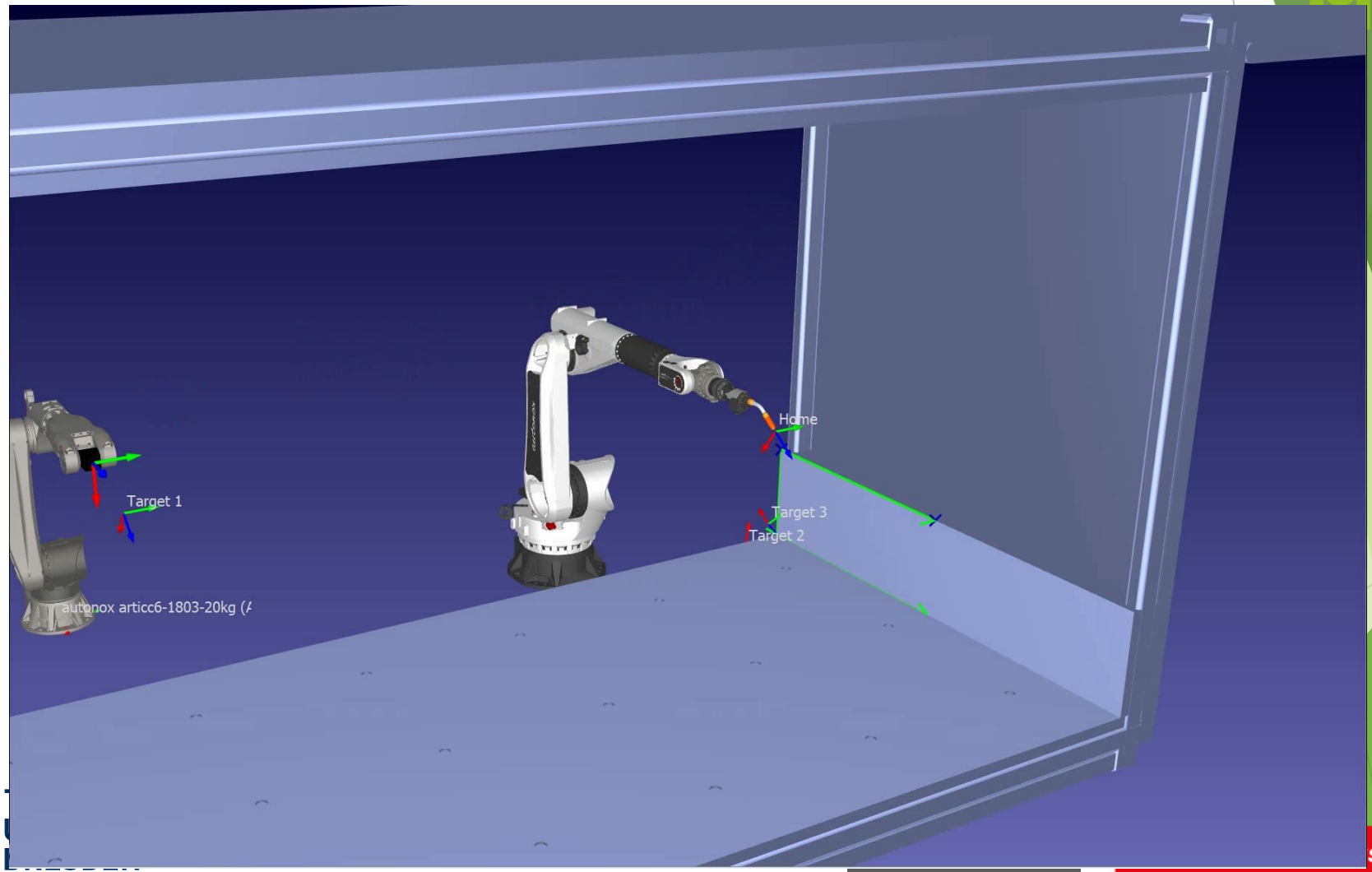


Technology Module:

- **Thermal joining:**
  - positioning, welding
- **Separable connections:**
  - threading, torque-oriented screwing
- **Machining:**
  - Force-controlled machining
- **Insertion of flexible structures:**
  - Component recognition, gripping and placing

4. Status of work – Manufacturing Technology

6-axis articulated robot articc6-2267-30kg



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4. Status of work – Preliminary tests

- concept solutions of the economic partners are tested in preliminary tests to determine whether a robot-assisted production is possible
- Increasing the degree of prefabrication

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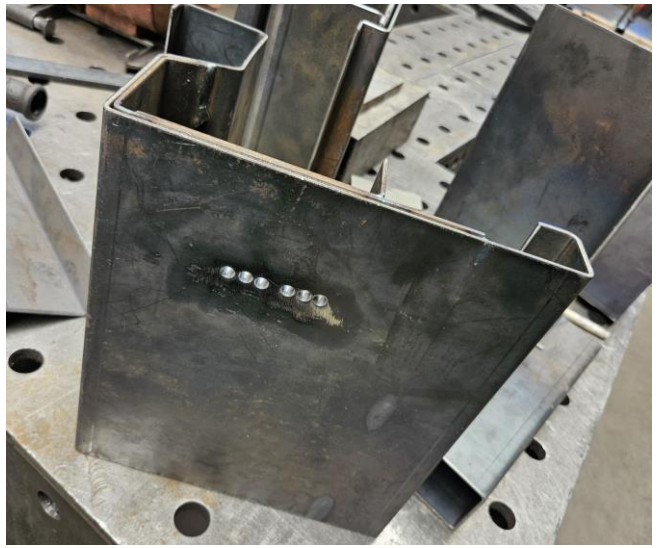
4. Status of work – Preliminary tests

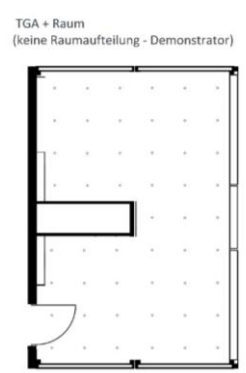


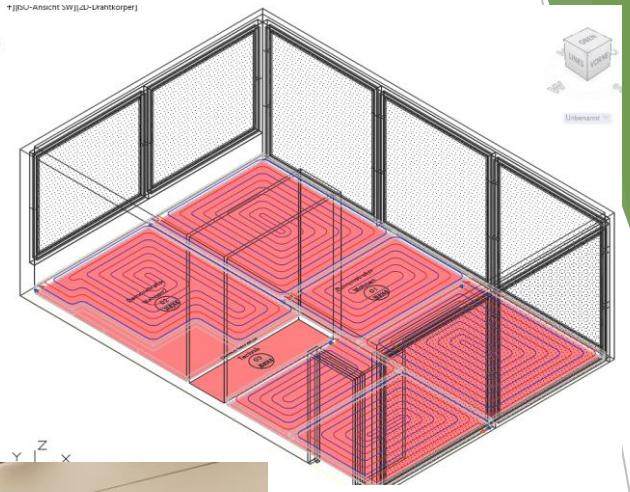
- concept solutions of the economic partners are tested in preliminary tests to determine whether a robot-assisted production is possible
- Increasing the degree of prefabrication

4. Status of work – Demonstrator

- Two room modules are planned as demonstrators to check the fabrication technologies and the building physics requirements

- After monitoring, the demonstrator will be used as a trade fair demonstrator





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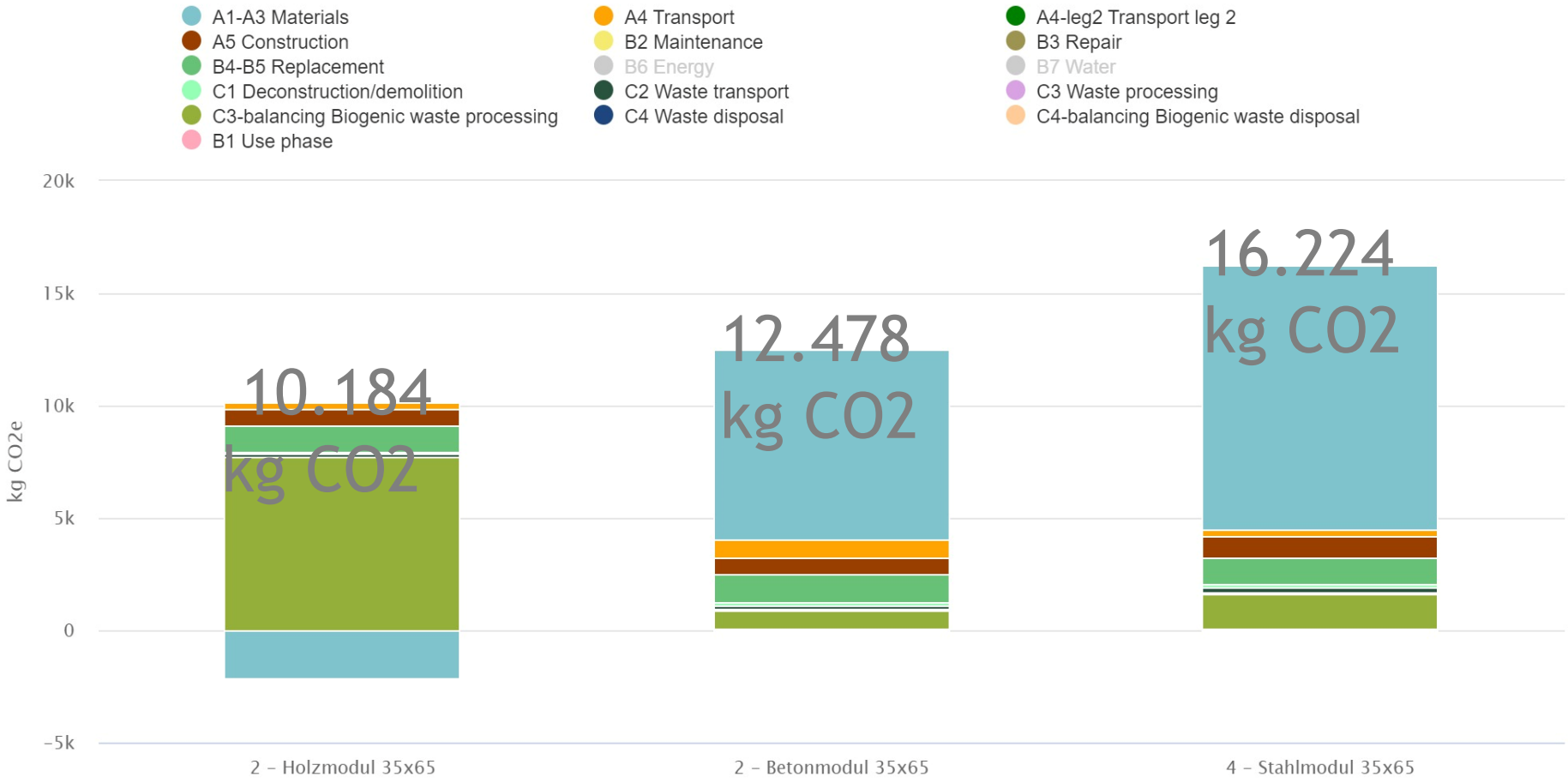
Thank you for your attention

Many thanks also to our partners for the good cooperation in the project consortium and with the Project executive organization, Projektträger Jülich.

3. Status of work – LCA



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