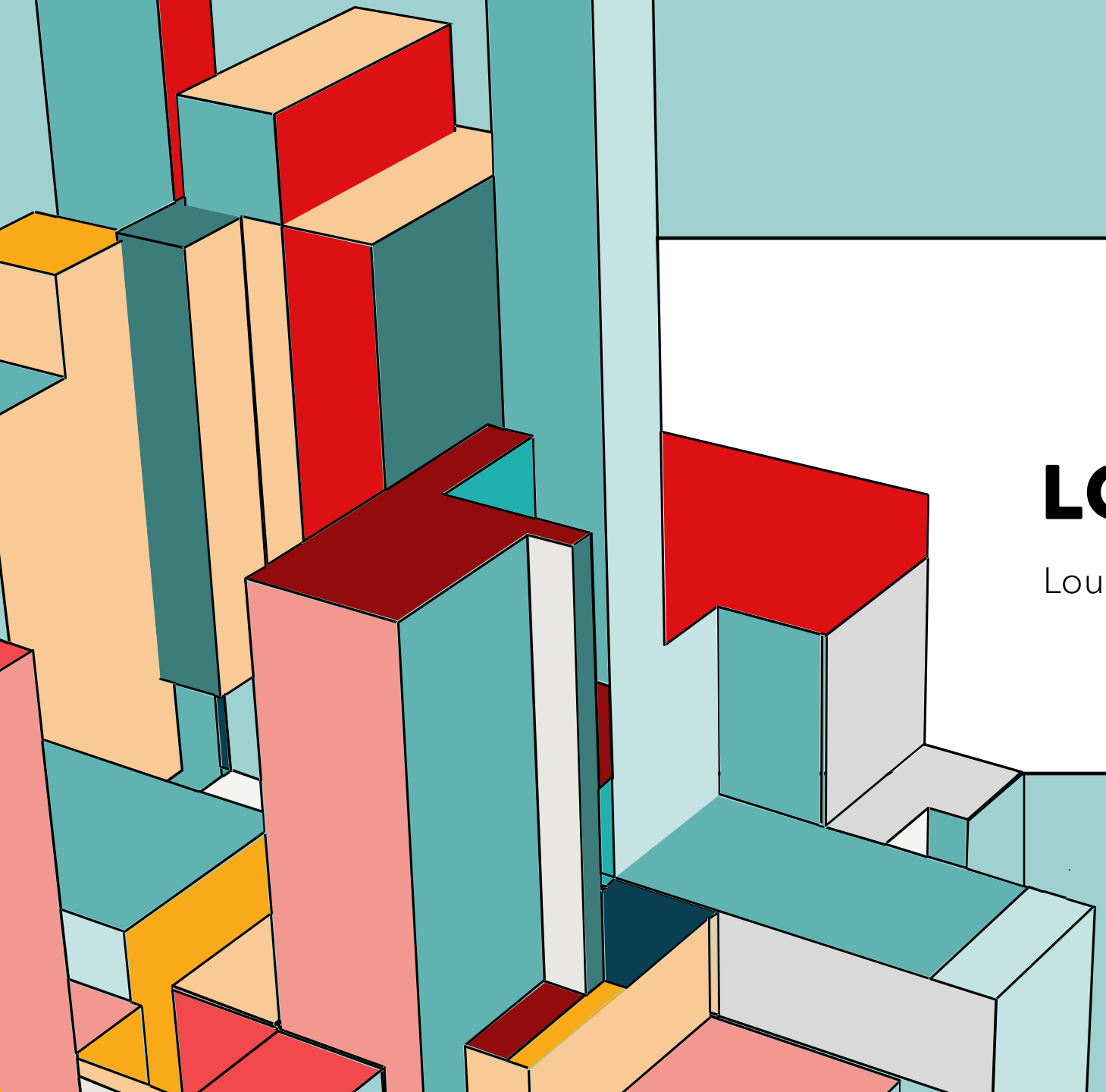


LCA AND BIM

Louis Trümpler

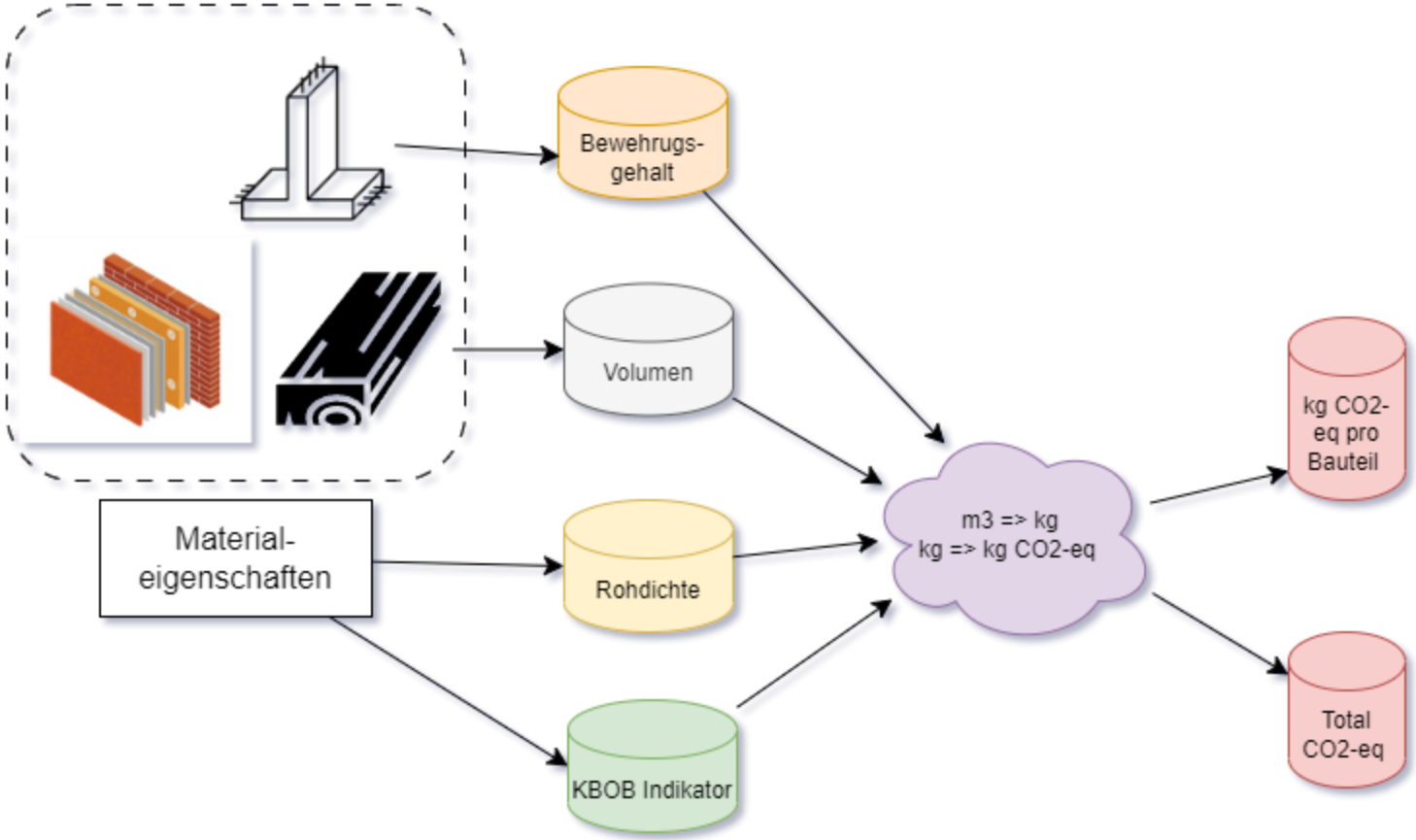
SYNERGY OF LCA AND BIM

Overview: Explore how BIM can underpin LCA and some challenges when aligning model based LCA with norms

Learning Goals: Recognize the benefits and potential downfalls when leveraging BIM data for environmental impact assessments.

Key Takeaway: Insight into the challenges and solutions for integrating detailed BIM outputs with broader LCA requirements.

HOW IT WORKS (IN THEORY)



We need:

- Volume per element (per layer for multilayer floors/walls/roofs)
- Material properties
  - Name
  - Density
  - Carbon indicator (KBOB in CH)

We can:

- Consider elements that aren't modelled like rebar or finishes
- Consider life expectancy according to specification/norm (SIA2032) per element / layer

SOME CHALLENGES

- Uncertainties in background data (environmental indicators) and foreground data (modelling, Bill of Materials):
  - How detailed is the model?
  - Calculation by weight/volume or area with element layers?
  - Which dataset represents the specified materials most accurately?
  - Densities can be challenging (SIA 2032 lists most, but not all)
  - Some data in KBOB should be updated (EPD for Fermacell is ½ of KBOB)
  - Some data is missing (Laminated veneer lumber…)

- Not modelled elements like
  - Rebar
  - Excavation
  - Wall and Floor finishes
  - Paint
  - etc.

- Various workflows for different goals: project optimization or certification? Not one fits it all, especially not in CH

- Comparability between projects may not be straightforward

WORKFLOWS AND APPROACHES

Overview: Outline of various workflows and methodologies that suit different stages of LCA integration in BIM.

Learning Goals: Learn to select and apply the appropriate workflow for each phase of a project.

Key Takeaway: Mastery of diverse workflows is crucial for seamless LCA integration and sustainable project outcomes.

COMMONLY USED WORKFLOWS

Classic Manual Process

Semi-Automatic Process

Fully Automated Process

CLASSIC MANUAL PROCESS

- User gathers all necessary documents (not shown below):
  - Floor plans
  - Sections
  - Material specification ("Baubeschrieb" or similar)
- "Manually" generate bill of quantities (preferably using suited quantity-takeoff software)
- "Manually" calculate Material weights (**kg per Material**) by multiplying **density** (from database, if specified) and **volume**
- Estimate **environmental impact** by multiplying **material weights** with corresponding **environmental indicators** from database
- Visualize and interpret results
- Whole process is usually done in **Excel** (except gathering bill of quantities/materials)

SEMI-AUTOMATIC PROCESS

- Generate **bill of quantities from BIM** software
- User manually or semi-automated **matches materials** present in model with entries from material database
- **LCA tool estimates environmental impact** for all matched materials with **densities from database** (usually not much insight for user into this part)
- Tool visualizes results, maybe connected to 3d model: e.g. user can select a category in report and all elements of category will be highlighted in 3d model, interpretation is up to user
- Process relies on proprietary Software that integrates into BIM modelling solutions and lets user connect to database for retrieval of environmental indicator. **Ensuring that material matches and densities are correctly assigned is crucial, always check which database and scope is used.**

FULLY AUTOMATED PROCESS

Identical…

except materials matching is done fully automatic or with minimal user input.

Applies too: Ensuring that material matches and densities are correctly assigned is crucial…

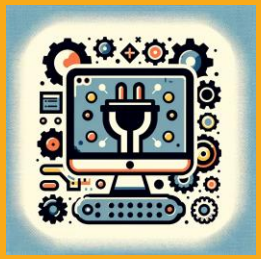
Pro´s and Con´s of fully automated workflows:

- Less manual input reduces errors and increases speed
- Allows using LCA as integral part of planning: "instant" LCA, e.g. during meeting with design changes
- Less freedom in material usage when modelling, usually less insight into calculation / material matching process
- Fully automated material matching based on IFC models with minimal user input is already doable today for structure, architectural models are an entirely different story, especially in early planning stages…

MOST COMMON APPROACHES

BILL OF MATERIALS

Still most commonly used, usually Excel-based



PLUGINS / STANDALONE

Solutions for Revit /Archicad or Desktop/ Web

IFC / OPENSOURCE

IfcOpenShell, IFC.js, BlenderBIM, LCAx etc.

BIM compatibility / interoperability

HOW IT WORKS WITH PYTHON

- Only 26 rows of code to get Volumes:
  - Using IfcOpenShell library (https://ifcopenshell.org)
  - Open IFC file (*ifcopenshell.open)*
  - Get volumes from BaseQuantities *(quantity.VolumeValue)*
  - Build list with element names *(element.name)* and volumes

get_volume_per_IFC_element.py

```python
import ifcopenshell

def get_element_volumes(ifc_file_path):
    ifc_file = ifcopenshell.open(ifc_file_path)
    element_volumes = {}

    processed_elements = set()  # Set to keep track of processed elements

    # Iterate over all IfcElement entities
    for element in ifc_file.by_type('IfcElement'):
        if element.GlobalId not in processed_elements:
            # Mark the element as processed to avoid double counting
            processed_elements.add(element.GlobalId)
            for relDefinesByProperties in element.IsDefinedBy:
                if relDefinesByProperties.is_a('IfcRelDefinesByProperties'):
                    propertySet = relDefinesByProperties.RelatingPropertyDefinition
                    if propertySet.is_a('IfcElementQuantity'):
                        for quantity in propertySet.Quantities:
                            if quantity.is_a('IfcQuantityVolume'):
                                element_name = element.Name if element.Name else 'Unnamed Element'
                                # Add volume to dictionary, creating a new entry if necessary
                                if element_name not in element_volumes:
                                    element_volumes[element_name] = 0.0
                                element_volumes[element_name] += quantity.VolumeValue

    return element_volumes
```

HOW IT WORKS WITH PYTHON

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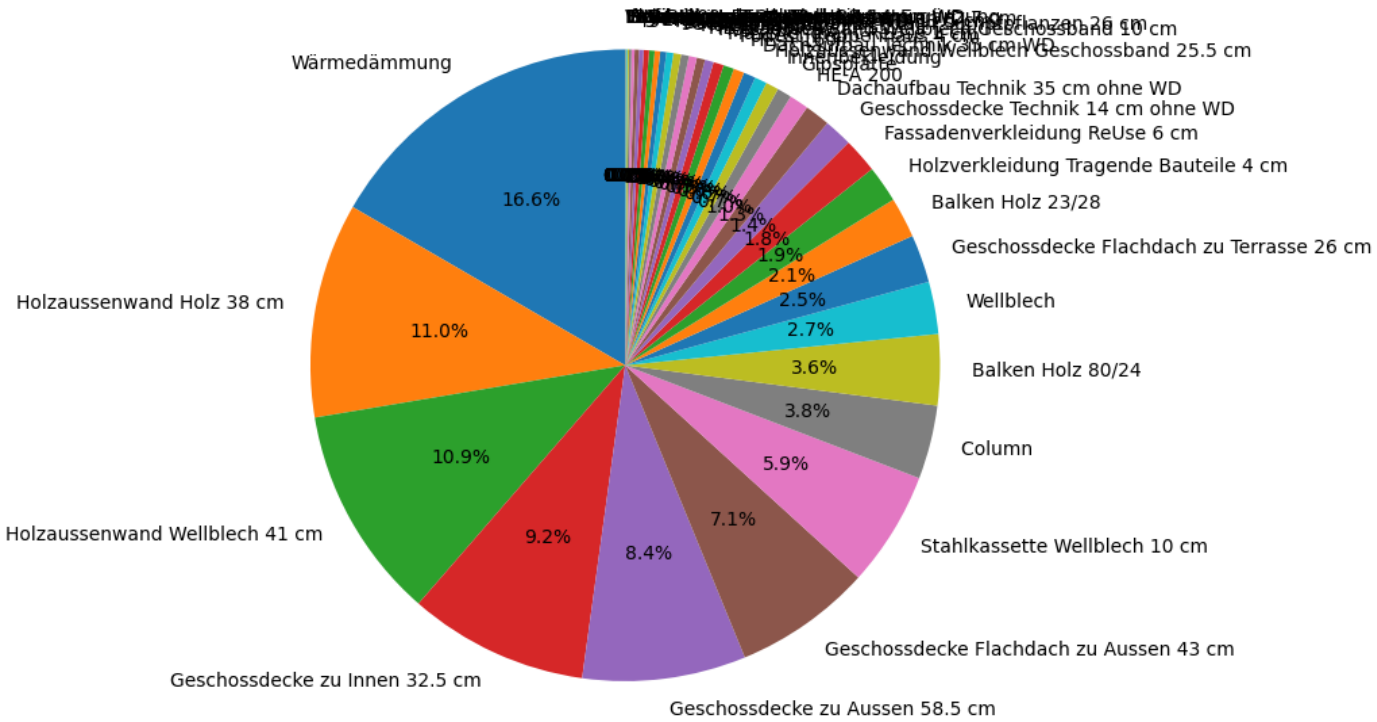
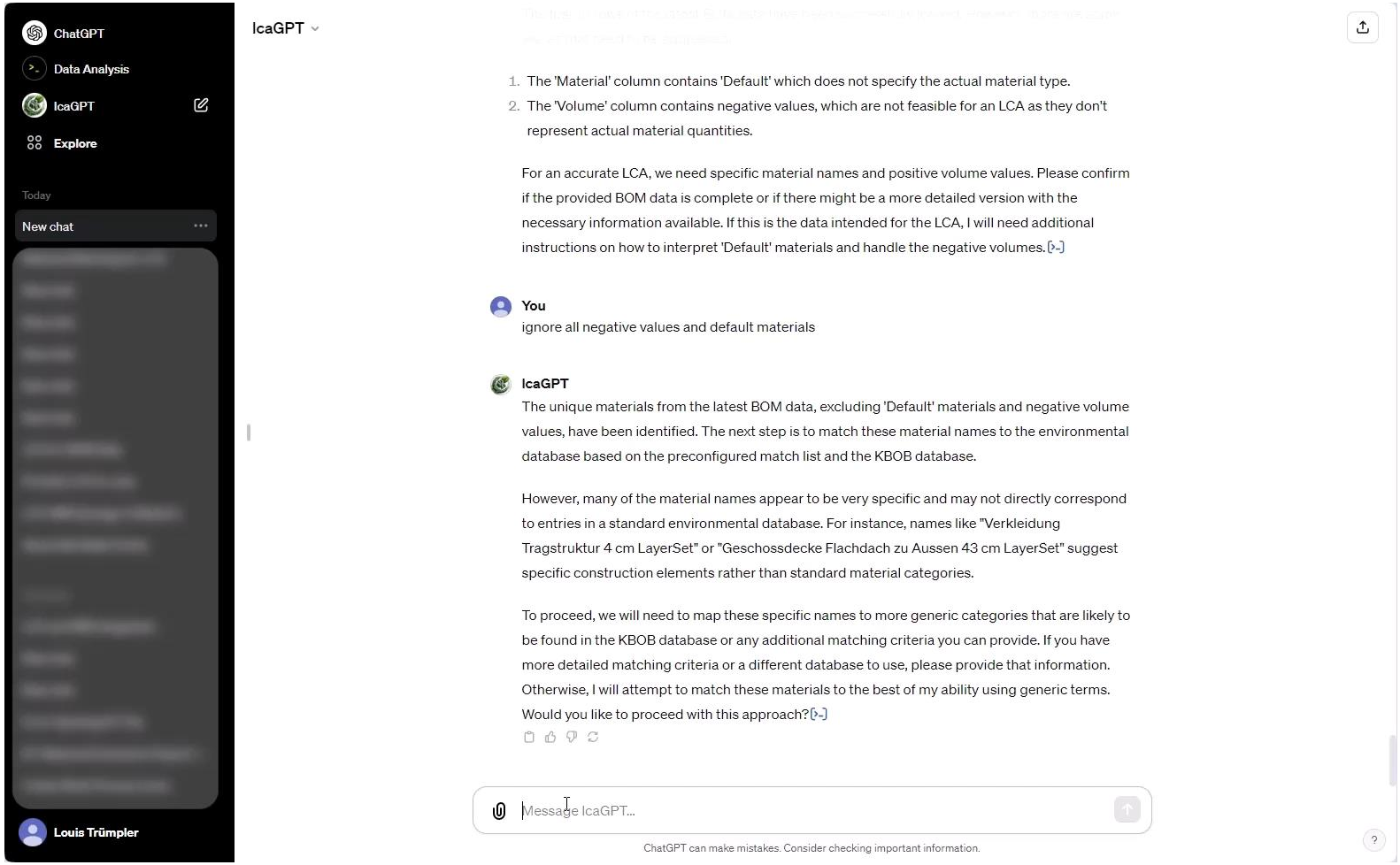


AND MACHINE LEARNING…



- OpenAI´s large language model
- **ChatGPTplus** (paid version)
- Custom GPT with KBOB data in memory
- Can calculate **LCA from user-uploaded Bill of quantities**
- Handles different **files formats**: CSV, Excel, Pdf and even Word etc.
- Various **visualizations** and **optimization suggestions**
- Possibilities: can be optimized to support picture uploads etc.

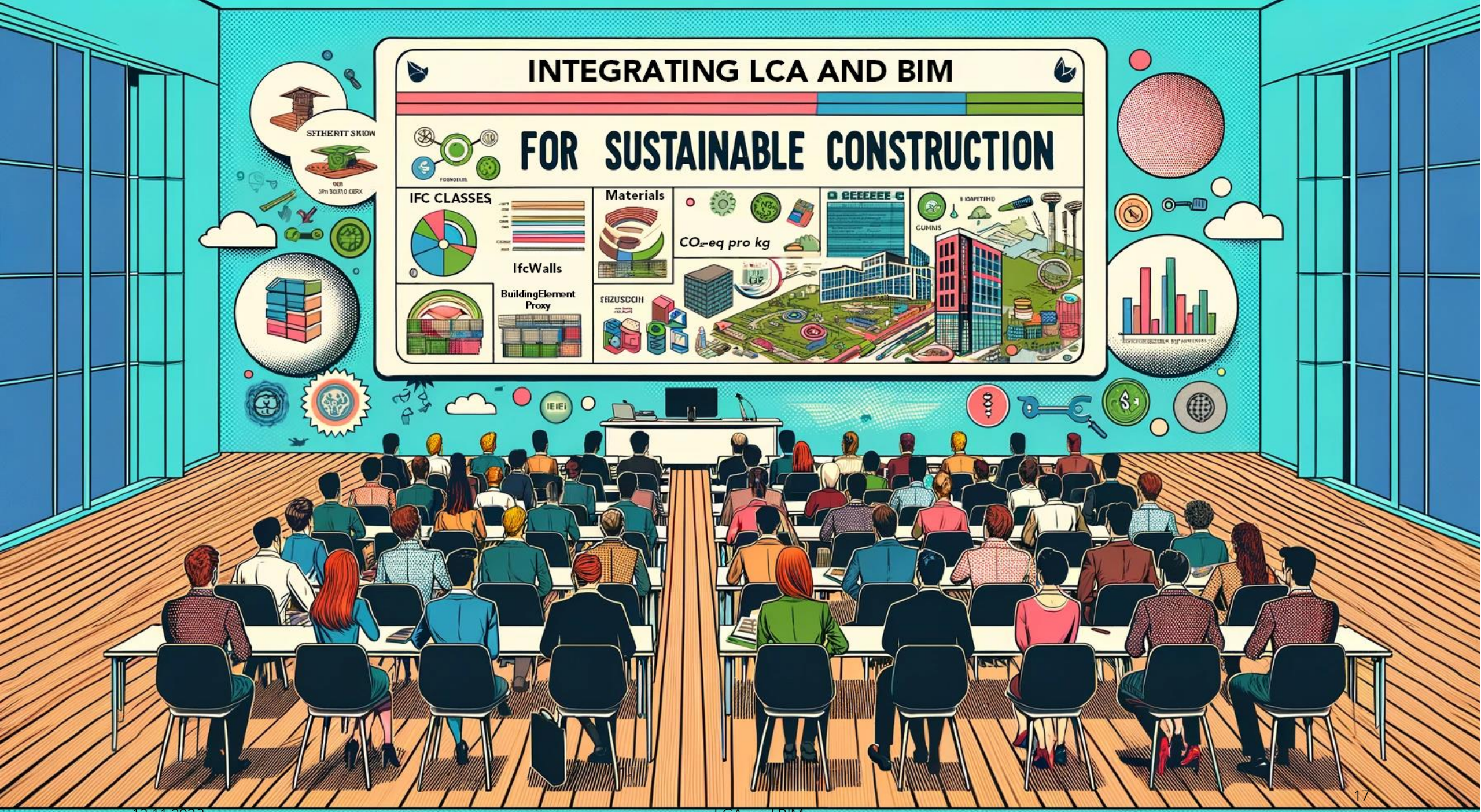
OVERVIEW OF AVAILABLE SOLUTIONS

INTERNATIONAL SOLUTIONS

Tool	Type	BIM connection	Link
Sphera (ex Gabi)	Desktop application	none	https://sphera.com/product-sustainability-software/
SimaPro	Desktop application	none	https://simapro.com
eLCA	Web-based	none	https://www.bauteileditor.de
OpenLCA	Desktop / web application	IFC import / BlenderBIM data connection (very basic)	https://www.openlca.org
Solibri Carbon Checker	IFC Model Checker	IFC import	https://help.solibri.com/hc/en-us/articles/15855465706135-The-Carbon-Checker-Extension
Oneclick LCA	Web-based / BIM Software Plugin	IFC / Revit / Archicad, Tekla Str., Excel, gbXML, simpleBIM, JSON etc.	https://www.oneclicklca.com
Tally	BIM Software Plugin (Revit)	Closed BIM (native Plugin only)	https://choosetally.com
CAALA	Web-based	IFC import	https://www.caala.de
Cocon-BIM (mainly FR)	Web-based	IFC / Archicad / AllPlan / Freecad / Revit etc.	https://www.cocon-bim.com/Building-information-model-BIM.html?lang=en

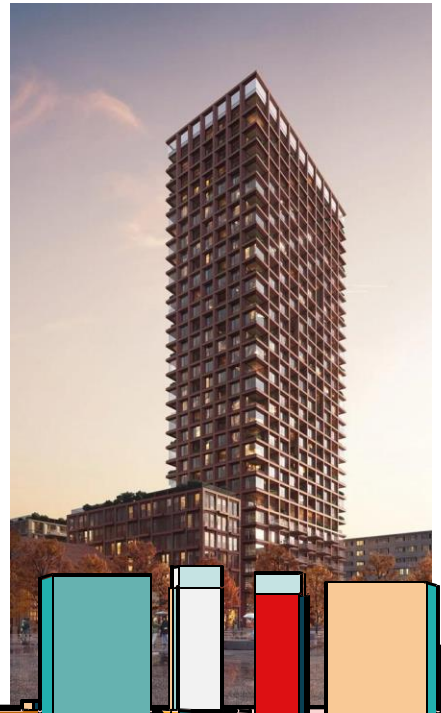
COMMON SOLUTIONS IN CH

Tool	Type	Phase	ECO Standards	Links
Eco-Sai	Desktop application	Early-Late design	Minergie ECO, SNBS, SIA2040	https://eco-sai.com
Lesosai	Desktop application	Late design	Minergie ECO, SNBS, SIA2040	https://lesosai.com
Minergie Eco	Excel-based	Early design	Minergie ECO	https://www.minergie.ch/media/210219_tool_graueenergie_minergie-eco_v2-02_d.xlsx
Energytools.ch	Excel-based	Early design	Minergie ECO, SNBS, SIA2040	https://www.energytools.ch/index.php/de/downloads/datenbanken/download/4-datenbanken/71-2032-graue-energie
Greg	Excel-based	Early design	Minergie ECO, SNBS	https://www.energiekonzepte.ch/greg/
ZPF ecotool	Excel / Web-based	Early design	-	https://app.ecotool.org
greenBIM	Revit / Archicad Plugin / (web)	Early design	-	https://greenbim.ch


INTEGRATING LCA AND BIM
FOR SUSTAINABLE CONSTRUCTION
IFC CLASSES
IfcWalls
BuildingElement Proxy
Materials
CO₂-eq pro kg

INTEGRATING LCA INTO PLANNING

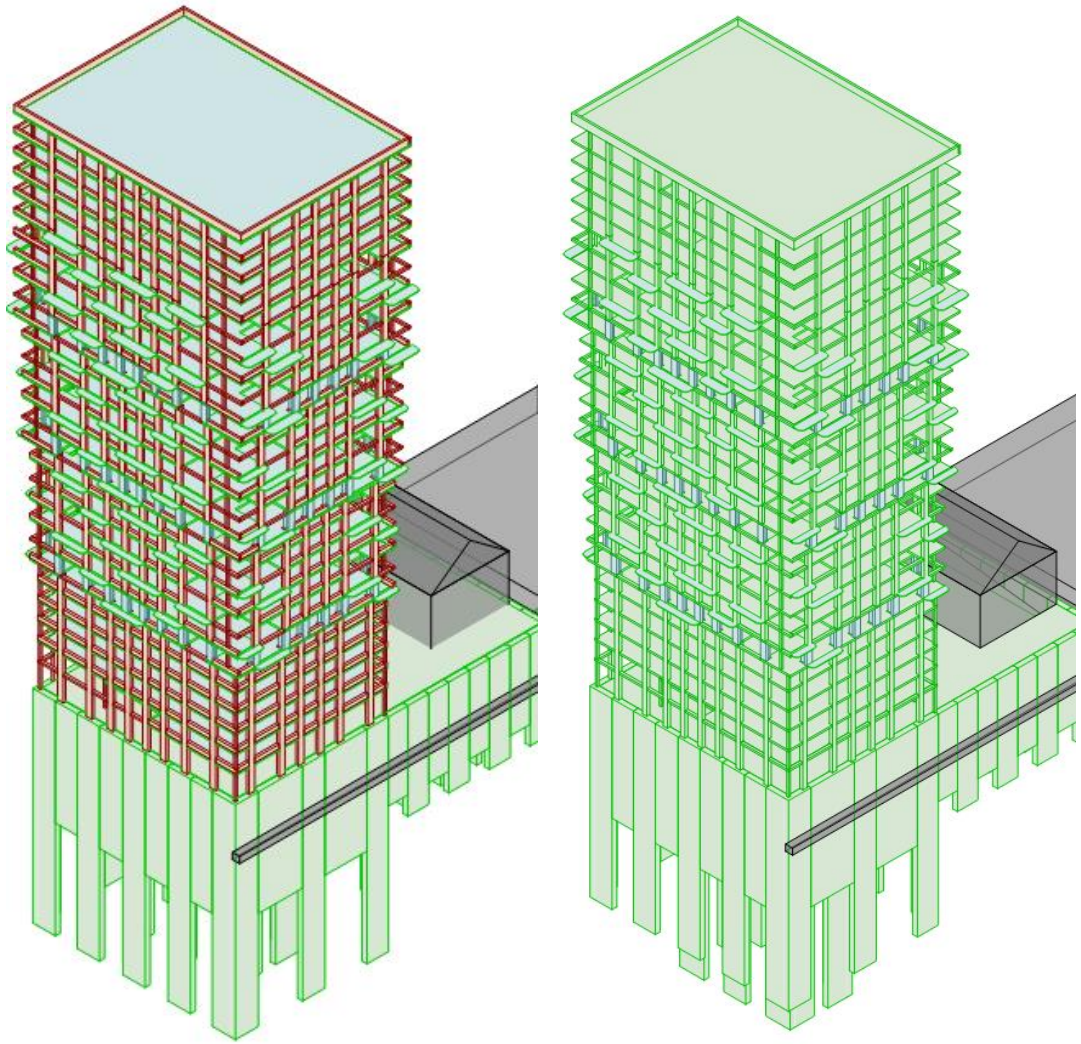
Rocket (Lokstadt, Implenia)



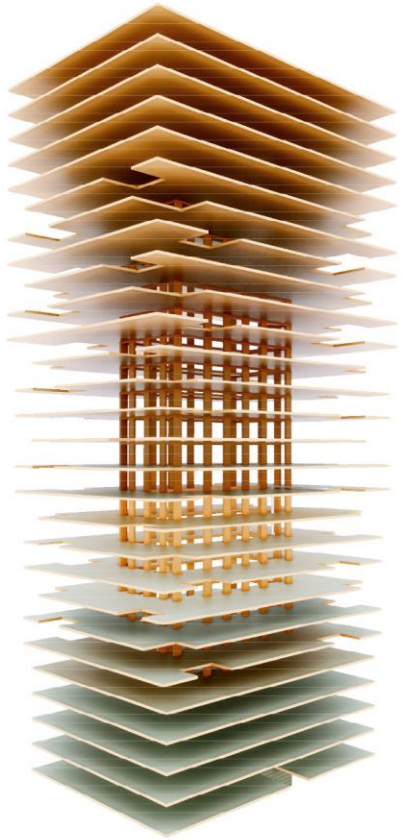
Projekt Pi (V-Zug)

PROJEKT PI

- 80m residential timber high-rise in ZUG
- Sustainability as important criteria in **design competition**
- Extensive analysis of environmental impact for all structural elements:
  - **Floor system** has biggest impact, **up to 60%**, depending on structural system
  - Foundation as another main driver
  - **Structure is highly relevant** comparing to other building elements: **30-60%** (again depending mainly on choice of structural system)
- Some important lessons learned:
  - Buildings must be **analysed and optimized holistically**
  - Dimensions, material and **rebar** amount must be considered per element
  - Modelling entire **comparison buildings** is feasible using modern BIM software and gives complete picture, along with nice renderings…

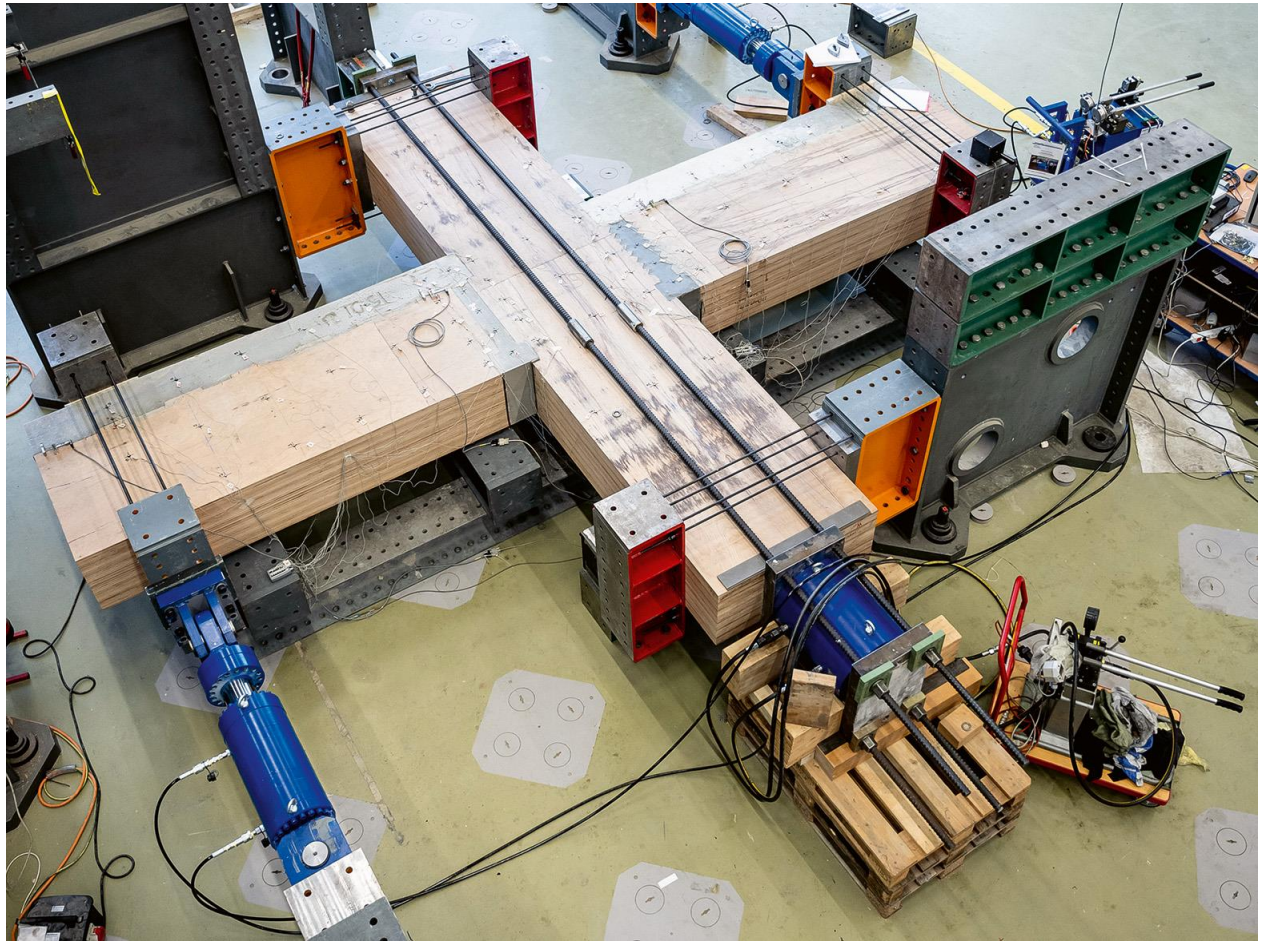


PROJEKT PI



- No structural core, only non-bearing elevator and stair shaft
- Structural moment frame near core and perimeter
- Extremely slim timber-concrete hybrid floor plate
- Loads get traversed into the ground directly compared to using a central core

PROJEKT PI

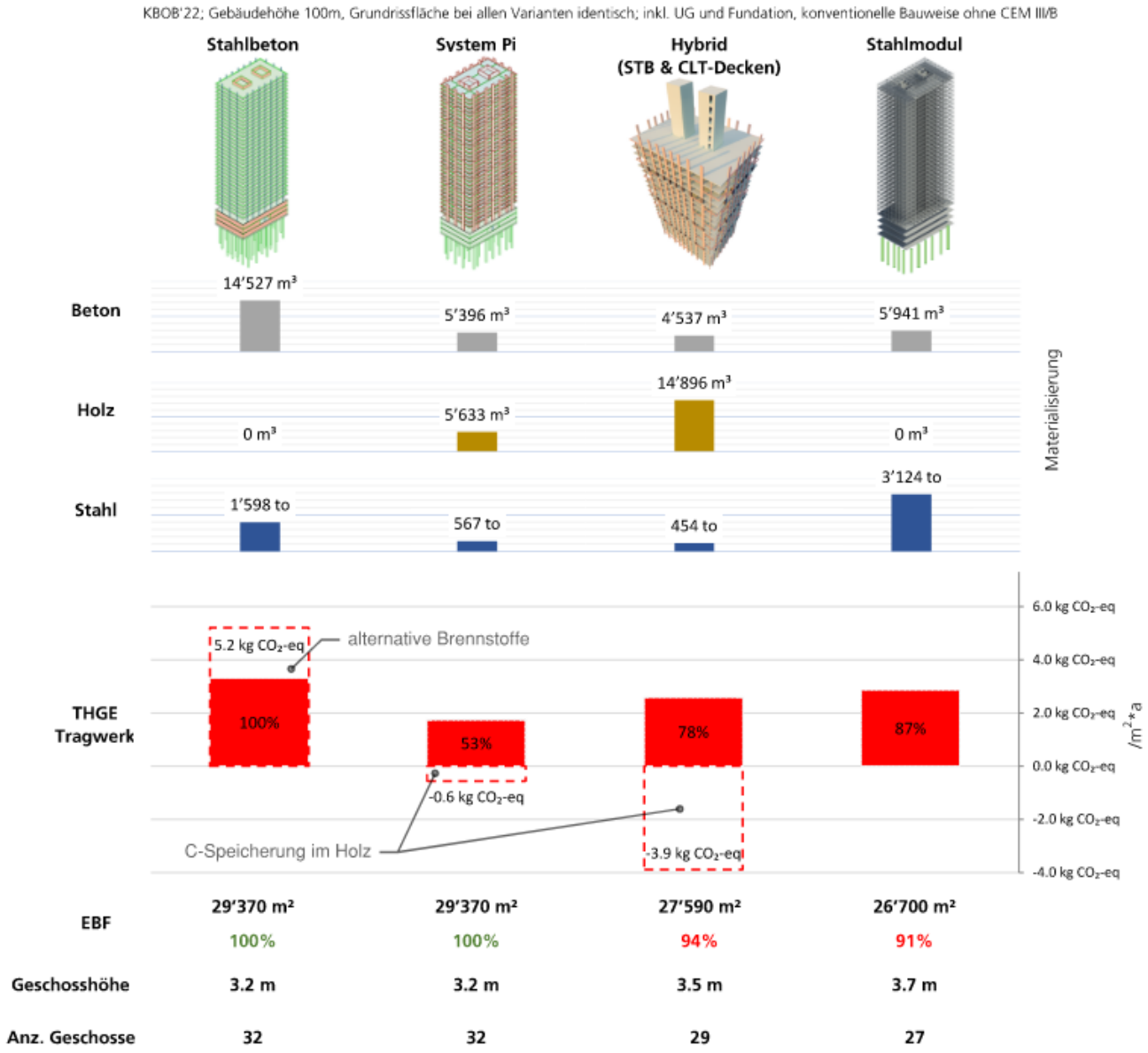


ROCKET

100m timber tower in Winterthur "Lokstadt" by Implenia

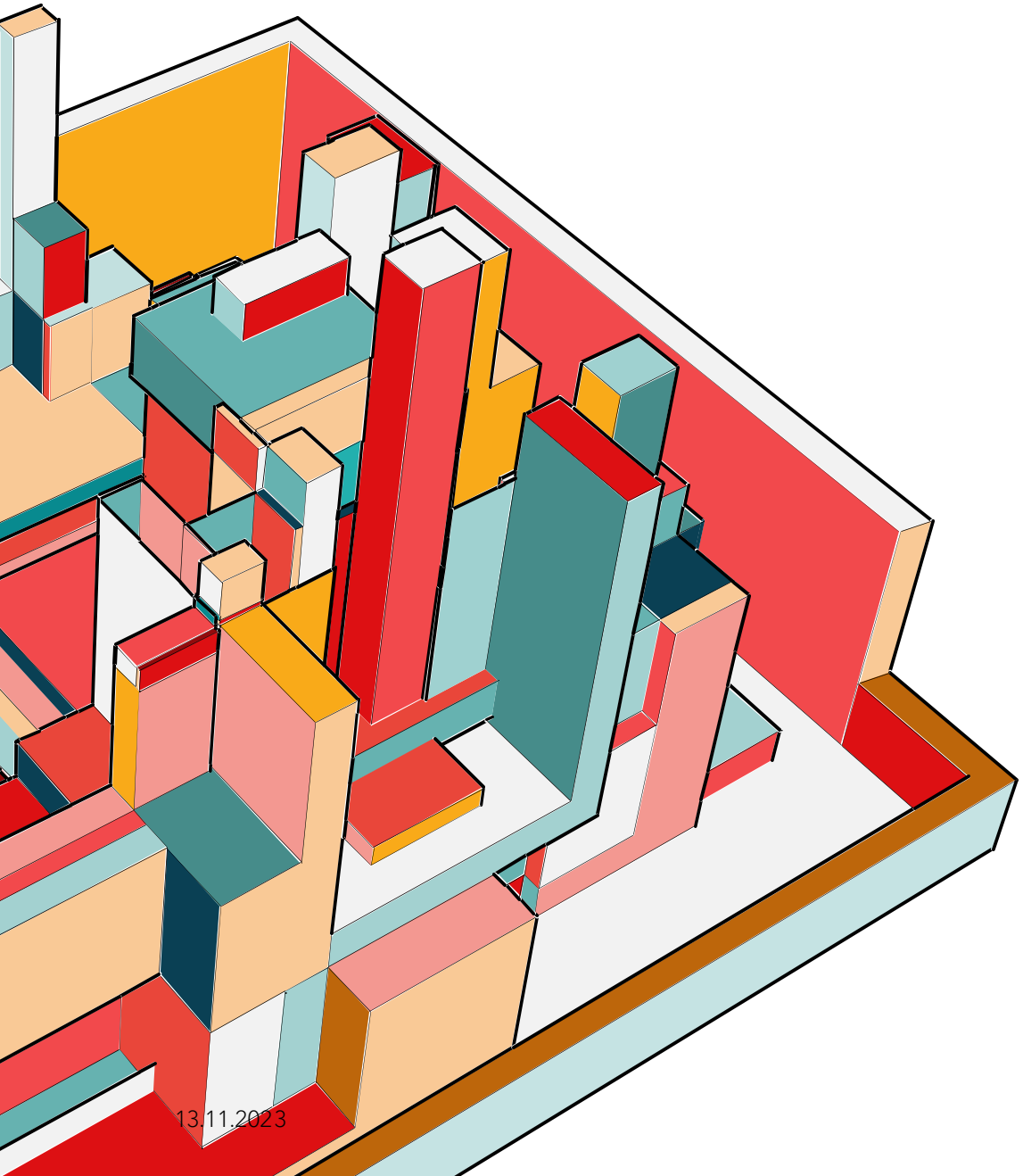
Extensive comparison of several options in feasibility study:

- **Timber** (System Pi) seemed most promising regarding carbon emissions
- **Hybrid** approach was considered but mixing systems brings certain disadvantages
- **Steel modules** are surprisingly inefficient
- **Concrete** could only work with CEMIII/B cement due to carbon budget but that proved impossible for such heights due to time constraints (longer curing time, especially in winter)



ROCKET

- Environmental impact as important criteria due to restrictions
- Design competition won by Danish architects Schmidt Hammer Lassen
- Model based **LCA defined as a Use Case** in Exchange Information Requirements (EIR)
- Involvement of entire project team to achieve defined goals



SUMMARY

I truly believe in the power of digital tools to lead the charge towards low-carbon, eco-friendly building solutions, and I feel like the field provides some great opportunities for emerging professionals to contribute to the quest for a more sustainable built environment…

THANK YOU

Louis Trümpler

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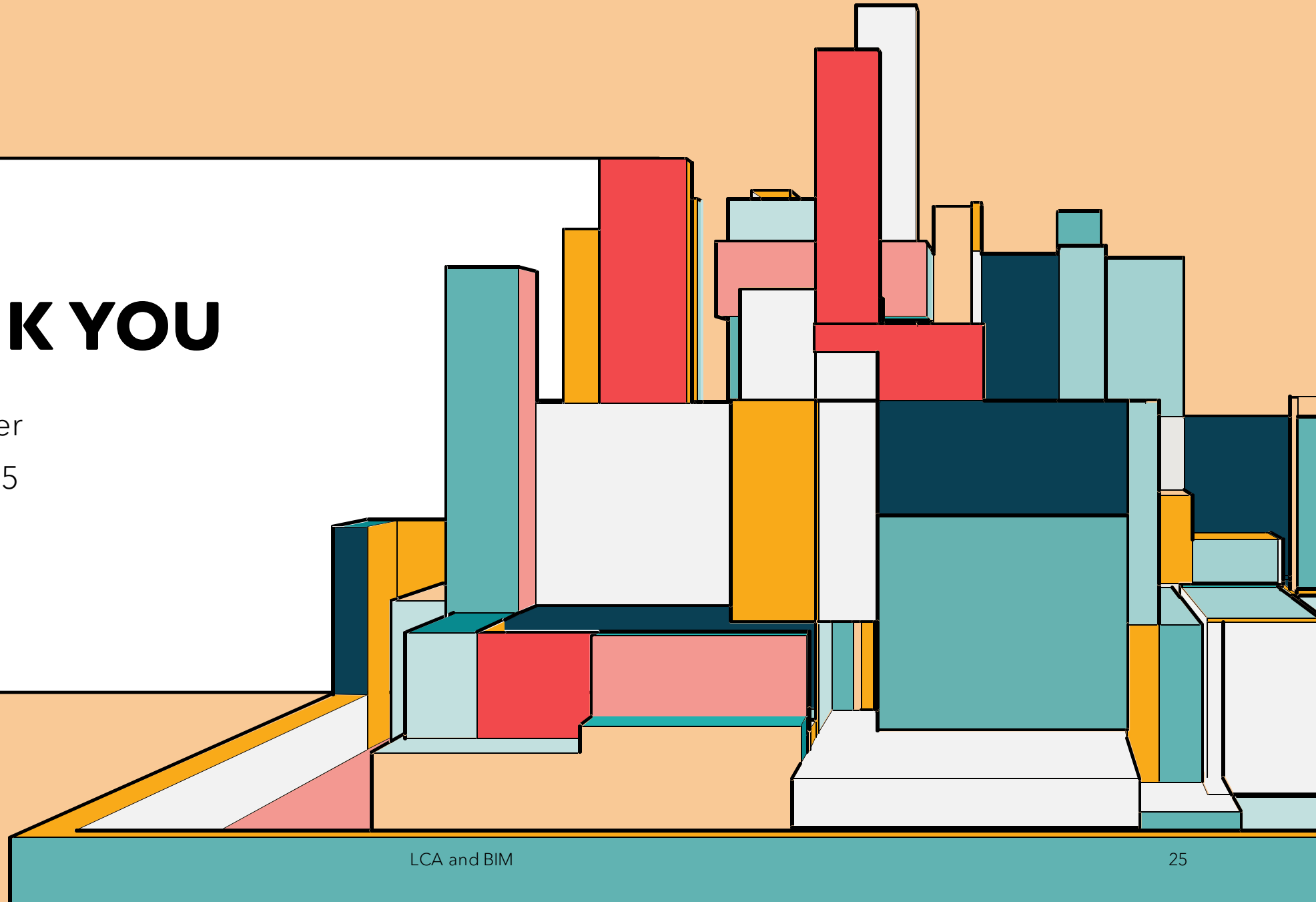
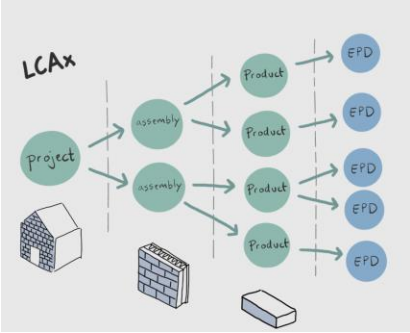
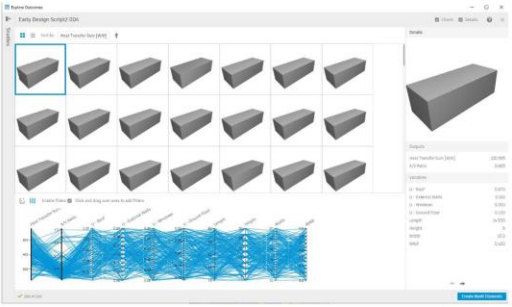
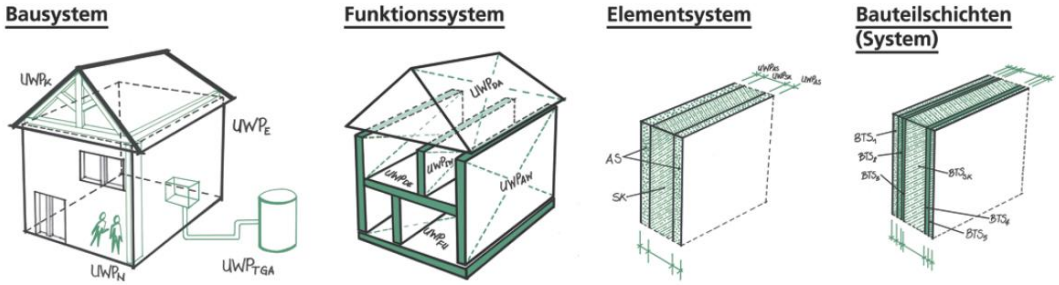


THANKS FOR PROJECT DETAILS

www.waltgalmarini.ch

SOURCES AND ADDITIONAL RESOURCES

- Design-integrated Life Cycle Assessment using BIM (BIM-LCA): https://www.research-collection.ethz.ch/bitstream/handle/20.500.11850/584886/e_BIM-LCA-FinalReport.pdf
- LCAxProject: https://lcax.kongsgaard.eu / https://github.com/ocni-dtu/lcax
- BIM-integrierte Ökobilanzierung: https://publications.cms.bgu.tum.de/theses/2018_Forth_Oekobilanzierung.pdf
- ZPF Tool Web: https://www.swiss-architects.com/de/architecture-news/meldungen/eine-neue-webanwendung-verspricht-die-einfache-berechnung-der-okobilanz
- BIM LCA Lernplattform (BFH): https://bim-lca.ch
- Ökobilanz- Integration in den Entwurfsprozess: https://www.ibp.fraunhofer.de/content/dam/ibp/ibp-neu/de/dokumente/sonderdrucke/bauphysik-gertis/7-oekobilanz.pdf
- Additonal specific calculation tools (concrete, timber): https://treeze.ch/de/rechner
- In der Werkstatt des Riesen (Article on Pi testing at ETH): https://ethz.ch/de/news-und-veranstaltungen/eth-news/news/2021/03/in-der-werkstatt-des-riesen.html
- Advancing the LCA ecosystem: https://carbonleadershipforum.org/advancing-lca-ecosystem