LEGOFIT

THE MULTIFACETED LEGOFIT APPROACH TO TACKLING BARRIERS TO ENERGY-POSITIVE HOMES

Sustainable Places 2024

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SUSTAINABLE PLACES 2024

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AGENDA

- INTRODUCTION
- LEGOFIT APPROACH
- LEGOFIT METHODOLOGY
- LEGOFIT BARRIERS
- LEGOFIT DRIVERS
- CONCLUSIONS

LEGOFIT AT A GLANCE

LEGOFIT *Adaptable technological solutions based on early design actions for the construction and renovation of Energy Positive Homes*

PROGRAMME: HORIZON-CL5-2022-D4-01-02

TYPE OF ACTION: HORIZON-IA

TOTAL BUDGET: 7.033.325,00 €

GRANTS AMOUNT: 5.599.531,25 €

DURATION: 48 months

LEAD PARTNER: De surdurulebilir enerji ve insaat sanayi ticaret limited sirketi - demir enerji - DEM

PROJECT PARTNERS: R2M; LIST; BDAB; CERT; OSM; AUG; METU; E2C; ABUD; EOS; VAL; OzU; IMP; IES

THE LEGOFIT OVERALL AIM

LEGOFIT aims to design, implement and validate an adaptable and dynamic **holistic approach** to accomplish **Energy-Positive Homes** (EPHs) based on smart and innovative solutions with **high scalability and replicability** for efficient building **construction and renovation**.

LEGOFIT provides **professionals and end-users** with an innovative holistic **design platform** with three **main functionalities**:

1

supporting
the **decision-making process**

2

aiding
the **design process**

3

setting up
an **innovative marketplace**

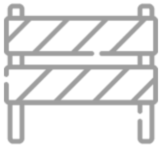
THE LEGOFIT APPROACH

Four main pillars to **underpin the LEGOFIT process**

- **A** DEFINING THE LEGOFIT **EPH** → Focus on the **building's inherent bioclimatic performance**
- **B** DEFINING THE **CONSTRUCTION / RENOVATION PROCESS PHASES** → Focus on **building renovation process**
- **C** ACTIVATING **FIVE PILOTS** TO DEMONSTRATE THE LEGOFIT VIABILITY → **Hungary, Luxembourg, Spain, The Netherlands and Turkey**
- **D** SETTING UP THE **LEGOFIT STAKEHOLDER COMMUNITY** TO **IDENTIFY BARRIERS / DRIVERS TO EPH AND SHAPE THE LEGOFIT SOLUTIONS** → **Target groups involved in planning/design/renovation / construction processes**

THE LEGOFIT CHALLENGE

How to accomplish **Energy Positive Homes**:



BARRIERS

CONSEQUENCES

NEED

FRAGMENTATION

Deep renovation and new construction processes are often fragmented, leading to **inefficiencies** and missed opportunities for energy optimization.

LACK OF AWARENESS

Citizens **have limited understanding** of the **long-term benefits** of **EPHs**, prioritizing immediate costs over future savings and environmental impact.

RESISTANCE TO CHANGE AND ADOPTION OF EPHs

Additionally, **lack of comprehensive planning** and coordination. Difficulty in **integrating energy-efficient technologies**.

COMPREHENSIVE METHODOLOGY

For **proactive planning**, **targeted interventions**, and **effective stakeholder engagement**, ultimately leading to a **smoother** and **more impactful renovation** and **construction process**.

THE LEGOFIT METHODOLOGY

Four main steps to identify and **map Barriers & Drivers**:

01 | SETTING UP THE FRAMEWORK

A structured *framework* was devised to categorize and map the identified **barriers** and **drivers** and gain a deeper understanding of which of them will influence the implementation.

02 | DATA COLLECTION

Through a in-depth **literature review** and a two days **collaborative mapping workshop** (*Miro board*) among Pilot Leaders, barriers and drivers were profiled.

03 | DATA ANALYSIS

Data analysis were launched during the workshop itself and finalizing later with a **qualitative analysis** to identify the **key themes** and **recurring patterns** within the barriers and drivers.

04 | VALIDATION AND REFINEMENT

As results, a **detailed understanding** of the barriers and drivers impacting building renovation /construction processes was achieved.

THE LEGOFIT METHODOLOGY

The profiling of the barriers and drivers was performed by involving directly the **LEGOFIT Pilot Leaders** in a **collaborative two-day mapping workshop** to:

- **collect** real market experience
- **share** ideas and knowledge
- **validate** the barriers and drivers identified through the literature analysis
- **identify** the barriers and drivers which are common to all the LEGOFIT Pilot
- **collect** suggestions for exploiting potentialities/drivers and overcoming barriers.

THE LEGOFIT METHODOLOGY

Criteria to **analyse the barriers**:

TYPE
Technical, regulatory, financial, social

DESCRIPTION
Clear outline of the barrier and its potential impact

PILOT COUNTRIES
Identifying relevant pilot

STAKEHOLDER IMPACT
Identifying stakeholders affected by or contributing to the barrier
Multi-level approach for the stakeholder analysis – Four levels considered

PROJECT PHASE
Categorizing barriers based on their impact during specific project stages

LEGOFIT CONTRIBUTION
Outlining how LEGOFIT will address barriers through services and solutions

PROJECT TYPE
Specifying whether the barrier impacts standard or advanced projects

HOW TO TACKLE THE TECHNICAL BARRIERS

LEGOFIT addresses **technical barriers** by:

ENHANCING INNOVATION

LEGOFIT leverages and enhances *BIM environments and integrates Digital Twins* to improve decision-making, tackle expertise gaps, and enable ad-hoc renovation studies

IMPROVING EFFICIENCY

The Platform makes it possible to streamline *data aggregation,* thus *overcoming fragmentation* and promoting cost savings

UPSKILLING

Targeted training programs bolster skills for professionals and construction workers, thus overcoming skill gaps and shortage of skilled workers

IMPROVING COLLABORATION AMONG STAKEHOLDERS

Improved collaboration through *the LEGOFIT Stakeholder Community and the Open Innovation Community for Building Energy Management (BEM) professionals* help to optimize resource allocation and overcome support challenges

HOW TO TACKLE THE REGULATORY BARRIERS

LEGOFIT addresses **regulatory barriers** by:

PROMOTING STRONGER REGULATIONS AND INCENTIVES

LEGOFIT promotes initiatives for sustainable construction and advocates for stricter requirements for building sustainability, tackling political constraints and low obligations for sustainable practices

REGULATORY IMPROVEMENT RECOMMENDATIONS

By leveraging insights from real-world pilot implementations and stakeholder input, LEGOFIT suggests improvements to streamline permit processes and address regulatory constraints on renewable energy sources and retrofitting preferences

PROMOTING RE-USED MATERIAL CERTIFICATION

The platform champions the development of regulations and certifications - Material Passport and Circular Building Passport - for re-used materials and components

HOW TO TACKLE THE FINANCIAL BARRIERS

LEGOFIT addresses **financial barriers** by:

PROMOTING COST REDUCTION FOR TECHNOLOGY AND SERVICES

Through technical and financial assessments, LEGOFIT helps to reduce the high costs associated with new technologies, services, and solutions

ENHANCED CLARITY AND POTENTIAL COST REDUCTION FOR EPHs

The platform promotes transparency and explores ways to decrease the additional costs for Energy-Positive Houses (EPHs) due to longer payback periods

OVERCOMING THE LACK OF SUITABLE BUSINESS MODELS

LEGOFIT seeks to overcome the lack of financial space for Positive Energy Districts (PEDs) and the absence of suitable business models for EPHs by replicating successful existing business models for renovations and leveraging Crowdfunding for building intervention

PROMOTING CIRCULAR ECONOMY AND MATERIAL REUSE

By introducing Material Passports and Circular Building Passports, LEGOFIT fosters a reduction of the price of circular products and facilitates the reselling of reused/recycled materials and components

HOW TO TACKLE THE SOCIAL BARRIERS

LEGOFIT addresses **social barriers** by implementing and rolling out:

USER-FRIENDLY PLATFORM

Providing tailored solutions and transparent impact predictions, empowering users to make informed decisions

RESIDENT-CENTERED CROWDFUNDING

Encouraging engagement and acceptance by allowing residents to financially participate in retrofitting projects

POESY TOOL

Enhancing the LEGOFIT process and reducing performance gaps through real-time occupant feedback on comfort levels

LEGOFIT STAKEHOLDER COMMUNITY

Connecting homeowners, professionals, and experts for seamless knowledge sharing and collaboration

TARGETED AND ACCESSIBLE TRAINING

On Energy Positive Homes (EPHs) to various stakeholders leveraging Real-world case studies and best practices which are showcased to provide inspiration and practical insights

THE LEGOFIT METHODOLOGY

Criteria to analyse the **drivers**:

DESCRIPTION
Outlining external factors that can influence stakeholders and drive innovation

PILOT COUNTRIES
Identifying relevant pilot

STAKEHOLDER IMPACT
Specifying the stakeholder category that can exploit the driver

PHASE OF OCCURRENCE
Determining project phases where the driver is most influential

LEGOFIT CONTRIBUTION
Describing how LEGOFIT can support stakeholders in exploiting the driver

HOW TO EXPLOIT THE REGULATORY DRIVERS

The project's holistic platform, integrating systematic energy and economic analysis, will leverage and capitalize on:

ANTICIPATED CARBON FOOTPRINT REGULATIONS
By providing a tool to assess and optimize the carbon footprint of new constructions and renovations

MANDATED ECO-FRIENDLY CLEANING MATERIALS
By incorporating their use into the project's design and operational recommendations

FORTHCOMING MINIMUM ENERGY PERFORMANCE STANDARDS
By proactively designing homes that exceed anticipated requirements

LEGALLY ENFORCED PERFORMANCE MONITORING
By enabling continuous tracking and optimization of building performance

HOW TO EXPLOIT THE FINANCIAL DRIVERS

The LEGOFIT project, with its comprehensive platform for energy and economic analysis, is well-positioned to leverage key:

CAPITALIZE ON THE GREEN ECONOMIC DEAL

By aligning with sustainable investment priorities and attracting green financing

EXCEED MORTGAGE PORTFOLIO STANDARDS RELATED TO ENERGY PERFORMANCE

By designing homes that meet or surpass stringent requirements, potentially improving access to financing

MITIGATE THE IMPACT OF HIGH ENERGY PRICES

By promoting energy-efficient home designs and technologies

BENEFIT FROM PREFERENTIAL PRICING FOR WHITE CERTIFICATES

By incorporating bioclimatic principles into home designs, creating more comfortable and energy-efficient living spaces

SUPPORT ESG REPORTING REQUIREMENTS

By providing quantifiable data on the environmental and social impact of energy-positive homes

HOW TO EXPLOIT THE SOCIAL DRIVERS

The LEGOFIT platform, by incorporating a systemic methodology for energy and economic analysis, has the opportinity to provide a contribution to a complex and challenging renovation landscape. This integration will enable the platform to:

FOSTER GREEN JOB CREATION
By stimulating demand for sustainable construction practices and technologies

ELEVATE SUSTAINABILITY IN POLITICAL DISCOURSE
By providing cities with concrete data and evidence on the benefits of energy-positive homes

LEVERAGE CITIZEN ENGAGEMENT TOWARDS SUSTAINABILITY
By demonstrating tangible economic and environmental benefits

ENCOURAGE THE ADOPTION OF SUSTAINABLE PRACTICES
By highlighting their financial viability and long-term value and providing transparent and reliable data

CONTRIBUTE TO ENERGY SECURITY AND INDEPENDENCE
By reducing reliance on external energy sources

CONCLUSIONS

The analysis of the **barriers** has shown that:

1. Most of the barriers **are substantial and systemic in each renovation/construction process**
2. Most of the barriers **are common to all the Pilot Countries** throughout the process
3. The barriers already present in **minor renovation projects are significantly amplified** in projects aiming at implementing the **high-efficiency targets of EPHs**
4. The barriers **mainly affect the stakeholders who must undertake the renovation / construction process**

CONCLUSIONS

The analysis of the **barriers** has shown that:

LEGOFIT is poised to ***potentially contribute*** **to the transformation of the** **extremely complex renovation landscape** since:

5 The LEGOFIT Platform offers **valuable solutions to the barriers**. It provides tailored financial/technical feasibility assessments for innovative solutions, improves the innovation level through **a BIM environment**, and **creates confidence in the process** through **effective communication / exchange among stakeholders**

6 LEGOFIT can provide tailored financial / technical **feasibility assessment for innovative solution and creates confidence** in the renovation process through an effective communication among stakeholders

CONCLUSIONS

The analysis of the **drivers** has shown that the regulatory, financial, and social drivers will mainly be exploited by service/solution providers and consequently **by homeowners**, who will benefit from more efficient homes.

LEGOFIT can contribute to exploiting the drivers in all phases of the renovation/construction processes, especially by:

1. Introducing a **systemic methodological approach for the energy / economic analysis**
2. **Increasing awareness** about the benefits of EPHs
3. Promoting **an efficient circular use of resources**

THANK YOU!

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CONSORTIUM

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Assessing the upfront carbon cost of structural adaptability

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PhD student | Structural engineer

[1]University of Sheffield [2]TATA STEEL [3]MOTT MACDONALD

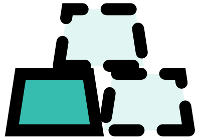
Background
Lean vs adaptable

Two philosophies to achieve embodied carbon reductions in structural engineering:

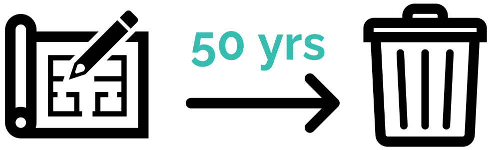
Lean design

Short-term thinking: Design for first use

Minimising upfront material usage

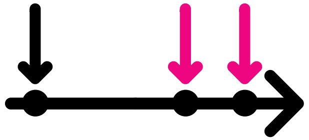


Designing within codes: 50-year design life

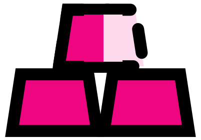


Design for adaptability

Long-term thinking: Consider alternative future uses



Whole life approach: Small upfront over-investment for long-term savings



Aligned with **circular economy**

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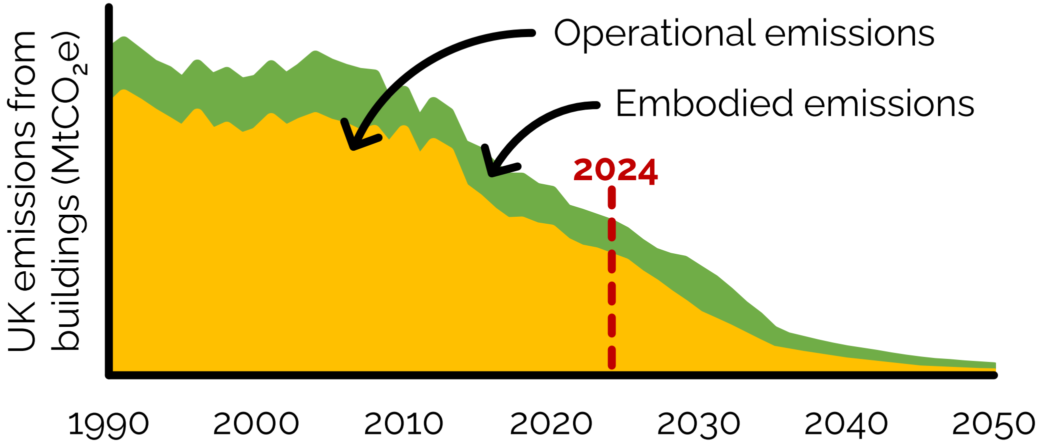
Background
Why buildings?

Built environment accounts for almost **40%** of global annual CO_2 emissions[1]



Decreasing operational emissions increasing embodied proportion[2]

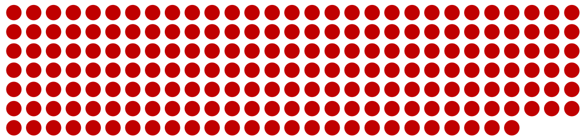
Structural engineers have a significant opportunity to reduce CO_2 emissions

Cut one return flight from London to New York — Save 1,000 $kgCO_2e$

Cut meat, dairy and beer from their diet — Save 2,000 $kgCO_2e$ per year

Stop driving their car — Save 3,000 $kgCO_2e$ per year

20% reduction in structural CO_2 on each of the projects they work



Save 200,000 $kgCO_2e$ per year

Contextualising the potential impact of a structural engineer[3]

[1] UN Environment Programme and Global Alliance for Buildings and Construction (2024), *Global Status Report for Buildings and Construction*. doi: https://doi.org/10.59117/20.500.11822/45095
[2] UK Green Building Council (2021) *Net Zero Whole Life Carbon Roadmap*. Available at: https://ukgbc.org/our-work/topics/whole-life-carbon-roadmap/ (Accessed: 16 September 2024)
[3] IStructE (2022). *How to calculate embodied carbon*. 2nd edn. London: The Institution of Structural Engineers

Background
Circular economy

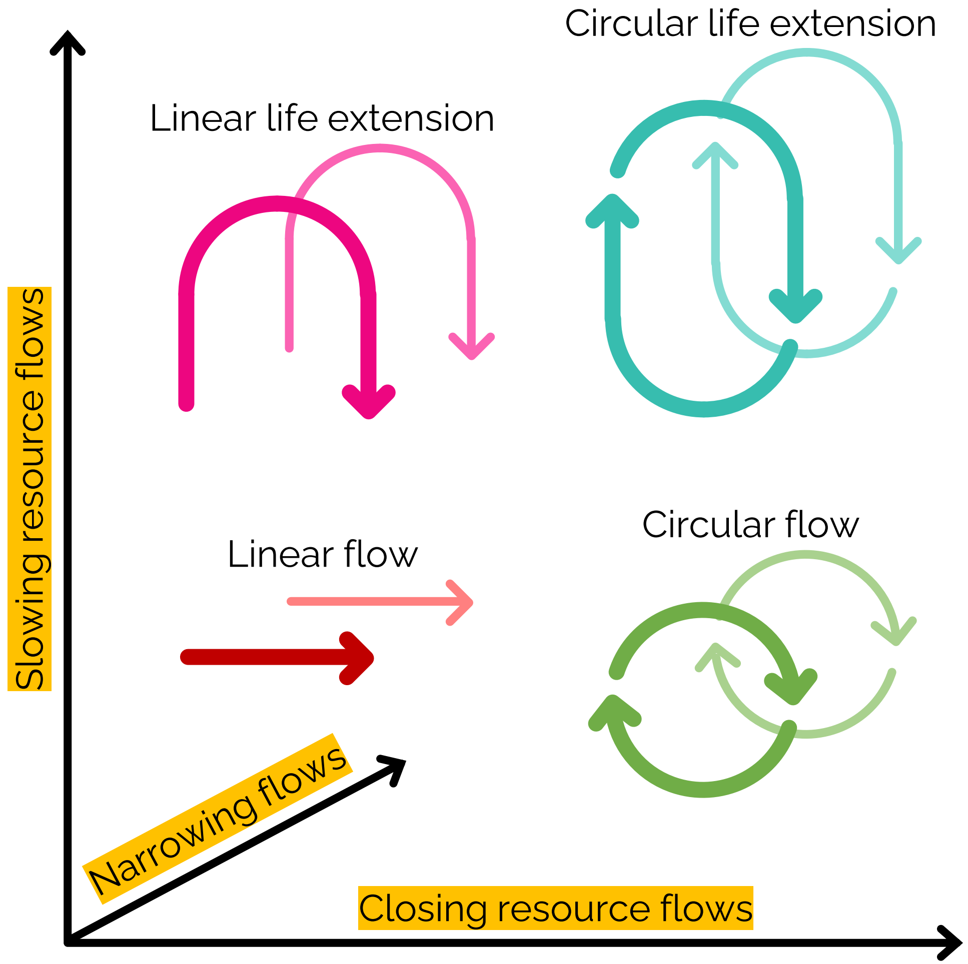
Aim of the circular economy:

"To keep materials at their highest value for as long as possible"

- A building as a building (i.e. **design for adaptability**)
- A beam as a beam (i.e. design for deconstruction)
- Steel as steel (i.e. separation of layers)

Three principles of the circular economy:

- Narrowing resource flows (i.e. **lean design**)
- Closing resource flows (i.e. design for deconstruction)
- Slowing resource flows (i.e. **design for adaptability**)



The three axes of the circular economy[4]

[4] Bocken, M. P., de Pauw, I., Bakker, C. and van der Grinten, B. (2016). 'Product Design and Business Model Strategies for a Circular Economy', *Journal of Industrial and Production Engineering*, 33(5), pp. 308–320. doi: https://doi.org/10.1080/21681015.2016.1172124

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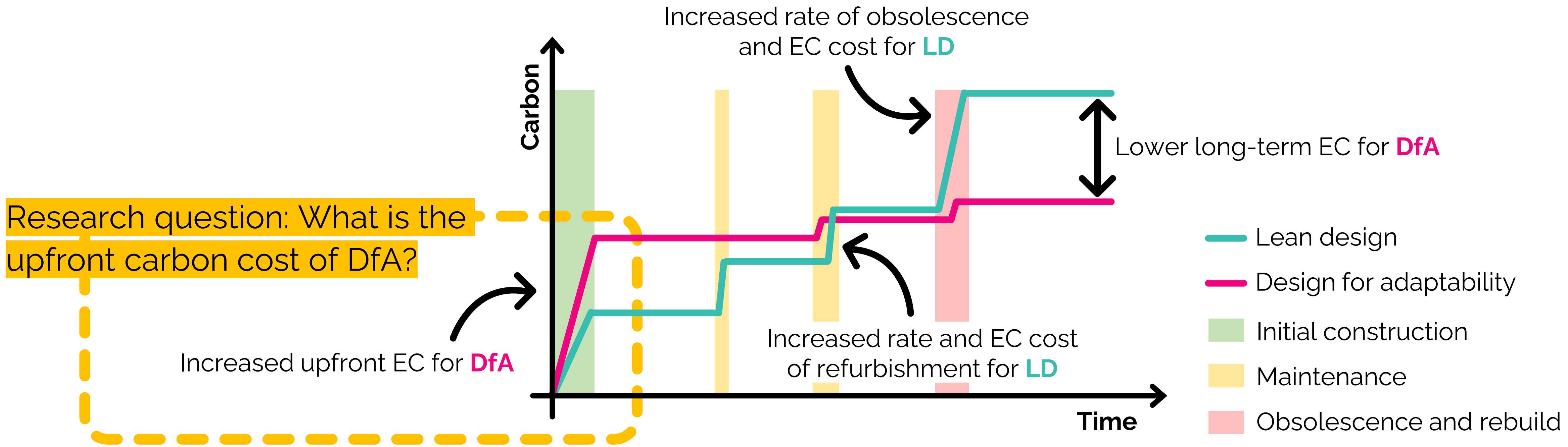
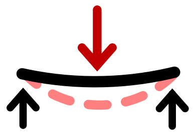
Background
Research hypothesis

"Whilst **Lean Design (LD)** can reduce upfront embodied carbon (EC), **Design for Adaptability (DfA)** will achieve greater EC reductions in the long-term."

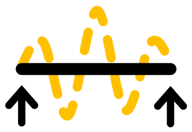


Methodology
Adaptability strategies

Reserve capacity:

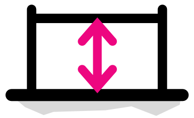


Imposed load
- The load the structure is designed to carry
- Dependent on building use type and fit-out specification

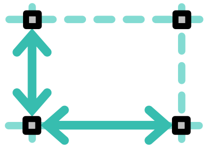


Vibration limit
- The sensitivity of the structure to 'respond' to rhythmic loading
- Acceptance level dependent on building use type

Open layouts:



Storey height
- The height between each floor, including the clear height, structural depth, service zones and finishes
- Dependent on building use type, and fit-out/servicing specification



Grid arrangement
- The distance between the columns
- Dependent on building use type and user expectations

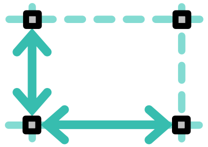
Ross, B. E., Chen, D. A., Conejos, S. and Khademi, A. (2016). 'Enabling adaptable buildings: Results of a preliminary expert survey', *Procedia Engineering*, 145, pp. 420–427. doi: https://doi.org/10.1016/j.proeng.2016.04.009
Watt, H., Davison, B., Hodgson, P., Kitching, C. and Densley Tingley, D. (2024). 'Assessing the upfront carbon cost of structural adaptability', [Submitted for review].

Methodology
Assessment process

Fixed inputs:
- Steel frame material
- Four storeys
- Building plan dimensions

PANDA

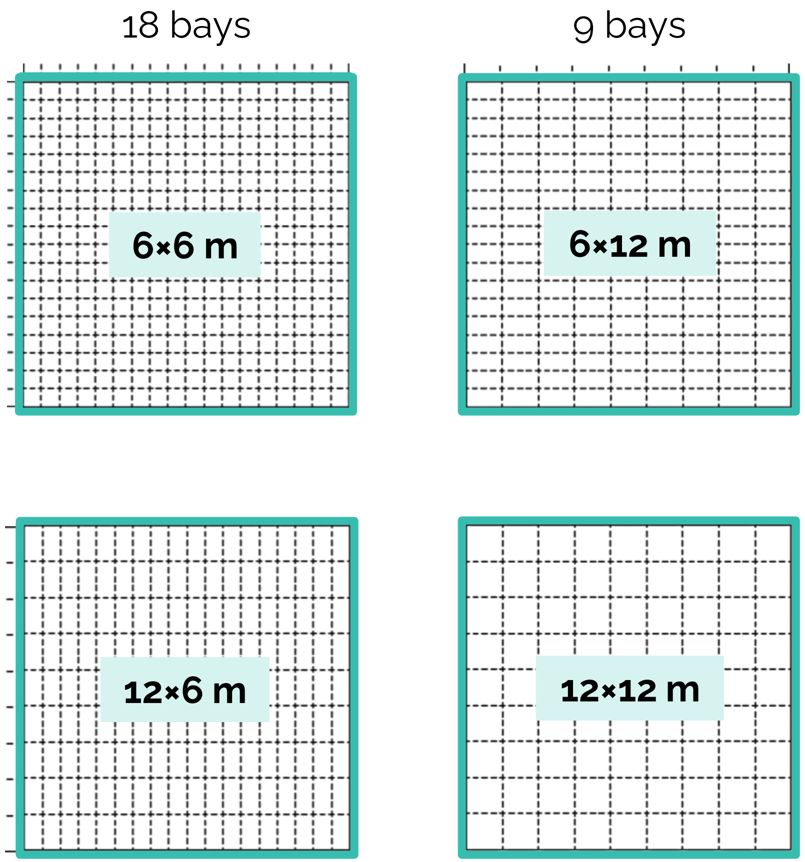
Range inputs:



- Grid arrangement:
  6.0 m min. span
  12.0 m max. span

$$\text{Max. bays} = \frac{\text{Plan dimension}}{\text{Min. span}} = \frac{108.0\text{ m}}{6.0\text{ m}} = 18\text{ bays}$$

$$\text{Min. bays} = \frac{\text{Plan dimension}}{\text{Max. span}} = \frac{108.0\text{ m}}{12.0\text{ m}} = 9\text{ bays}$$



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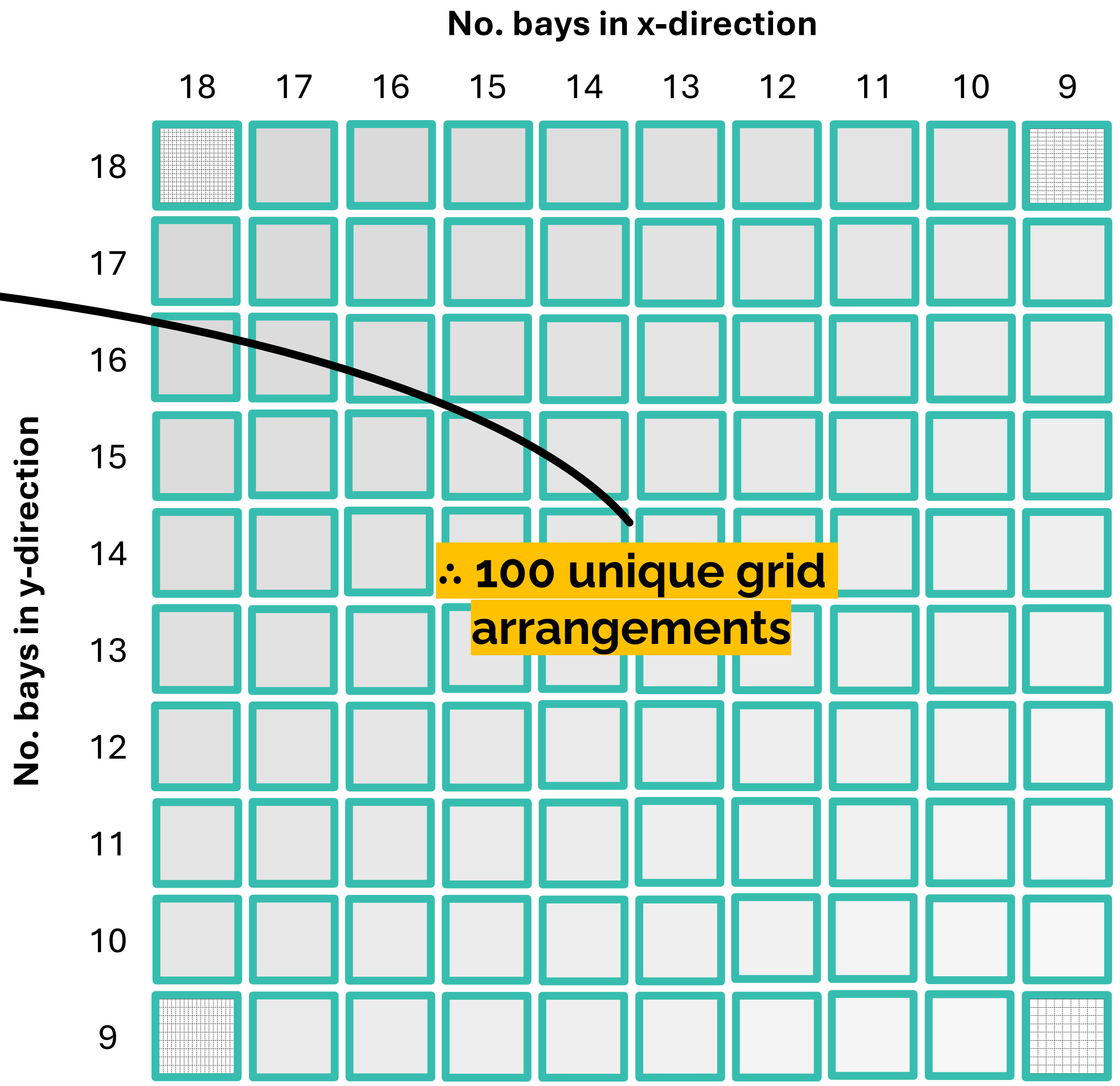
Methodology
Assessment process

Fixed inputs:
- Steel frame material
- Four storeys
- Building plan dimensions

PANDA

Range inputs:
- Grid arrangement: 6.0 m min. span 12.0 m max. span

Incremental inputs:
- Imposed load: 1 2 3 4 5 6 7 8 (kN/m²)
- Vibration limit: 2 4 6 8 10 12 14 16 (Hz)
- Storey height: 3 4 5 6 7 8 9 10 (m)



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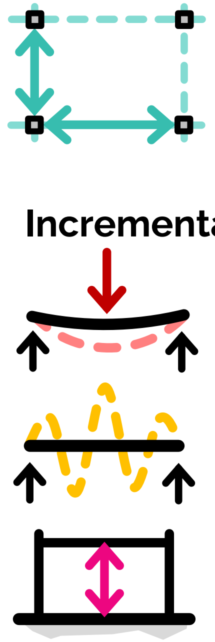
Methodology
Assessment process

Fixed inputs:
- Steel frame material
- Four storeys
- Building plan dimensions

Range inputs:
- Grid arrangement: 6.0 m min. span 12.0 m max. span

Incremental inputs:
- Imposed load: 1–8 kN/m²
- Vibration limit: 2–16 Hz
- Storey height: 3–10 m



LCA inputs:
- A1-3 + A4 carbon factors
- A5w wastage rates
- A5c construction factors

PANDA

***PANDA* outputs:**
- Material mass relationships for each adaptability parameter

IStructE LCA

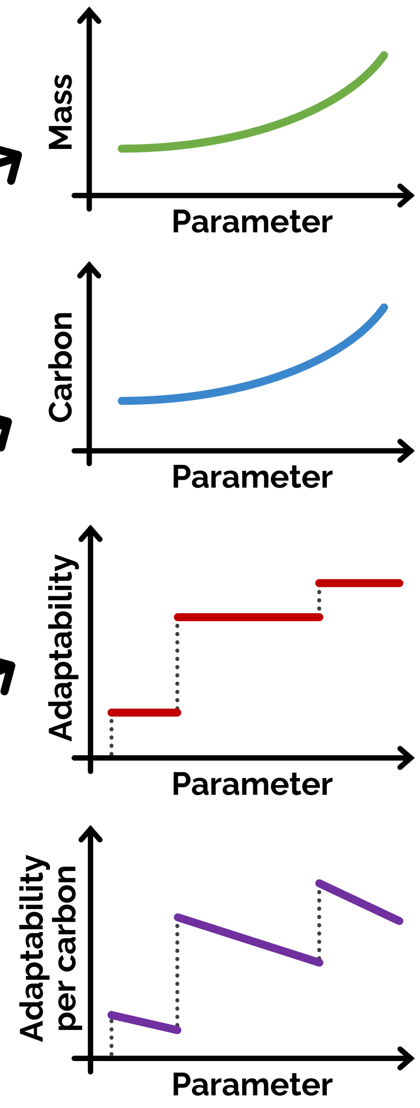
LCA outputs:
- Embodied carbon relationships for each adaptability parameter

Lit. review

Literature review outputs:
- Adaptability scoring relationships for each adaptability parameter

Python

***Python* outputs:**
- Adaptability per carbon relationships for each design parameter



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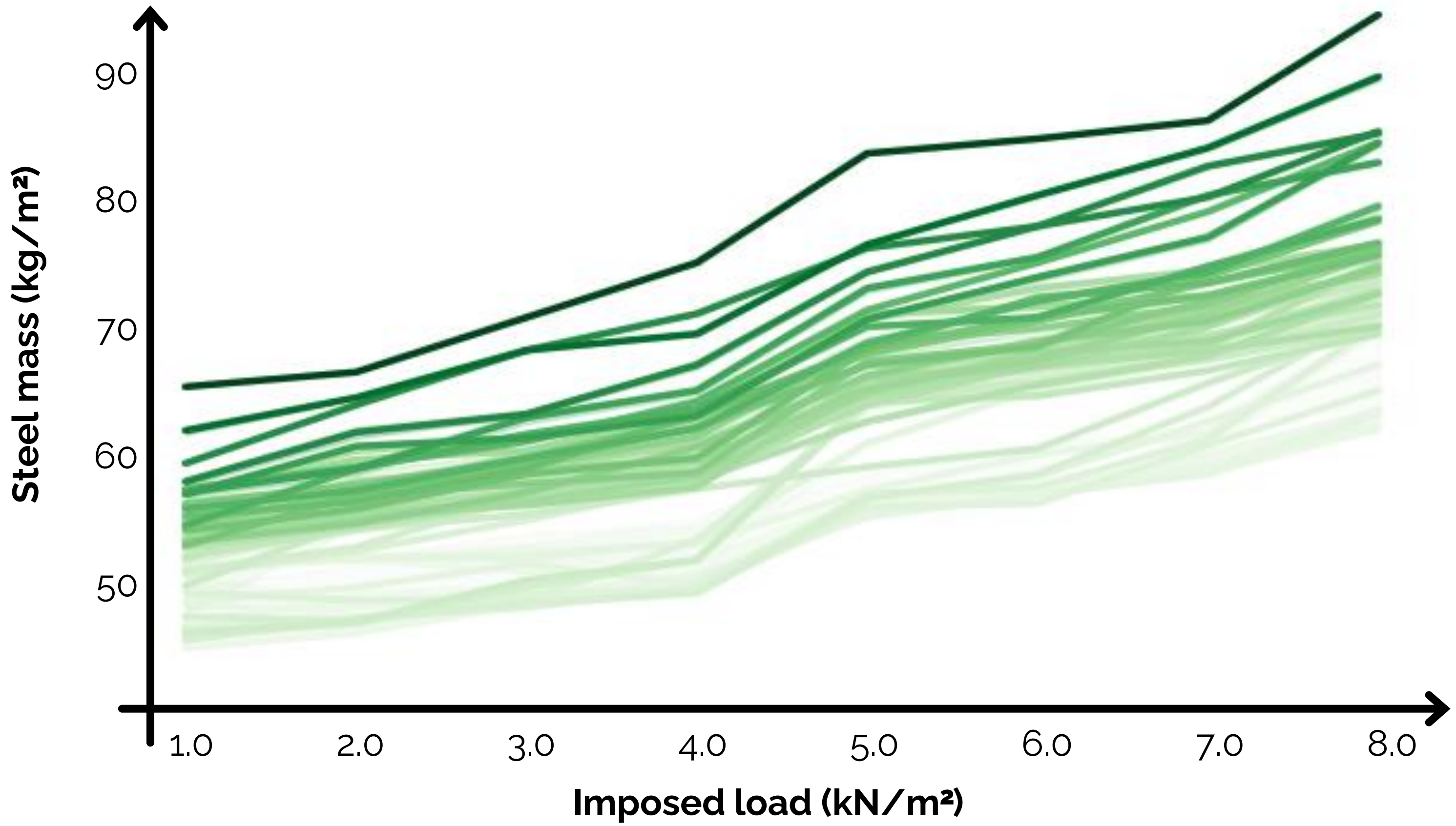
Carbon results

Imposed load



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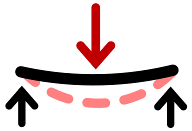
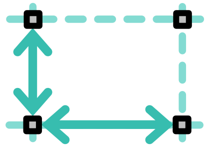
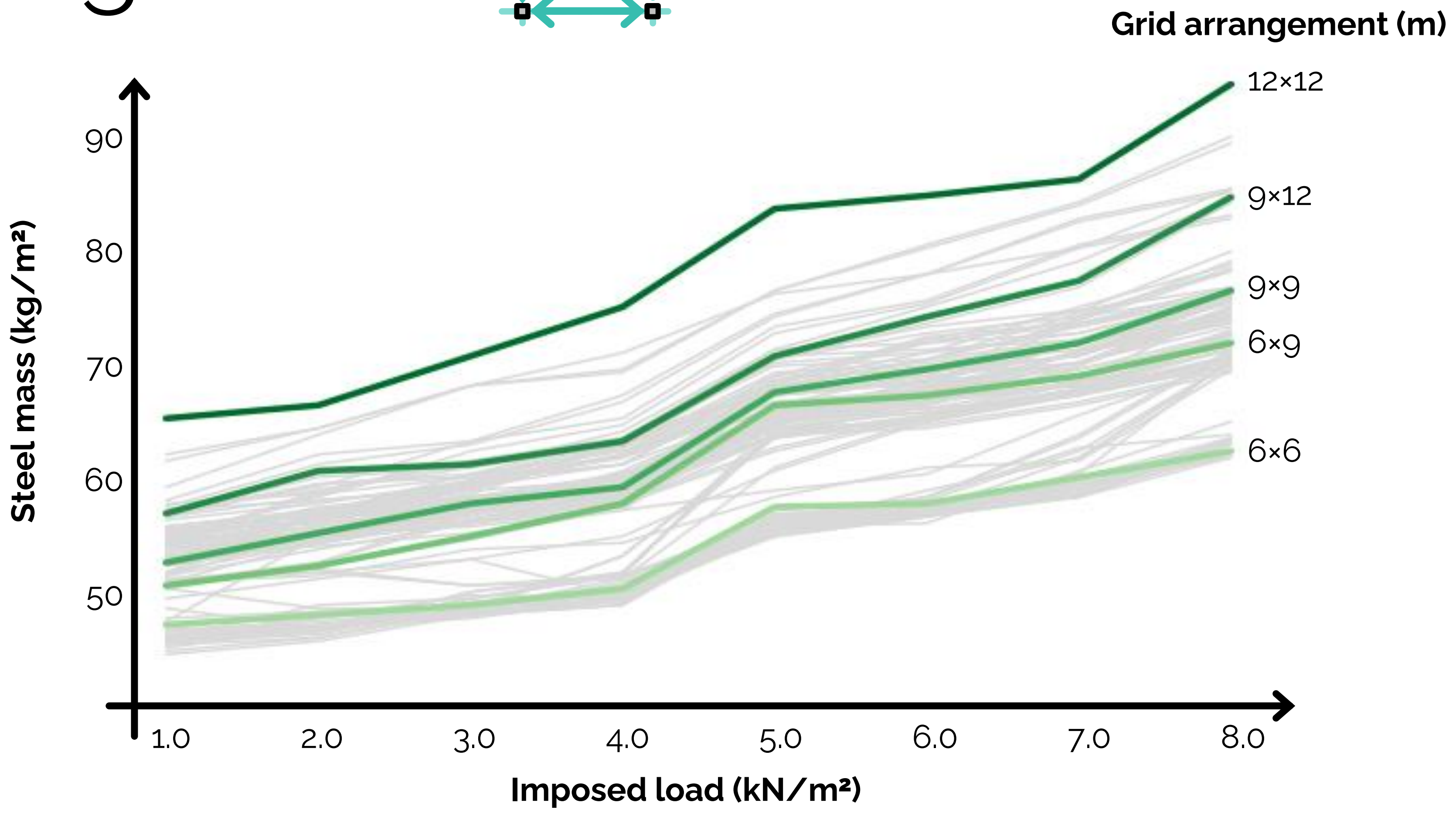
Carbon results

Imposed load 

Grid arrangement 



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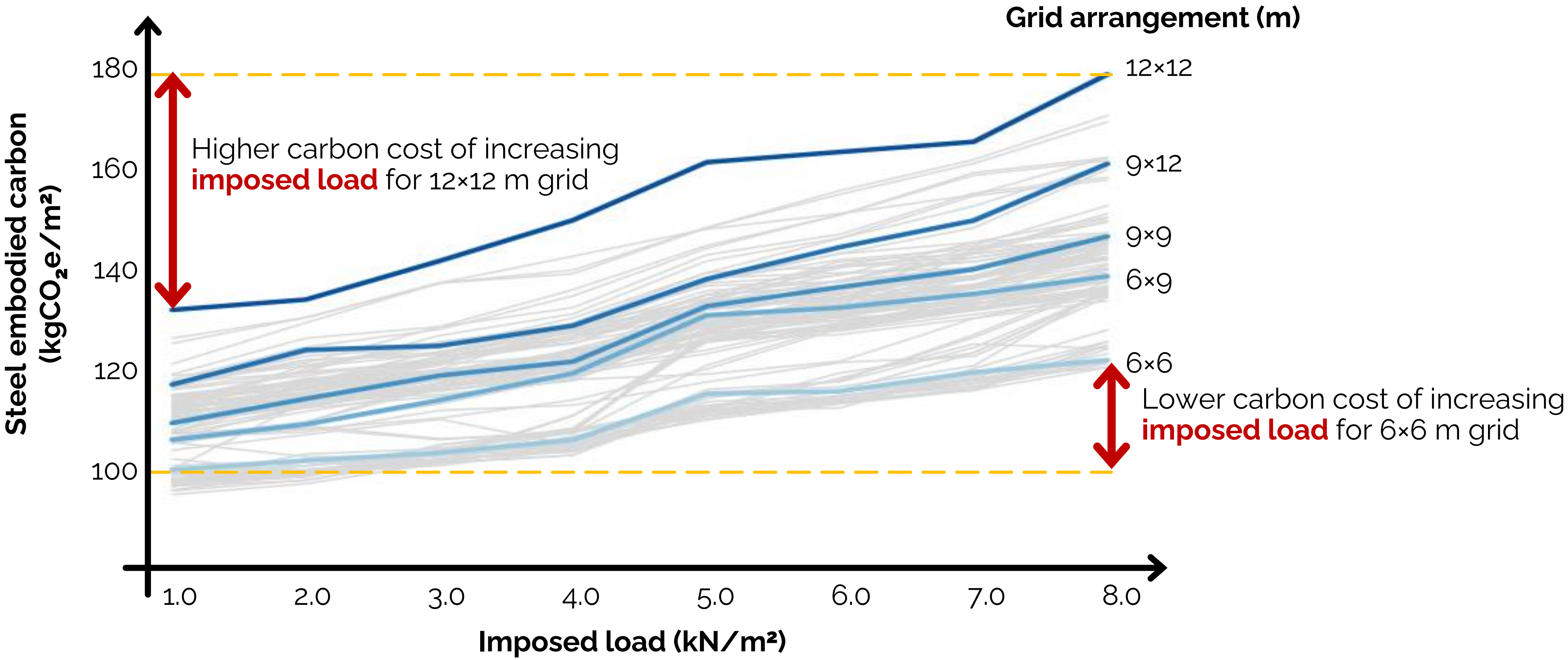
Carbon results
Imposed load
Grid arrangement

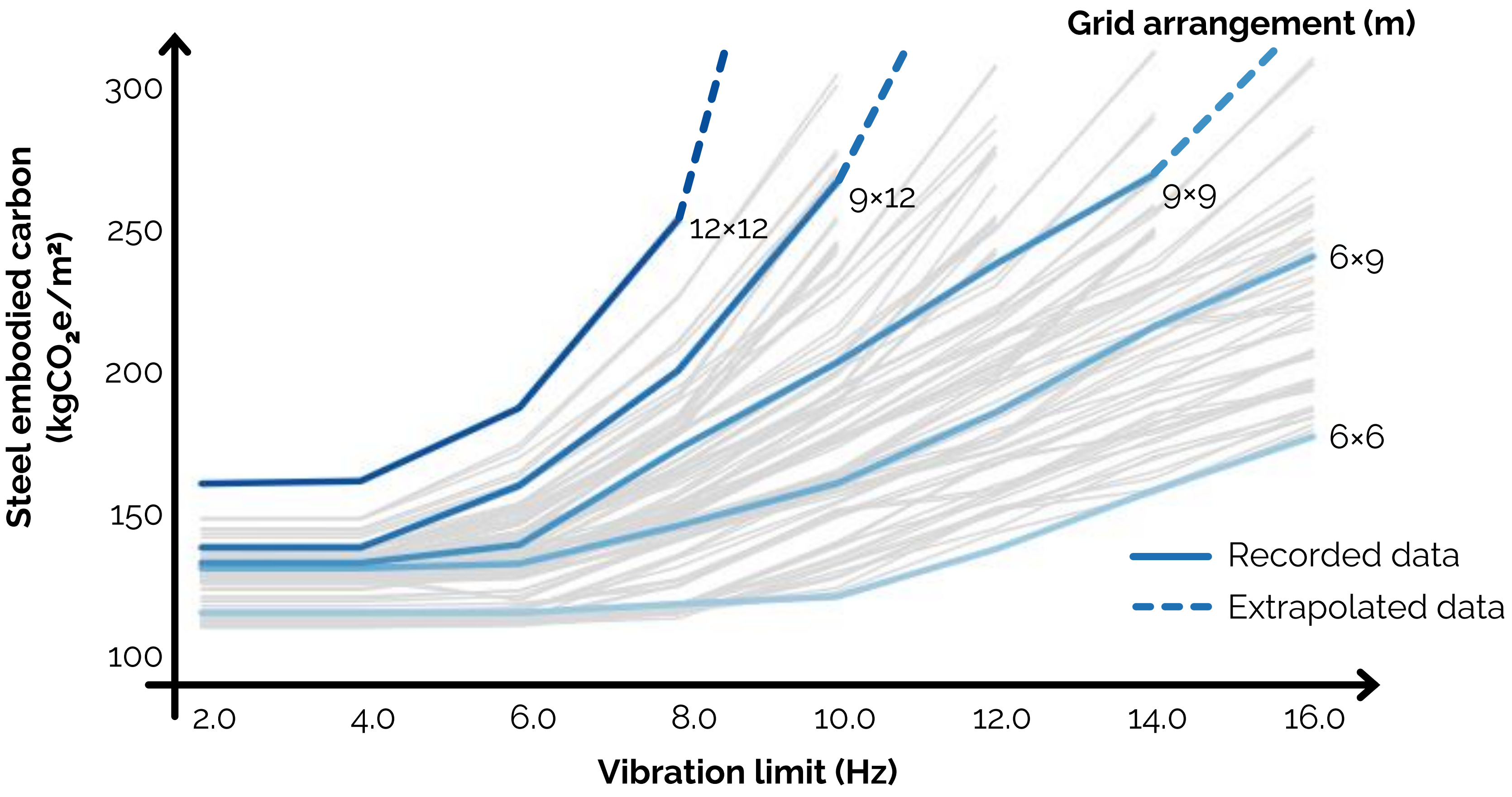


Watt, H., Davison, B., Hodgson, P., Kitching, C. and Densley Tingley, D. (2024). 'Assessing the upfront carbon cost of structural adaptability', [Submitted for review].

Carbon results

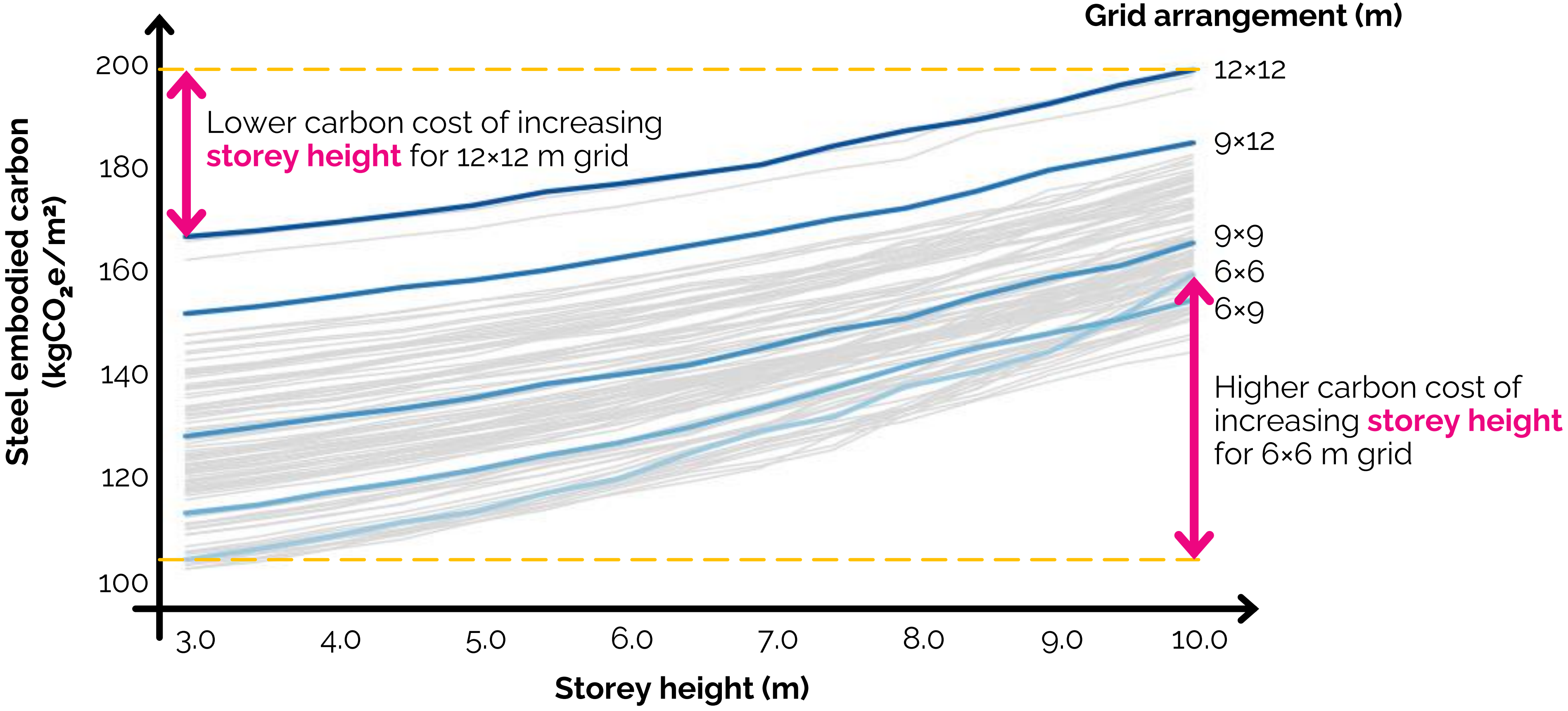
Vibration limit

Grid arrangement



Watt, H., Davison, B., Hodgson, P., Kitching, C. and Densley Tingley, D. (2024). 'Assessing the upfront carbon cost of structural adaptability', [Submitted for review].

Carbon results
Storey height
Grid arrangement



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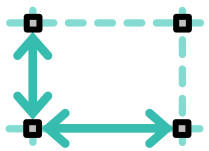
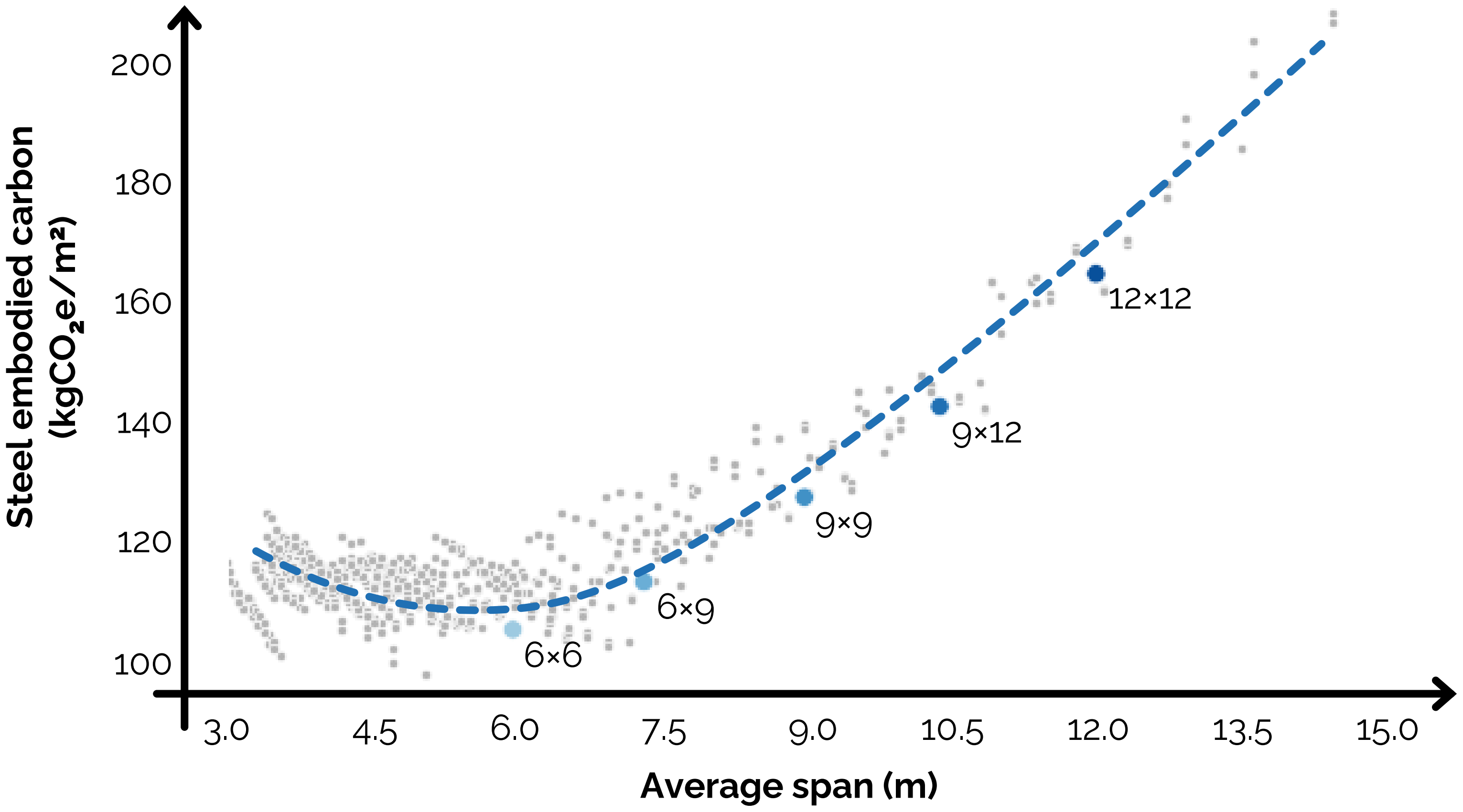
Carbon results

Grid arrangement



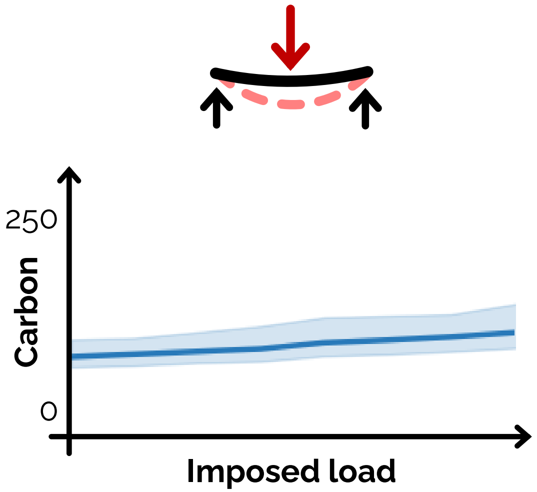


Watt, H., Davison, B., Hodgson, P., Kitching, C. and Densley Tingley, D. (2024). 'Assessing the upfront carbon cost of structural adaptability', [Submitted for review].

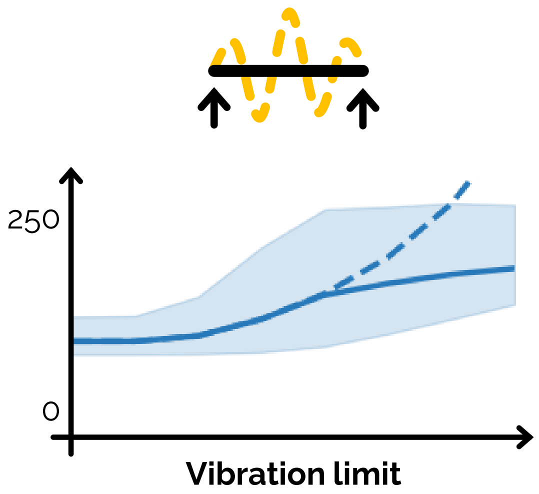
Carbon results

Summary

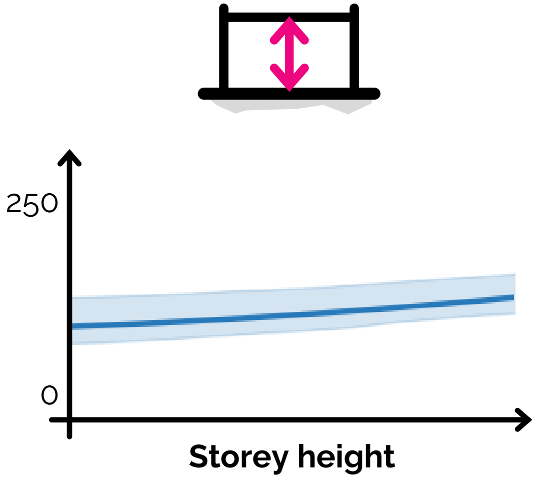
Imposed load



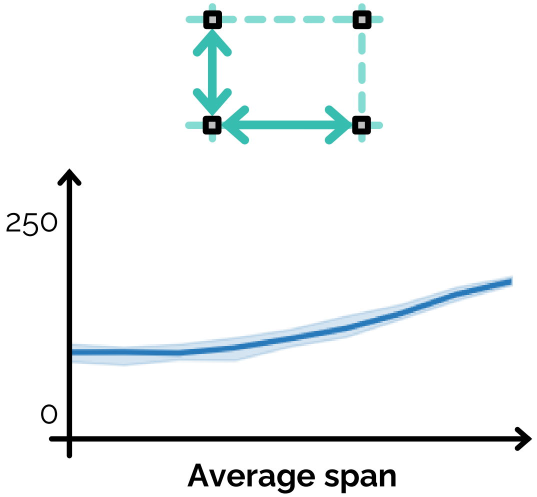
Vibration limit



Storey height



Grid arrangement



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Adaptability scoring
Imposed load

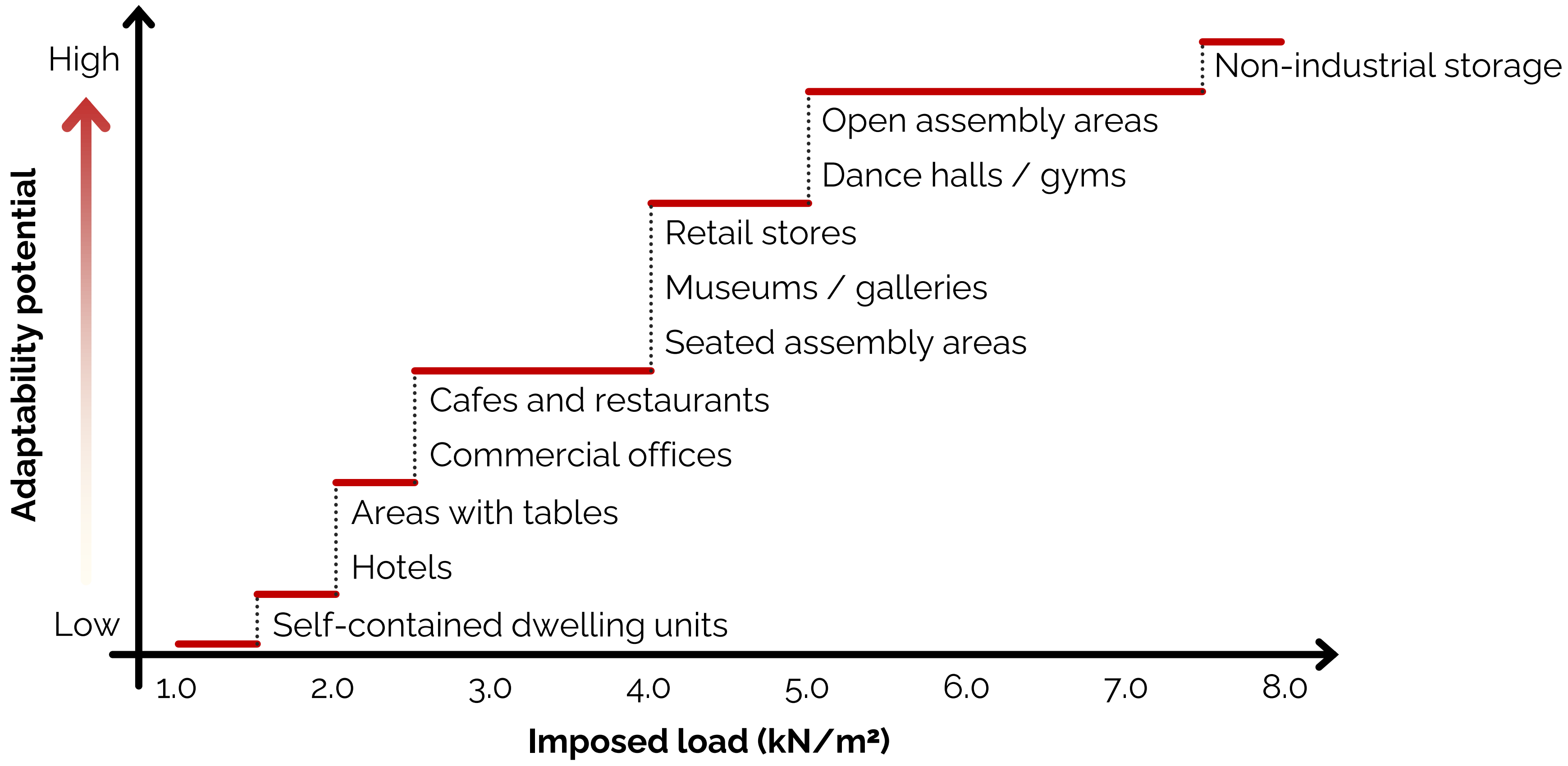
Building use categories and imposed load values[6]

Building use	Imposed load (kN/m²)
Non-industrial storage	7.5
Open assembly areas	5.0
Dance halls / gyms	5.0
Retail stores	4.0
Museums / galleries	4.0
Seated assembly areas	4.0
Cafes and restaurants	2.5
Commercial offices	2.5
Areas with tables	2.0
Hotels	2.0
Self-contained dwelling units	1.5

[6] BSI. (2010). BS EN 1991-1-1:2002. London: British Standards Institution.

Adaptability scoring

Imposed load



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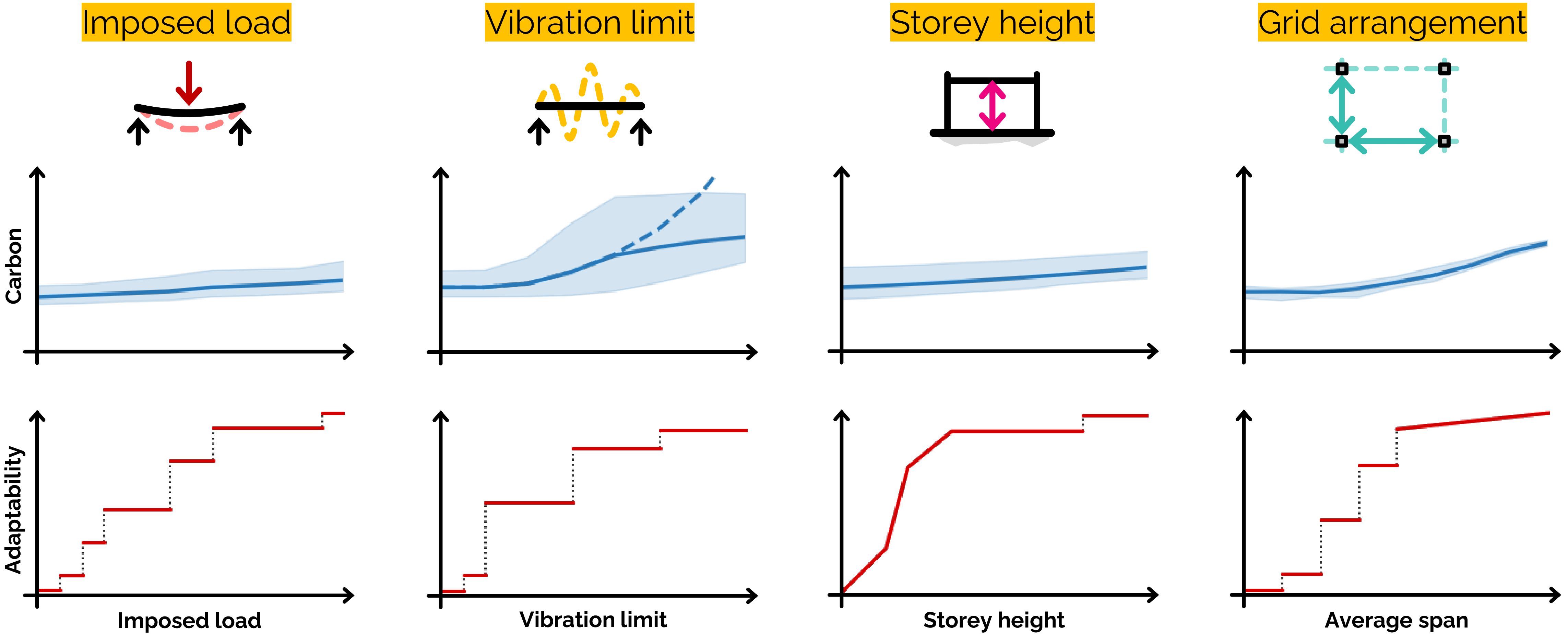
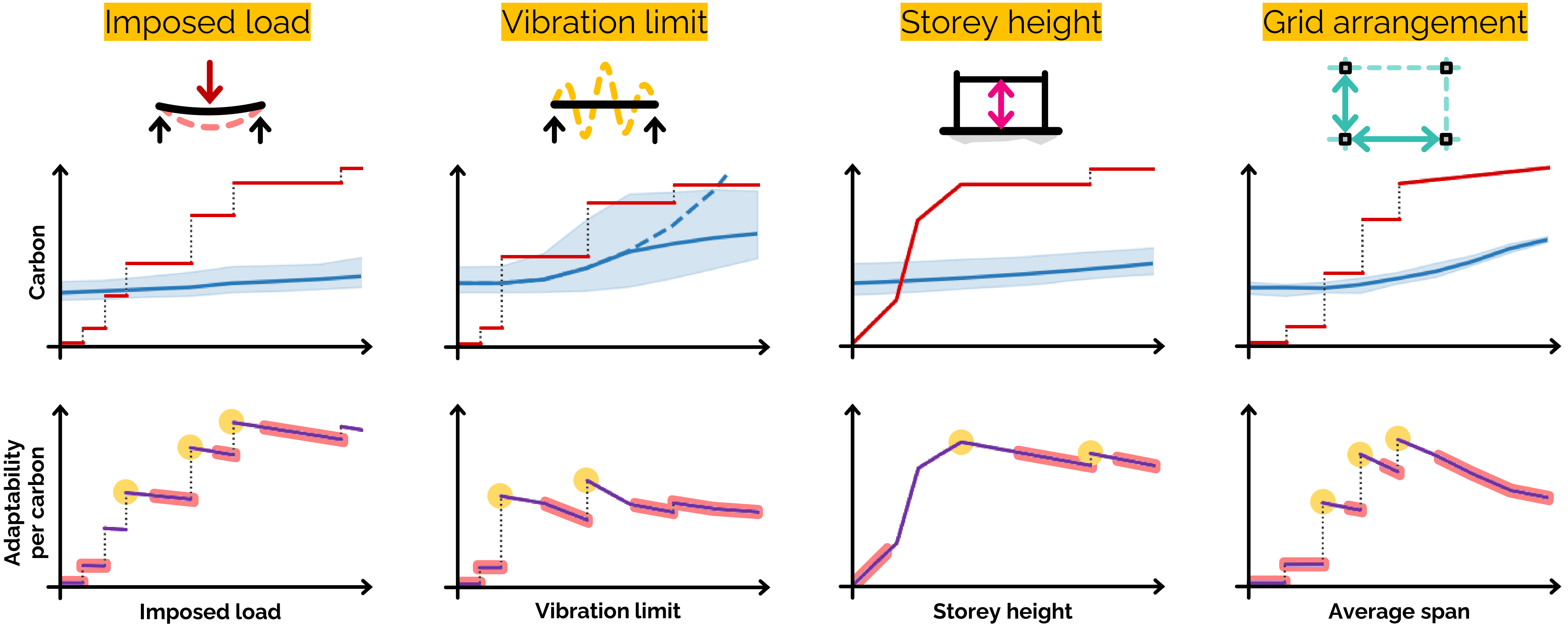
Adaptability scoring
Summary



Watt, H., Davison, B., Hodgson, P., Kitching, C. and Densley Tingley, D. (2024). 'Assessing the upfront carbon cost of structural adaptability', [Submitted for review].

Adaptability per carbon

Summary



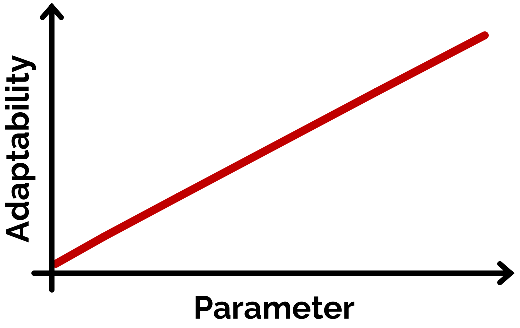
Watt, H., Davison, B., Hodgson, P., Kitching, C. and Densley Tingley, D. (2024). 'Assessing the upfront carbon cost of structural adaptability', [Submitted for review].

Conclusion
So what?

1. Carbon cost

- Carbon cost is not necessarily linear
- Not all adaptability parameters cost the same
- Carbon costs of strategies compound

2. Adaptability scoring

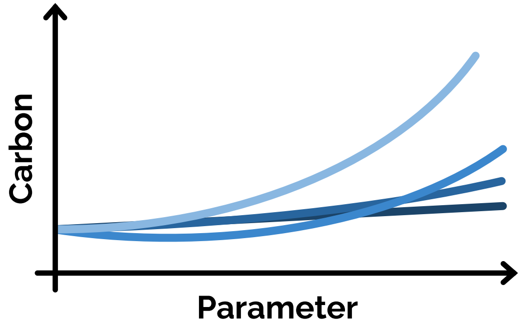


- Adaptability potential to parameter relationships are:

Watt, H., Davison, B., Hodgson, P., Kitching, C. and Densley Tingley, D. (2024). 'Assessing the upfront carbon cost of structural adaptability', [Submitted for review].

Conclusion
So what?

1. Carbon cost



- Carbon cost is not necessarily linear
- Not all adaptability parameters cost the same
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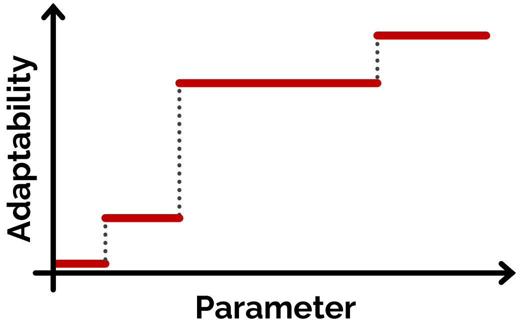
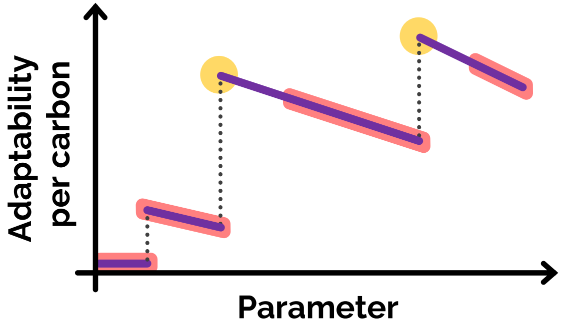
2. Adaptability scoring



- Adaptability potential to parameter relationships are:
  - Non-linear
  - Discontinuous

3. Adaptability per carbon



- Adaptability benefit must be balance with carbon cost
- Optimum adaptability per carbon at moderate parameter values; not extreme highs or lows

Watt, H., Davison, B., Hodgson, P., Kitching, C. and Densley Tingley, D. (2024). 'Assessing the upfront carbon cost of structural adaptability', [Submitted for review].

Engineering and Physical Sciences Research Council

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Upcoming paper:

Assessing the upfront carbon cost of structural adaptability

Harry Watt[1,3], Buick Davison[1], Pete Hodgson[2], Chris Kitching[3], Danielle Densley Tingley[1]

[1]University of Sheffield [2]TATA STEEL [3]MOTT MACDONALD

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LinkedIn: linkedin.com/in/harry-henry-watt/

Previous paper:

What should an adaptable building look like?
Watt, et al. (2023). Resources, Conservation & Recycling Advances, 18

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EIHP
ENERGETSKI INSTITUT HRVOJE POŽAR

USES4HEAT

USES4HEAT - Underground Large Scale Seasonal Energy Storage for Decarbonised and Reliable Heat

Hrvoje Dorotic
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hdorotic@eihp.hr

Sustainable Places 2024, 23-25.9.2024. Luxembourg

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor CINEA can be held responsible for them.

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District heating and cooling

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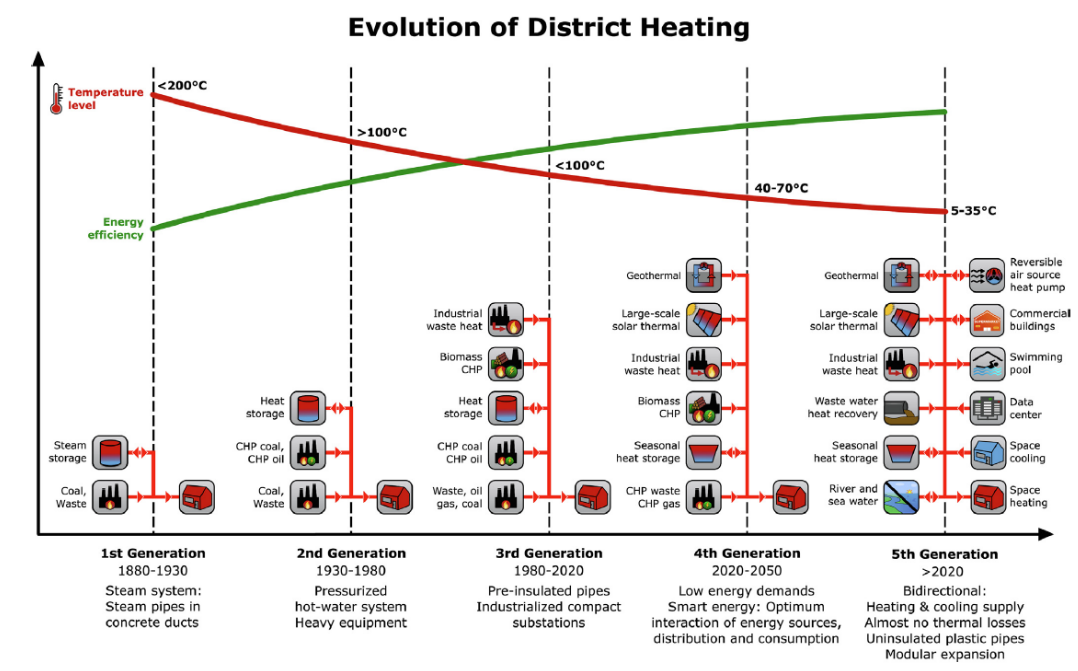
Conclusion

District heating and cooling evolution

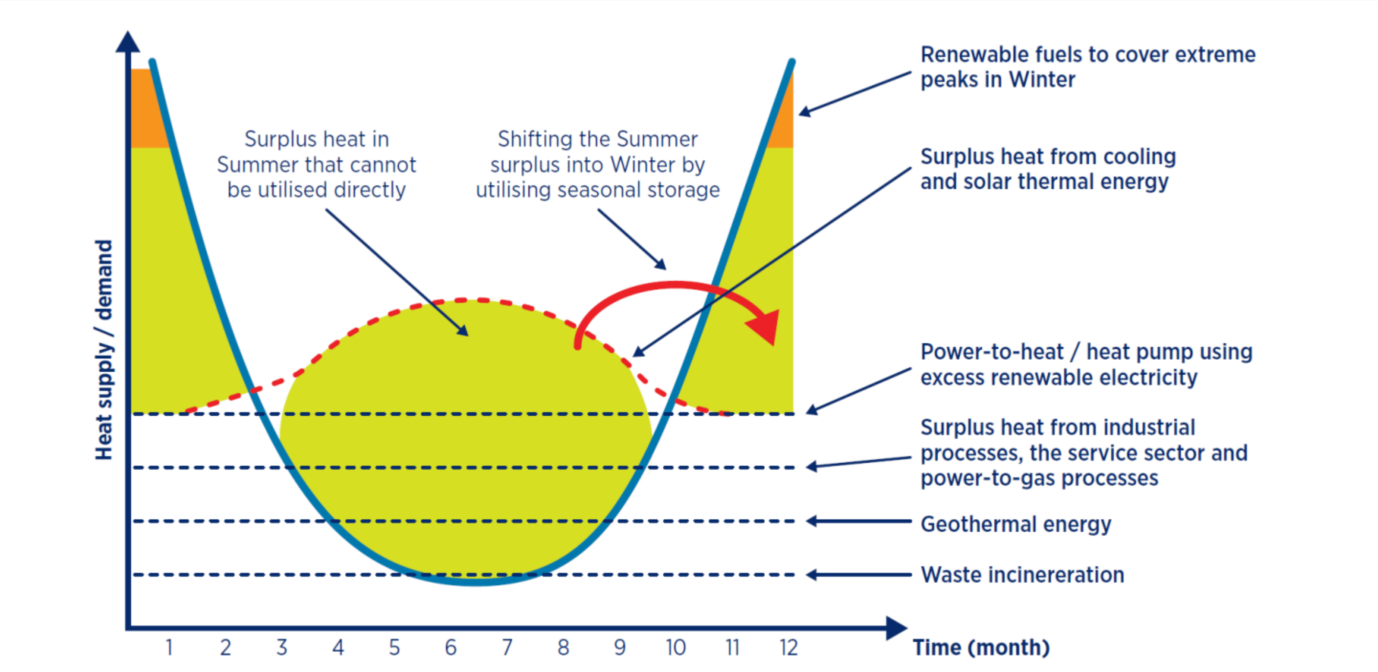
- Temperature reduction enables various technologies – thermal energy storage (TES) needed



https://doi.org/10.1016/j.enbuild.2020.110245

Seasonal thermal storage

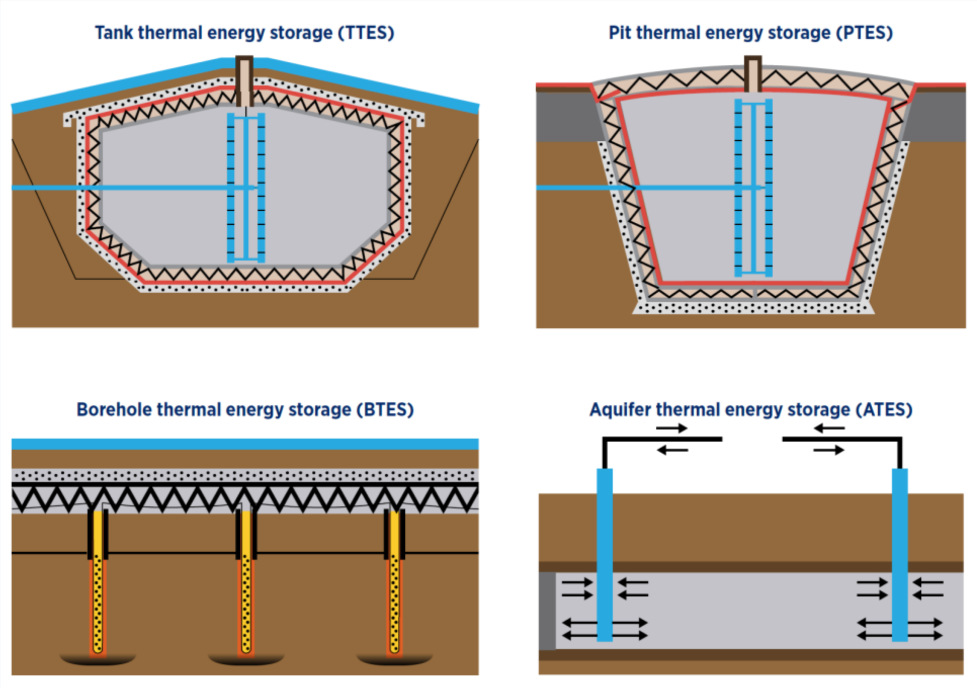
- Heat demand and various sources have seasonal characteristics → need for seasonal TES



IRENA, 2023

Various seasonal TES available

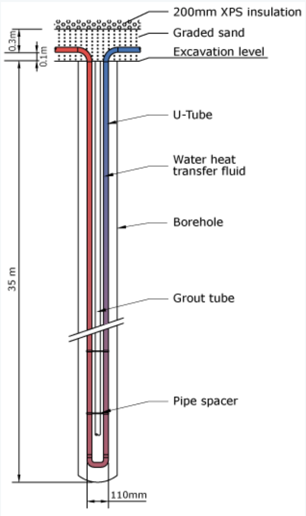
- Tank, Pit, Borehole (BTES), Aquifer (ATES)

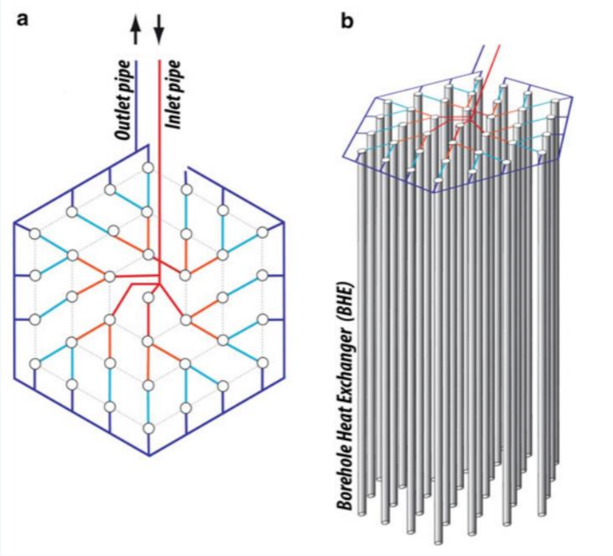


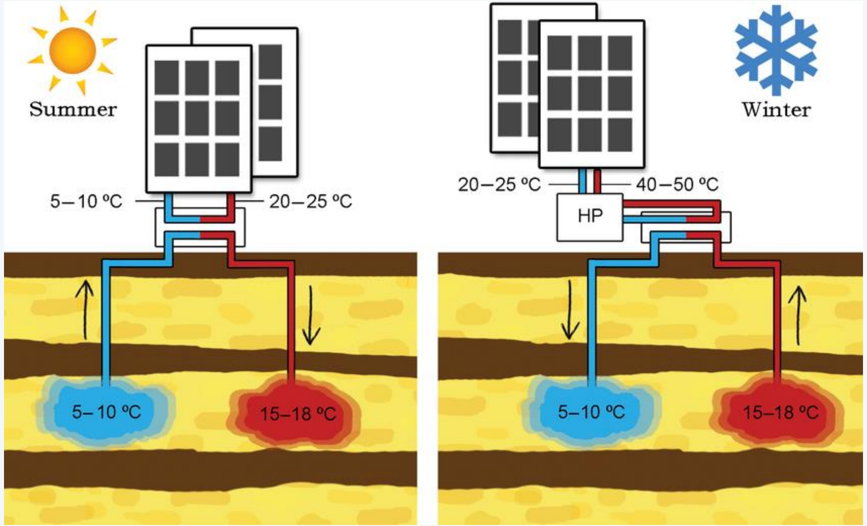
IRENA, 2023

Various seasonal TES available

- Borehole thermal storage (BTES)
- Aquifer thermal storage (ATES)



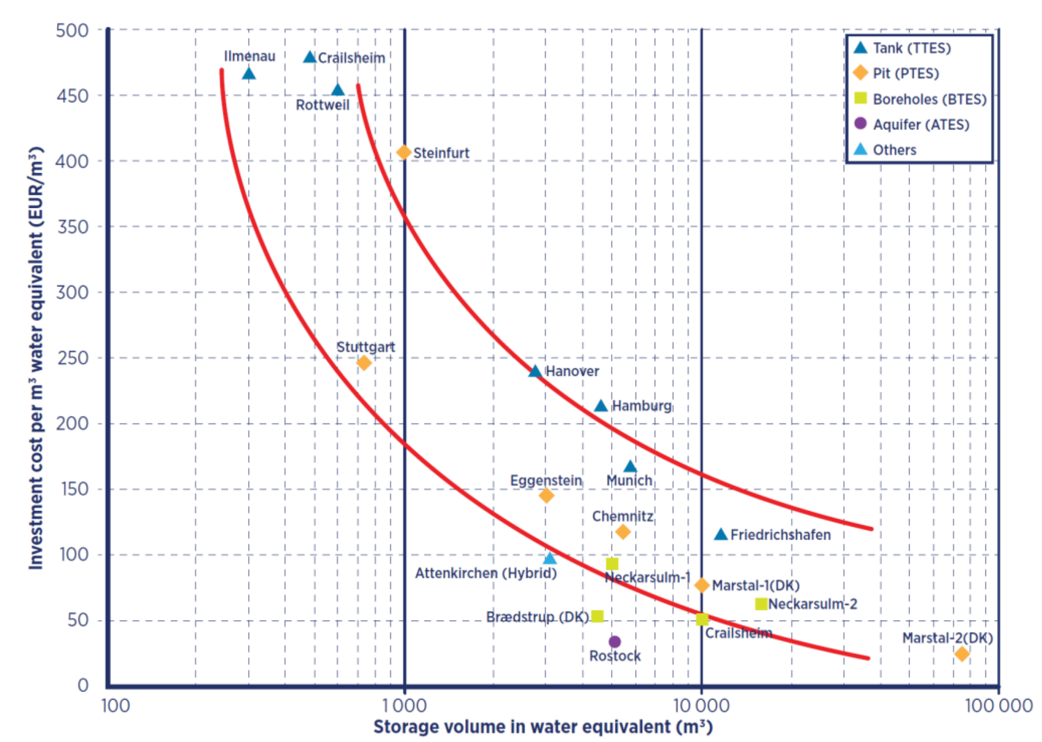




Various seasonal TES available

- **Pit** TES **commercial** level, **traditional** solution, high energy density, **higher temperatures**
- However **complex construction** and maintenance

- **ATES** and **BTES** utilizing existing „infrastructure" (**underground**)
- **Lower temperature** regimes
- Demonstrated in several geological conditions (countries)
- **Relatively expensive** (per MWh)
- **→ USES4HEAT ...**



IRENA, 2023

USES4HEAT

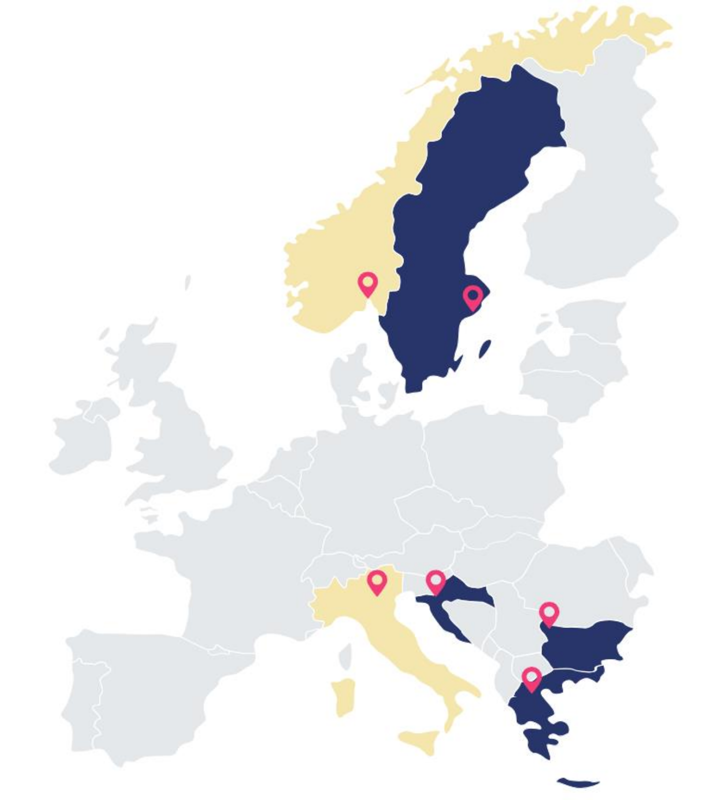
- USES4HEAT aims to demonstrate **innovative**, **large scale**, **seasonal** thermal energy storage (TES) solutions enabling a future decarbonised and reliable heating supply.

- 27 partners across Europe, Coordinated by KTH Royal Institute of Technology (Sweden), Project period 12/2023-11/2027

6 key enabling technologies

- New **drilling technology** for geothermal applications
- **Innovative groundwater heat pump** at high temperature
- Novel layered **collector pipes for borehole solutions**
- Highly efficient **solar thermal collectors**
- Highly efficient **hybrid photovoltaic thermal** panels
- **AI driven and big data analytics** based predictive energy software

Demonstration sites



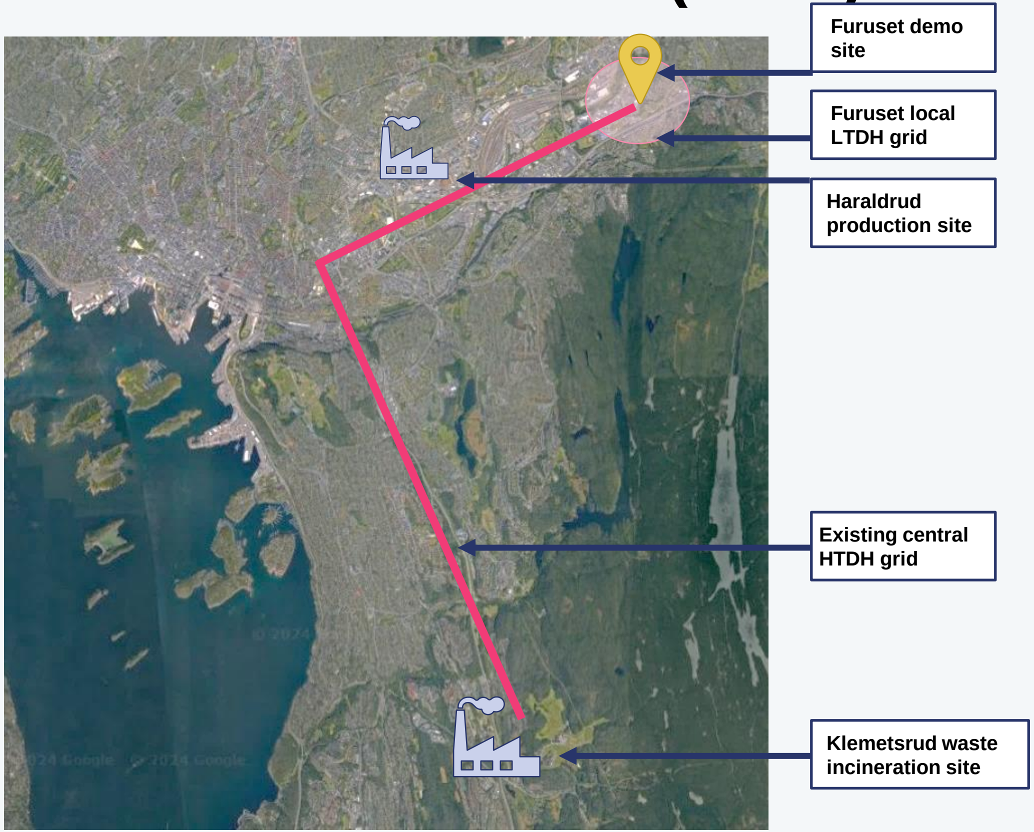
Pilots:

- Oslo, Norway (BTES)
- Riva dek Garda, Italy (ATES)

Replicators

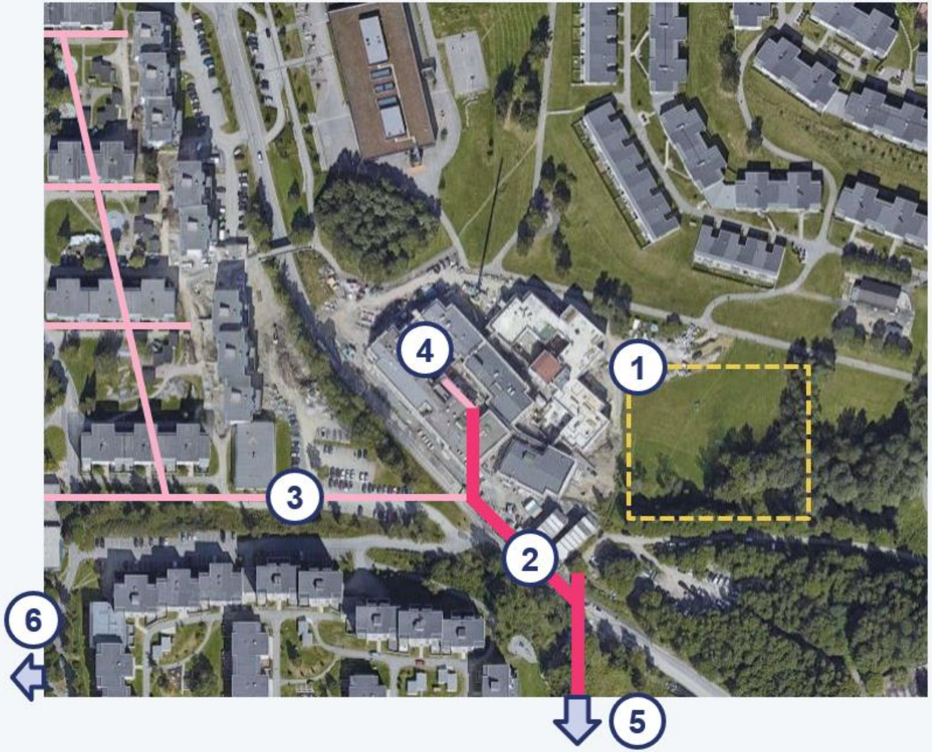
- Zagreb, Croatia
- Lom, Bulgaria
- Kozani, Greece
- Kvarnholmen, Sweden

Oslo – Borehole TES (BTES)



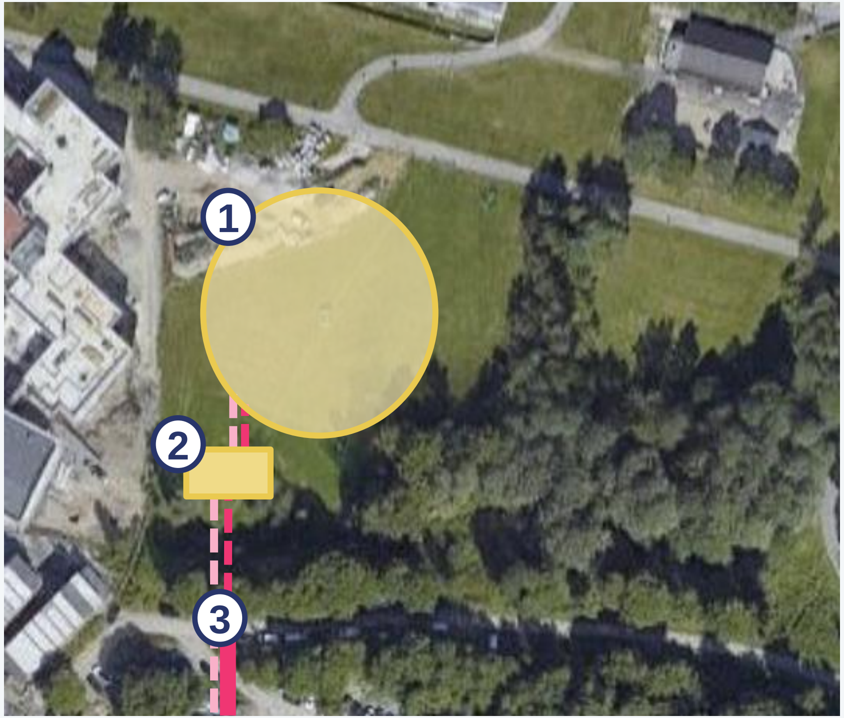
- Geothermal seasonal energy storage, located in a park in the northeast of Oslo (Furuset)
- Will be connected to the district heating system
    - Using excess heat from central district heating grid to charge during summer
    - Supplying heat to local low temperature district heating grid in winter
- Part of an energy project at Furuset consisting of microgrid, LTDH and flexibility with several local partners

Oslo – Borehole TES (BTES)



1. Energy storage demo site location (see next page for details)
2. Local district heating network (90-120ºC), connected to central grid
3. Planned low temperature district heating (50-70ºC)
4. Building adapted to LTDH that will receive heat from the storage
5. Klemetsrud waste incineration plant, charging storage through central grid
6. Haraldrud district heating facility (connected to local district heating network)

Oslo – Borehole TES (BTES)



1. Circular borehole energy storage (150 m deep)
2. Technical building, with necessary electromechanical equipment
3. Connection point between existing district heating pipes and planned pipes

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Oslo – Borehole TES (BTES)

BENGT DAHLGREN

- Studies on performance and dimensioning of the storage
- Design of the BTES facility
- Contribute to the assessments

CARTIF

- Compile relevant data provided by Celsio
- Contribute to establishing and monitor baseline
- Contribute to the assessments

CHALMERS

- Contribute to establishing and monitor the baseline
- Contribute to the assessments

Hafslund Oslo Celsio

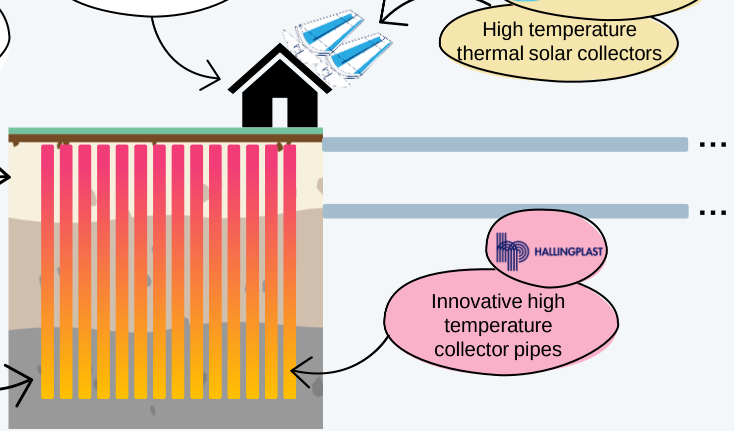
Klemetsrud waste incineration plant

Excess heat from waste incineration is used to charge the energy storage during summer.

Energy central

ABSOLICON SOLAR COLLECTORS

High temperature thermal solar collectors



Hafslund Oslo Celsio

Borehole thermal seasonal storage

HALLINGPLAST

Innovative high temperature collector pipes

CARTIF

WP2: Comprehensive system modelling

FONDAZIONE BRUNO KESSLER

WP3: AI driven predictive O&M and EMH

ivl Swedish Environmental Research Institute

WP 6: Techno-economic potential and environmental impact assessment

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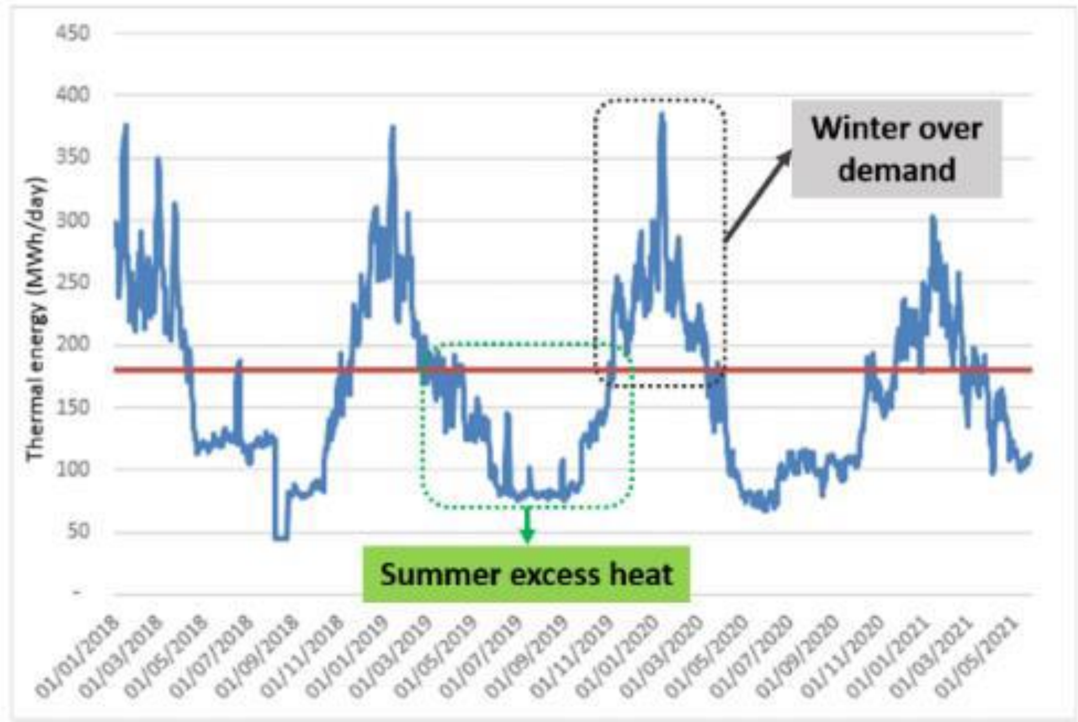
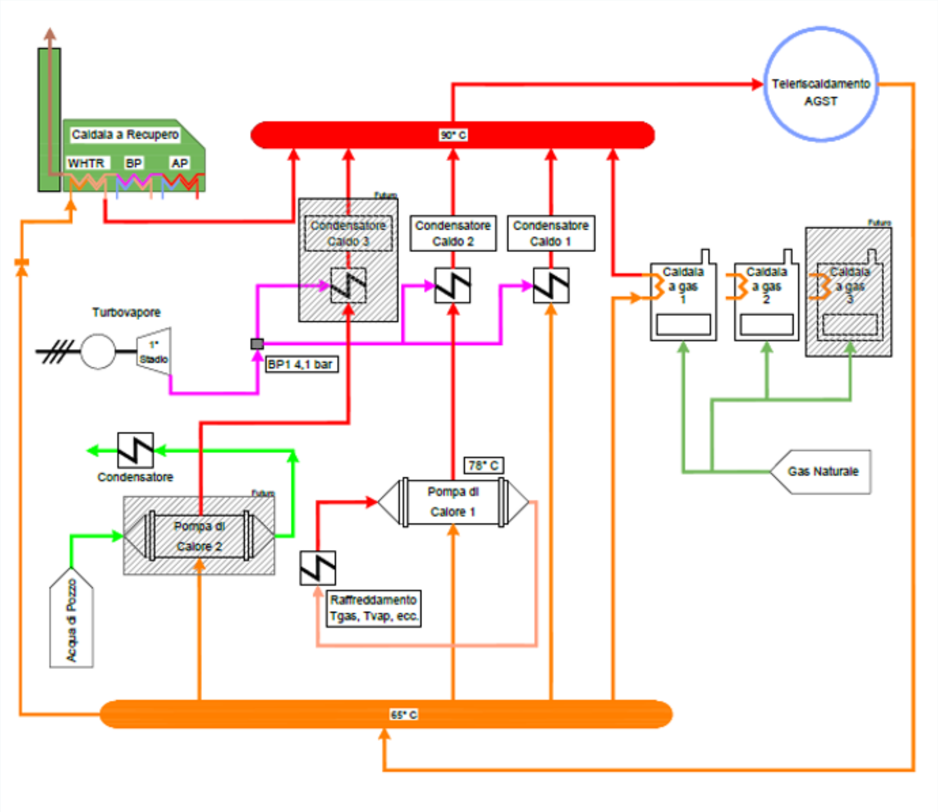
Riva del Garda – Aquifer TES (ATES)



- The main goal is to **recover the Alto Garda Power excess heat** of the spring - summer - autumn period
- **store it underground, in a new large-scale ATES** (Aquifer Thermal Energy Storage)
- **integrate it into the DH during** the winter season **by means of a new geothermal heat pump**

Riva del Garda – Aquifer TES (ATES)

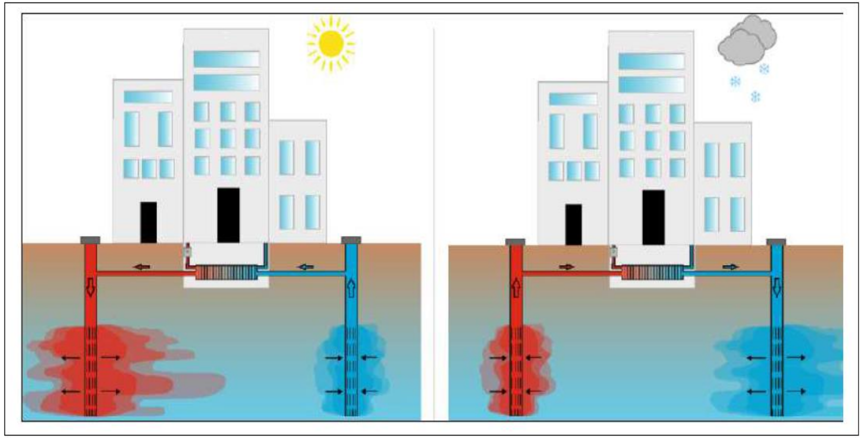


- Taking up the original AGP project, the integration of a second **1.5 MWth** low GWP **heat pump** ("Pompa di calore 2") feeded by the **ATES groundwater** ("Acqua di Pozzo")
- supplying renewable and waste heat to the Riva del Garda DH network (Teleriscaldamento) is planned

Riva del Garda – Aquifer TES (ATES)

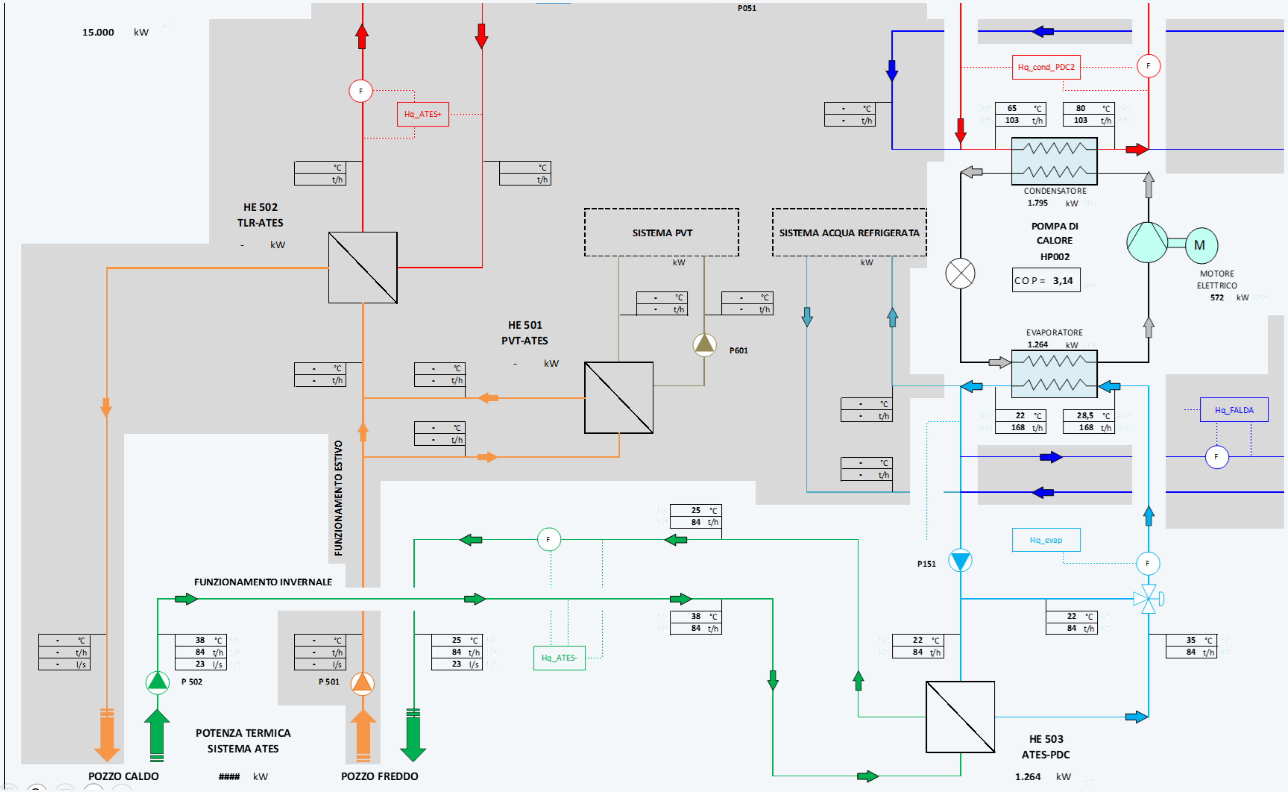
In Riva del Garda will be placed Low-Temperature ATES, which work below 40°C:

- LT-ATES:
  - SUMMER SEASON: Injection 40°C, Extraction 14°C
  - WINTER SEASON: Extraction 38°C, Injection 25°C
- WATER FLOW RATE: 24 l/s (86 m^3/h)
- MAXIMUM DEPTH: 200m
- DIRECT CIRCULATION DRILLING



Will be drilled two wells (Warm & Cold)
Both working in the deep confined aquifer (2nd aquifer), localized between 140-170 m depth.

Riva del Garda – Aquifer TES (ATES) – Winter / heating mode



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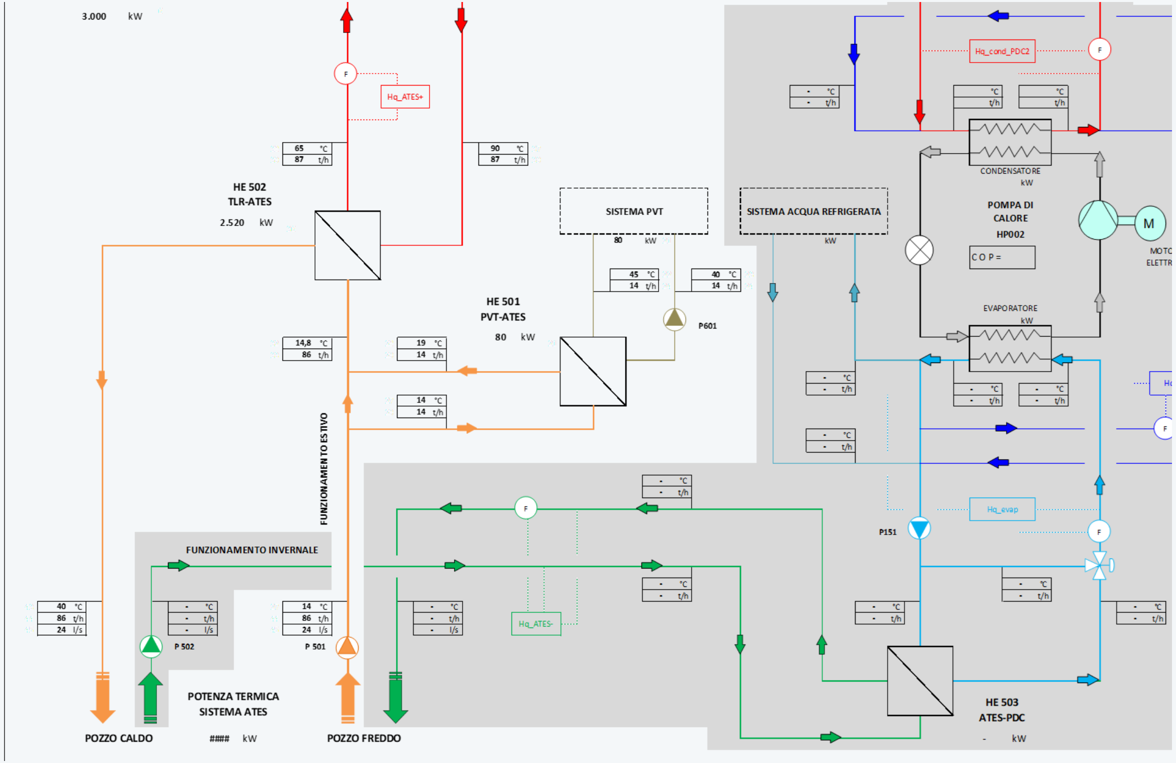
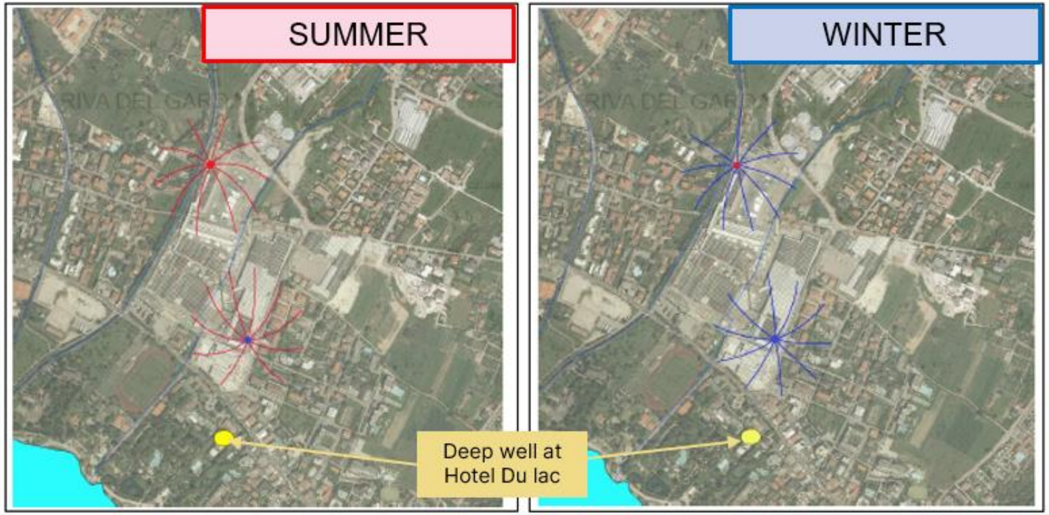
Riva del Garda – Aquifer TES (ATES) – Summer/cooling mode



Riva del Garda – Aquifer TES (ATES)

FIRST EVALUATION OF THERMAL ENERGY EFFECTS:

- No effects on the first aquifer – the first and the second aquifer are separated
- COLD WELL in the south mimimize the thermal effects downstream
- Interference between the two well's thermal plume is not expected
- Injection at 40°C: LOW TEMPERATURE ATES



Conclusion

- The project focuses on large-scale seasonal thermal storage systems (ATES and BTES)
- Demonstration activities in countries – Norway (BTES) and Italy (ATES)
- Early project stage → final designs to be completed and construction begins soon
- Other project activities:
  - Energy models development – optimization → CAPEX / OPEX (hourly)
  - Model validation on demo and replicators

More on that next time ☺

Check out the websites!

Project website / Subscribe to Newsletter
https://www.uses4heat.eu/the-project/

LinkedIn
https://www.linkedin.com/showcase/uses4heat/

Thank you for your attention

Hrvoje Dorotic
Energy Institute Hrvoje Pozar
Mail: hdorotic@eihp.hr

ÉTS École de technologie supérieure — Le génie pour l'industrie — Université du Québec
GRIDD Groupe de recherche en intégration et développement durable en environnement bâti

Circularity through modularity & adaptability of buildings

Ivanka Iordanova, Ph.D.
Full Professor, ÉTS, Montreal

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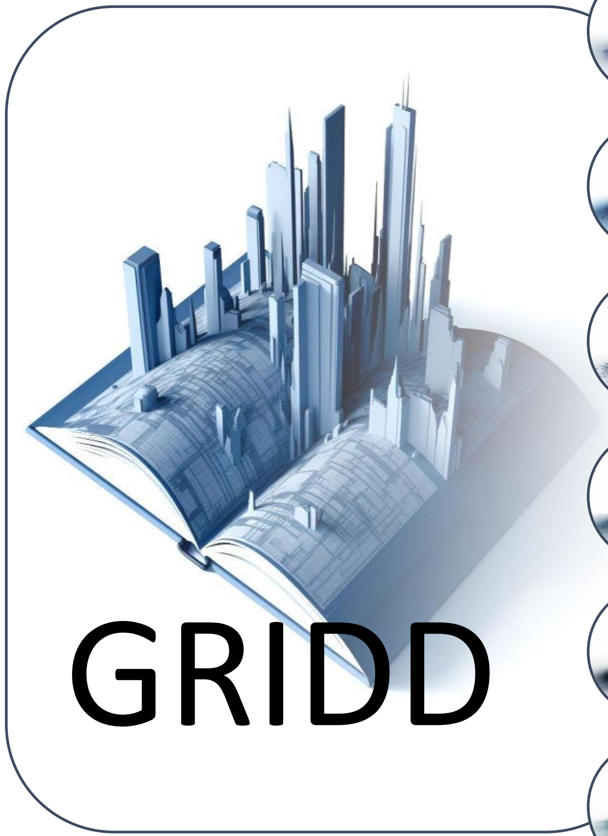
Groupe de recherche
en intégration et
développement durable
en environnement bâti



- BIM and information lifecycle management
- Digital Twin and artificial intelligence
- Construction industrialization and automation
- Legislation, regulations and contracts
- Integration, collaboration and Lean construction
- Sustainable development and circular economy

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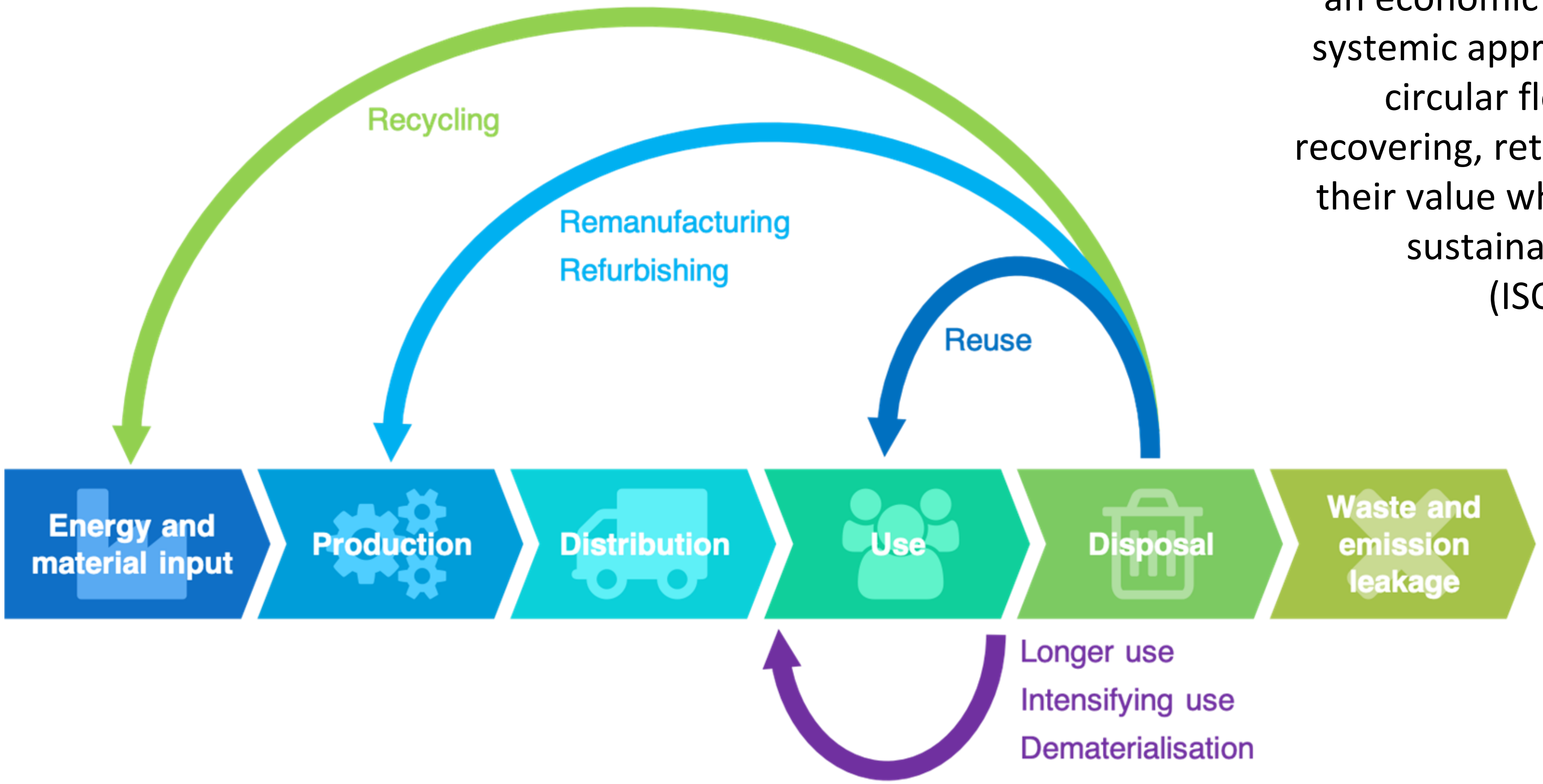
https://gridd.etsmtl.ca

Main points

1. *Circularity in the built environment*
2. *Adaptability of buildings*
3. *Design for adaptability (DfAd) framework*
4. *Modularity and standardization Industrialization*
5. *Future research*

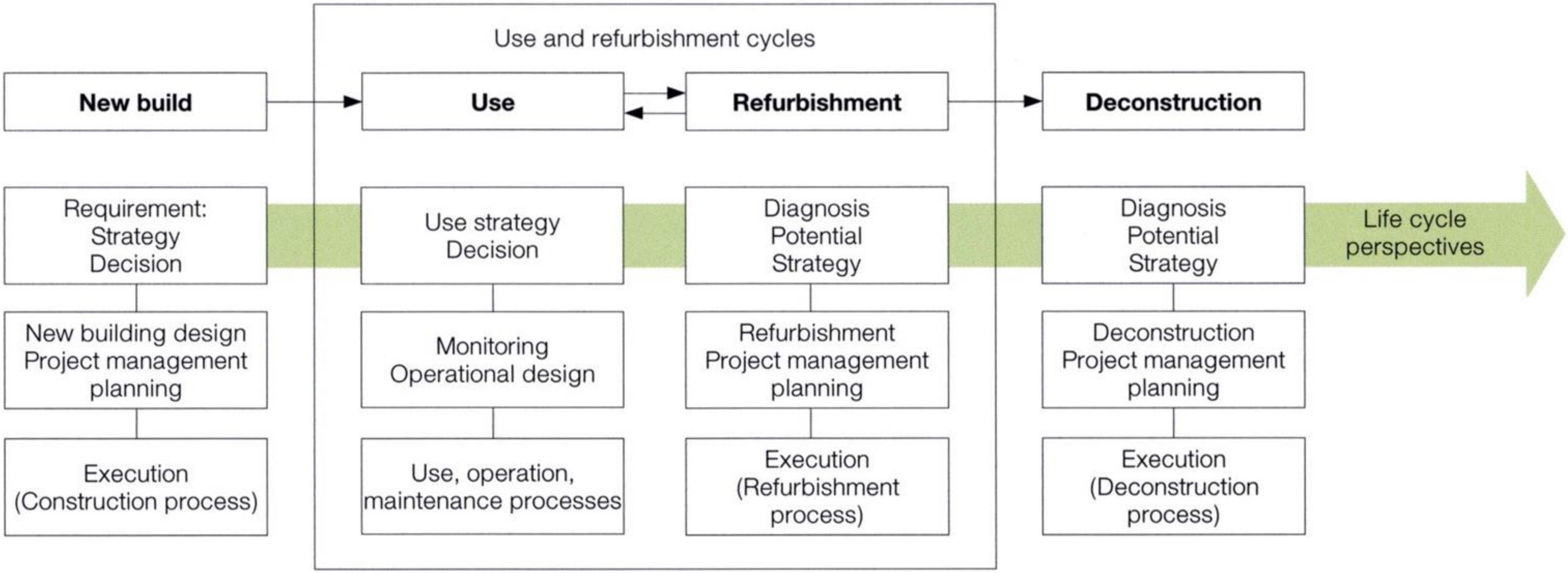
Circular economy



Circular Economy is defined as "an economic system that uses a systemic approach to maintain a circular flow of resources by recovering, retaining or adding to their value while contributing to sustainable development". (ISO/DIS 59004, 2021)

Source: Geissdoerfer et al. (2020)

Phases and processes in a built asset lifecycle



Source: König et al. (2010)

Why adaptability?
…reversibility?

Link to circular economy?

Strategies for circular economy

Circular economy

↑

Linear economy

Strategy group			Description
Smarter product use and manufacture	**R0**	**Refuse**	Make product redundant by abandoning its function or by offering the same function with a radically different product
	R1	**Rethink**	Make product use more intensive (e.g. through sharing products or by putting multi-functional products on market).
	R2	**Reduce**	Increase efficiency in product manufacture or use by consuming fewer natural resources
Extend lifespan of product and its parts	**R3**	**Reuse**	Re-use by another consumer of discarded product which is still in good condition and fulfils its original function
	R4	**Repair**	Repair and maintenance of defective product so it can be used with its original function
	R5	**Refurbish**	Restore an old product and bring it up to date
	R6	**Remanufacture**	Use parts of discarded product in a new product with the same function
	R7	**Repurpose**	Use discarded products or its part in a new product with a different function
Useful application of materials	**R8**	**Recycle**	Process materials to obtain the same (high grade) or lower (low grade) quality
	R9	**Recovery**	Incineration of material with energy recovery

Potting et al. (2017)

Adaptability of buildings

Adaptability is the ability of the building to adapt to the changing needs of occupants, society and the environmen with minimal disruption to delay the end of the building's cycle. *(Ross et al. 2016)*

The primary goal of design for adaptability is to lengthen a building's lifespan by making it possible to adapt the spac with minimal disruption. This has many advantages, most notably the preservation of the building's cultural and economic value and help circular economy.

Seeking global sustainability requires a shift in our design culture of buildings towards embracing a new vision of a dynamic buildings, which flexibly cope with the different variables over their life time.

Reasons to change:
Physical, functional, technological, environmental, economic, social, legal, cultural, etc.

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Baienat (2024)

Designing adaptable buildings

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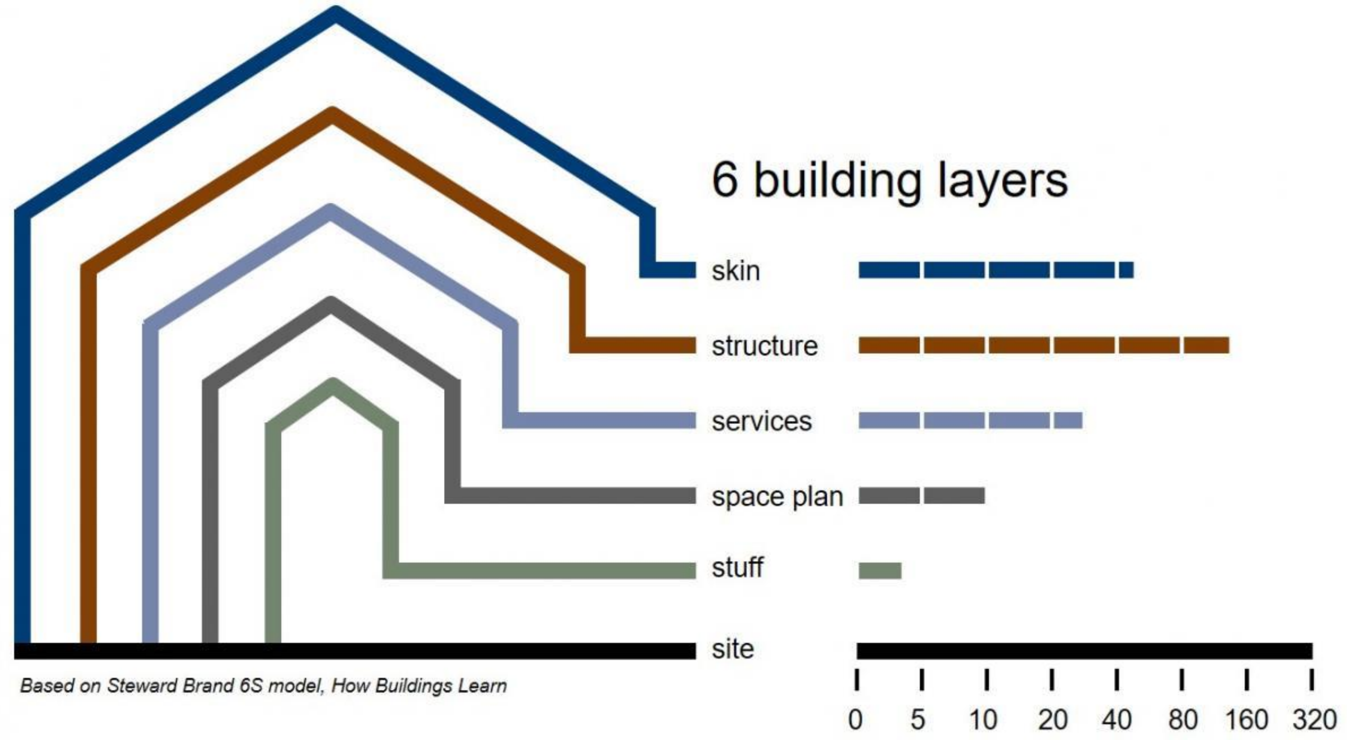
Main strategy:
Building Layers (shearing layers)

Layers provide a way of thinking about the building that links both time and the building's material form, conceiving components as different 'layers' of longevity.

Design strategies:

- Sparate the building systems according to longevity
- Use 'dry' mechanical connections
  - Modular construction
  - IBS (Industrialized Building Systems)
- Structural decomposition 'Super Skeleton & Intelligent Infill'
- Open Building concept
- Systemic multilevel grids
- Open engineering systems



Source: based on Brand, 1994

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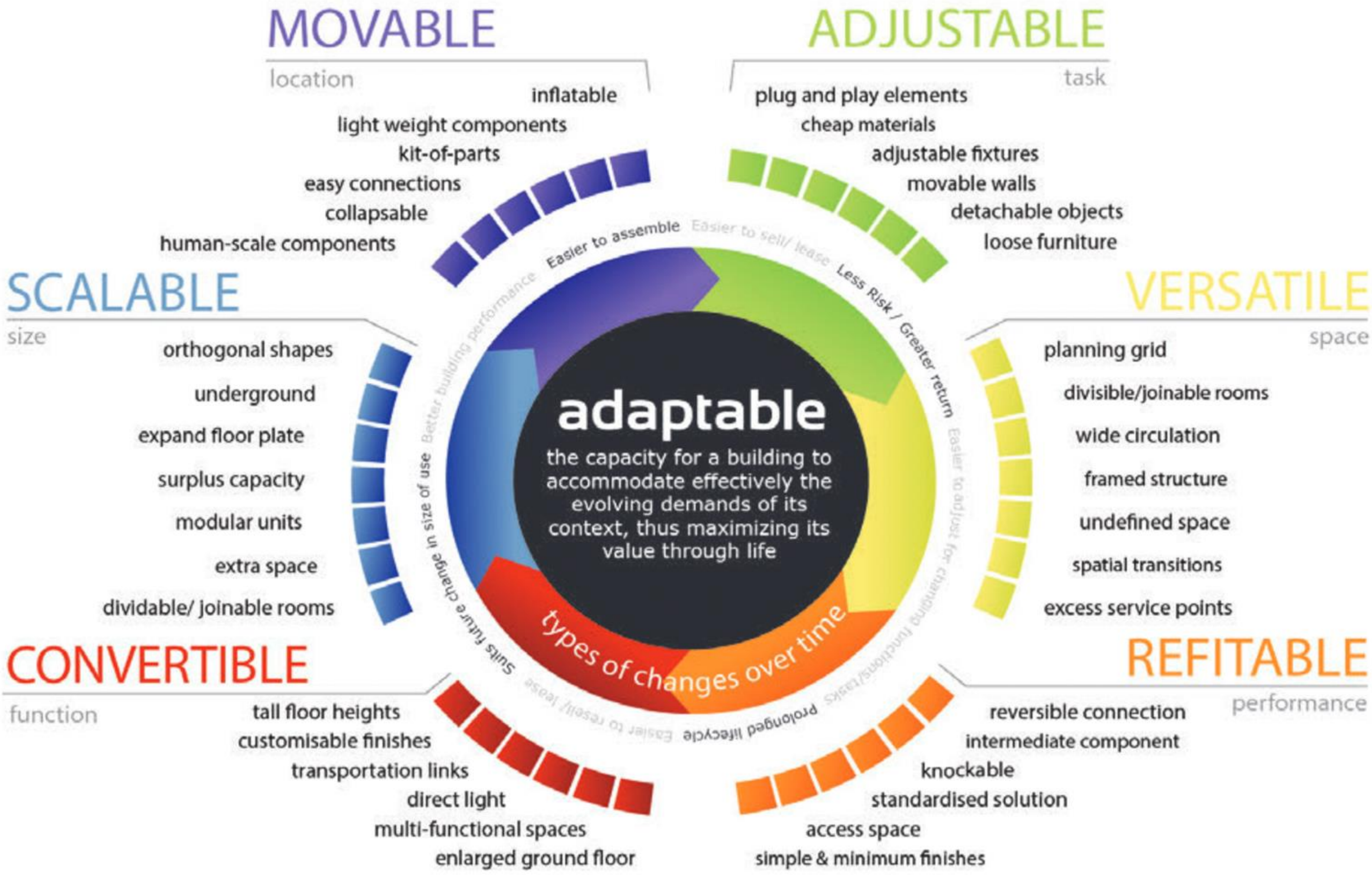
Adaptability typologies



Source: Schmidt & Austin, 2016

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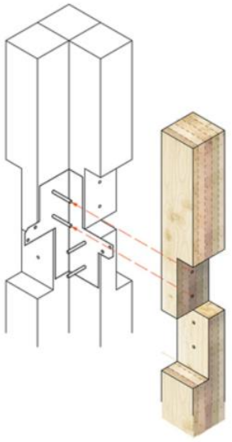
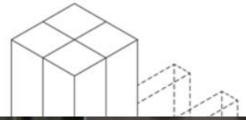
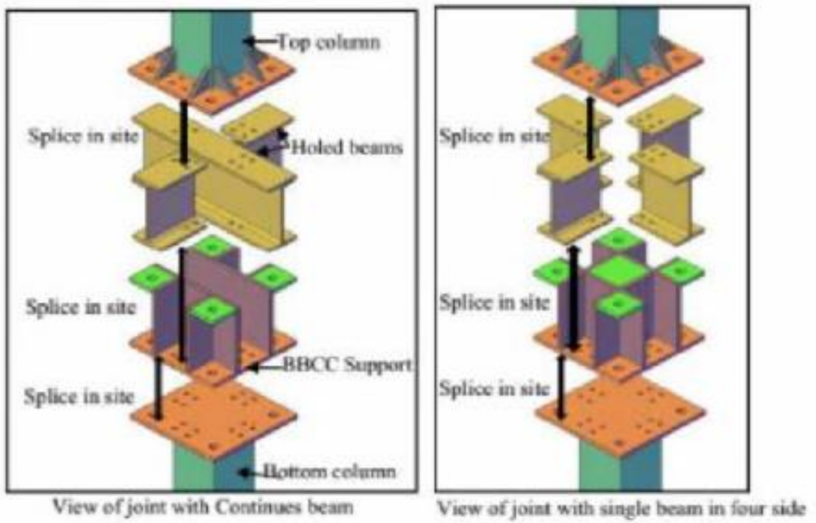
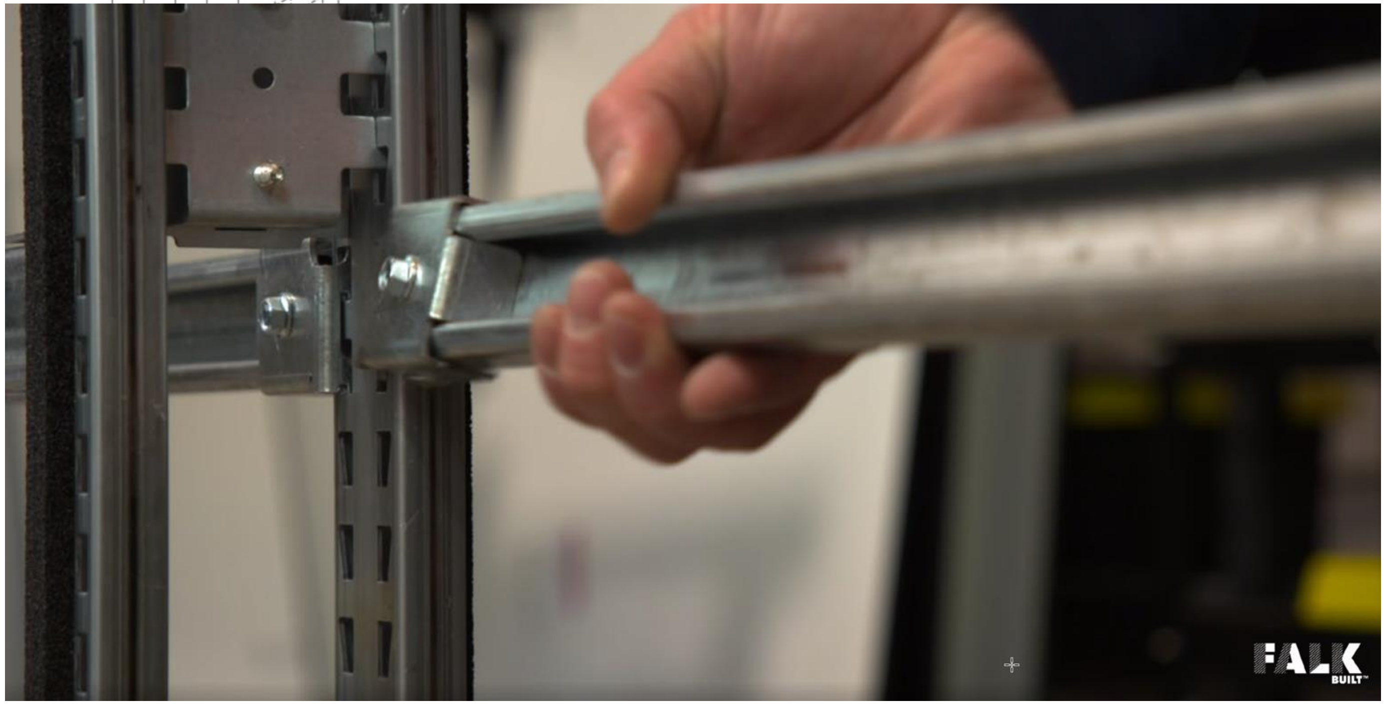
Prerequisite:
'Dry' mechanical connections

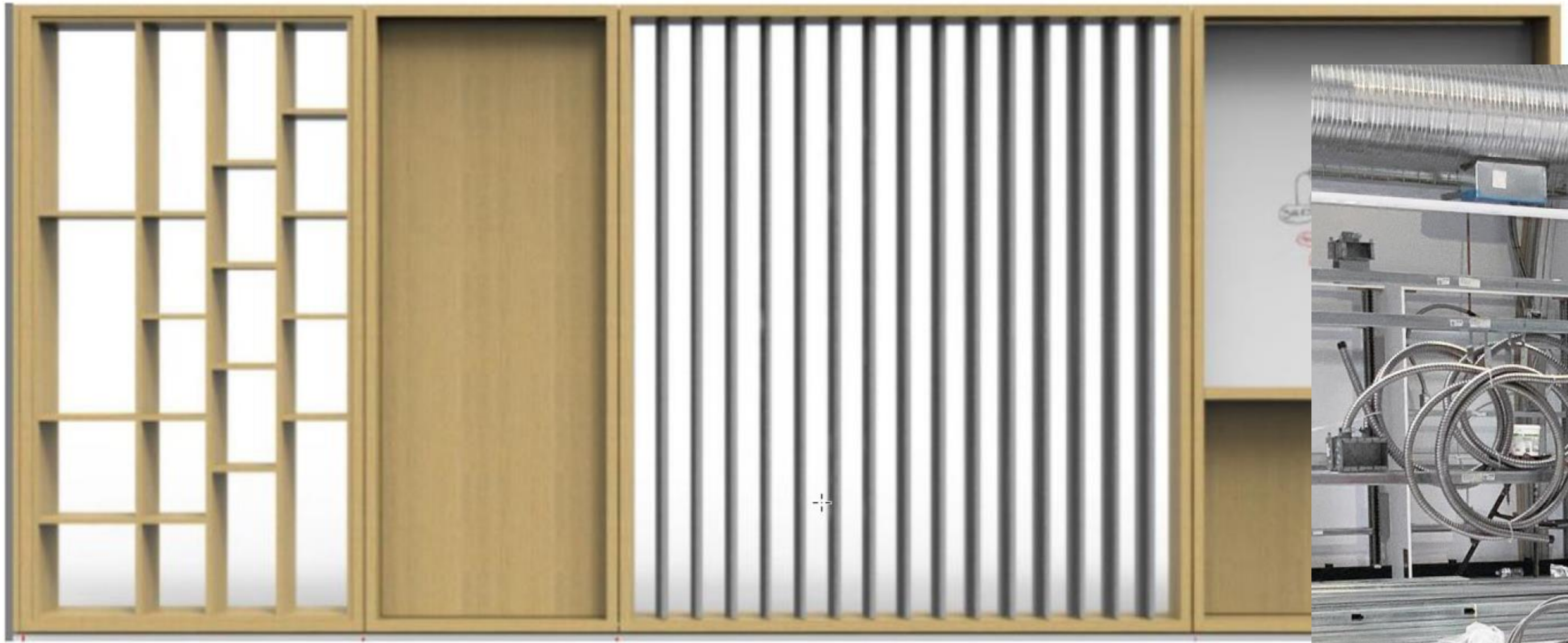



Source: ArchDaily

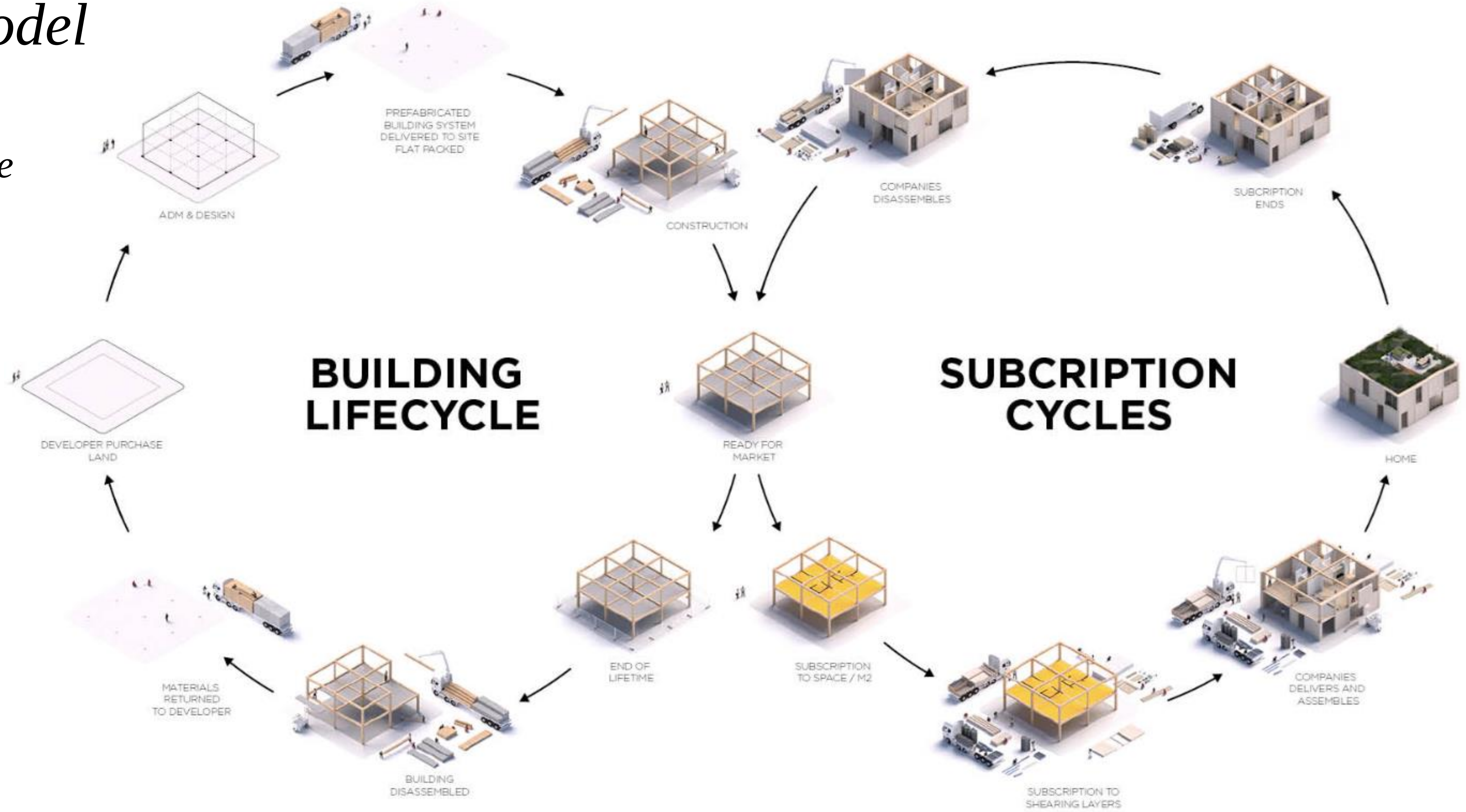


Prerequisite: Modularity and standardisation of the interfaces



Changing the business model

The Urban Village Project

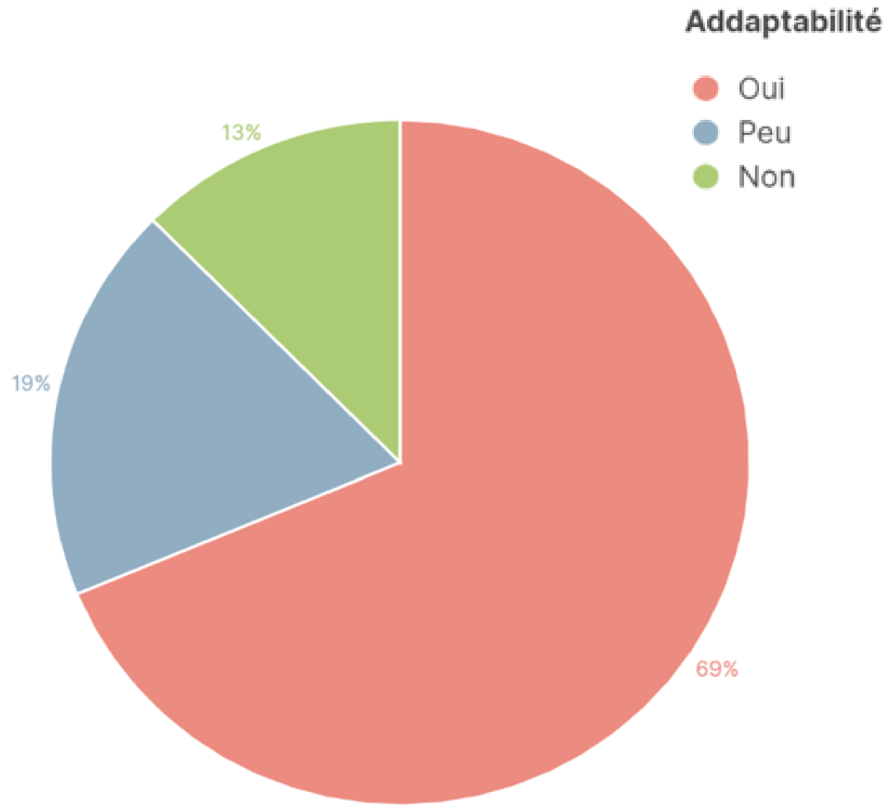


https://www.effekt.dk/urbanvillage

What is the awareness about building adaptability in Quebec?

Results from interviews with 16 AECO professionals

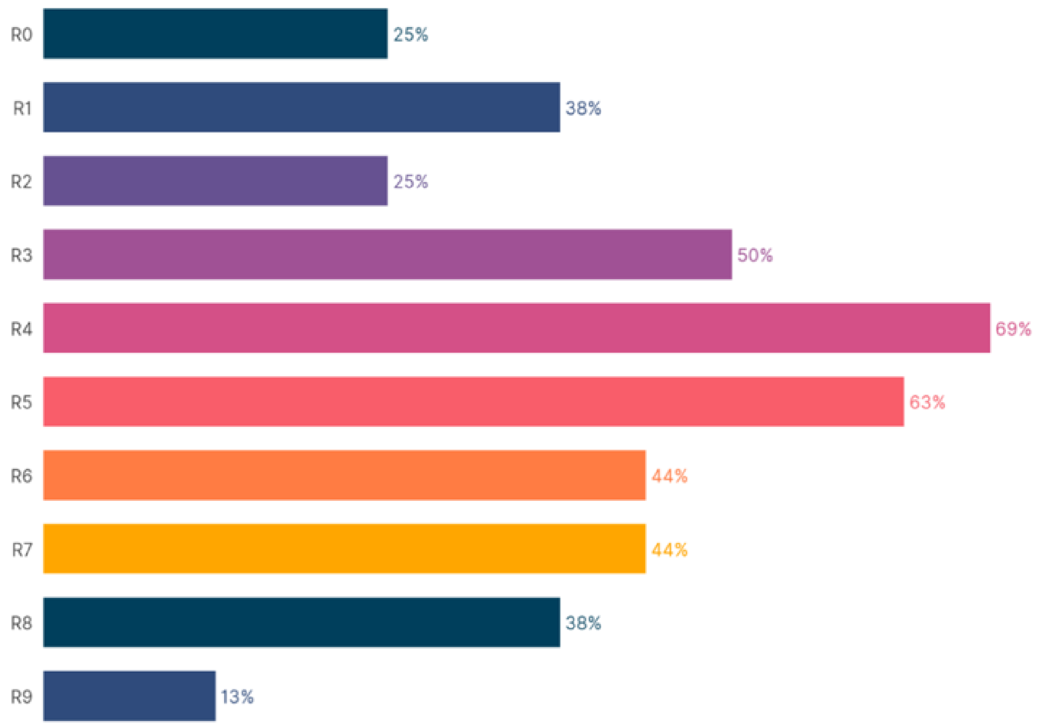
- Important to raise the awareness of owners/clients
- Adaptability is considered but using different terminology
- No certification for adaptability of design; slightly related to LEED



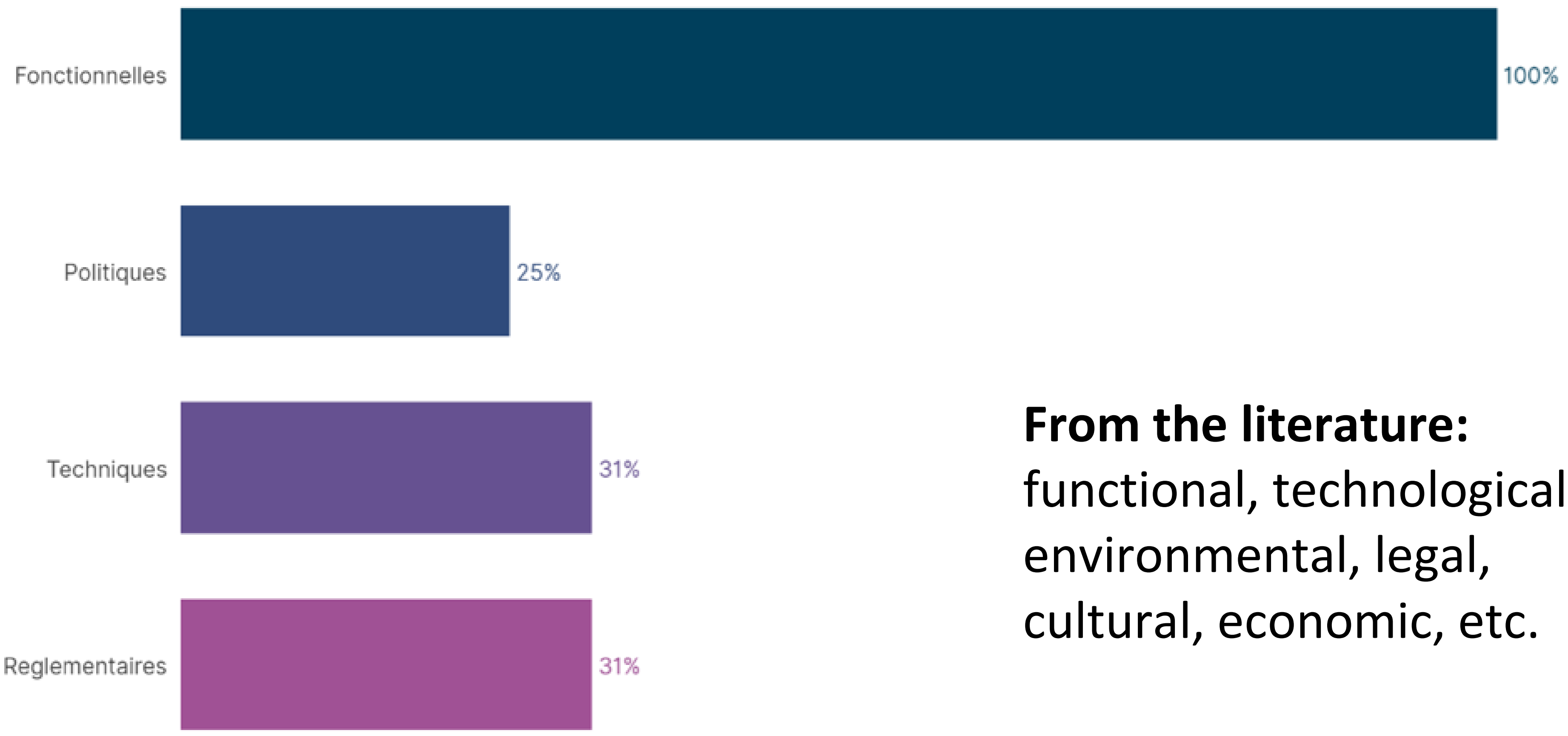
Application de l'adaptabilité dans les projets des participants

Most frequent strategies mentioned by the participants

Utilisation et fabrication plus intelligentes des produits	R0	Refuser	Rendre le produit superflu en abandonnant sa fonction ou en offrant la même fonction avec un produit radicalement différent
	R1	Repenser	Rendre l'utilisation du produit plus intensive (ex.: en partageant les produits ou en mettant sur le marché produits multifonctionnels)
	R2	Réduire	Accroître l'efficacité de la fabrication ou de l'utilisation du produit en consommant moins de ressources naturelles
Prolongement de la durée de vie des produits et de leurs parties	R3	Réutiliser	Réutilisation par un autre consommateur d'un produit mis au rebut qui est encore en bon état et remplit sa fonction initiale
	R4	Réparer	Réparation et entretien du produit défectueux afin qu'il puisse être utilisé selon sa fonction d'origine
	R5	Rénover	Restaurer un ancien produit et le mettre à jour
	R6	Réusiner	Utiliser les parties d'un produit mis au rebut dans un nouveau produit ayant la même fonction
	R7	Réorienter	Utiliser un produit mis au rebut ou ses parties dans un nouveau produit ayant une fonction différente
Application utile des matériaux	R8	Recycler	Transformer les matériaux pour obtenir une qualité identique (haute qualité) ou inférieure (basse qualité)
	R9	Récupérer	Incinération de matériaux avec récupération d'énergie

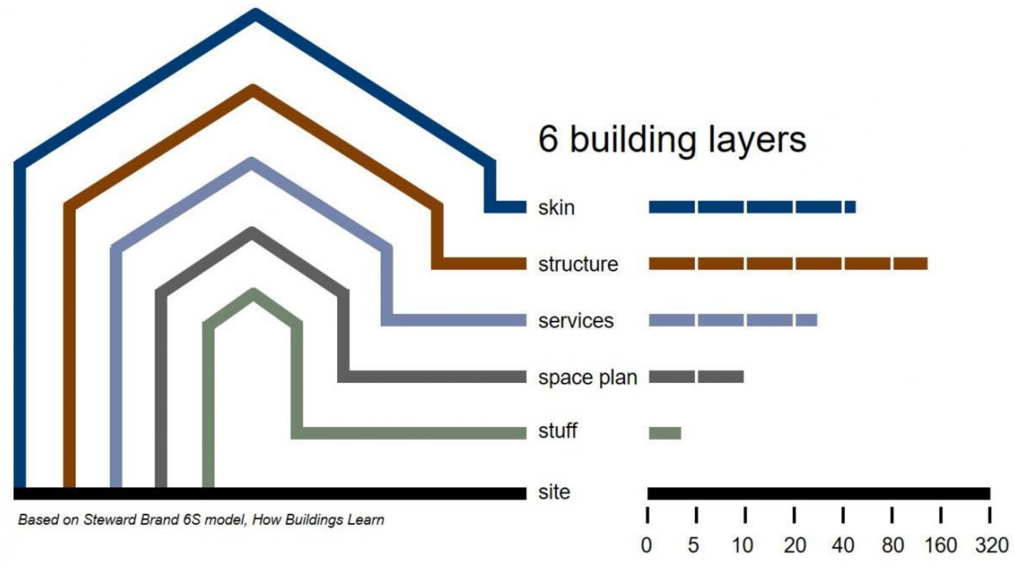


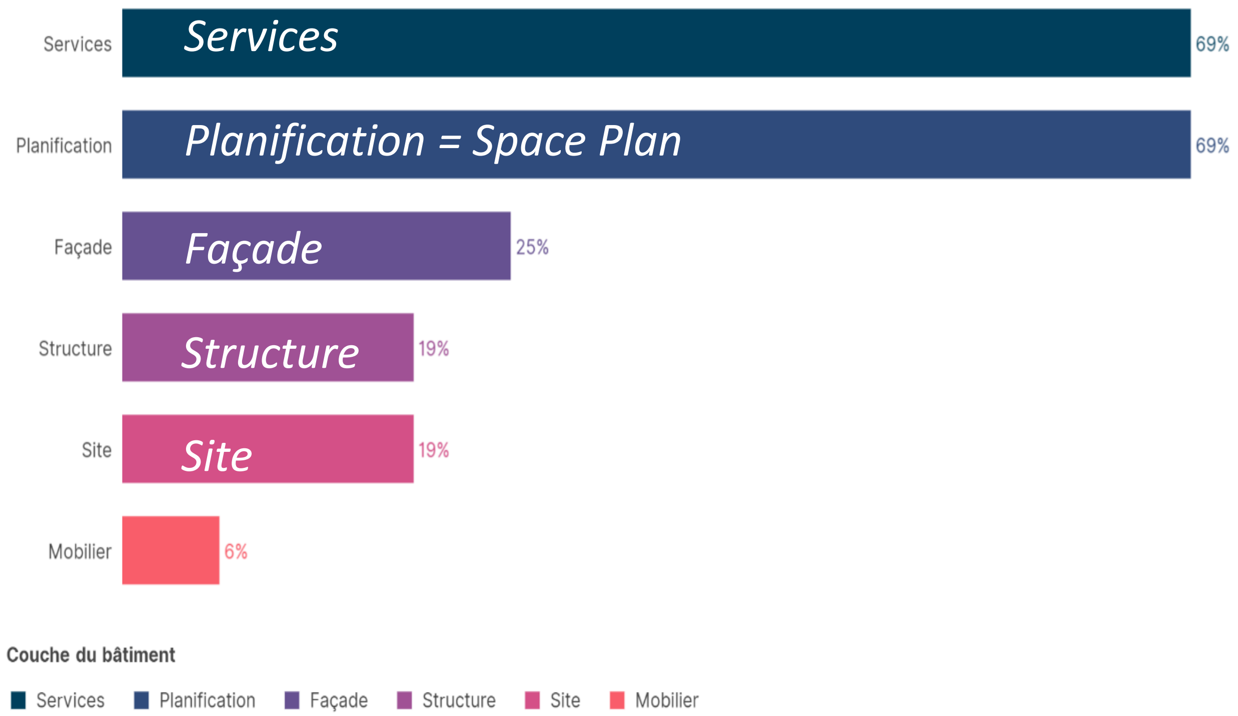
Reasons provoking the need for a change



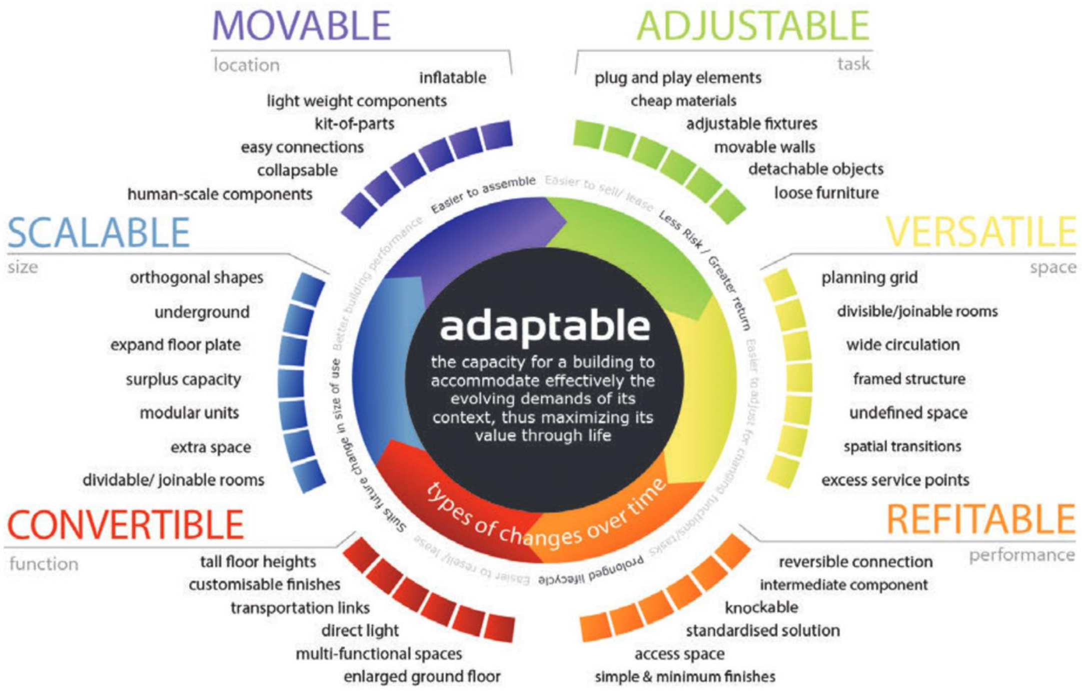
From the literature:
functional, technological, environmental, legal, cultural, economic, etc.

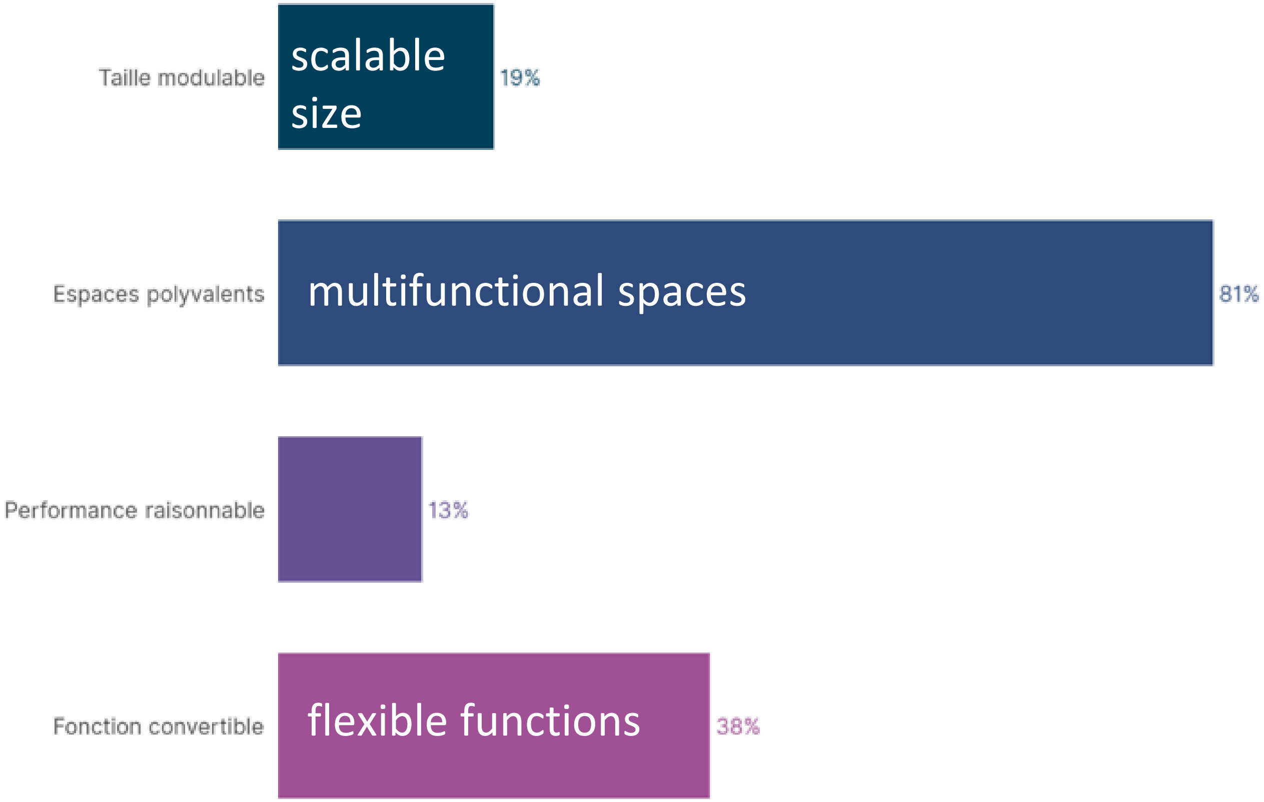
Layers with most frequent changes for adaptation





Most frequent strategies used





Framework for Design of adaptable buildings

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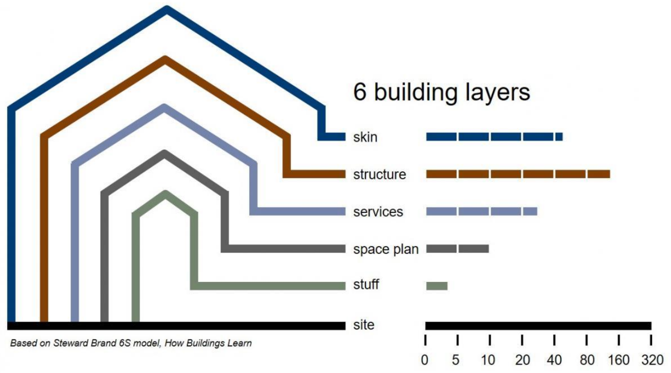
CERIEC Centre d'études et de recherches intersectorielles en économie circulaire

SUSTAINABLE PLACES 2024

Genesis of the proposed Framework

A.Structural requirements			
A.1 Access	A.2 Measurement Systems	A.3 Facade	A.4 Function
A.1.1 Access to building	A.2.1 Floor height	A.3.1 Insulation of the façade	A.4.1 Daily multifunctionality
A.1.2 Specified acccess for disablers	A.2.2 Surplus of building space	A.3.2 Material	A.4.2 Seasonal multifunctionality
A.1.3 Reuse of stairs and elavators	A.2.3 Modular coordination	A.3.3 Movability of the façade components	A.4.3 Dual functionality
A.1.4 Location of of the vertical access	A.2.4 Fire resistant load bearing	A.3.4 Daylight facilities	
	A.2.5 Extendible building/ Horizontal unit	A.3.5 Maintenance access	
	A.2.6 Extendible buildig/ Vertical unit	A.3.6 Digital integration	
	A.2.7 Insulation between stories and units	A.3.7 Accessibility to utilities	
	A.2.8 Shape of columns	A.3.8 Heritage preservation	
	A.2.9 Independency of unit	A.3.9 Regulatory compliance	
	A.2.10 Location of the core of the building	A.3.10 Community engagement	
	A.2.11 Material	A.3.11 Attachment system	
	A.2.12 Assembly sequences		
	A.2.13 Installation equipment		
	A.2.14 Dissassembly		
	A.2.15 Structural grid		
	A.2.16 Load bearing foundation for extending stories		



B.Technical Requirements					
B.1 Energy saving	B.2 Water consumption	B.3 Light	B.4 Air quality	B.5 Insulation	B.6 Connections
Optimise material use for heating / cooling	Waste water treatment and local reuse	Using natural ligh for interior spaces	Fine dust/ Exhaust system	Fire safety/ resistancy	Bolted connections
natural ventilation	Local water collection	Optimize color use to light absorption/reflection	Natural ventilation	Energy modeling	Interchangable fixtures
local cooling	Grey water recycling	Location and size/shape of daylight facilities	Green lungs	Moisture control	Plug- and- play Services
local energy/heat storage	Rainwater harvesting	Lighting control	Façade windows to be opened	insulation material durability	Labling and documentation
Optimize color use to heat absorption/reflection	Water metering	Smart lightning system	Smoke control	insulation integrity	User training
Eliminate Energy losses through façade	Smart water control	Lightning zoning	Wellness certification	Green roof insulation	
Insulation and acoustics system	Plumping accessibility	Daylight harvesting	Maintenance protocols	High insulation R-values	
Glazing and shading		Emergency Lightning	Indoor plants	Climate responsive insulation	
Orientation of the building		LCC analysis	Ventilation system design	Air sealing	
Maintenance access			Air filteration		
Scalability					
Remote control and automation					
Energy storage					

C. Spatial
Distinction between infills
Dividing by flexible partition or movable walls
Prosity of spaces (Open building theory)
Material selection
Spatial capacity
Natural lightning

D. Site
Expandable site
Multifunctional site
Safety and security
Quality of mobility
Natural landscape
Walkability

E. Social
Privacy
Occupants engagements
Affordability
Community well-being
Cultural preservation
Youth and Elderly-Friendly

Source: Schmidt & Austin (2016) – design tactics + LR

Proposed Framework (criteria related to services)

Services

		Explanation	Ref.	Contribution to CE	Contr. - prolonging life of the building	Contributes to the ease of change
(Services) A.3.2	natural ventilation	Natural ventilation can significantly contribute to the adaptability of a building in multiple ways. Firstly, it enhances energy efficiency by reducing the reliance on mechanical HVAC systems, lowering energy consumption and operating costs, and ensuring compliance with evolving energy efficiency standards. Secondly, natural ventilation supports indoor air quality, providing occupants with fresh air and reducing the risk of indoor pollutants and health-related issues, which is crucial for the adaptability of the building in terms of occupant well-being.	(Awbi, 2003), (Nicol et al., 2012)	Incorporating natural ventilation reduces reliance on mechanical systems, saving energy and resources. It exemplifies the CE concept of minimizing resource input while maximizing functional output, aligning with sustainable design principles.		Designing for natural ventilation can often allow for changes in how spaces are used and ventilated without altering mechanical systems.
(Structure) B.2.2	Structural grid	In the context of adaptable buildings, the structural grid system must support various configurations and changes over time. The Grid Structural Analysis service, which integrates the parallel application and utilizes computers distributed over the internet, enables architects and engineers to explore and analyze numerous structural options without oversimplifying the structure or incurring high costs. This flexibility is crucial in adaptable buildings, where the structure may need to adapt to different uses or extensions. Moreover, the ability to conduct realistic simulations of large dimension buildings during the design stage using this service helps in making informed decisions about the structural integrity and feasibility of various design alternatives. This not only saves time and resources but also ensures that the adaptable building will be safe, functional, and efficient throughout its lifecycle.		Reduce Waste: Efficient structural design minimizes material use. Lifecycle Extension: A flexible grid allows for building adaptability over time. Resource Looping: Designing for disassembly and reuse of structural components.	A flexible structural grid allows for various layout configurations, enhancing the building's adaptability over time.	

	A.2.6	High insulation R-values	[illegible] contribute to a building's adaptability. Firstly, they enhance energy efficiency by minimizing heat transfer, reducing heating and cooling costs, and allowing the building to meet evolving energy efficiency standards and regulations .Secondly, higher R-values contribute to consistent indoor comfort by preventing temperature fluctuations and drafts, making the building adaptable for various climates and occupant preferences.	[illegible] (Lstibůrek & Carmody, 2012)	[illegible]	Higher R-values indicate better insulation performance, which can prolong the building's thermal efficiency and reduce the need for retrofitting.	
	A.2.7	Climate responsive insulation	Climate-responsive insulation plays a pivotal role in enhancing a building's adaptability by tailoring insulation solutions to specific climate conditions. Such an approach allows for better control of the indoor environment, leading to several benefits. Climate-responsive insulation optimizes energy efficiency by adapting insulation strategies to local climate patterns, reducing the building's reliance on mechanical heating and cooling systems and aligning with evolving energy efficiency regulations. It fosters year-round comfort by mitigating temperature extremes, ensuring the building remains adaptable to seasonal changes and variable weather conditions .	(International Energy Agency, 2015), (Olesen et al., 2019)	[illegible]	Insulation that responds to climate conditions helps in maintaining the building's interior environment, contributing to prolonging its use and comfort.	
	A.2.8	Air sealing	Air sealing in insulation significantly contributes to a building's adaptability by enhancing energy efficiency, indoor comfort, and overall building performance. By preventing unwanted drafts and air leaks, air sealing minimizes heat loss in cold weather and heat gain in hot weather, reducing heating and cooling costs and ensuring the building meets evolving energy efficiency standards .	https://www.energy.gov/energysaver/weatherize/air-sealing-your-home		Effective air sealing improves energy efficiency and prolongs the building's performance by preventing uncontrolled air leakage.	

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https://www.effekt.dk/urbanvillage

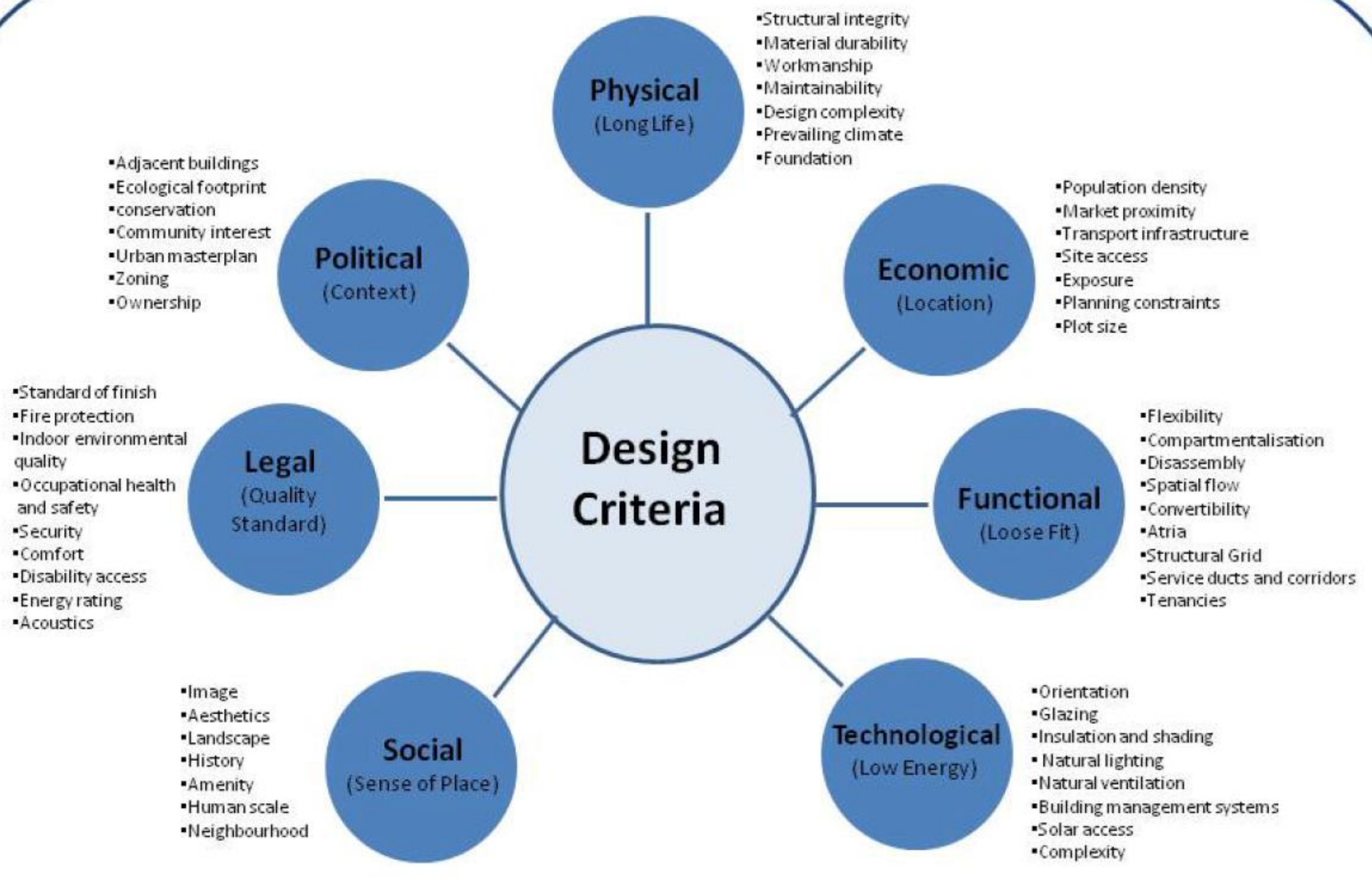
Proposed Framework (criteria related to the enveloppe)

			Explanation	Ref.	Contribution to CE	Contr. - prolonging life of the building	Contributes to the ease of change
Enveloppe	C.5	Digital integration	Digital integration in the facade of a building enhances adaptability by improving environmental control, user comfort, data-driven decision-making, security, maintenance efficiency, scalability, and sustainability. It makes the building more versatile and responsive to the dynamic needs of both occupants and the environment.	Anousha doroudian (2021)	Advanced digital systems enable efficient building management, energy conservation, and adaptability to changing technologies, aligning with sustainable use and resource optimization.		Incorporating digital systems into building operations allows for updates and changes in how buildings are managed and interacted with over time.
Planification spatiale	D.2	Material choices	Material selection plays a crucial role in the adaptability of a building, much like choosing the right ingredients is essential in creating a versatile recipe. In the realm of construction, materials are not just the building blocks; they define the building's capacity to adapt and evolve over time. Opting for modular, lightweight, and durable materials, for instance, can facilitate easy reconfigurations, allowing a building to morph as per changing needs without extensive renovations. Similarly, the use of sustainable materials contributes to a building's long-term viability, aligning with evolving environmental standards and societal values.	Hisham Said a,⁎, Khaled El-Rayes (2013) ,Mayyadan Fahmi Hussein(2012)	Selecting sustainable, durable materials reduces environmental impact and prolongs the building's life, a key aspect of the circular economy.	Selecting durable materials can prolong the lifespan of a building by reducing the need for frequent replacements or repairs.	
	D.6	Modular design	Modular design, as exemplified by the Modular Building System (MBS), is a game-changer in the realm of adaptable building construction. The essence of MBS lies in its use of prefabricated units, which are designed for easy transport and assembly on-site. This approach to building design is crucial in addressing today's construction challenges, offering flexibility, efficiency, and sustainability. A key aspect of MBS is the focus on the structural integrity of connections between modules, which is vital for ensuring the overall stability and performance of the assembled structure. The study and refinement of these inter-modular connections are central to advancing MBS technology. By optimizing connection designs, buildings can be assembled, disassembled, and reconfigured with greater ease and less environmental impact, catering to the evolving needs of users and the environment.	Shabtai, Bock, Stoliar a. (2016), Heshachan et al (2021)	Modular elements can be easily replaced or repurposed, facilitating building adaptation and reducing the need for new materials.		Modular elements can be reorganized, replaced, or updated, making the building highly adaptable to new functions or design trends.

How to measure (evaluate) adaptability?

Mesure the reuse potential of an existing building

Types of measures:
- Discrete
- Subjective, intangible
- Quantitative, objectively measurables



adaptSTAR Model

(Conejos et al., 2014)

Framework for evaluating the adaptability of a building

Édifice Gaston Miron

	Sub-criteria	Questions	Answers	Best condition	Worst condition	1	2	3	4	5
1	Diversity of the environment and site	How is the diversity of functions in the environments (e.g., commercial, residential, recreational) ?	It is located in city center and surrounded by residential, commercial and religious buildings.	The ideal stage of diversity in adaptable buildings is characterized by flexibility and inclusivity.	The least favorable stage in adaptable buildings is marked by isolating the building with limitted building with different funtionality					
2 3	Cultural and heritage preservation	.How does the adaptable building's design contribute to the preservation and integration of local cultural and heritage values? . What strategies are in place to ensure that any adaptive changes to the building remain sensitive to its cultural and historical context?	In the process of renovating a historic library, established in 1960 and situated centrally in the city, efforts were made to preserve its original function. This included the temporary relocation of all books to an alternate site during the renovation phase, with the intention of restoring them to their original location upon completion of the building work. Structural elements, particularly the walls featuring opals and glazing, were largely maintained, with modifications limited to certain sections for aesthetic or functional enhancements. All columns within the structure were retained, undergoing refurbishment to align with modern standards. The majority of the alterations were focused on updating the building's services and spatial layout to meet contemporary requirements, ensuring both the preservation of its historical integrity and the adaptation to current functional needs.	In the best scenario, building modifications respect and preserve the historical and cultural significance of the structure. This involves retaining key architectural features and historical elements that define the building's character. Renovations are carried out sensitively, blending modern functionality with historical aesthetics.	In the worst scenario, building modifications disregard the cultural and heritage value of the structure. Key historical features are often removed or altered beyond recognition to make way for modernization, leading to a loss of the building's original character and historical significance.					
4	Multifunctionality	Do you think this building has th potential to change the function over time? If yes,What design strategies are employed to ensure that the adaptable building can effectively serve multiple purposes over its lifecycle?	Currently, the building no longer serves as a library, with plans underway to repurpose its function. However, the extensive renovations and refurbishments carried out in 2011 and 2012 have enhanced its adaptability. Featuring an open space plan and a robust structural framework, the building is well-suited to accommodate a variety of other uses. This versatility stems from the strategic updates made in the past decade, which have not only preserved the building's integrity but also expanded its potential for diverse applications in the future.	An adaptable building features spaces that can easily transform to serve multiple purposes, catering to a wide range of activities and user needs. The design includes modular elements and smart systems that allow for quick and efficient reconfiguration. Such buildings effectively balance functionality, comfort, and aesthetics, making them highly efficient and user-friendly.	an adaptable building fails to offer genuine multifunctionality, with spaces being rigid, difficult to reconfigure, and limited in their use.					
5	Expandable site	How is the building's site designed to accommodate possible future expansion or downsizing?	The expansion of the building, either vertically or horizontally, is constrained due to several factors. Its status as an older structure poses limitations on vertical additions, ensuring the preservation of its original architectural integrity. Similarly, horizontal expansion is not feasible, given the surrounding urban landscape, which includes adjacent streets and buildings.	An adaptable building is designed with the potential for easy expansion, both vertically and horizontally, to accommodate future growth or changing requirements.	An adaptable building lacks any real potential for expansion, with a rigid structure that cannot be easily modified or extended.					
6	Building Codes and Regulations	What types of building codes and regulations are applicable to modifications in adaptable buildings?	some regulations in 2011 and 2012 were followed. (the detail were not reminded to interviewee	Adaptable buildings are designed and modified in strict adherence to current building codes and standards, ensuring safety, accessibility, and environmental sustainability.	Adaptable buildings fail to comply adequately with existing building codes and standards, compromising safety, accessibility, and environmental performance.					
7	Energy modeling	What energy modelling software or tools were used to design and analyze the building's energy efficiency?	For this building, no form of energy analysis was conducted.	Energy modeling is extensively utilized in adaptable buildings, guiding design and operational decisions to maximize energy efficiency and sustainability. This proactive approach involves simulating various scenarios to optimize building performance, leading to reduced energy consumption and lower environmental impact.	Energy modeling is either overlooked or inadequately used in the design and operation of adaptable buildings. This neglect results in inefficient energy use, higher operational costs, and a larger carbon footprint.					
8		How does the building's energy performance compare to industry standards or benchmarks for similar adaptable structures?								
9	Remote control and automation	1. Do you have a Building Management System (BMS) installed in your adaptable building? 2. Is your building's lighting system remotely controllable? 3. Does your adaptable building feature automated HVAC controls? 4.Is your building equipped with remote-controlled smart windows or shades?	The building lacks any remote control systems for its services or structural elements. All lighting systems are manually operated, and there are no remotely controlled shading devices. However, it is equipped with an HVAC system, which, to some extent, may have remote control capabilities, although this detail is not precisely recalled.	Adaptable buildings are equipped with advanced remote control systems that manage various building functions like lighting, temperature, and security efficiently.	Adaptable buildings lack effective remote control systems, leading to manual management of essential functions like lighting and HVAC, which is less efficient and more time-consuming					
10	Daylighting	How do the occupants perceive the visual comfort provided by the daylight harvesting system (e.g., light levels, glare control)?	The majority of the lighting fixtures and their placements have been retained from the building's previous incarnation as a library, where the lighting design was specifically tailored for that purpose. However, no formal analysis was conducted on the effectiveness of this lighting setup, and feedback regarding lighting satisfaction was not systematically gathered from the building's occupants.	Adaptable buildings are designed to maximize daylight harvesting, using strategically placed windows, reflective surfaces, and skylights.	An adaptable building fails to effectively utilize daylight, resulting in reliance on artificial lighting and increased energy consumption.					

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Framework for evaluating the adaptability of a building

Édifice Gaston Miron										
	Sub-criteria	Questions	Answers	Best condition	Worst condition	1	2	3	4	5
12	Waste water treatment and local reuse	Have you integrated any graywater recycling systems within the building's infrastructure?	No	Adaptable buildings incorporate advanced wastewater treatment and local reuse systems, allowing them to recycle water efficiently for non-potable purposes like irrigation and flushing toilets.	Adaptable buildings lack any system for wastewater treatment and local reuse, resulting in the wasteful disposal of water and increased environmental strain.					
13	Smart water control	Does your adaptable building utilize smart water control systems to optimize water usage?	No	Adaptable buildings feature smart water control systems, utilizing sensors and automation to optimize water usage and reduce waste.	adaptable buildings lack smart water control systems, leading to inefficient water usage and potential wastage.					
14	Natural Ventilation	Could you describe any innovative strategies or technologies that have been incorporated to enhance natural ventilation?	The building equiped with mechanical ventilation but for natural ventilation just use windows.	Adaptable buildings are designed to maximize natural ventilation, using strategic placement of windows, vents, and atriums to facilitate air flow.	Aadaptable buildings fail to incorporate effective natural ventilation, resulting in stale, poorly circulated indoor air and an overreliance on energy-intensive mechanical systems.					
15	Façade windows to be opened	What is the projected lifespan of the window mechanisms, and what are the anticipated maintenance needs and costs?	Cost estimations were not specifically undertaken for these modifications, but it is noted that the building's façade was largely preserved in its original state, with renovations confined to select areas.	adaptable buildings feature façade windows that can be opened, allowing for natural ventilation and a connection to the outdoor environment.	adaptable buildings have façade windows that are fixed and cannot be opened, limiting natural ventilation and user control over the indoor					
16	Glazing (natural lights) and shading	However it is located in a very cold location, many glassess are used in façade. .Are there specific design principles that guide the selection of glazing and shading systems in the adaptable building?	The selection of glazing types did not involve energy simulations; instead, it adhered to the building standards prevalent in 2011 and 2012. Regarding thermal comfort, considerations were limited to ventilation, cooling, and heating systems, without conducting any detailed analysis.	The selection of glazing and shading systems in adaptable buildings is guided by specific design principles that prioritize energy efficiency, occupant comfort, and environmental responsiveness.	In the worst scenario, the selection of glazing and shading systems lacks clear design principles, leading to suboptimal choices that do not align with energy efficiency or occupant comfort.					
17	Moisture control	How has the building's design taken into account the potential for moisture infiltration or leakage during adaptation phases? Can you describe the moisture-resistant materials and construction techniques used in the building's envelope, such as roofing and exterior walls?	Certain specialized materials were employed to manage moisture levels, a crucial consideration given the building's original use as a library. However, specific details of these materials are not recalled. It is noteworthy that there were no instances of leakage reported.	Adaptable buildings are equipped with effective moisture control systems that maintain optimal indoor humidity levels, preventing mold growth and structural damage.	In the worst scenario, adaptable buildings lack adequate moisture control, leading to high indoor humidity levels, potential mold growth, and structural deterioration.					
18	Scalability of interior spaces	How is the scalability of the adaptable building defined in terms of its ability to accommodate growth or changes in space requirements? 2. Are there specific design principles or architectural features that enable the building's scalability?	The interior walls of the building offer flexibility, allowing for their removal or reconfiguration to enlarge or reduce spaces. This adaptability facilitates the accommodation of various functions within the structure.	In the best scenario, adaptable buildings are designed with scalability in mind, featuring flexible interior spaces that can be easily resized or reconfigured to meet changing needs	In the worst scenario, the interior spaces of adaptable buildings are rigid and inflexible, making it difficult to adjust or repurpose areas as needs evolve.					
19	joints	What innovative joining techniques are being employed in your design to allow for adaptability without compromising structural integrity?	Just used masonary and traditional joints and techniques.	In the best scenario, adaptable buildings utilize innovative joining techniques for structural and non-structural joints, enhancing flexibility and durability. These advanced techniques, such as modular connections and reversible fastenings, allow for easy assembly, disassembly, and reconfiguration of building components.	In the worst scenario, adaptable buildings rely on traditional, rigid joining techniques that limit the flexibility and adaptability of the structure. Fixed and permanent joints make it challenging to modify or repurpose building components, leading to a lack of versatility in the building's design.					
20	joints	In what way does the joint design support the building's capacity for future technological integrations?	Just used masonary and traditional joints and techniques.	In the best scenario, joint designs in adaptable buildings are meticulously planned to support future technological integrations, allowing for seamless incorporation of new systems and upgrades. These joints are designed to be flexible and modular, facilitating easy access for maintenance and the integration of advanced technologies like smart building systems. This foresight in design ensures that the building can evolve with technological	In the worst scenario, joint designs in adaptable buildings do not consider future technological integrations, resulting in a rigid structure that hinders the incorporation of new systems. These traditional joints complicate the process of updating or adding new technologies, often requiring extensive and costly modifications.					

Prerequisites – digitalization + industrialization

Benefits from digitalization *(among others)*

- Precise coordination (BIM)
- Simulation of the adaptability
- DfMA – DfMAd (*Design for Manufacturing & Adaptability*)
- *Digital thread of the* information during building's lifecycle

Benefits from industrialization / prefabrication *(among others)*

- Mechanical connections (dry)
- Standardization of the interfaces
- Modularisation
- Simplified assembly and disassembly (*Plug-and-play*)

Modularity, standardization

The potential of the industrialization of construction

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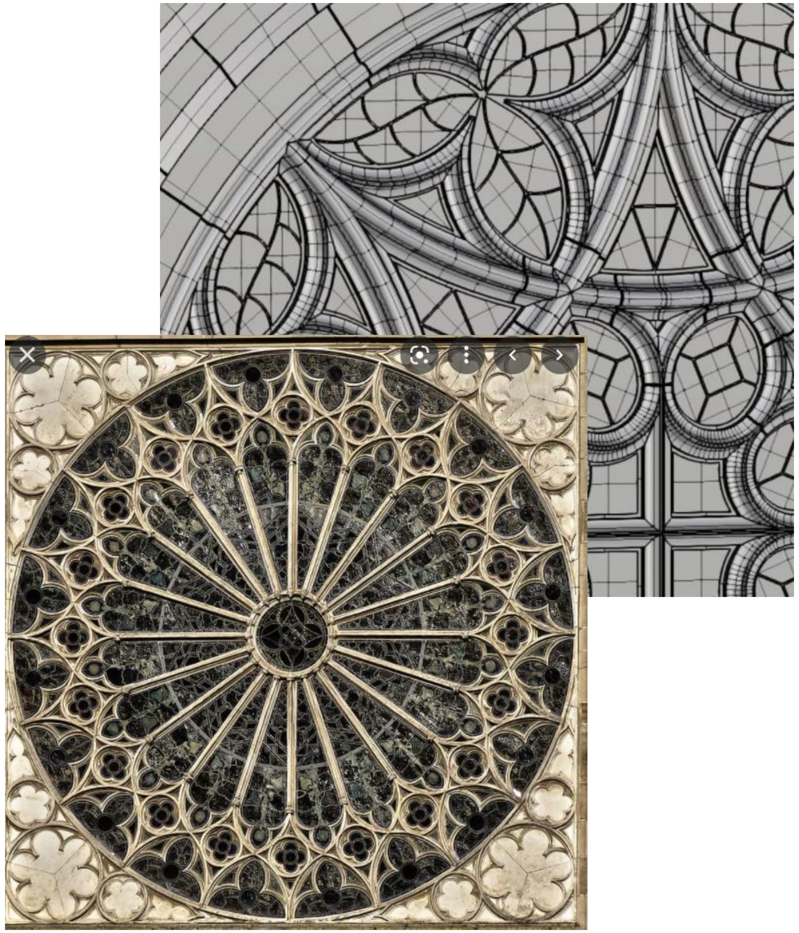
ÉCOLE DE TECHNOLOGIE SUPÉRIEURE
Le génie pour l'industrie
Université du Québec

GRIDD
GROUPE DE RECHERCHE EN INTÉGRATION ET DÉVELOPPEMENT DURABLE EN ENVIRONNEMENT BÂTI

SUSTAINABLE PLACES 2024

Modularity, standardization

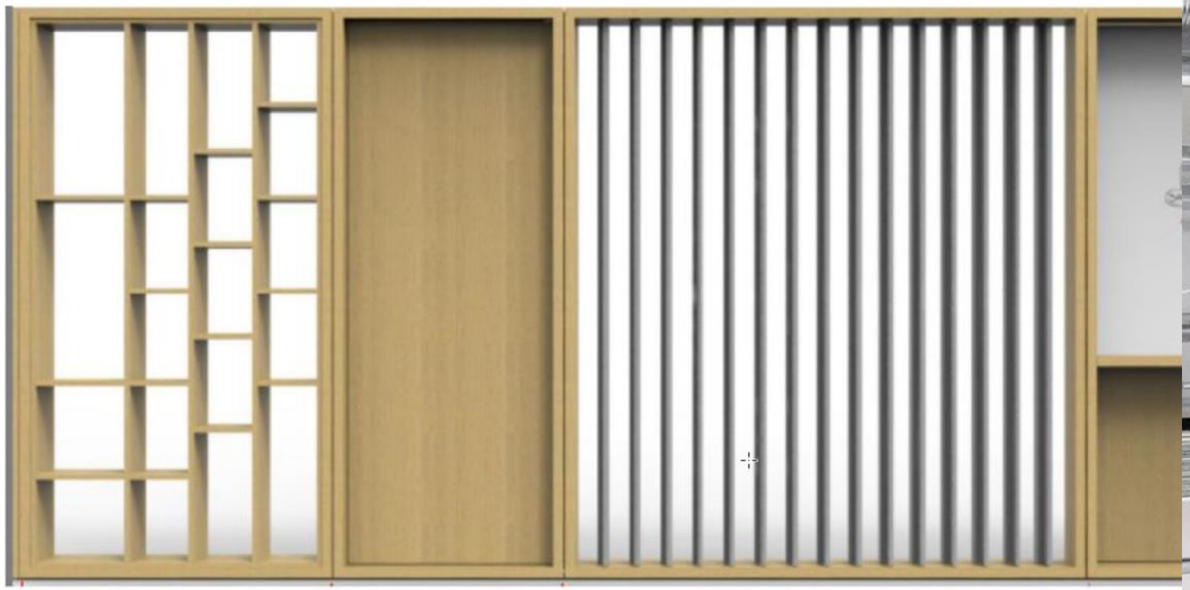


Rodin's small model of 'Three Shades' (1897).

PHOTO: CHRISTIAN BARAJA/MUSÉE RODIN

Modularity, standardization of the interfaces

Modularity in design refers to dividing a system into smaller parts or modules that can be independently created and used in different systems. This approach offers significant benefits in adaptability, cost-effectiveness, and sustainability. (Nakib, 2010)



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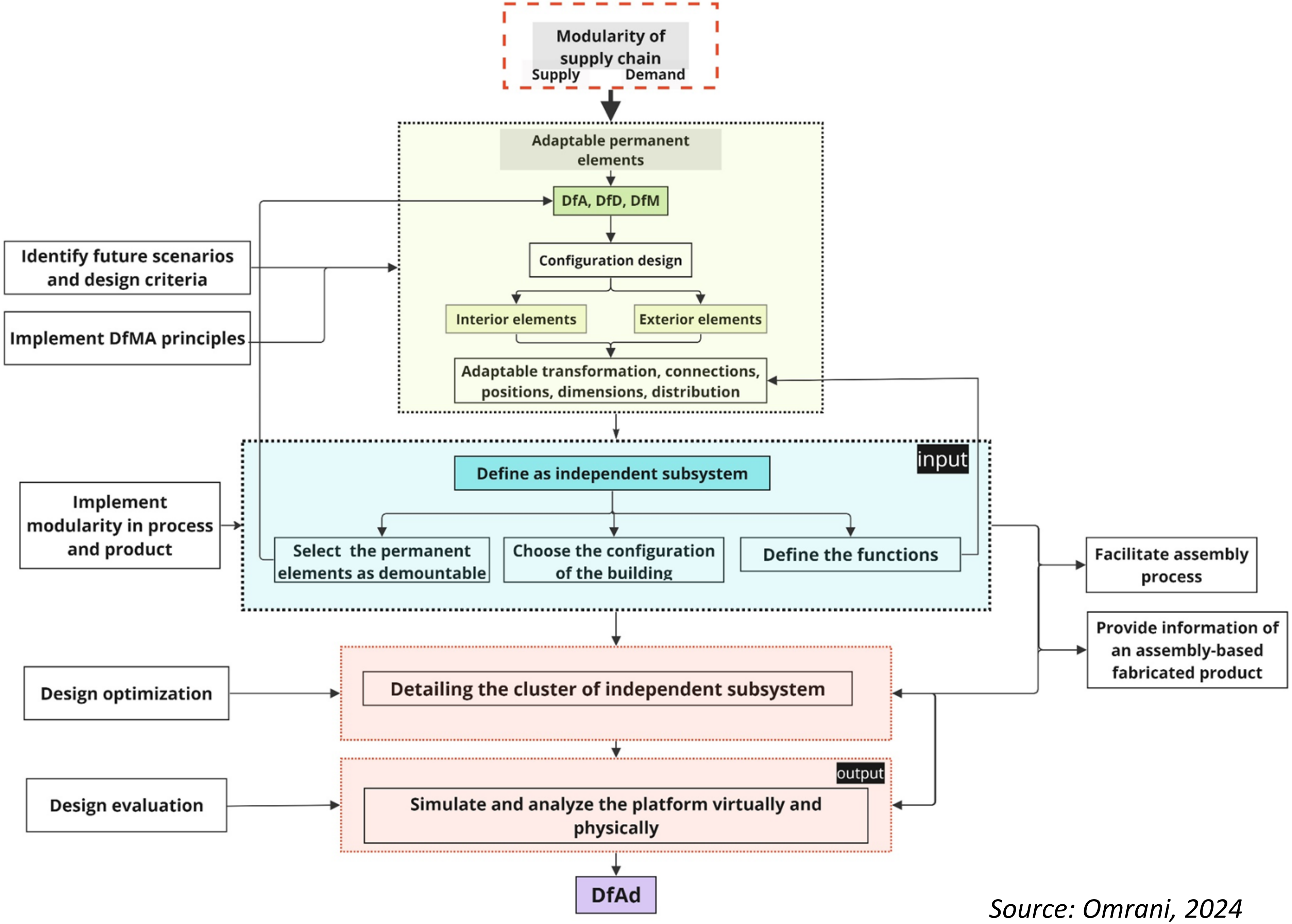
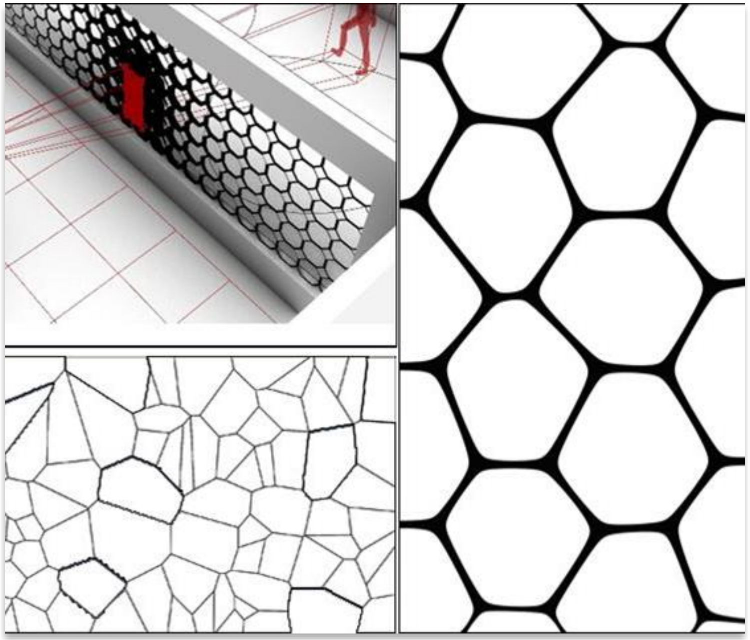
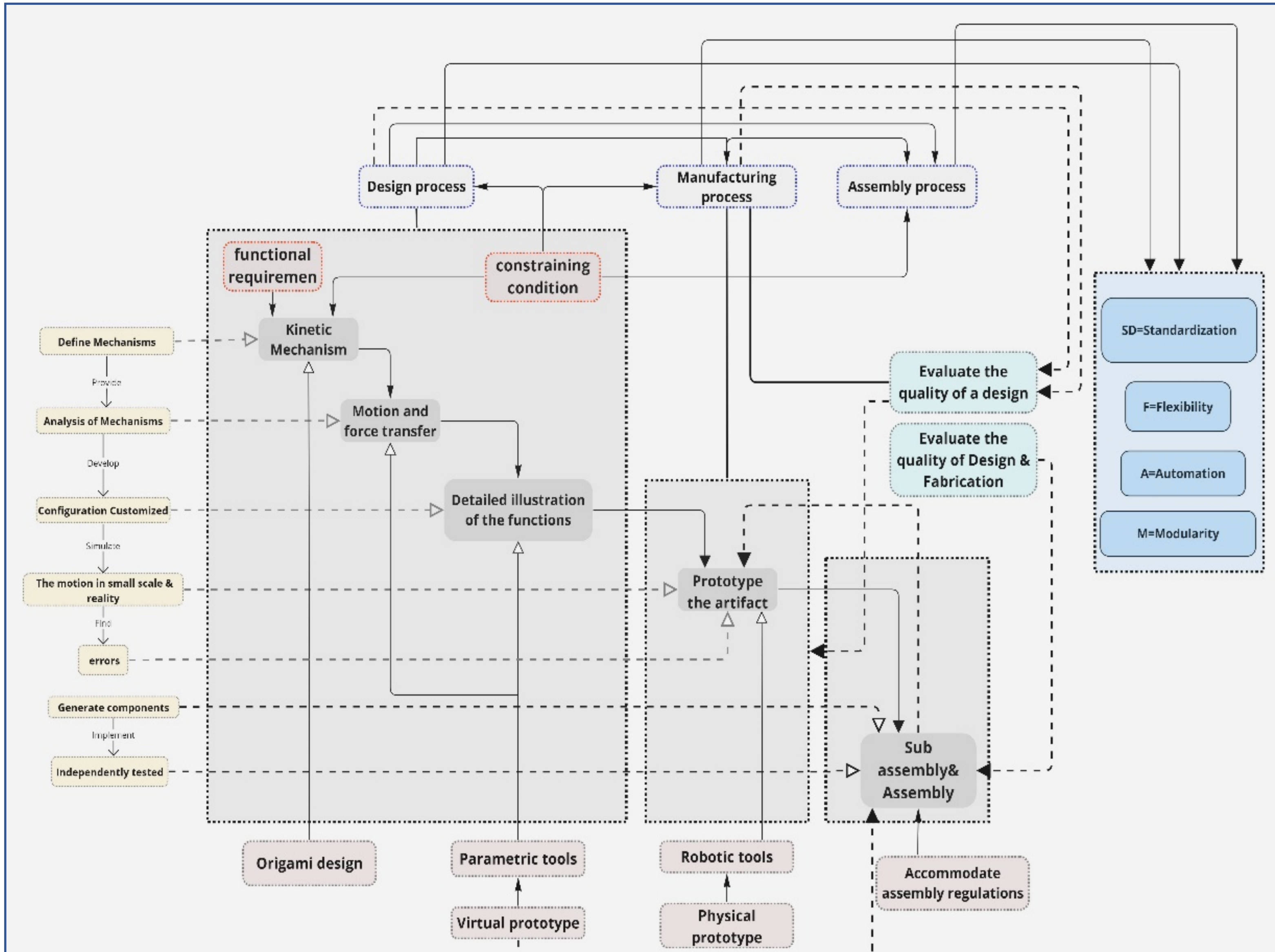
Conceptual Framework for DfAd through Modularity



Source: Omrani, 2024

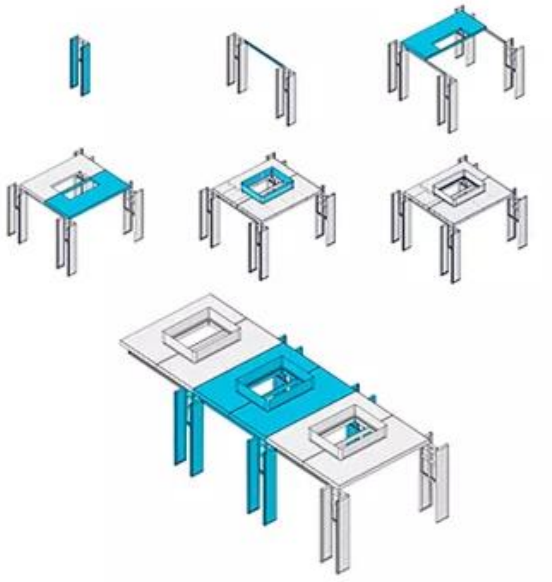
Modular prototype - digital design and fabrication





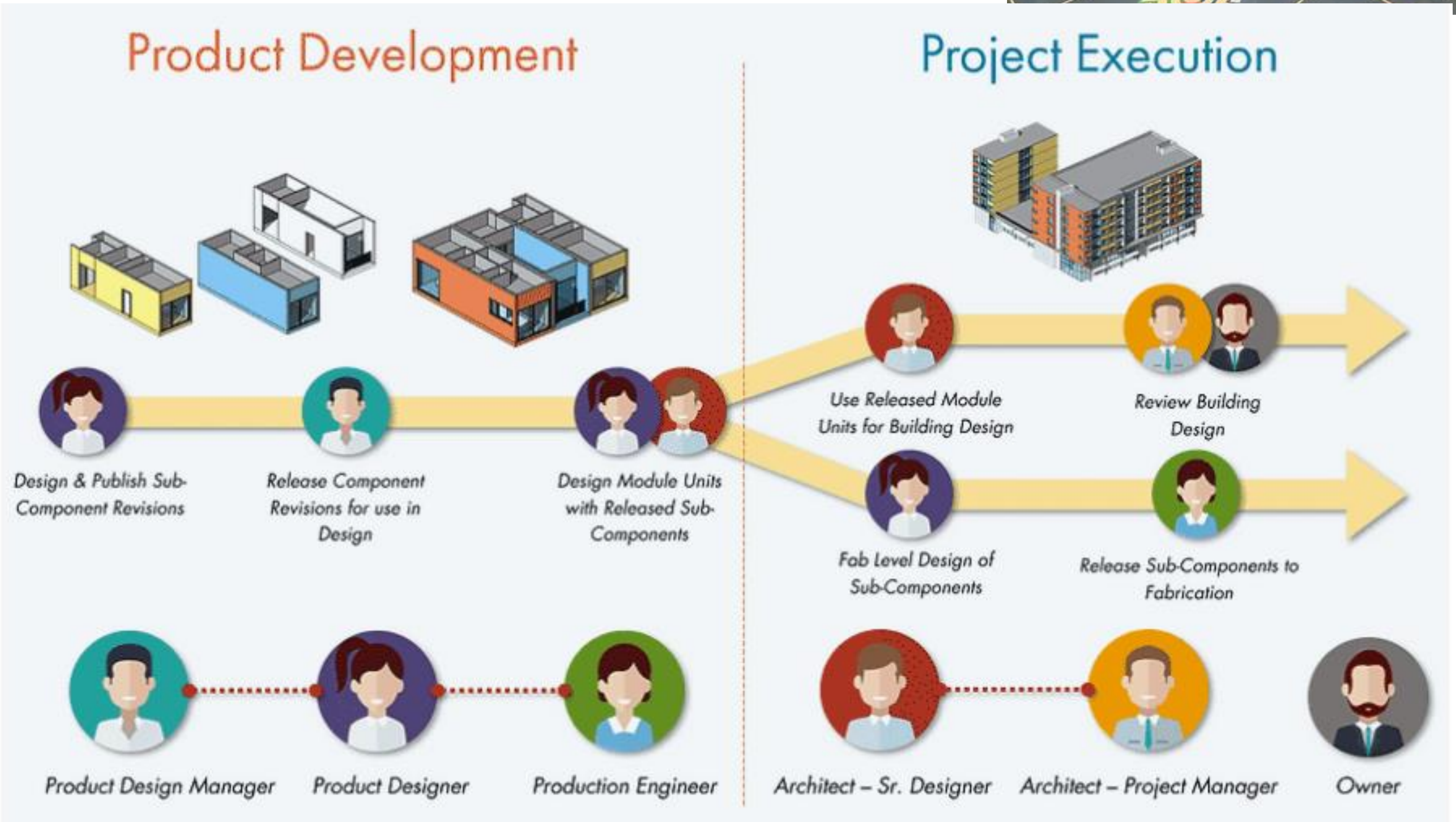
Source: Omrani, 2024

Open systems, platforms, kits of parts



Kitconnect

OpenBuilding.co



https://www.projectfrog.com/kit-of-parts

www.projectfrog.com/flex-building-program

https://builtoffsite.com.au/news/kitconnect-taking-it-to-the-cloud-mmc-and-a-standardised-kit-of-parts/

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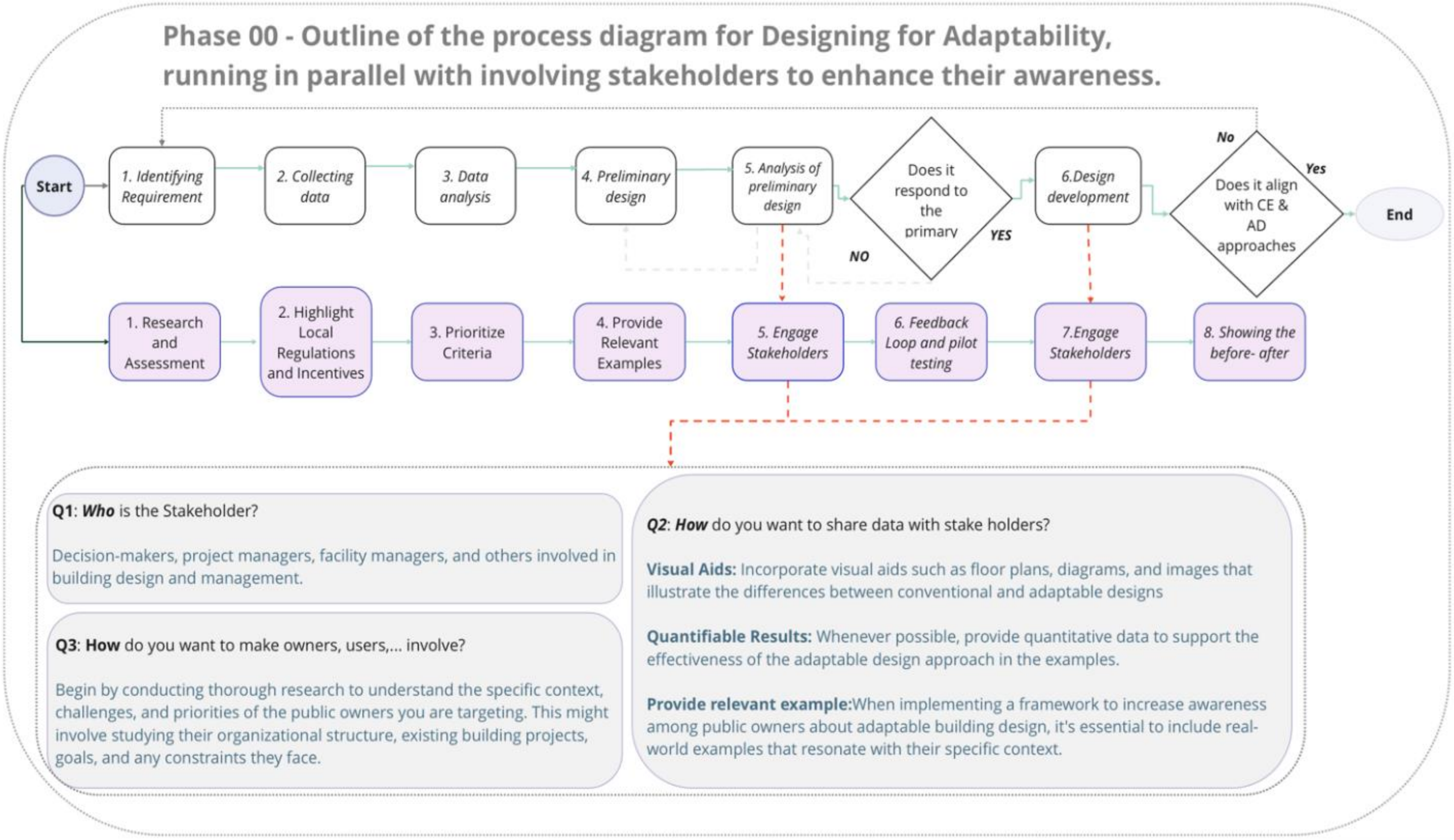
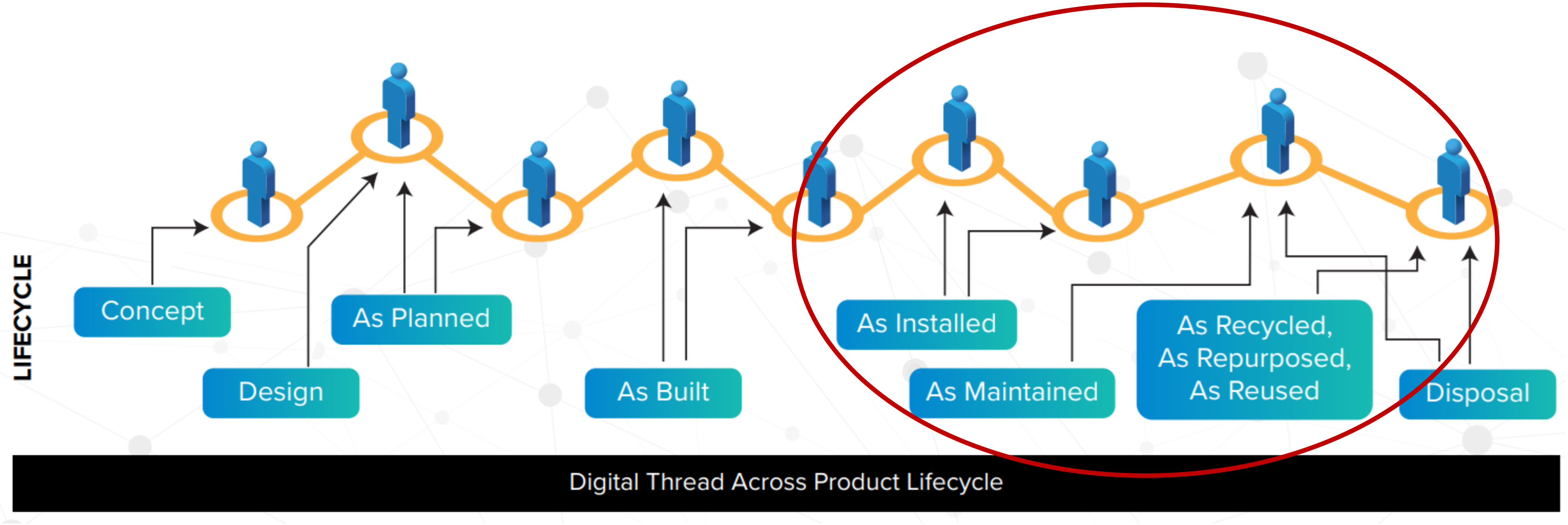
Future research

DfAd framework for different stakeholders

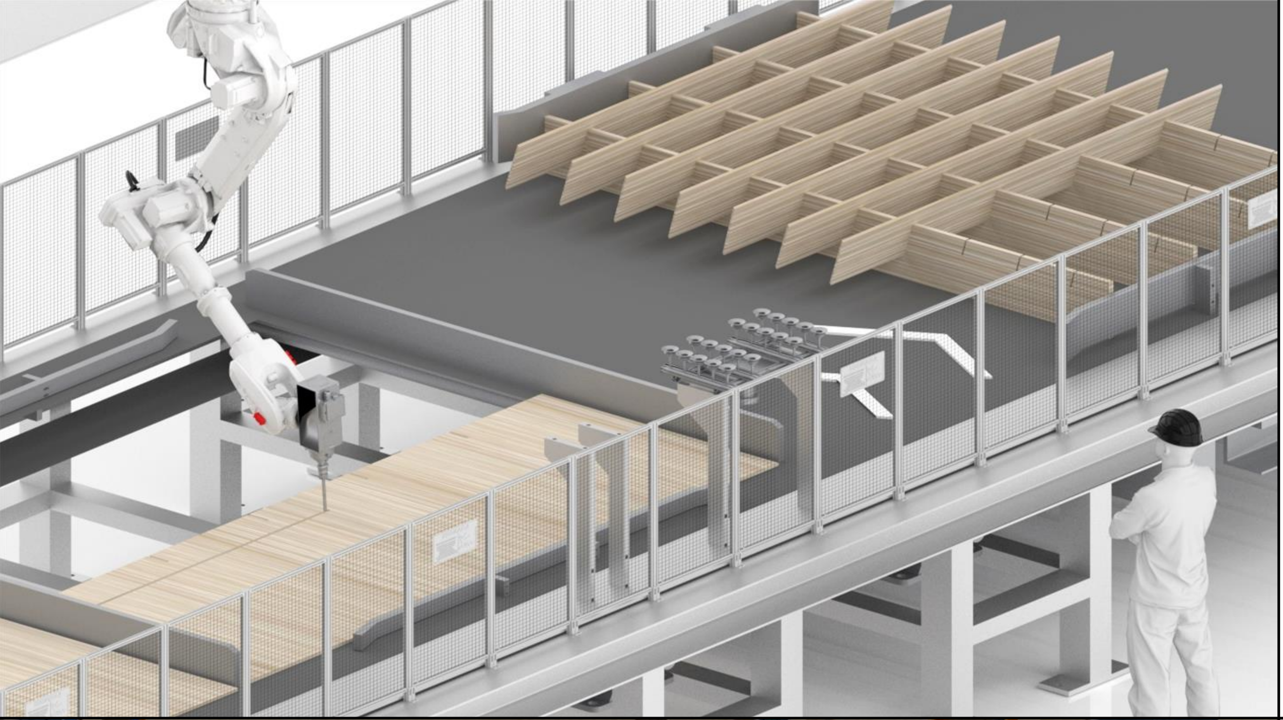


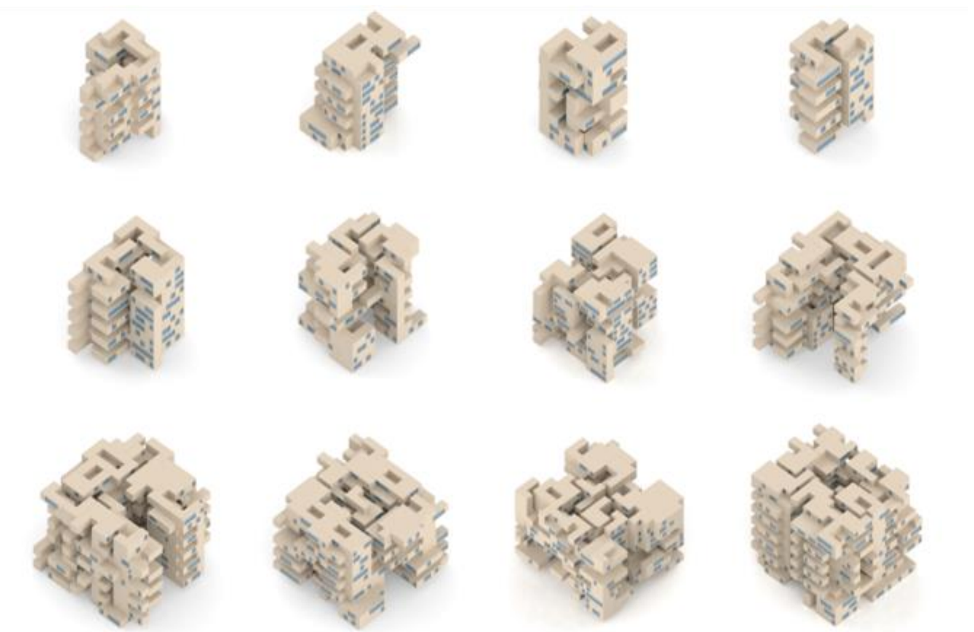
Digital thread

BIM Model of operations, maintenance, adaptability…

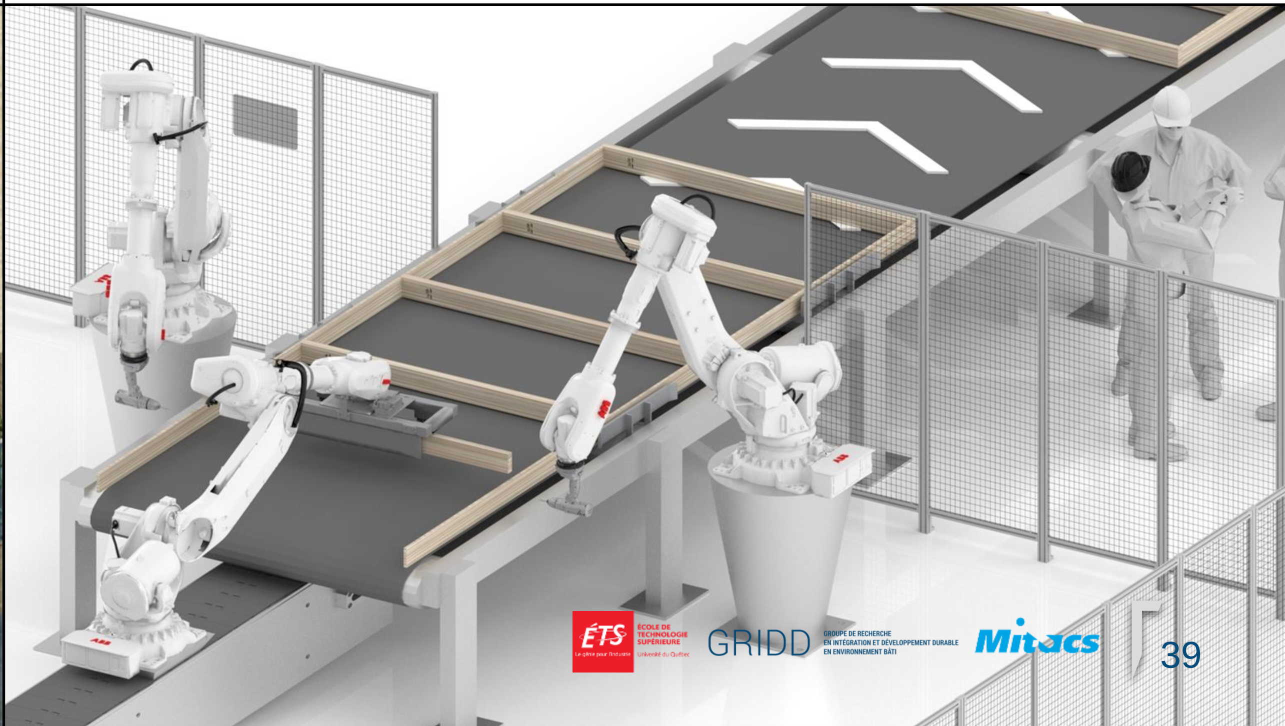


https://hexaware.com/wp-content/uploads/2023/08/POV-Digital-Thread-The-Digital-Twin-to-Realize-Game-Changing-Products_V3_compressed.pdf





Source: Anane, 2022



Educate the ‘change agents’ of the future

SHORT PROGRAM IN BIM (MASTER’S LEVEL)

SPECIALIZED DIPLOMA IN BIM AND DIGITAL INNOVATIONS (MASTER’S LEVEL)

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GRIDD GROUPE DE RECHERCHE EN INTÉGRATION ET DÉVELOPPEMENT DURABLE EN ENVIRONNEMENT BÂTI

SUSTAINABLE PLACES 2024

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Thank you!

Merci!

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AI FOR SMART CITIES

TESTING AND EXPERIMENTING AI SOLUTIONS

September 2024
Pascal LHOAS

AGENDA

01 The CitCom.ai project

02 The Luxembourg TEF Site

03 Luxembourg TEF services

The CitCom.ai project

#01

SUSTAINABLE PLACES 2024

THE CITCOM.AI PROJECT

CitCom AI

In a nutshell

Digital Europe Programme

€40 million budget

5 years

Jan. 2023 – Dec. 2027

36 partners

11 countries

CitCom.ai aims at facilitating the uptake of AI in Europe, by bringing trustworthy AI services to smart cities more efficiently.

35 partners, covering 11 countries are gathered to design a Testing and Experimentation Facility (TEF) for AI in the field of smart cities.

WHAT IS A TEF?

TEFs are large-scale reference testing and experimentation facilities, combining physical & virtual facilities, bringing support to technology providers to test & experiment AI solutions in real-world environment.

Goals:

- Bring trustworthy AI to the market more efficiently
- Facilitate AI uptake in Europe
- Contribute to the implementation of the AI act

Characteristics

- Scope : AI & robotics
- World-class reference sites
- Networked
- Combining physical & virtual facilities
- Open to all technology providers across Europe (>TRL 6)
- Offering permanent & sustainable services

THE CONSORTIUM & RELATED TOPICS

COORDINATOR University Aarhus

WITH SUPPORT FROM OASC, EuroCities, Enoll and Fiware

WITHIN THE CONTEXT OF living-in.eu initiative

+25 PARTNERS IN 3 THEMATIC SUPER NODES

NORDIC

POWER

Climate and sustainable environment

- Energy
- Environmental solutions
- Cyber, Ethics, Edge

University Aarhus

CENTRAL

MOVE

Logistics and mobility

- Urban M&L algorithms
- Smart Interesection
- **Electromobility**
- Autonomous driving

IMEC

LIST
SIGI

University G Eiffel
UTAC

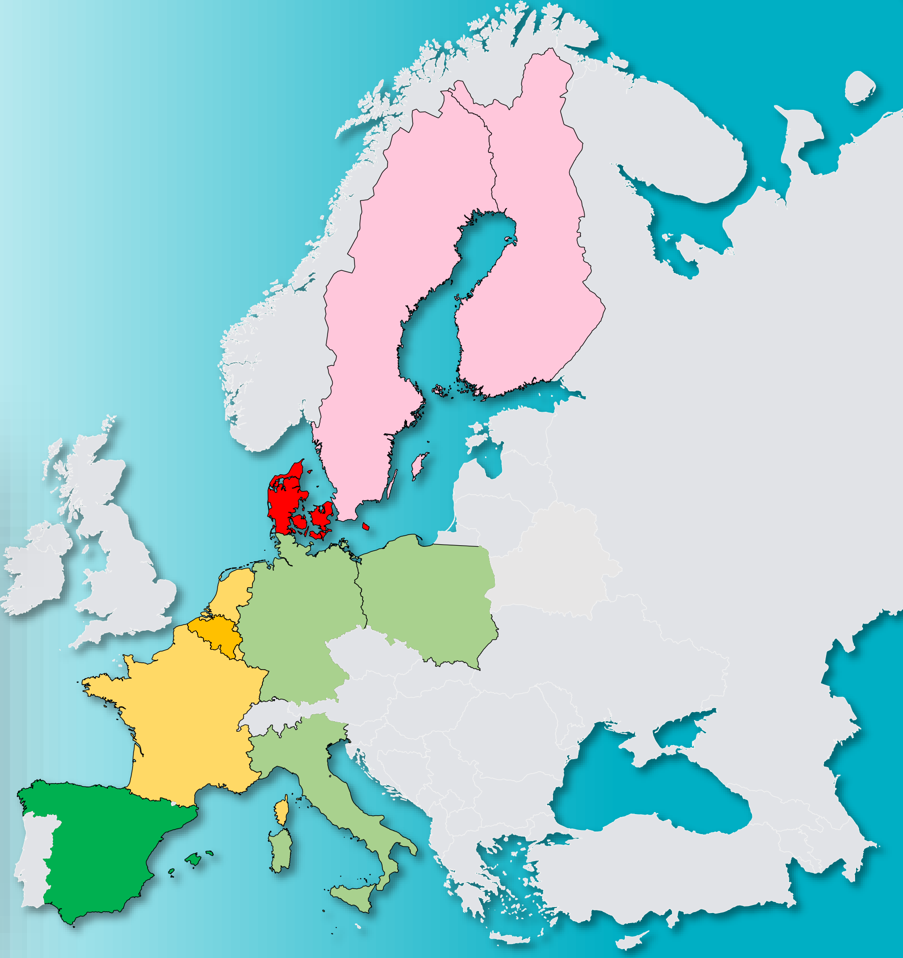
SOUTH

CONNECT

Local infrastructures

- Pollution, GHG, noise
- Urban development
- Water and water-waste
- Facility
- Drone delivery
- Tourism

Università Politecnica Valencia



DIGITAL EU CITCOM.AI

Luxembourg TEF site

#02

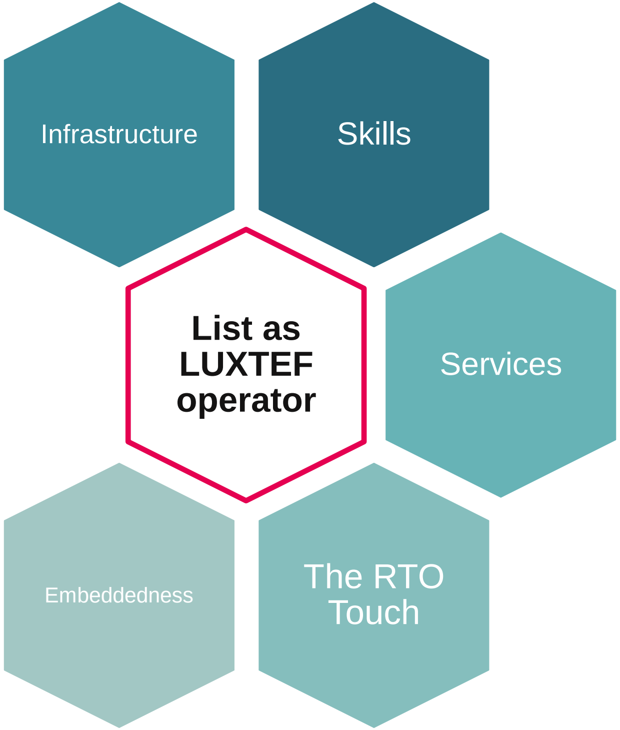
SUSTAINABLE PLACES 2024

MISSION STATEMENT

The CitCom.ai TEF site in Luxembourg (LUXTEF) focuses on electromobility, which plays a crucial role in the decarbonization of cities, and the reduction of air and noise pollution. Further to the national context, we aim at bringing trustworthy AI services to smart cities and communities more efficiently and facilitate their uptake and adoption all over Europe.

LIST AS LUXTEF OPERATOR

The backbone of the Testing and Experimentation Facility (TEF) of Luxembourg is a unique combination of hardware, software layers and competences to supports AI Innovators and businesses in prototyping, testing, and experimenting tailored AI solutions, making the most of the wealth of the data using most relevant machine learning and human-in-the-loop.



LIST AS LUXTEF OPERATOR

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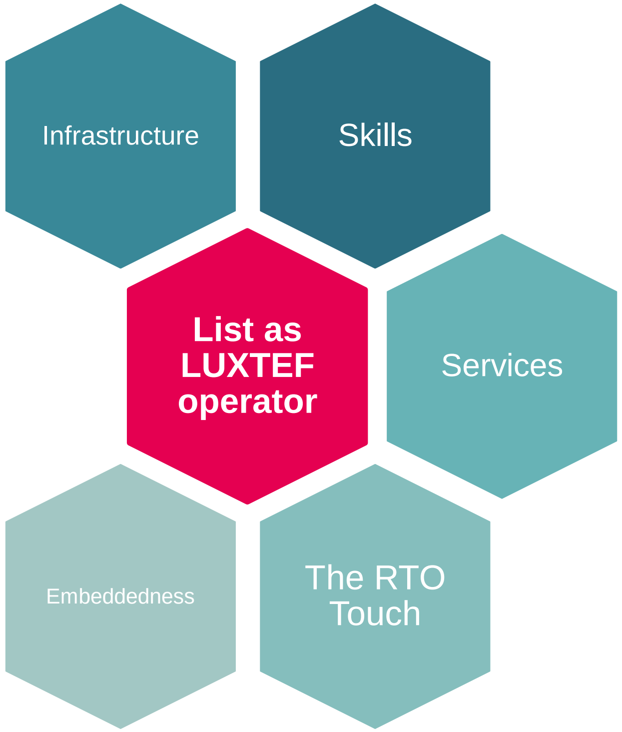
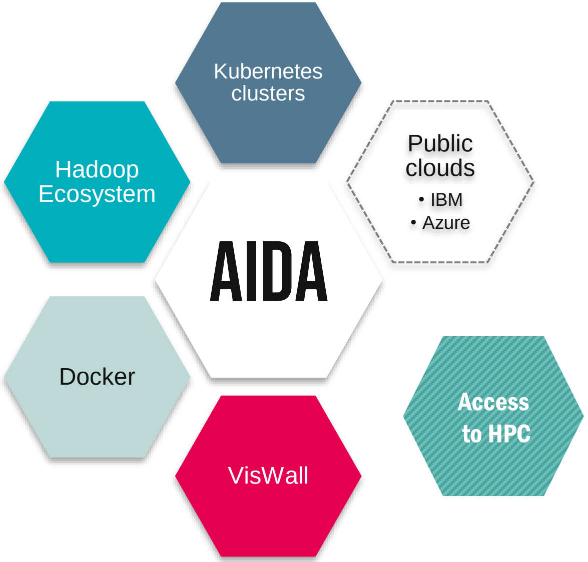


AIDA RESEARCH AND TECHNOLOGY INFRASTRUCTURE

A versatile toolbox for Artificial Intelligence and High-Performance Data Analytics



Hardware

GPU powered computing clusters hosted & operated by LIST

Software

Open-source + proprietary data analytics & AI stacks

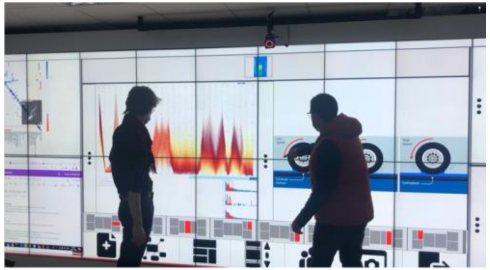
Latest capabilities in Data Analytics (IBM Cloud Pak, Hortonworks, Hadoop…)

from beginner to expert user

Cloud services

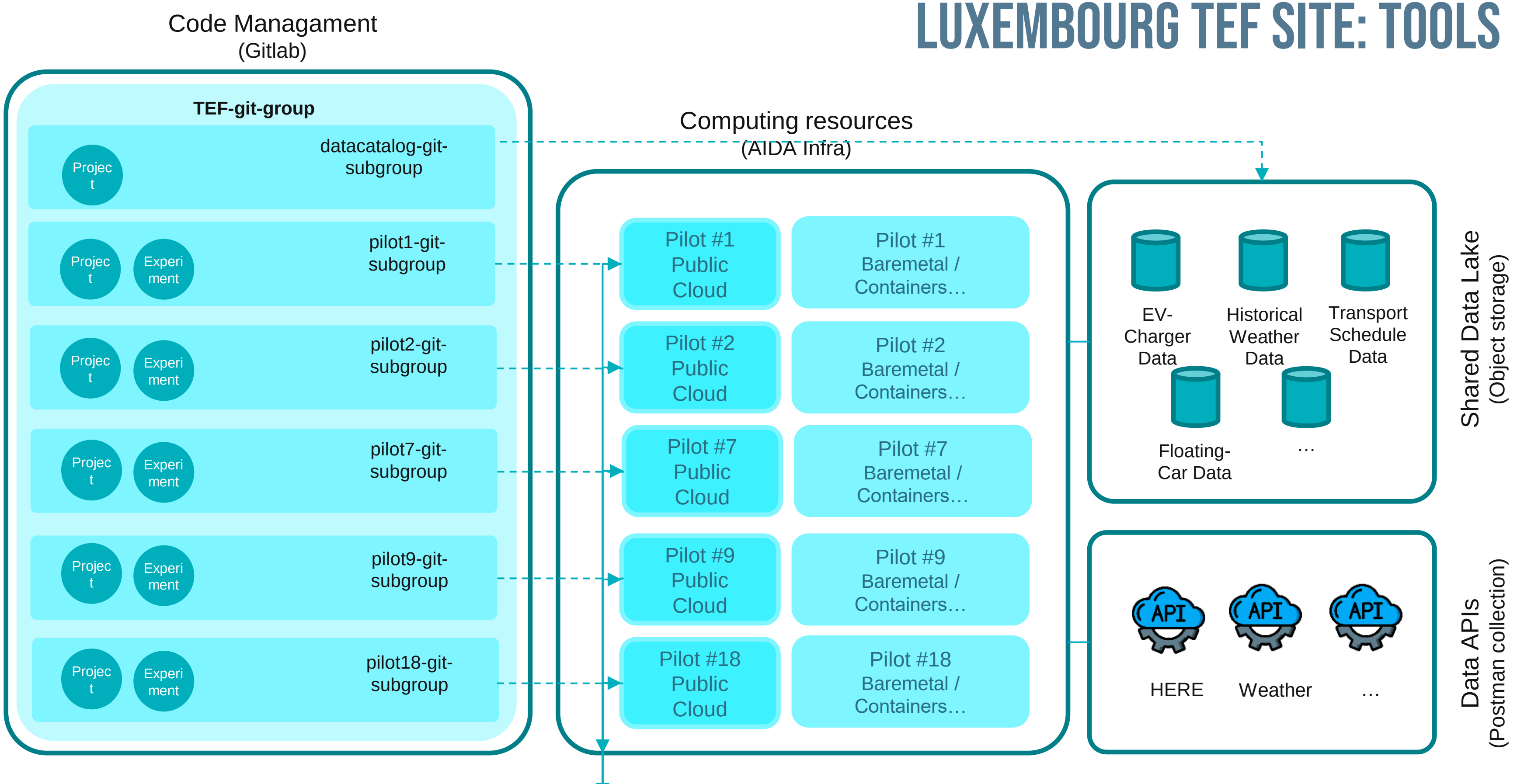
EUROPEAN UNION
European Regional Development Fund

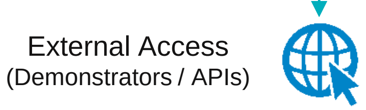
VISWALL



Large-Scale visualisation for collaborative decision making

LUXEMBOURG TEF SITE: TOOLS



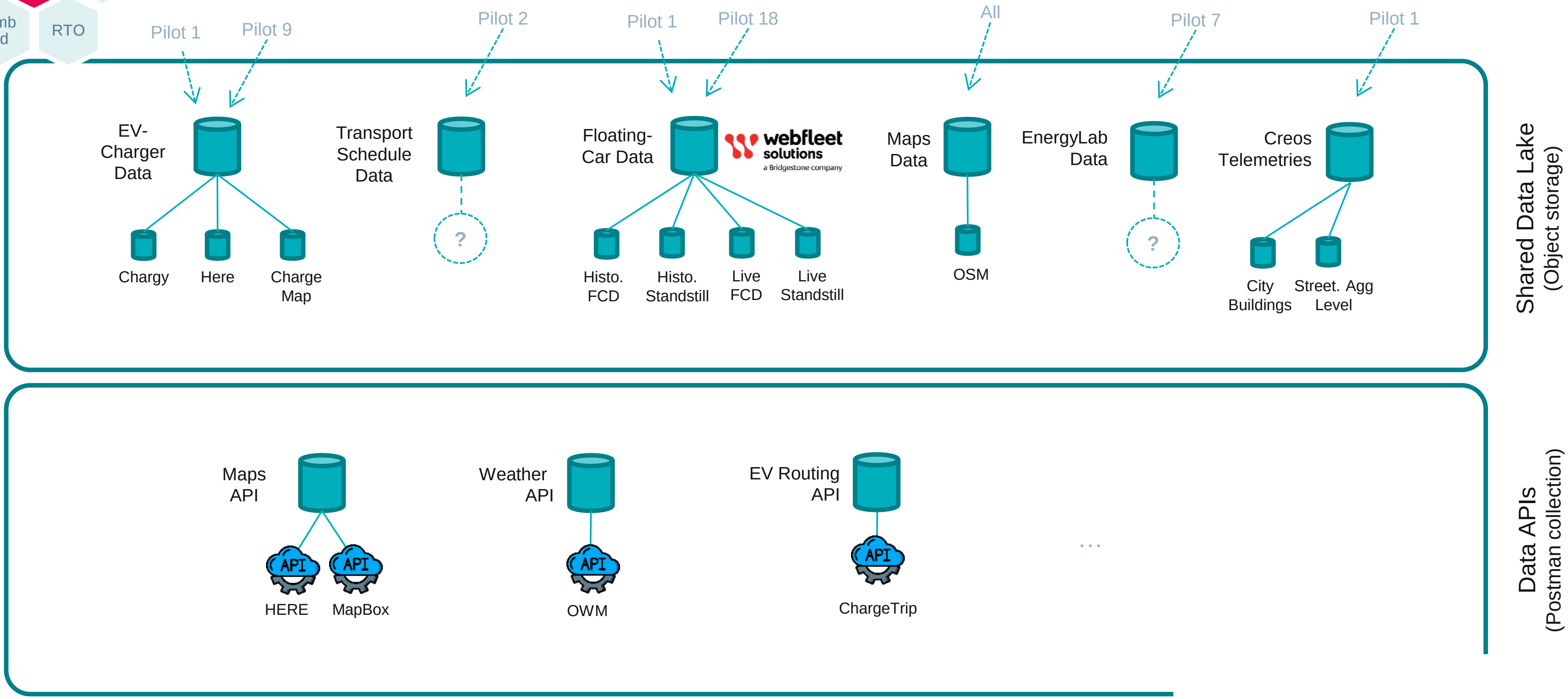


Sandbox for each pilot experimentation of services

Basic kit : 300 Gb storage, accessible from H cluster (bare metal with GPU, ssh access to Ubuntu & python) and Docker cluster (GUI accessible from Portainer).

Dedicated ticketing service: https://forge.list.lu/projects/aida-support/issues/new

LUXEMBOURG TEF: AVAILABLE DATA



LIST WIDE RDI EXPERTISE

RDI EXPERTISE ...

Data visualisation

Natural Language Processing

Optimisation

Computer Vision (ML powered)

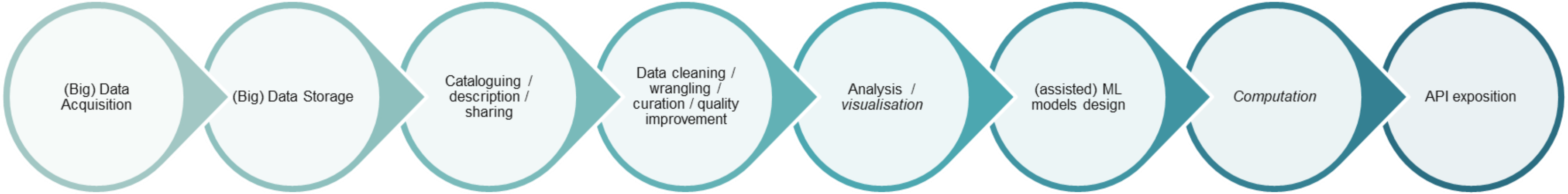
Time series analysis

Signal processing

Streams analytics (real time)

Machine Learning

...COVERING THE SCOPE OF DA/AI



SUPPORTED BY TECHNOLOGICAL EXPERTISE

Supporting user experience of our services

Accelerating the development of “rapid prototypes”

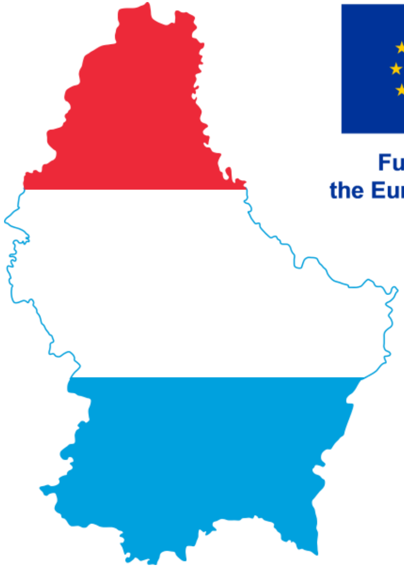
Providing “test before invest”

Improving the quality and reusability of the code produced by the LIST RDI experts

Facilitating TRL-raising of assets

EMBEDDEDNESS

Luxembourg and EU research and innovation ecosystem



Funded by the European Union

LUXEMBOURG DIGITAL INNOVATION HUB
Member of EDIH European Digital Innovation Hubs Network

Smart and sustainable cities and communities

OPEN & AGILE SMART CITIES

Ville de Differdange

Mobility

TICE

CityMoS

SVO

DATATHINGS

Infra
Skills
TEF
Serv
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Emb
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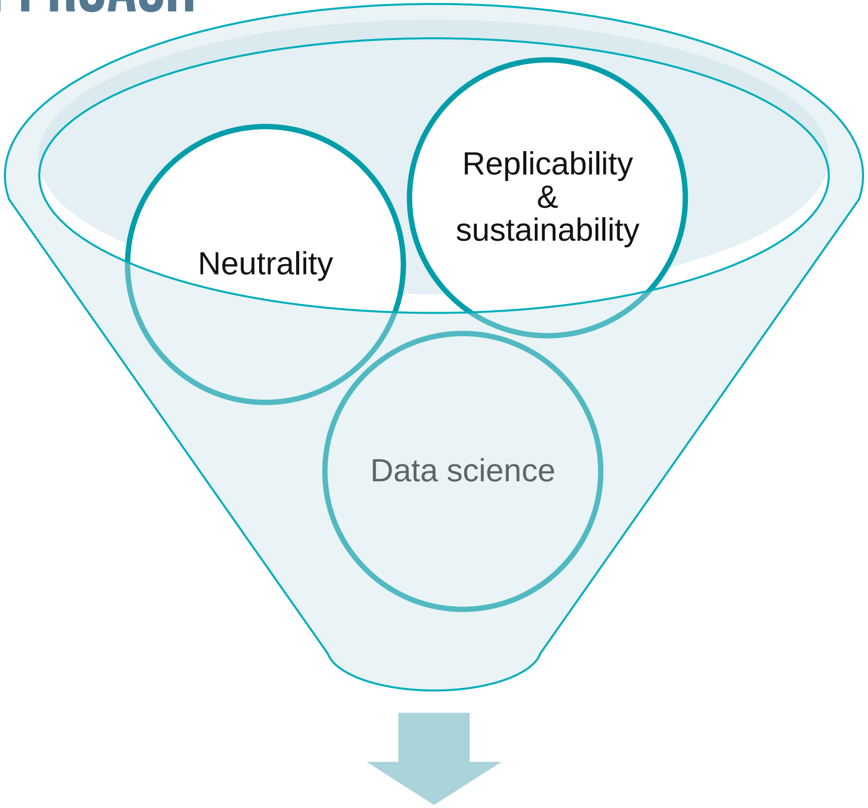
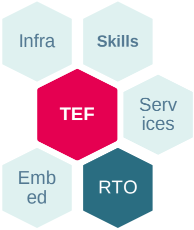
RTO

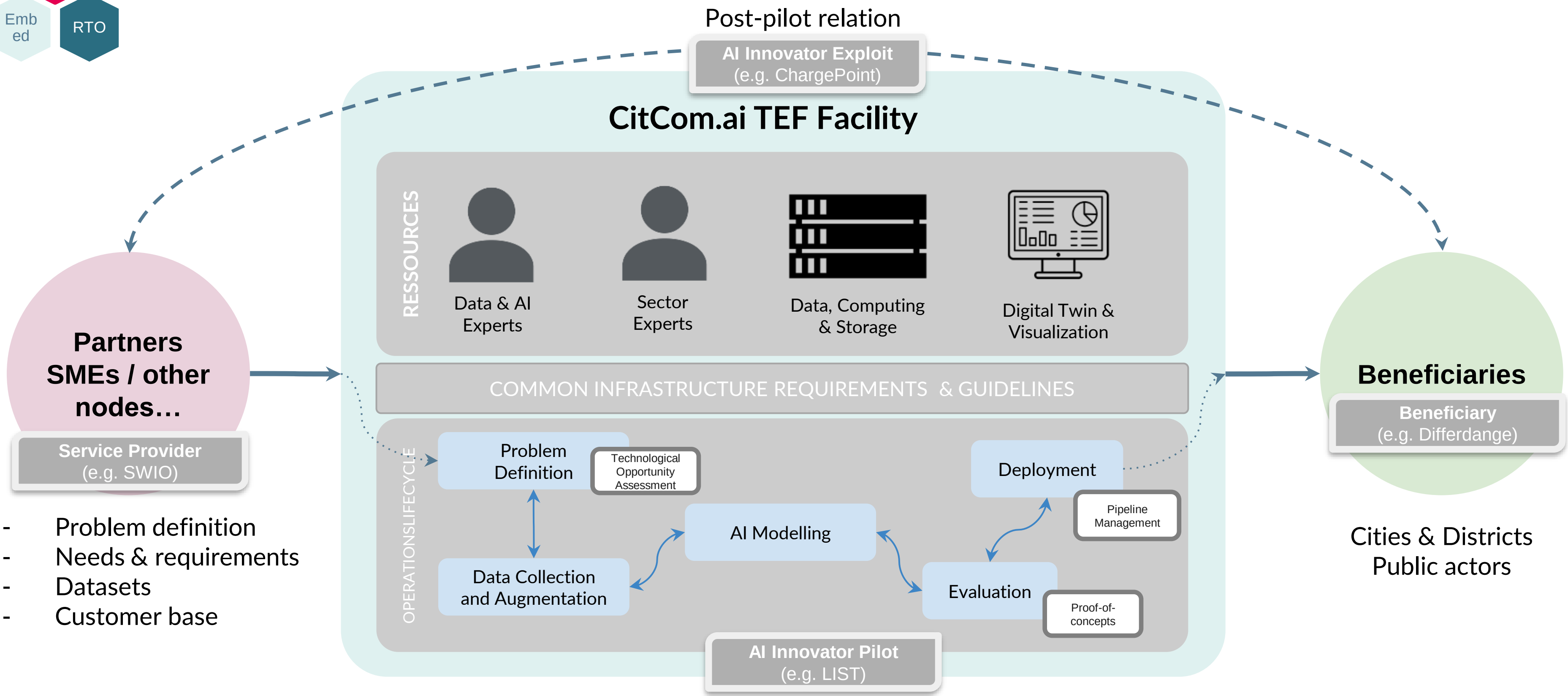
LIST, A RTO APPROACH



IMPACT & TRUST



LUX TEF POSITIONNING



- Problem definition
- Needs & requirements
- Datasets
- Customer base

Luxembourg TEF services

#03

SUSTAINABLE PLACES 2024

OUR SERVICE OFFER

Electromobility services are proof-of-concepts where AI innovators and cities come together to experiment with reusable technical assets aimed at advancing electromobility. These initiatives rely on developing replicable and scalable tools in the field of electromobility.

Transversal services provide essential support to AI innovators in the scoping and experimentation phases of their AI solutions for Smart and Sustainable Cities. These services encompass methodology and skills, enabling innovators to effectively develop and implement their AI-driven solutions in urban contexts.

TRANSVERSAL SERVICES – CUSTOMER JOURNEY

Expert guidance services helping you design & experiment the best suited approach

Scoping the best AI solution

Digital Opportunity Assessment for AI

3 workshops to draw the best AI approach to your needs, maturity and context (includes hands-on technology testing)

Digital Twin Scoping

3 workshops to draw the best DT approach to your needs, maturity and context (includes hands-on technology testing)

Co-designing tailored AI solutions

Exploratory Data Analysis

Expert analysis of your data fitness for purpose

Proof-of-Concepts

Tailored AI or DT prototype to validate feasibility and impact

Data-driven decision-making & change management

Large Scale interactive visualisation

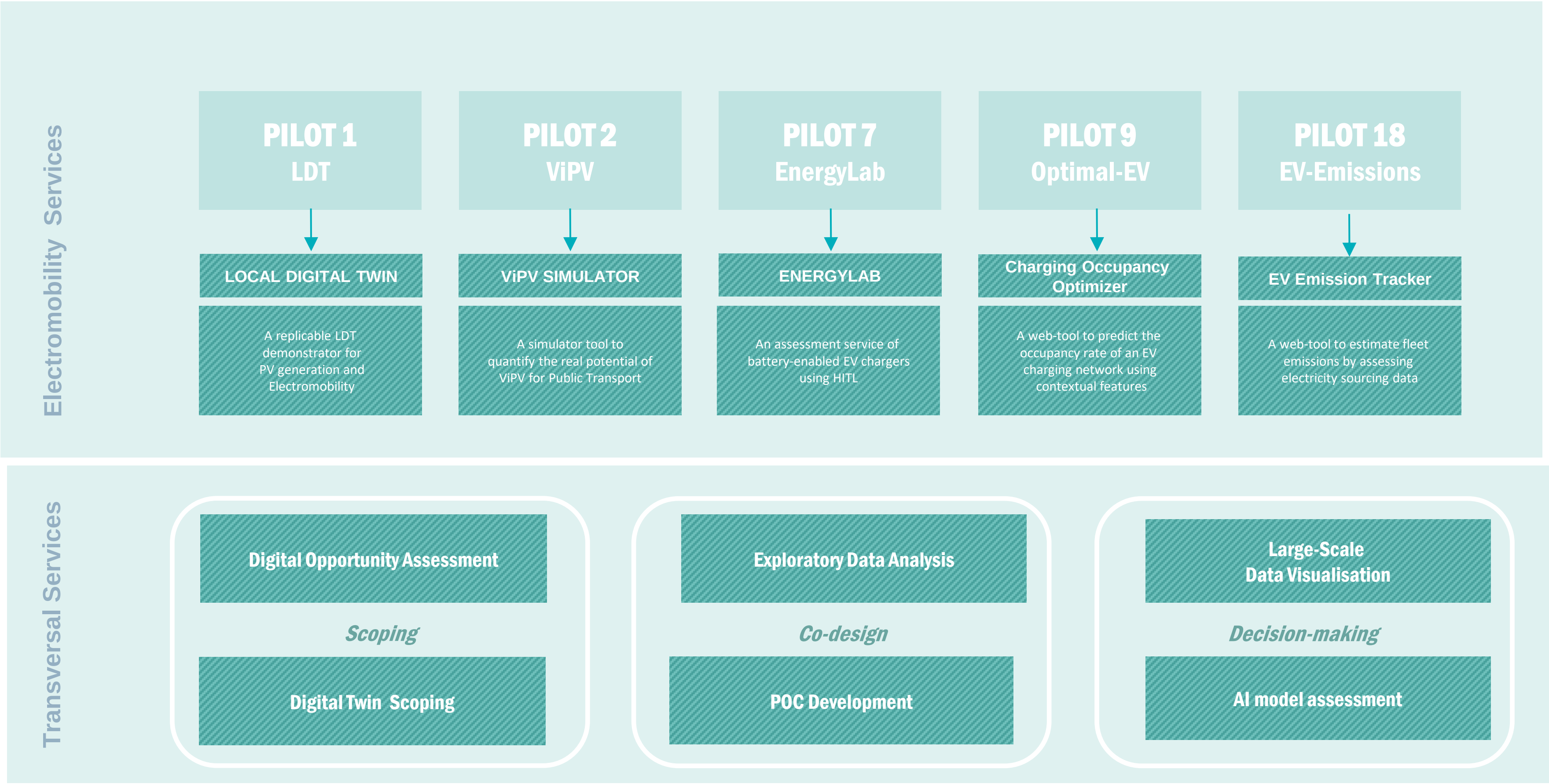
Share large scale simulations to engage in collaborative decision-making

AI assessment service

Assess your AI model for performance, fairness, bias and other metrics

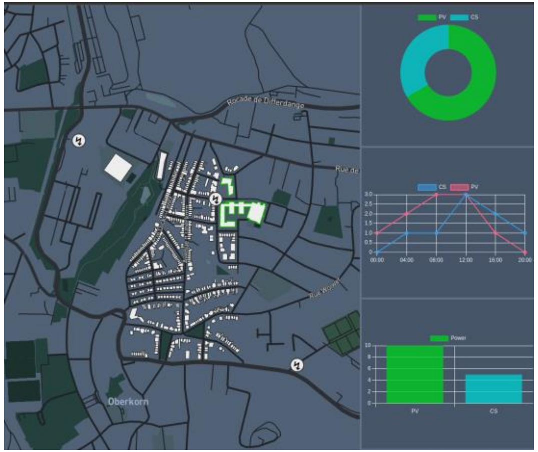
Level of (technical) maturity

ELECTROMOBILITY & TRANSVERSAL SERVICES



LOCAL DIGITAL TWIN

A true a replicable DT for electromobility



A true Digital Twin demonstrator tool for cities and districts using real mobility, built-up and grid data to allow the beneficiary to assess the impact of PV and EV-mobility scenarios in the energy balance. Cities interested in using the service will provide data about their current EV charging and PV generation infrastructure so that an instance of the Local Digital Twin can be deployed. Cities will be able to analyze the interplay between PV generation and EV-charging consumption patterns and simulate predefined what-if scenarios. Describe the experiment: what is the problem / opportunity context, how can artificial intelligence benefit the problem or take advantage of the opportunity and what is the desired goal.

Assessing the potential of solar energy for vehicle integration and fleet management

Quantify the potential production of photovoltaic energy, to support transportation or heavy-duty fleet operators evaluate the benefit of ViPV to reduce their carbon footprint and operational costs.

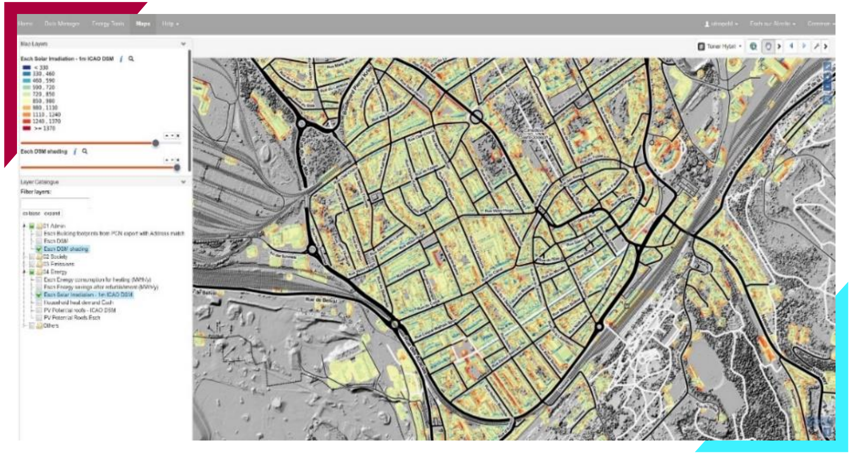
Represent any urban infrastructure and other 3D objects

Attributes of surfaces:

- Textures
- Optical properties (e.g. albedo reflectivity, transmissivity)
- other cadaster information…

Compute Solar irradiation for all required

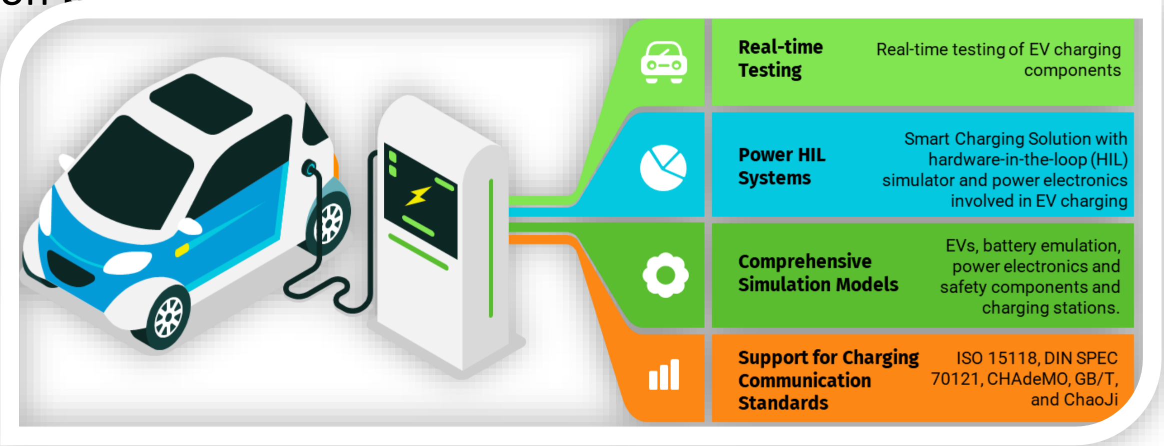
locations accounting for shading from surroundings



ENERGY LAB

An assessment service of battery-enabled EV chargers using HITL

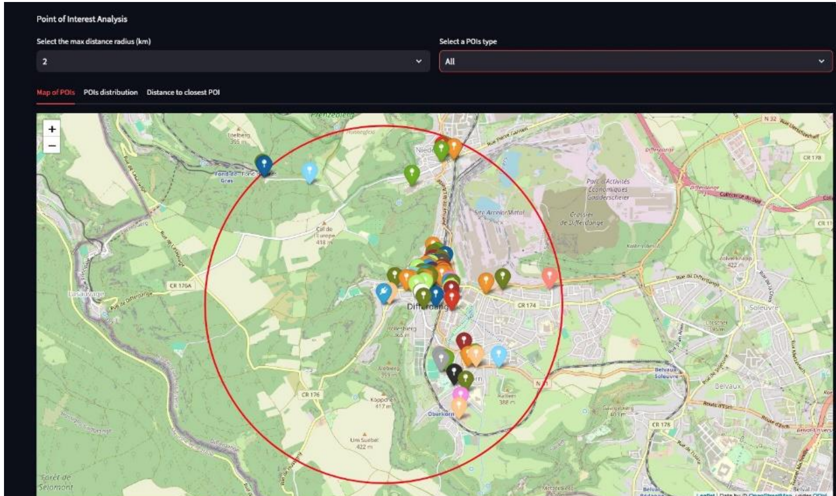
The **energy lab** helps assessing the performance of a charger in real conditions to be used by a public charging service provider to have quality checks of their charging networks in a real scenario. The service will get access to real-time data from the EV chargers already installed by the partner (for example, connecting remotely to the EV chargers in their backend) and provide high-resolution predictions about their usage in a consolidated dashboard.



OPTIMAL EV

Optimising charger occupancy

With this platform that locates charging stations and monitor their usage (including detecting anomalies), public charger providers can predict the occupancy rate at a given pricing of new charger based on AI-models on historical data from chargers and assess the optimal location of new charging infrastructure.



CLEAN FLEET : EV EMISSION TRACKER

Driving sustainable decisions

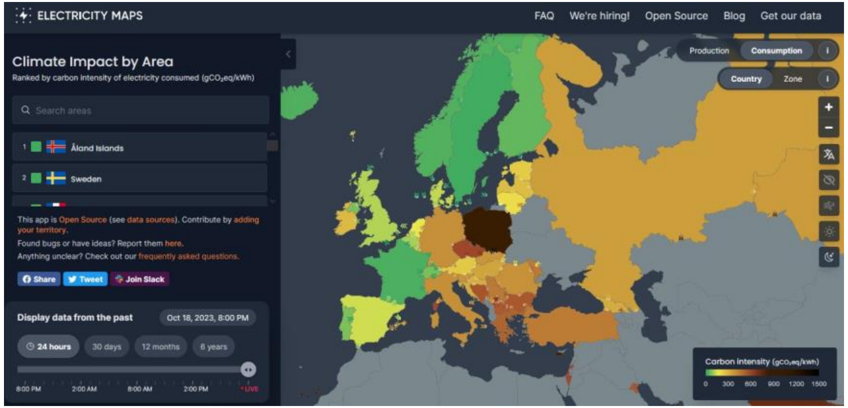
Provides comprehensive environmental insights for fleets, addressing **CO_2 emissions** but also **material usage** or **primary energy footprint** for a life cycle perspective.

1. Real-time Data Insights:

- Live "CO_2 counter" offering accurate fleet emissions data.
- Dashboard for tracking progress and making informed decisions.

2. Decision-making Tool:

- Test fleet renewal scenarios based on demand, budget, and environmental impacts.
- Embedded Total Cost of Ownership (TCO) calculations for smarter budgeting.



DIGITAL OPPORTUNITY ASSESSMENT FOR AI

3 steps to the best-suited Data Analytics proof of concept

Exploration Workshop

Map business challenges, data & DA/AI techniques

2-4 hours workshop to identify use cases

Capacity Workshop

Assess partners DA/AI readiness

2-4 hours workshop to specify the approach

Hands-on Workshop

Discover the technologies & start to use with own data

2-4 hours hands-on workshop + remote work + consolidation meeting

You get:
A development for a tailored POC


EXCELLENCE
FOR IMPACT
LIST.lu
Contact : tef@list.lu