Refurbishment of historic buildings at a district scale: *Enhancement of cultural value and emission reduction potential*

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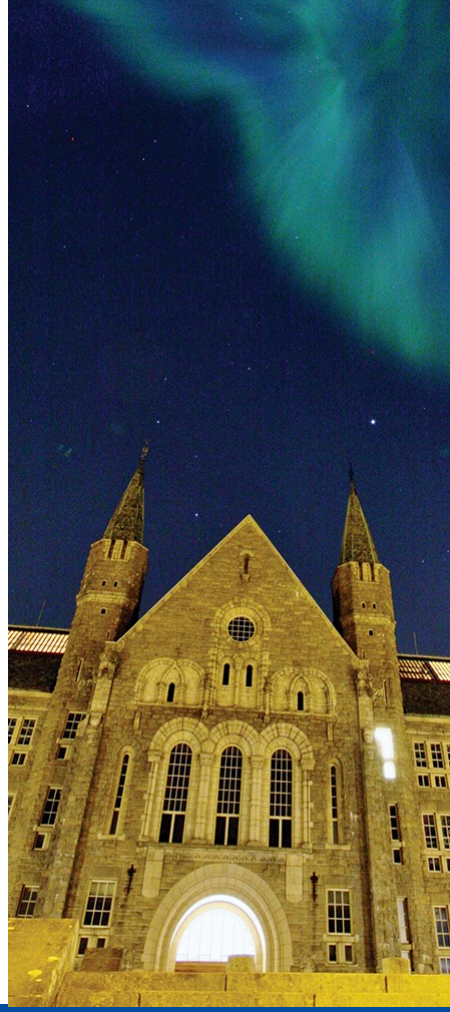


1.a) Importance of intervention

Why is it important to intervene in historic urban districts?

1) As part of existing buildings, their improvement plays a significant role towards decarbonised and climate resilient society.
2) They hold a substantial value in providing a sense of identity to the cities and the community.
3) Due to their relatively older age, they show the highest ratio of living discomfort to the inhabitants.

1.b) Historic building

1) Single manifestation of immovable tangible **cultural heritage in the form of an existing building** (*Note 1 to entry: A historic building does not necessarily have to be a heritage-designated building*)

(EN 15898:2011 Conservation of cultural property - Main general terms and definitions)

2) Apart from some very valuable historic buildings (the so-called monuments), we find a large number of buildings in European towns and cities which are far **less important from a historical and architectural point of view**. **However, these buildings, taken as a whole, represent an important part of heritage**.

(COST Action, C5 – Urban Heritage – 2001)

2.a) Involved stakeholders

Three main groups of interest

Challenges

- Interdisciplinary research and wide range of required expertise
- The affected groups of interest attempt to make decisions in their favour and the collaboration among different stakeholders seems complicated
- Lack of an integrated framework covering the different perspectives
- The improvements are based on the operational phase and are primarily focused on energy efficiency solutions

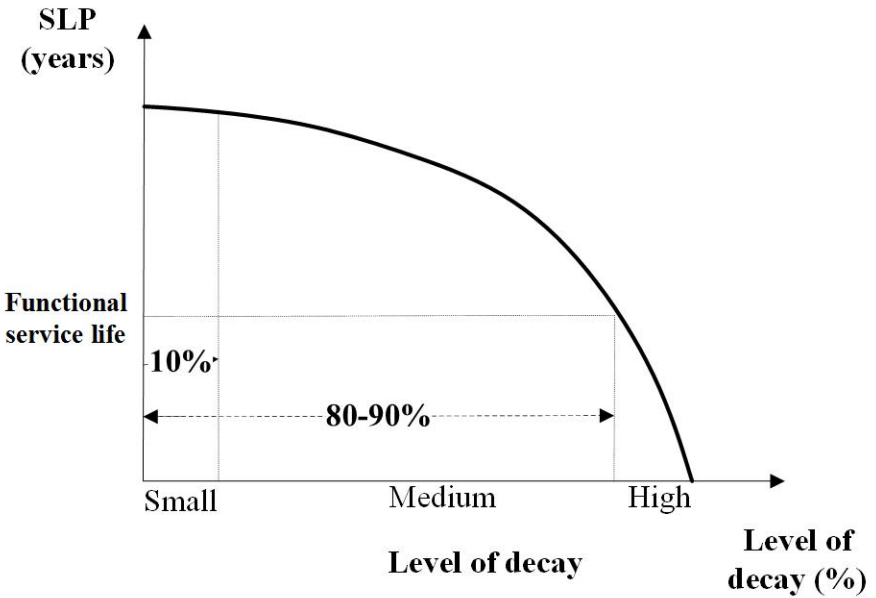
2.b) Decay assessment of materials and components

- Estimation of service life (SL) of materials and components using methodologic approaches e.g. the factor method

$$ESL = RSL \cdot f_A \cdot f_B \cdot f_C \cdot f_D \cdot f_E \cdot f_F \cdot f_G$$

ESL – Estimated Service Life
RSL – Reference Service Life
$f_A \div f_G$ – Correcting factors

- Link between SL and level of decay



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2.c) Historic value assessment

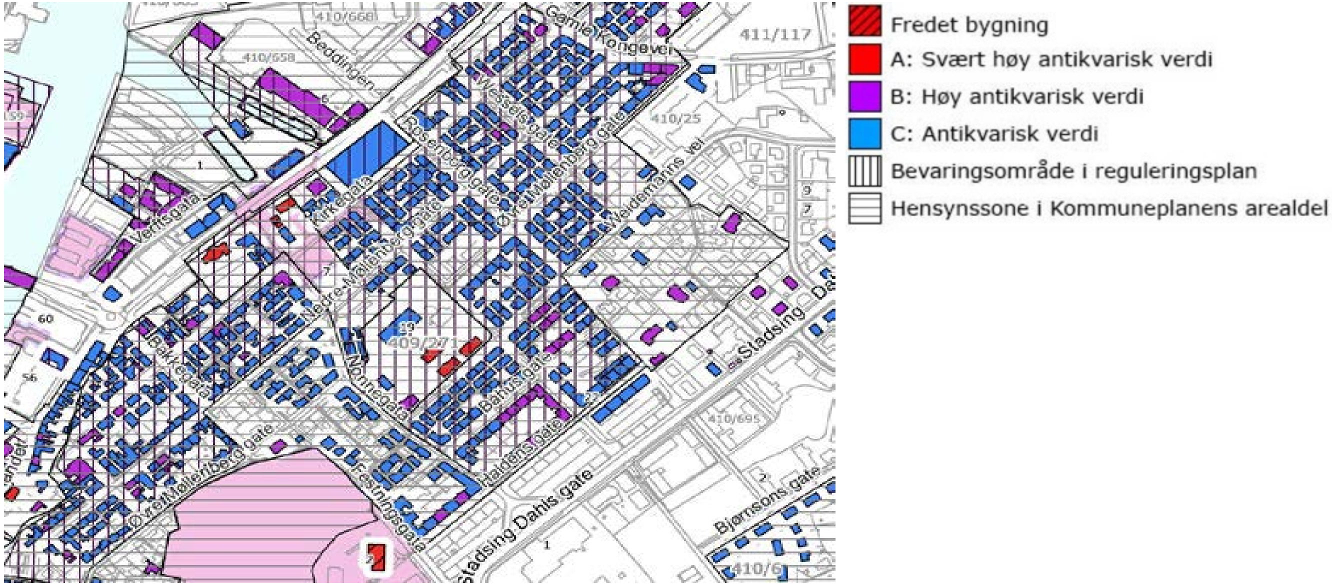
- **Cultural Heritage**
  - Categorisation

Level	Institution responsible	Legal basis
National	the Directorate for Cultural Heritage (Riksantikvaren)	the Cultural Heritage Act (Lov om kulturminner)
Municipal	Local government	the Building and Planning Act (Plan- og bygningsloven)

  - Every municipality in Norway can list the cultural heritage inside the municipality and can create its own marking system which is developed from the Cultural Heritage Management Office (Byantikvaren).

2.c) Historic value assessment

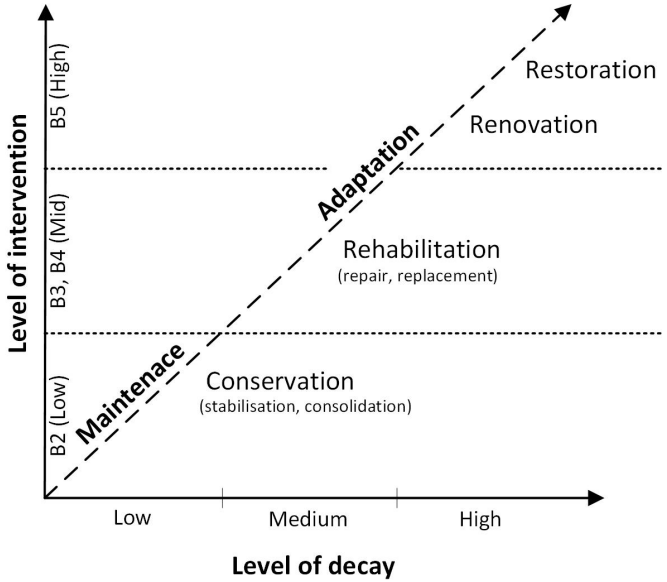
- **Trondheim municipality**
  - Apart from the listed buildings (marked with F), there is a large number of protected buildings (Vernet) categorised in three main groups (A, B and C)



2.d) Environmental assessment

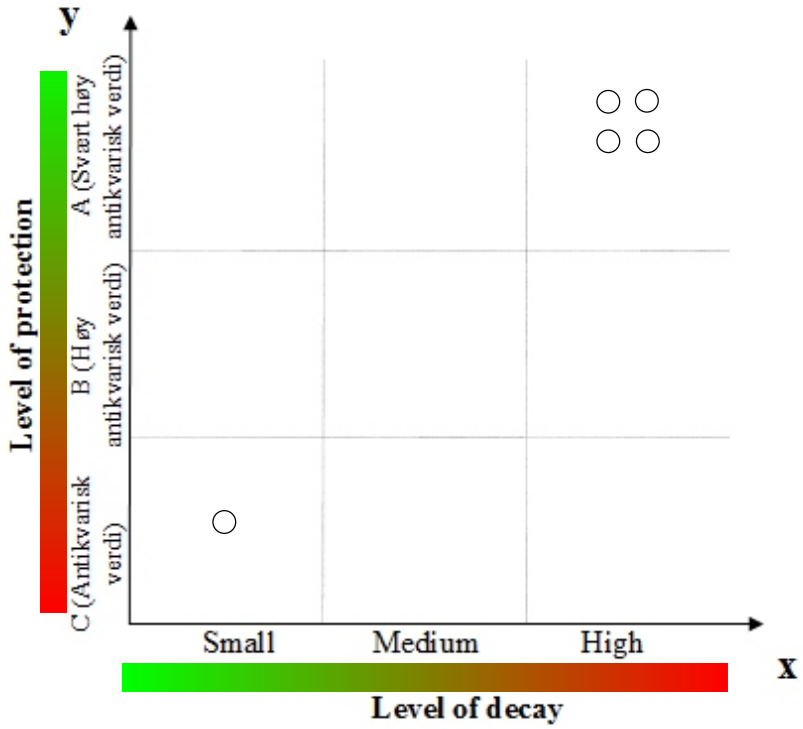
– For intervention processes, the calculation of the emissions is performed for modules B2-B5 according to the EN15978:2011:

A1-3			A4-5		B1-7							C1-4				Beyond the life cycle
PRODUCT STAGE			CONSTRUCTION STAGE		USE STAGE							END OF LIFE				Benefits and loads beyond the system boundary
A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D
Raw material supply	Transport	Manifacturing	Transport	Construction installation process	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction demolition	Transport	Waste processing	Disposal	Reuse-Recovery-Recycling potential



3.a) 2D matrix of combination

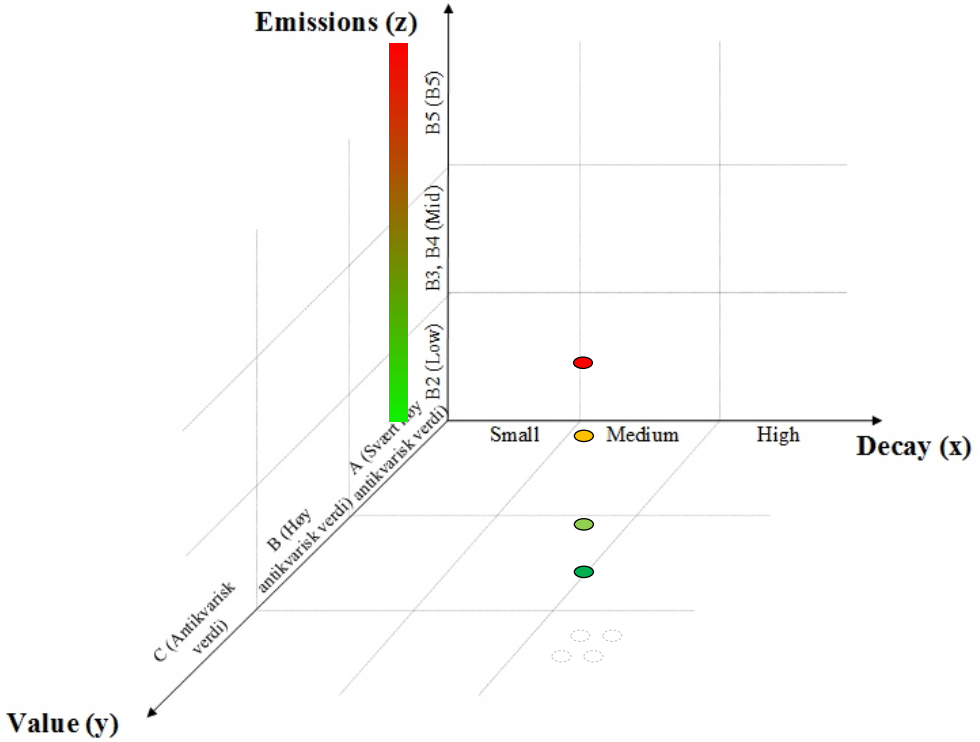
- Main focus will be given to external components such as outer walls, windows, roofs.
- The results of the decay and historic assessments (which are independent of each other) are combined in a 2D diagram.
- Each cell contains 1m^2 of wall/window/roof together with the intervention scenario(s) that fulfil both the requests



3.b) 3D matrix of combination

- When more than one scenario is recommended, the most appropriate intervention scenario is selected in accordance with its environmental impact.

- The emissions are calculated for one unit level of 1m^2 and then for building level or directly to neighbourhood scale.

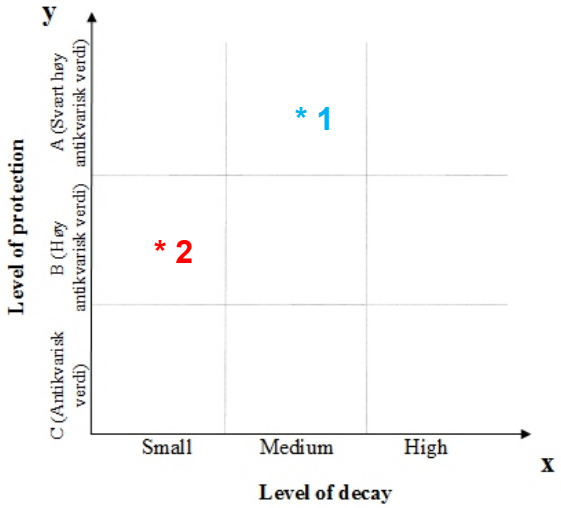


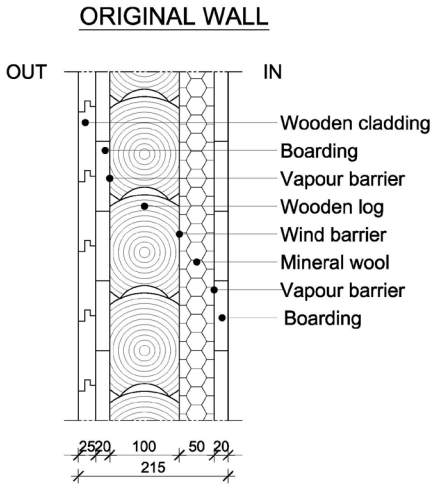
3.c) Example of application

1)

2)

Building	Class of protection	Level of decay
1	C – antikvarisk verdi	Medium (ESL ≈ 35 years)
2	B – høy antikvarisk verdi	Small (ESL ≈ 62 years)





$U = 0.32 W/(m^2K)$

$TEK17 \rightarrow U = 0.18 W/(m^2K)$

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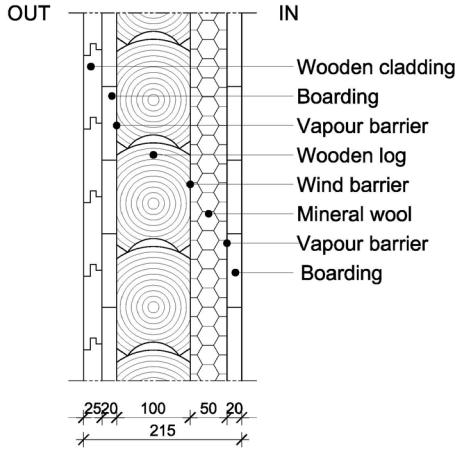
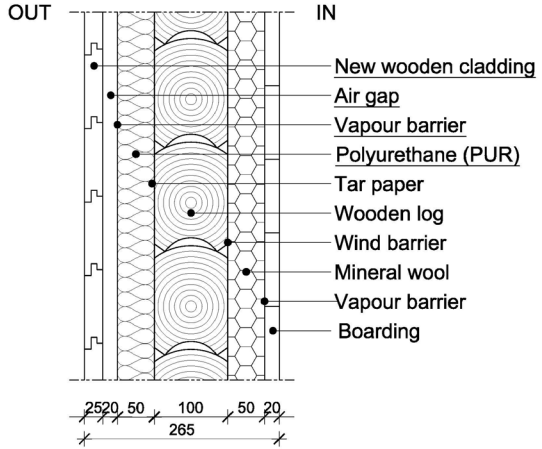
3.c) Example of application

- **Building 1**

ORIGINAL WALL



SCENARIO 1



$U = 0.16 W/(m^2 K)$

$$E = E_{(p)} + E_{(t)} + E_{(i)} + E_{(eol)} = 19.17 + 0.64 + 0.23 + 2.45 = 22.49 kgCO_{2eq} / m^2$$

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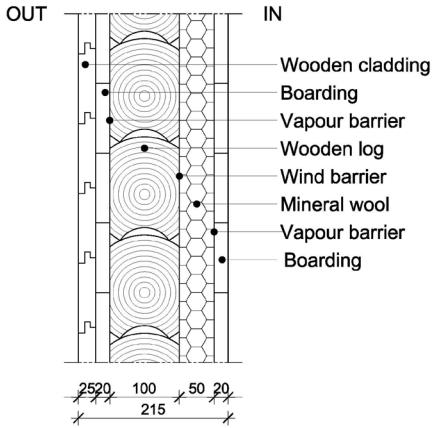
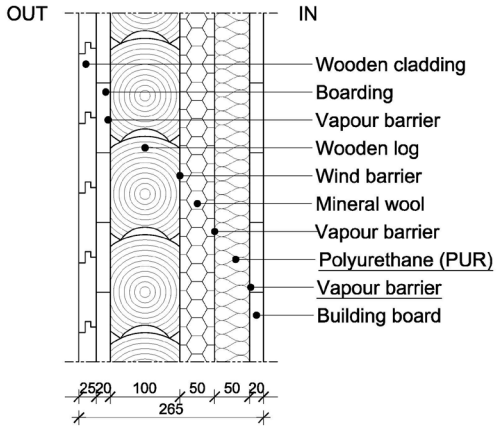
3.c) Example of application

- **Building 2**

ORIGINAL WALL

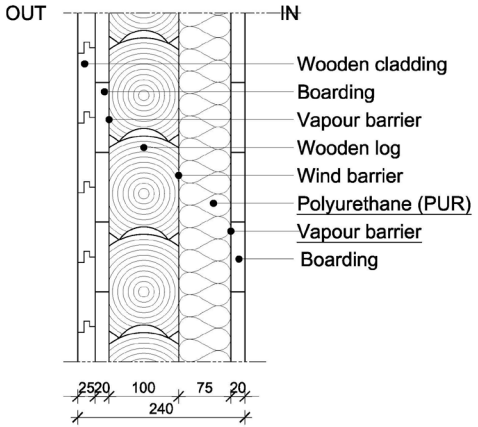


SCENARIO 1



$U = 0.179W/(m^2K)$

SCENARIO 2



$U = 0.179W/(m^2K)$

$$E_1 = \left[E_{(p)} + E_{(t)} + E_{(i)} + \cancel{E_{(eol)}} \right]_1 = 5.70 + 0.14 + 0.08 = 5.92 kgCO_{2eq} / m^2$$

$$E_2 = \left[E_{(p)} + E_{(t)} + E_{(i)} + E_{(eol)} \right]_2 = 8.65 + 0.14 + 0.12 + 3.55 = 12.46 kgCO_{2eq} / m^2$$

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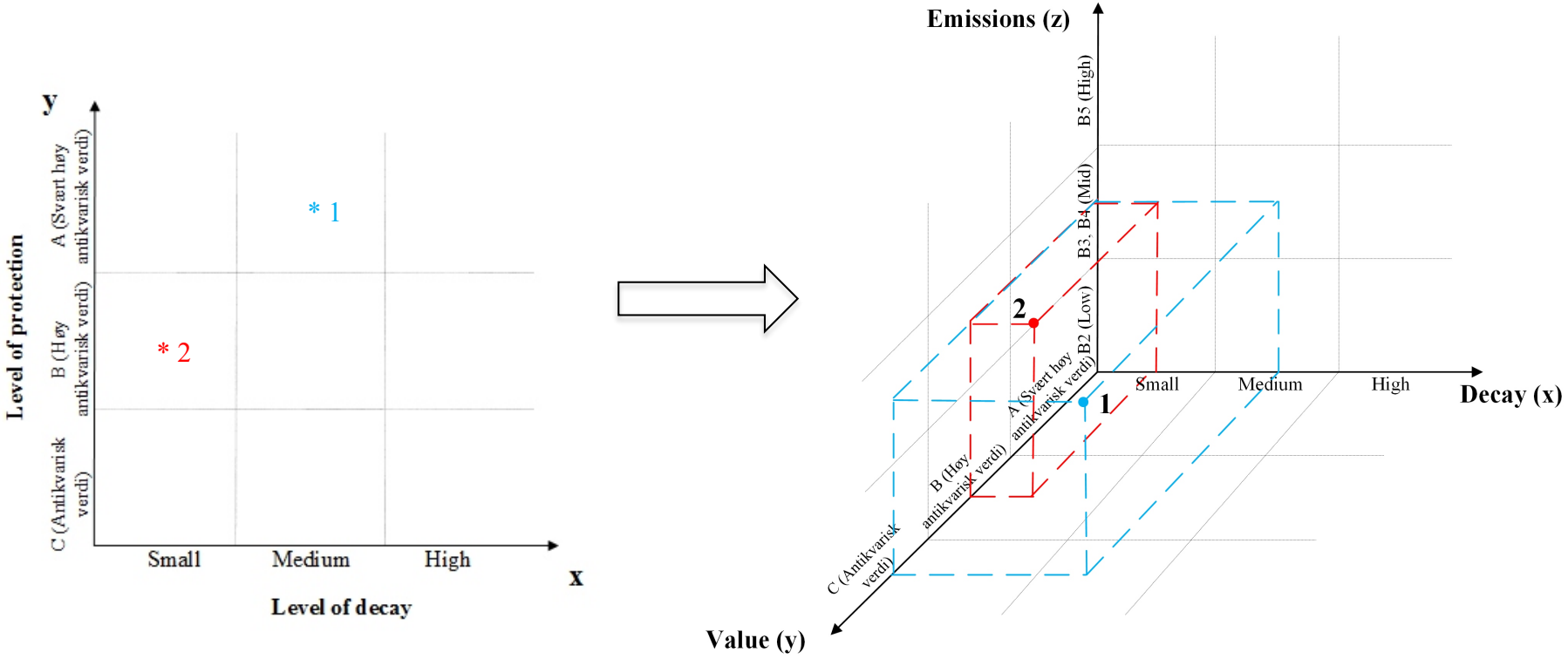
3.c) Example of application



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4. Discussions and conclusions

- In the 3D matrix, the results of each community remain independent and the recommendations of each of them are taken into account.

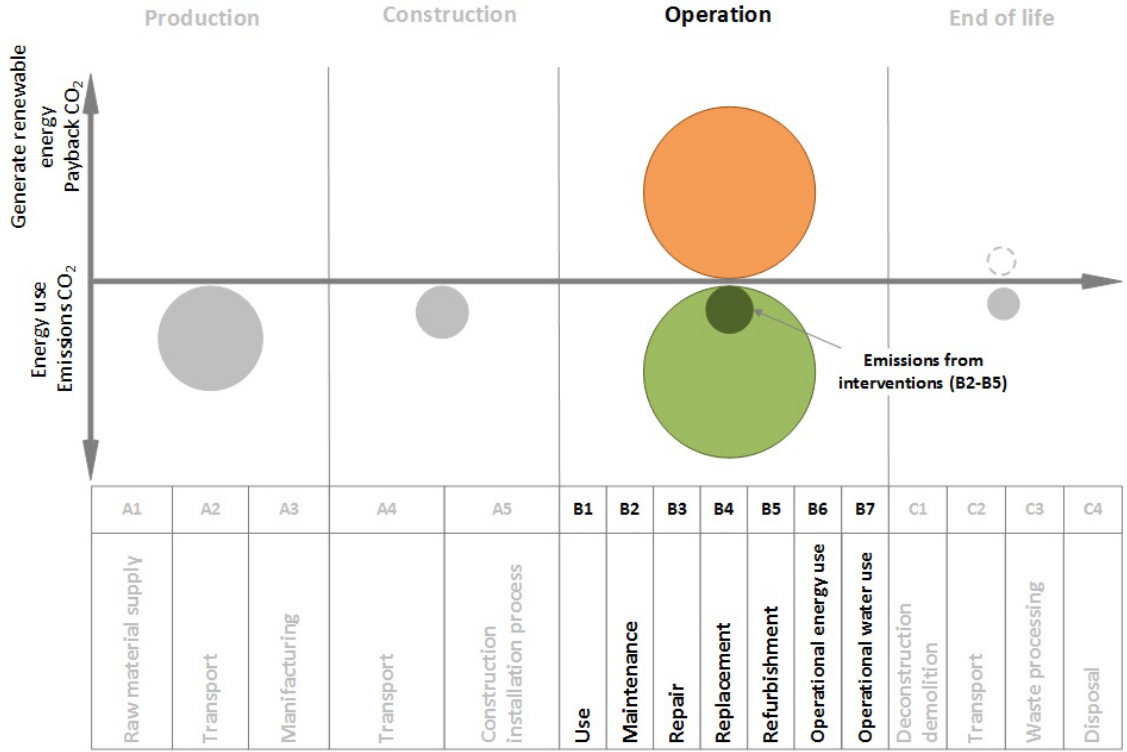
- The proposed framework does not treat the buildings individually, but it gives suggestions on a neighbourhood scale.

- The extension reflects the refurbishment needs for specific categories of buildings, mostly residential houses, which were neglected in the previous interventions as they were not holding memorable historic values

- The emissions of the intervention process, together with the energy efficiency reduction due to improvement, help to estimate the operational energy which serves as a base for the calculation of energy from the renewables, thus facilitating the move towards Zero Emission Neighbourhoods in historic urban areas.

4. Discussions and conclusions

- **ZEB balance for historic buildings**



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Thank you for your kind attention! ☺

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