IISA2024

Title: A Decision Support Tool for Aggregation and Prioritisation of Energy Efficiency Investments in Buildings

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Background (1/2)

HIGH

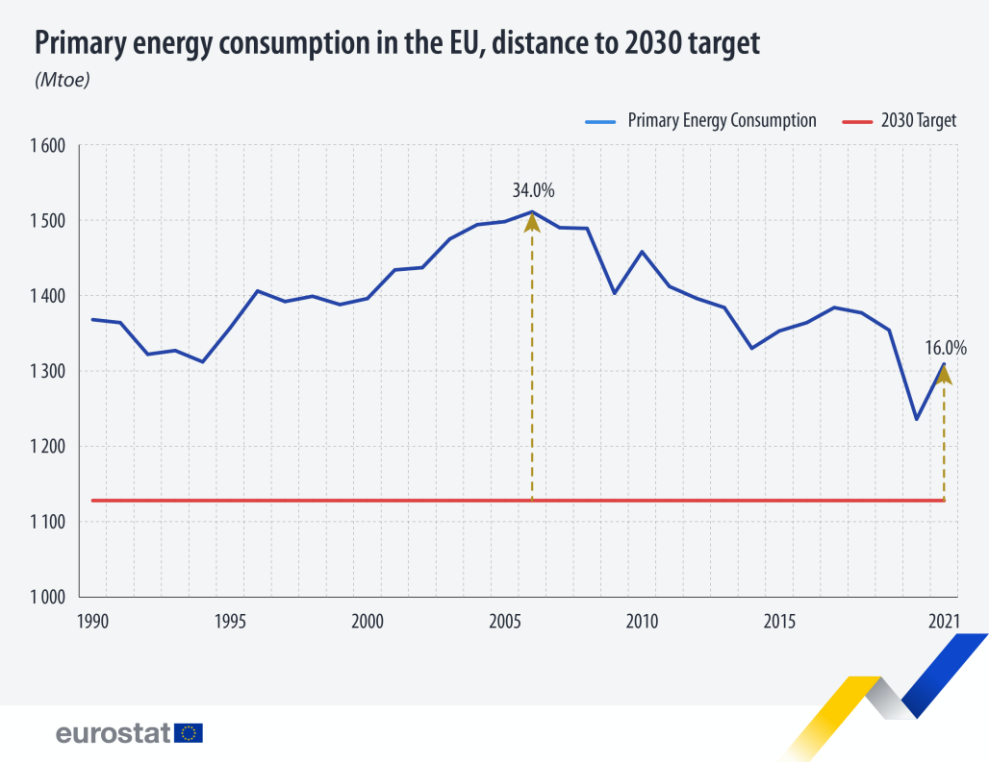
The building sector accounts for **40% of energy consumption** and **36% of GHG emissions** (European Commission, 2020)

The **untapped potential** of energy efficiency in the building sector is high (EIB, 2020)

EU firms give a low priority in **investments in energy efficiency** (EIB, 2020)

The **renovation rates** of buildings in the EU remain too low. The current rate of energy-renovation in the EU is 1% annually (BPIE, 2022)

LOW



Source: Eurostat, 2022

Background (2/2)

Building side VS Financial side

Needs

Building side
- Access to finance
- Technical expertise
- Simplified processes

Financial side
- Reliable data on EE projects
- Large financeable packages
- Project evaluation and risk assessment

Interests

Building side
- Energy and cost savings
- Property value enhancement
- Enhanced Comfort and Indoor Environment Quality

Financial side
- Investment Security
- Sustainable Investment Opportunities
- Portfolio Diversification

Barriers

Building side
- High upfront costs
- Complexity of procedures
- Lack of awareness and information

Financial side
- Perceived Risks
- Lack of Standardised Procedures
- Uncertain or weak economic environment

Need for **decision-making process, methodologies and tools** for EE projects financing, with **good quality and standardised data**

The ENERGATE project

ENERGATE
ENERGY EFFICIENCY MARKETPLACE

Smart energy marketplace for sustainable investments

January 2023 – December 2025

The ENERGATE vision

Enable easy, predictable and risk-weighted renovation investments

Project Partners:

Project Coordinator: EPU N·T·U·A

REHVA – Federation of European Heating, Ventilation and Air Conditioning Associations

enerbrain – For an intelligent use of energy

EnerSaveCapital

IEECP – Institute for European Energy and Climate Policy

GREENESCO Energy Services

Attica Finance

flexiwatt

SUSTAINABLE CITY – City Network

Global Green Growth Institute

Riga Planning Region

LDK Consultants

commuty

Project development of retrofitting actions

Access to sustainable finance for renovation projects

Business matchmaking in a user-friendly ICT-enabled platform

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The ENERGATE project – Scope of the study

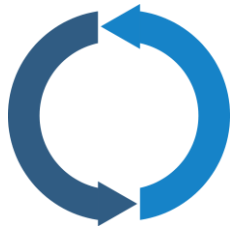
ENERGATE Platform Stages

FETCH STAGE



Collection of project-related information

PROCESS STAGE



Matchmaking and aggregation of EE products with appropriate financing

DELIVER STAGE

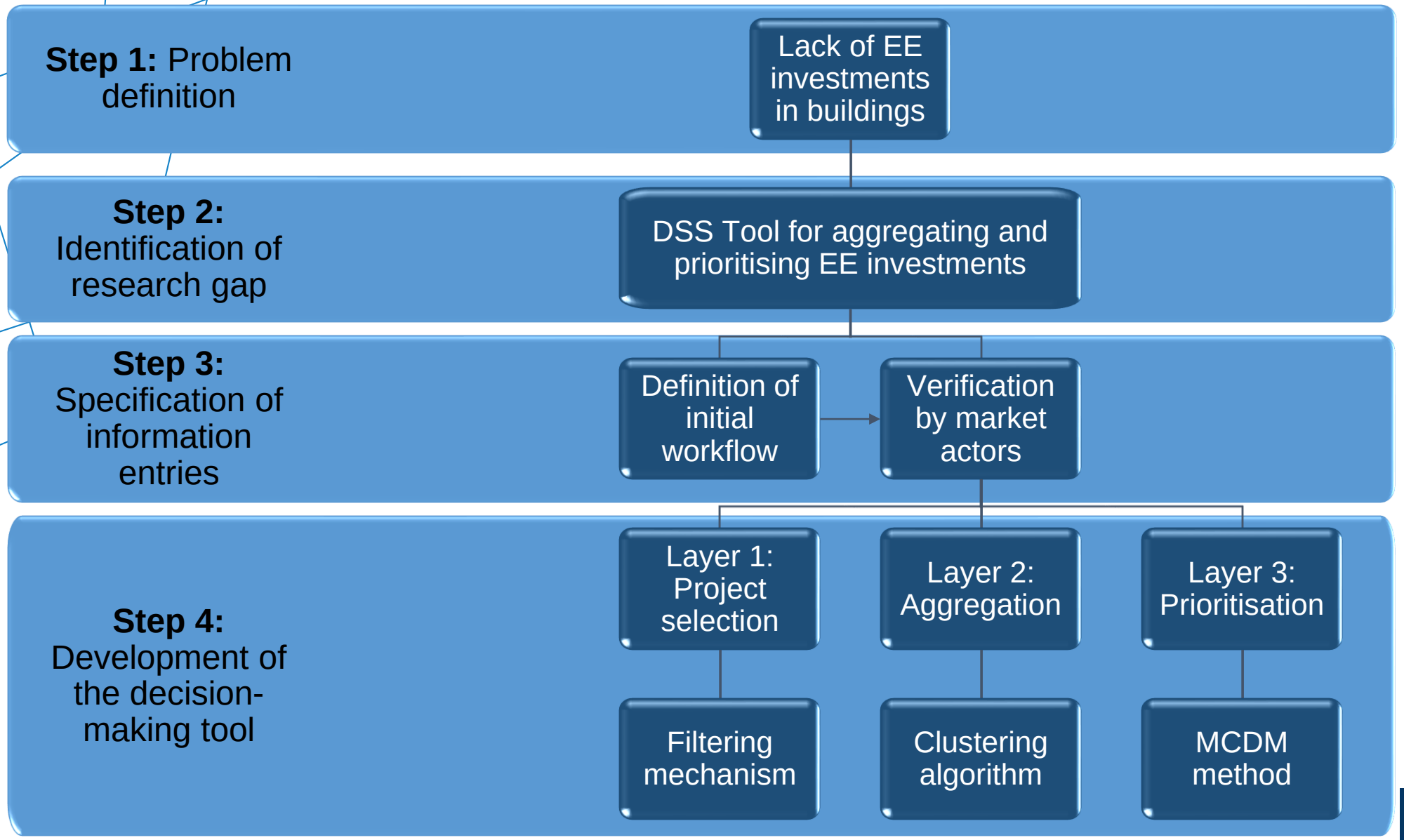


Follow-up on realised projects: feedback & validation

The scope of the study is to propose a **decision support tool** that allows investors to **select, bundle and prioritise EE projects** to enable **aggregation** of smaller projects and **matchmaking** among key actors.

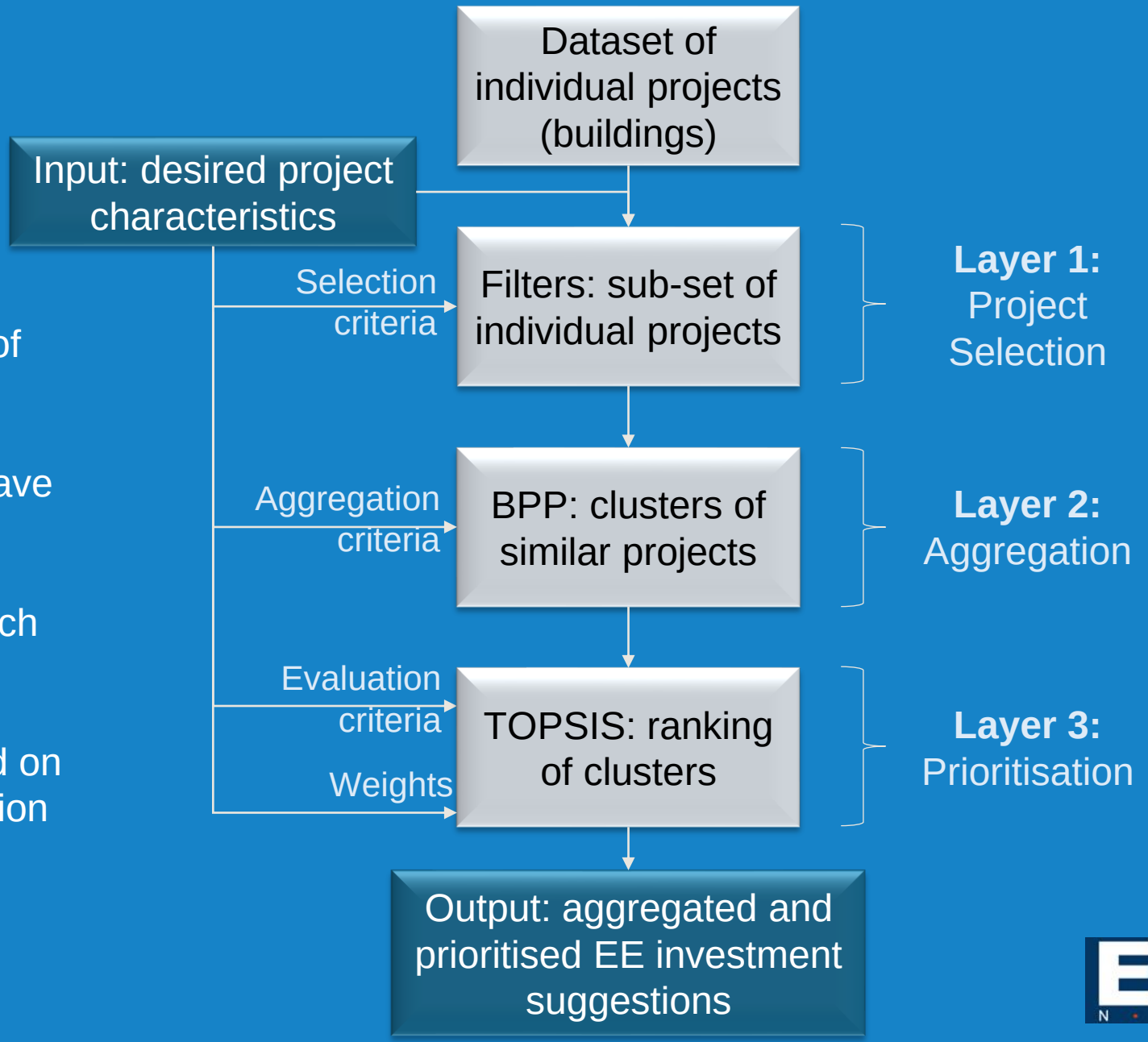
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Proposed approach



Aggregation and Prioritisation decision support tool (1/9)

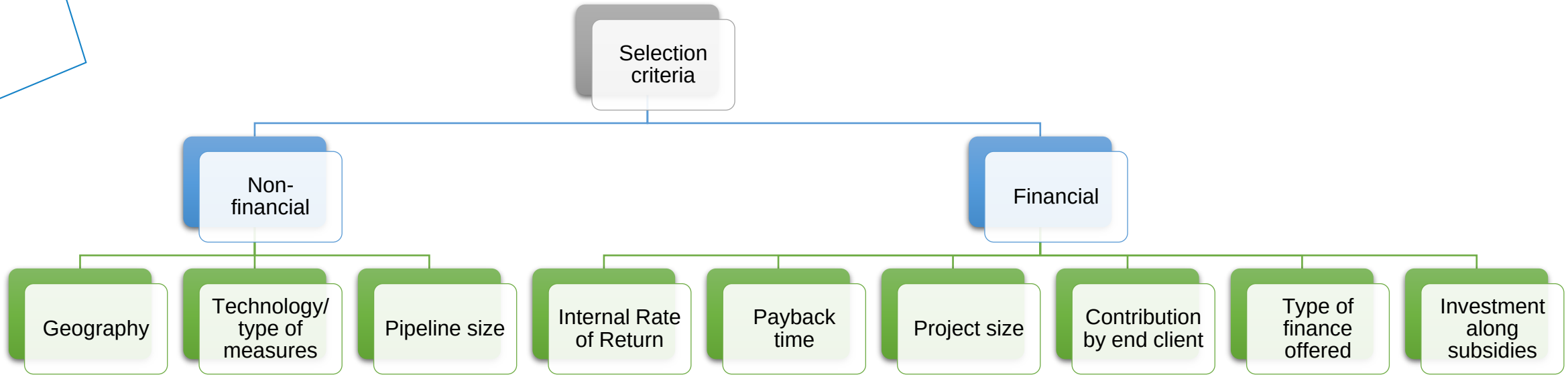
- ✓ The decision support tool consists of three layers
- ✓ Suitable algorithms and methods have been leveraged
- ✓ Different KPIs are considered at each stage
- ✓ The KPIs have been decided based on literature and stakeholder consultation



Aggregation and Prioritisation decision support tool (2/9)

Layer 1: Project selection

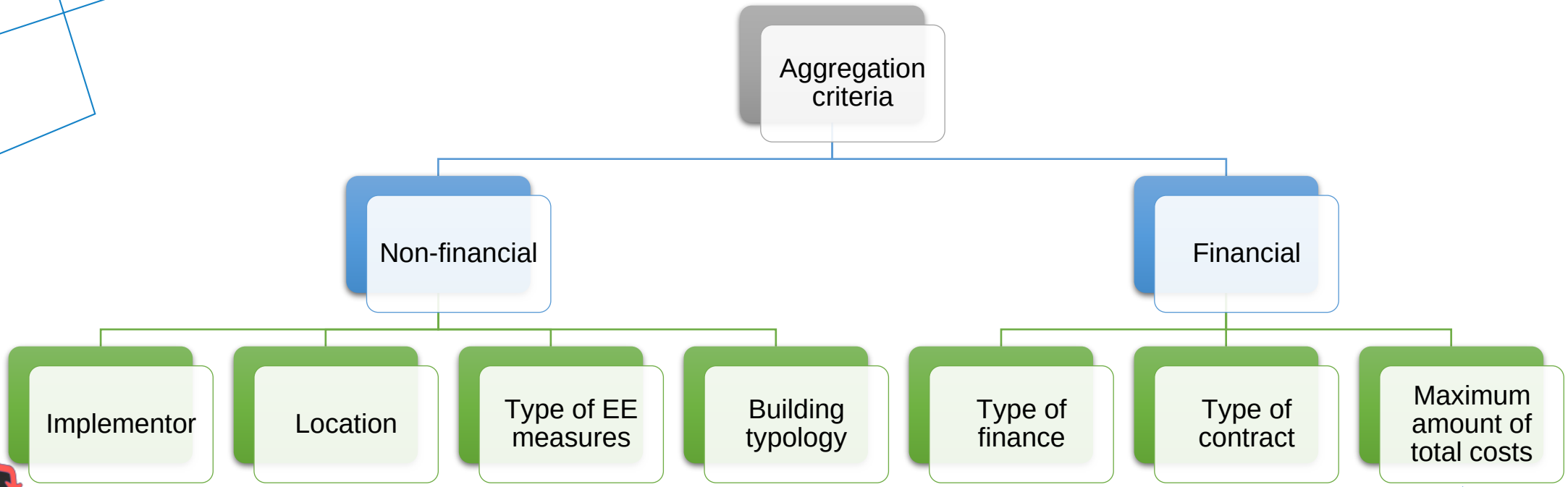
- ✓ Screening a dataset of EE projects looking for financing
- ✓ Minimum and maximum values for specific indicators are defined
- ✓ The exclusion of irrelevant projects enables speed and efficiency



Aggregation and Prioritisation decision support tool (3/9)

Layer 2: Aggregation (1/4)

- ✓ Identifying similarities between projects
- ✓ Clustering projects to increase their attractiveness for financing
- ✓ The similarities are defined based on the aggregation criteria



Aggregation and Prioritisation decision support tool (4/9)

Layer 2: Aggregation (2/4)

- ✓ The clusters are likely to exceed the upper limit
- ✓ The total CAPEX should closely align with the upper limit
- ✓ The formation of numerous smaller clusters in terms of CAPEX should be prevented
- ✓ The **Bin Packing Problem** is used

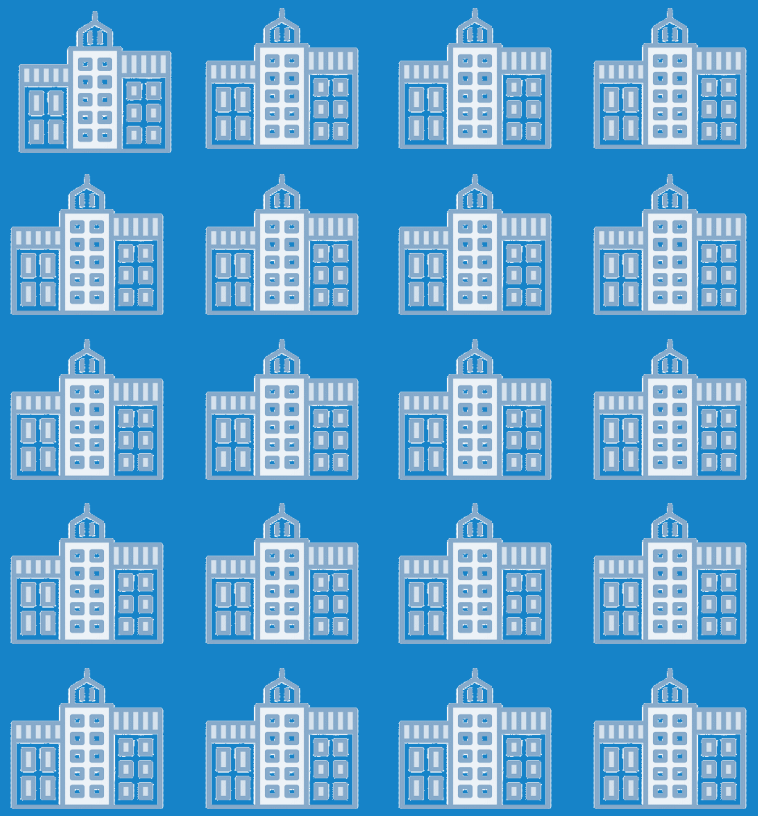
$$\sum_{i=1}^{n} CAPEX_i \cdot x_{ij} \leq L, j = 1, 2, 3 \ldots m$$

- ➢ **n** total buildings, **m** total clusters
- ➢ If the **i** building is included in the **j** cluster, then **xij= 1**. If it is not, then xij= 0
- ➢ **L** represents the upper limit
- ➢ **Minimisation of m** (number of clusters)

Aggregation and Prioritisation decision support tool (5/9)

Layer 2: Aggregation (3/4)

INPUT



Bin Packing Algorithm

OUTPUT

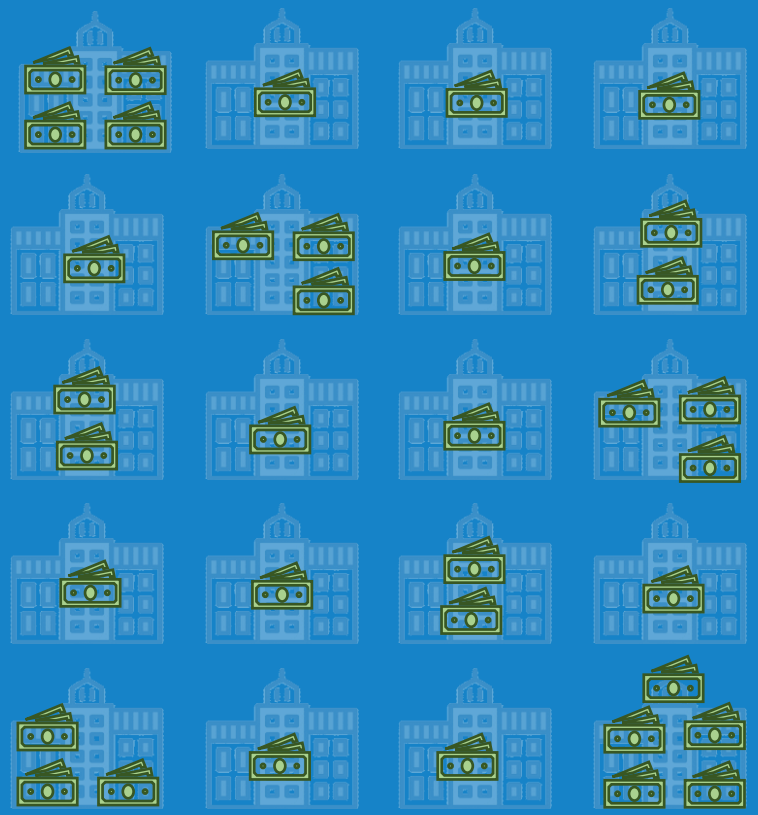
Cluster 1 | **Cluster 2** | ... | **Cluster m**

- ✓ The input of the algorithm is items (=buildings) with assigned weights (=CAPEX).
- ✓ The output is clusters, with total CAPEX lower than the upper limit L.

Aggregation and Prioritisation decision support tool (6/9)

Layer 2: Aggregation (4/4)

INPUT

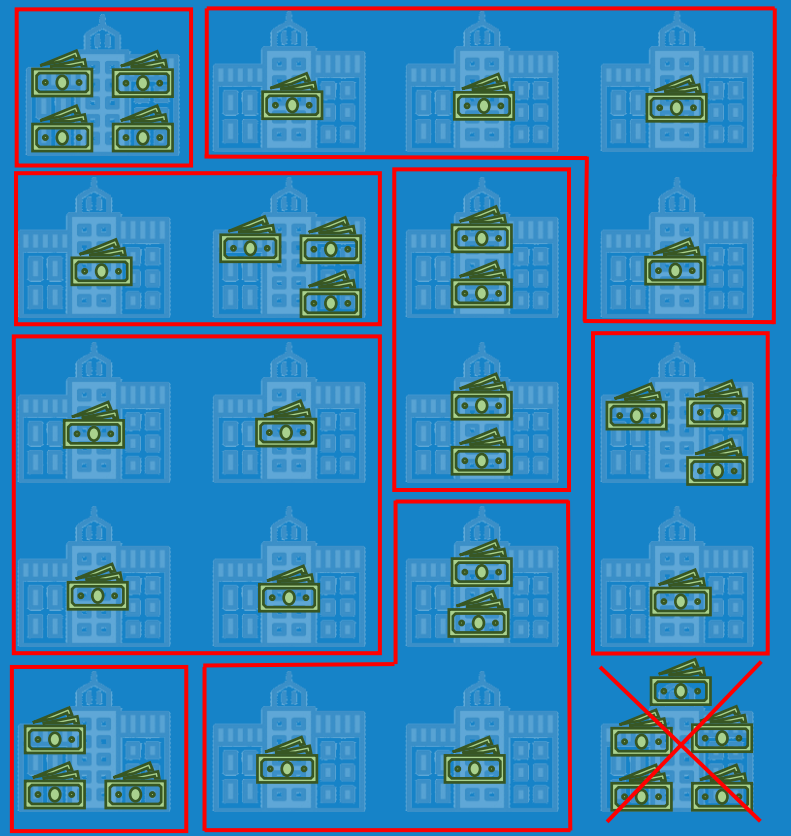


Bin Packing Algorithm

L =



OUTPUT



Aggregation and Prioritisation decision support tool (7/9)

Layer 3: Prioritisation (1/3)

Selection of evaluation criteria

Energy related and **financial** KPIs, divided in beneficial and non-beneficial criteria

Selection of weighting method

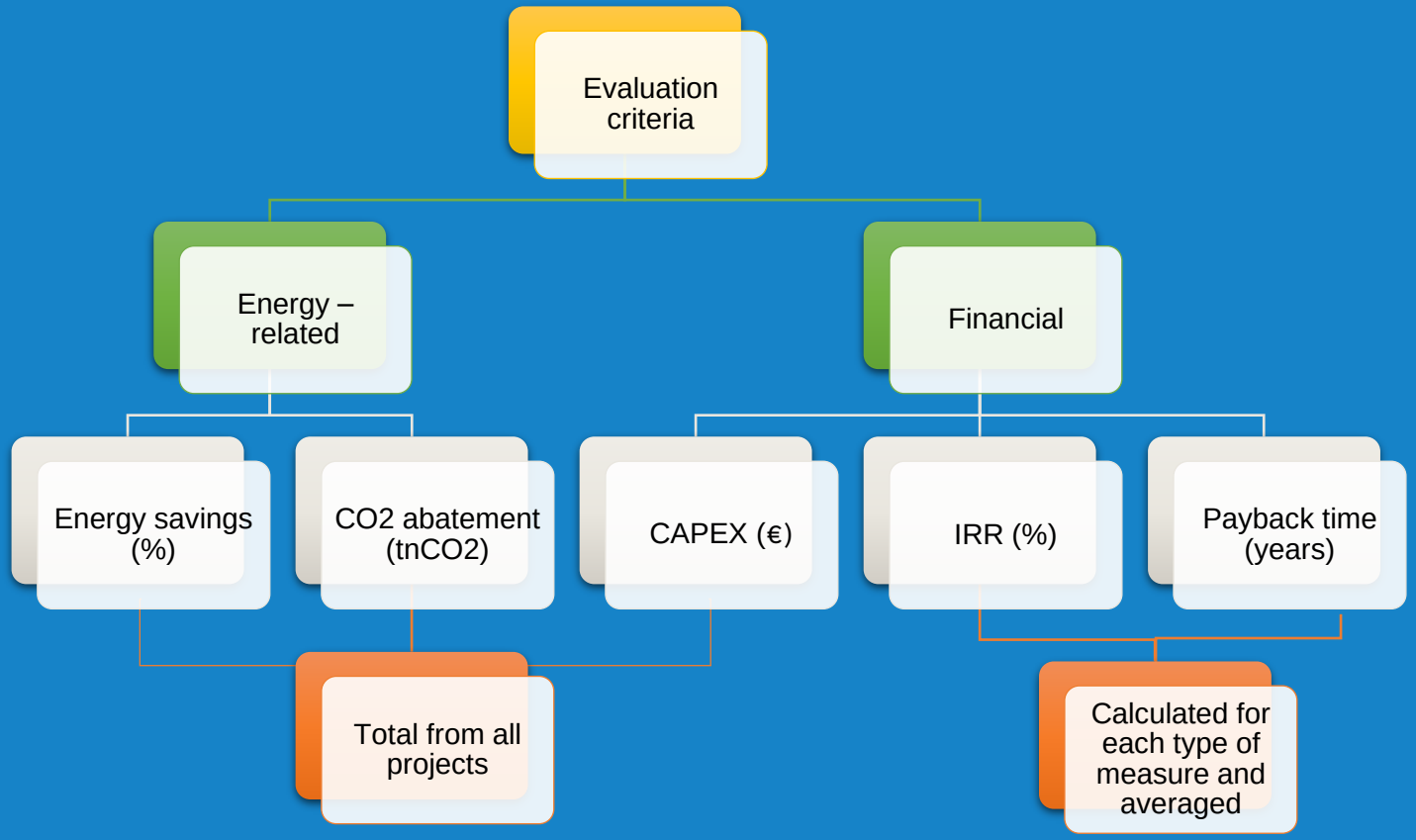
The **direct weighting** method is selected, since it ensures simple and **user-friendly** acquisition of the weighting factors

Selection of MCDM method

The **TOPSIS** method is selected, because it is an **easily programmable** computational procedure with the capacity to deal with **numerous alternatives**

Aggregation and Prioritisation decision support tool (8/9)

Layer 3: Prioritisation (2/3)



- ✓ Energy savings, CO2 abatement, CAPEX and IRR are beneficial criteria
- ✓ Payback time is a non-beneficial criterion
- ✓ The weights allow the user to specify the importance of each criterion
- ✓ Each user will get a different list based on their specific preferences

Aggregation and Prioritisation decision support tool (9/9)

Layer 2: Prioritisation (3/3)

Step 1: Decision matrix → Step 2: Weights & normalisation → Step 3: Normalised decision matrix →

$$M = \begin{pmatrix} x_{11} & \cdots & x_{1j} \\ \vdots & \ddots & \vdots \\ x_{i1} & \cdots & x_{ij} \end{pmatrix}$$

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} {x_{ij}}^2}} \qquad w_i = \frac{a_i}{\sum_{i=0}^{5} a_i}$$

$$P = \begin{pmatrix} p_{11} & \cdots & p_{1j} \\ \vdots & \ddots & \vdots \\ p_{i1} & \cdots & p_{ij} \end{pmatrix}$$

Step 4: Ideal and ani-ideal solution vectors → Step 5: Euclidean distances from ideal and ani-ideal solution → Step 6: Final score of each alternative

$$P^+ = ({p_1}^+, , {p_2}^+, , {p_3}^+ \, {p_4}^+ \, {p_5}^+)$$

$$P^- = ({p_1}^-, , {p_2}^-, , {p_3}^- \, {p_4}^- \, {p_5}^-)$$

$$S_i^- = \sqrt{\sum_{j=1}^{5} (p_{ij} - p_j^-)^2}$$

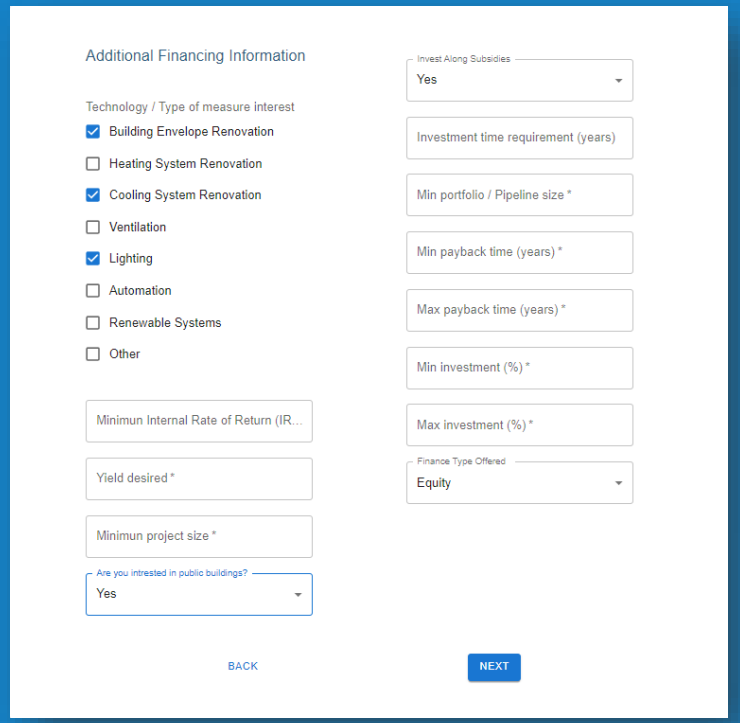
$$S_i^+ = \sqrt{\sum_{j=1}^{5} (p_{ij} - p_j^+)^2}$$

$$D_i = \frac{S_i^-}{S_i^+ + S_i^-}$$

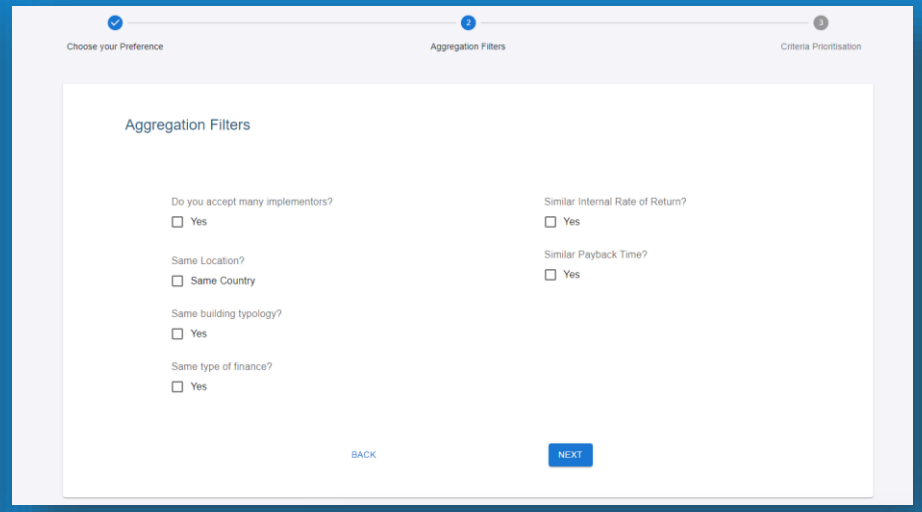
Application (1/2)

DSS tool user interface

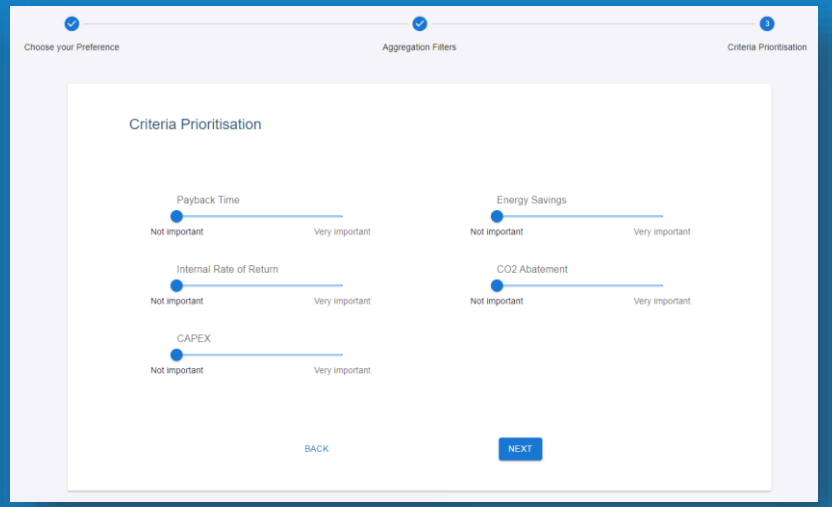
Layer 1: Project selection

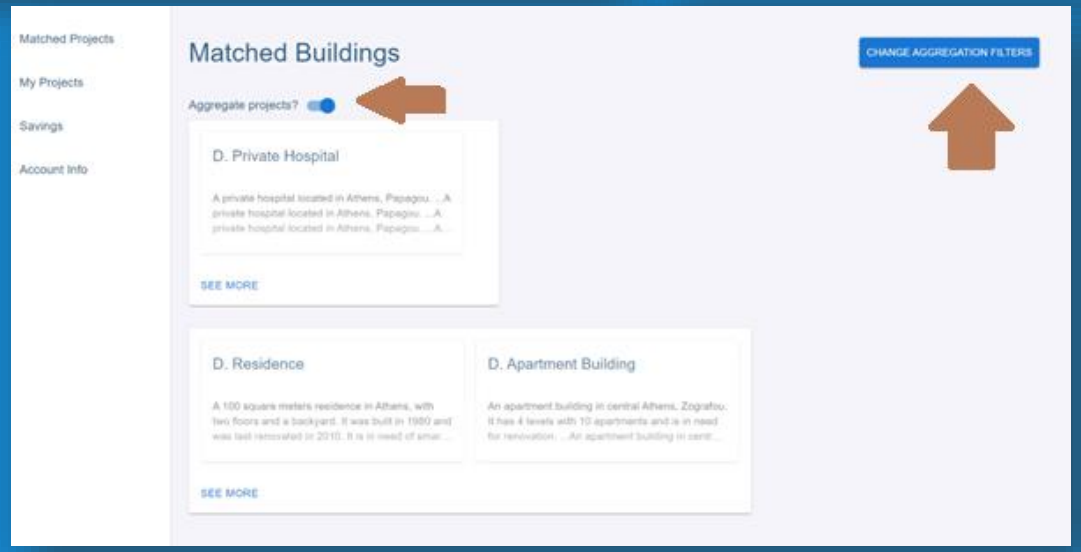


Layer 2: Aggregation



Layer 3: Prioritisation





Application (2/2)

The DSS tool is useful for:

Potential users:

- Investors, financing bodies, and institutions: Financiers that want to invest in retrofitting projects.

Other market actors:

- ESCOs, project developers, and project promoters.
- Better understanding of important financial investment criteria.

Researchers:

- Robust methodological approach for decision support tool creation.
- Reference point for modeling decision-making problems in ICT environments.

✓ The tool has been tested with data from implemented projects in Greece

✓ The testing showed that the tool functions correctly and efficiently

Conclusions & future research (1/2)

The proposed methodology and tool:

- Helps users navigate large datasets of potential EE projects.
- Detects projects that meet user requirements.
- Combines EE projects into investment packages.
- Evaluates and prioritises projects based on financial and energy-related criteria.
- Is tailored to user needs and emphasises user-friendliness.
- Requires short list of user inputs.
- Deploys efficient and speedy data processing methodologies.
- Implements an easy-to-follow, time-efficient and standardised procedure for reliable outputs.

Conclusions & future research (2/2)

Further research may focus on:

Expansion of evaluation and selection criteria

- Social impact
- Investment risks

Integration of different approaches

- Other MCDM methods
- Combinations of methods
- Sensitivity analysis

Verification mechanisms

- Enable calculations to verify the expected impact of the projects
- Benchmarking based on previously implemented projects

Testing through ENERGATE project

- Pilot countries: Greece, Italy, Spain, France, Latvia, Austria
- Various building typologies: residential, healthcare, retail, office etc.

THANK YOU

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