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WORKSHOP
ENERGY LABELLING OF BUILDINGS AND COST-OPTIMAL LEVEL CALCULATIONS
22 April 2025 - Astana, Kazakhstan

Optimal level of energy efficiency: balance of costs, economic and environmental benefits

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Main types of building energy efficiency (EE) codes

Prescriptive EE codes

Establish specific performance **criteria for individual building components and systems**

Key Requirements:

- **Thermal performance:** U-values for walls, windows, roofs, and other building envelope elements
- **Equipment efficiency:** Minimum efficiency standards for lighting systems, boilers, ventilation units, and HVAC systems
- **Compliance focus:** Component-level compliance based on predefined benchmarks

Performance-based EE codes

Focus on the overall energy performance of the entire building rather than individual components. Allows trade-offs between components, such as reduced insulation offset by higher window efficiency

Key Requirements:

- **Energy limits:** Maximum allowable energy use or energy intensity (e.g., kWh/m² per year)
- **Specific energy consumption metrics** – energy labels, e.g., total energy consumption (kWh/m²/year) or peak power demand (W/m²)

Outcome-based EE codes

Require actual energy performance to be demonstrated and verified post-occupancy over a defined period (e.g., 12 months)

Key Requirements:

- **Measured performance:** Evaluation of real-world energy use based on operational data
- **Efficiency of building systems** such as ventilation (m³/Wh - air volume moved vs. energy use) and lighting systems (lm/W - lumens per watt)
- **Verification process:** Ongoing monitoring and/or laboratory tests to ensure compliance

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Setting Energy efficiency standards

Technical reasons

Prevent the formation of structural-physical defects in buildings and their structure elements

- Prevent the formation of structural-physical defects in buildings and their structural elements
- Reduce the risk of conduction losses and frost damage to the building envelope
- Prevent mold formation and moisture accumulation risks
- Minimize drafts and thermal bridging
- Reduce the risk of accidents related to structural damage or system failures

Health and comfort reasons

Provides the necessary user comfort conditions in the building (living, working, learning, etc.)

- Provides optimal comfort levels
- Increases productivity
- Reduces indoor air pollution and associated health risks
- Prevents respiratory illnesses caused by mold and dampness

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Setting Energy efficiency standards

Macroeconomics
(national perspective) perspective

Overall development of the construction sector and the national economy

- New business opportunities. Positioning the country as a leader in energy-efficient building technologies
- Creation of jobs in construction, retrofitting, and energy service industries
- Focus on energy efficiency instead of energy subsidies, reducing fiscal burdens
- Rational use of resources
- Adaptation to climate change - snow loads, rainwater drainage, and other related aspects

Microeconomics
(private perspective) perspective

The perspective of private building owners and investors

- Higher real estate value
- Lower energy and maintenance cost
- Aesthetics and architectural integration
- Reduced exposure to energy price fluctuations
- Increased pride, prestige, and reputation through sustainable practices
- Enhanced marketability for rental or resale purposes

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Why is it important to understand the cost-optimal energy efficiency level in buildings

«When establishing energy efficiency requirements, a critical question is to understand the point at which further investments in energy efficiency improvements remain cost-effective, as each additional kilowatt-hour (kWh) saved typically comes at a higher cost.»

This can be considered the «*assets*» of an energy efficiency project. The implemented energy efficiency measures generates revenue, which benefits the homeowners

This can be considered the «*liability*» of an energy efficiency project.

O&M=operc

Do we have to pursue the improvement of energy efficiency based on a demand reduction approach? — demand side (investments in buildings) — or, on the contrary, should we focus on improving the energy efficiency of the energy transformation? — supply side (investments in energy generation)

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Microeconomics private perspective

- **Homeowner association / homeowners**
  - The goal is to provide sufficient information for taking and informed decision on the building renovation project
  - Understand the risk of doing "nothing"!

- **Financial institution**
  - The goal is to provide sufficient information to understand risks and cash flows for taking a decision to finance the project

Key factors:

✓**Profitability**: important for to understand if the project will generate enough revenue (income) to cover project costs

✓**Solvency**: important because it looks at the ability of the home owners in meeting financial obligations and current housing expenditures (utility bills, house repairs, administration, etc.)

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Macroeconomics country perspective

- Renovating apartment buildings creates **significant economic value**, generating **17 jobs per 1 million EUR** invested annually—**10 in construction**, and **7 across consultancy and manufacturing**
- **Tax revenues cover 32–33%** of total renovation costs, making public support for renovation programs close to **fiscally neutral**
- Compared to minimal repair strategies, **integrated energy-efficient renovation** improves living quality, asset value, and national economic performance - confirming that such investments offer **strong returns for both individuals and government budgets**

     

* E. Pikas, J. Kurnitski, R. Liias, M. Thalfeldt, Quantification of economic benefits of renovation of apartment buildings as a basis for cost optimal 2030 energy efficiency strategies, Energy and Buildings, Volume 86,

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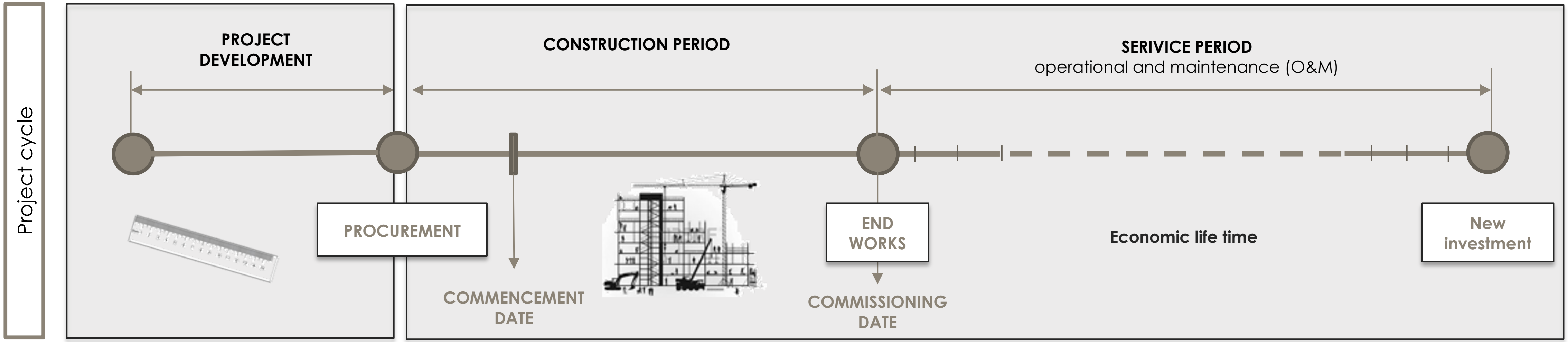
Investment costs in building renovation



- ✓ Energy audit,
- ✓ Technical engineering appraisal,
- ✓ Architectural design,
- ✓ Technical design,
- ✓ Permits,
- ✓ Grant application
- ✓ Financing costs, like bank fees for arranging loans
- ✓ Taxes like VAT

- ✓ Construction & installation costs (organisation of construction site material, equipment, work, etc.),
- ✓ Supervision,
- ✓ Documentation,
- ✓ Commissioning,
- ✓ Training,
- ✓ Taxes like VAT

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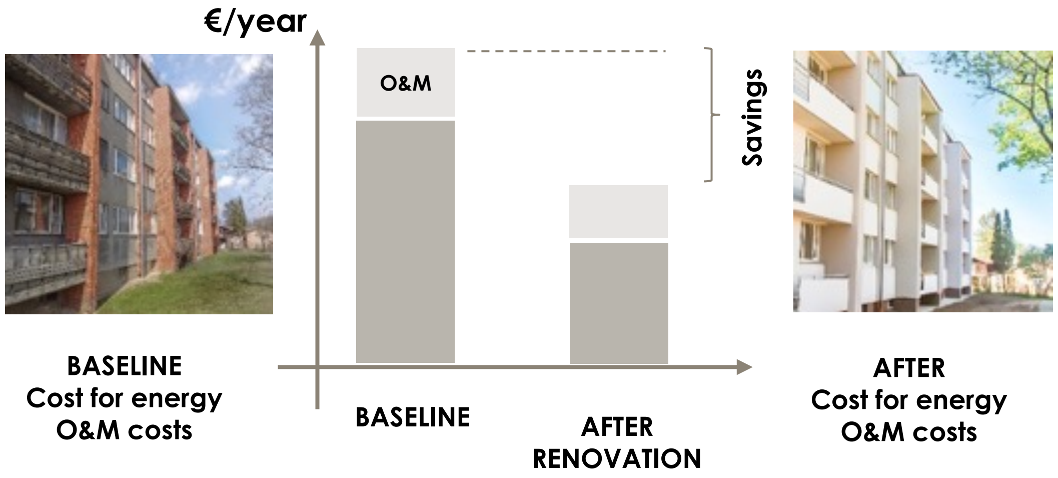
Annual net savings

ENERGY SAVINGS

In Energy Efficiency projects after the implementation of the measures resulting from the investment made, energy consumption (MWh/year) is reduced compared to the baseline

ADDITIONALITIES

In additional to saved energy, if the measures require additional maintenance (e.g. a new ventilation system) or less maintenance (e.g. avoid emergency repairs of heating pipe) this should be considered



$C = S \cdot E \pm \Delta O\&M$		
C	Annual net savings	€/year
S	Energy saved	MWh/year
E	Energy tarifs	€/MWh
ΔO&M	Changes in O&M cost	€/year

O&M: operational and maintenance costs

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Cash flow and profitability

Reference average building:

- Series type building series
- Billing area
  - 3000 m^2
- Current heat energy consumption:
  - 297kWh/m^2 year
  - 891MWh/year

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Profitability calculation – simple payback time

Simple Payback Time $\quad SPBT = \dfrac{\text{Investment}}{\text{Annual net saving}} = \dfrac{C_0}{C}$ $\quad$ expressed in years

Example

- Project – Normative package
- Investment – € 269 000
- Annual net savings – 41,2%
- Annual net savings – €/year

- $SPBT = \dfrac{\text{Investment}}{\text{Annual net saving}} = \dfrac{\mathbf{269\ 000€}}{\mathbf{3670{,}86\ €/year}} \sim 73\ \text{years}$

	Before	**After**	**Savings**
Energy consumtion MWh/year	891	523.91	367.09
Tariff €/MWh	10	10	10
Energy consumtion €/year	8910	5239.14	**3670.86**

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District Heating Tariff

District heating (April 2025)

District heating	Residential
Astana	~5,76 EUR/MWh
Almaty	~12,93 EUR/MWh
Riga	~74,17 EUR/MWh

Electricity (April 2025)

Electricity	Residential
Astana	~33,8 EUR/MWh
Almaty	~45,2 EUR/MWh
Riga	~100 EUR/MWh

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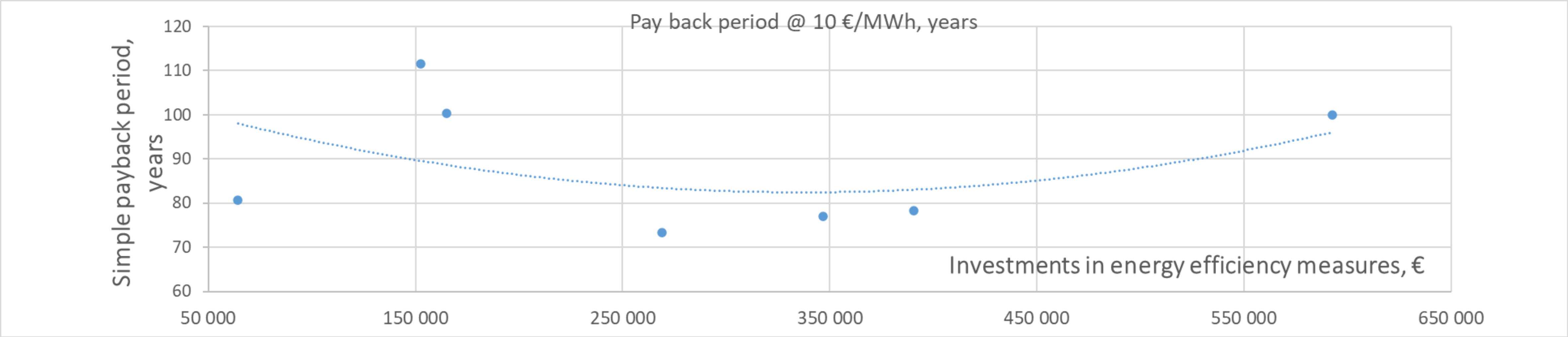
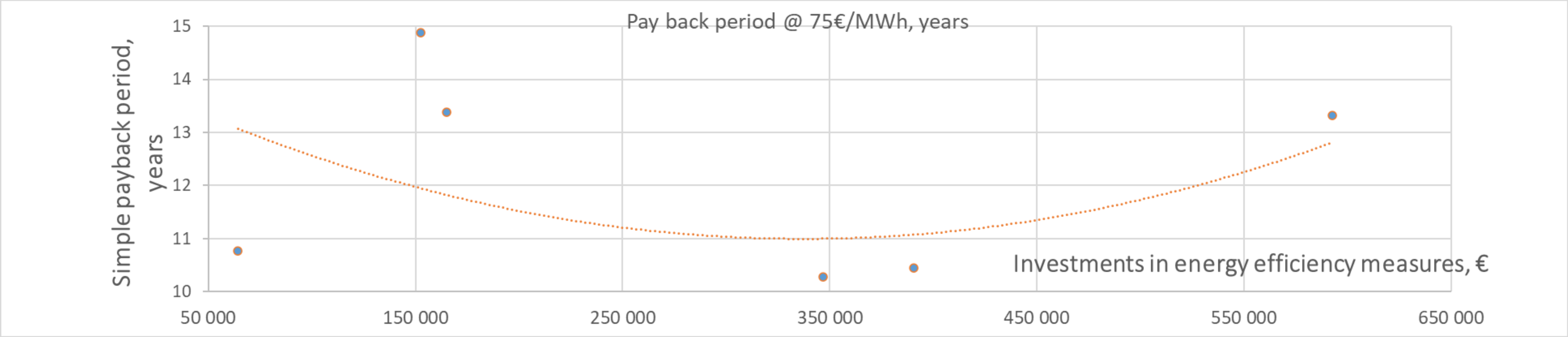
Analysis of energy efficiency measures

Energy efficiency improvement measures		Simpler packages of measures			Basic Package	Min overall package	Improved package	High energy efficiency package
Windows replacement	U-value (W/m²K)					1.54	1.10	1.10
Thermal insulation of external walls	Thickness (m)				0.12	0.15	0.20	0.20
Exterior door replacement	U-value (W/m²K)					2.0	1.3	1.2
Thermal insulation of technical attic/roof	Thickness (m)		0.19	0.19	0.19	0.19	0.2	0.25
Thermal insulation of basement ceiling slab	Thickness (m)			0.10	0.10	0.14	0.1	0.15
New heat substation with automatic temperature compensation		✓	✓	✓	✓	✓	✓	✓
Refurbishment of the space heating system		Partial	full	full	full	full	full	full
Mechanical ventilation with heat recovery								✓
Estimated investment costs		**64,300 € 21 €/m²**	**152,600 € 51 €/m²**	**164,900 € 55 €/m²**	**269,000 € 90 €/m²**	**346,700 € 116 €/m²**	**390,500 € 130 €/m²**	**592,700 € 198 €/m²**
Estimated energy savings		8.9%	15.3%	18.4%	41.2%	50.5%	55.9%	66.6%
Simple pay back period *Heating tariff: **10 €/MWh, years**		**80.74**	**111.58**	**100.41**	**73.27**	**77.02**	**78.37**	**99.90**
Simple pay back period *Heating tariff: **75 €/MWh, years**		**10.76**	**14.88**	**13.39**	**9.77**	**10.27**	**10.45**	**13.32**

Simple payback period





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Cash flow for specific renovation scenario

- Investment – 381,381 € (including VAT)
- Annual net savings – 3,564 €/year (including VAT)
- Inflation – 6.5% (CPI) & 3% (energy)
- Economic life-time 20 years
- Annuity loan – interest rate 10.5%, maturity 15 years

Project Cash flow	0	1	2	3	4	5	...	11	12	13	14	15	16	...	19	20
Investment	-381,381															
Financing																
Loan commercial bank	266,967															
Equity	114,414															
Subsidy / grants	-															
Debt service costs		-36,107	-36,107	-36,107	-36,107	-36,107	...	-36,107	-36,107	-36,107	-36,107	-36,107	-	-	-	-
Net annual savings		3,564	3,740	3,916	4,093	4,269	...	5,326	5,502	5,679	5,855	6,031	6,207	...	6,736	6,912
Net Cash flow	-114,414	-32,543	-32,366	-32,190	-32,014	-31,838	...	-30,781	-30,604	-30,428	-30,252	-30,076	6,207	...	6,736	6,912
Accumulated cash flow		-146,957	-179,324	-211,514	-243,528	-275,366	...	-462,692	-493,296	-523,724	-553,976	-584,052	-577,845	...	-558,165	-551,253

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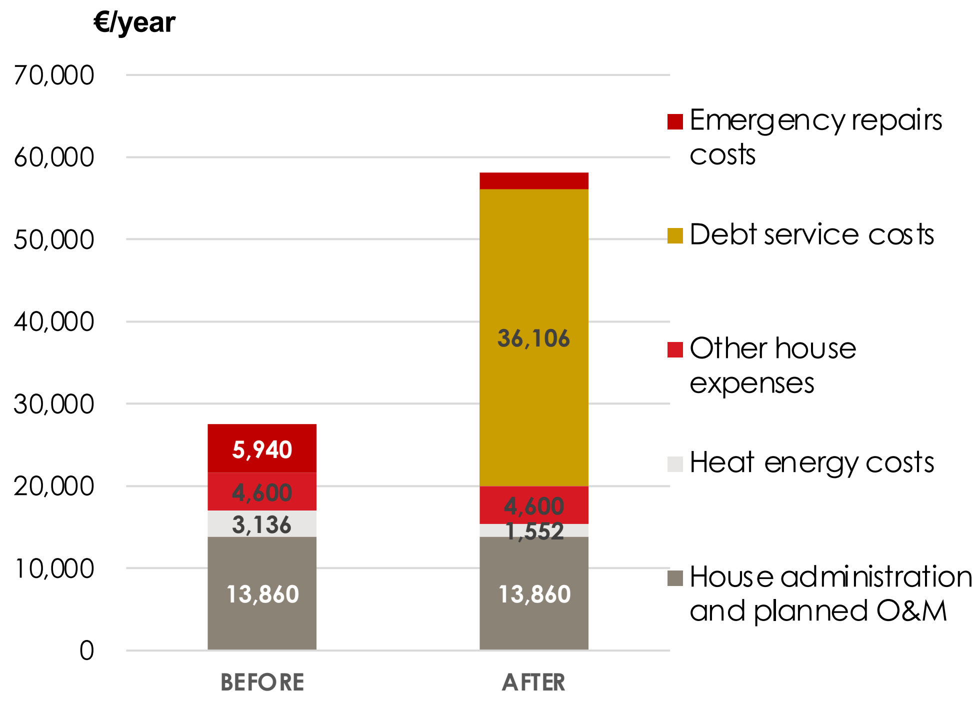
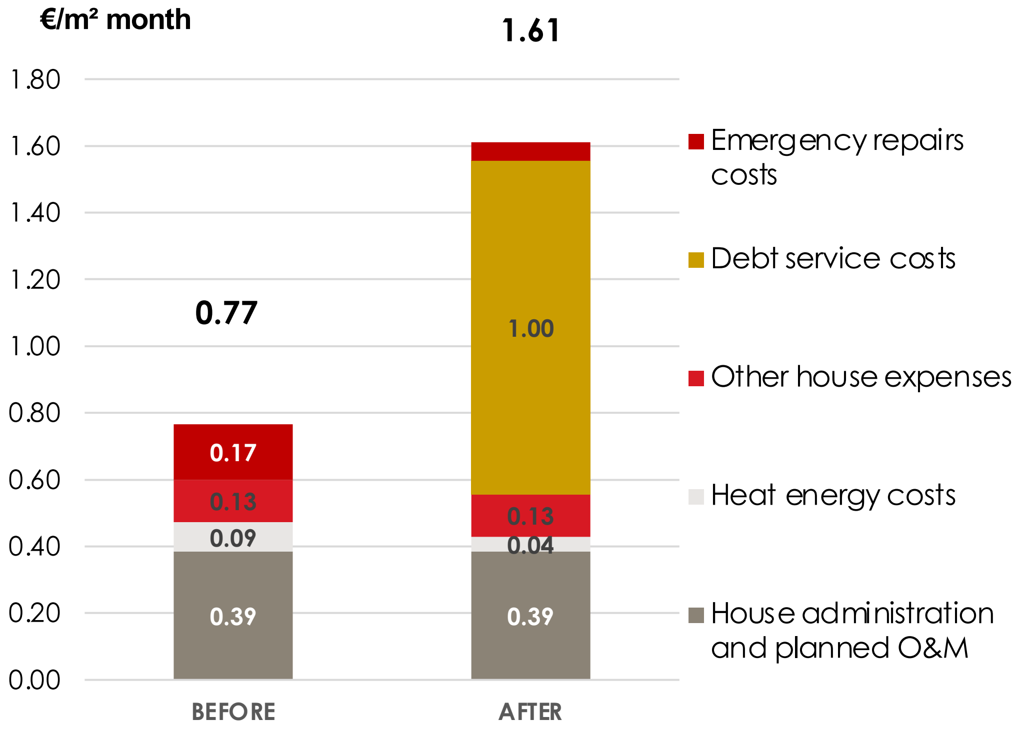
Presenting the results





Energy savings → 3,136€ - 1,552€ = 1,584€

Energy cost → $\frac{1552€/\text{year}}{3000\text{m}^2 \cdot 12\text{month}}$=0.04 €/m² month

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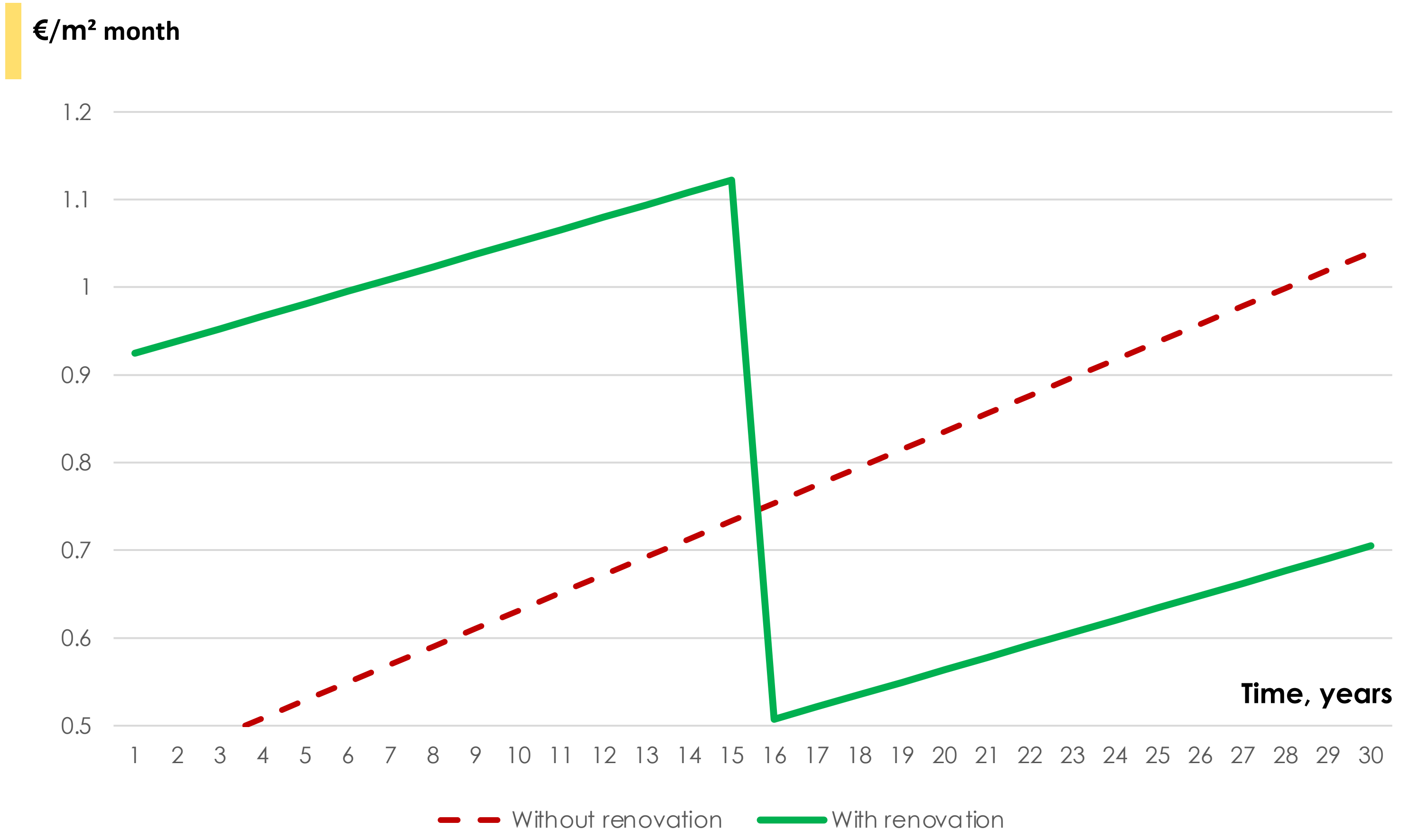
Presenting the results



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Other benefits from building renovation that should be monetized

Item	Wish to have	Value ($ - EUR) (high / medium / low)	Paid by whom	Willingness to pay (high / medium / low)
More comfort	High	Low (not willing to pay)	Homeowners	Low
Lower future maintenance costs	High	Low / medium	Homeowners Municipality legal obligation (?)	Low
50+ years extended lifespan of buildings	Low	High	Homeowners	Low (lack of awareness)
Cleaner air to breath in the city	High	High	Government	Obligation to pay
Reduction of greenhouse gasses	Low	Medium (link to sales of GHG emissions)	Trading / via Government	Depending on GHG market
Saving energy (natural resources)	Low	Medium/high How much could be exported instead	Government / Taxpayers	Low
Other……				

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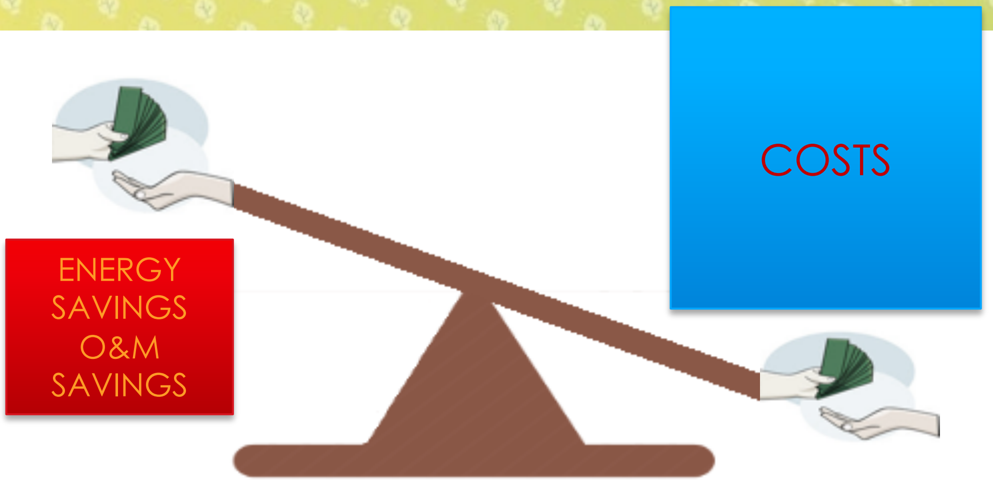
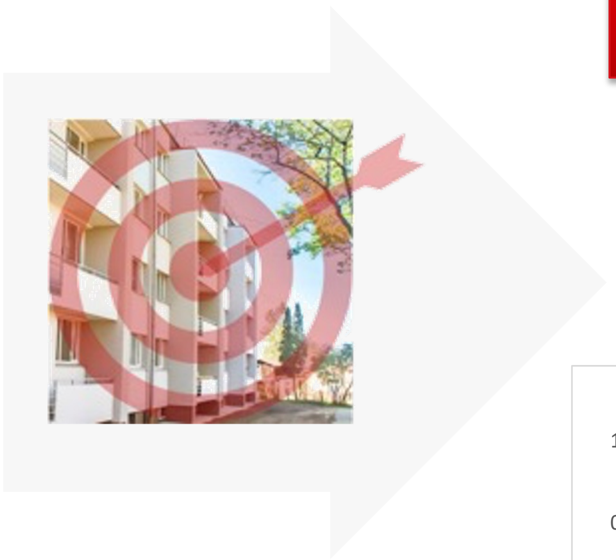
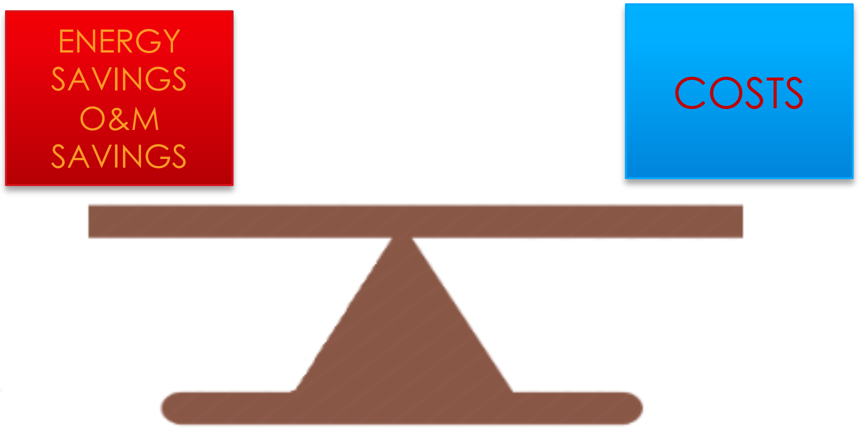
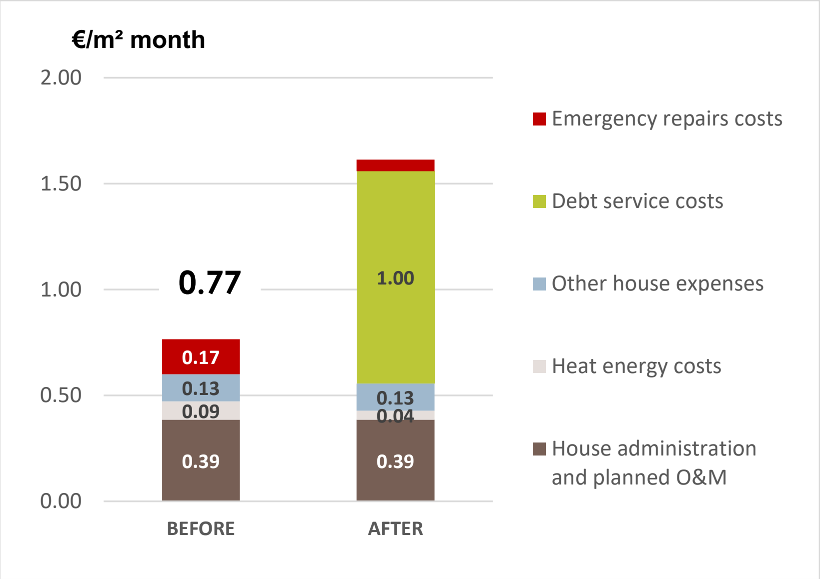
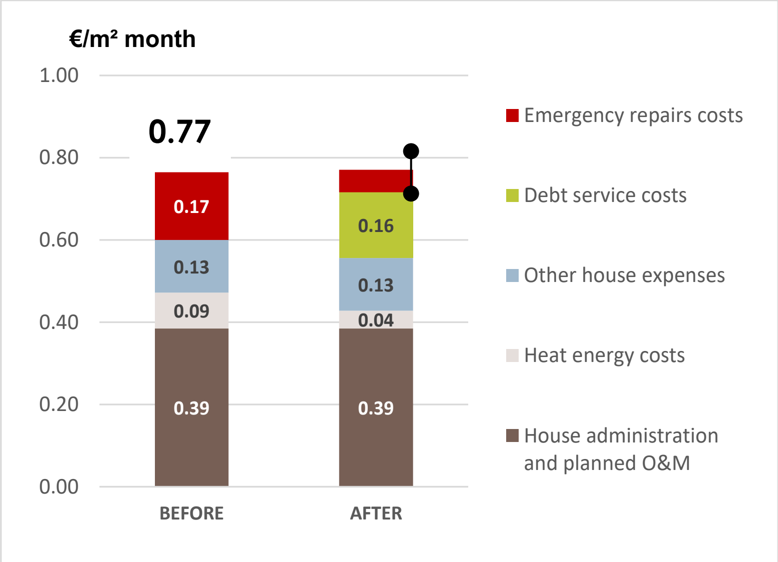
The aim of the cost – optimality analyses











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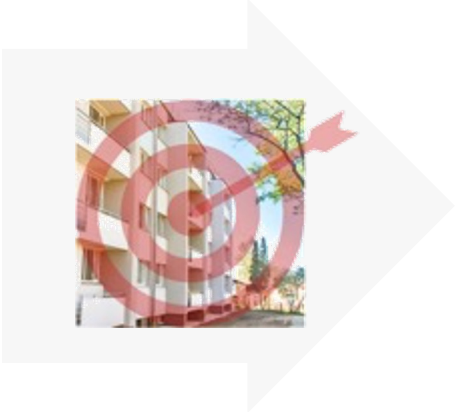
Cost-optimality

This can be considered the «*assets*» of an energy efficiency project. The implemented energy efficiency measures generates revenue, which benefits the homeowners



This can be considered the «*liability*» of an energy efficiency project.

O&M=operational and maintenance repair expenses

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Methodology for national study

- Statistical data
- Building technical norms

Definition of refence buildings (residential, office ect.) and climate zones

Calculation of average DWH consummation (Consumption module: ISO 15316)

- Identification of energy efficiency measures

Output: Definition of retrofitting/energy efficiency packages

Energy demand calculation (Demand module: ISO 13790 and/or ISO 50002 family standards)

Overview of energy performance of packages of measures

Energy efficiency investment costs

Energy costs

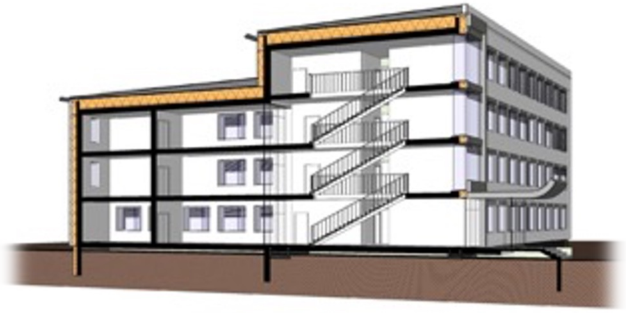
Economic framework: inflation, discount rate

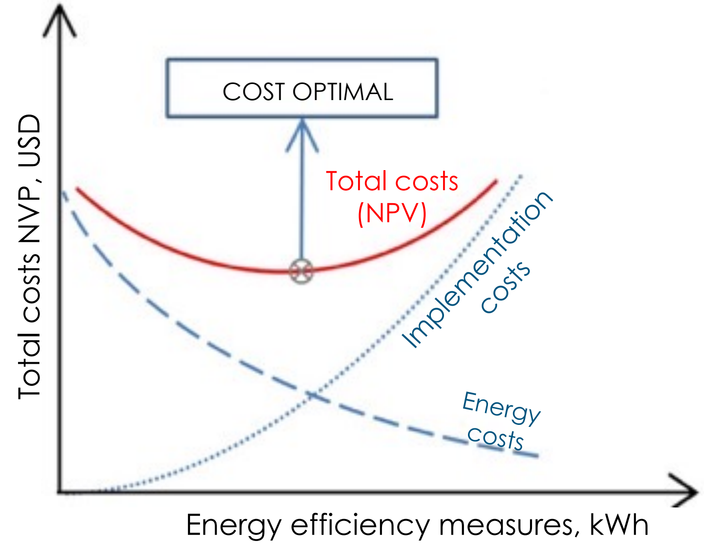
Calculation of economic performance (Costs module: CBA, Regulation (EU) No 244/2012)

Uncertainly analyses (energy costs impact of results)

Main outputs: Global costs NPV and energy saving potential

Optimal energy efficiency performance levels for refence buildings types





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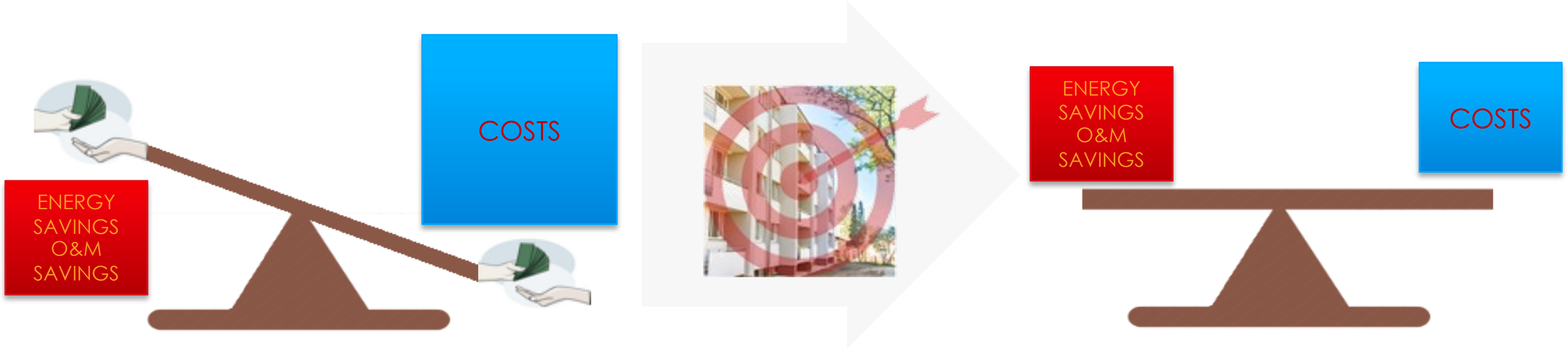
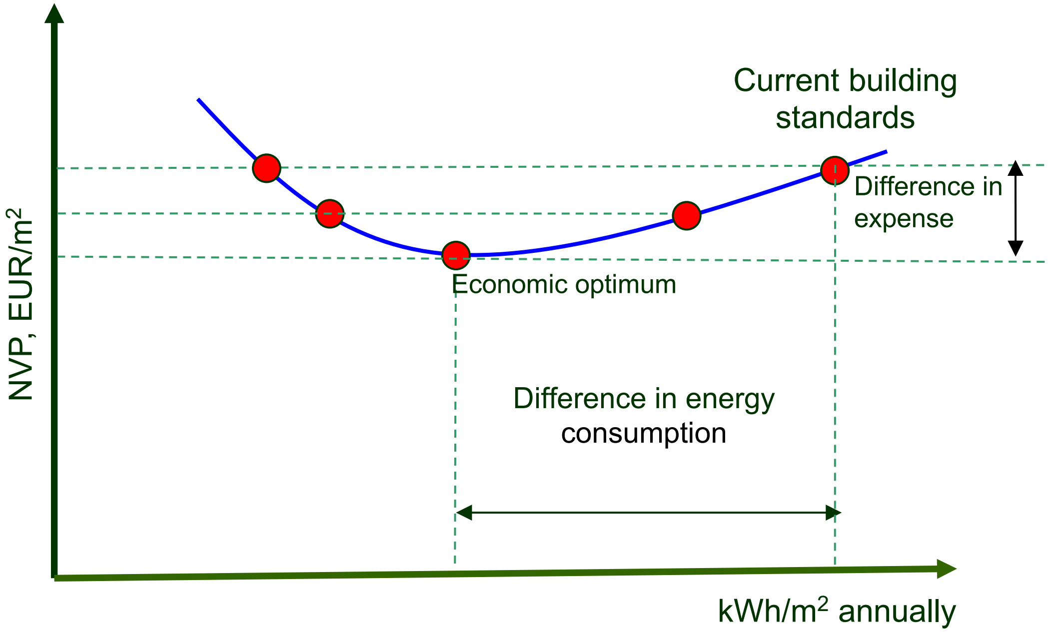
Calculation of economic performance





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Definition of refence buildings

Reference Building Selection Methodology

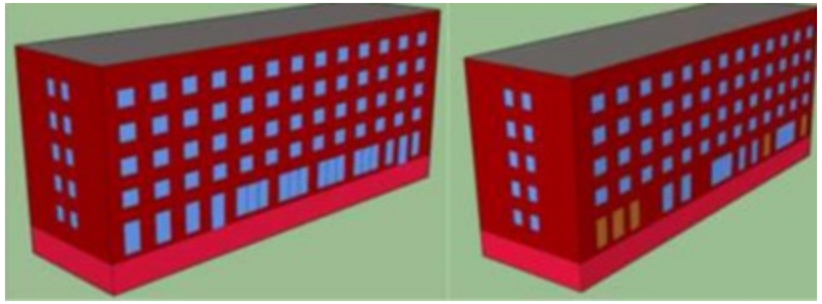
Identify at least one reference building for **new constructions** and at least two for **existing buildings** within the following categories:

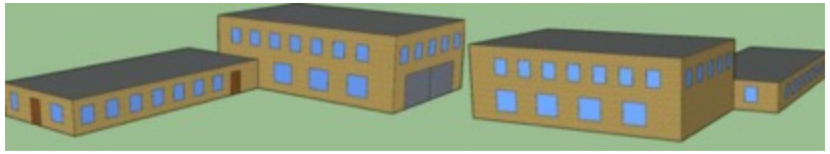
- Single-family residential buildings
- Apartment blocks / multi-family residential buildings
- Office buildings
- Other non-residential buildings

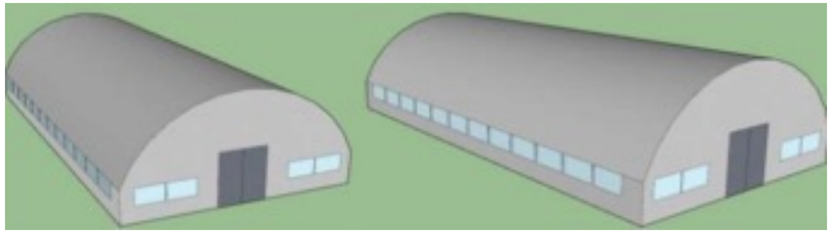
Reference buildings should feature **simple, representative geometries** that are **technically feasible and reproducible in practice**.

Required input data includes:

- National building stock statistics
- Typical construction types and thermal characteristics
- Standard weather data (heating and cooling seasons)
- Building usage characteristics and occupancy profiles







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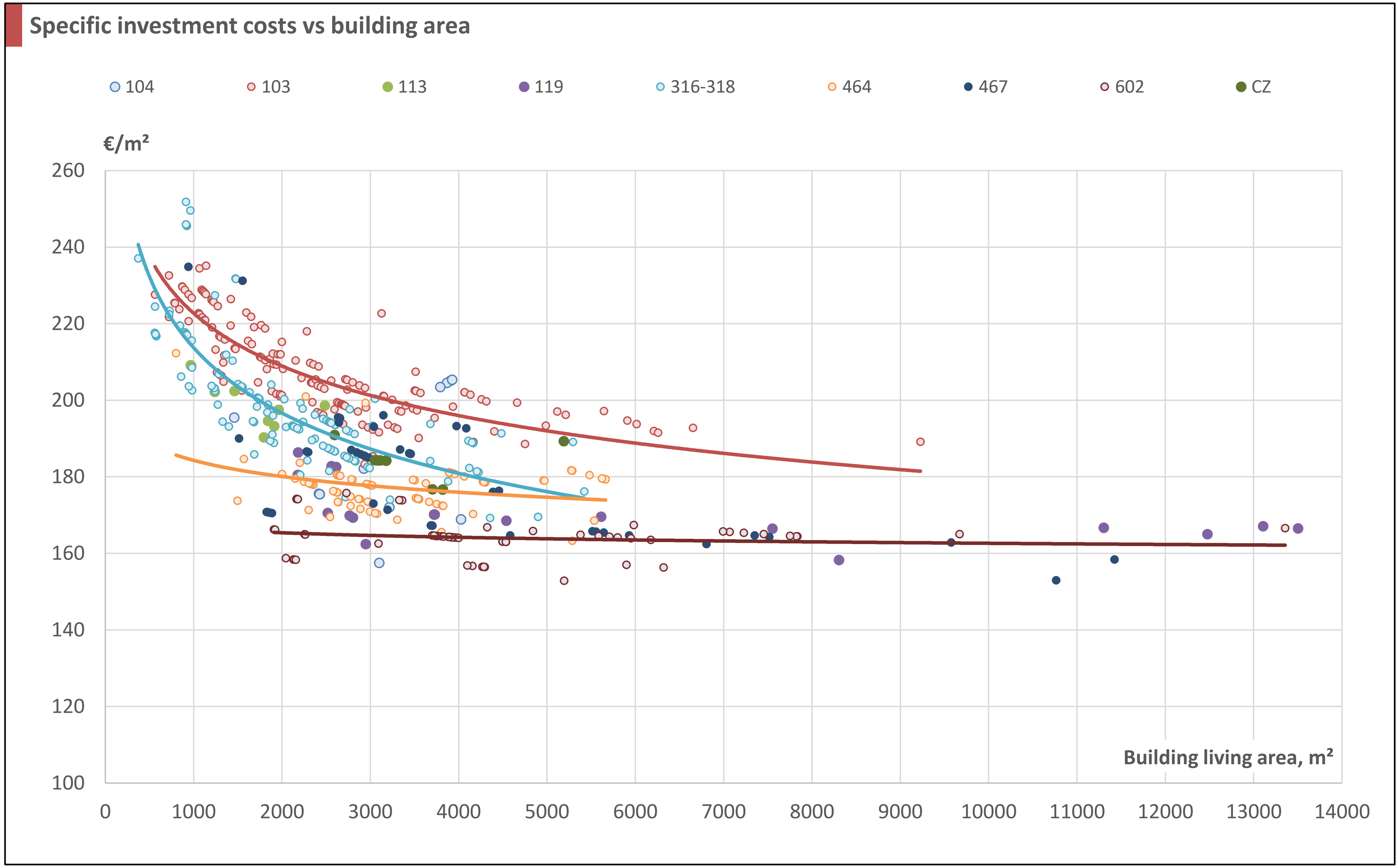
EXAMPLE: INVESTMENTS COSTS FOR DEEP RENOVATION



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Example of reference building

Area

- 2000 m²

Investment costs for deep renovation:

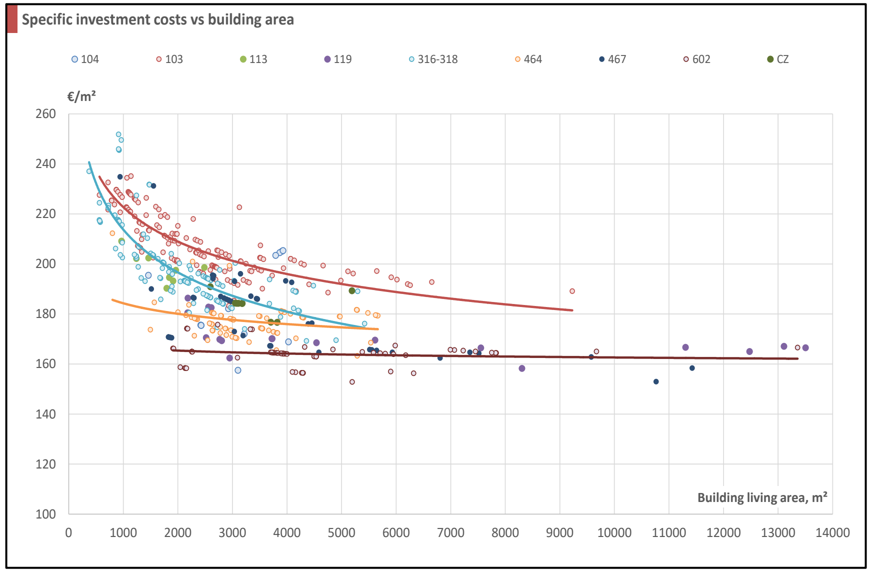
- 246 €/m²

Heating energy consumption before renovation

- Space heating 150 kWh/m² year

Total energy consumption after renovation

- space heating 65 kWh/m² year)



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Calculation of economic performance

Building data and construction costs

				Excluding VAT		Including VAT	
A	Number of dwellings	30	-				
B	Building billing area	2000	m²				
C	Construction costs for energy efficiency measures	200.0	€/m²	400 000	€	440 000	€
D	Construction costs for aestetical and strucural measures	20.0	€/m²	40 000	€	44 000	€
E	Project development costs (energy audit, technical studies, desi	7.0%	%				
		15.4	€/m²	30 800	€	33 880	€
F	Management and supervision of construction site	2.0%	%				
		4.4	€/m²	8 800.0	€	9 680	€
G	Unforeseen costs for construction and risk margin	3.0%	%				
		6.6	€/m²	13 200	€	14 520	€
→	Total construction costs	**246.4**	**€/m²**	**492 800**	**€**	**542 080**	**€**

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Calculation of economic performance

2	**Energy drivers**				
A	Heat energy tariff	87.0	€/MWh	95.7	€/MWh
B	Pre renovation energy use for heating	150.0	kWh/m² a		
		300	MWh/year		
C	Post renovation energy use for heating	65.0	kWh/m² a		
		130	MWh/year		
D	Energy Savings Ratio	56.7%	%		
3	**Maintenance**				
A	PRE renovation				
	House maintenance fee - BEFORE renovation	0.350	€/m² month	0.3850	€/m² month
	House maintenance reserve fund / emergency repairs	0.150	€/m² month	0.1650	€/m² month
B	POST renovation				
	House maintenance fee - AFTER renovation	0.350	€/m² month	0.3850	€/m² month
	House maintenance reserve fund / emergency repairs	0.100	€/m² month	0.1100	€/m² month

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Calculation of economic performance

4 Finance

A	Subsidy		
	Investment grant as % of total investment costs	-	%
	Investment grant amount	0	€
B	Financial plan		
	Debt to equity ratio	80.0%	%
	Debt	433 664	€ (with VAT)
	Equity	108 416	€ (with VAT)
	Interest on debt	3.0%	%
	Interbank rate	4.0%	%
	Tenor	15	years

5 Economic and tax

A	Consumer price Inflation	6.5%	%
B	Energy price inflation	3.0%	%
C	VAT on Energy	10.0%	%
D	VAT on construction / services / energy savings	10.0%	%

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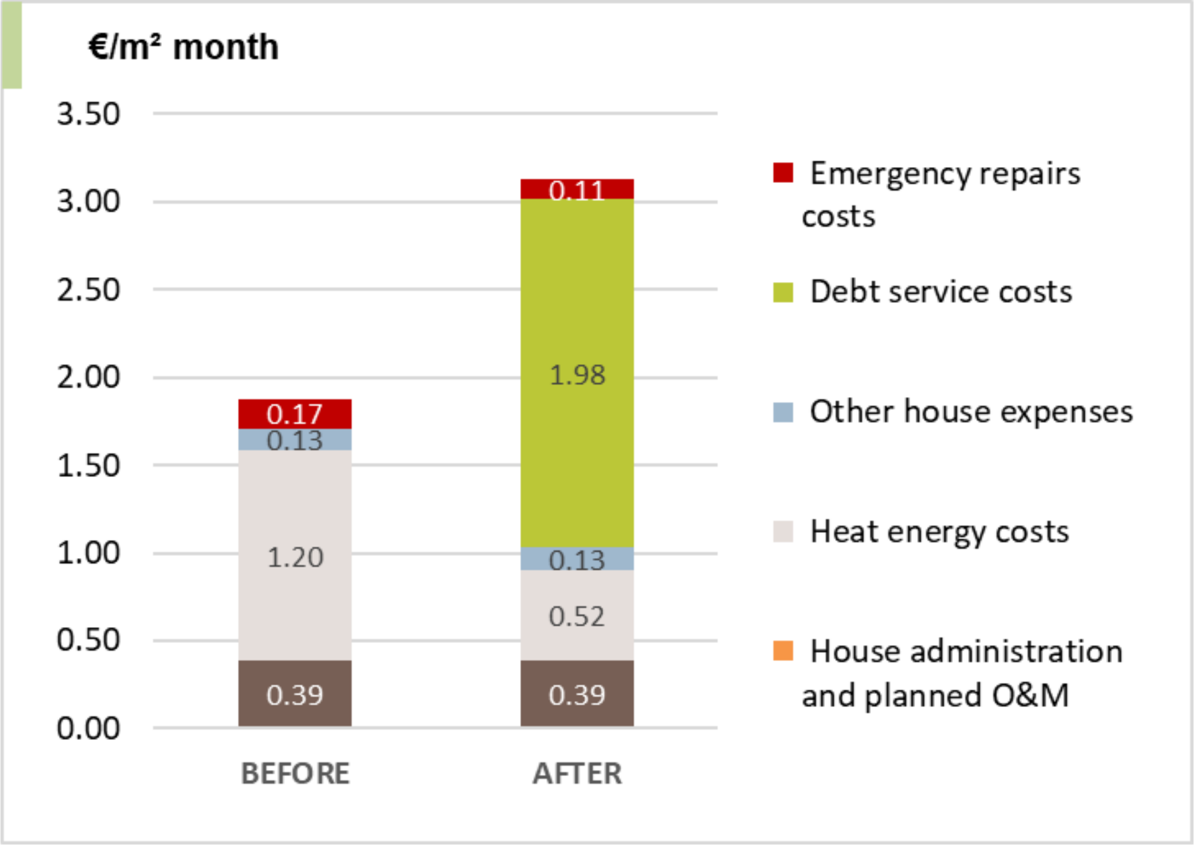
Calculation of economic performance



- At energy costs 87 €/MWh
- With investments costs for renovation 240 + VAT €/m²
- Loan 3% + EURIBOR and 15 years long
- Without any subsidies

$$\text{Simple payback time} = \frac{542080\ €}{130\ MWh * 87\ EUR/MWh} = 47\ \text{years}$$

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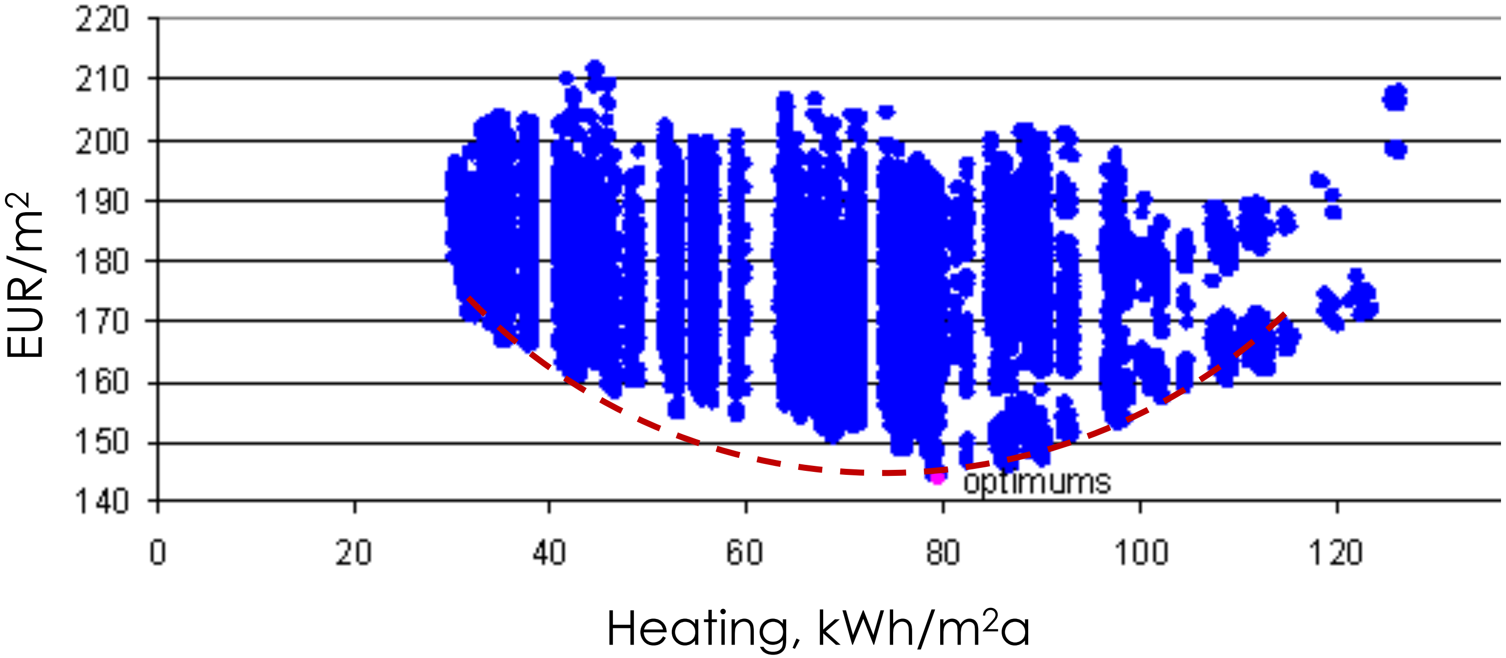
Optimization example



Optimization results for a standard multi-apartment building for a 20-year calculation period. The optimum forms between 75 and 85 kWh/m^2 per year

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Key takeaways

- The calculated **cost curves proofed to be a valuable basis for the analysis of cost-effective savings vs supply** at the national as well as regional level and for the prioritization of policy intervention in different parts of the building stocks
- **Deep building renovation is difficult to justify from an individual business-case perspective** in the context of low energy prices. But the **main reason is that buildings still require technical upgrades** (new heating system and substation, roof, sewage). Drivers for the renovation typically also include improving the overall building quality, indoor environment, as well as the image and value of a building and city district
- At the national level, energy savings contribute to rational use of resources and allow for resource exports, while also delivering environmental and employment benefits
- Energy efficiency programs can prioritize cost-effective measures with short payback periods, such as heat substation replacement, attic insulation, and heating pipe insulation
- However, to **address the poor condition of the building stock**, deep renovation is necessary—**closely linked to broader housing policy goals, including the provision of affordable and safe housing**

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