Investigating the business case for a zero-energy refurbishment of residential buildings by applying a pre-fabricated façade module

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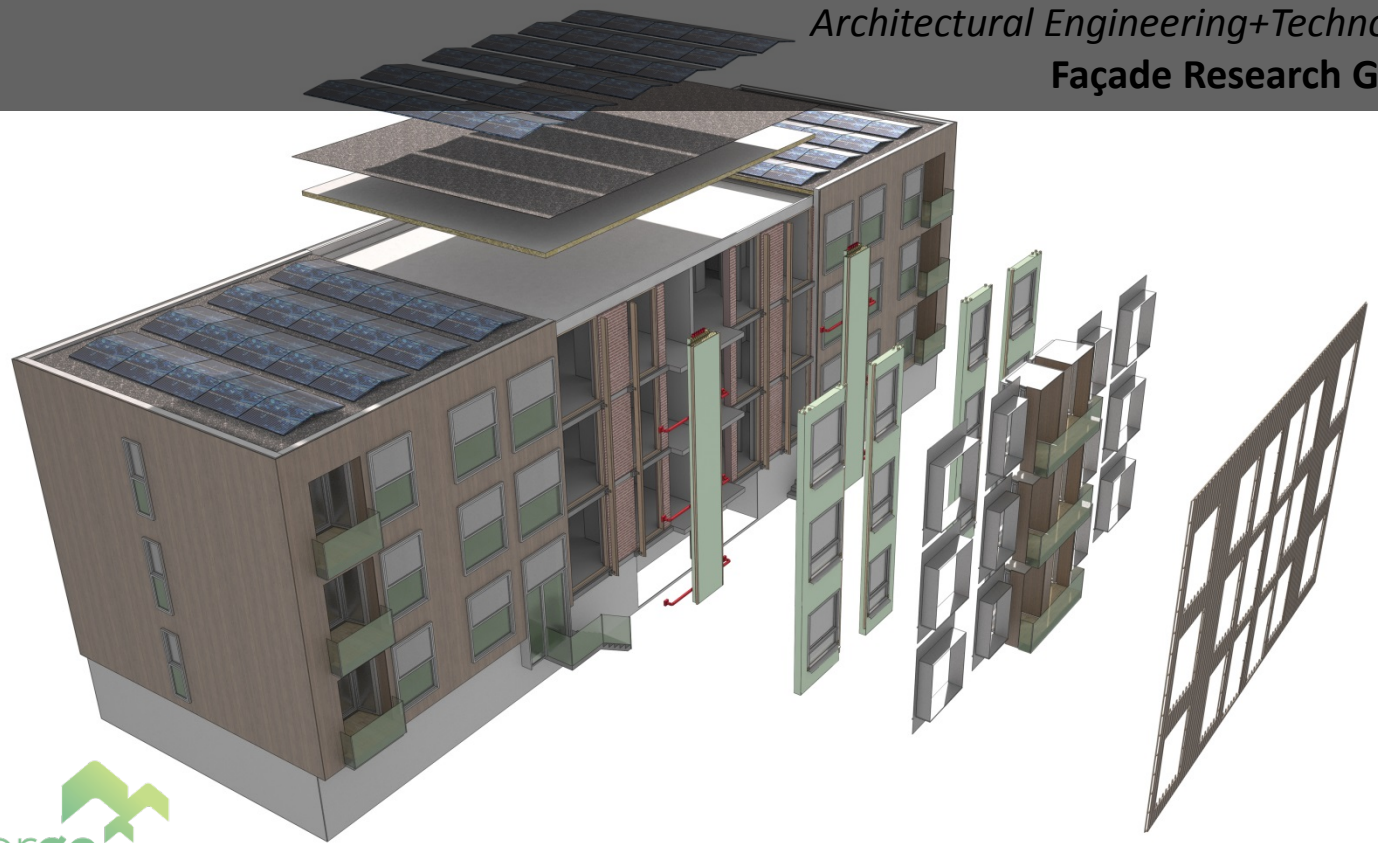

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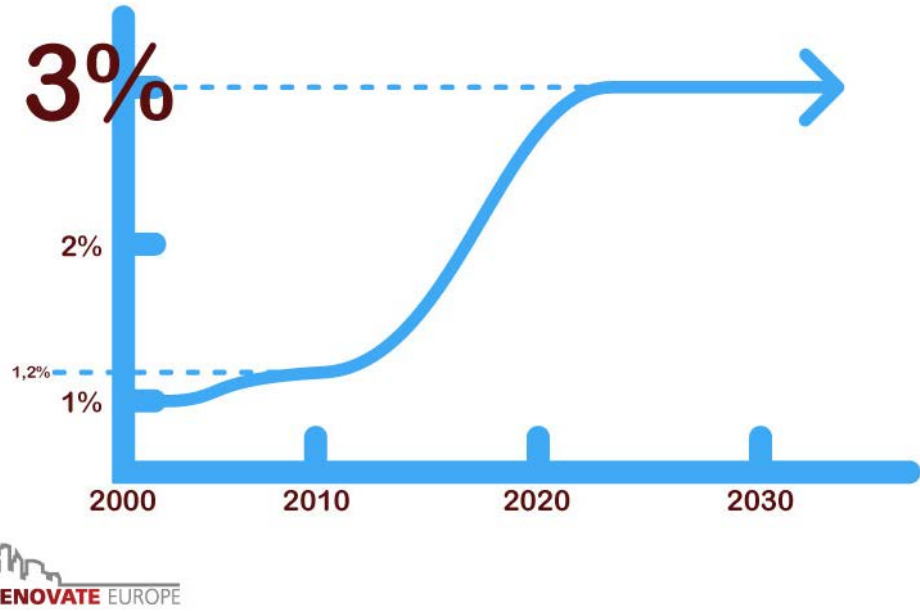
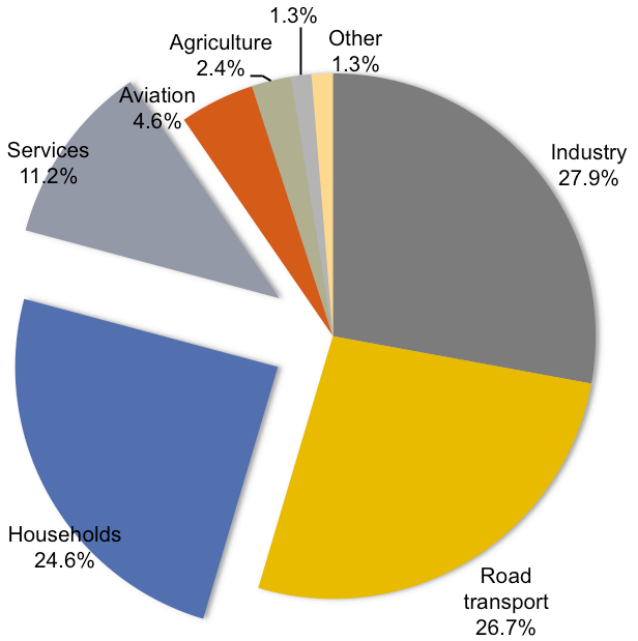
Motivation



http://renovate-europe.eu/the-campaign/ambition-objectives/

Climate relevance and impact

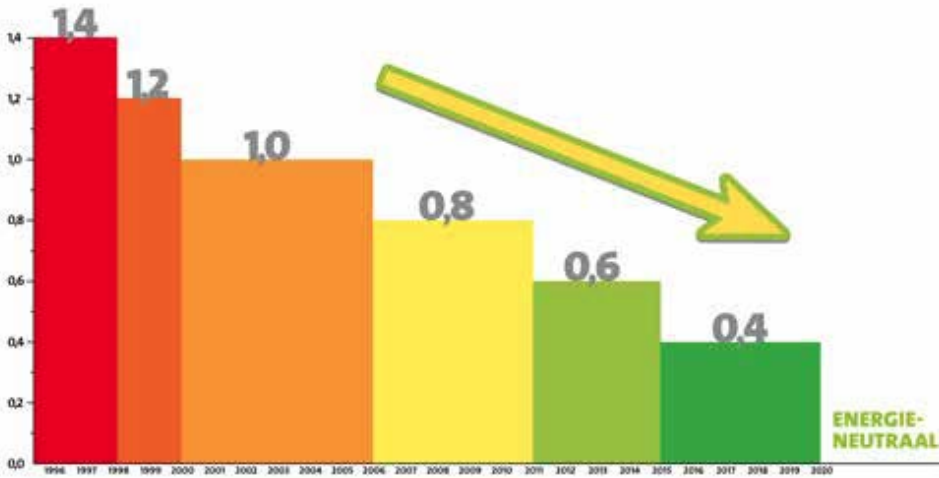
- 40% of the energy usage; 2/3 is used in residential
- only 1% /yr added to building stock
- Built under far lower energy and sustainability standards
- Refurbishment rate and depth needs to double or triple



Final energy consumption, EU-27, 2007 (Eurostat, 2009)

Deep Renovation to Zero-energy building

- In the NL, 300.000 dwellings should be renovated annually
- Housing associations apprx 34% of the total housing stock
- Ambition to achieve an average label B by 2020
- Some corporations have an explicit goal to do zero-energy renovations



Kapfenberg, Austria (Nussmueller, 2015)

Prefabrication

- High performance solutions
- Minimising on-site construction time
- Possible building services integration

TES EnergyFacade

Stromversnelling, Soesterberg, 109 woningen naar Nul op de Meter

Kapfenberg, Austria (Nussmueller, 2015)

Prefabrication

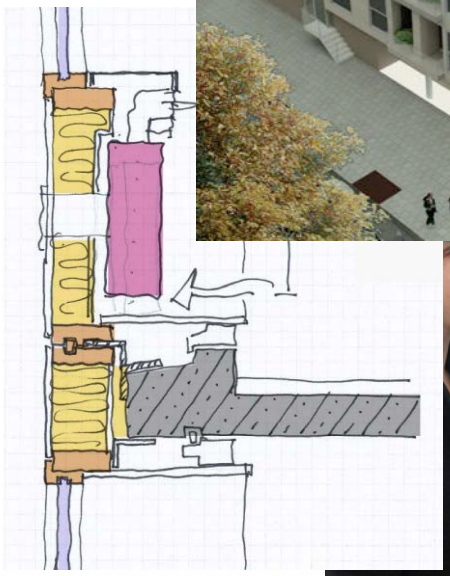
- High performance solutions
- Minimising on-site construction time
- Possible building services integration
- Still challenging to achieve energy neutral tenement apartment for affordable price and acceptable for the residents

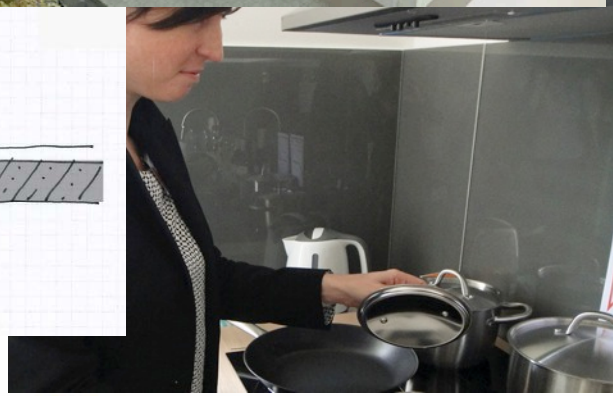
TES EnergyFacade

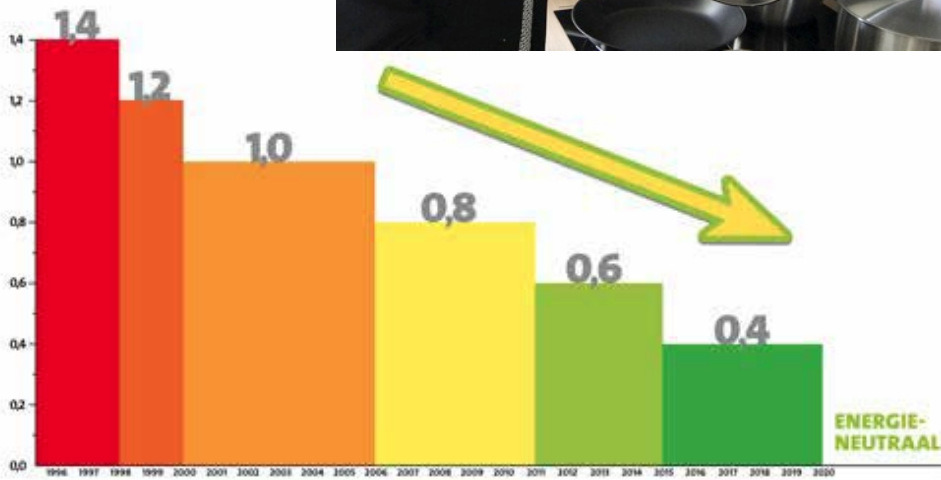
Stromversnelling, Soesterberg, 109 woningen naar Nul op de Meter

2ndSkin Project Objectives

- Innovative, integrated façade technology
    - •Zero energy consumption (Null op de meter)
    - •Minimum intervention to the interior
- Business Development
    - Low cost
    - Upscalling
    - New business model of supply chain
- User Aspects
    - •Renovation acceptance
    - •Monitor behaviour and energy use
    - •Improve interaction with new systems







2ndSkin Partners

Business Models

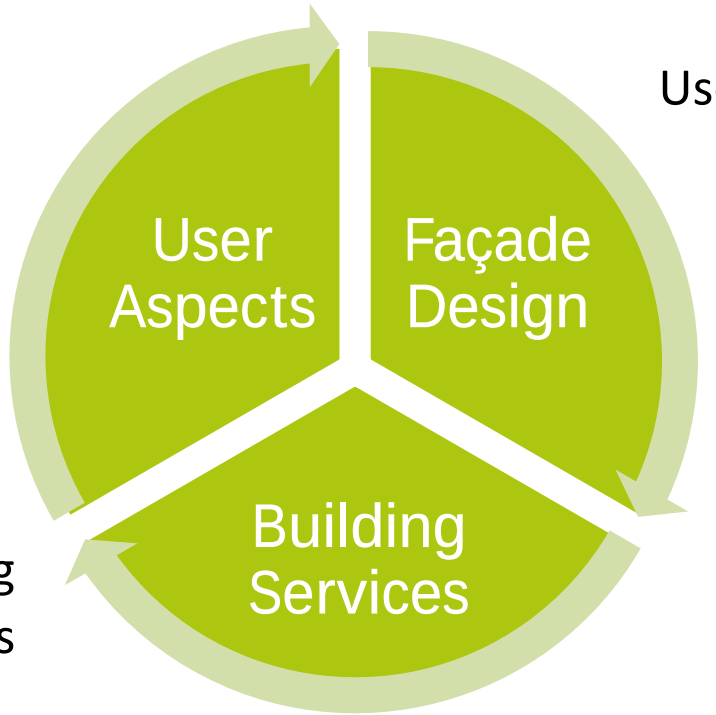
User needs

Building typologies and market

Housing Cooperation's

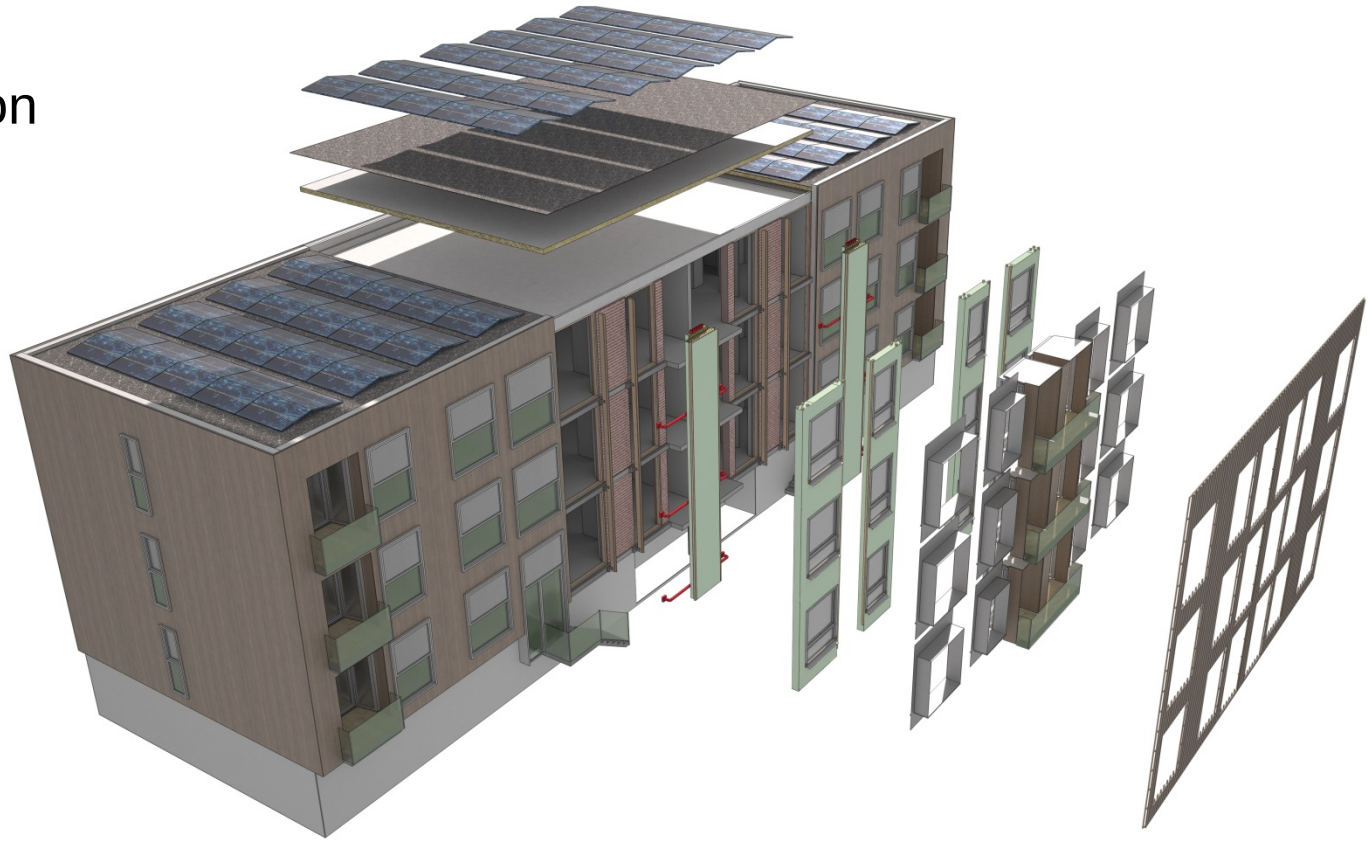
Architectural Design

Maintenance

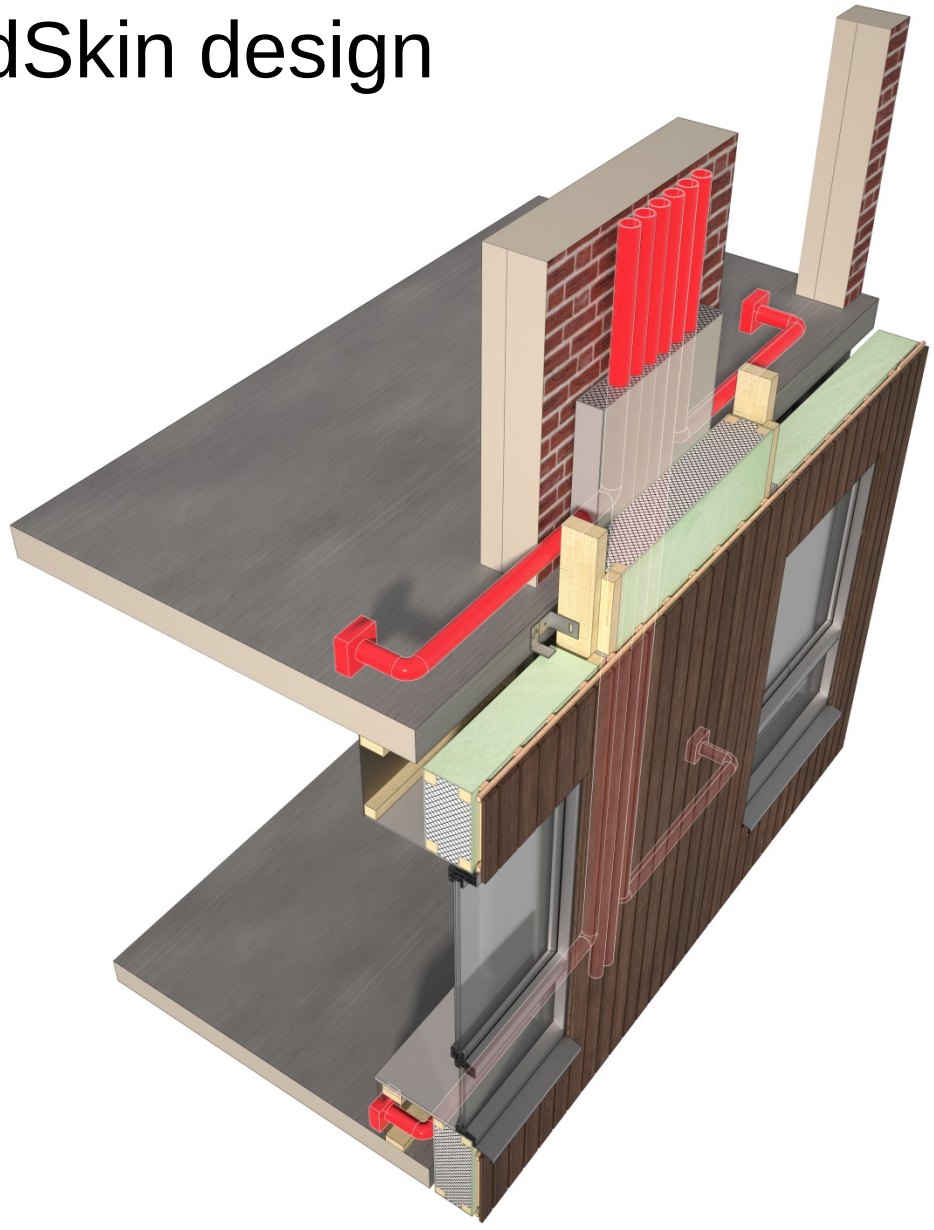


2ndSkin Technical solution

- Remove existing windows
- Installation layer
- Wall insulation and new windows
- Cladding
- Roof insulation
- PV panels



Current 2ndSkin design

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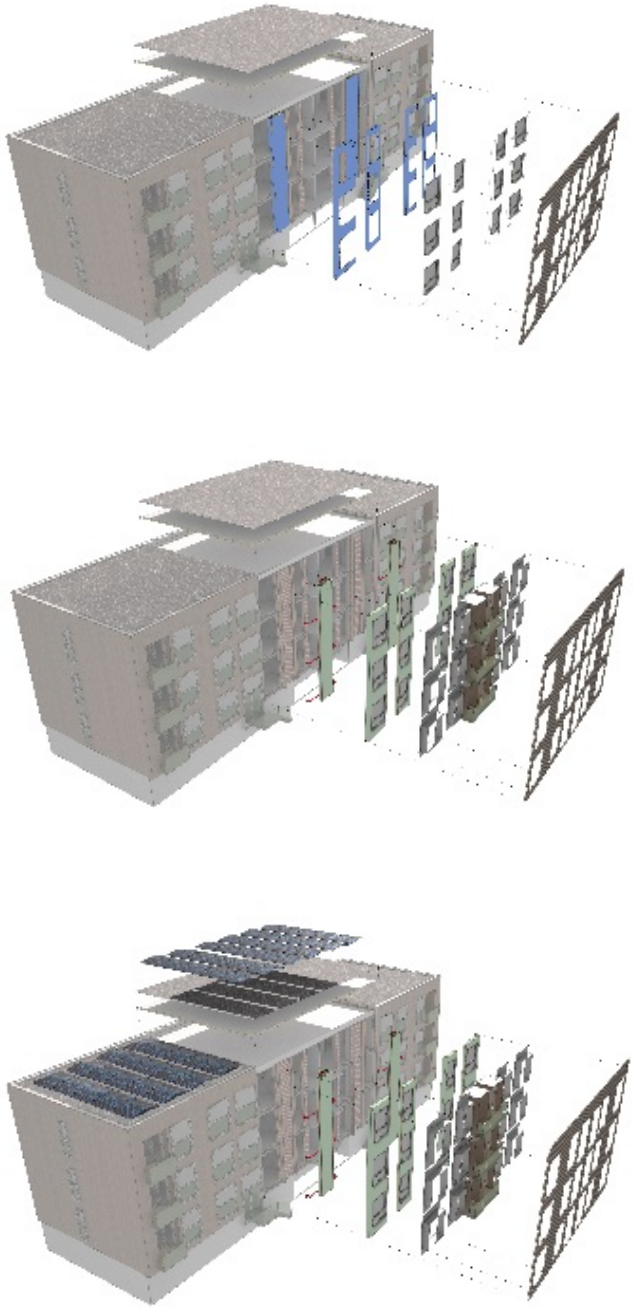
The study:

Financial breakdown of the case-study concept

Performance of the investment

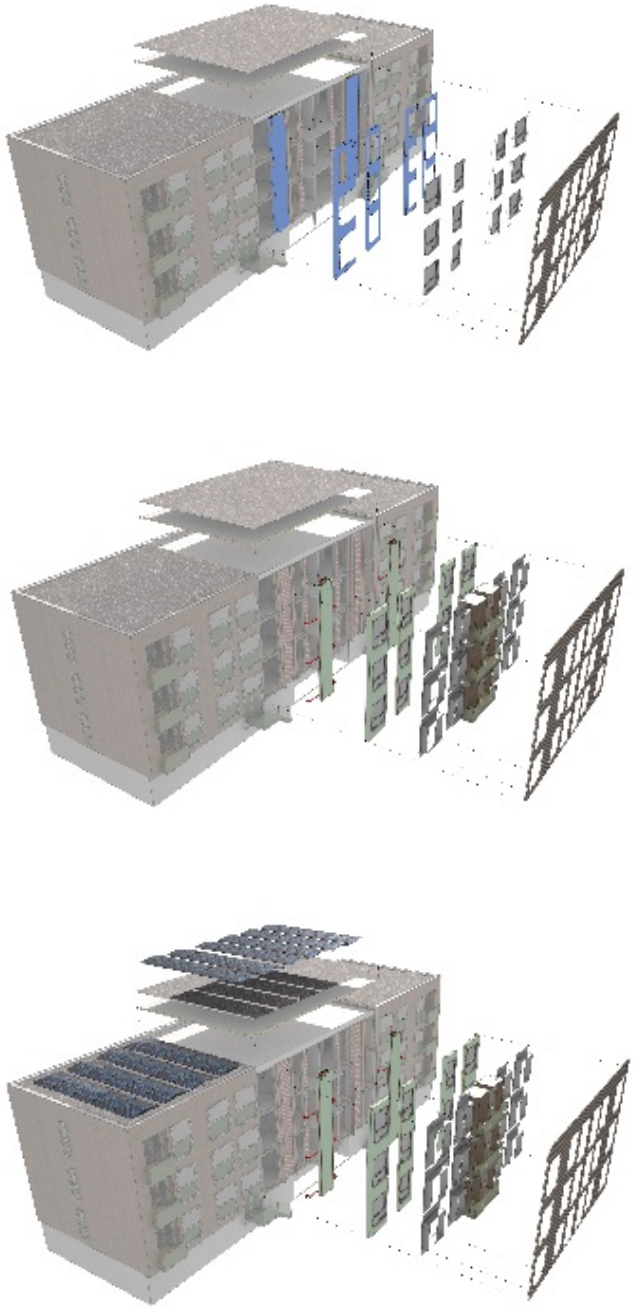
Identify parameters for the business case



Method

Refurbishment solution variations

- Traditional exterior renovation
- 2ndSkin NOM-ready
- 2ndSkin NOM



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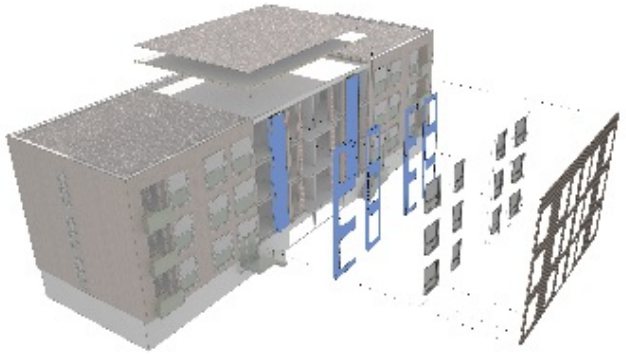
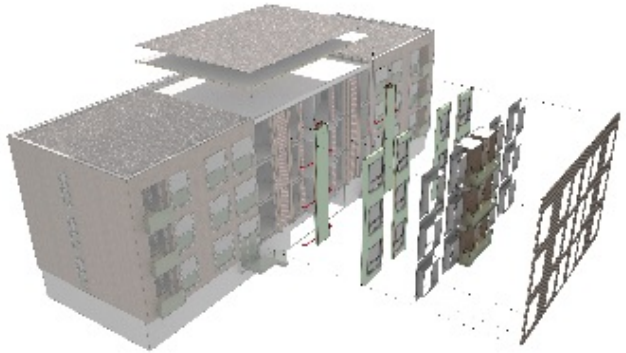
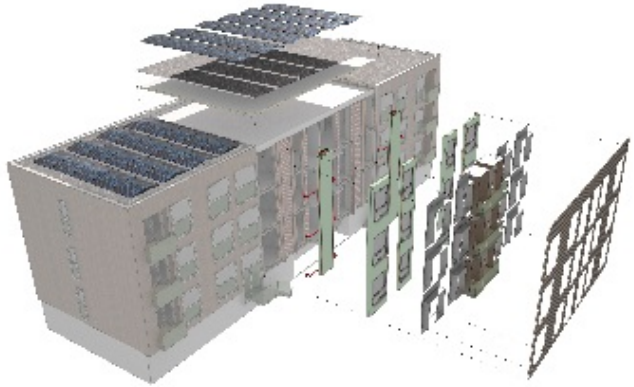




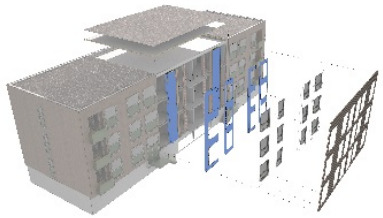
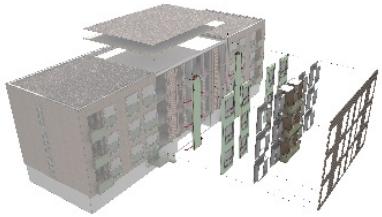
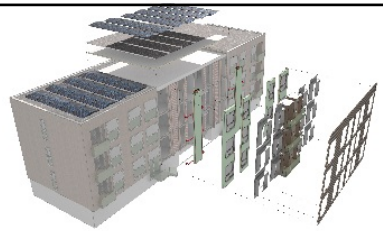
Financial feasibility study

Stage 1. Sensitivity analysis

Stage 2. Property analysis



Refurbishment solution variations

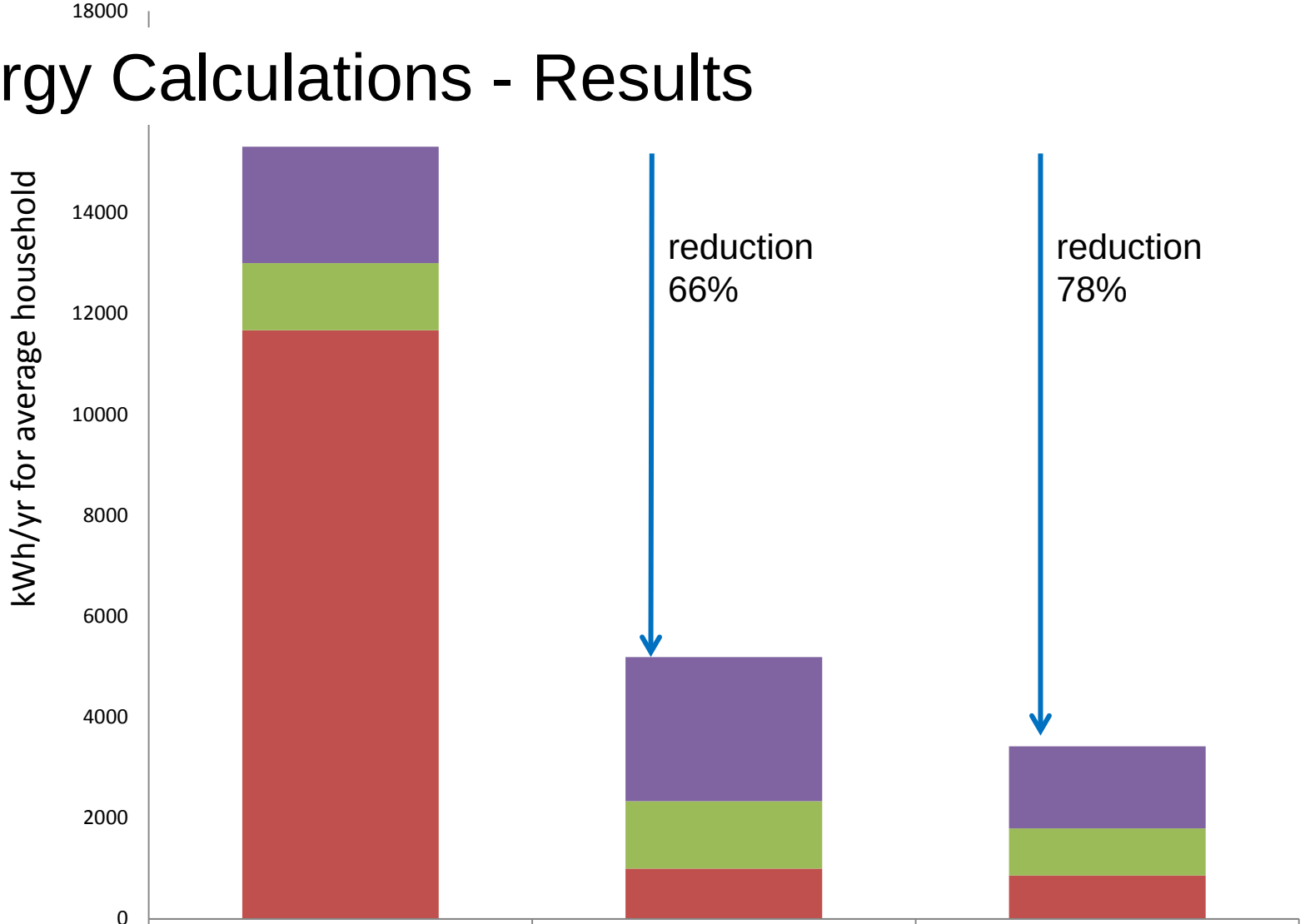
	Traditional insulation from the outside	2ndSkin NOM-ready	2ndSkin NOM
			
Façade	External insulation and finishing system (EIFS) 190 mm, with brick cladding, Rc 6.5 New high performance windows U 0.8	2ndSkin prefabricated panel Rc 6.5 New high performance windows U 0.8	2ndSkin prefabricated panel Rc 6.5 New high performance windows U 0.8
Roof	● Roof insulation sandwich panels Rc 4.5	● Roof insulation sandwich panels Rc 4.5	● Roof insulation sandwich panels Rc 4.5
Building services	Existing gas boiler Mechanical ventilation system with heat recovery	Existing gas boiler Mechanical ventilation system with heat recovery	● Pv-panels, 255Wp Air-to-water heat pump for heating (all-electrical system) Mechanical ventilation system with heat recovery

Energy calculations - Method

- Building-related (heating, ventilation, lighting) and user-related (domestic hot water, appliances) energy consumption
- Two behavioural scenarios were used
- Two scenarios for electric appliances

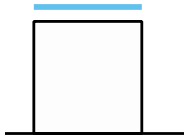
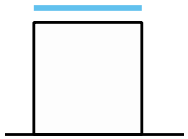
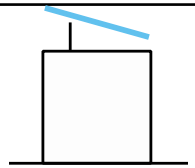
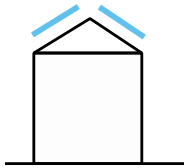
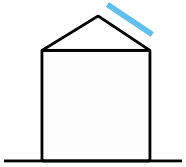
Guerra-Santin, O., Bosch, H., Budde, P., Konstantinou, T., Boess, S., Klein, T., & Silvester, S. (2016). *2ndSkin approach to zero energy renovation*. Paper presented at the BEHAVE 2016, Coibra, Portugal.

Energy Calculations - Results



	Before renovation (apartment blocks, based on WoON)	After renovation (scenario 1. inefficient appliances, unchanged behavior)	After renovation (scenario 2. efficient appliances,heat recovery shower, adapted behavior)
Appliances	2306,6	2861,2	1625
DHW	1333,11	1333,11	933,18
Heating	11671,0026	997,9	862,5

Energy Generation

Scenario	Orientation	Type of roof
EW_flat	East-West	
NS_flat	North-South	
NS_flat_b	North-South	
EW_pitch	East-West	
NS_pitch	North-South	

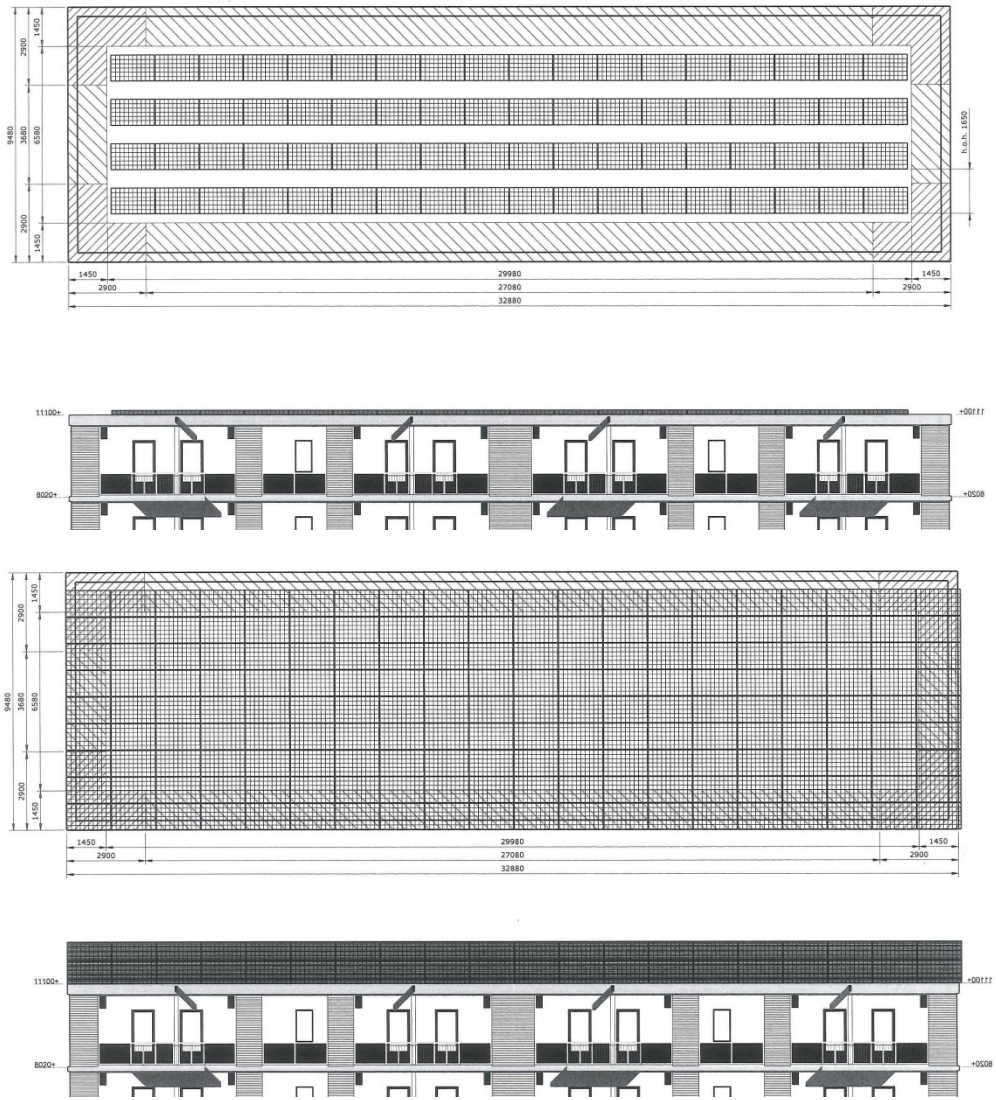
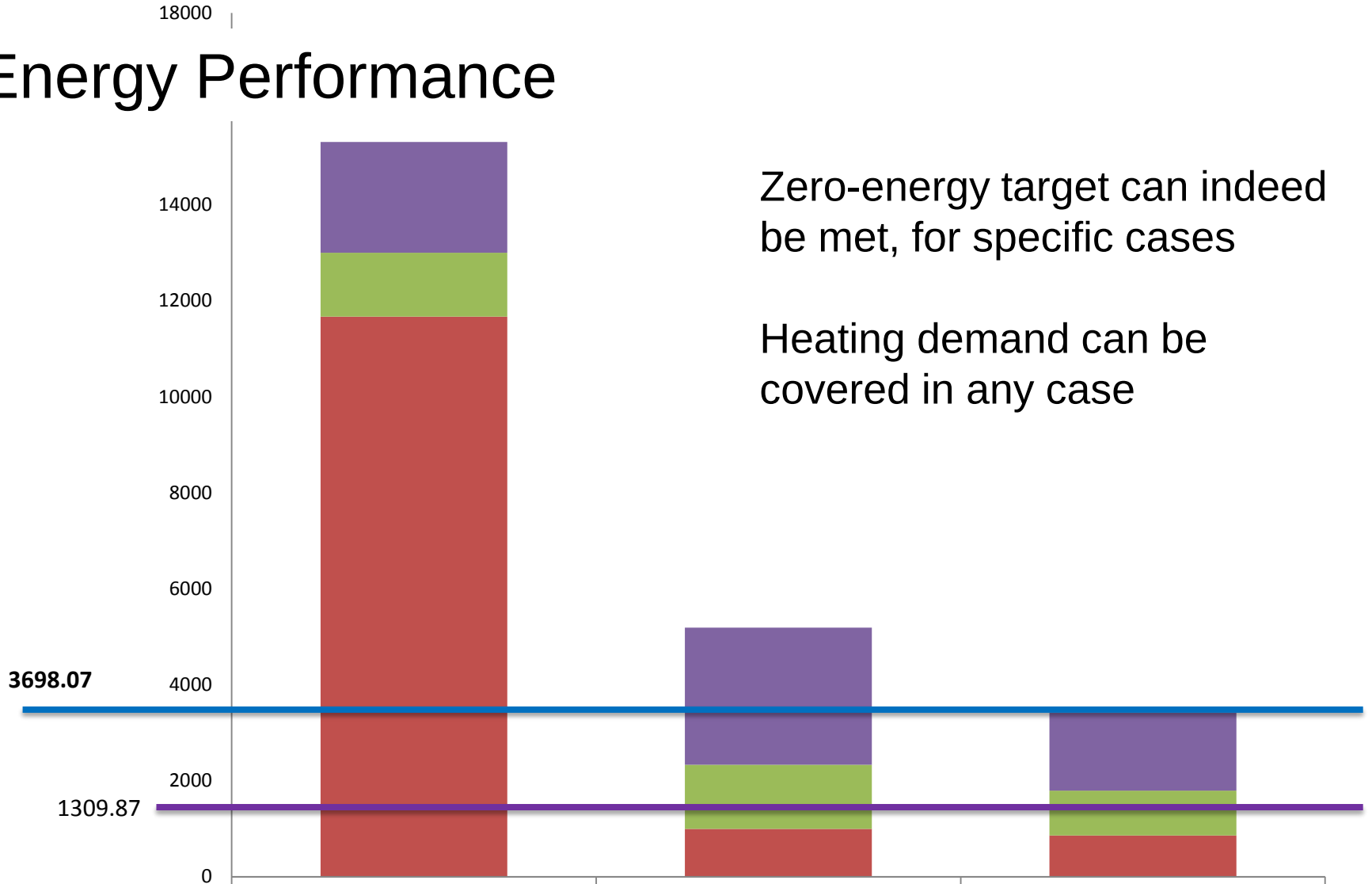


Table 2. Total energy production per apartment in kWh/year per building/roof scenario

Energy Performance



Zero-energy target can indeed be met, for specific cases

Heating demand can be covered in any case

	Before renovation (apartment blocks, based on WoON)	After renovation (scenario 1. inefficient appliances, unchanged behavior)	After renovation (scenario 2. efficient appliances,heat recovery shower, adapted behavior)
Appliances	2306,6	2861,2	1625
DHW	1333,11	1333,11	933,18
Heating	11671,0026	997,9	862,5

Financial feasibility study-
Stage 1.Sensitivity analysis

Financial feasibility study-
Stage 1.Sensitivity analysis

Projected cash-flow:

Expenses: renovation cost, energy consumption

Income: projected added value, rent income

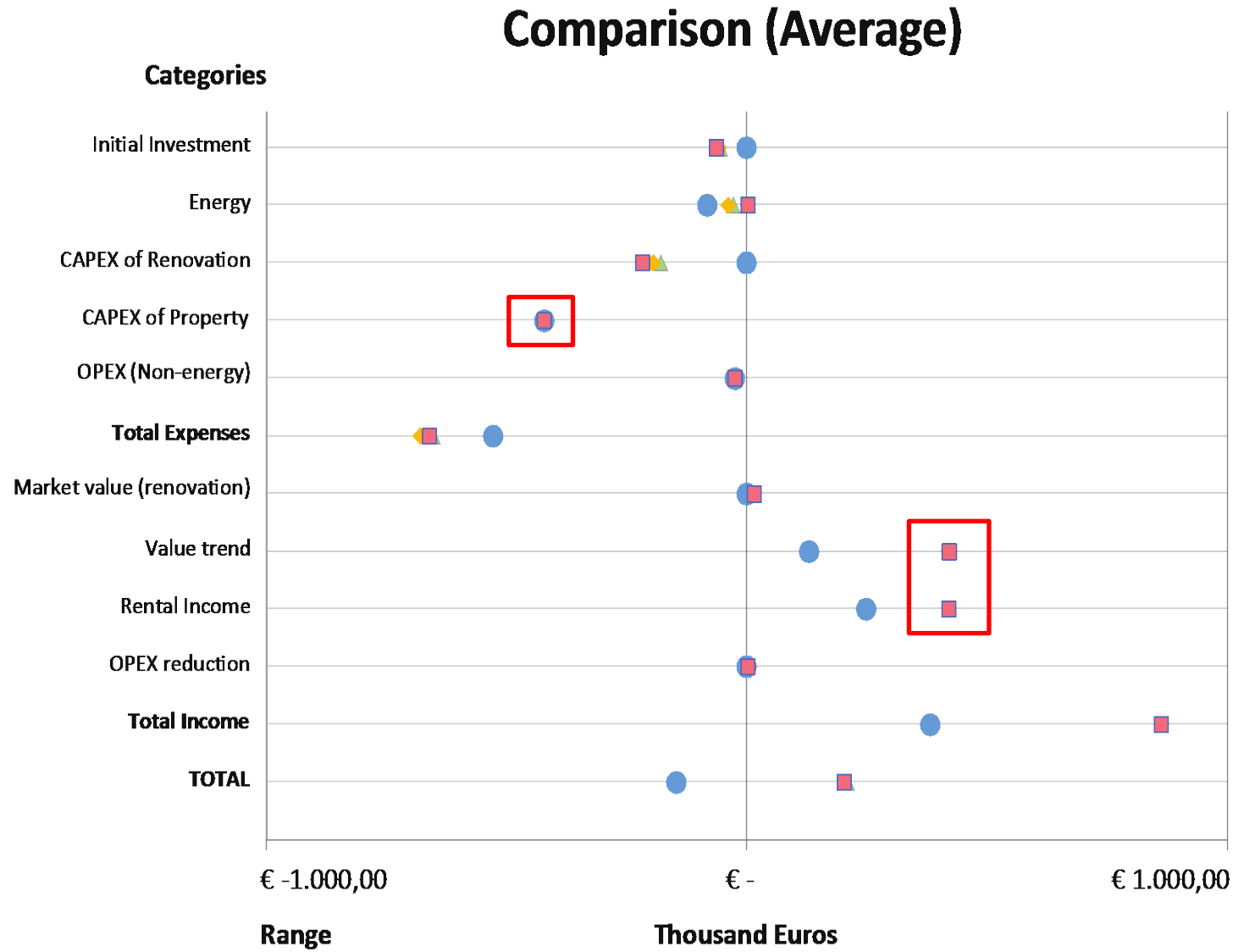
Total balance

Key parameters	Value range			
Time of study (Years)	30			
Renovation strategy	**No renovation**	**External renovation**	**2nd Skin NOM-Ready**	**2nd Skin + PV NOM**
Renovation cost	€ 0	€ -55.000	€ -60.000	€ -66.800

Financial feasibility study-
Stage 1.Sensitivity analysis

	Key parameters	Negative	Average	Positive
Industrial parameters	Economy of scale reduction (1,000 prefabricated units)	0%	5%	10%
Property parameters	Market value of apartment unit (pre-renovation)	€ 75.600	€ 130.000	€ 175.500
	Market value increase after renovation (one time)	5%	8%	11%
	Value trend of apartment unit (with renovation)	2%	4%	6%
	Value trend of apartment unit (without renovation)	-2%	0%	2%
	Occupancy rate before renovation	65%	75%	85%
	Occupancy rate after renovation	75%	85%	95%
	Rent per unit per month (exclusive)	€ 540	€ 920	€ 1.240
	Rental profit per unit per year (Rent - 20% (Admin + OPEX))	€ 5.184	€ 8.832	€ 11.904
	Rent increase per apartment (with renovation)	2%	4%	6%
Economic parameters	Rate of Inflation	0,25%	2%	3,50%
	Energy price increase (per year)	2%	4,5%	7%
Financial parameters	CAPEX (Capital Expenses)	6,0%	4,0%	2,0%
	Non-Energy OPEX (Operational Expenses)	10,0%	15,0%	20,0%
	OPEX savings after renovation	5,0%	15,0%	25,0%

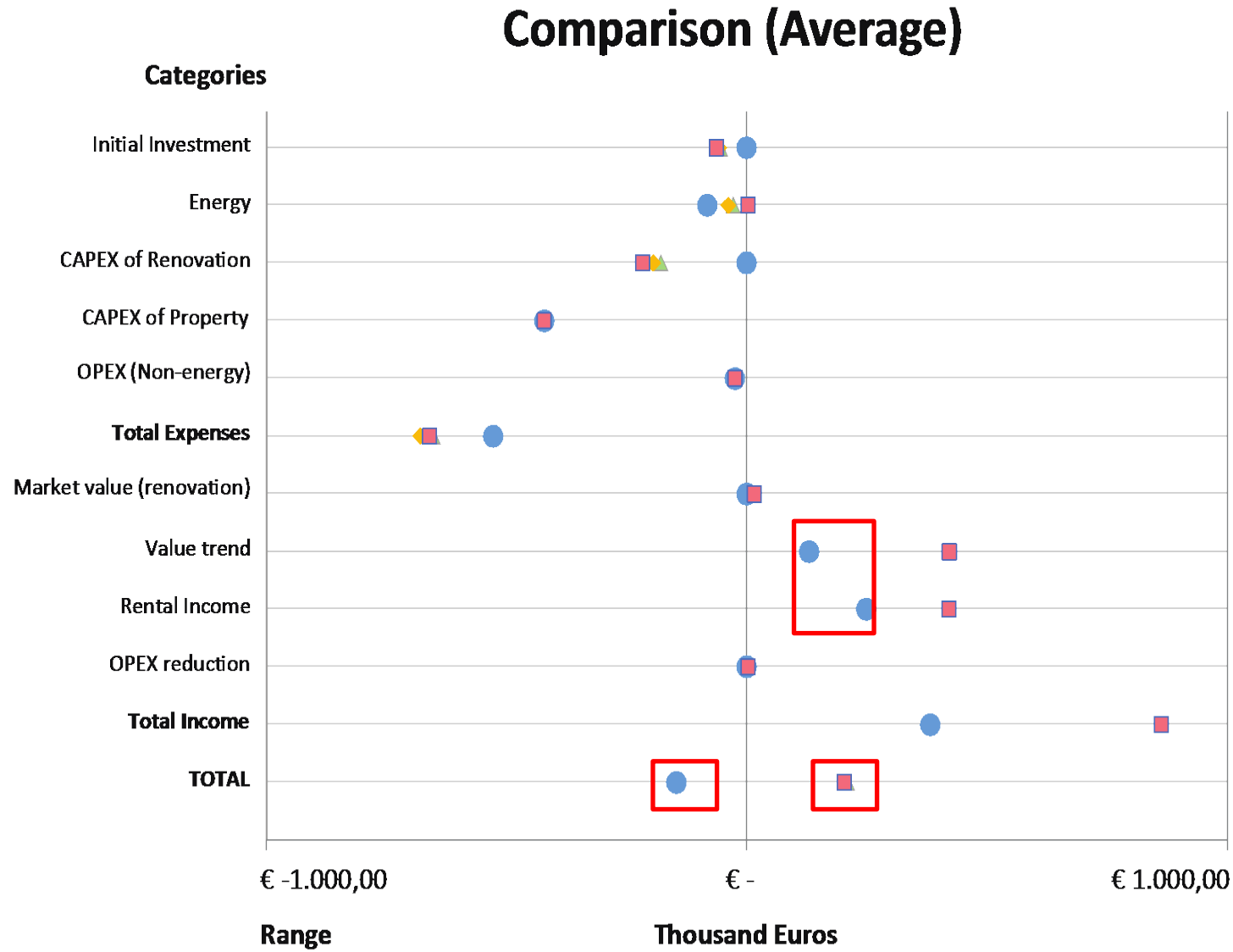
Financial feasibility study- Stage 1.Sensitivity analysis



- Most determinant CAPEX incurred from ownership
- Most generated gains from the projected value increase trend and rental income

Comparison graphs showing the performance of the four distinct renovation strategies on an apartment with a median market value.

Financial feasibility study- Stage 1.Sensitivity analysis



- All renovation strategies lead to positive returns
- Non-renovated apartment likely performs financially poorly due to its expected drop in real estate value

Comparison graphs showing the performance of the four distinct renovation strategies on an apartment with a median market value.

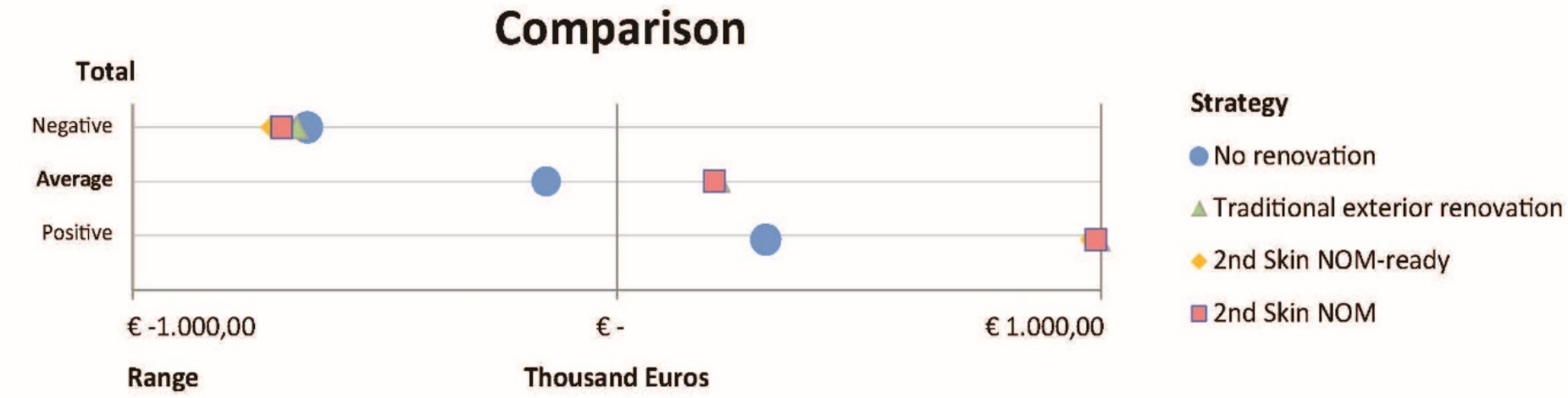
Financial feasibility study-
Stage 1.Sensitivity analysis

Pessimistic scenario: all strategies perform poorly and lead to losses.

The additional capital invested lead to only a minor additional loss when compared with the non-renovated model.

Average or positive economic: renovated properties perform significantly better than non-renovated models.

Optimistic scenario: all renovated models perform as much as three times better than the non-renovated option.



Total balance (Income-Expenses) for each renovation strategy, on a median-valued apartment, based on Negative, Average and Positive scenarios.

Financial feasibility study-
Stage 2. Property analysis

Impact of property value differences

Expected performance of a full 2ndSkin NOM renovation (balance expenses income)

three comparable apartments with diverse market values:
1.300 euros/m2 (social housing in suburban areas), 2.000/m2 euros (median value), and 2.700 euros/m2 (high-end, inner city location).

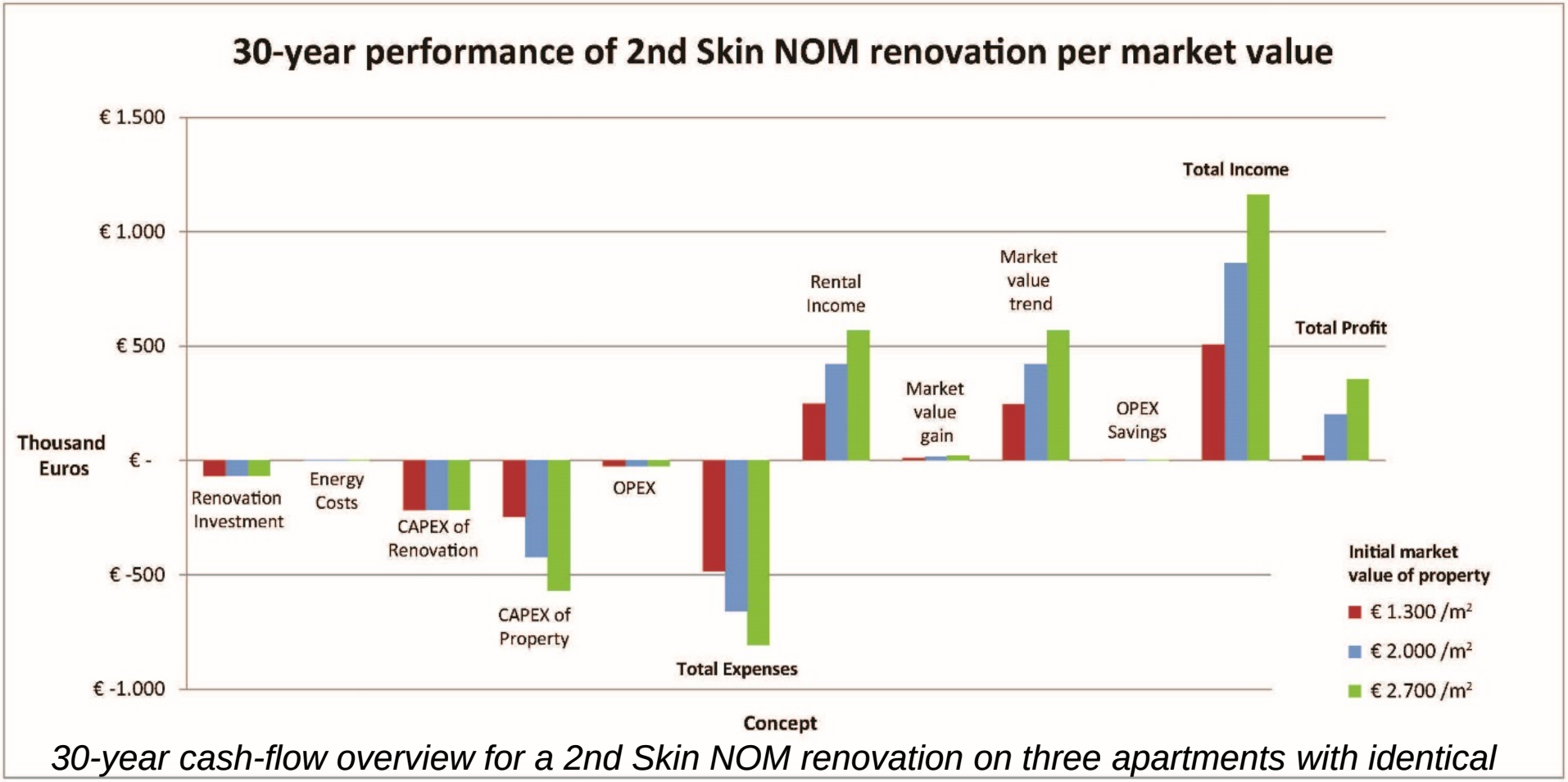
Rental cost per apartment is correspondingly calculated per square meter according to the market value of the property

Energy and non-energy operational expenses are assumed to be the same for all apartments,

Determine the expected Internal Rate of Return for each property

Financial feasibility study- Stage 2. Property analysis

High-end property :5%
Median market value: 3,4%
Low (social-housing): 0,5%



30-year cash-flow overview for a 2nd Skin NOM renovation on three apartments with identical floor areas but diverse market values (eg. due to location)

Financial feasibility study-
Stage 2. Property analysis

High-end property :5%
Median market value: 3,4%
Low (social-housing): 0,5%

- One-time subsidy for NOM-grade renovations (25%)

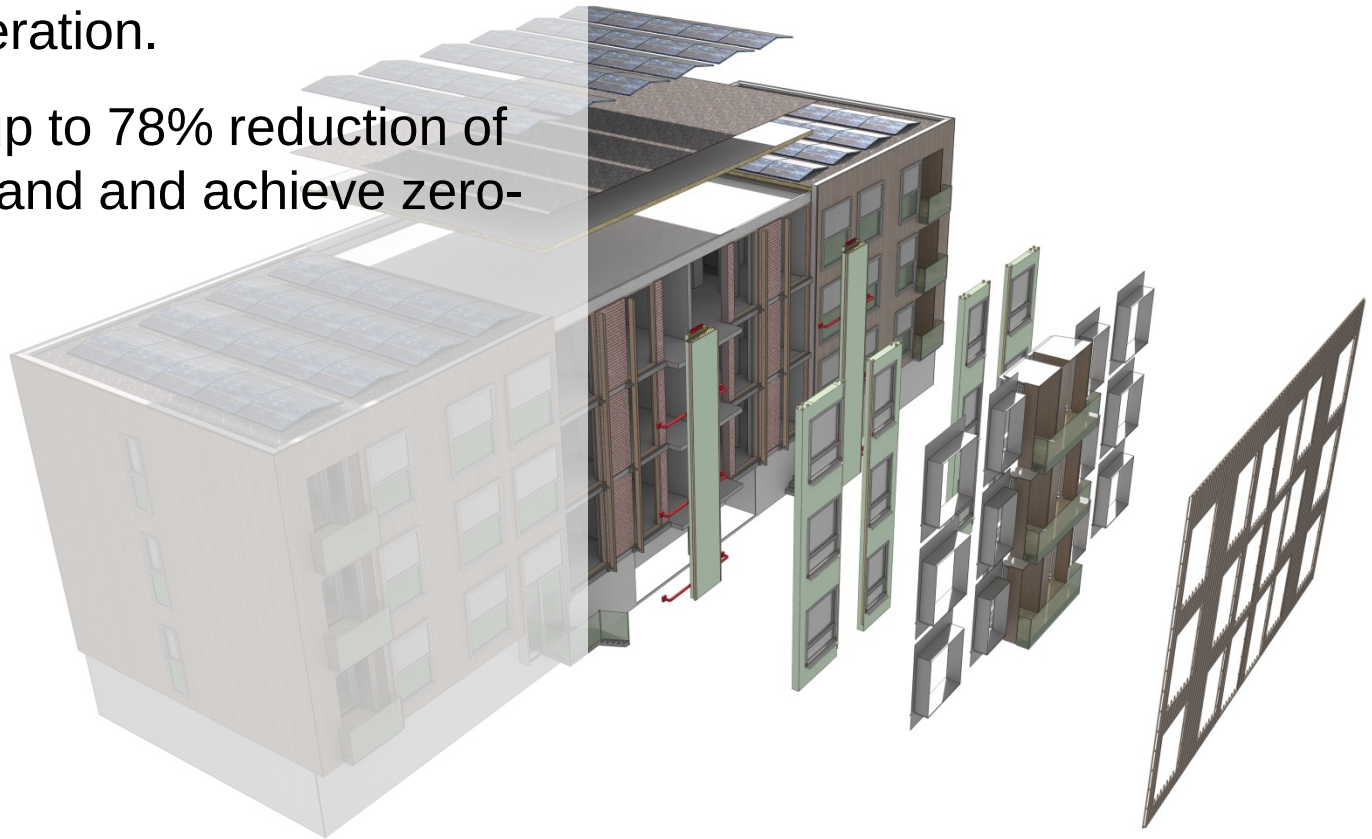
Improve the IRR to 2% per year (for low market value)

- Reduced interest rate improve further IRR

High-end property : 8,7%
Median market value: 7,3%
Low (social-housing): 4,3%

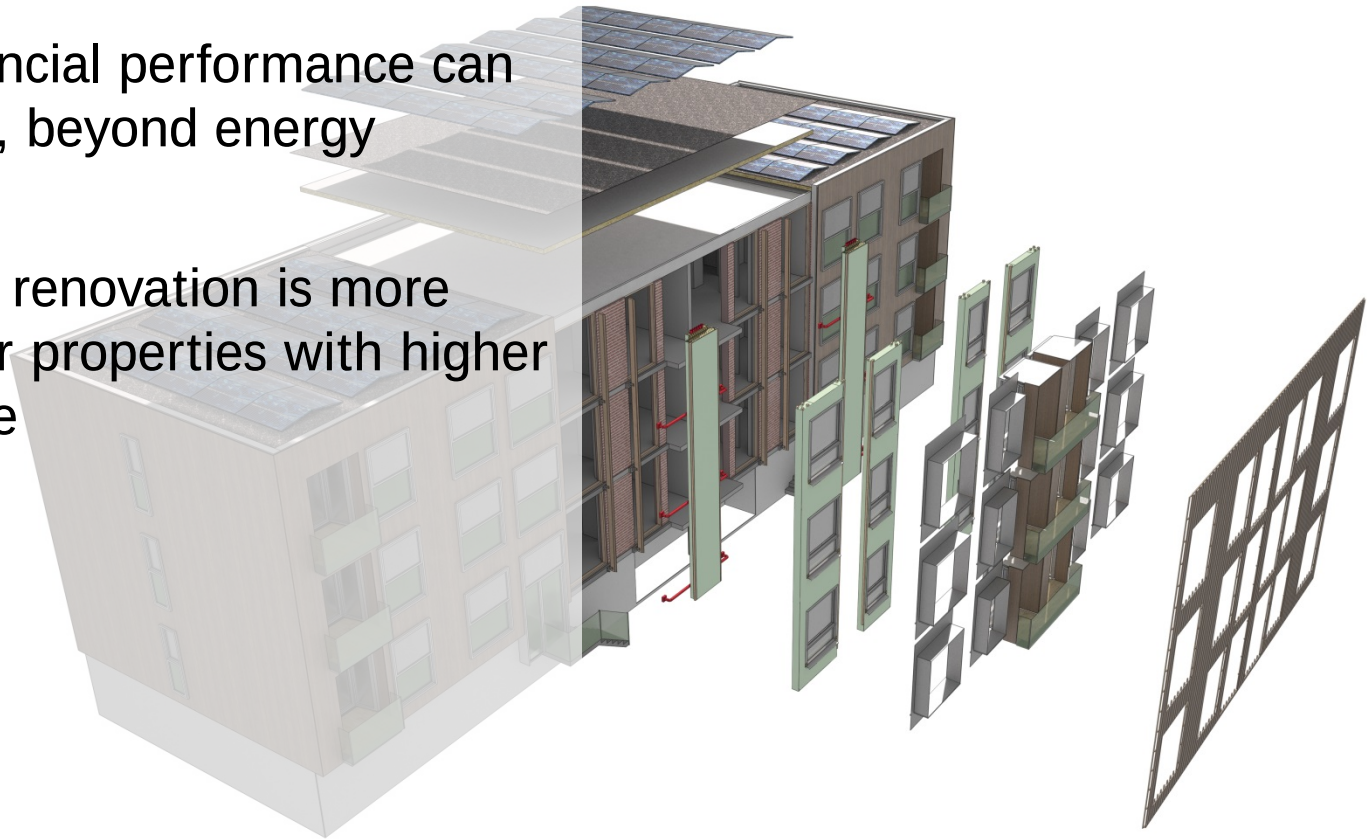
Discussion

- Need to eliminate the energy demand of existing dwellings
- Prefabricated façade modules, integrating building services and energy generation.
- Can reach up to 78% reduction of energy demand and achieve zero-energy



Discussion

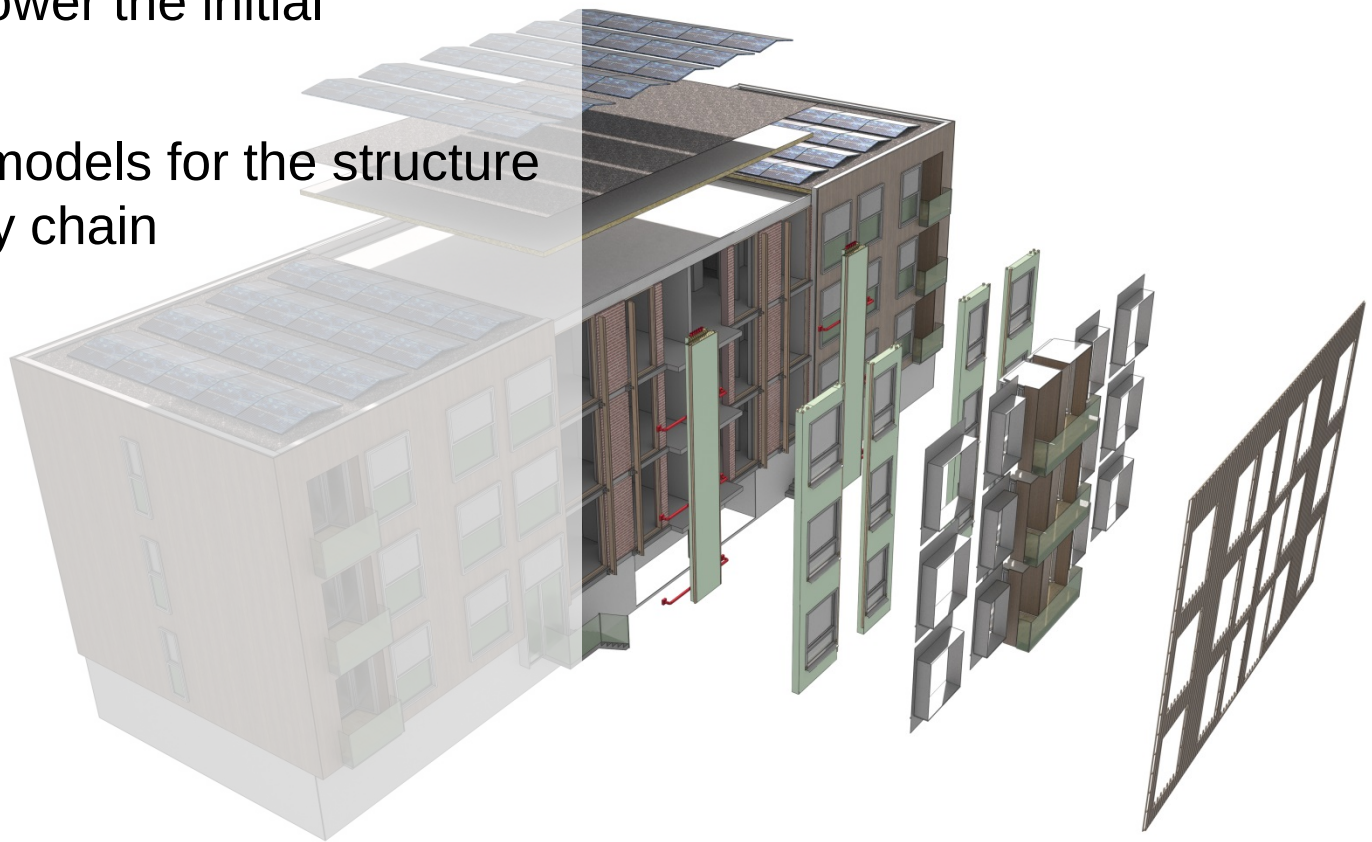
- Renovation scenarios perform better than do-nothing
- A form of future-proofing a rental property portfolio
- Positive financial performance can be achieved, beyond energy savings
- Zero energy renovation is more attractive for properties with higher market value



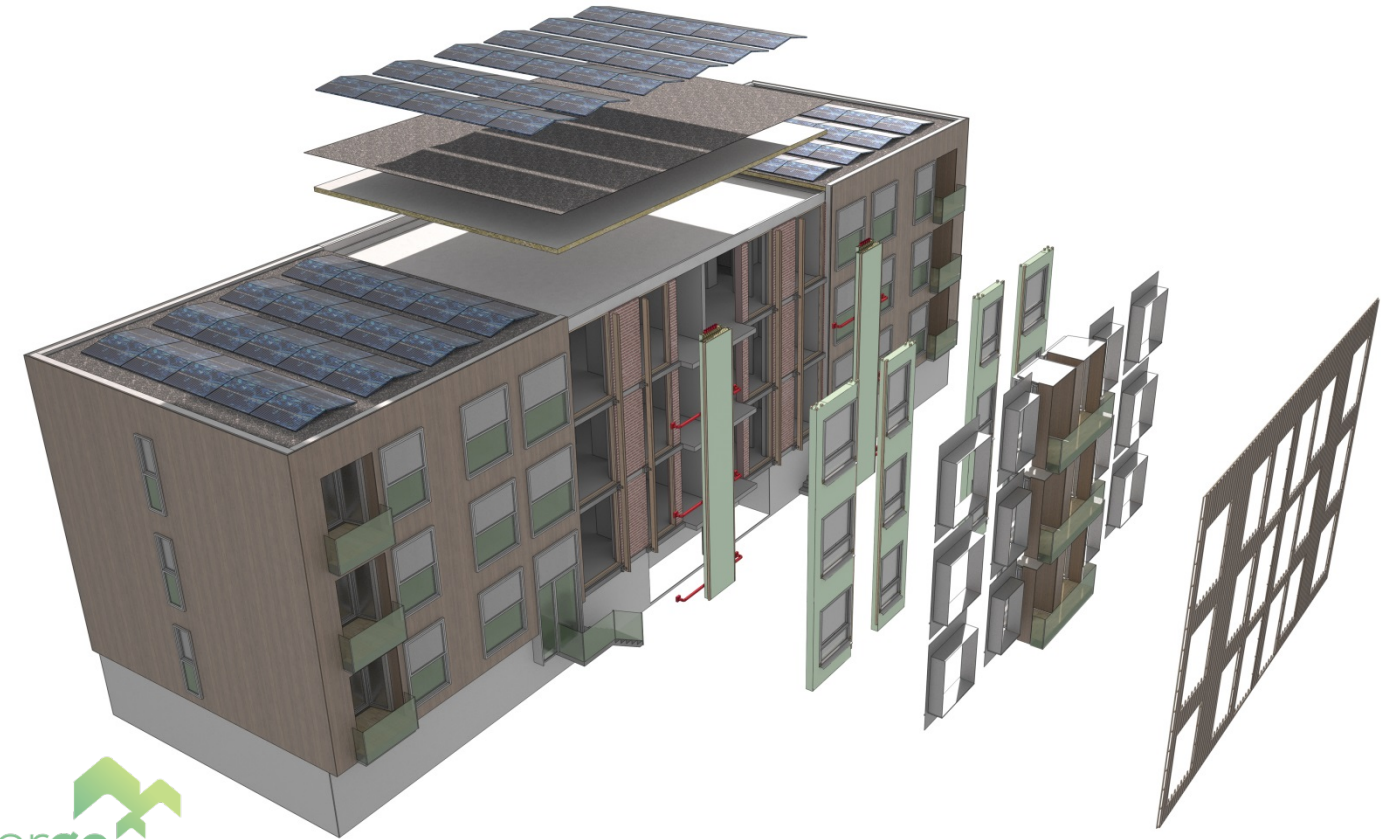
Conclusion

Further research:

- Investigate and test financing strategies
- Options to lower the initial investment
- Alternative models for the structure of the supply chain



…Successful business cases determines the implementation,
to answer to the need to upgrade the building stock



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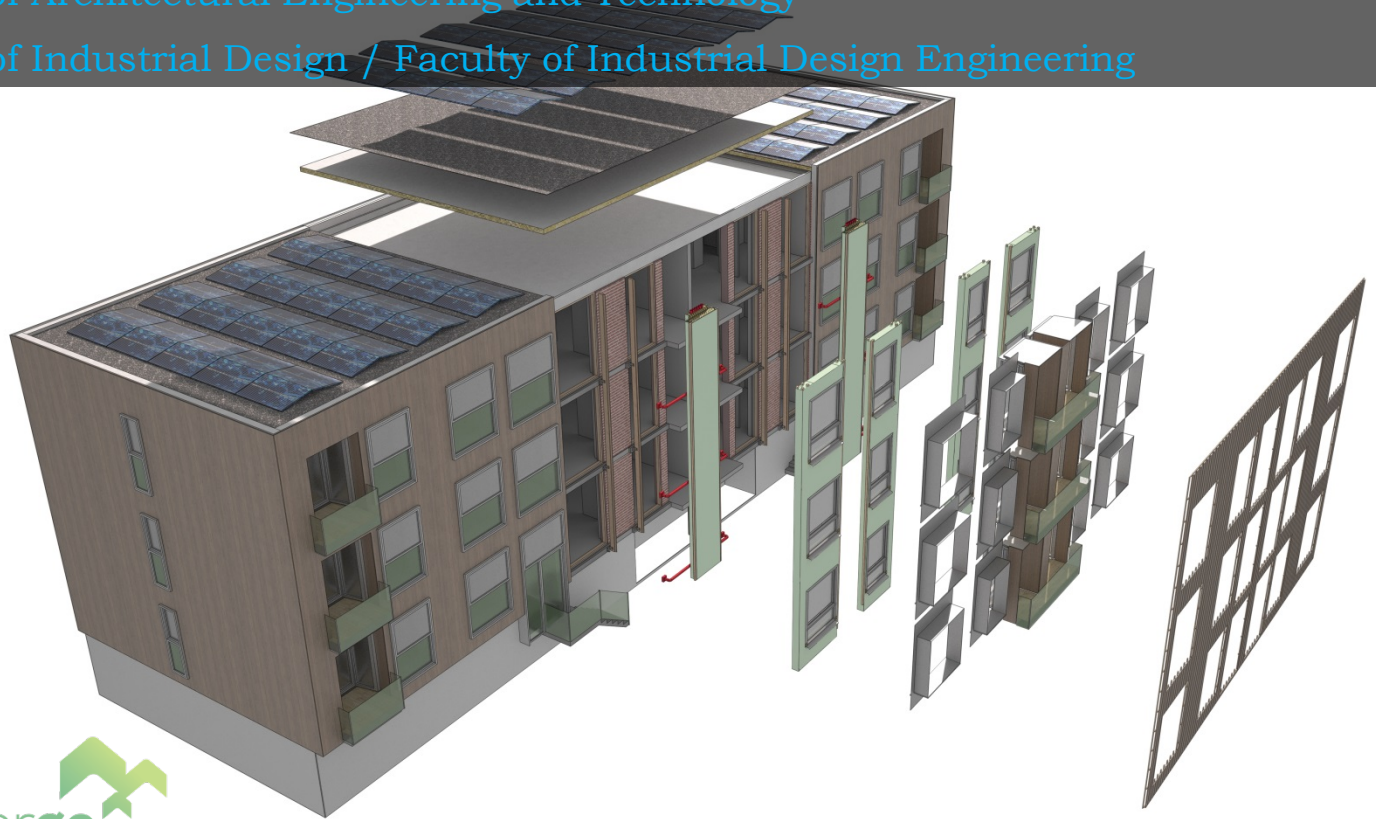
1 Department of Architectural Engineering and Technology

2 Department of Industrial Design / Faculty of Industrial Design Engineering



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Financial feasibility study- Sensitivity analysis

Study and renovation parameters
Time of study
Cost of renovation
Industrial parameters of production processes
Economy of scale reduction

Property parameters
One-time market value increase after renovation
Value trend of apartment
Occupancy rate
Rental income
Rent increase

Economic parameters.
Rate of Inflation
Energy price increase (per year)

Financial parameters
CAPEX – Financial expenses related to the Cost of Capital
OPEX – Operational expenses (excluding energy