Reliability of Advanced Retrofit Annex 55 (RAP-RETRO)

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Start : April 2010
Ends: 2013-2014

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Background

Improving the energy efficiency is often the main focus.

Adding insulation and changing the air and vapor tightness results in a different building envelope.

Complex interaction between building envelope, building services, external climate and the users.

As a result retrofitting measures not only often do not meet the energy targets; they also result in performance failures.

The *scope* of the work:

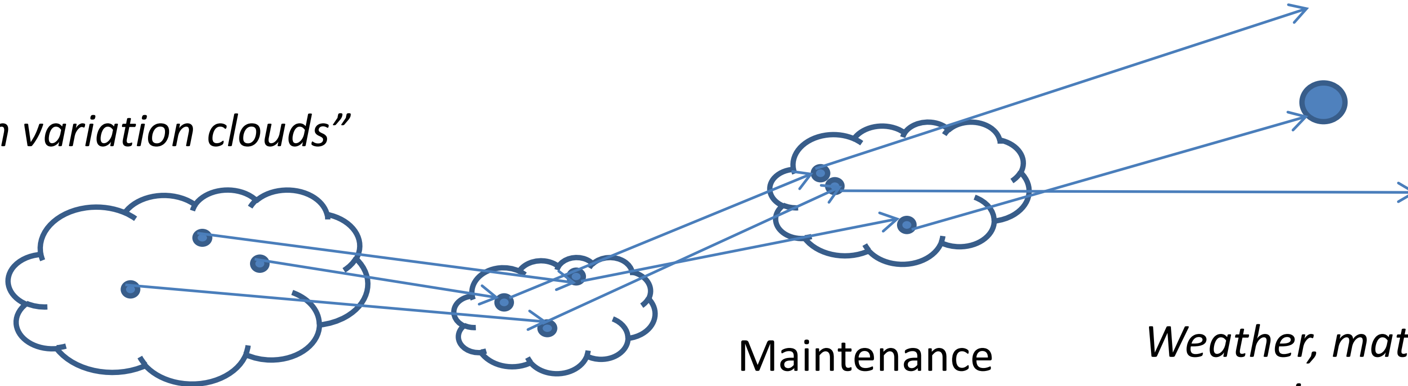
To develop and provide decision support data and tools for energy retrofitting measures leading to substantial upgrading.

The tools will be based on probabilistic methodologies for prediction of energy use, life cycle cost and functional performances.

- Energy
- Thermal comfort
- Performances:
  - U-values, Airtightness
  - Durability (frost, rot, mould and algae growth)
- Cost

Probabilistic approach

"Random variation clouds"



Production

Maintenance
operation

*Weather, material
properties,
exposure to spores,
human behavior,…*

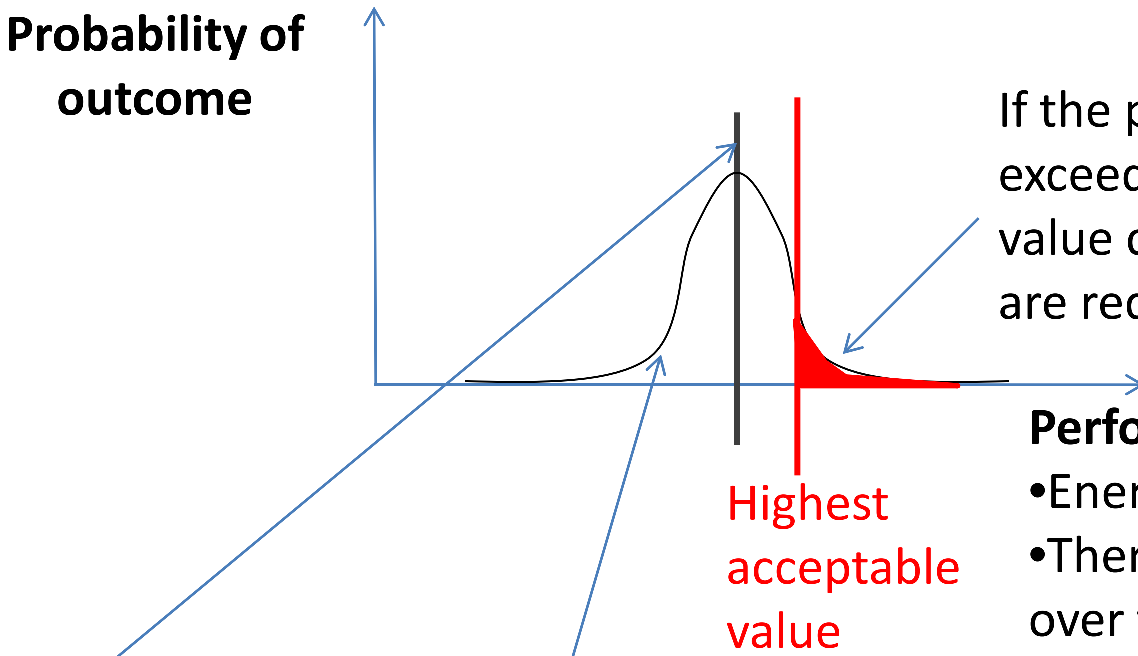
Examples of
random variations in:

*Indoor moisture sources, internal gains
airing, aging of material,
cracks in façades,…*

*Workmanship
initial conditions of material,…*

Spread in LCC due to performance variations

Probability assessment of performance



If the performance exceeds the acceptable value costly measures are required.

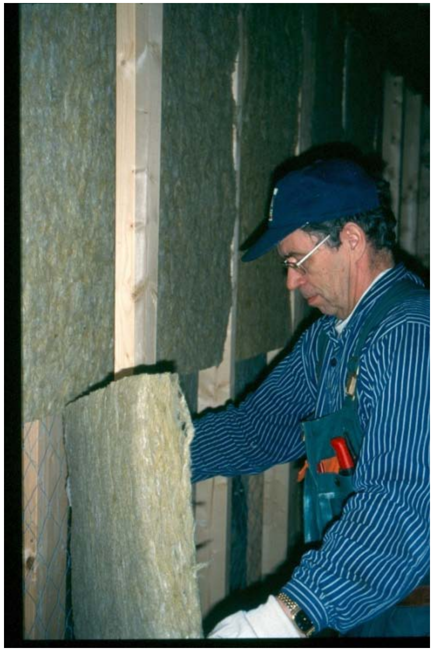
Performance

- Energy use
- Thermal comfort (draught, over temperatures, cold floors)
- Durability

Conventional analysis gives a single value.

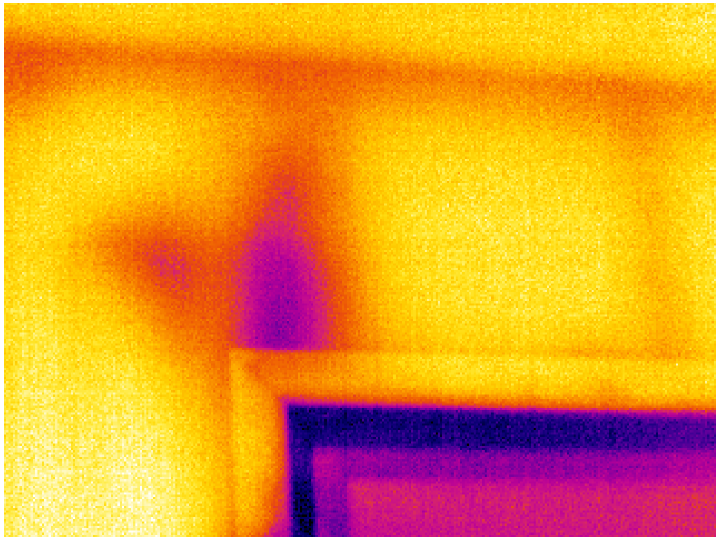
Probabilistic analyses gives a range of values and the probability of exceeding a certain value (critical value or required value) can be assessed.

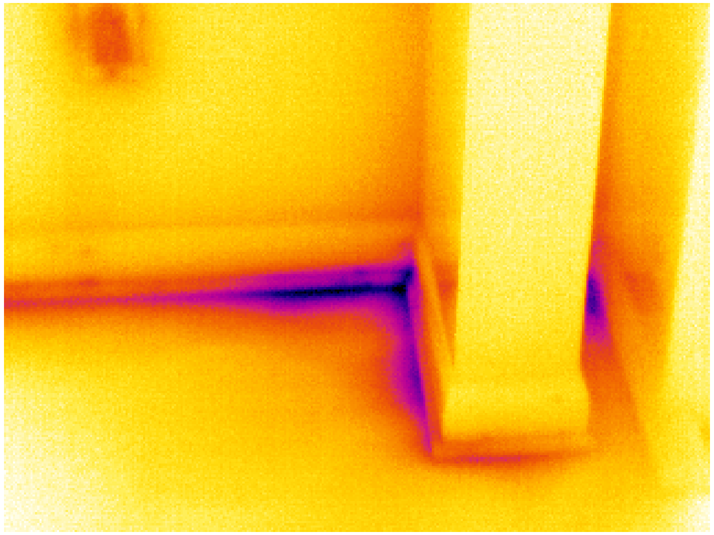
Example: Airtightness:



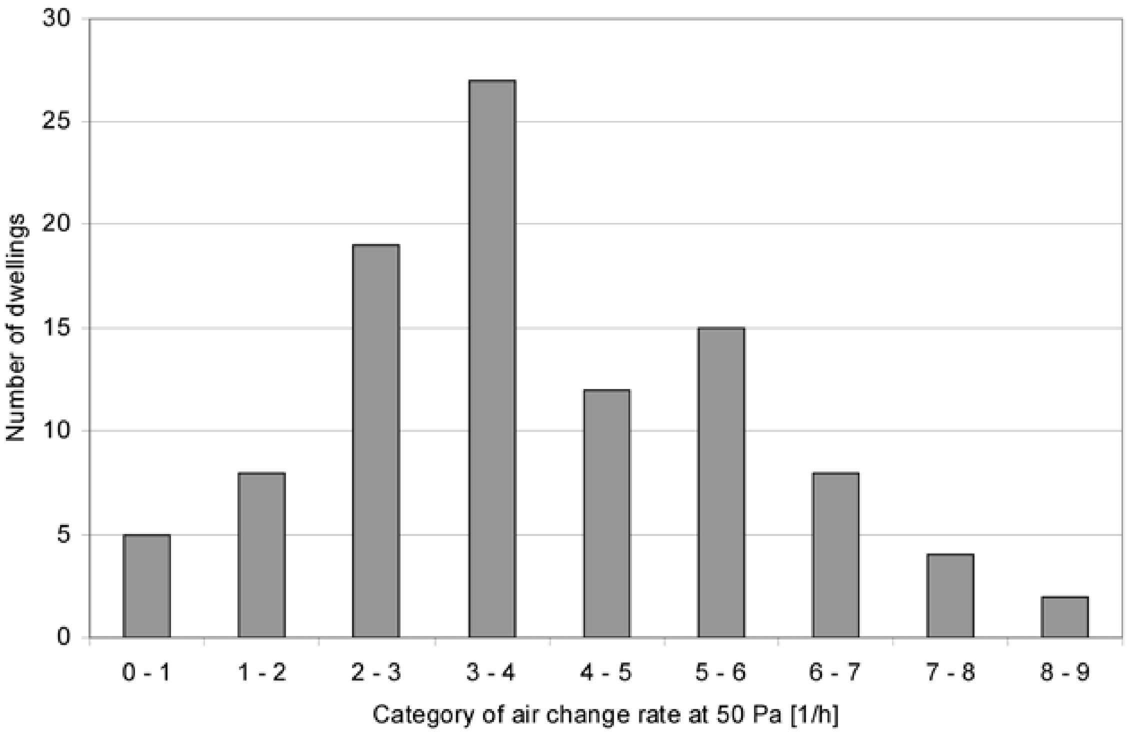
Design
Workmanship

A crucial quality!





Performance -Air tightness at 50 Pa of 100 timber-framed Finnish buildings built after year 2000

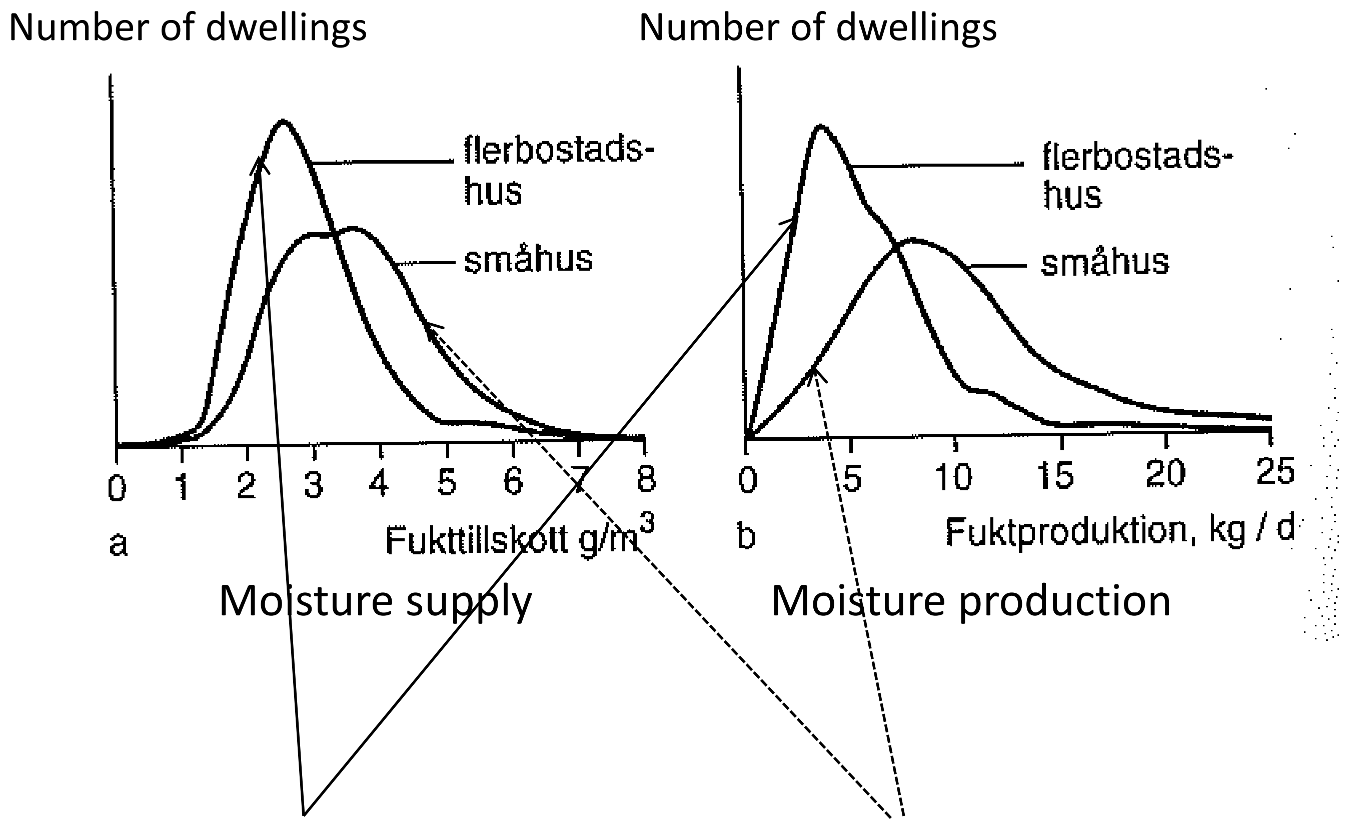


<u>Impact of airtightness:</u>

- Energy
- Thermal comfort
- Durability -Moisture safety
- Indoor air quality
- …

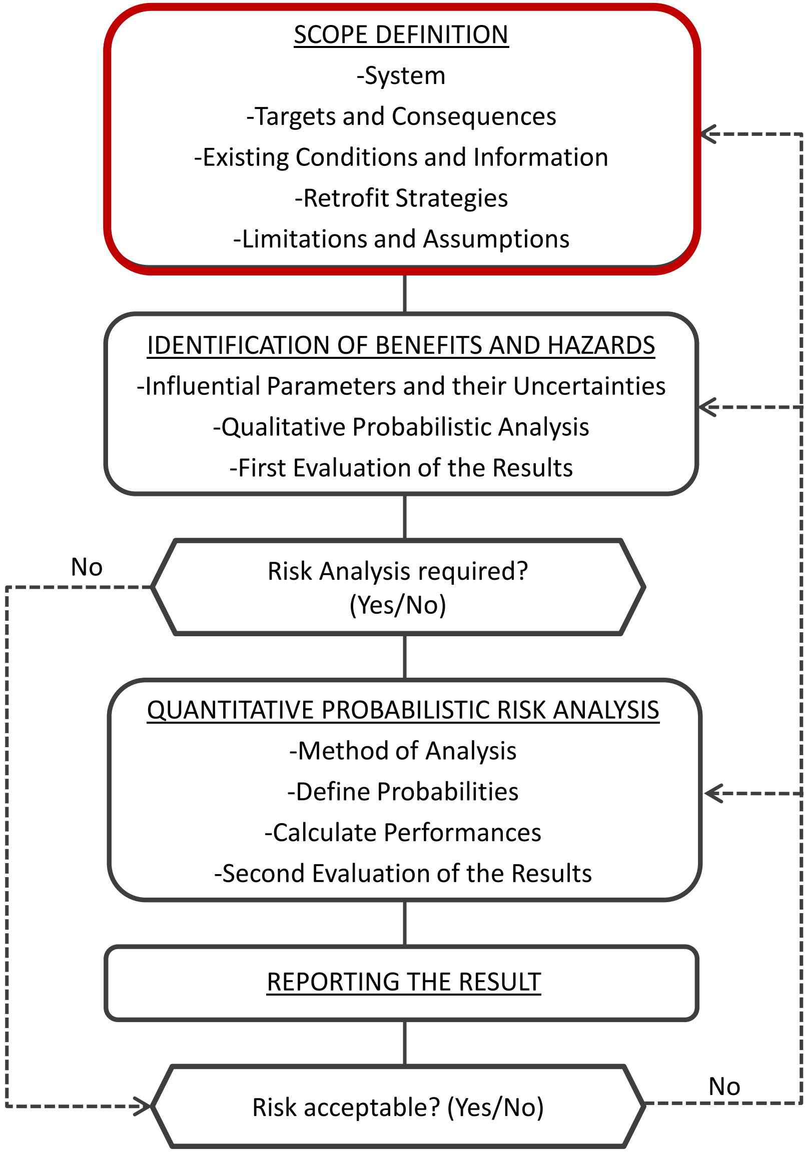
The level of the interior moisture supply can be important! But how big is it?

Field study of 2000 Swedish dwellings

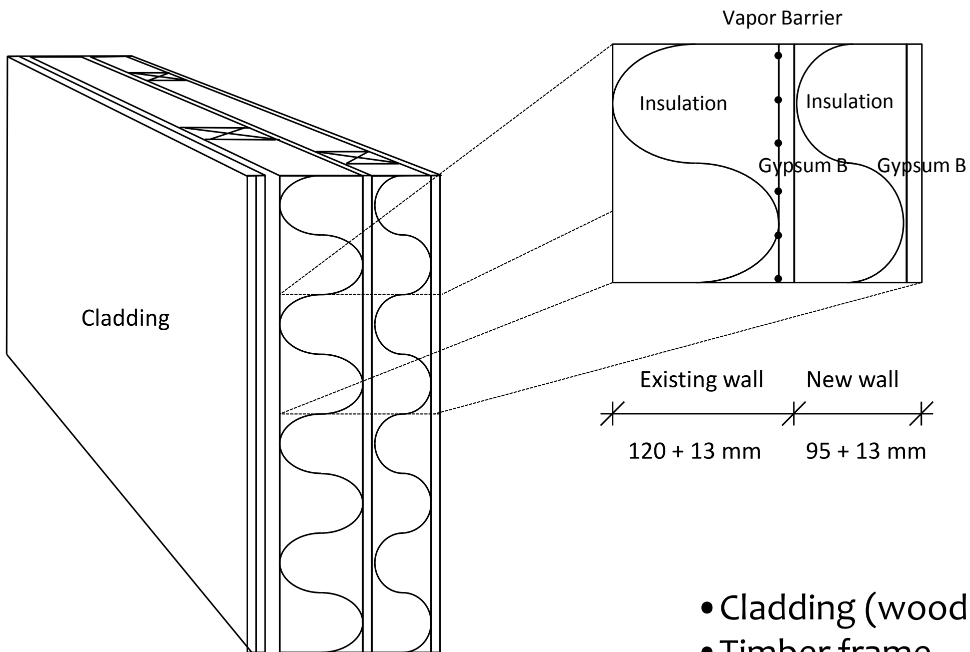


Multi residential buildings   One-family houses

Frame work for risk assessment

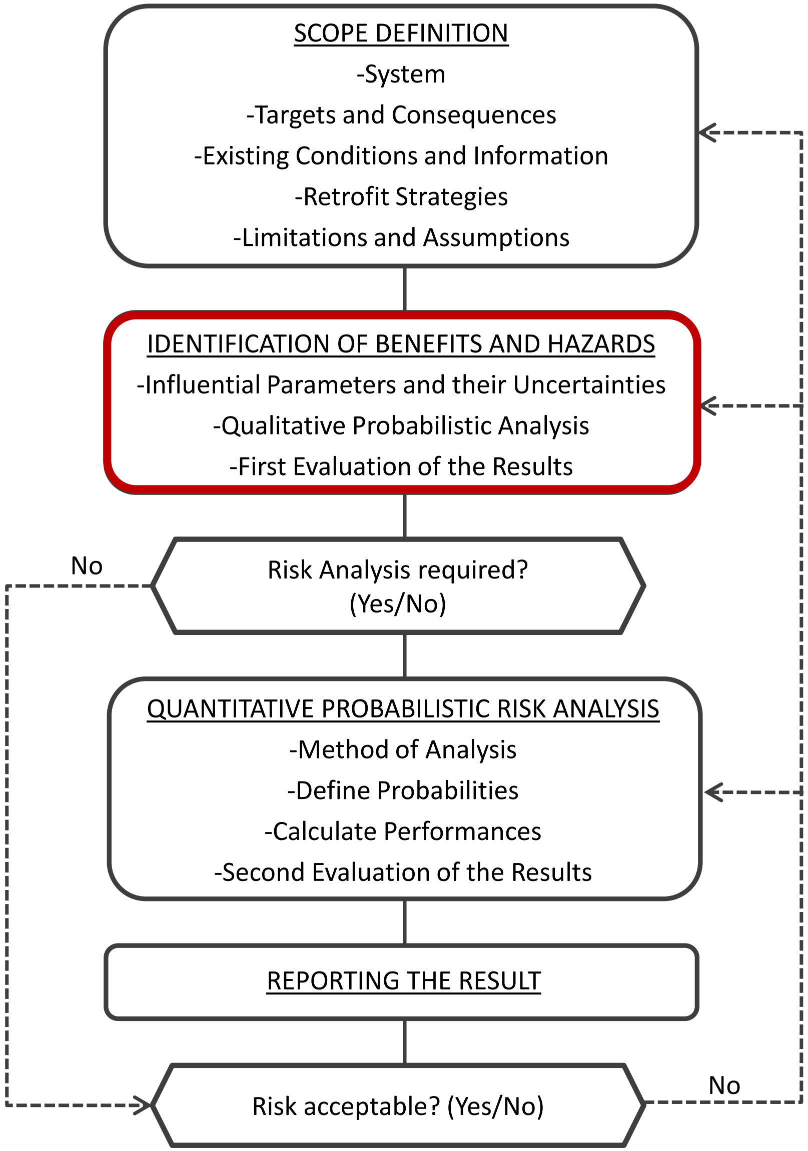


Case: Interior Additional Insulation

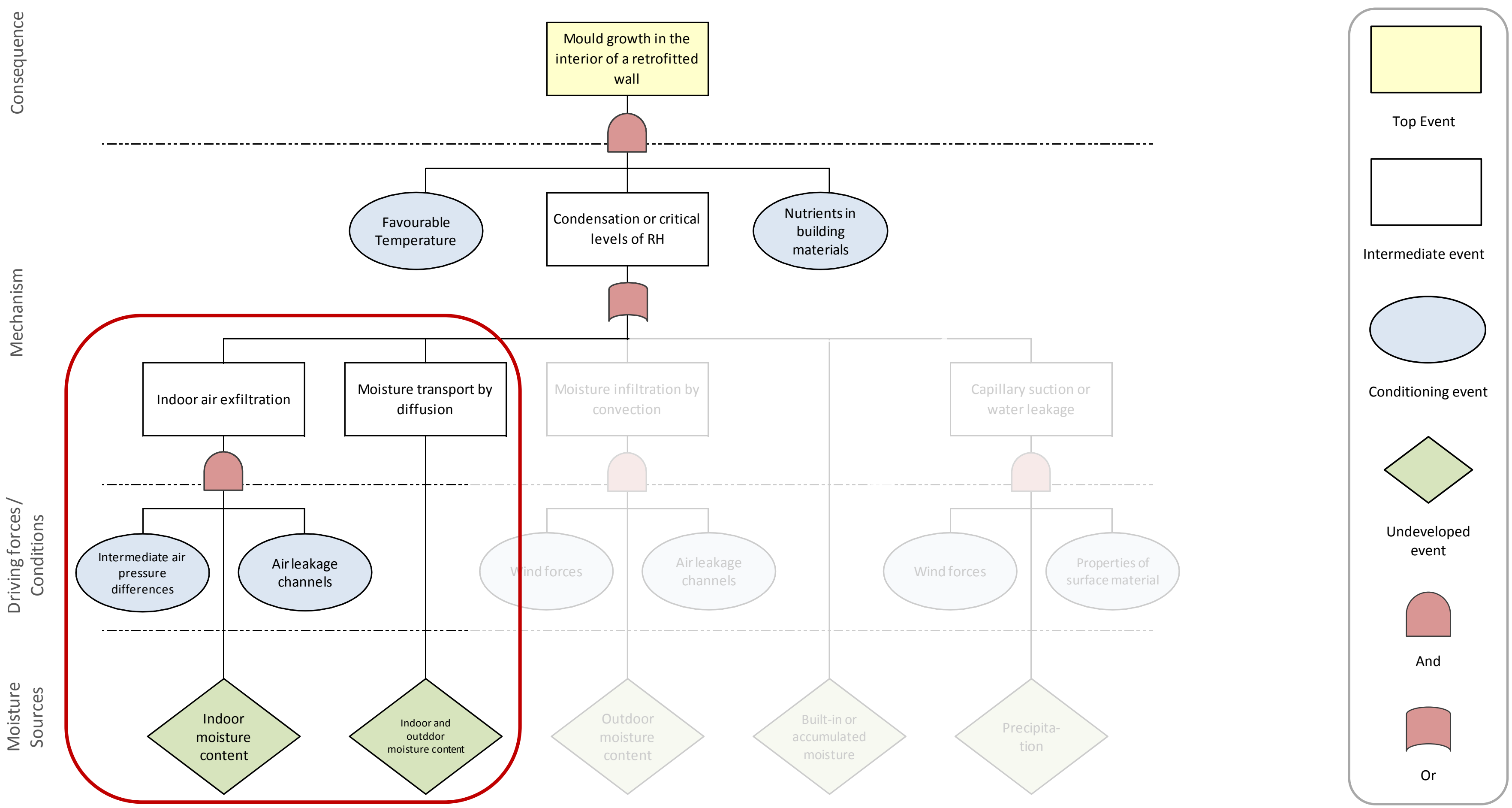


• Cladding (wood panel)	22+22 mm	Existing wall
• Timber frame	120 mm	
• Vapor Barrier		
• Gypsum Board	13 mm	
• Insulation	95 mm	New wall
• Gypsum Board 13 mm		
• Wall paper		

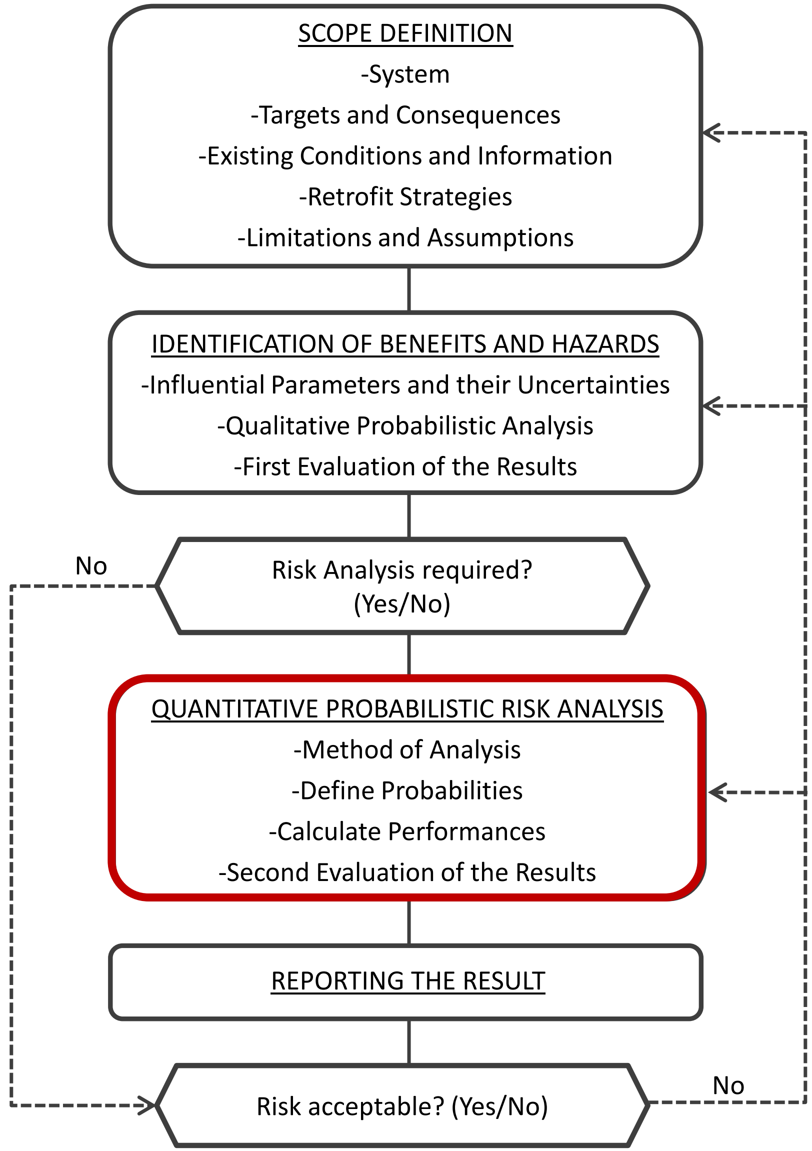
The Risk Analysis Approach



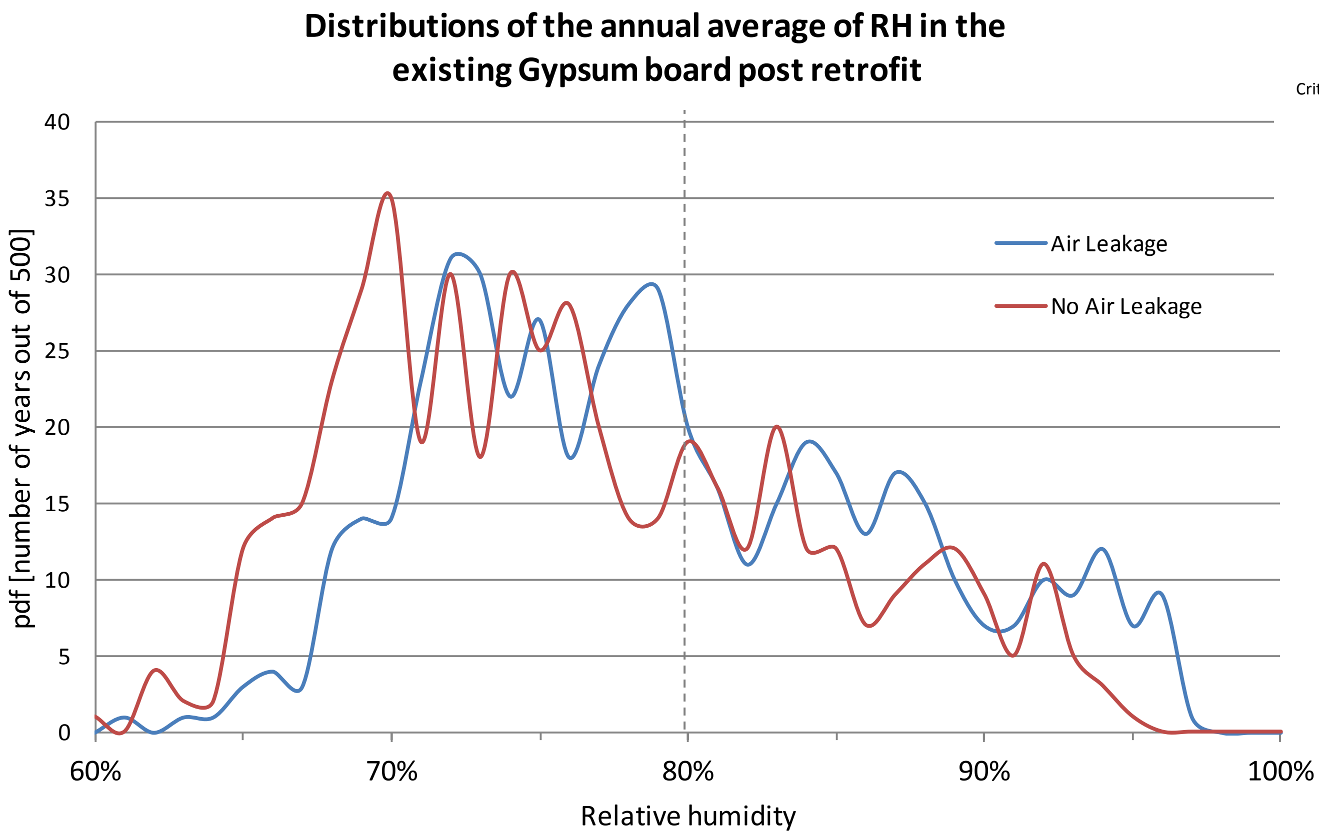
Fault Tree Analysis

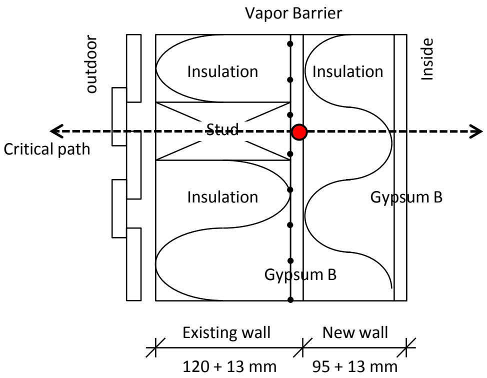


The Risk Analysis Approach



Result from simulations





$RH_{mean} > 80\%$

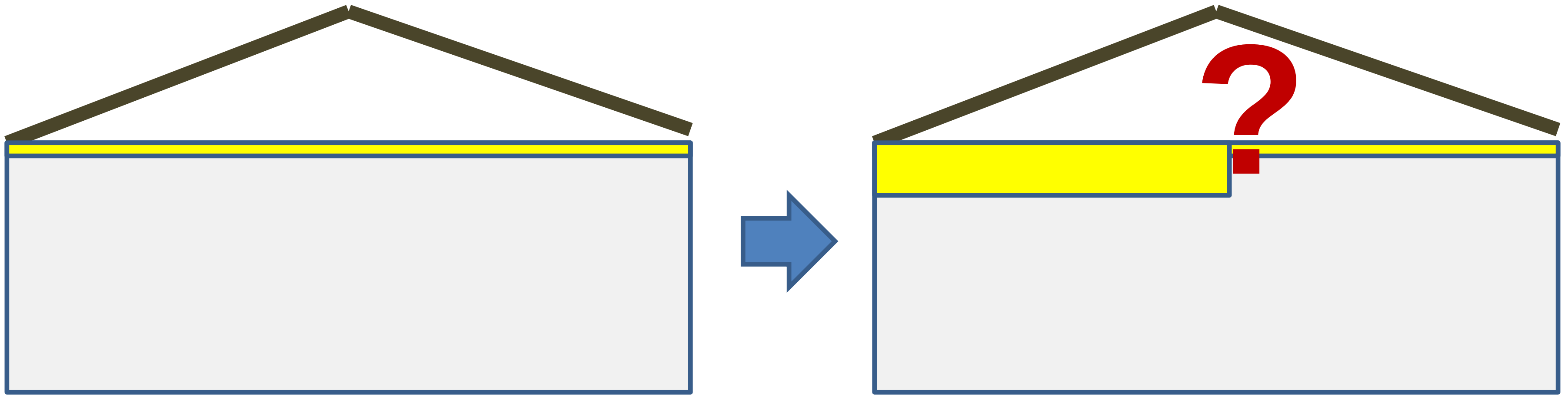
39% 28%

Looking at economics!

Advise an ESCO (Energy Saving Company) in a retrofitting project of 237 dwellings – 10 years outcome

Target: minimise the risks, maximise the benefits

Example: Retrofitting of attic insulation

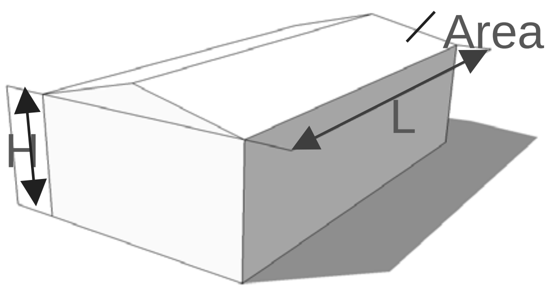


Different possible scenarios for retrofitting, but of course each renovation measure corresponds to a certain cost, will result in certain benefits (energy savings) and may result in hygrothermal risks (mould growth)

What is the renovation measure (applicable to all dwellings) that results in the largest overall profit ?

Variations taken into account

1. variation on existing structure, loads, orientation of dwellings,..



input parameter	symbol	distribution
Height of building H (m)	H	U(4,8)
Area of ceiling and roof A (m^2)	Area	U(50,200)
Orientation of one of eave sides (-)	BSangle	U(0,180)
Venting area per meter eave A_e (m^2/m)	Ae	U(0.01,0.05)
Length of building (eave side) L (m)	Length	U(7,20)
Thickness of wooden underlay d (m)	d	U(0.01,0.02)
Vapour diffusivity of wood δ_v (m^2/s)	deltav	N(10^{-6},2 10^{-7})
Initial relative humidity of wood φ_0 (-)	startRH	U(0.5,0.9)
Thermal conductivity of wood λ_{roof} (W/mK)	lambda	N(0.13,0.02)
Resistance of roof insulation R_r (m^2K/W)	Rr	U(0,1)
Effective leakage area per m² of ceiling A_c (m^2/m^2)	Ac	U(10^{-5},10^{-4})
U-value of the ceiling U_c (W/m^2K)	Uc	U(1,3)
Indoor temperature T_i (°C)	Ti	N(20,1.5)
Indoor moisture supply (kg/m^3)	MS	N(0.005,0.002)

Variations taken into account

1. variation on existing structure, loads, orientation of dwellings,..
2. variations on renovation measures

Increasing insulation of attic floor

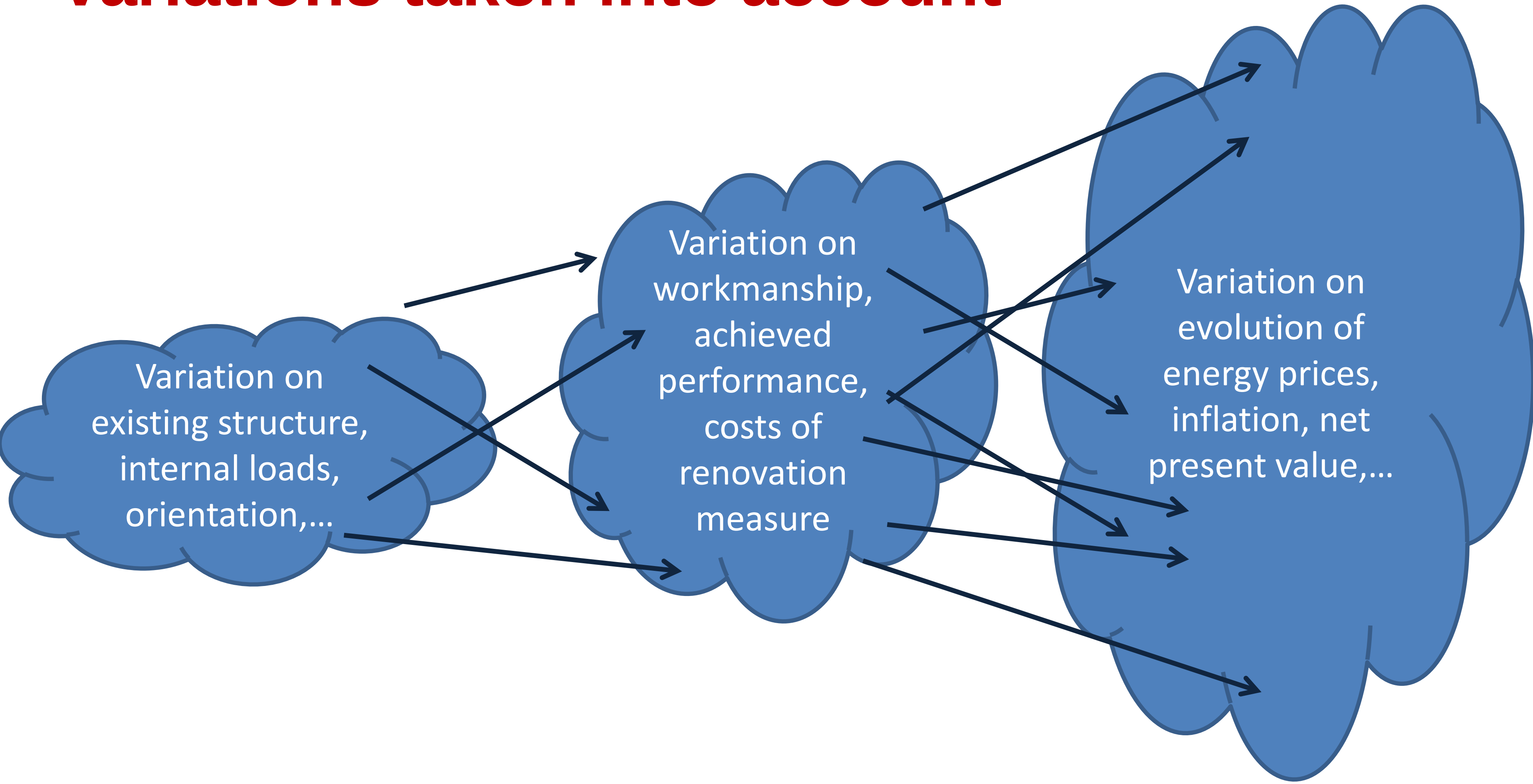
Increasing air tightness of the attic floor

Sealing the ventilation gaps at the eaves

Variations taken into account

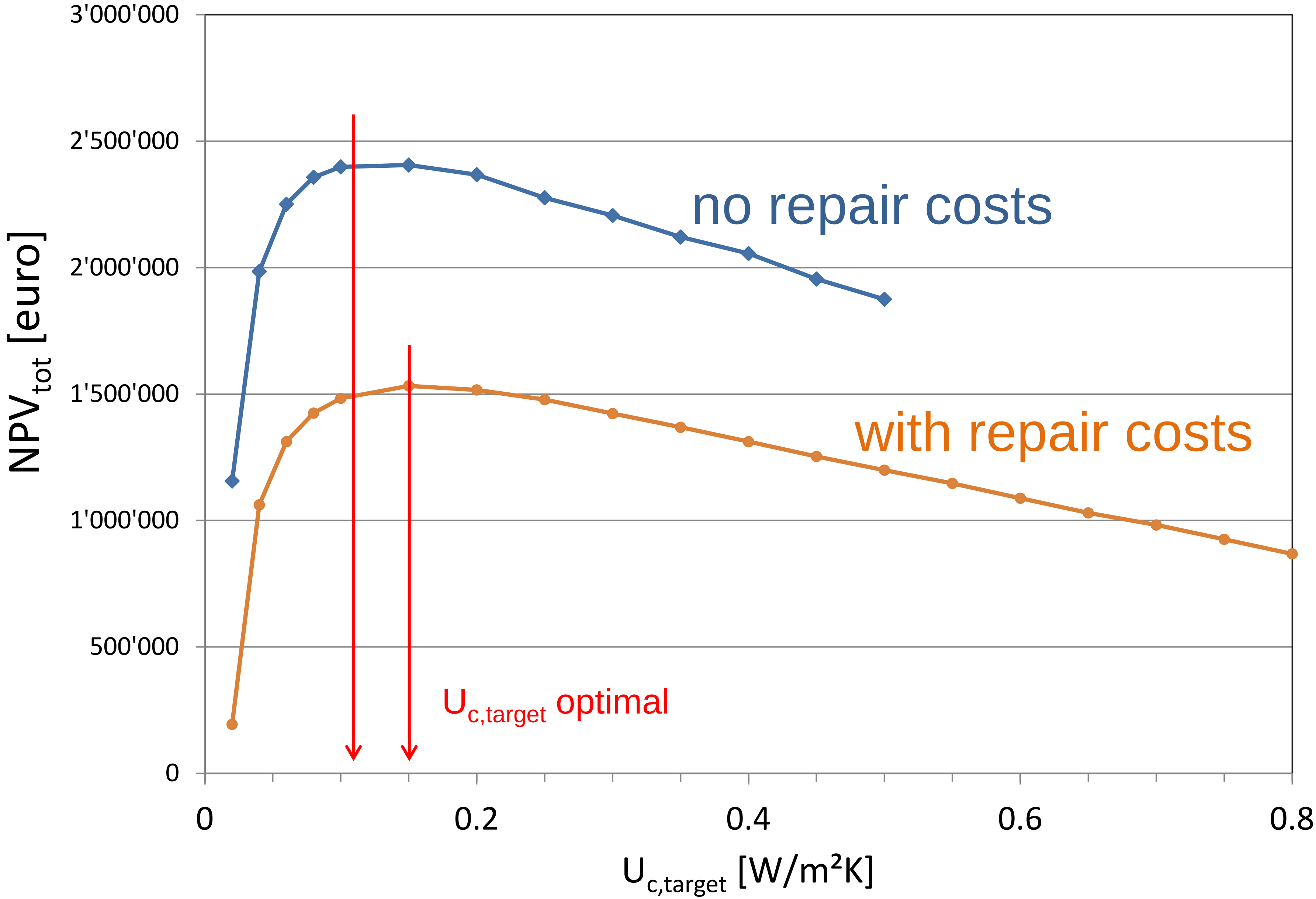
1. variation on existing structure, loads, orientation of dwellings,…
2. variations on renovation measures
3. evolution of energy prices and present value factor

Variations taken into account

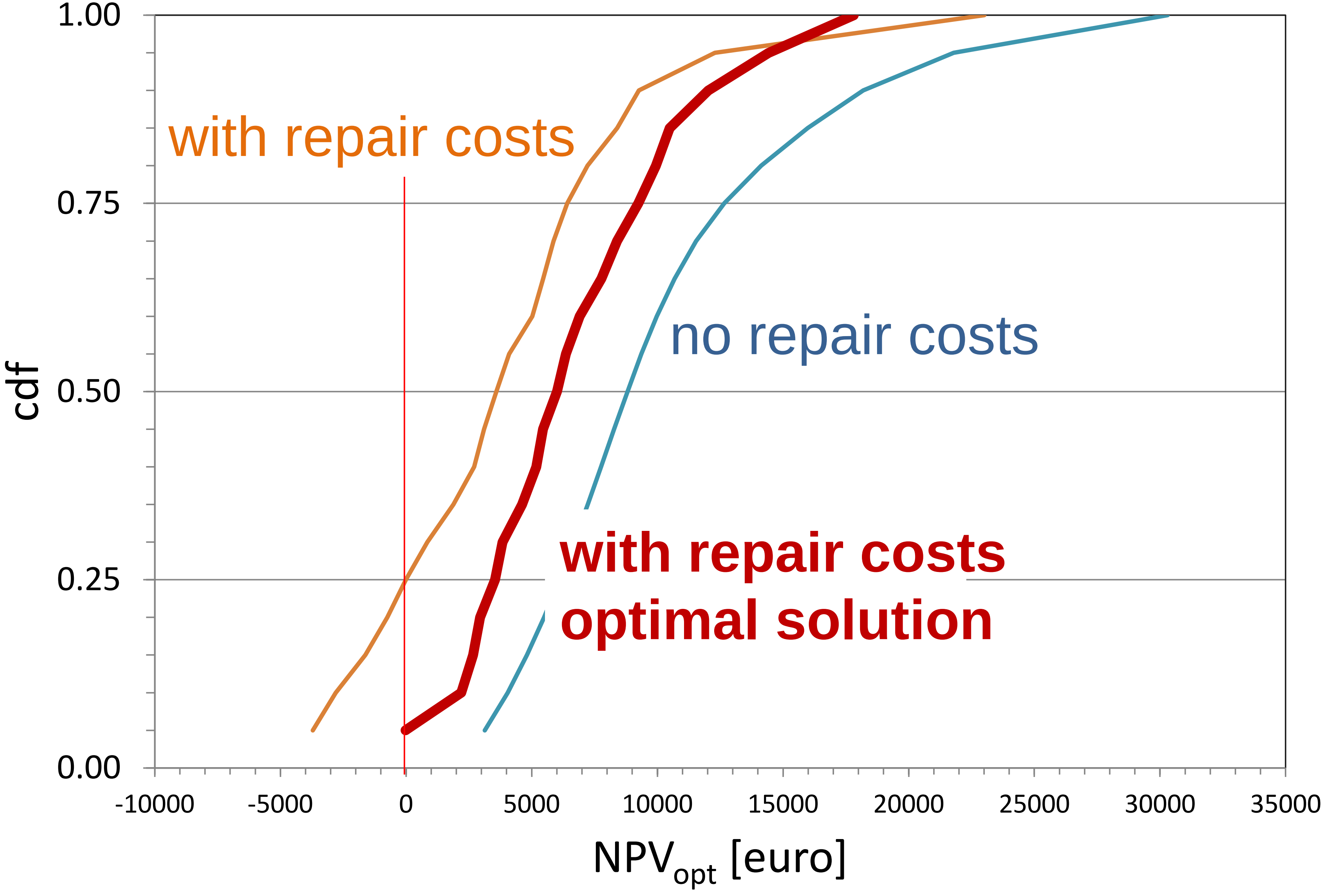


What is the renovation measure (applicable to all dwellings) that results in the largest overall profit ?

Outcome of analysis:
Total Net Present Value for all 237 dwellings



CDF of Net Present Value for optimal solution



A better building process is needed in general!

Reliability/Risk assessment can contribute to this!

<u>Thanks!</u>

Figure 8 Left: appearance of MBG on retrofitted façade. Right: MBG removed from the façade by water.