EBC

Energy in Buildings and Communities Programme

Reliability of Energy Efficient Building Retrofitting- Probability Assessment of Performance and Cost Annex 55 (RAP-RETRO)

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Outline of presentation

- Background
- Annex 55 RAP-RETRO
- Risk management/assessment
- Framework

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Subtask 1: Gathering of stochastic data

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Subtask 4: Practice and Guidelines

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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:

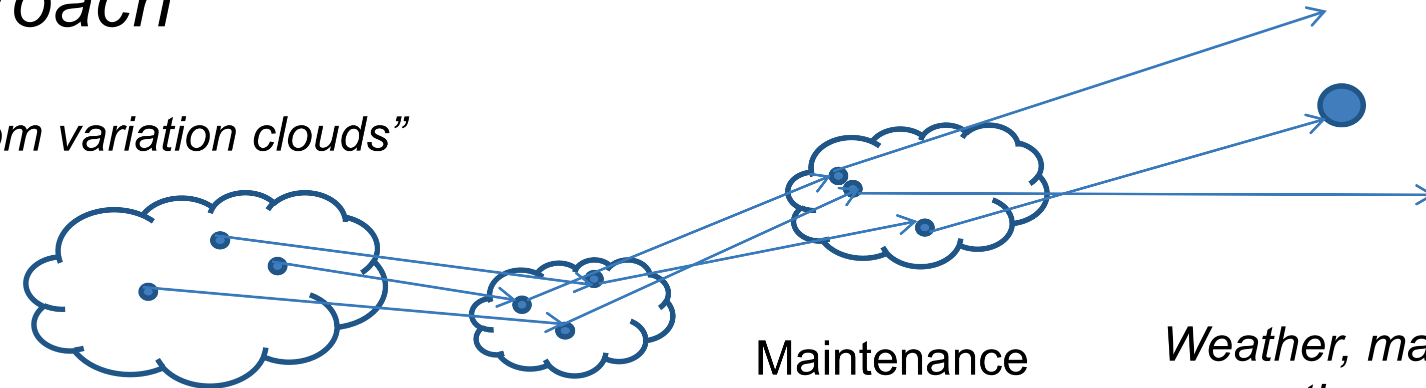
To develop and provide decision support data and tools for energy retrofitting measures leading to substantial upgrading.

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"



Maintenance operation

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

Production

Examples of random variations in:

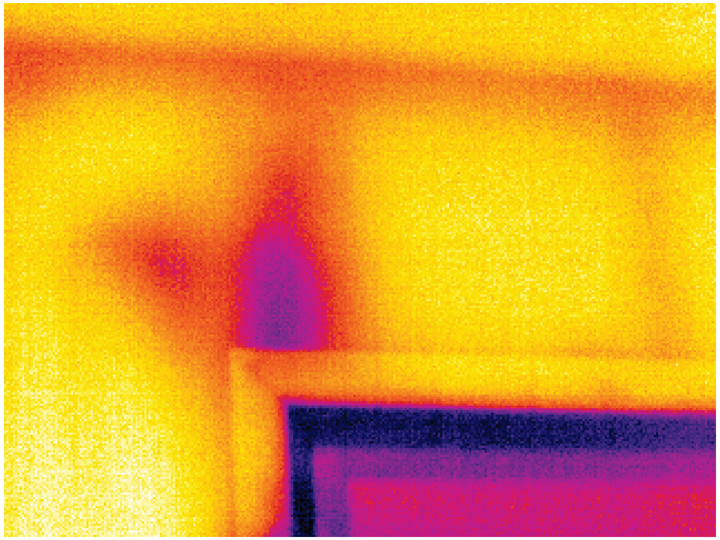
Indoor moisture sources, internal gains airing, aging of material, cracks in façades,…

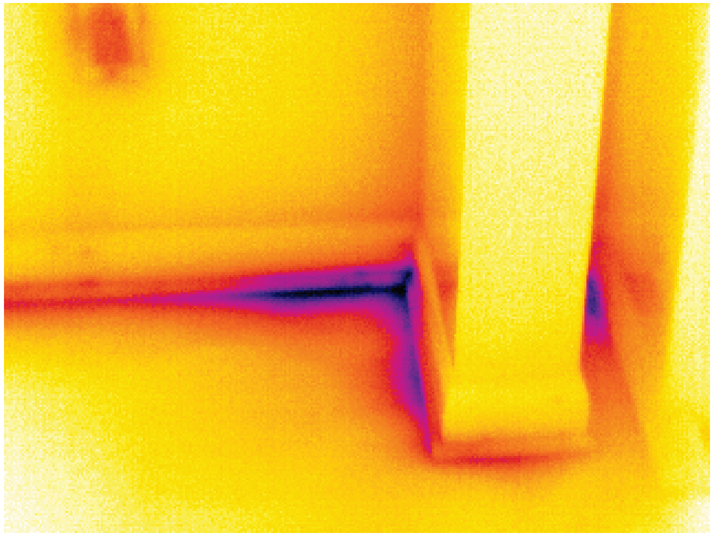
Workmanship initial conditions of material,…

Example: Airtightness:

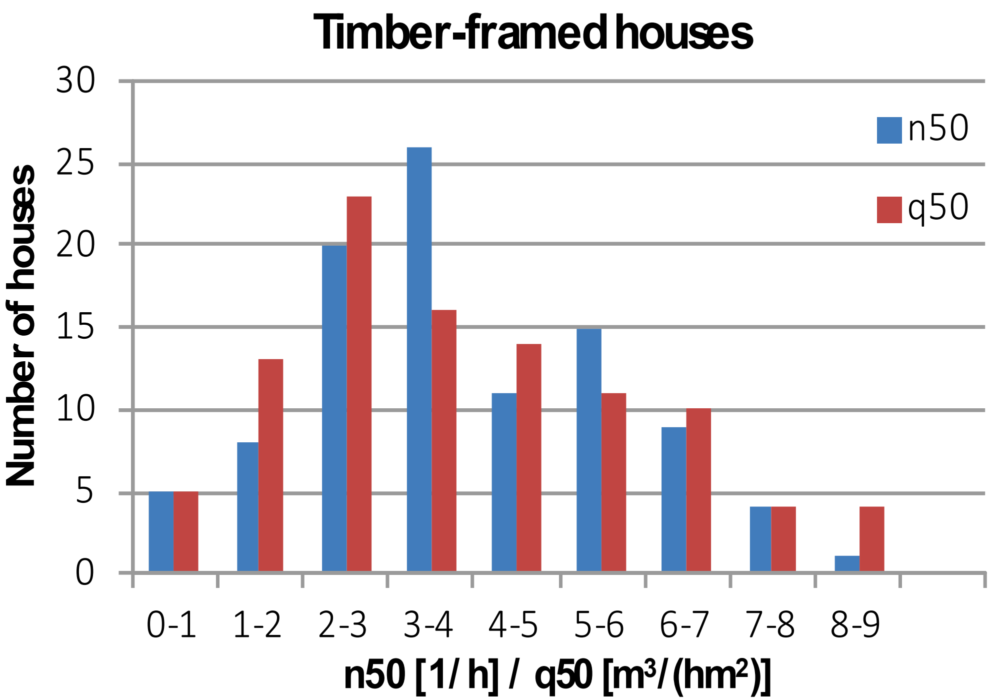
Design
Workmanship

A crucial quality!





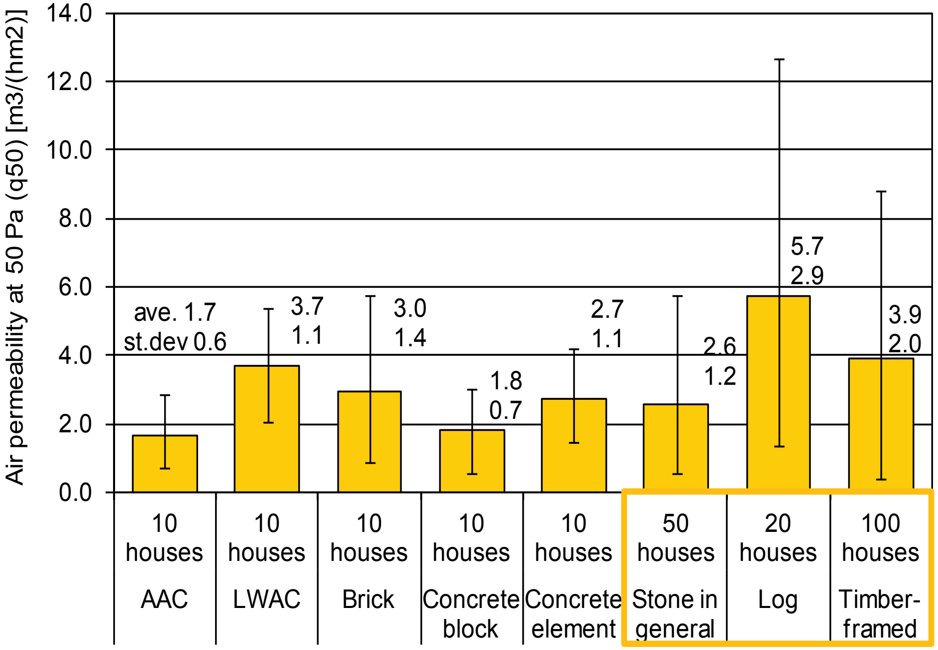
Performance -Air tightness at 50 Pa of 100 timber-framed Finnish buildings built after year 2000

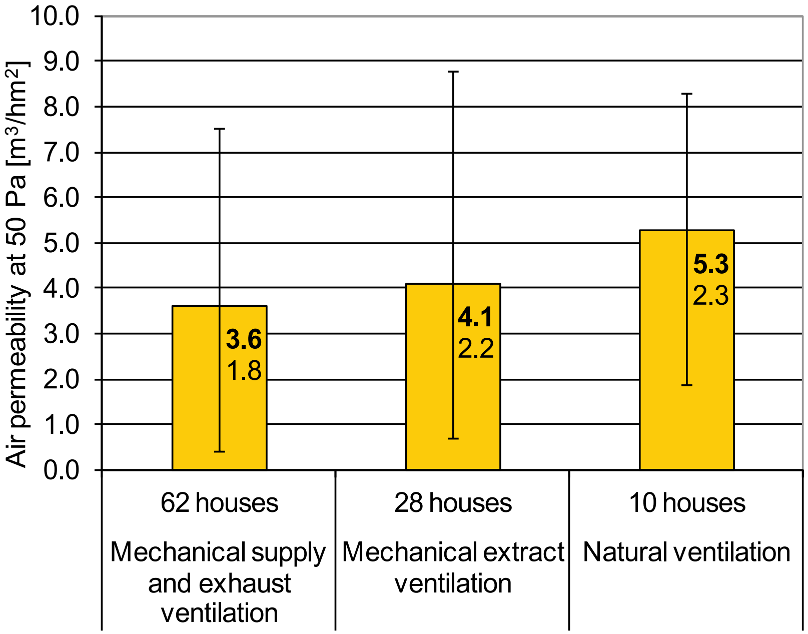


Impact of airtightness:

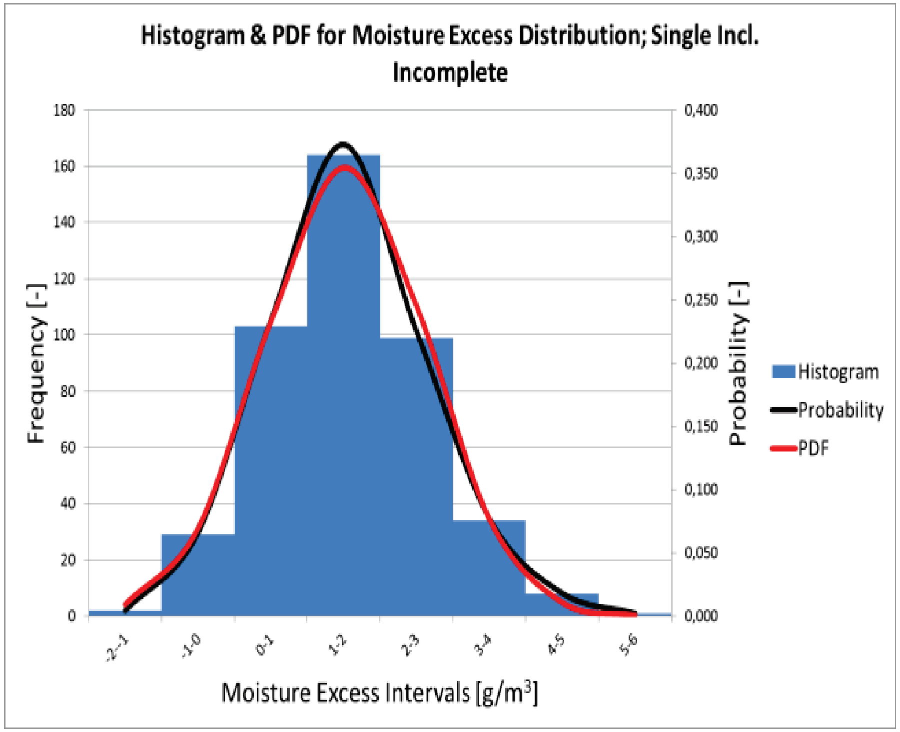
- Energy
- Thermal comfort
- Durability -Moisture safety
- Indoor air quality
- …

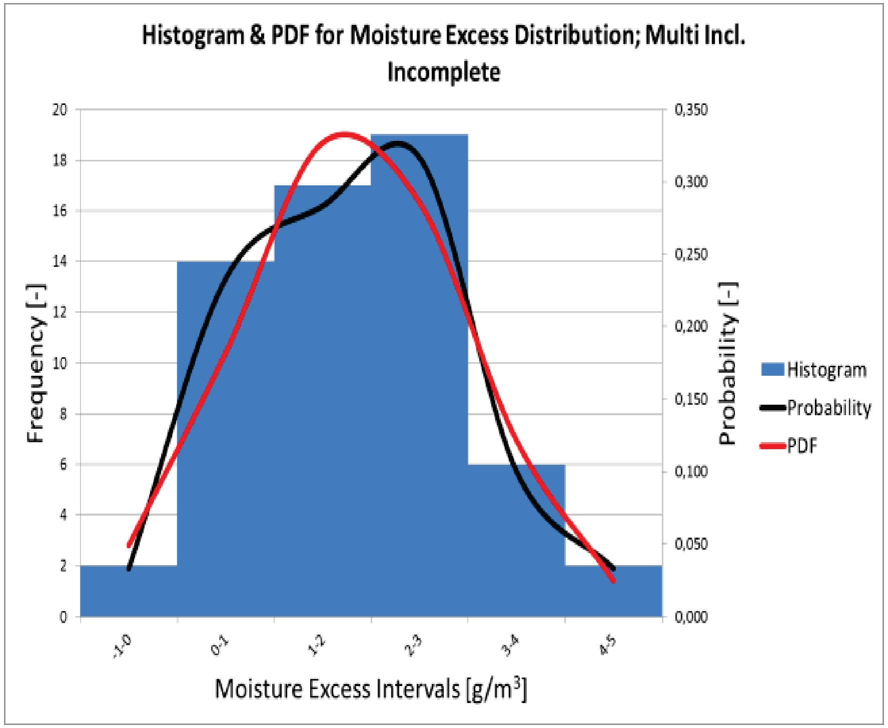
Airtightness – The spread!





Moisture loads





Envelope - Material properties statistical description

Minimum Input Information

Hygrothermal basic parameters

Parameter	Symbol	Unit	Mean	StdDev	Min	Max	Remarks
Bulk density	ρ	[kg/m^3]	1741.0	44.0	1657.2	1787.5	
Specific heat capacity	c	[J/kgK]	939	72.7	868	1092	
Thermal conductivity	λ_{dry}	[W/mK]	0.656	0.117	0.543	0.871	
Open Porosity	θ_{por}	[m^3/m^3]	0.352	0.011	0.336	0.375	
Capillary saturation	θ_{cap}	[m^3/m^3]	0.254	0.011	0.231	0.266	
Dry cup value	μ_{dry}	[---]	18.0	05.8	08.6	24.5	
Water absorption coefficient	A_w	[kg/m^{2}s$^{0.5}$]	0.175	0.047	0.107	0.227	

Water Retention (Desorption)

Arguments	Mean	StdDev	Min	Max	Remarks
pc [hPa]	θ_l [m^3/m^3]				
0	0.332	0.016	0.313	0.357	
30	0.320	0.017	0.297	0.351	
60	0.318	0.016	0.296	0.345	
150	0.308	0.016	0.289	0.335	
300	0.295	0.032	0.232	0.334	
600	0.282	0.038	0.212	0.334	
900	0.262	0.042	0.206	0.316	
2000	0.163	0.047	0.100	0.221	
4000	0.093	0.037	0.047	0.146	
8000	0.075	0.034	0.041	0.137	
14000	0.062	0.028	0.030	0.120	

Sorption Isotherm (Desorption)

Arguments	Mean	StdDev	Min	Max	Remarks
φ [%]	θ_l [m^3/m^3]				
97.4	0.0250	0.0130	0.0037	0.0427	
96.0	0.0182	0.0112	0.0033	0.0380	
90.0	0.0122	0.0060	0.0028	0.0185	
84.7	0.0097	0.0049	0.0025	0.0164	
75.4	0.0062	0.0032	0.0024	0.0111	
58.2	0.0043	0.0016	0.0019	0.0060	
43.2	0.0032	0.0016	0.0013	0.0053	
32.9	0.0026	0.0016	0.0008	0.0051	

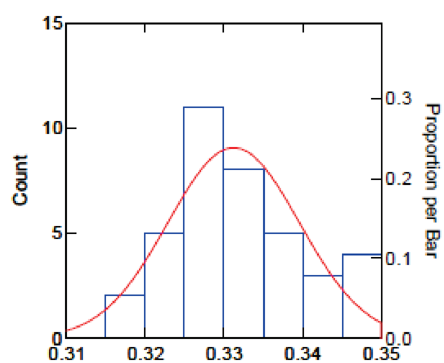
Additional Input Information

Water vapour permeability

Arguments		Mean	StdDev	Min	Max	Remarks
φ_{insite} [%]	$\varphi_{outsite}$ [%]	μ [-]				
5.0	30.0	18.0	5.8	8.6	24.5	DryCup
96.0	82.0	13.7	4.6	8.5	20.8	WetCup

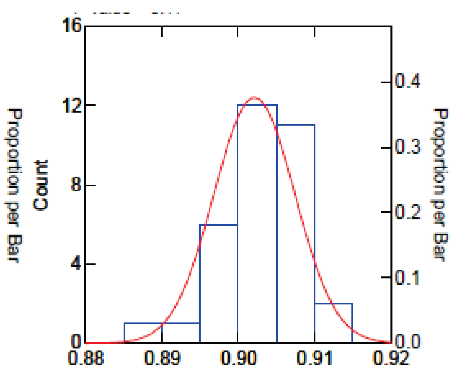
Liquid water conductivity

Arguments		Mean	StdDev	Min	Max	Remarks
θ_l [m^3/m^3]	mean pc [Pa]	K_l [s]				
0.33		3.1E-09	3.4E-09	8.6E-10	1.1E-08	



Lime sands brick

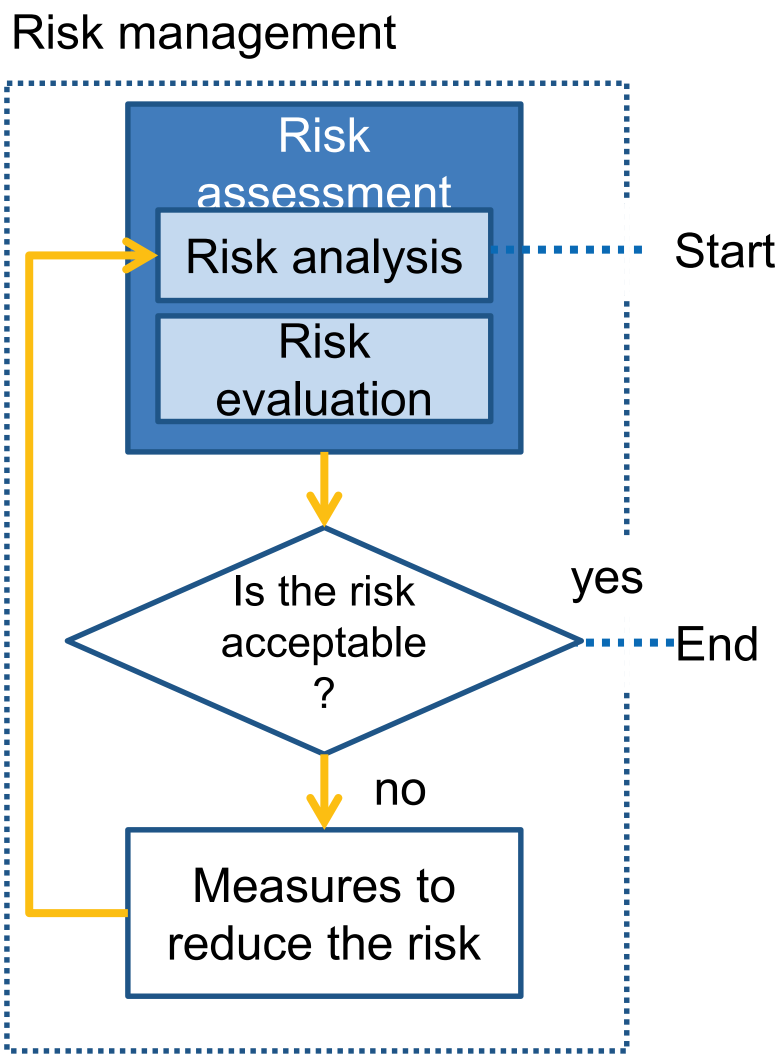
Estimated: mean = 0.33, SD = 0.008
Kolmogorov-Smirnov test statistic =0.11
Shapiro-Wilk test statistic for normality = 0.969
P-value = 0.36



Calcium silicate

Estimated: mean = 0.903, SD = 0.007
Kolmogorov-Smimov test statistic =0.129
Shapiro-Wilk test statistic for normality = 0.95
P-value = 0.12

Risk management and Risk assessment



- Risk assessment should be preferably performed by experts.
- Renovation projects may involve risks for which expert knowledge is lacking.
- We can build-up knowledge while performing risk assessment.
- A framework helps in performing the assessment methodically and transparently (well documented)

Framework includes questions and actions that guide you through the assessment

Risk assessment
- Risk analysis
- Risk evaluation

Start

- What is to be retrofitted?
- What is the aim of the retrofit?
- Desired values and consequences?
- What are the renovation strategies?

Risk analysis

- What is known about the chosen renovation strategies?
- What causes deviations?
- Qualify and quantify the deviations

Risk evaluation

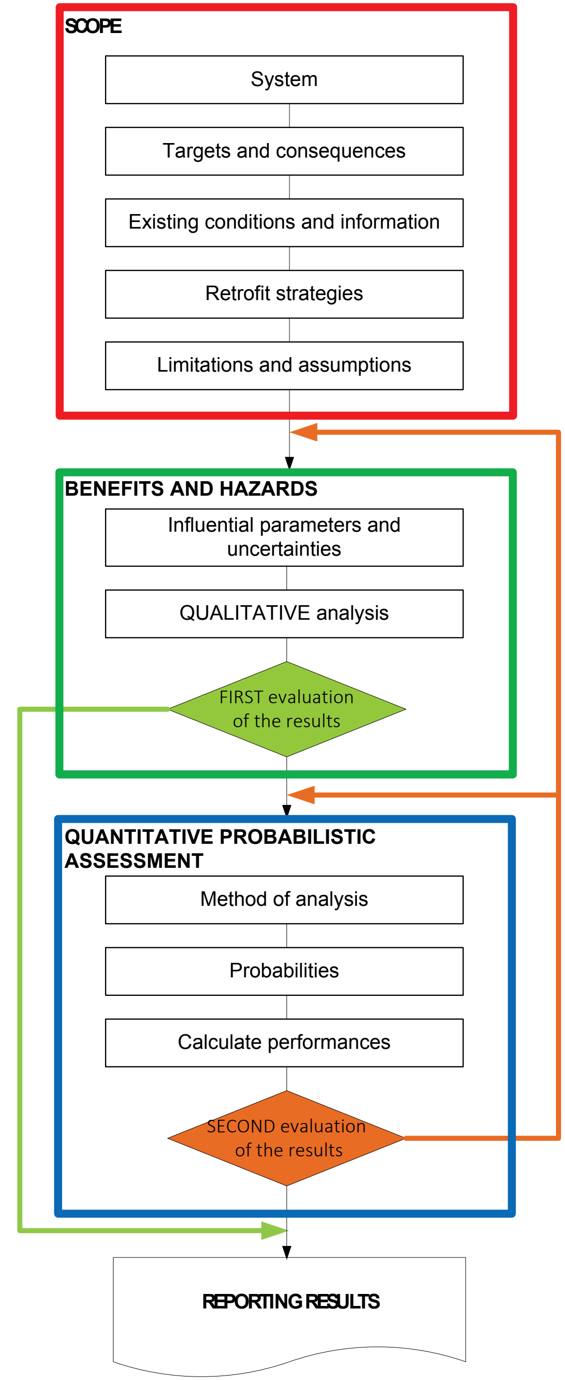
- How well does the renovation strategy meet the purpose of the renovation?
- Any limitations with the recommended renovation?

The Framework as a flow chart

Different sections and loops.

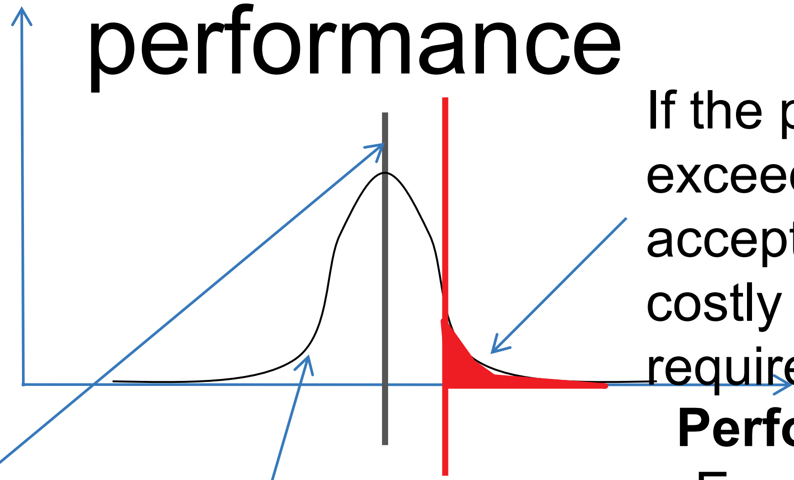
Outgoing loops mean quick 'exit' , i.e. when the assessment shows too high or very low risk.

Backward loops – that's usually a trouble, i.e. mistake made in the assessment process



Probability assessment of performance

Probability of outcome



Highest acceptable value

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.

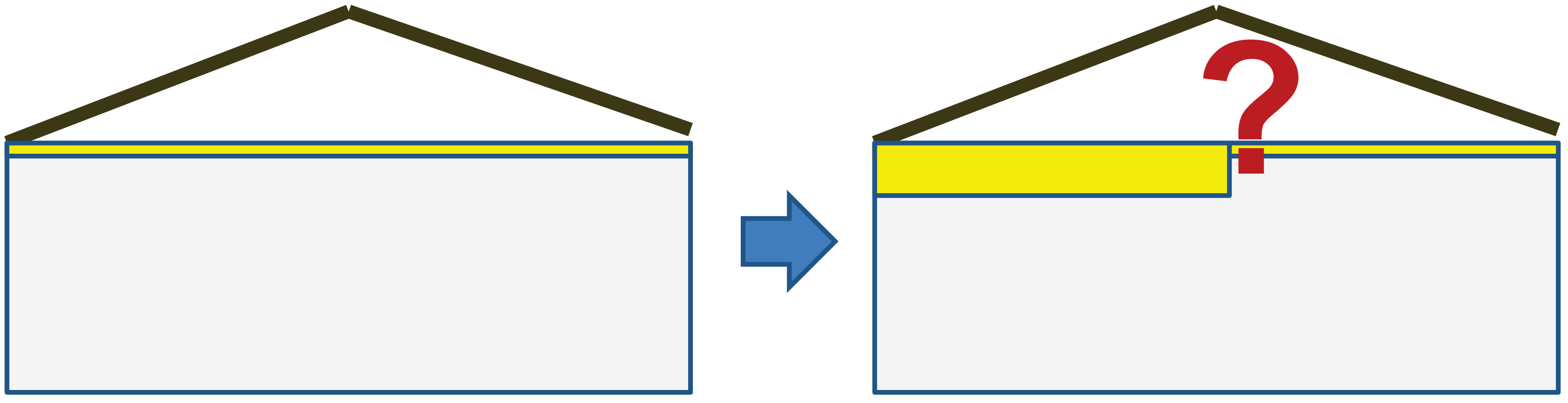
Probabilistic analyses gives a range of values and the probability of exceeding a certain value (critical value or required value) can be assessed.

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

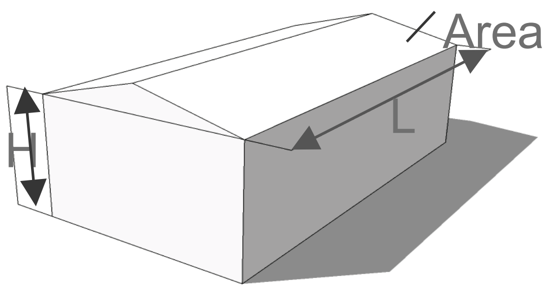


Different possible scenarios for retrofitting, but of course each renovation measure corresponds to a certain cost, will result in certain benefits (energy savings) and may result in hygrothermal risks (mould growth)

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

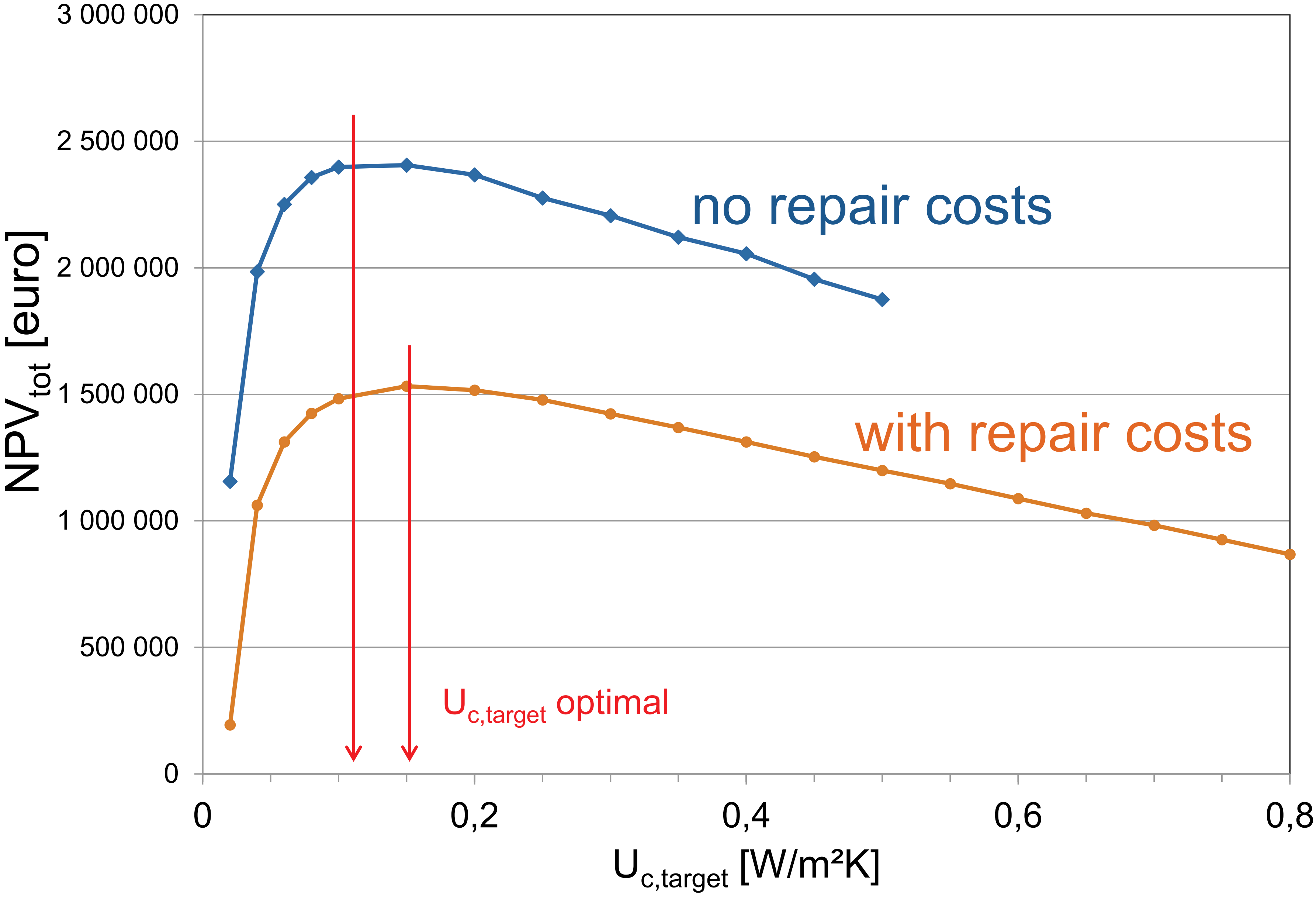
Variations taken into account

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

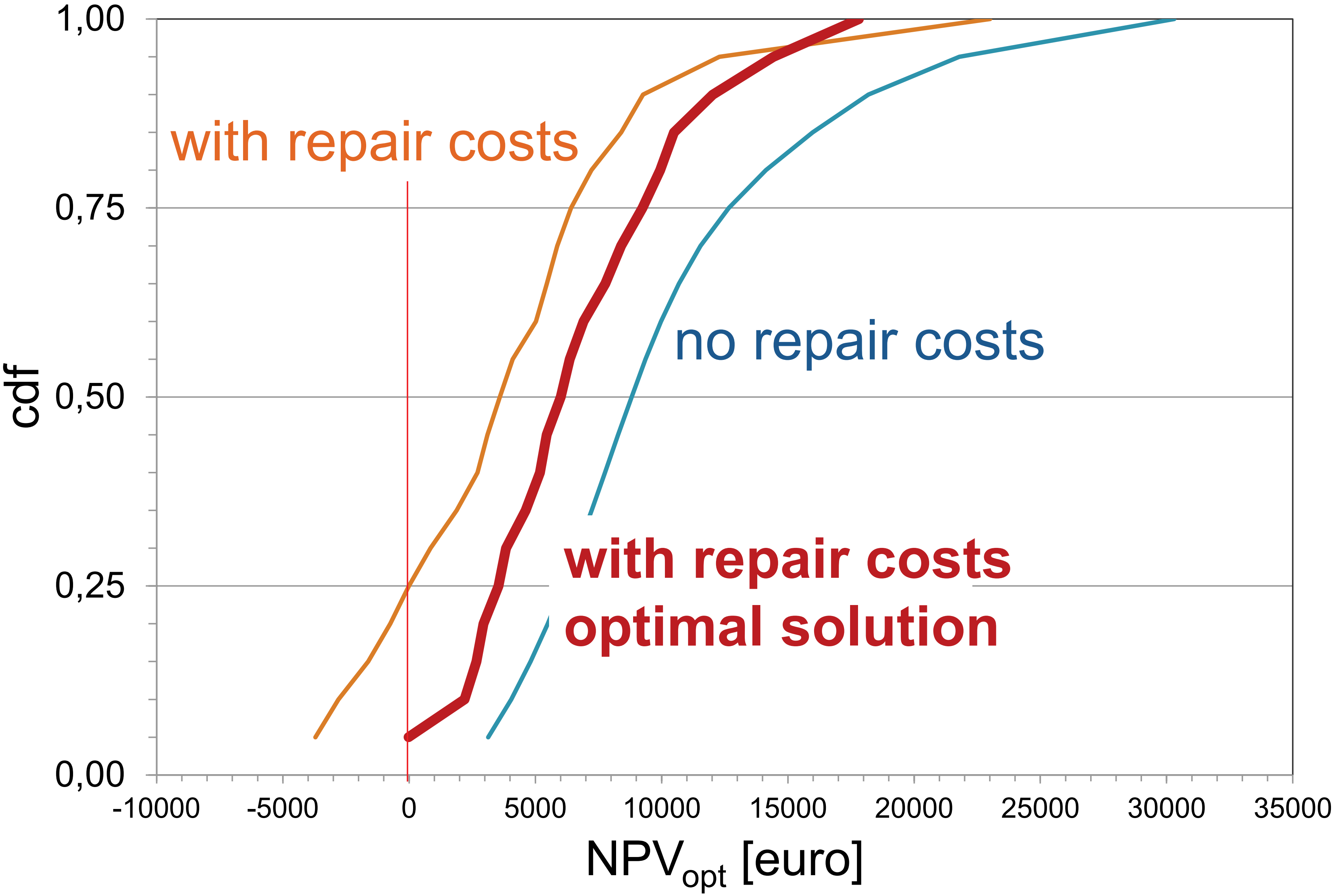


input parameter	symbol	distribution
Height of building H (m)	H	U(4,8)
Area of ceiling and roof A (m^2)	Area	U(50,200)
Orientation of one of eave sides (-)	BSangle	U(0,180)
Venting area per meter eave A_e (m^2/m)	Ae	U(0.01,0.05)
Length of building (eave side) L (m)	Length	U(7,20)
Thickness of wooden underlay 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/m²)	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)

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!

Thanks!

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