6th International Conference on Smart Energy Systems
6-7 October 2020
#SESAAU2020

Life cycle cost and primary energy analysis of a multi-storey residential building retrofit to different energy levels with varied materials

Chiara Piccardo

Leif Gustavsson

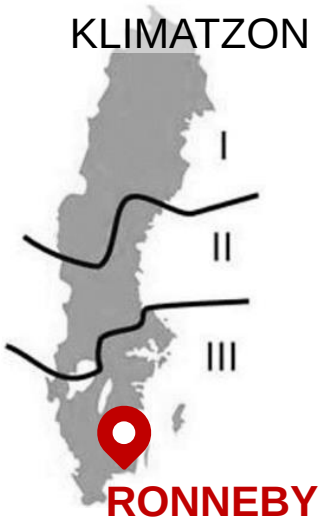
Powered by

Aim of the study

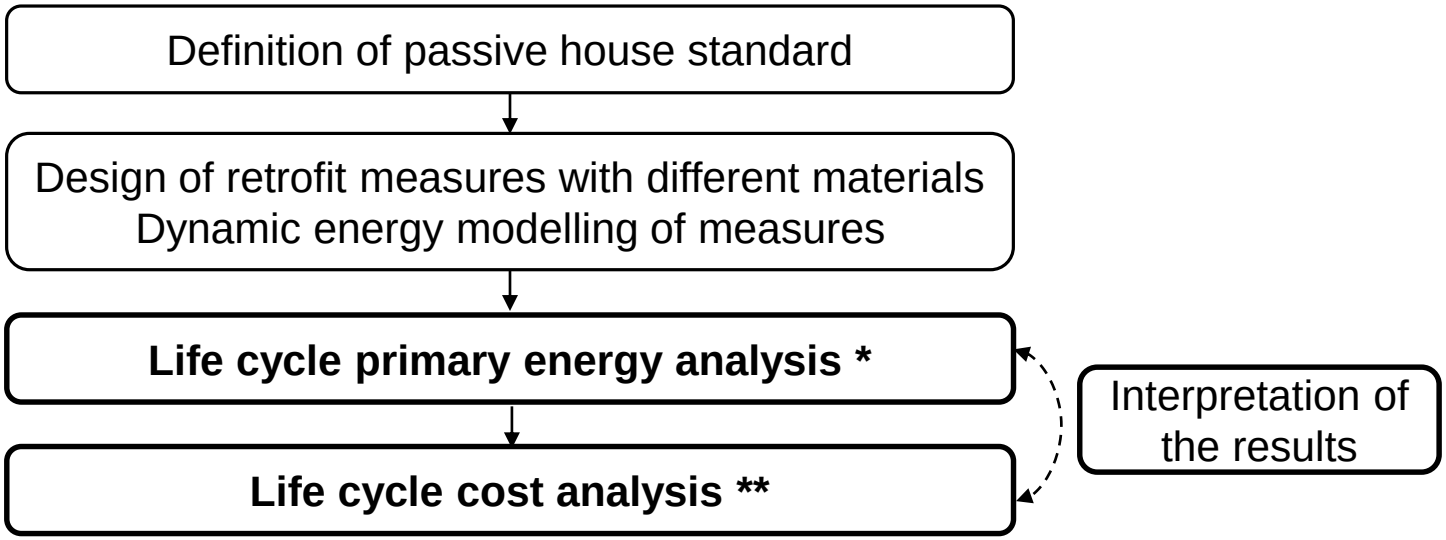
To analyze the effect of different retrofit materials on primary energy and cost savings when retrofitting a building to passive house levels.

Case-study building with an expected remaining lifetime of at least 50 years

- Year of construction: 1972
- Living floor area: 2000 m^2 (heated volume: 5400 m^3)
- Initial final heat use: 110 kWh/m^2 (building connected to the local district heating system)



Research structure and methods



Data sources:

* Ecoinvent database

** Wikells database (average contractor prices in Sweden)

Powered by

AALBORG UNIVERSITY DENMARK
energy CLUSTER DENMARK
sEEnergies
Innovation Fund Denmark
reINVEST
midt regionmidtjylland
DEN EUROPÆISKE UNION Den Europæiske Fond for Regionaludvikling Vi investerer i din fremtid
GRØN ENERGI
kamstrup
LOGSTOR
Ørsted
Aalborg Forsyning

Definition of passive house standard

We selected two different passive house standards applicable in Sweden to be achieved in the retrofitted buildings:

Passive house standard	Energy use* [kWh/m^2, year]
Forum Energy Efficiency Buildings (FEBY)	≤ 50
Passive House Institute (PHI)	≤ 30

* space and tap water heating

Design of retrofit measures

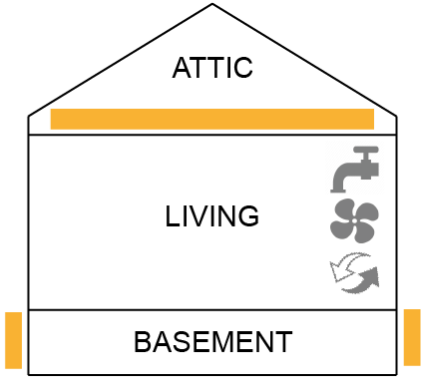
Upgrade of technical devices

- energy-efficient ventilation fans
- ventilation heat recovery (VHR) units
- efficient water taps

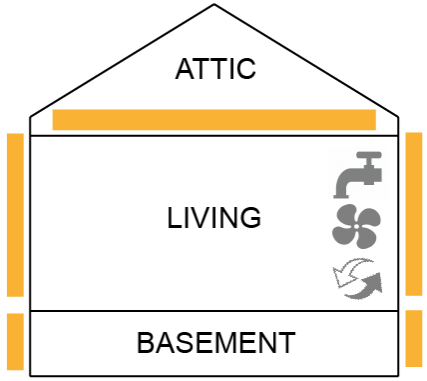
Improvement of thermal envelope

- extra insulation and airtightness
  - basement
  - attic
  - windows (U = 0.8 W/m²K in FEBY and **0.6 W/m²K in PHI**)
  - **external walls (and new cladding) – only PHI option**

FEBY = 50 kWh/m²,year



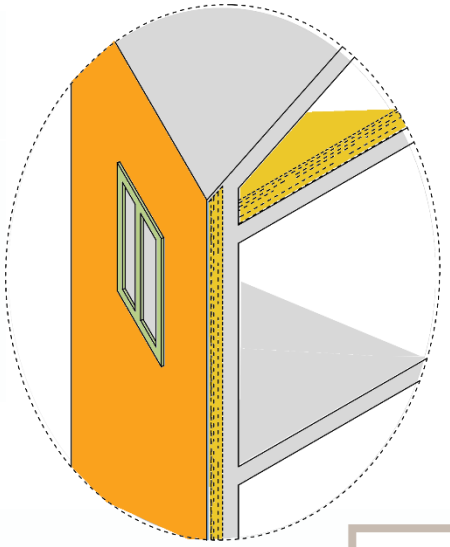
PHI = 30 kWh/m²,year



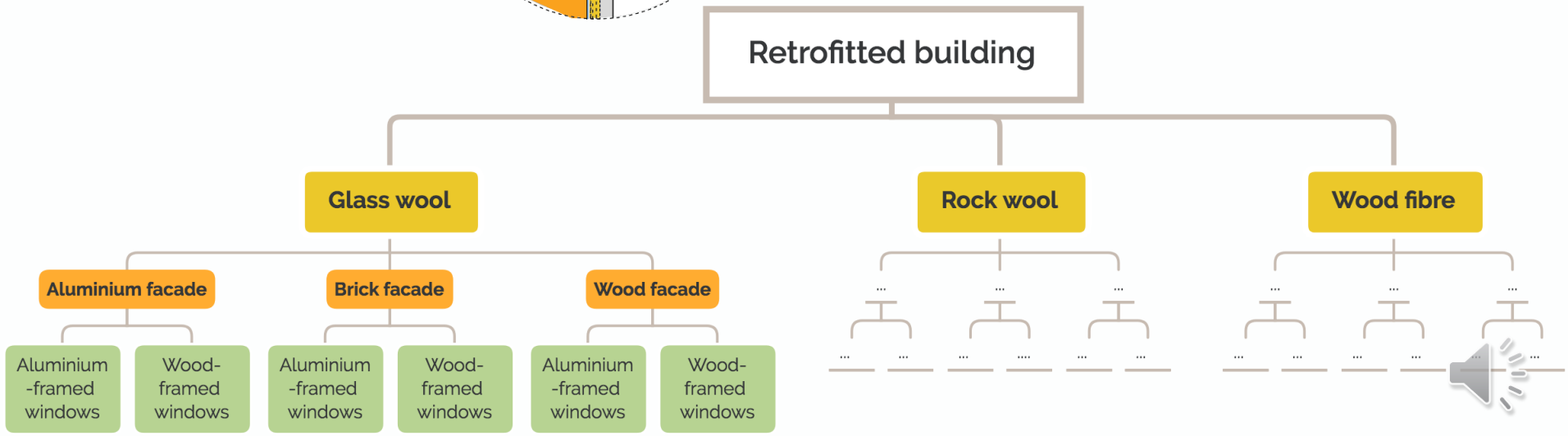
Material options

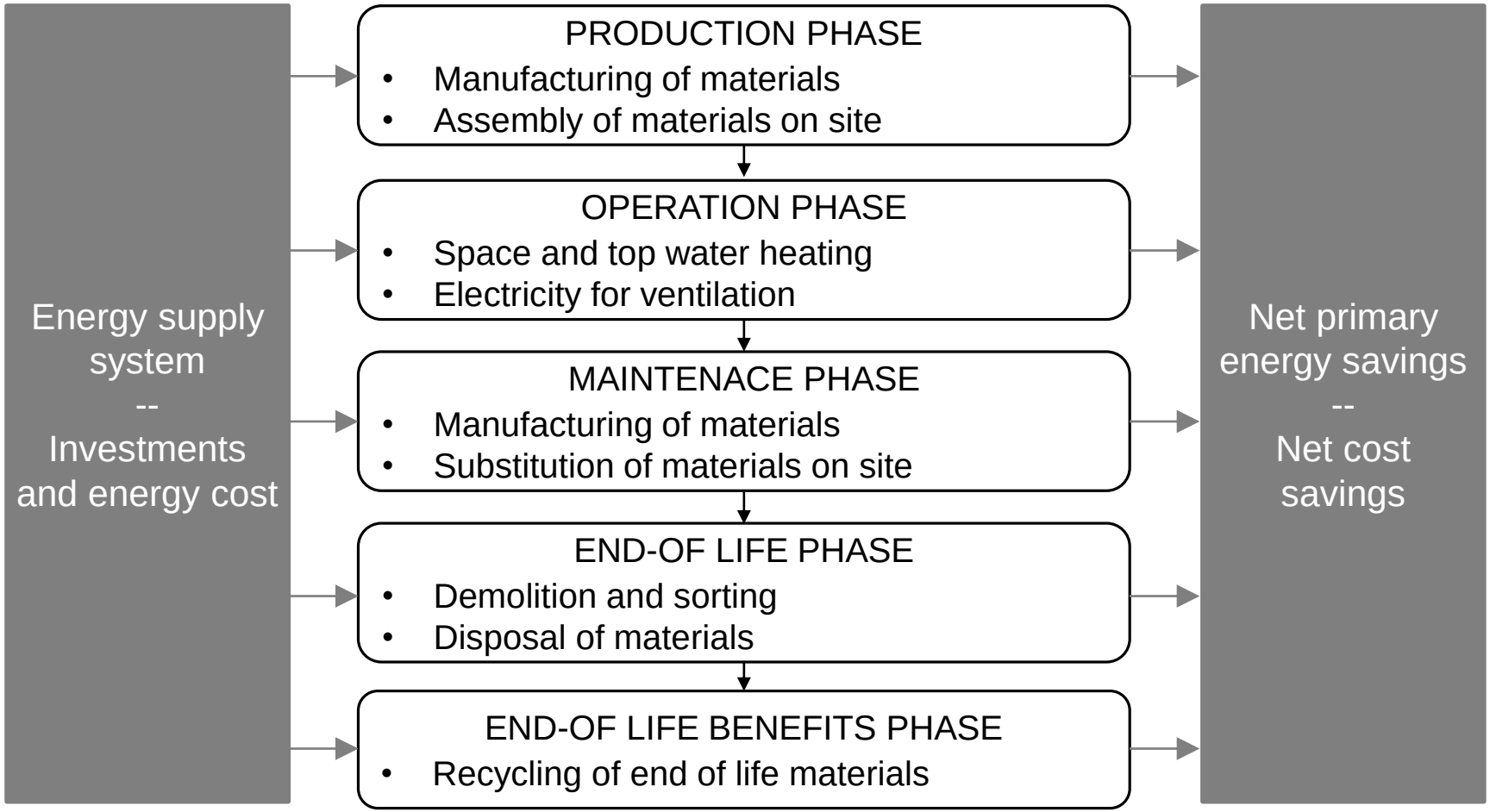
We combine alternative retrofit materials for:

- **Thermal insulation**
- **Facade system**
- Window frame



We obtain
- 6 material options for FEBY,
- 18 material options for PHI.





Price scenarios

Three price scenarios are adopted following an approach already used in other studies from our research group, Sustainable Built Environment Research (SBER):

	Business as usual (BAU) scenario	Intermediate scenario	Sustainability scenario
Real discount rates	5%	3%	1%
Annual energy price increase	1%	2%	3%

A discount rate of 6% is used for investments in energy supply.

Primary energy and cost savings from retrofit

Primary energy and cost savings are calculated assuming two energy scenarios:

1) Fossil gas is the marginal electricity energy source
   (the cost of district heat is calculated based on current reference electricity);
2) Wind (70%) and biomass (30%) are the marginal electricity energy source
   (the cost of district heat is calculated based on wind-bio reference electricity*).

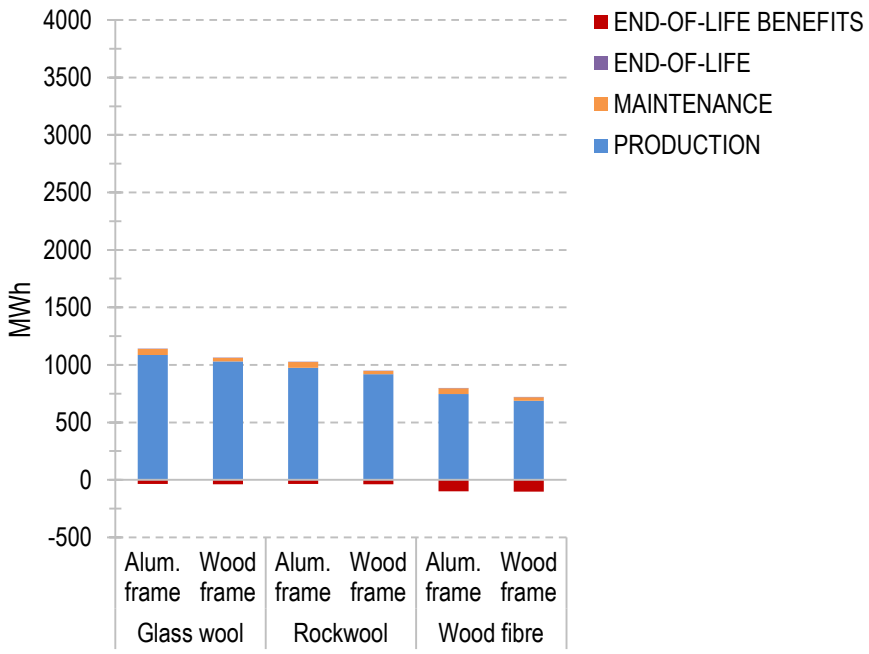
Varied real discount rate of 1%, 3% and 5%

	FEBY								PHI							
	Fossil gas				Wind-bio				Fossil gas				Wind-bio			
	Primary energy savings [MWh]	Cost savings [k€] 5%	3%	1%	Primary energy savings [MWh]	Cost savings [k€] 5%	3%	1%	Primary energy savings [MWh]	Cost savings [k€] 5%	3%	1%	Primary energy savings [MWh]	Cost savings [k€] 5%	3%	1%
Space and tap water heat	221	5	7	10	221	4	5	8	280	6	8	12	280	5	6	9
Electricity for ventilation	-4	0	0	0	-1	0	0	0	-4	0	0	0	-1	0	0	0
Total	**217**	**5**	**6**	**10**	**220**	**4**	**5**	**8**	**276**	**6**	**8**	**12**	**279**	**5**	**6**	**9**

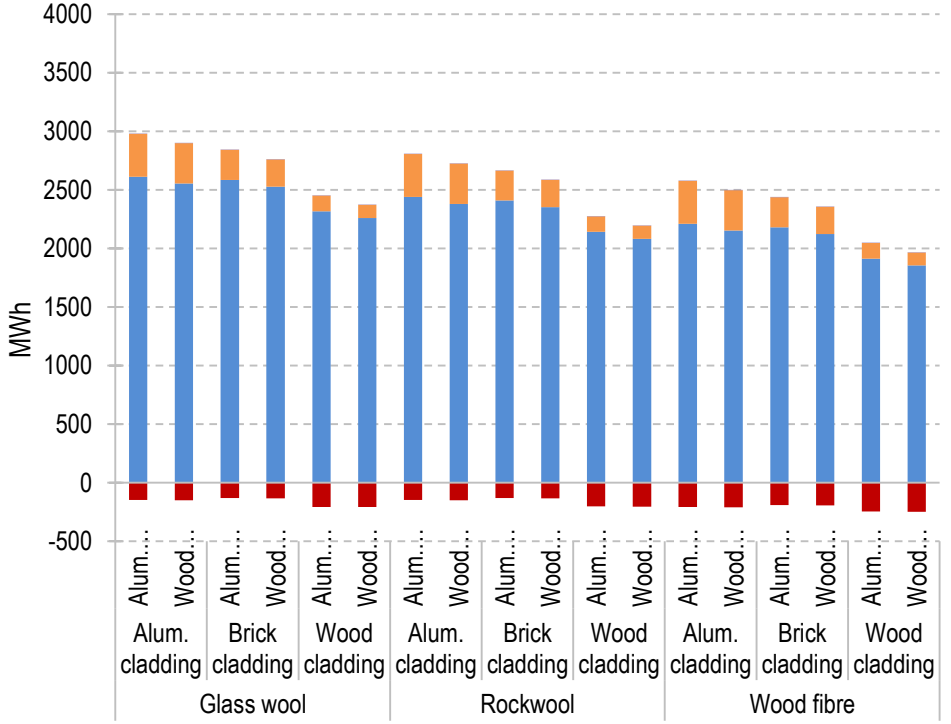
*The biomass price is assumed to be 18.7 €/MWh.

Primary energy use to retrofit *

FEBY (50 kWh/m², year)



PHI (30 kWh/m², year)



* fossil gas is assumed to be marginal electricity source

Powered by

AALBORG UNIVERSITY DENMARK

energy CLUSTER DENMARK

sEEnergies

Innovation Fund Denmark

reINVEST

midt regionmidtjylland

DEN EUROPÆISKE UNION Den Europæiske Fond for Regionaludvikling Vi investerer i din fremtid

GRØN ENERGI

kamstrup

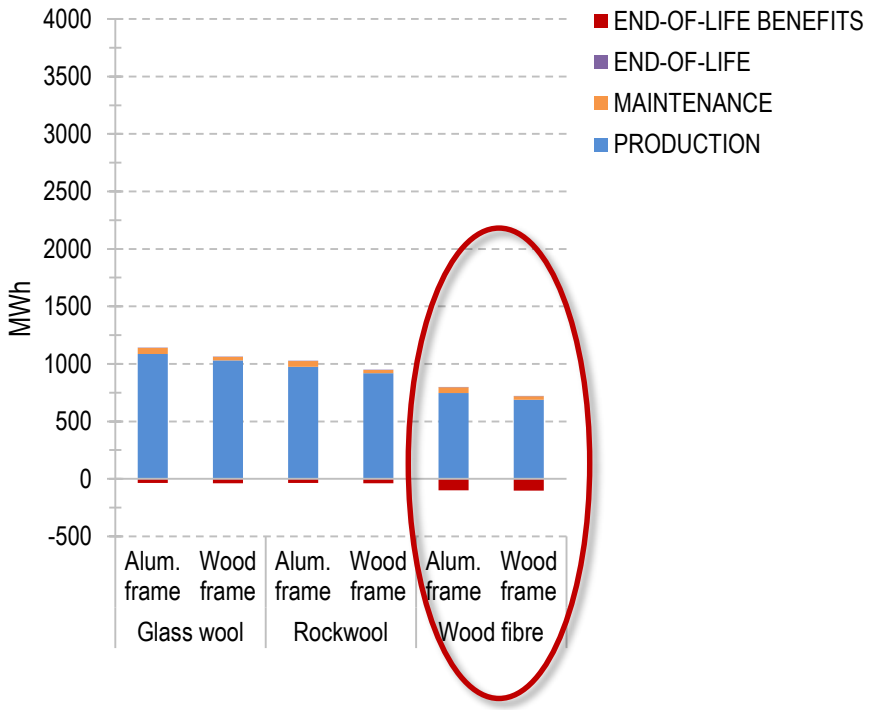
LOGSTOR

Ørsted

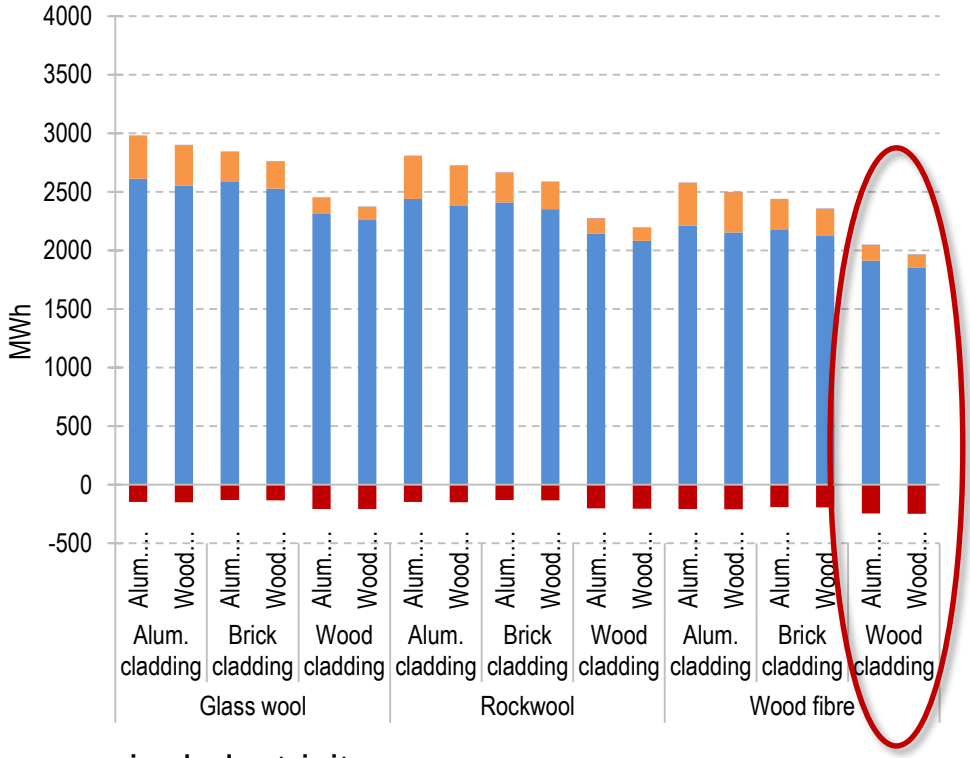
Aalborg Forsyning

Primary energy use to retrofit *

FEBY (50 kWh/m², year)



PHI (30 kWh/m², year)

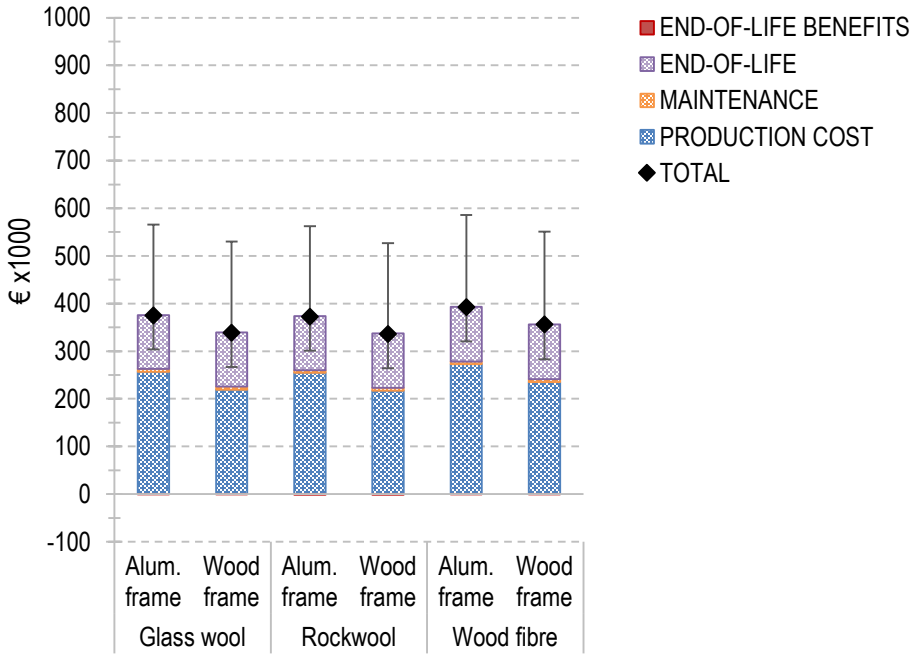


* fossil gas is assumed to be marginal electricity source

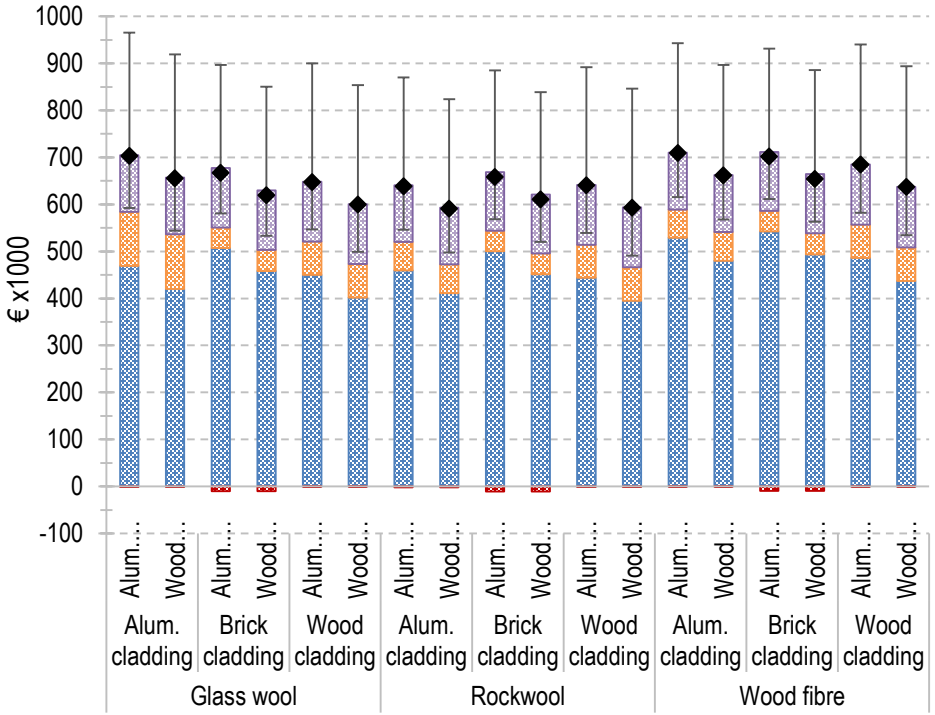
Powered by

Life cycle cost to retrofit excluding saved energy cost*

FEBY (50 kWh/m², year)



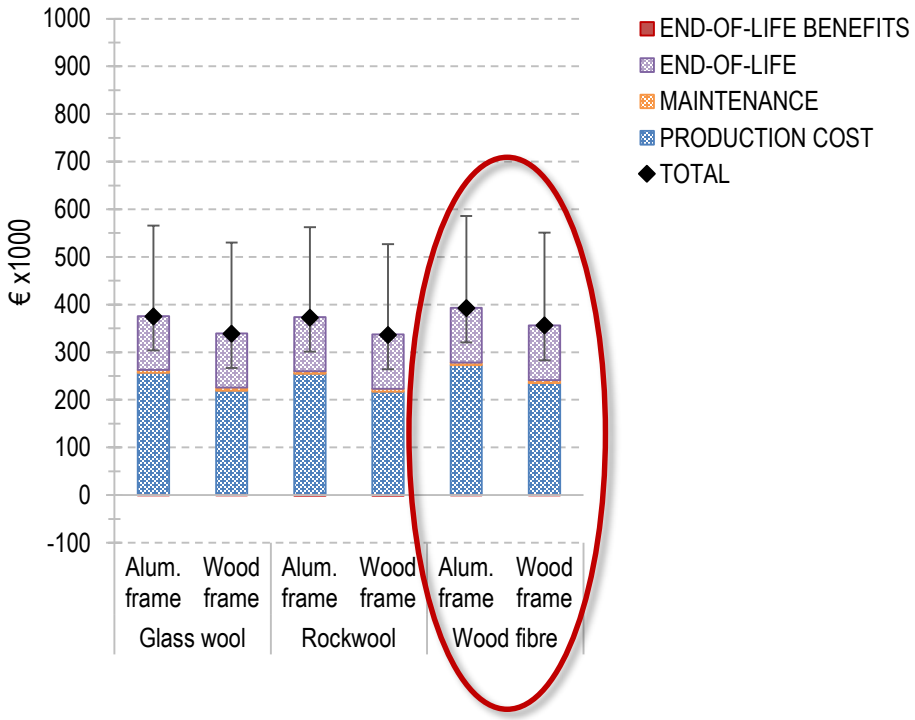
PHI (30 kWh/m², year)



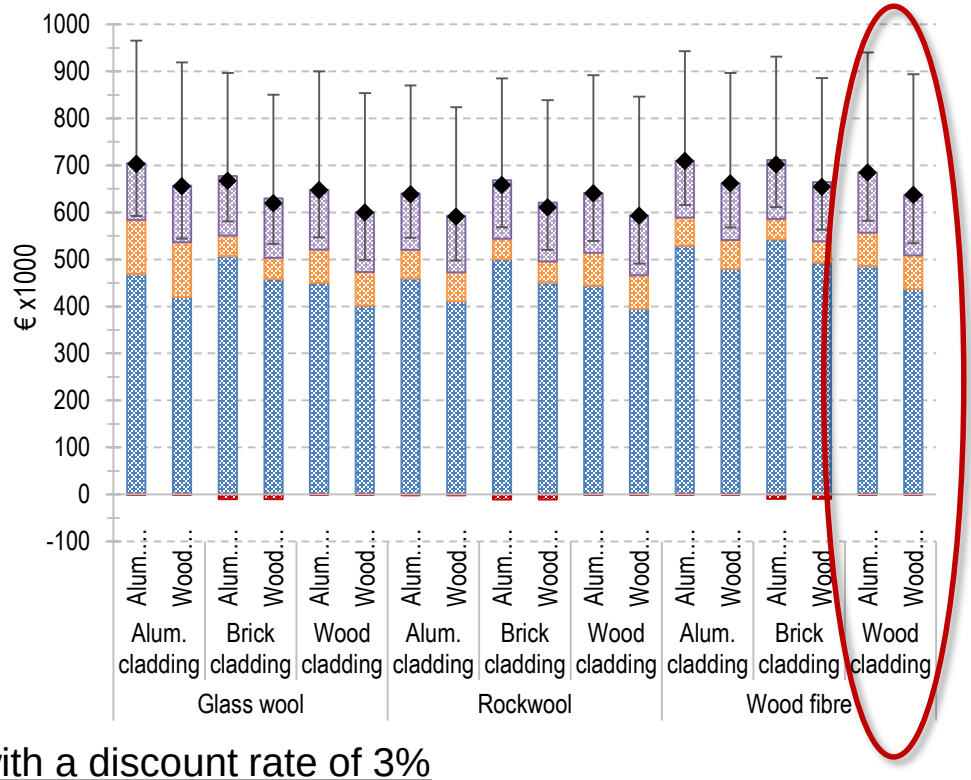
*costs are calculated with a discount rate of 3%
error bars represents the total cost with a discount rate of 5% (minimum) and 1% (maximum)

Life cycle cost to retrofit excluding saved energy cost*

FEBY (50 kWh/m², year)



PHI (30 kWh/m², year)

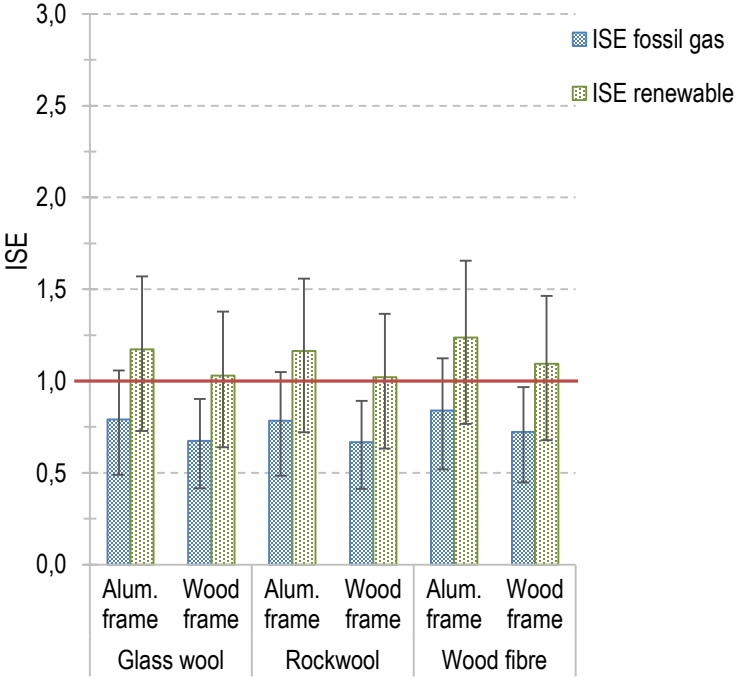


*costs are calculated with a discount rate of 3%
error bars represents the total cost with a discount rate of 5% (minimum) and 1% (maximum)

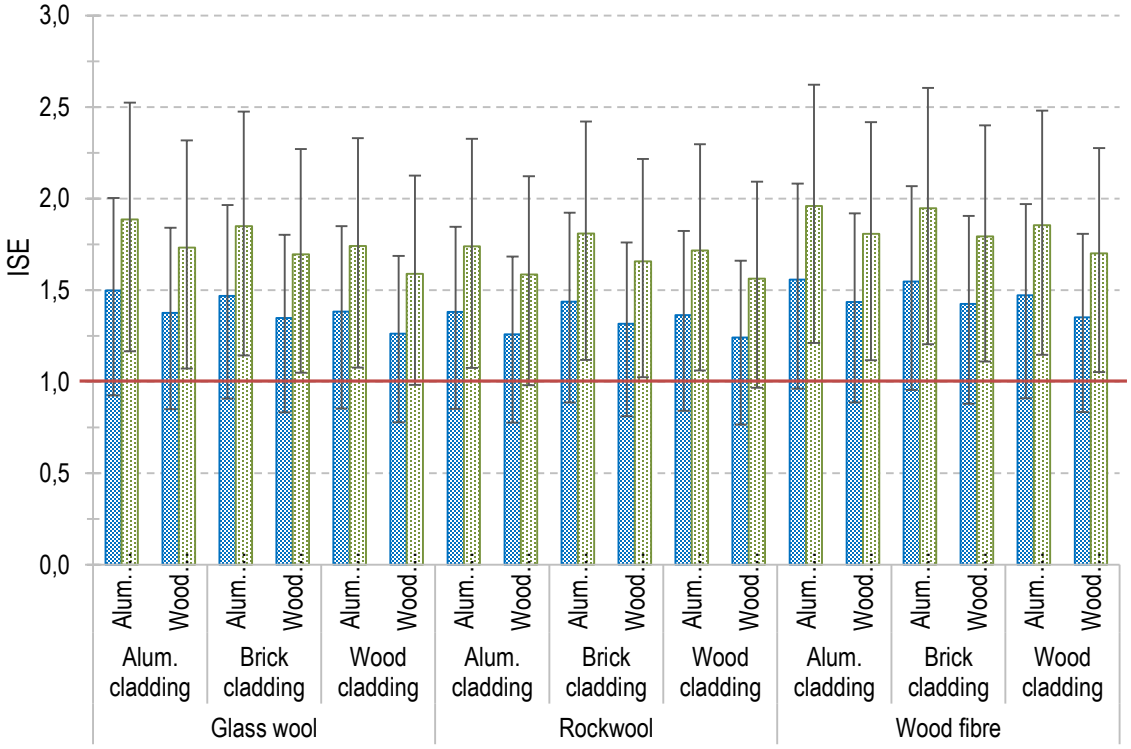
AALBORG UNIVERSITY DENMARK
energy CLUSTER DENMARK
sEEnergies
Innovation Fund Denmark
reINVEST
midt regionmidtjylland
DEN EUROPÆISKE UNION Den Europæiske Fond for Regionaludvikling Vi investerer i din fremtid
GRØN ENERGI
kamstrup
LOGSTOR
Ørsted
Aalborg Forsyning

Ratio between initial investment (production phase) and saved energy cost (ISE) *

FEBY (50 kWh/m², year)



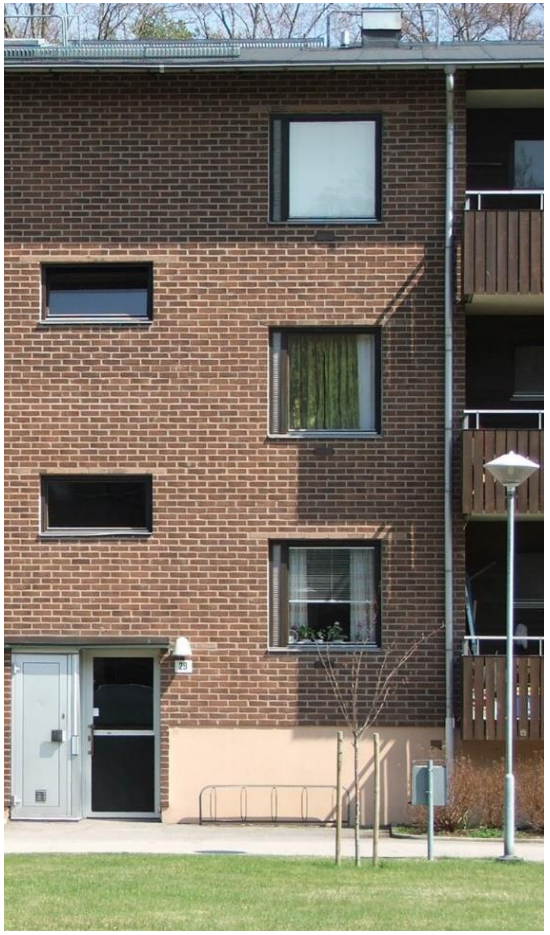
PHI (30 kWh/m², year)



* costs are calculated for two marginal energy scenarios (i.e. fossil gas and renewables) with a discount rate of 3%; error bars represents costs with a discount rate of 5% (min.) and 1% (max.)

Conclusions

- Different material options for building retrofit show different trends for life cycle primary energy use and cost.
- The production phase accounts for the highest share of primary energy use and costs in both the FEBY (50 kWh/m^2,year) and PHI (30 kWh/m^2,year) retrofits. The maintenance phase is also relevant when the retrofit meets the PHI standard.
- Different material options can affect the cost efficiency (ISE ratio) by up to 12% in FEBY and 30% in PHI retrofit.
- The use of bio-based materials results in up to 40% lower primary energy use. However, the use of wood fibre insulation can increase the costs by up to 7% in the FEBY (50 kWh/m^2, year) and 14% in the PHI (30 kWh/m^2,year) retrofits.
- The study assumptions, i.e. real discount rate and energy scenario, can affect the results significantly.



Thank you for your attention!

Contacts:

chiara.piccardo@lnu.se

leif.gustavsson@lnu.se

Powered by