

1 Supplementary Materials

2 **Table S1.** Main features of the building envelope components for all the scenarios analyzed.

Building envelope component	Area m ²	Thermal transmittance W/(m ² K)	Description
External walls, basement	78.21	0.13	Concrete wall, high insulation
External walls, other floors	151.53	0.19	Timber framed wall, high insulation
Roof, original	56.15	0.09	Wood pitched roof, very high insulation
Roof, new parts	14.28	0.14	Wood pitched roof, high insulation
Floor outwards	17.50	0.17	Wood flat roof, high insulation
Floor on ground, original	62.40	0.32	Concrete slab, high insulation
Windows	29.02	0.88	Low-e three glasses, argon filled, wood frame
External doors	3.80	1.1	Wood-aluminum frame, high insulation

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4 **Table S2.** LCA inventory for building components in all the scenarios analyzed.

Building component	Main materials	Process in Ecoinvent 3.1	Quantity	Waste factor (-)	Distance from production place to construction site (km)
Basement floor	Expanded polystyrene	Polystyrene foam slab {RER} production Alloc Rec, U	133.95 kg	0.05	60
	Reinforcing steel	Reinforcing steel {RER} production Alloc Rec, U	150 kg	0.05	340
	Concrete	Concrete, normal {CH} production Alloc Rec, U	6.06 m ³	0.05	100
	Concrete blocks	Concrete block {DE} production Alloc Rec, U	21.40 kg	0.05	100
	Polyethylene	Polyethylene, high density, granulate {RER} production Alloc Rec, U	13.14 kg	0.05	130
Foundation walls	Expanded polystyrene	Polystyrene foam slab {RER} production Alloc Rec, U	234.87 kg	0.05	60
	Fiber cement	Fibre cement facing tile {CH} production Alloc Rec, U	61.60 kg	0.05	60
	Reinforcing steel	Reinforcing steel {RER} production Alloc Rec, U	55.80 kg	0.05	340
	Concrete	Concrete, normal {CH} production Alloc Rec, U	1.98 m ³	0.05	100

Bearing structures	Laminated wood	Glued laminated timber, for indoor use {RER} production Alloc Rec, U	0.13 m ³	0.07	450
	Softwood	Sawnwood, softwood, kiln dried, planed {RER} planing, softwood, kiln dried Alloc Rec, U	0.04 m ³	0.07	220
	Steel	Steel, low-alloyed {RER} steel production, converter/electric Alloc Rec, U	3.00 kg	0.05	340
External walls	Glass wool	Glass wool mat {CH} production Alloc Rec, U	287.28 kg	0.05	60
	Softwood	Sawnwood, softwood, kiln dried, planed {RER} planing, softwood, kiln dried Alloc Rec, U	5.61 m ³	0.05	242
	Polyethylene	Polyethylene, high density, granulate {RER} production Alloc Rec, U	30.50 kg	0.07	160
	Paint	Alkyd paint, white, without solvent, in 60% solution state {RER} production Alloc Rec, U	102.43 kg	0.05	100
	Particleboard	Particle board, for indoor use {RER} production Alloc Rec, U	0.45 m ³	0.05	160
Internal walls	Glass wool	Glass wool mat {CH} production Alloc Rec, U	79.26 kg	0.05	60
	Softwood	Sawnwood, softwood, kiln dried, planed {RER} planing, softwood, kiln dried Alloc Rec, U	0.66 m ³	0.07	418
	Polyethylene	Polyethylene, high density, granulate {RER} production Alloc Rec, U	28.89 kg	0.07	160
	Gypsum plaster	Gypsum plasterboard {CH} production Alloc Rec, U	693.81 kg	0.07	95
	Paint	Alkyd paint, white, without solvent, in 60% solution state {RER} production Alloc Rec, U	211.83 kg	0.05	100
Ceilings and roof	Glass wool	Glass wool mat {CH} production Alloc Rec, U	468.81 kg	0.05	60
	Softwood	Sawnwood, softwood, kiln dried, planed {RER} planing, softwood, kiln dried Alloc Rec, U	5.03 m ³	0.07	357
	Particleboard	Particle board, for indoor use {RER} production Alloc Rec, U	2.78 m ³	0.07	160

	Laminated wood	Glued laminated timber, for indoor use {RER} production Alloc Rec, U	0.54 m ³	0.07	450
	Softwood/ Oriented strand board	Sawnwood, softwood, kiln dried, planed {RER} planing, softwood, kiln dried Alloc Rec, U Oriented strand board {RER} production Alloc Rec, U	3.56 m ³	0.07	800
	Polyethylene	Polyethylene, high density, granulate {RER} production Alloc Rec, U	14.16 kg	0.07	160
	Polyurethane	Polyurethane, rigid foam {RER} production Alloc Rec, U	44.00 kg	0.07	160
	Bitumen	Bitumen adhesive compound, cold {RER} production Alloc Rec, U	503.37 kg	0.07	160
	Gypsum plaster	Gypsum plasterboard {CH} production Alloc Rec, U	844.83 kg	0.07	95
	Paint	Alkyd paint, white, without solvent, in 60% solution state {RER} production Alloc Rec, U	90.95 kg	0.05	100
	Ceramic tiles	Ceramic tile {CH} production Alloc Rec, U	260 kg	0.05	100
Windows	Wooden frame	Window frame, wood, U=1.5 W/m ² K {RER} production Alloc Rec, U	8.71 m ²	0.00	350
	Coated glass	Flat glass, coated {RER} production Alloc Rec, U	195.03 kg	0.00	350
	Uncoated glass	Flat glass, uncoated {RER} production Alloc Rec, U	390.06 kg	0.00	350
External doors	Wood-aluminum	Door, outer, wood-aluminum, {RER} production Alloc Rec, U	3.80 m ²	0.00	350
Sanitary appliances	Ceramic	Sanitary ceramics {CH} production Alloc Rec, U	105.00 kg	0.00	100
External drainage	Gravel	Gravel, crushed {CH} production Alloc Rec, U	23,760 kg	0.00	100
	Polyethylene	Polyethylene, high density, granulate {RER} production Alloc Rec, U	152.30 kg	0.07	100
	Polyethylene pipe	Polyethylene pipe, corrugated, DN 75 {RER} production Alloc Rec, U	24.20 m	0.00	100

Table S3. LCA inventory for technical building systems in all the scenarios analyzed.

Technical building system	Process in Ecoinvent 3.1	Quantity	Waste factor (-)	Distance from production place to construction site (km)
Ventilation system	Air filter, central unit, 600 m ³ /h {RER} production Alloc Rec, U	1 p*	0.00	100
	Blower and heat exchange unit, Avent E 97 {RER} production Alloc Rec, U	1 p	0.00	100
	Ventilation duct, steel, 100x50 mm {RER} production Alloc Rec, U	50 m	0.00	100
	Exhaust air outlet, steel/aluminum, 85x365 mm {CH} production Alloc Rec, U	15 p	0.00	100
	Outside air intake, stainless steel, DN 370 {RER} production Alloc Rec, U	3 p	0.00	100
	Supply air inlet, steel/SS, DN 75 {RER} production Alloc Rec, U	15 p	0.00	100
Wood stove	Furnace, logs, 6kW {CH} production Alloc Rec, U	1 p	0.00	100
Electric floor heating	Copper {RER} production, primary Alloc Rec, U	11.90 kg	0.00	100
	Polypropylene, granulate {RER} production Alloc Rec, U	97.54 kg	0.00	100
Electric radiators	Steel, low-alloyed {RER} steel production, converter/electric Alloc Rec, U	53.30 kg	0.00	100
	Polycarbonate {RER} production Alloc Rec, U	1.95 kg	0.00	100
	Corrugated board box {RER} production Alloc Rec, U	3.90 kg	0.00	100
Water radiators	Steel, low-alloyed {RER} steel production, converter/electric Alloc Rec, U	165 kg	0.00	100
DHW boiler	Hot water tank, 600l {CH} production Alloc Rec, U	1 p	0.00	100
Heat pump	Heat pump, brine-water, 10kW {CH} production Alloc Rec, U	1 p	0.00	100
PV system	Photovoltaic panel, single-Si wafer {RER} production Alloc Rec, U	25 m ²	0.00	100
	Inverter, 2.5kW {RER} production	1 p	0.00	100
Solar thermal system	Evacuated tube collector {GB} production Alloc Rec, U	8 m ²	0.00	100
	Expansion vessel, 25l {CH} production Alloc Rec, U	1 p	0.00	100
	Pump, 40W {CH} production Alloc Rec, U	1 p	0.00	100

* p=unit

Table S4. Main input data for the dynamic energy simulations in all scenarios.

Energy simulation parameters	Value
Indoor temperature during operation time (°C)	21
Indoor temperature outside of operation time (°C)	19
Internal gains from lighting (W/m ²)	1.95
Internal gains from electric appliance (W/m ²)	1.8
Internal gains from occupants (W/m ²)	1.5
Heating, DHW, lighting, and electric appliance operation time (h)	5,824
People occupation time (h)	8,736
Lighting energy need during operation time (W/m ²)	1.95
Electric appliance energy need during operation time (W/m ²)	3
DHW energy need during operation time (W/m ²)	5.1
Air-to-air heat pump COP (-)	2.5
Air-to-water heat pump COP (-)	3.0
Wood stove efficiency (%)	85
DHW boiler efficiency (%)	95
Mechanical ventilation air flows [m ³ /(h m ²)]	1.2
Mechanical ventilation system operation time (h)	8,736
Specific fan power in ventilation system [kW/(m ³ s)]	1.5
Mechanical ventilation heat exchanger efficiency (%)	85

Table S5. Main features of the PV and solar thermal systems for the scenarios S5, S6, and S7.

Description	PV system	Solar thermal system
Technology	Crystalline	Evacuated tube collectors
Total panel area (m ²)	25	8
Slope (°)	45	45
Azimuth (°)	0	0
Estimated system losses (%)	14	
Peak power (kWp)	4	
Collector efficiency intercept (-)		0.7
Collector efficiency slope (-)		2
Effectiveness of heat exchange (-)		0.7
Collector flow rate (kg/s)		0.7
Storage tank volume (m ³)		0.7
Circulation pump power (W)		70
Total annual energy produced (kWh)	3,980	3,875

Table S6. Maintenance measures for all the scenarios analyzed. The 'x' indicates whether the measure applies to the specific scenario.

Maintenance measure	S1	S2	S3	S4	S5	S6	S7
Repainting external walls every 8 years	x	x	x	x	x	x	x
Repainting internal walls every 15 years	x	x	x	x	x	x	x
Repainting internal ceilings every 15 years	x	x	x	x	x	x	x
Substituting windows every 30 years	x	x	x	x	x	x	x
Substituting external doors every 30 years	x	x	x	x	x	x	x
Replacing roof covering every 30 years	x	x	x	x	x	x	x
Replacing electric radiators every 20 years	x	x		x	x	x	
Replacing water radiators every 30 years			x				x
Replacing wood stove every 25 years	x			x			
Replacing electric floor heating every 25 years	x	x		x	x	x	
Replacing DHW boiler every 20 years	x	x	x	x	x	x	x
Replacing heat pump every 20 years	x		x				x
Replacing ventilation system every 25 years	x	x	x	x	x	x	x
Replacing PV system every 25 years					x	x	x
Replacing solar thermal system every 25 years						x	x
Renovating bathroom every 25 years	x	x	x	x	x	x	x
Replacing external drainage every 40 years	x	x	x	x	x	x	x

Table S7. Main costs used for the replacement measures in all the scenarios analyzed.

Replacement measure	Cost, incl. value-added tax	
Painting, interior	111	NOK/ m ²
Painting, exterior	173	NOK/ m ²
Roof asphalt membrane	150	NOK/ m ²
Windows, external walls, wood	4,958	NOK/ m ²
Windows, roof	13,720	NOK/ m ²
External doors, wood	12,391	NOK per unit
Heat pump, air-to-air	37,144	NOK per unit
Heat pump, air-to-water	80,000	NOK per unit
Fireplace, wood stove	10,631	NOK per unit
Balanced ventilation system	610	NOK/ m ²
Electric radiator	365	NOK/ m ²
Electric floor heating	1,173	NOK/ m ²
Water radiator	419	NOK/ m ²
Boiler for DHW, with tank	10,000	NOK per unit
Photovoltaic system, 4.5 kWp	139,359	NOK per unit
Solar thermal system	88,141	NOK per unit
Bathroom renovation	30,000	NOK/m ²
External drainage and works	143,750	NOK per unit