

Combined Environmental and Economic Assessment of Energy Efficiency Measures in a Multi-Dwelling Building

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Received: 9 May 2019; Accepted: 25 June 2019; Published: 27 June 2019

Table S1. Case Study Building Information.

Basic Information	
Latitude	60.49 N
Longitude	16.4 E
Elevation (m)	153
Number of storeys	3
Total heated are (m ²)	2822
Building gross volume (m ³)	8387
Number of apartments	36
Type of heating system	Hydronic heating system. District System
Type of ventilation	Mechanical exhaust ventilation
Total U-*Value (W/K m ²)	1.47
Heat demand (KWh/m ² year)	152

Table S2. Renovations Scenarios.

Renovation Scenario	Outer Walls	Unheated Attic	Windows	Ventilation	Heating Source	Others
0	120 mm mineral wool insulation	150 mm mineral wool insulation	Double casement	Mechanical	District Heating	
1	120 mm mineral wool insulation	150 mm mineral wool insulation	Double casement	Mechanical	District Heating	Photovoltaic panel system
2	120 mm mineral wool insulation	150 mm mineral wool insulation	Double casement	Mechanical	Geothermal Heat Pump	
3	120 mm mineral wool insulation	150 mm mineral wool insulation	Double casement	Heat Recovery Ventilation	District Heating	
4	120 mm mineral wool insulation	150 mm mineral wool insulation	Double casement	Heat Recovery Ventilation	Geothermal Heat pump	Photovoltaic Panels
5	480 mm mineral wool insulation	300 mm mineral wool insulation	3-glass argon filled low emissivity pane	Mechanical	District Heating	Photovoltaic panes
6	480 mm mineral wool insulation	300 mm mineral wool insulation	3-glass argon filled low emissivity pane	Mechanical	Geothermal Heat pump	
7	480 mm mineral wool insulation	300 mm mineral wool insulation	3-glass argon filled low emissivity pane	Heat recovery ventilation	District Heating	
8	480 mm mineral wool insulation	300 mm mineral wool insulation	3-glass argon filled low emissivity pane	Heat recovery ventilation	Geothermal Heat pump	Photovoltaic panes

Table S3. Materials datasets not listed in the article.

Resource	Quantity	Unit	Service Life	Country
Ventilation exhaust unit	3	pcs	25 years	France
Dry mortar	71,800	kg	As building	Norway
Gypsum plasterboard	1198	m ²	As building	Norway
Mineral wool. Insulation	1198	m ²	As building	Denmark
Radon and moisture membrane 1.2 mm	1198	m ²	30 years	Norway
Calcium silicate block 115 mm	1198	m ²	As building	Germany
Min. wool insul. for pitched roof 300 mm	971	m ²	As building	Denmark
Triple glazed windows, wood-alum. frame	298	m ²	40 years	Norway
Heating system	2822	m ²	As building	Finland
Ventilation system	2822	m ²	30 years	Finland
Heat Recovery Ventilation unit	1	pcs	25 years	Germany

Table S4. Fuel use (%) for district heating 2016.

Fuel Use (%)	Borlänge Energi	Göteborg Energi
Recycled energy	67	70.4
Industrial Excess Heat	20	29.7
Flue Gas Condensing	1.6	11.1
Heat from Heat Pumps (Netto)	0.5	5.7
Municipal Solid Waste (MSW) Incineration	44.3	23.9
Blast Furnace Gas	0.6	0
Renewable energy	30.7	9.9
Pellets, Bricks and powder	0	1.3
Secondary biofuels	28.6	4.3
Bio oil and tall oil pitch	0	0.2
Renewable electricity	2.1	4.2
Others	1.2	2
Hot water from other companies, renewables and recycled energy	1.2	2
Fossil energy	1.1	17.7
Oil	1.1	0.2
Natural Gas	0	17.5

Table S5. Greenhouse gas emissions (GHG) emission factors for DH 2016.

GHG Emissions (g CO ₂ eq/kWh)	Borlänge Energi	Göteborg Energi
Total Emissions	66	79
Combustion	62	69
Fuel transport and production	4	10

Table S6. LCC parameters.

Resource	Quantity	Unit	Unit Cost (SEK)
Ventilator, central, 5,000 m ³ /h with heat recovery	1	unit	200,000
Electric heat pump (brine-water, geothermal probe), 70 kW	1	unit	100,000
Pipework for electric heat pump (brine-water, geothermal probe), 70 kW	1	unit	1,500,000
Photovoltaic panel system for roofs, 300 Wc capacity,	67	unit	8611
Heating system (steel pipes and heat distribution center), room area m ²	2822	m ²	350
Ventilation system with plastic pipes, room area m ²	2822	m ²	350
Ventilator, central, 5,000 m ³ /h with heat recovery	1	unit	200,000
Electricity, Sweden	154	kWh	2.05
Gypsum plasterboard, 12.5 mm, 9 kg/m ² ,	1198	m ²	139.81
Thermal insulation for external wall, average product)	1198	m ²	3683.79
Radon and moisture membrane for site construction	1198	m ²	66.76
Calcium silicate block	1198	m ²	6557.6
Dry mortar	71,880	kg	26.26
Window, triple glazed, wood-alu frame	298	m ²	3937

Table S7. End of life scenarios.

Material Group	Material Group	Materials Included	C3–C4, Waste Processing and Landfilling	D, Recycling Benefits
Mineral building materials	Recycling for ground works	Concrete, Cement, Bricks, Porcelain, Plaster, Clay products, Stone, Ceramics, Asphalt	C3: Construction waste preparation for recycling	Recycling benefit from replacing the primary gravel
Metals	Metal preparation and recycling	Aluminum, Steel, Stainless steel, Galvanized steel, Copper coated, Copper uncoated, Brass, Zinc, Lead	C3: Metal waste preparation	Recycling benefits for replacing virgin metal
Bio based materials with heating value	Incineration and energy recovery	Wood, Wood products	C3: Construction waste incineration for energy recovery	Recovered energy (replacing average energy production)
Other materials with heating value	Incineration and energy recovery	Plastics	C3: Construction waste incineration for energy recovery	Recovered energy (replacing average energy production)
Other materials that can be landfilled in construction waste site	Disposal/landfilling of inert material	Coatings, Synthetic materials, Panels and boards, Insulating materials, Glass, Window and façade components	Disposal of inert construction waste	-