ZEROCO2
Interreg Europe

Study on transformation of one building to Near Zero CO2 emission Building due to energy use

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Thermopolis Oy
ZEROCO2

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1 Short presentation of the building

1.1 General

Day care “Metsätähti” is located in Ilmajoki, Finland and owned by the City of Ilmajoki. The building’s heated floor area is 446 m^2 and the heated volume is 1 390 m^3. It was constructed in 2000. The building is heated using an oil boiler and wall mounted radiators. The air ventilation system is equipped with a heat recovery unit and a heating radiator.

Table 1. Description of building envelop

Structure	Description
Exterior walls	Chip rock board - vapour barrier - wood frame with 600 mm mineral wool – 25 mm wind barrier – Wood panelling
Roof	Chip rock board – wood frame with 50 mm mineral wool – vapour barrier – 250 mm cellulose wool – roof
Floor	Concrete slab – cell polystyrene board

	100mm - roofing

1.2 Energy performance calculation

Table 2. Energy consumption, building energy class and CO2 emmissions.

	Building status
Energy need for heating kWh/a	53 700[1]
Energy need for cooling kWh/a	-
Use of electricity kWh/a	49 200[1]
CO2 emissions kg/a	24 116[2]
Building energy class (A – G)	G

[1]Real data for year 2015, heating value has been normed according to outdoor temperature variations.
[2]Light fuel oil 261 kg CO2/MWh, Oil consumption 5.3 m^3, Electricity 209 kg CO2/MWh (Finnish average).

Table 2 presents the energy consumption of the building. The values are real consumption values from the year 2015. However, the heating energy has been normed using heating degree days and an assumption that 30 % of heating energy is used for heating domestic hot water. The actual oil consumption for the year 2015 was 5.3 m^3 (53 000 kWh). The oil boiler was assumed to have an efficiency of 85 %. Thus the actual needed heat for the building in the year 2015 was 45 050. Since the year 2015 was warmer than usual the normed value is 53 700 kWh/a. This value will be used as the heating need for the building.

2 Measures for achieving ZEROCO2 target

2.1 Variant 1 – PV (55kWp)

In the first variant, the oil boiler remains as the main heating system and electricity is produced using photovoltaic (PV). The solar panels are placed on the roof and on separate stands at the optimal slope and azimuth (free standing). The system includes an inverter and it is connect to the grid. Irradiation used in calculations is from PVGIS. The energy production and financial data has been calculated using a free solar power investment tool found on the solar energy information website of Aalto University called FinSolar. No shading has been taken into account.

The PV system's peak power is 55 kWp. The panel area is approximately 347 m^2. The yearly production is estimated at 53 600 kWh/a. The investment is estimated to be 88 000 €.

32 % of the produced solar power can be used onsite. The rest will be fed into the grid and sold at a price of 6.0 cent/kWh. The price of bought electricity is 10 cent/kWh with a 1 %

annual increase. The interest rate is estimated at 2.0 %. In the 15th year, it is estimated that the inverters will need to be replaced at a cost of 8 % of the initial investment. With this data the payback time is 29 years (NPV).

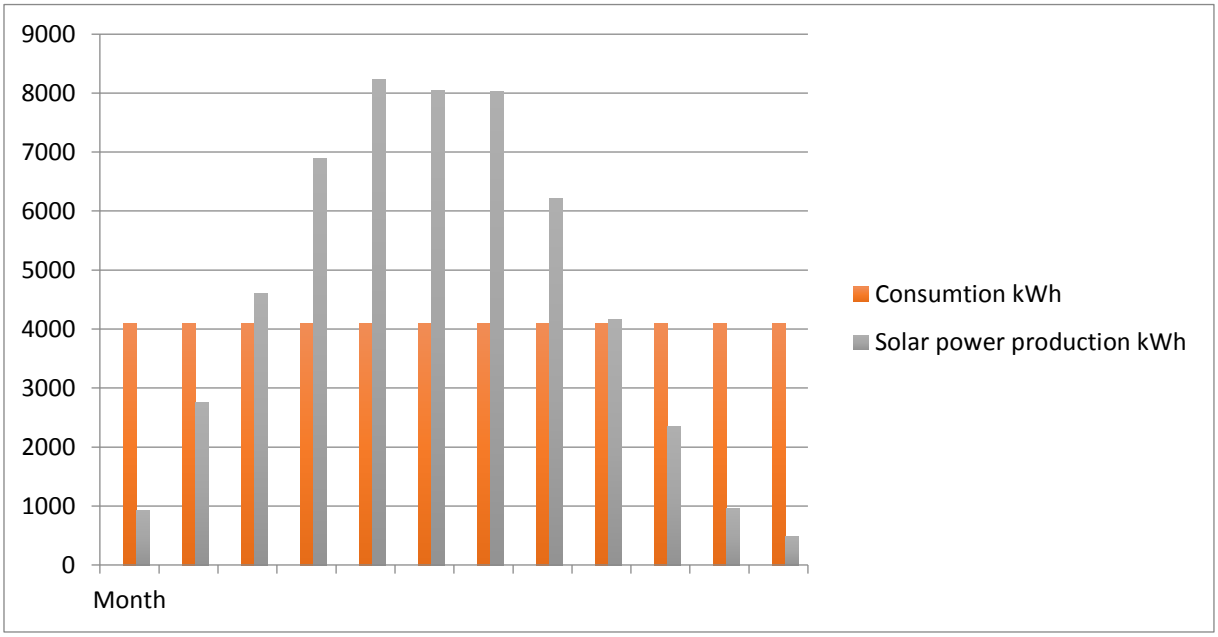

Figure 1. Solar power production and electricity consumption for variant 1.

2.2 Variant 2 – Ground Source Heat Pump

In variant 2, the building will be equipped with a ground source heat pump (28 kW).

The heat source is two 150 meter deep bore holes. The heat sink is a 2 000 liter hot water accumulator. The heat pump is designed to cover 100 % of the heating need.

The COP of the heat pump is estimated to be 3. To produce 53 700 kWh/a the heat pump would use 17 890 kWh/a of electricity. The share of free energy would be 35 800 kWh/a.

The heat pump investment would be around 40 000 €. The price of bought electricity is 10 cent/kWh with a 1 % annual increase. The price of oil is estimated to increase 1 % annually. The starting oil price is 0.83 €/dm^3. The interest rate is estimated 2 %. In the 15th year, it is estimated that the compressor will need to be replaced at a cost of 8 % of the initial investment. With this data the payback time is 12 years (NPV).

The electricity consumption for this variant is (23 600 kWh/a + 17 890 kWh/a) 67 090 kWh.

2.3 Variant 3 – Wood chip

The building will be equipped with a wood chip boiler and a 1000 litre water accumulator. The wood chip requires storage for the wood chips. The planned storage will contain 10 m^3

of wood chips. This would be enough to store 1 week worth of wood chips when the temperatures are low. The boiler would have a capacity of 30 kW heating.

The investment would be around 40 000 €. The price of oil is estimated to increase 1 % annually. The starting oil price is 0.83 €/dm^3. The interest rate is estimated 2 %. Wood chip and maintenance yearly costs are estimated to be a little under 2000 €/a. With this data the payback time is 11 years (NPV).

2.4 Variant 4 – PV (12 kWp)

This variant is the installation of a small PV system that would produce enough electricity to cover the summer consumption. This option could be combined with variants 2 and 3.

The PV system's peak power is 12 kWp. The panel area is approximately 82 m^2. The yearly production is estimated at 11 710 kWh/a. The investment is estimated to be 19 200 €.

97 % of the produced solar power can be used onsite. The rest will be fed into the grid and sold at a price of 6.0 cent/kWh. The price of bought electricity is 10 cent/kWh with a 1 % annual increase. The interest rate is estimated at 2.0 %. In the 15th year, it is estimated that the inverters will need to be replaced at a cost of 8 % of the initial investment. With this data the payback time is 21 years (NPV).

3 Comparison

Table 3. Comparison of different proposed variants.

	Building-current status	Building – NZCO2EB measures PV 55 kWp	Building – NZCO2EB measures Heat pump	Building – NZCO2EB measures Wood chip	Building – NZCO2EB measures PV 12 kWp
Energy need for heating kWh/a	Oil 53 700	Oil 53 700	Heat pump 53 700 (of which 35 780 free energy)	Wood Chip 53 700 (wood chip 63 100)	Oil 53 700
Energy need for cooling kWh/a[1]	-	-	-	-	-
Use of electricity kWh/a	Grid 49 200	PV 53 700	Grid 67 090	Grid 49 200	PV 11 710 Grid 37 500
CO2 emissions kg/a	24 116	14 008	14 022	10 283	21 843
Operating	10 154	5 472[2]	6 922[3]	6 876[4]	9 039[2]

costs per year (EUR/a)					
Initial investment (EUR)	-	88 000	40 000	40 000	19 200
Payback period (years)		29	12	11	21

[1]No active cooling.
[2]For the solar power system operation cost is the change of inverters in the 15th year. This cost has been divided evenly over the 30 year operational life time.
[3] For the heat pump system the operation cost is the consumption of electricity and the cost of the replacement of the compressor in the 15th year divided evenly to 30 years.
[4] For the wood chip boiler option the operation cost is the consumption wood chips and the yearly maintenance costs.

Variants 1-4 present ways to replace either the grid electricity or heating oil with renewables. This division is chosen to show how each change impacts the variables of CO2 emissions, operational costs and initials investments. From the presented variants 1 and 4 can be combined with 2 and 3. Table 4 presents the possible combined variants.

Table 4. Combination of variants.

	Heat pump + PV 55 kWp	Wood chip + PV 55 kWp	Heat pump + PV 12 kWp	Wood chip + PV 12 kWp
Energy need for heating kWh/a	Heat pump 53 700 (of which 35 780 free energy)	Wood Chip 53 700 (wood chip 63 100)	Heat pump 53 700 (of which 35 780 free energy)	Wood Chip 53 700 (wood chip 63 100)
Use of electricity kWh/a	Grid 13 390 PV 53 700	PV 53 700	Grid 55 380 PV 11 710	Grid 37 490 PV 11 710
CO2 emissions kg/a	2 799	0	11 574	7 835
Operating costs per year (EUR/a)	1 680[1,2]	2 191[1,3]	5 695[1,2]	5 756[1,3]
Initial investment (EUR)	128 000	128 000	59 200	59 200

[1]For the solar power system operation cost is the change of inverters in the 15th year. This cost has been divided evenly over the 30 year operational life time.
[2] For the heat pump system the operation cost is the consumption of electricity and the cost of the replacement of the compressor in the 15th year divided evenly to 30 years.
[3] For the wood chip boiler option the operation cost is the consumption wood chips and the yearly maintenance costs.

Figure 2Figure 3 compare the cumulative cost and CO2 emissions of the presented different options. The cumulative costs are calculated over 30 years of operation. No interest is included.

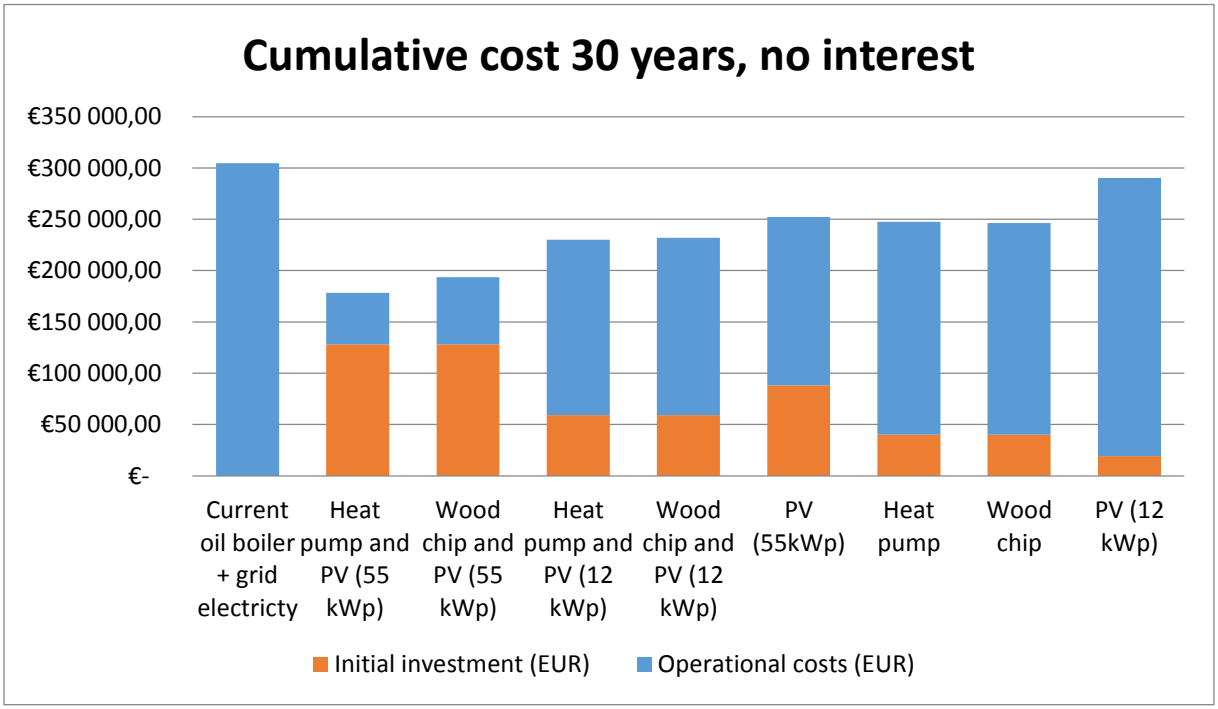

Figure 2. Cumulative costs over 30 years of operation. No interest included.

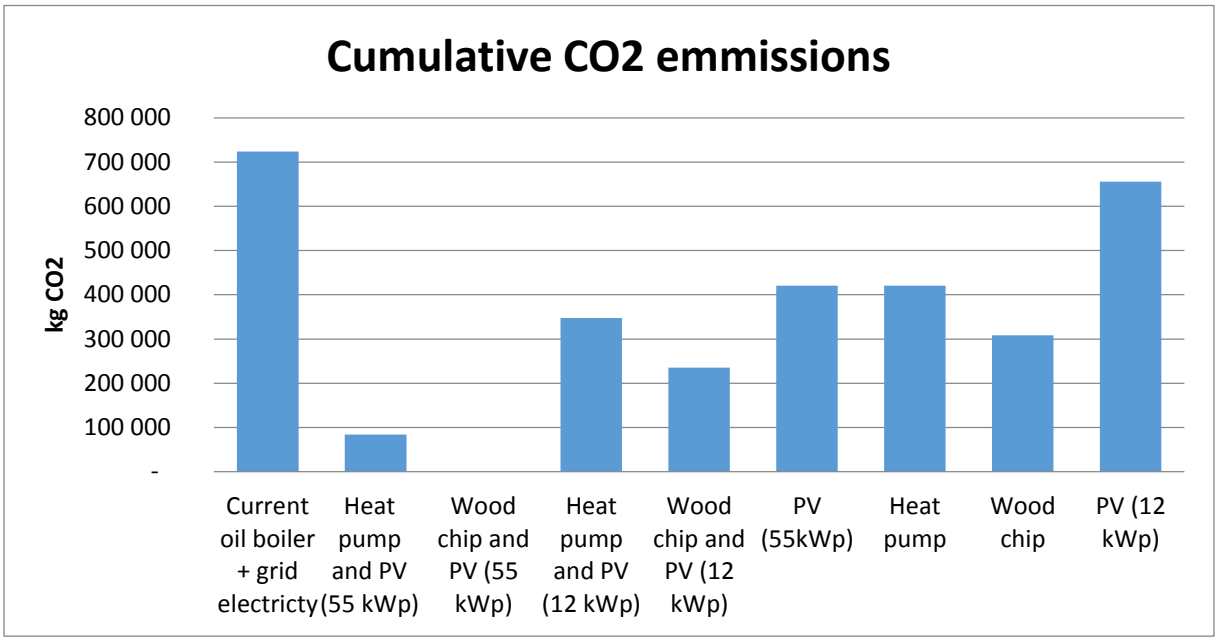

Figure 3. Cumulative CO2 emissions over 30 years of operation.

4 Conclusion

From the NearZeroCo2 point of view the optimal option would be the combination of a wood chip boiler and the larger PV system of 55 kWp. This would produce zero CO2 emmissions. However, from the cumulative cost point of view the best option would be combination of the heat pump and the PV 55 kWp.

Comparing the different non-combined variants the heat pump and wood chip solutions seem to be rather equal.