

Heat Pumps

Scope

The scope of this exercise was to produce the calculations required to be able to quantify the Return of Investment resulting from replacing boilers with heat pumps. The boilers could be used to supply hot water for space heating and/or domestic hot water.

Overview

The calculation is modular, based on a number of boilers. It is assumed that three types of fuel can be used: Liquefied Petroleum Gas (LPG), Light Fuel Oil (LFO) and Diesel.

The user inputs the variables listed in Table 1 for each boiler or number of similar boilers. Variables i1 to i7 describe the current system. The user selects whether the boiler runs on diesel, LFO or LPG. The volume of diesel, LFO or LPG is specified in variables i2 to i4.

The efficiency of the boilers is inputted in variables i5 to i7. The boiler efficiency value should be based on the Gross (Higher) Calorific Value of the fuel used and should only be related to the boiler itself. Losses such as thermal losses along the pipework should not be included. Such an efficiency is also called Fuel-to-steam efficiency.

The Coefficient of Performance (COP) of the proposed heat pump (HP) is inputted in variable i8. The seasonal COP should be rated for the operating water and evaporator temperatures.

Input variables i1 to i8 are inputted for the different boilers (numbered 1 to n).

Variable No	Input Variable	Symbol	Unit
i1	No of similar boilers	N	No
i2	Annual Fuel Consumption per boiler - Diesel	V_D	litres/year
i3	Annual Fuel Consumption per boiler - LFO	V_{LFO}	litres/year
i4	Annual Fuel Consumption per boiler - LPG	V_{LPG}	litres/year
i5	Boiler Efficiency - Diesel	$B_{eff.D}$	%
i6	Boiler Efficiency - LFO	$B_{eff.LFO}$	%
i7	Boiler Efficiency - LPG	$B_{eff.LPG}$	%
i8	Coefficient of Performance (COP) of Proposed Heat Pump	COP_N	n/a

Table 1: Required Inputs – Motor Upgrades

The annual fuel costs for diesel, LFO and LPG are specified in financial inputs fi1 to fi3 (listed in Table 2).

The user inputs the heat pump costs in financial variables fi4 to fi7 and defines the discount rate and the required Return of Investment (ROI) period in variables fi8 and fi9 respectively. The appropriate electricity tariff is defined in variable fi10. The tariffs are shown in Appendix 1.

Variable No	Input Variable	Symbol	Unit
fi1	Annual Fuel Cost - Diesel	C_D	€/year
fi2	Annual Fuel Cost - LFO	C_{LFO}	€/year
fi3	Annual Fuel Cost - LPG	C_{LPG}	€/year
fi4	Dismantling Cost	C_1	€
fi5	Disposal Cost	C_2	€
fi6	Capital Cost	C_3	€
fi7	Installation Cost	C_4	€
fi8	Discount Rate	i	%
fi9	ROI period	R	Years
fi10	Electricity Tariff	r	€/kWh

Table 2: Required Inputs – Financial

The algorithm calculates and presents the outputs listed in Table 3 and Table 4.

The current, proposed and saved energy consumption and corresponding costs are calculated in variables o1 to o17 and fo1.

The Return of Investment and the Payback period (variables fo3 to fo6) are calculated based on the savings (variable fo1) and the total investment cost (variable fo2).

Variable No	Output Variables	Symbol	Unit
o1	Fuel Energy Consumption – Boiler N - Diesel	$E_{CN,D}$	kWh/year
o2	Fuel Energy Consumption – Boiler N - LFO	$E_{CN,LFO}$	kWh/year
o3	Fuel Energy Consumption – Boiler N - LPG	$E_{CN,LPG}$	kWh/year
o4	Water Heating Requirement – Heater N	Q_N	kWh/year

o5	Proposed Electricity Consumption – Heat Pump N	E_{PN}	kWh/year
o6	Energy Savings – Heater N	E_{SN}	kWh/year
o8	Percentage Energy Savings – Heater N	S_N	%
o7	Total Fuel Energy Consumption – Diesel	$E_{C,D}$	kWh/year
o9	Total Fuel Energy Consumption – LFO	$E_{C,LFO}$	kWh/year
o10	Total Fuel Energy Consumption – LPG	$E_{C,LPG}$	kWh/year
o11	Total Fuel Energy Consumption	E_C	kWh/year
o12	Total Annual Fuel Cost	C_C	€/year
o13	Total Proposed Electricity Consumption	E_P	kWh/year
o14	Total Annual Proposed Electricity Cost	C_P	€/year
o15	Total Annual Energy Consumption Savings	E_S	kWh/year
o16	Percentage Energy Savings	S_E	%
o17	Percentage Cost Savings	S_C	%

Table 3: Calculated Outputs

Variable No	Output Variables	Symbol	Unit
fo1	Total Annual Energy Cost Savings	C_S	€/year
fo2	Total Investment Cost	C_t	€
fo3	Pay Back Period - Simple	t_{SPB}	years
fo4	Pay Back Period - NPV	T_{NPV}	years
fo5	ROI after R years	ROI_R	€
fo6	Percentage ROI after R years	$ROI_{R\%}$	%

Table 4: Calculated Outputs - Financial

Conclusion

A preview with three heaters and dummy values is shown in Appendix 2. The three options shown are for (i) diesel fired boiler, (ii) LFO fired boiler, and (iii) LPG fired boiler. The number of water heaters can be increased accordingly.

Appendix 1: Enemalta Tariffs

Band	Cumulative Consumption (kWh)	Tariff (€/kWh)
1	0 - 2,000	0.1215
2	2,001 - 6,000	0.1275
3	6,001 - 10,000	0.1373
4	10,001 - 20,000	0.1485
5	20,001 - 60,000	0.1613
6	60,001 - 100,000	0.1500
7	100,001 - 1,000,000	0.1403
8	1,000,001 - 5,000,000	0.1275
9	5,000,000 & over	0.1080

Appendix 2: Excel version of Calculations

Boiler Number	Similar Heaters	Annual Fuel Consumption - per boiler			Boiler Efficiency			Current Fuel Energy Consumption			Water Heating Requirement	Proposed Heat Pump COP	Proposed Electricity Consumption	Energy Savings	
		Diesel	LFO	LPG	Diesel	LFO	LPG	Diesel	LFO	LPG				E_{SN}	S_N
		N	V_D	V_{LFO}	V_{LPG}	$B_{eff.D}$	$B_{eff.LFO}$	$B_{eff.LPG}$	$E_{CN.D}$	$E_{CN.LFO}$				$E_{CN.LPG}$	Q_N
No	litres/year	litres/year	litres/year	%	%	%	kWh/year	kWh/year	kWh/year	kWh/year	n/a	kWh/year	kWh/year	%	
1	1	4000			90	90	90	42,739	0	0	38,465	4	9,616	28,849	75.0
2	1		4000		90	90	90	0	44,215	0	39,794	4	9,948	29,845	75.0
3	1			4000	90	90	90	0	0	29,088	26,179	4	6,545	19,635	75.0
								42,739	44,215	29,088	104,438		26,110		

INPUTS

Cost Item	Symbol	Value	Unit
Annual Diesel Cost	C_D	5,000	EUR/year
Annual LFO Cost	C_{LFO}	5,000	EUR/year
Annual LPG Cost	C_{LPG}	5,000	EUR/year
Dismantling Cost	C_1	2,000	EUR
Disposal Cost	C_2	500	EUR
Capital Cost	C_3	20,000	EUR
Installation Cost	C_4	2,500	EUR
Discount Rate	i	2.00	%
ROI period	R	4	years
Electricity Tariff	r	0.1403	EUR/kWh

OUTPUTS

Cost Item	Symbol	Value	Unit
Total Investment Cost	C_t	25,000	EUR
Total Fuel Energy Consumption	E_C	116,042	kWh/year
	C_C	15,000	EUR/year
Proposed Electricity Consumption	E_P	26,110	kWh/year
	C_P	3,663	EUR/year
Energy Consumption (savings)	E_S	89,933	kWh/year
	C_S	11,337	EUR/year
	S_E	77.5	%
	S_C	75.6	%
Pay Back Period	Simple	t_{SPB}	2.21 years
			26.5 months
	NPV	t_{NPV}	2.28 years
			27.3 months
Return of Investment after year no. R (using NPV)	ROI_R	18,168	EUR
	$ROI_{R\%}$	72.7	%