D3.2 – ROI Estimation (for use case 1,2, and 3)

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WP 3, T 3.2

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Heat pipE TECHnologies for INdustrial Applications.

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Technical References

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[1] PU = Public
PP = Restricted to other programme participants (including the Commission Services)
RE = Restricted to a group specified by the consortium (including the Commission Services)
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Summary

In this deliverable the return on investment (ROI) of the three of heat pipes based heat exchangers (HPHE) designs that will be installed in three demonstration sites is presented . Each HPHE is specified in base of the available and required energy for each of the three use cases:

- Use Case 1 (UC1): representative of non-ferrous sector,
- Use Case 2 (UC2): representative of steel sector and
- Use Case 3 (UC3): representative of ceramic sector.

This report describes how the ROI was estimated taking into account the primary energy saving cost and the carbon reduction savings.

The estimated ROI of the intial designs of the designed HPHEs varied between 7 months to 19 months among the the three demo cases.

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Introduction

Heat pipe heat exchanger (HPHE) are very efficient technology for heat recovery in challenging applications. HPHEs can be upsized to maximise the heat recovery from waste stream, however sizing the HPHPE reaches a limit where any further increasing in the scale of the system will slightly increase the duty of the unit in comparison to a great increment in the cost of the system. Based on the that HPHEs in this project are desired to be designed to recover 40% of the waste stream within back period less than three years.
The ROI of the initial design for the three use cases was estimated to evaluate the designs from an economical point of view. The ROI was estimated based on the cost of the unit and the working hours per year and conversion factors reported in D2.1.
It should be mentioned that the designs of the HPHEs for the three demo sites are initial and might be developed or changed depending on the demonstration sites requirements. Therefore, the ROI of the HPHE will be changed.

1 ROI Estimation Methodology

Return on investment (ROI) measures the gain or loss generated on an investment relative to the amount of money invested. The ROI in this report is expressed as a payback period in months.

The general return on investment formula is:

$$ROI = (Net\ Profit\ /\ Cost\ of\ Investment)\ x\ 100$$

The net profit can be calculated as followed:

The Capital Cost is the cost of the unit delivered to the demo site.
Additional costs because of the HPHE installation are:

- An additional cost can be the installation cost, however the ROI is going to be calculated without considering the installation cost since it greatly differs between each demo case depending on the installation site and its complexity.
- Additional cost is the parasitic load which represents any power consumption on any electrical equipment that has been installed as a part of the recovery system. The parasitic load can be the power consumption of an additional fan or pump etc.
- Additional cost is the operating and maintenance cost (O&M) which the cost of the maintenance of the HPHE annually

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The utilisation of the HPHE for waste heat recovery in industrial application includes saving in expenses at different points.
The main energy savings is due to energy recovered directly by the HPHE
An additional energy saving is saving in energy losses in the burner where the efficiency of the burner varies between 0.95 and 0.85 generally.
Further savings results from the reduction in the carbon emissions per annum.
The ROI in this report is represented by the payback period of the system which is calculated as follows:

$$\mathrm{ROI} = \frac{Cumulative\ Cash\ flow}{Annual\ Net\ Benefit} \times 12\ (\mathrm{months})$$

Where

$$Cumulative\ Cash\ flow\ at\ the\ beginning\ of\ year\ 1\ = HPHE\ Cost$$

$$Annual\ Net\ Benefit\ Excluding\ taxes = EC_{Sav\_NG} + C_{CO2\_emission\_saved} - E_{BOP} - C_{O\&M}$$

The definitons of the symbols used to estimate the ROI in the above equation with their formulas are presented in Table 1.

Table 1 Variables, Expression, and factors used to estimate the ROI

Expression	Symbol	Formula	unit
Total CO_2 cost saving	$C_{CO2\_emission\_saved}$	$m_{CO2saved} \times C_{CO2\_emission}$	€/y
CO_2 emission cost	$C_{CO2\_emission}$		€/tCO_2e
Total CO_2 quantity saving	$m_{CO2\_NG\_sav}$	$PE\ \dot{Q}_{NG,sav}$ x $ConvF_{NG}$	tCO_2e/y
Parasitic Load energy cost	E_{BOP}	$EC_E \times \dot{E}_{BOP} \times R_{time,HPHE}$	€/y
Electrical energy cost	EC_E		€/MWh
Working hours of the system per year	$R_{time,HPHE}$		hr/y
Reduction in fuel Cost	EC_{Sav_NG}	$PE\dot{Q}_{NG,sav} \times EC_{NG} \times R_{time,HPHE}$	€/y
Natural Gas Cost	EC_{NG}		€/MWh
Primary energy savings	$PEQ_{NG,sav}$	$\dot{Q}_{SSt} * Eff_{NG}$	MWh
Thermal power recovered by the HPHE	$\dot{Q}_{SSt}$	$\dot{m}_{sst} \times Cp \times (T_{sst,out}-T_{sst,in})$	kW,MW
Conversion factor for natural gas	Eff_{PEN}		
Cost of Mintinance	$C_{O\&M}$		€/y

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2 UC1: ROI Estimations

Thermal design of the HPHE for Use Case 1 is based on the data provided in D2.2
The thermal design of the HPHE for use case 1 is presented in Table 2.

Table 2 Thermal Design of Use Case 1

Flow rates		
Exhaust	1,580	kg/hr
Air	1,802	kg/hr
Specific Heat		
Exhaust average specific heat capacity	0.264	kcal/kg.°C
Air average specific heat capacity	0.246	kcal/kg.°C
Temperatures		
Exhaust entry	450	°C
Exhaust exit	259	°C
Air entry	145	°C
Air exit	324	°C
Heat recovered		
Total Duty of the Unit	**93**	**kW**

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Based on the methodology presented in the section 1, the ROI of Use Case 1 and the corresponding savings are presented in Table 3. Cash flow for the investment in Use Case 1 is presented in Figure 1. Where the corresponding saveing are based on the thermal performance of the HPHE i.e the maximum heat recovery of the HPHE.

Table 3 ROI estimation for Use Case 1

Variable	Value
Unit Duty, Thermal energy transferred to secondary streams	93 kW
Working hours	5784 hr/y
Thermal energy transferred to secondary streams per year	537.9 MWh/y
Eff_{PEN}	1.149
Primary energy savings $PEQ_{NG,sav}$	618 MWh/y *
EC_{NG}	29.376 €/MWh (1)
EC_{Sav_NG}	15801 €/y
$Conv_{FNG}$	237.39 kgCO2/MWh(HHV) (2)
$m_{CO2saved}$	127.7 t/y
$C_{CO2\_emission}$	22 €/t (3)
$C_{CO2\_emission\_saved}$	2809 €/y
Unit Cost	35300 €
ROI	**23 months**

(*) caused by natural gas consumption reduction; the influence of electricity consumption variation is not included yet
(1) Gas price obtained from Eurostat data for medium size industries of Spain prices in 2017. Taxes not included. (http://ec.europa.eu/eurostat/tgm/refreshTableAction.do?tab=table&plugin=1&pcode=ten00118&language=en)
(2) Values based on “Well to tank Report, version 4.0” of Joint Research Institute
(3) Carbon price per ton from http://markets.businessinsider.com/commodities/co2-emissionsrechte

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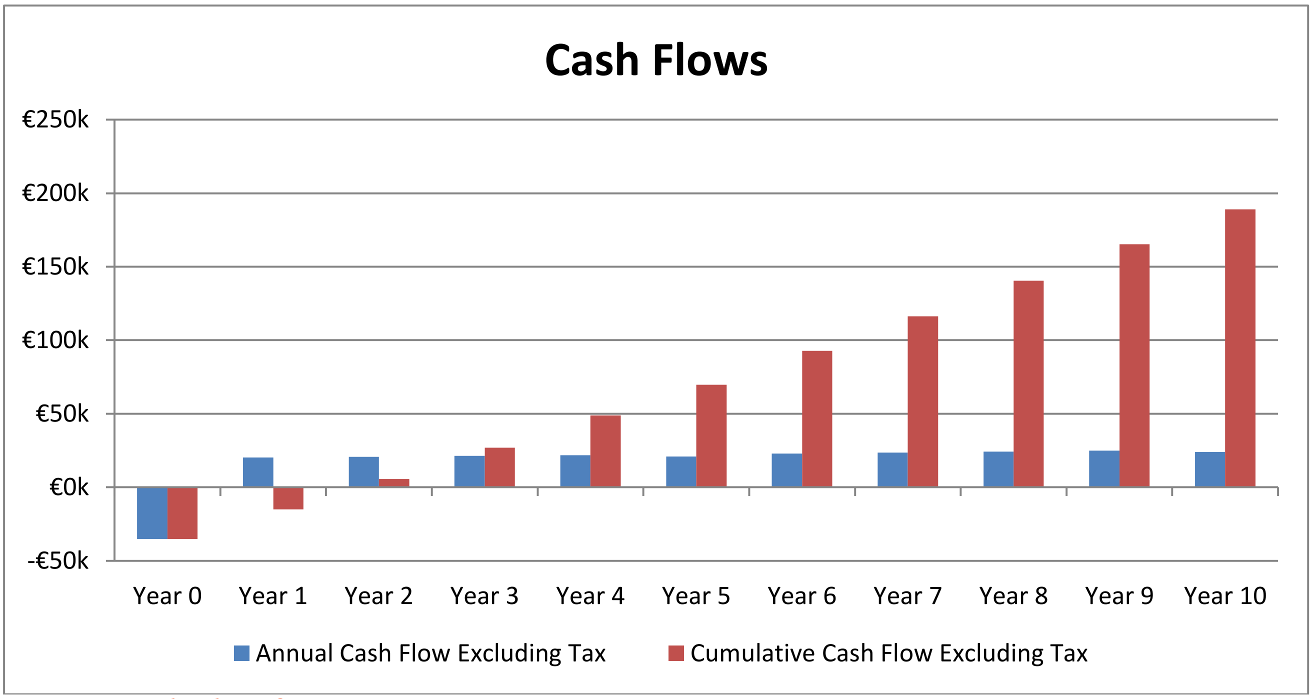

Figure 1 Cash Flow for Use Case 1

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3 UC2: ROI Estimations

The HPHE for use case 2 was deseigned on the maximum values of the flow rates and temperatures in the exhaust stream where the temperature of exhaust after the HPHE is 150 °C. As a result the designed HPHE utilises more than 40% of the waste stream. The thermal design of the HPHE is presented in Table 4.. As a result the estimated energy saving in this report are different from D2.1. It should be highlted that developing the initial design of the HPHE will change the cost and the thermal prefroamnce and the ROI of the system.

Table 4 Thermal design of HPHE for use case 2

Flow rates		
Exhaust mass flow rate	8000	kg/h
Air mass flow rate	4525	kg/h
Water mass flow rate	18000	kg/h
Specific Heat		
Exhaust average specific heat capacity	0.257	kcal/kg.°C
Air average specific heat capacity	0.241	kcal/kg.°C
Water average specific heat capacity	1	kcal/kg.°C
Temperatures		
Exhaust inlet temperature	400	°C
Exhaust outlet temperature	150	°C
Air inlet temperature	25	°C
Air outlet temperature	176	°C
Water inlet temperature	70	°C
Water outlet temperature	89	°C
Heat recovery		
Recovered heat (air side)	191	kW
Recovered heat (water side)	406	kW
Total heat recovery	598	kW

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The ROI of Use Case 2 and the corresponding savings are presented in Table 5. The cash flow of Use Case 2 is presented in Figure 2. Where the corresponding saveing are based on the thermal performance of the HPHE i.e the maximum heat recovery of the HPHE.
Table 5 ROI estimation for Use Case 2

Table 5 ROI estimation for Use Case 2

Variable	Value
Unit Duty, Thermal energy transferred to secondary stream1 (Air)	191 kW
Unit Duty, Thermal energy transferred to secondary stream2 (water)	406 kW
Unit Duty, Thermal energy transferred to secondary streams	597 kW
Working hours (for the Air stage)	8050 hr/y
Working hours (for the water stage)	5015 hr/y
Equivalent working hours	5989 hr/y
Thermal energy transferred to secondary streams per year	3575.6 MWh/y
Eff_{PEN}	1.18
Primary energy savings $PEQ_{NG,sav}$	4219 MWh/y *
EC_{NG}	24.925 €/MWh **
EC_{Sav_NG}	105159 €/y
$ConvF_{NG}$	199 $kgCO_2$/MWh
$m_{CO2saved}$	840 t/y
$C_{CO2\_emission}$	22 €/t (1)
$C_{CO2\_emission\_saved}$	18471 €/y
Unit Cost	68500 €
ROI	**7 months**

(*) caused by natural gas consumption reduction; the influence of electricity consumption variation is not included yet
(**)gas price obtained from the Statistical Office of the Republic of Slovenia data for medium size industries (I4: 100 000 do 1 000 000 GJ) for 2017.
(http://pxweb.stat.si/pxweb/Dialog/varval.asp?ma=1817502S&ti=&path=../Database/Repozitorij_SLO/&lang=2)
(1) Carbon price per ton from http://markets.businessinsider.com/commodities/co2-emissionsrechte

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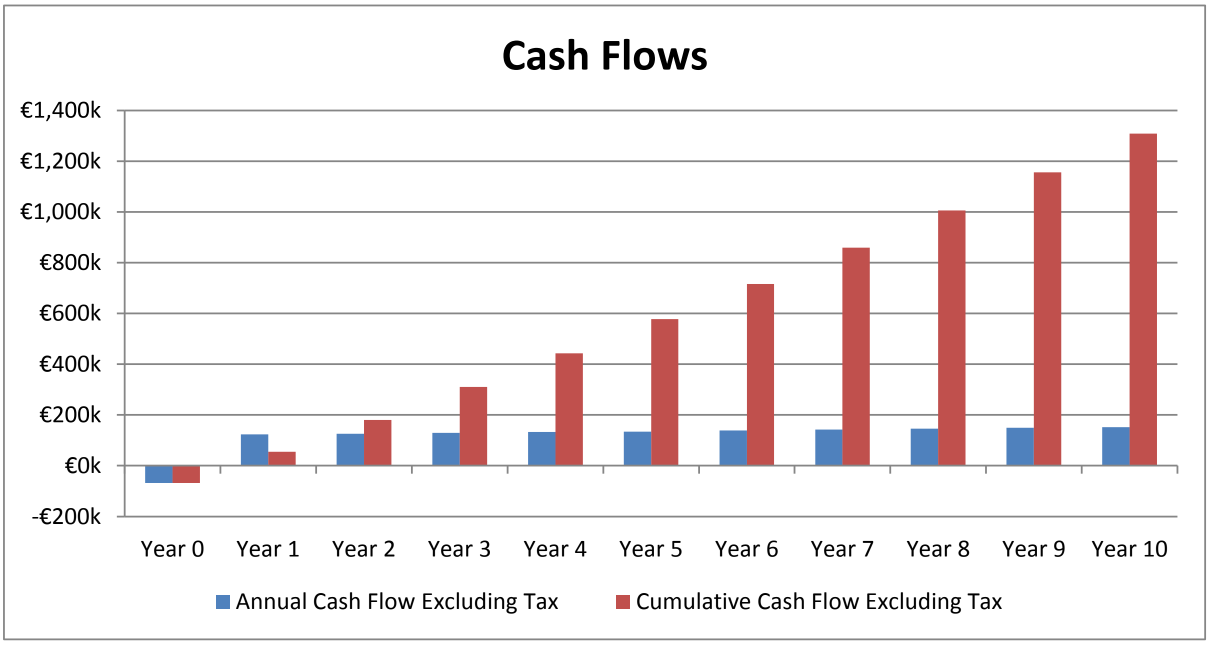

Figure 2 Cash Flow in Use Case

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4 UC3: ROI Estimations

The thermal design of the HPHE is presented in **Table 6** based on the data obtained from measurements in demo site 3. It should be mentioned that developing the HPHE thermal or mechanical design will change the cost and the thermal prefromance which change the ROI.

Table 6 Thermal design of the HPHE for use case 3

Flow rates		
Exhaust mass flow rate	29785	kg/h
Water/glycol mass flow rate	14300	kg/h
Specific Heat		
Exhaust average specific heat capacity	0.265	kcal/kg.°C
Water/Glycol average specific heat capacity	0.927	kcal/kg.°C
Temperatures		
Exhaust inlet temperature	245	°C
Exhaust outlet temperature	155	°C
Air inlet temperature	115	°C
Air outlet temperature	167	°C
Heat recovery		
Recovered heat	827	kW

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Based on the methodology presented in the section 1, the ROI of Use Case 3 and the corresponding savings are presented in Table 7. The cash flow of Use Case 3 is presented in Figure 3. Where the corresponding saveing are based on the thermal performance of the HPHE i.e the maximum heat recovery of the HPHE.

Table 7 ROI estimation in Use Case 3

Variable	Value
Unit Duty, Thermal energy transferred to secondary streams	827 kW
Working hours	6300 hr/y
Thermal energy transferred to secondary streams per year	5210 MWh/y
Eff_{PEN}	1.01
Primary energy savings $PEQ_{NG,sav}$	5262 MWh/y
EC_{NG}	32 €/MWh *
EC_{Sav_NG}	168384 €/y
$ConvF_{NG}$	203.99 $kgCO_2$/MWh
$m_{CO2saved}$	1073 t/y
$C_{CO2\_emission}$	22 €/t **
$C_{CO2\_emission\_saved}$	23606 €/y
Unit Cost	210560 €
ROI	**13 months**

(*)"ec.europa.eu/eurostat/statistics-explained/images/2/29/Electricity_and_gas_prices%2C_second_half_of_year%2C_2013%E2%80%9315_%28EUR_per_kWh%29_YB16.png
(**) Carbon price per ton from http://markets.businessinsider.com/commodities/co2-emissionsrechte

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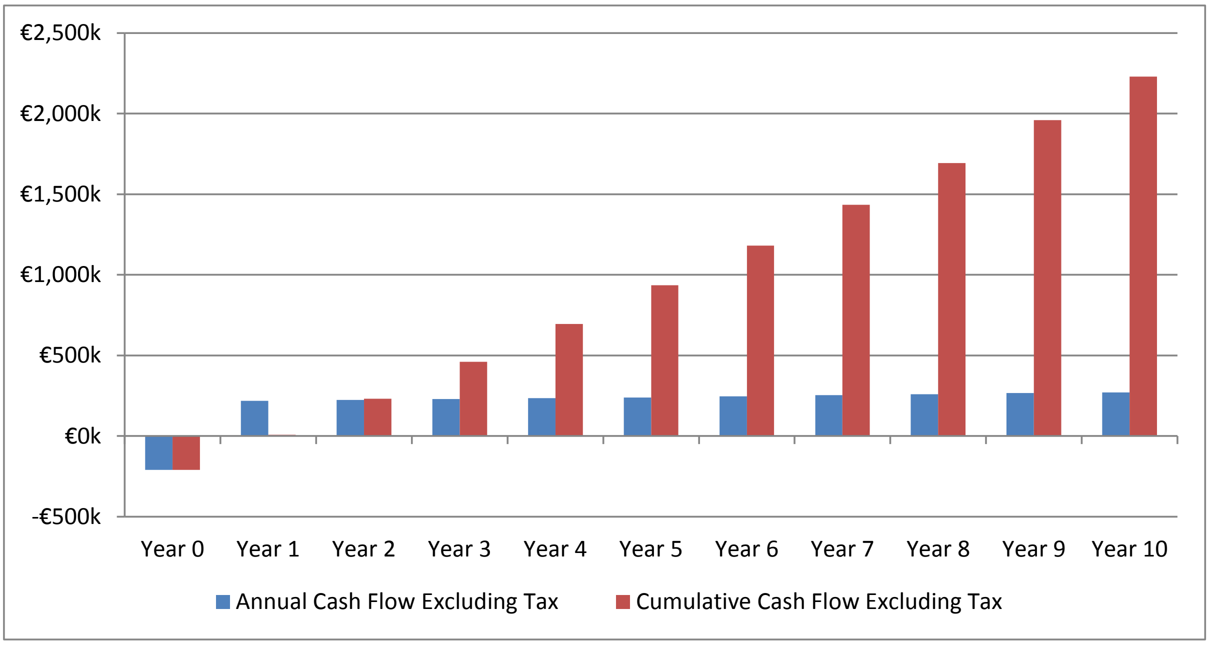

Figure 3 Cash Flow in Use Case

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