Technical-Economic Assessment of Energy Efficiency Measures in a Mid-Size Industry

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Abstract

The industry sector is facing many challenges such as global competition, energy pricing, environmental impact amongst others. Consequently, the necessity of energy efficiency measures has become evident; framing the objective of this project as to assess the technical and economic pre-feasibility of implementing energy efficiency measures in a dairy products manufacturing company located at the south of the Reunion Island with the help of RETSCreen ® a Clean Energy Project Analysis Software. The scope of the project is focused in one of the nine buildings where the company accomplishes different production processes, specifically in the ultra-high temperature pasteurization facility building (UHT).

I. Introduction

For the realization of this project, it was studied the real case of a mid-size dairy products manufacturing industry called “CILAM” located in Saint Pierre, South of Reunion Island. CILAM produces various dairy products such as milk, beverages, desserts, cheese, ice-creams, and accounts for about 60% of the dairy market on the island (Agro-oi.com, 2015).
The aim of this study is to develop a pre-feasibility study in order to evaluate the impact of implementing energy efficiency measures at CILAM. Thus, the outcome will be energy and money savings within a short payback ratio.

The Reunion Island located in the Indian Ocean, east of Madagascar, about 200 kilometres southwest of Mauritius (nearest island). It is an integral part of the French Republic with the same status as those situated on the European mainland. The import of oil products at Reunion Island is primarily intended to cover the energy demand of the transportation and electricity generation sector, as well as industry and agricultural activities. In 2000, the fuel supply was 886.9 ktoe. Between 2000 and 2011, the fossil fuel supply has increased in 6.1% making the island very dependent on the exterior sources. Reunion Island imports as much as ⅞ of its final energy consumption corresponding to fossil fuels, while the other ⅛ comes from local resources.

Thus, as part of the effort to accomplish the stipulations and guidelines portrayed in the Agenda 21 (Agenda21france.org, 2015) Reunion Island Government has adopted a strategy of energy autonomy based on energy efficiency and renewable energy alternatives. One of the main objectives of the Agenda 21 is that Energy Self-Sufficiency must be achieved by 2030 (Ricci et al., 2014). In consequence, by the end of 2010, Reunion Island had PV installations which represent approximately an installed capacity of 80 MWp for an electricity production of 60 GWh/year, Solar Thermal installations that produce near 120 kWh/day which corresponds to a total of 20,16 MWh of electricity saved during the summer; additionally, the cooling plants have saved 16,5 tons of CO_2 yearly, Wind energy installations produce 15,5 MWh of electricity per year taking advantage of trade winds on the island’s east side, whilst Hydropower installations produce 632 GWh and Biomass 300 KWh, both on a yearly basis (Praene et al., 2012).

Moreover, since the industry sector is facing many challenges as global competition, energy pricing, environmental impact amongst others. Consequently, the necessity of energy efficiency measures has become evident; framing the objective of this project as to assess the technical and economic pre-feasibility of implementing energy efficiency measures in a dairy products manufacturing company located at the south of the Reunion Island. The scope of the project is focused in one of the nine buildings where the company accomplishes different production processes, specifically in the ultra-high temperature pasteurization facility building (UHT).

Nowadays, dairy industries as well as the majority of other economic sectors are moving towards sustainable production, minimization of energy consumption and impact on the environment. Application of best energy practices is a field of interest not only to government and environmental regulators, but also for company senior management and stakeholders due to their interest on the profitability of the business. In this study, two main sectors of energy-use at the UHT building of dairy production plant are targeted: Savings on electrical energy and savings on thermal energy. Savings on electrical energy can be achieved by redesigning the lightning system and improving the processes involved on the cooling system performance. On the other hand, additional savings are foreseen for thermal energy by the reduction of steam losses and the installation of a heat recovery unit for the boiler, which represents economic advantages regarding the consumption of electricity and fossil fuel.

The technical and economic prefeasibility study was carried out in RETScreen®, a Clean Energy Management Software system for energy efficiency, renewable energy and cogeneration project feasibility analysis as well as ongoing energy performance analysis. This Excel-based software is a tool that helps decision makers to determine the technical and financial viability of potential clean-energy projects in a quick and unexpensive way.

The performed study showed that the proposed energy efficiency actions represent benefits for CILAM and are qualified to be implemented in order to reduce operational costs, carbon footprint and augment the quality of the goods produced. The analysis was done from the point of view that, the industrial parks at the Reunion Island are committed to support the strategy conducted by the regional government, with the purpose of achieve the energy autonomy based on greater energy efficiency and renewable energy alternatives; stated in the islands' 2030 goals and Reunion Agenda 21.

Nomenclature

CILAM	: Compagnie Laitière des Mascareignes
UHT	: Ultra High Temperature
HVAC	: Heating, Ventilation and Air-Conditioning.
Charcs.	: Characteristics
Op. hrs.	: Operating Hours
P_{steam}	: Steam Pressure
$T_{cond.}$	: Condensation Temperature
$T_{Wmakeup}$	: Temperature Water Makeup
T_{sh}	: Super Heated Temperature
IRR	: Internal Rate of Return
NPV	: Net Present Value
LED	: Light Emitting Diode
kWh	: Kilowatt-hour
INRS	: Institut National de Recherche et de Securite
GHG	: Green House Gases

II. Methodology

The prefeasibility analysis, is done using RETScreen. The inputs concerned or researched for the project where those associated with the pasteurization at ultra-high temperature. The technical data is obtained through an energy management data collection system owned by CILAM. Input data implemented in RETscreen was considered for one year consumption based on 2013. The tasks to reach the results were carried out by the researchers with the support of two more parties: the academic tutor and the energy manager of the company on site. To manage the communication and adjust the schedules it was implemented the use of helpful tools such as Dropbox, Google Docs and Skype calls for online meetings with the international partners.

III. Pre-feasibility study

III.1. General Description of the facility

The company consists of 9 buildings where different processes are performed, however for this study only the UHT Process Building will be considered.
This paper considers the most energy intense processes:
• Steam production and leakages for pasteurization and sterilization
• General refrigeration system for cooling of products and storage purposes
• Lighting in the building

III.2. Data collection

The consumption for different energy sources was obtained from the annual energy bill of the company in 2013. This data was proportioned by the Energy Manager of CILAM industry. Moreover, reliable and high quality data was placed as an input in RETScreen thanks to his direct involvement on the different processes performed in the company[1].

AutoCAD drawings of the industry were used to determine the area of the UHT building, which has a surface of 2688 m². In addition, according to the Energy Manager, the industry uses air conditioning systems only for offices in the social/commercial building. Production buildings such as the UHT building do not have any HVAC system installed and use natural ventilation due to the stable weather of Reunion Island. Consequently, space heating and cooling are not carried into account for this pre-feasibility analysis.

III.3. General Considerations

Some assumptions are made to complete the pre-feasibility analysis and are presented as follows:

• Steam leakages were estimated at around 20% of the total steam production by the energy manager during an audit in 2013 locating 12 visible leakages in the network. From that audit on, the leakages have been reduced to 5% of the total production. Even though the steam leakages problem has been already solved in the company, the profitability of such energy efficiency improvement will be analysed in this report.

• Actual lighting data information was not available; hence the lighting information was estimated with standard values for industries with no energy efficiency measures.

For this study the financial parameters presented in Table 1 will be used for financial analysis.

[1] Energy consumptions of processes, operational parameters, technical drawings, pictures, etc.

Table 1: Financial Parameters

Parameter	Value
Inflation Rate	1.0% (1)
Discount Rate	9.0% (2)
Project Lifetime	10 years
Fuel Cost Escalation Rate	5.5% (3)

[1](INSEE, 2014); [2](RETScreen Data Base); [3](CNR, 2014)

Since the analysis is based on 2013 energy consumption data in the company, fuel prices considered for this pre-feasibility analysis are based on the price of energy in Reunion Island during the same year.

- Electricity: 0.098 €/kWh
- Diesel: 0.784 €/L

At this moment, there is no defined incentive or subsidy exclusively for the implementation of Energy Efficiency measures in Reunion Island industry.

III.3. Base case

In first place, an assessment of the actual conditions of the industry was addressed (base case). Table 2 shows the discrepancy between the simulation in RETscreen and the historical consumption from energy bills of 2013.

Table 2: Comparison between RETScreen simulation and real consumptions of the industry

Fuel type	Fuel consumption - unit	Fuel consumption - historical	Fuel consumption Base case	Fuel consumption - variance
Electricity	MWh	5 345	5 381	1%
Diesel (#2 oil)	L	736 000	726 890	-1%

The base case energy distribution scheme during 2013 is shown in Fig.1 *(APPENDIX)*. The values calculated by RETScreen account for the energy consumption related to the systems and equipment used by UHT building processes, represented in a Sankey diagram.

III.4. Energy efficiency improvements

After gathering the data and analyzing the impact to the energy consumption of this industry, four main aspects to improve were identified: (a) lack of heat recovery from flue gas; (b) sources of significant steam leakages; (c) lighting system; and (d) system refrigeration unit performance.

III.4.1. Boiler – steam production

Table 3 shows the characteristics and operating parameters of the boiler related to the systems and equipment used by UHT building processes.

Table 3: Boiler characteristic and operating parameters

Charcs.	Operating parameters	Energy consumption: useful steam
465 KW η = 0.85 Uses diesel	Steam flow: 877kg/h Op.hrs: 24h/d P_{steam}: 12bars T_{sh}: 170°C Cond. return: 60% $T_{cond.}$: 85°C $T_{Wmakeup}$: 25°C	From energy bills and audit: 5473 MWh/year Estimated by RETscreen: 5280 MWh/year Discrepancy: 3.5% Share of total energy consumption: 40.2%

In order to improve the current energy consumption of the boiler it was agreed the installation of an economizer to recover part of the heat contained in the flue gas. According to the manufacturer LOOS, now part of BOSH Company, “The heat contained in the flue gases is recovered and the efficiency increased in this way by up to 7 % in dry running operation” (Efficiency on a large scale Steam boilers, n.d.) for the integration of an economizer in a boiler, but due to possible insulation problems we account it as 5%. Table 4 shows the financial data for this energy saving technology.

Table 4: Financial impacts of economizer implementation

Costs	Savings	Simple payback time
Investment: 35 000 € the 1st year Maintenance: 2 000 €/year	384 MWh/year of diesel (42 393 L of diesel/year) 33 236 €/year	35 000 €/ 33 236 €/year = 1.1 year

III.4.2. Steam leakages

An energy audit was performed in 2013 and it was determined that about 20% of the steam produced in the boiler was lost due to leakages or to steam traps. During further inspections twelve steam plumes of about one meter were identified. Table 5 summarizes characteristics of the leakages identified.

Table 5: Leakages characteristics and operational parameters

Characteristics	Operating parameters	Energy consumption: steam leakages
12 Units 1 Leakage/unit 1 m plume	Steam flow/units: 16 kg/h Steam pressure : 12 bar Superheated temperature: 170°C Operating hours: 24 h/d	1370 MWh/year Estimated by RETscreen: 1307 MWh/year Discrepancy: 4.6% Share of total consumption: 9.9%

It has been finally considered that the 75% of the leakages (9 units) can be fixed with an immediate action based on professional plumbing service which would cost approximately 5500 € per leakages according to another RETscreen case study (RETScreen International, 2012). Financial parameters of this improvement are indicated in Table 6.

Table 6: Financial impacts of steam leakages reduction

Costs	Savings	Simple payback time
Investment: 50 000 € 1st year Maintenance: -4000 €/year	981 MWh/year of diesel (108 302 L of diesel/year) 84 824 €/year	50 000 €/ 84 824 €/year = 0.6 year

Table 7 provides an estimation of diesel and cost reduction after economizer implementation and steam leakages reduction.

Table 7: Estimated diesel and cost reduction after economizer implementation and steam leakages reduction

	Diesel consumption	Costs
Before improvements (based on 2013 data)	726 m3/year = 7 749 MWh/year	569 882 €/year
After improvements	576 m3/year = 6 144 MWh/year	451 822 €/year
Estimated savings	150 m3/year = 1 605 MWh/year 20% reduction	118 060 €/year

III.4.3. Lighting

Since the available information provided by CILAM's energy manager, did not include the conditions and the actual electricity consumption of lighting, the estimation of the consumption was made according to the National Institute of Safety and Research of France (INRS), taking into the consideration that currently fluorescent light bulbs are installed in the building.
Table 8 contains data about estimated benefits of replacing old light bulbs with LED, based on the lightning requirements of INRS (120 lum/m^2) representing an investment cost of 3456 € (GE Lighting LED, 2012/2013), and savings of 22.318 €/year and simple payback time in 0.15 year, according to RETSCreen simulation.

Table 8: Estimated electricity and cost reduction after lighting changes

	Lighting power load	Electricity consumption	Costs
Before improvements	10.80 W/m²	253 MWh/year	24.657 €/year
After improvements	1.07 W/m²	24 MWh/year	2.339 €/year
Estimated savings	9.73 W/m²	229 MWh/year 90% reduction	22.318 €/year

III.4.4. Refrigeration System

Data for CILAM's current refrigeration system used for cooling and storage purposes is indicated in Table 9.

Table 9: Refrigeration system characteristics and operating parameters

Charcs.	Operating parameters	Energy consumption: cooling products and storage
450 KW COP = 1.3	Duty cycle: 70% Operating hours: 24h/d Drive by electricity	From energy bills: 2209 MWh/year Estimated by RETscreen: 2170 MWh/year Discrepancy: 1.7% Share of total consumption: 16.5%

Energy savings for refrigeration system were proposed by replacing the old cooling system. The aim is to install a new one with higher coefficient of performance (COP=5) to reduce the electricity consumption from 2170 MWh to 564 MWh per year, according to RETScreen simulation. Financial impacts of this measure are listed in Table 10.

Table 10: Financial impacts of a new PAC chiller

Costs	Savings	Simple payback time
Investment: 370 000 € the first year [4]	1606 MWh/year 156 711 €/year (Electricity)	370 000 € 156 711 €/year = 2.4 year

[4] (Sabroe PAC Chillers, 2015).

III.4. Proposed Case

After applying the identified possible improvement of energy efficiency, the energy savings are estimated at 3440 MWh/year in total (26.2% of savings). The energy distribution of industrial site after applying the measures proposed would be as shown in Fig.2.

IV. Results and discussions

From the analysis made using RETScreen software, the results obtained are as follows.

IV.1. Emission Analysis

Reunion Island electricity mix and its associated Green House Gases (GHG) emissions are defined based on data from the annual report of energy production in Reunion Island (Arer.org, 2015). The improvement proposed in the industry should lead to a reduction of GHG emission in 1876 tons of CO2 equivalent per year (equivalent to 800 m3 of gasoline not consumed).

IV.2. Financial Analysis

After implementing the proposed energy efficiency measures, and according to the financial parameter presented above in table 1, the pre-feasibility shows positive NPV of 2.052.109 € with an Annual Life Cycle Savings of 319,760 €/yr. The main saving is observed due to the reduction in the fuel consumption, considering Diesel Fuel and Electricity as the inputs to run the UHT process shown in Table 11.

Table 11: Ultra High Temperature Process Energy Costs

UHT Process Energy Costs				
		BASE	PROPOSED	SAVINGS
ELECTRICITY (+COOLING)	kWh Consumed	5 381 600	3 547 200	1 834 400
	Cost (€)	525 240 €	346 211 €	179 029 €
DIESEL	Diesel Consumed (L)	726.890	576.304	150 586
	kWh Consumed	7 749 400	6 143 800	1 605 600
	Cost (€)	569 882 €	451.822 €	118 060 €

The total savings achieved with the energy efficiency measures proposed is 297.089 € at year 0 value, as it can be also observed in Table 11, regarding the savings in electricity and diesel consumption.
In addition, to complete the financial analysis, is required to take in consideration the cumulative cash flows graph, shown in appendix Figure 3, the short payback period of 1.5 years is remarkable. Such a short period of time may encourage the quick implementation of the improvements. Finally, the net Benefit-Cost (B-C) ratio is 5.5 which indicates the high profitability for this project.

IV.3. Risk Analysis

In order to calculate the risk of implementing the proposed efficiency measures in this case study, a set of uncertainties are prescribed as shown in Table 12.

Table 12: Uncertain Range for defined input parameters

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Initial costs	€	455,001	10%	409,501	500,501
O&M	€	-1,999	10%	-1,799	-2,199
Fuel cost - proposed	€	798,033	5%	758,131	837,935
Fuel cost - base case	€	1, 095,122	0%	1, 095,122	1, 095,122

The range of uncertainty for the Fuel Cost on the base case is 0% because the current fuel cost value was used throughout the study. For the fuel cost of the proposed case an uncertainty value of 5% was selected since it is unlikely that the price of the fuel will drastically change within the following year.

As it is observed in Fig. 4, RETScreen displays a "Tornado Chart", identifying which parameters have the most influence on the variability of a selected financial parameter, such as the after-tax IRR as it is analysed in this case. The impact graph shows how much of the variation in the financial parameter can be explained by variation in each input parameter in the risk analysis. This is expressed in relative terms how future changes in fuel cost will impact the feasibility of the proposed energy efficiency measures, as well as, any fluctuation on the initial cost will influence the viability of the project. The fuel and initial costs are the most critical input parameters; an increase of one standard deviation in the fuel cost leads to a decrease in the IRR of nearly 0.8 standard deviations, also an increase of one standard deviation in the initial cost leads to a decrease in the IRR of nearly 0.6 standard deviations.

The Monte Carlo analysis shown in figure 5, generates a probability distribution for the financial parameter, based on the assumed variations for the input parameters. Specifying a desired level of risk in 5%, RETScreen indicates the range of outcomes for which the after-tax IRR will fall outside the range of 67.1% to 82.5%. The model calculates the after-tax internal rate of return (IRR) on equity (%), which represents the true interest yield provided by the project equity over its life, after income tax. The yields returned for the project, regarding the propose case implementation, are gains in the order of 2% and 15%, positive values which measure how much cash flow the company will get for each dollar invested in an equity position.

V. Conclusions

In Reunion Island, as in many other islands around the globe, power generation relies mainly on expensive and high polluting technologies and methods like diesel generators (P. Blechinger et al.2013) Nowadays, during permanent increase of energy prices and production growing it is highly important to implement energy saving technologies as much as possible. However, due to economic situation worldwide, stakeholders of industrial assets would like to be aware about different aspects of technologies that would allow them to choose best option for the investment. RETScreen software provides the possibility to perform the analysis of energy saving procedure and evaluate its attractiveness not only from environmental, but also financial point of view.

In this paper, was performed the analysis of four different technologies for boosting the energy efficiency at dairy plant: installation of economizer for boiler, steam leakages decreasing, improvements in lighting and installation of more efficient refrigeration system. It was estimated, that biggest savings of energy were made with improvements in refrigeration system, however it got biggest investment costs and longest payback. Installation of economizer and steam leakages made a total diesel savings of 20% what make these measures financially attractive.

Thanks to the energy saving technologies that could be implemented the total savings forecasted are 26.2% of total energy use, 319,760 €/yr of life cycle and 1876 tons of CO_2 annual savings. These numbers combined with a short payback period of 1.5 years show that proposed improvements are reasonable and profitable. In addition the results here presented are aligned with the initiatives of diesel-free power generation. By using fewer diesels the power systems are less dependent on the diesel's volatility price which at the same time decreases the risk of the Island's energy supply (P. Blechinger et al.2013). For further studies, research about possible introduction of renewable energy sources and optimization of production equipment can be performed. Moreover, opportunity of governmental financial support should be taken into account during the decision-making process due to their ability to increase total project profitability.

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APPENDIX

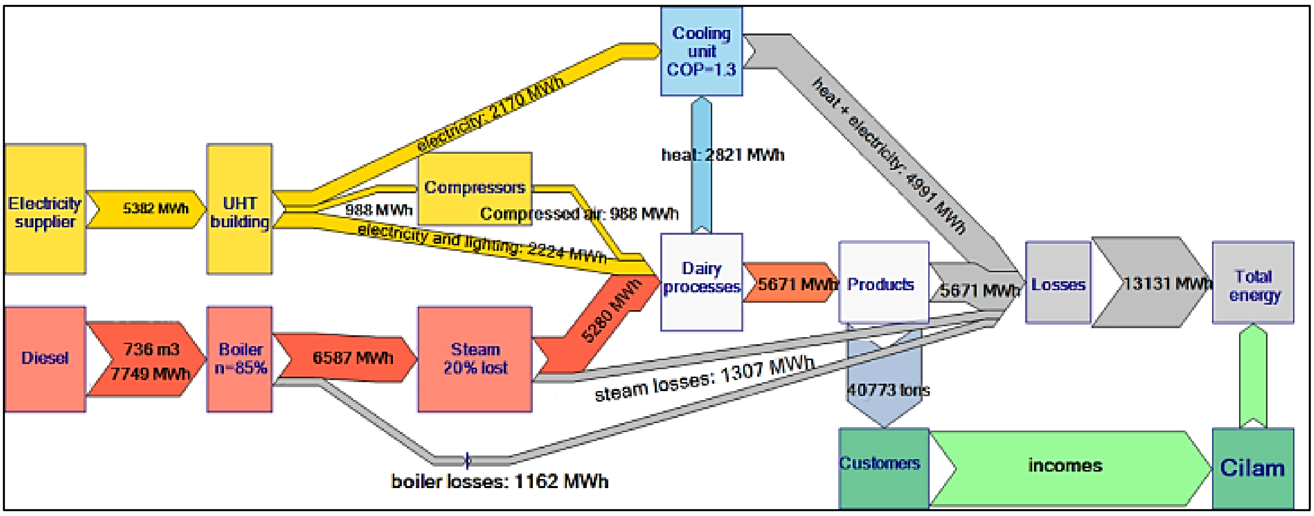

Fig 1: Energy Distribution for Base Case

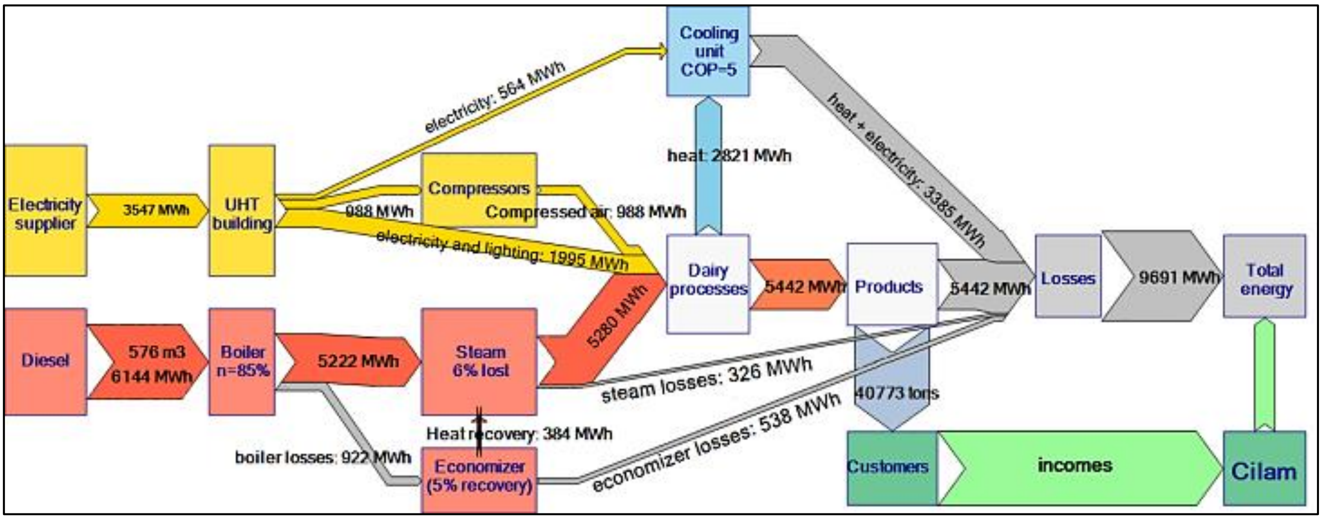

Fig 2: Energy Distribution for Proposed Case

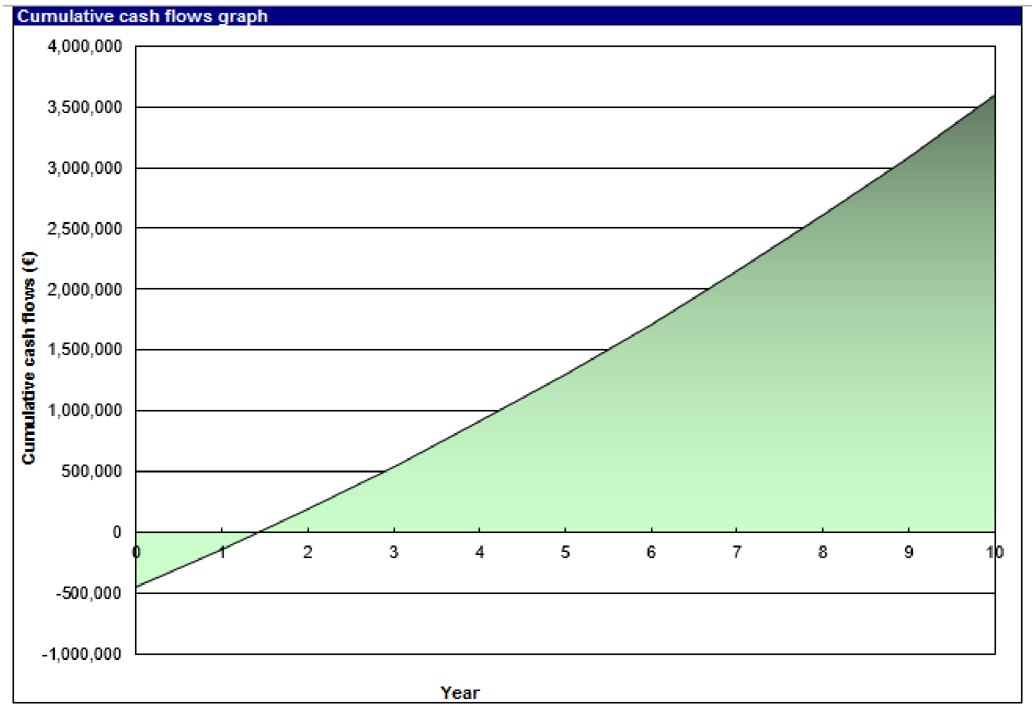

Fig 3: Cash flow of benefits of proposed case over base case

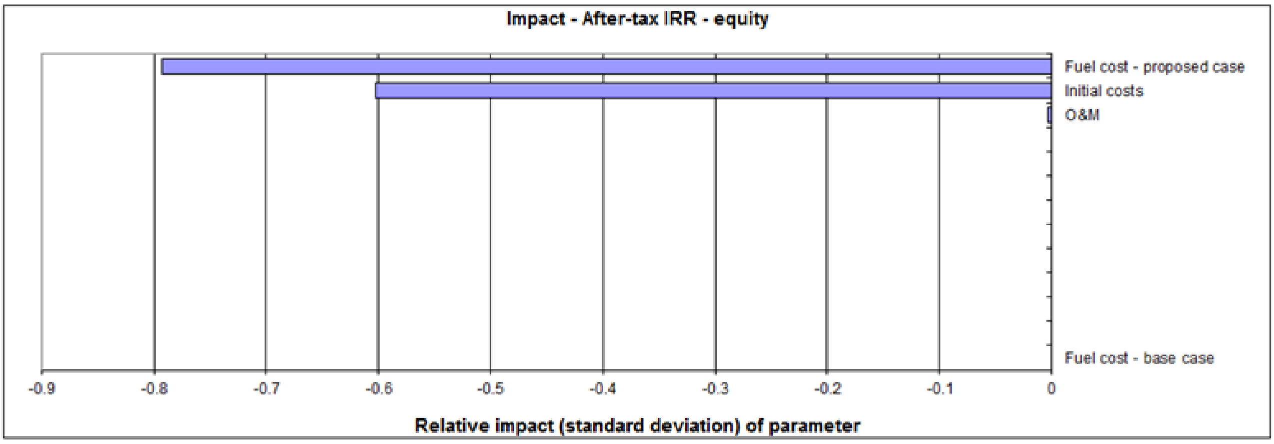

Fig 4: Tornado Chart analysis from RETscreen Simulation

Median	%	74.1%
Level of risk	%	5.0%
Minimum within level of confidence	%	67.1%
Maximum within level of confidence	%	82.5%

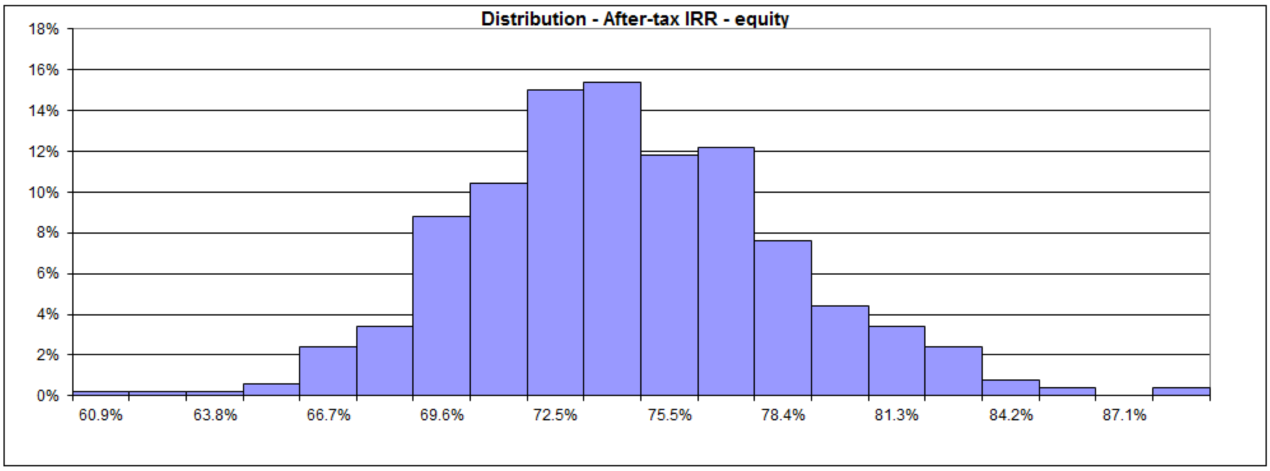

Fig 5: Monte Carlo analysis from RETscreen Simulation

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