H2020 Work Programme

D3.5 – FINANCING AND ESCO MODELS FOR INDUSTRIAL WH/C RECOVERY AND EXPLOITATION TOWARDS REPLICATION

Lead Contractor: ELEUKON GLOBAL (ELEU)

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1 PU = Public
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	Beneficiary
Deliverable leader	Pablo Fernández Arias (ELEU)
Contributing Author(s)	Pablo Fernández Arias (ELEU), Juan José Otero López (ELEU), José María Cuartas Alonso (ELEU), Ángel Manuel Ferradas Soage (ELEU), Diego Castro López (ELEU), José Manuel Meis Martínez (ELEU), Andrés Vilaboa Díaz (ELEU), Vicente Mira Arnau (ELEU), Sofia Klugman (IVL), Pedro Santos (2GOOUT), Matteo Porta (RINA-C), Andrea Welti (RINA-C)
Reviewer(s)	Francesco Peccianti (RINA-C), Pedro Santos (2GOOUT)
Final review and quality approval	Francesco Peccianti (RINA-C) (30/11/2020)

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Abbreviations

ASHRAE: American Society of Heating, Refrigerating and Air-conditioning Engineers

ASTM: American Society for Testing and Materials

BAS: Building Automation System

BOP: Blow-Out Preventer

CAFE: Clean Air For Europe

CAPEX: Capital Expenditures

CHP: Combined Heat and Power

CMVP: Certified Measurement and Verification Professional

CSP: Concentrated Solar Power

CV(RMSE): Coefficient of Variation of the Root Mean Squared Error

DALY: Disability Adjusted Life Years

DC: Direct Costs

DCF: Discounted Cash Flow

DH/C: District Heating / Cooling

DHN: District Heating Network

DPP: Discounted Payback Period

DRF: Dose-Response Function

EC: Energy Contracting

ECM: Energy Conservation Measure

EIB: European Investment Bank

ELENA: European Local Energy Assistance

EMEP/MSC-W: European Monitoring and Evaluation Programme/Meteorological Synthesizing Centre-West

EMS: Energy Management System

EPC: Energy Performance Contracting

EPS: Earnings Per Share

ESC: Energy Supply Contracting

ESCO: Energy Service Company

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EU: European Union

Euribor: Euro Interbank Offered Rate

EVO: Efficiency Valuation Organization

ExternE: External Costs of Energy

FCI: Fixed Capital Investment

FEMP: Federal Energy Management Program

GDP: Gross Domestic Product

HE: Heat Exchanger

HVAC: Heating, Ventilation and Air Conditioning

IC: Indirect Costs

IEC: Integrated Energy Contracting

IEE: Intelligent Energy Europe

IOC: International Oil Companies

IPA: Impact Pathway Approach

IPMVP: International Performance Measurement and Verification Protocol

IQ: Intelligence Quotient

IRENA: International Renewable Energy Agency

IRR: Internal Rate of Return

ISC: Industrial Source Complex

KMG: KazMunayGas

LCOE: Levelized Cost Of Energy

LCOEH: Levelized Cost Of Excess Heat

LCOH: Levelized Cost Of Heat

LED: Light-Emitting Diode

M&V: Measurement and Verification

MBE: Mean Bias Error

MEPD: Ethylene Propylene Diene type M ASTM

MIRR: Modified Internal Rate of Return

MPI: Materials Processing Institute

MWe: Megawatts electric

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N/A: Not Available or Not Applicable

NEC: National Emissions Ceilings

NI: Net Income

NMVOC: Non-Methane Volatile Organic Compounds

NO_x: Nitrogen Oxides (NO + NO_2)

NPV: Net Present Value

NWh: Negawatt-hour (unit of energy saved as a direct result of ECMs, such as reducing the use of heat or electricity)

O&M: Operation and Maintenance

OC: Other Costs

OPEX: Operating Expenses

PAHs: Polycyclic Aromatic Hydrocarbons

PDF: Potentially Disappeared Fraction

pH: Hydrogen potential

PM: Particulate Matter

PM10: Particles with an aerodynamic diameter < 10 µm

PM2.5: Particles with an aerodynamic diameter < 2.5 µm

PV: Photovoltaic

PVC: Polyvinyl Chloride (C_2H_3Cl)

PWR: Pressurized Water Reactor

QAI: Quality Assurance Instrument

R&D: Research and Development

R+D+I: Research, Development and Innovation

RBD: Reliability Block Diagram

RES: Renewable Energy Sources

RET: Renewable Energy Technologies

RFP: Request For Proposal

RFQ: Request For Qualifications

RMS: Root Mean Square

SCADA: Supervisory Control And Data Acquisition

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SME: Small and Medium-sized Enterprise

S-R: Source-Receptor

STE: Solar Thermal Energy:

TCI: Total Capital Investment

TMY: Typical Meteorological Year

TPF: Transaction Processing Facility

TVM: Time Value of Money

UK: United Kingdom

UN-ECE: United Nations Economic Commission for Europe

VFD: Variable Frequency Drive

VOC: Volatile Organic Compound

WH/C: Waste Heat / Cold

WP: Work Package

WtE: Waste-to-Energy

WTM: Windrose Trajectory Model

WTP: Willingness To Pay

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Executive Summary

This document represents the Deliverable 3.5, titled "Financing and ESCO models for industrial WH/C recovery and exploitation towards replication", which sits under Task 3.4 ("Financing methodologies and ESCO models") in Work Package 3 (WP3: "SO WHAT tool outcomes: business model analysis") of the SO WHAT project.

To enhance the market introduction of both, industrial WH/C recovery and RES investments, there have been evaluated the capital requirements for the investment, the return of the investment and type of investor. The impact of the environmental and social aspects, of special importance nowadays (such as GHG emissions), related to the financing decision has been analysed. There has been carried out an economic analysis of district heating network installations. This economic analysis is based on the evaluation of the levelized cost of excess heat (LCOEH) and on the minimum heat selling price. The evaluation of these parameters allows to identify the competitiveness of projects investments. There has been realised a deep analysis of the value chains for industrial WH/C recovery and the most common RES technologies, applying it to some of the SO WHAT demo-sites. The financing schemes for this kind of projects have been evaluated, together with the financing schemes employed by the Swedish Lighthouse partners. A deep analysis of the ESCO models, Energy Supply Contracting (ESC), Energy Performance Contracting (EPC), and Integrated Energy Contracting (IEC) has been developed. For some of the SO WHAT demo-sites there have been identified the financing schemes together with the energy contracting (ESCO model). Finally, the input of D3.5 that should be integrated into the SO WHAT tool has been proposed.

The deliverable is structured into the following eight main sections:

- Chapter 1: Introduction
- Chapter 2: Industrial WH/C and RES Investments
- Chapter 3: Levelized Cost of Heat (LCOH)
- Chapter 4: Value Chains of the SO WHAT Demo-Sites
- Chapter 5: Financing Schemes
- Chapter 6: ESCO Model
- Chapter 7: Financing and ESCO Models of the SO WHAT Demo-Sites
- Chapter 8: Input to the SO WHAT Tool

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1 Introduction

Waste Heat/Cold (WH/C) recovery is a suitable, appealing and enabling option to reach the environmental and sustainability goals. This kind of projects usually have to face some kind of limitations or barriers that constrain their execution. Economic, cultural and organizational problems are the main reasons that block these projects.

It is well-known that financial issues related with the capital investment and long paybacks are the main drawbacks for WH/C recovery implementation. Actually, it is the first barrier for every project to be carried out.

Therefore, the assessment of the necessary economical effort is a prior requirement which is influenced by external factors, such as the stakeholders and environmental circumstances. An eco-friendly mind-set and responsibility can reduce the monetary weight in the final investment decision.

First of all, there are eight ways to capitalize WH/C recovery which are relevant to consider at this point before investing (1):

- Saving fuel.
- Generating electricity and mechanical work.
- Selling heat and electricity.
- Reducing cooling needs.
- Reducing capital investment costs.
- Increasing production.
- Reducing greenhouse gas emissions.
- Transformation of heat into useful forms of energy.

In terms of the WH/C infrastructure need, the cost depends on:

- The working fluid.
- The cycle configuration.
- The equipment type.
- The equipment cost model.

Conditioning factors in the heat recovery decision:

Mainly, three factors can block or influence in the capital investment for heat recovery. They can be grouped in:

- Commercial factors:
    - **Funds availability:** It has a huge impact in small investors and companies with less resources.
    - **Payback:** In general, an investment recovery time of less than two years is expected. Longer periods tend to discard any proposal.
    - **Business risk:** Industries can identify heat recovery as a risky deal due to It could be a new and unknown business for the company and the potential customers (further

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analysed in the SO WHAT report D3.4 "Business and risk models for industrial WH/C recovery and exploitation towards replication").

- Real implementation and technical drawbacks:
    - **Integration and availability:** Technical decisions about the adequate heat source and its inclusion in the present system could be seen as a barrier for the industries.
    - **Space availability:** Sometimes the lack of space is a problem when a new installation is needed, or conversely, the final-users are too many and the heat is not enough.
    - **Confidence in the technology:** People are often reluctant to changes and do not sometimes confidence in new technologies, so the efficiency and the calculated paybacks could be questioned.
    - **Programmed shutdowns:** The continuous service should take into account the potential cuts in the service.
- Business priorities:
    - Companies tend to be focused on their final product as the most profitable business, even though they are large enough to have their own efficiency department in order to identify their potential of heat recovery. Small companies do not usually detect their waste heat.
    - "Quick Wins" (when with relatively low investments a fast return on investment is achieved.) due to energy recovery cannot be seen as a large percentage of the benefit.
    - Eco-friendly and environmental concerns can encourage the industries to focus on heat recovery.

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2 Industrial WH/C and RES Investments

The financial and economical efforts need to be separated depending on the investor type which flows directly from the size and the structure of the company. Thus, there are companies with an annual budget for energy efficiency and individual procedure for improvement and developing. On the hand, "simplest" structured companies rely that areas on external companies and audits, where new installations proposal takes longer periods of evaluation.

Even if how the business is run can be completely different, the way of face financing is more or less similar. Therefore, the basic information needed is structured as in the following table:

Table 1: Basic information needed for a business case

Monetary information	Technical information	Extra information
Cost/benefit assessment	Technical evaluation of waste	Safety and Health study
Payback period	Practical implications	
Capital investment	Maintenance requirements	Impact on other improvements
Maintenance and operability cost	Environmental impact	
	Social impact	

Waste heat is the one that is generated in a process by the way of fuel combustion or chemical reaction, and then "dumped" into the environment, even though it could still be reused for some useful and economic purposes. The essential quality of heat is not the amount but rather its "value". The strategy of how to recover this heat depends in part on the temperature of the waste heat gases and the economy involved. Large quantity of hot flue gases is generated from Boilers, Kilns, Ovens and Furnaces. If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved (before performing a waste heat recovery it is essential to carry out an energy efficiency analysis of the process). The energy lost in waste gases cannot be fully recovered, however, some of it could be, improving the efficiency of the process.

Depending on the type of process, waste heat can be rejected at virtually any temperature from that of chilled cooling water to high temperature waste gases from an industrial furnace or kiln. Usually the higher the temperature, the higher the quality and more cost effective is the heat recovery. In any study of waste heat recovery, it is absolutely necessary that there be a use for the recovered heat. Typical examples of use would be preheating of combustion air, space heating, or pre-heating boiler feed water or process water. With high temperature heat recovery, a cascade system of waste heat recovery may be practiced to ensure that the maximum amount of heat is recovered at the highest potential. An example of this technique of waste heat recovery would be if the high temperature stage is used for air pre-heating and the low temperature stage is used for process feed water heating or steam raising.

In any heat recovery situation, it is essential to know the amount of recoverable heat and also how it can be used.

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2.1 BUSINESS EXPENSES

Business Expenses (also known as "deductions" in the literature) are the costs that a company has to address to develop its business operation. Business Expenses include Capital Expenditures (CAPEX) and Operating Expenditures (OPEX).

2.1.1 Capital Expenditures (CAPEX)

Capital Expenditures (CAPEX) are the goods or services that companies invest money in for a use of more than one year. The investment can be a new asset or an improvement for an old one in use, with the purpose of increasing the profitability, productivity, reliability or another aspect of the company. In general terms, CAPEX are usually depreciated over a period between 5 and 10 years, leaving aside the case of real estate which may increase the amount of time up to more than 20 years.

CAPEX should include:

- Building expansions.
- Equipment purchases.
- Hardware purchases.
- Improvements implementation.
- Plant purchases.
- Vehicles purchases.

2.1.2 Operating Expenses (OPEX)

Operating Expenses (OPEX) are the day-to-day costs of the company that has to address in its normal business operations. Unlike CAPEX, OPEX are tax-deducted in the same accounting period in which they were purchased. Besides, if a good considered CAPEX is leased instead of purchased, it becomes OPEX.

OPEX should include:

- Energy (electricity, fuels, etc.) and water consumes.
- Business travels.
- Property taxes.
- Rents.
- Research & Development (R&D).
- Salaries and pension plan contributions.
- Sales, General & Administrative expenses on the Income Statement.

2.1.3 Income Statement and Net Income (NI)

Business Expenses are part of the Income Statement, which together with the Balance Sheet and the Cash Flows are the three main financial statements that companies use to report about their financial performance over a period of time. The Income Statement focuses on revenue, gains, losses and expenses. Business Expenses are subtracted from revenue to calculate the Net Income (NI), which is an indicator of the profitability of the company used for calculating the Earnings Per Share (EPS, profit attributable to shareholders).

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NI (also known as "bottom line" or "net earnings" in the literature) is calculated from the following formula:

$$NI = (Revenue + Gains) - (Losses + Expenses)$$

Formula 1: Net Income (NI)

Where:

- **Revenue:** Sum of Operating Revenue (income derived from the main activity of the company) and Non-Operating Revenue (income derived from secondary activities of the company).
- **Gains:** Also known as "other income" in the literature, Gains are derived from other activities of the company, like the sale of assets.
- **Loses:** Loss-making sales, unusual costs or lawsuits.
- **Expenses:** Sum of Capital Expenditures (CAPEX) and Operating Expenses (OPEX).

In turn, the Income Statement can be Single-Step or Multiple-Step. The associated advantages and disadvantages are summarized in the following table:

Table 2: Income Statement advantages and disadvantage

Type of Income Statement	Advantages	Disadvantages
Single-Step	Shows in a simplified way revenue and expenses of the company.	May have lack of information.
	Makes record-keeping easier.	Makes difficult to determine the source of most expenses.
	Net Income shows the vitality of the company.	Makes difficult to predict the profitability of the company.
Multiple-Step	Allows a deeper analysis of the margins.	Its elaboration requires a lot of work.
	Provides more accurate representations of the costs of goods sold.	
	Shows a clearer vision of how a company manages its business.	

2.2 Capital Requirements

The Total Capital Investment (TCI) is determined by Fixed Capital Investment (FCI) and Other Costs (OC), like in the following formula:

$$TCI = FCI + OC = (DC + IC) + OC$$

Formula 2: Total Capital Investment (TCI)

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FCI is formed by Direct Costs (DC) and Indirect Costs (IC):

- **Direct Costs:** Include the cost of the equipment contained in the power plant, the installation cost of the corresponding equipment, the cost of pipes providing the utilities, the cost of the land for constructing the power plant, and so on. For instance, a Direct Cost would be the heat exchanger needed to heat water from the inherit waste heat contained in a non-useful fluid of a process.
- **Indirect Costs:** Are produced by engineering, construction, administration, and so on. Other Costs (OC) can be licenses, allowances and the commissioning.

2.3 Capital Budgeting

Capital Budgeting is the prior step to start a business. It assesses the projects economic potential for their rejection or acceptance.

Investors have to evaluate the cash flows (inflow and outflow) during a perspective of time (lifetime) in order to know the potential returns of the project. It will determine if the project meet the goals expected. The procedure can also be found as "investment appraisal" in the literature.

Capital resources are limited, thus, it is needed to identify which project offer the best return over a period of time. Typically, Capital Budgeting methods rely on: Throughput Analysis, Net Present Value (NPV), Internal Rate of Return (IRR), Discounted Cash Flow (DCF) and Payback Period.

2.3.1 Throughput Analysis

The most complex but most accurate Capital Budgeting is the Throughput Analysis. The whole company is assumed as a unique unit, which means that all profits are considered part of the system, as well as the expenses. Almost all costs are "OPEX" (they refer to the expenses that a company has to address in its normal business operations). In that way, bottlenecks operations within the company are taken into account, by the way that any internal risk is evaluated.

For the Throughput Analysis, the use of the Reliability Block Diagram (RBD) approach is very widespread for industries that need to analyse and model production or process lines, in order to estimate the production capacity and identify bottlenecks. RBD allows to include capacity information of each equipment and then simulate the system to calculate throughput indicators, such as equipment throughput, excess capacity, etc.

Therefore, the projects with higher rank by the Throughput Analysis will be investment priorities for the managers.

2.3.2 Discounted Cash Flow (DCF) Analysis

The purpose of the Discounted Cash Flow (DCF) Analysis is to estimate the investment benefits, taking into account the temporary value of money. DCF works with the initial funding needed to run a project, the cash inflows as incomes and maintenance and other costs outflows.

The Net Present Value (NPV) and the Internal Rate of Return (IRR) are both calculated in a capital investment study as complementary analysis and are commonly employed together.

2.3.2.1 Net Present Value (NPV)

The profitability of an investment or project is analysed in Capital Budgeting through the use of the Net Present Value (NPV). NPV is calculated by subtracting from the present value of the cash inflows, the present value of the cash outflows over a period of time.

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NPV is calculated from the following formula:

$$NPV = \sum_{t=1}^{n} \frac{R_t}{(1+i)^t}$$

Formula 3: Net Present Value (NPV)

Where:

- Rt = Net cash inflow-outflows during a single period "t".
- i = Discount rate or return of alternative investments.
- t = Number of timer periods.

According with the Net Present Value Rule:

- NPV > 0: The investment will be profitable.
- NPV < 0: The investment will not be profitable.

Higher NPV value ranks over others, unless one or more are "mutually exclusive" (a situation where the occurrence of one outcome supersedes another).

2.3.2.2 Internal Rate of Return (IRR)

The Internal Rate of Return (IRR) is used in Capital Budgeting for the process of calculating the profitability of potential investments. IRR works as a discount rate, making the Net Present Value (NPV) equal to zero.

IRR is calculated from the following formula:

$$0 = NPV = \sum_{t=1}^{T} \frac{C_t}{(1+IRR)^t} - C_0$$

Formula 4: Internal Rate of Return (IRR)

Where:

- Ct = Net cash inflow during the period "t".
- Co = Total initial investment costs.
- NPV = Net Present Value.
- t = The number of timer periods.

In general terms, the higher the IRR of a project, the greater the profitability.

Although IRR is simple to understood, it has some weak points. The major one is that IRR does not pay attention to the total value of the profit and it only evaluates a given interest rate, while NPV can be applied for variable ones.

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IRR main benefits and limitations are summed up in the table below:

Table 3: IRR benefits and limitations

Benefits	Limitations
Focuses on all cash flows of the project.	Neglects showing the impact (added value to the Business).
Takes into consideration the Time Value of Money (TVM).	Money make up businesses cash flows, not percentages.
Describes the project in terms of the rate of return earned.	Ranking Projects by NPV is more accurate (which may yield a different ranking than IRR).
	Money earned must be reinvested to get true IRR.
	Some projects have multiple IRRs, due to cash flow fluctuations (positive and negative).

2.3.2.3 Modified Internal Rate of Return (MIRR)

The Modified Internal Rate of Return (MIRR) is based on the fact that positive cash flows are reinvested taking into account that the initial investment is financed at the cost of the company. Thus, MIRR measures more accurately the cost and profitability of a project. MIRR calculations are based on the NPV formula.

MIRR is calculated from the following formula:

$$MIRR = \sqrt[n]{\frac{FV(Positive\ cash\ flows\ x\ Cost\ of\ capital)}{PV(Initial\ outlays\ x\ Financing\ costs)}} - 1$$

Formula 5: Modified Internal Rate of Return (MIRR)

Where:

- FV = The future value of positive cash flows at the cost of capital for the company.
- PV = The present value of negative cash flows at the financing cost of the company.
- n = Number of periods.

MIRR is used to rank investments and projects of unequal size, being a solution for the two major IRR problems:

1- **The same project can have multiple solutions:** MIRR has only a single solution for each project and the reinvestment rate of positive cash flows is much more valid in practice.
2- **The reinvestment of positive cash flows is considered impractical:** MIRR has also the possibility of changing the assumed rate of reinvested growth from stage to stage in a project, which is very useful for project managers.

Although IRR is used by most business managers, it tends to be very optimistic in terms of profitability of the project, what can lead to investment mistakes. MIRR solves this issue, as well as the problem

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that happens when a project has different periods of positive and negative cash flows. In this situation IRR obtains more than one number, while MIRR obtains only one, being less confuse.

The major limitation of MIRR is that the estimation of cost of capital in order to make a decision is a subjective calculation. Also, for selecting "mutually exclusive" (a situation where the occurrence of one outcome supersedes another) investments the Net Present Value (NPV) is a more effective solution than MIRR.

2.3.3 Payback Analysis

Despite being the least accurate form of Capital Budgeting, Payback Analysis is still widely used due to its simplicity to give to managers a quick knowledge of the real value of a project. The Payback Period and the Discounted Payback Period (DPP) make up the Payback Analysis.

2.3.3.1 Payback Period

The aim of the Payback Analysis is to calculate the "Payback Period" (recovery time of the investment cost in years), dividing the cost of the investment by the average yearly cash inflow that the project will generate. The shorter the Payback Period, the more desirable the investment, having also less risk of loss due to possible market conditions changes.

The Payback Period is calculated from the following formula:

$$Payback\ Period = \frac{Initial\ Investment}{Estimated\ Annual\ Cash\ Flow}$$

Formula 6: Payback Period

The major issue of the Payback Period is that it does not take into account the Time Value of Money (TVM), unlike DCF Analysis methods, such as the Net Present value (NPV) and the Internal Rate of Return (IRR).

The Time Value of Money (TVM) is based on the concept that an amount of money nowadays has more value than the same amount in the future, due to its potential earning capacity.

The future value of money is calculated from the following formula:

$$FV = PV\ x\ [1 + (i/n)]^{(n\ x\ t)}$$

Formula 7: Future Value of Money (FV)

Where:

- FV = Future value of money.
- PV = Present value of money.
- i = Interest rate.
- n = Number of compounding periods per year.
- t = Number of years.

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Moreover, the Payback Period does not take into account inflows of cash after the Payback Period, which makes impossible to compare the profitability of a project with another one.

Due to the Payback Period limitations, it is commonly applied as a first analysis and then be complemented with other ones, such as the Net Present Value (NPV) or the Internal Rate of Return (IRR).

2.3.3.2 Discounted Payback Period

The Discounted Payback Period (DPP) is a more complete way to calculate the profitability of a project. DPP is the amount of time (in years) that it takes to break even from undertaking the initial expenditure, by discounting future cash flows and taking into account the Time Value of money (TVM).

To calculate the DPP, the periodic cash flows of the project have to be estimated and reduced by their present value in a discounting process. This methodology is usually done by using a spreadsheet applying the present value function.

Due to the initial cost investment, the cumulative discounted cash flows start with a negative value, changing in a positive direction as soon as cash is generated each year. The DPP occurs when the negative cumulative discounted cash flows become positive.

The general rule applied in DPP analysis is to accept the projects in which the Discounted Payback Period is shorter than the target timeframe.

The following table summarize the main benefits and limitations of the Payback Analysis methods (Payback Period and DPP):

Table 4: Payback Analysis (Payback Period and DPP) benefits and limitations

Payback Period	Discounted Payback Period (DPP)
Simplicity to give to managers a quick knowledge of the real value of a project.	More complete way to calculate the profitability of a project.
Does not take into account the Time Value of Money (TVM).	Takes into account the Time Value of Money (TVM).
Does not take into account inflows of cash after the Payback Period, which makes impossible to compare the profitability of a project with another one.	Takes into account future cash flows.

2.4 Types of Investors

Within the types of investors for WH/C and RES there are two main categories, private and public. Private investors are split into three non-financial and three financial types that differ by their function with respect to the energy sector. Public investors are split into government agencies and three types of state-controlled or state-owned entities that match their private counterparts (2).

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The different types of investors for WH/C and RES are summarized below (2):

- Private investors:
  - Non-financial types:
    - Energy firms: Component manufacturers, project developers, fossil fuel firms with investments in RES, etc.
    - Private utilities.
    - Industrials: All remaining non-financial companies.
  - Financial types:
    - Commercial banks.
    - Institutional investors: Non-bank financial firms, such as private equity firms or pension funds.
    - Charities: Non-profit investors such as, foundations or cooperatives.
- Public investors:
  - Government agencies.
  - State-controlled or state-owned entities:
    - State banks: State-owned investment funds.
    - State utilities: State-owned utilities.
    - Other state corporations: Other non-financial state-owned companies.

The following table shows the share of finance provided by RES investors for the period between 2004 and 2014:

Table 5: Share in cumulative finance provided by RES investors (2004-2014) (2)

Category	Investor	Share of finance provided
Private	Private utilities	17.1
	Commercial banks	11.7
	Energy firms	11.3
	Industrials	10.4
	Institutional investors	7.2
	Charities	0.8
Public	State utilities	12.6
	State banks	7.6
	Other state corporations	4.4
	Government agencies	2.5
Unclassified	Unclassified	15.0

It is observed that the highest share of finance provided by private investors came from private utilities (17.1%), while for public investors it came from state utilities (12.6%).

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Regarding the type of RES, the following table shows the share of investment received for the period between 2004 and 2014:

Table 6: Technologies ranked by share of investment received (2004–2014) (2)

Technology	Share of finance received (%)
Onshore wind	49.2
Solar PV (crystalline silicon)	18.1
Biomass & Waste	8.5
Conventional or first-generation biofuels	6.7
Offshore wind	6.7
Solar: Concentrating Power (CSP)	3.7
Other Solar PV	2.5
Small hydro	2.2
Geothermal	1.4
Advanced or second-generation biofuels	0.7
Marine	0.2

It is observed that the technology with highest share of finance received was onshore wind (49.2%), followed by solar PV (20.6%), leaving the rest of the RES technologies in a second step.

Regarding the RES investment risk, the development of new, high-risk technologies that require small amounts of capital is funded by venture capital, while the deployment of low-risk technologies occurs via existing energy firms with bank debt through project finance, as represented in the figure below (2):

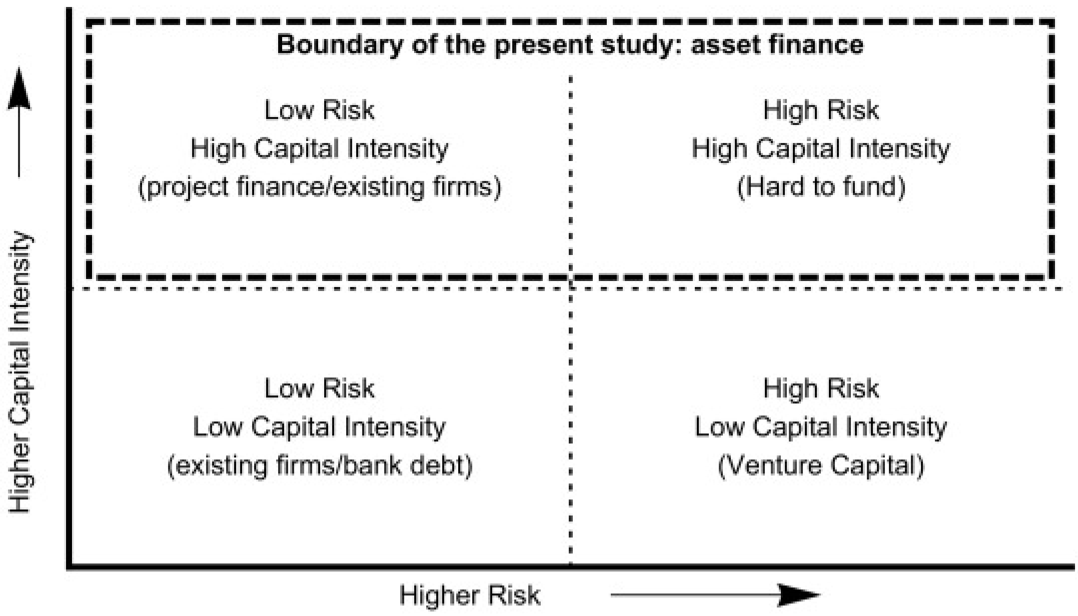

Figure 1: Risk-capital intensity classification of RES finance (2)

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2.5 Environmental Impact

The environmental impact of waste heat can be divided in two categories: The impact due to the atmosphere release of the pollutants contained in the waste heat and the energy inherit in the steam or water.

Pollutants depend on the composition and volume of the discharged fluid. Nevertheless, any kind of use of that waste will increase the overall efficiency of the system and consequently, will entail a reduction in fossil fuels and pollutants.

The potential economic benefit estimation is a complex task due to it involves many areas. The fuel savings are straightforward, but the emissions have an effect in the water/air, as well as in the animals and humans. For instance, the water temperature increment in the surrounding of a waste emissary will change the oxygen concentration, the species, the reproductive cycles and so on.

There are some tools which help to calculate the environmental cost of emissions, but for sure the impact is too huge to evaluate the deep scale effects of pollutions. An example of one of these tools is "ExternE", which is analysed in the below chapter.

2.5.1 ExternE

The ExternE ("External Costs of Energy") Methodology (3) is an approach of calculating environmental external costs, developed during the "ExternE Project-Series" (4) called Impact-Pathway-Approach. It was supported by more than 50 research teams in over 20 countries since 1991 to 2005, whose considerations were implemented into the EcoSense Model (5), which calculates environmental external costs and was developed and updated since 2005 to 2012 by many other projects. Despite the complexity of environmental external costs estimation, ExternE has become a well-recognised methodology (there should be noted that, whilst including External Costs of Energy are not directly in scope of the SO WHAT software tool, feedback for inclusion should be sought from stakeholders during the replication studies and if applicable, include potential additions to the requirements of the tool for exploitation/commercialisation after the project).

2.5.1.1 External Costs

An External Cost (also known as an "externality" in the literature) takes place when the activity of a group of people has an impact on another group, being the second one not fully compensated by the first one. A clear example of External Costs are the pollutant emissions generated by the industry, specifically Environmental External Costs. The pollutant emissions are not intentionally generated, but are not taken into account by the owners of the companies when making decisions, which makes them Environmental External Costs that result from the absence of property rights or markets for these environmental effects (6).

There are several ways of taking into account the Environmental External Costs:

- **Via Eco-Taxes:** Taxing damaging fuels and technologies (for instance, increasing the electricity invoices derived from the Environmental External Costs of generating electric power through coal combustion) (6).
- **Via Grants:** Subsidizing cleaner technologies (electric power generation through renewable energies, such as wind energy, solar photovoltaic, hydro power…) and fuels (heat production through biomass combustion) (6).

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The following table shows the impact of the External Costs of Energy and Transport on the Environment and Human Health. Highlight that the impact on ecosystems and global warming assumes uncertainty in the estimations (6):

Table 7: External Costs of energy and transport (6)

Impact category	Pollutants	Effects
Human health (mortality)	PM_{10}, $PM_{2.5}$, SO_2, O_3	Life expectancy reduction due to short and long time exposure.
	Diesel particles, radionuclides, heavy metals, Benzene, Benzo-[a]-pyrene 1,3-butadiene	Life expectancy reduction due to short and long time exposure.
	Accident risk	Fatality risk from traffic and workplace accidents.
	Noise	Life expectancy reduction due to long time exposure.
Human health (morbidity)	PM_{10}, $PM_{2.5}$, SO_2, O_3	Respiratory hospital admissions.
	PM_{10}, $PM_{2.5}$, O_3	Restricted activity days.
	PM_{10}, $PM_{2.5}$, CO	Congestive heart failure.
	Diesel particles, radionuclides, heavy metals, Benzene, Benzo-[a]-pyrene 1,3-butadiene	Cancer risk (non-fatal), osteoporosis, ataxia, renal dysfunction.
	PM_{10}, $PM_{2.5}$	Cases of chronic bronchitis, cases of chronic cough in children, cough in asthmatics, lower respiratory symptoms.
	Mercury	Loss of intelligence quotient (IQ) of children.
	O_3	Asthma attacks.
	Noise	Myocardial infarction, angina pectoris, hypertension, sleep disturbance.
	Accident risk	Risk of injuries from traffic and workplace
Building material	Acid deposition, SO_2	Ageing of building materials: Galvanised steel, limestone, mortar, sandstone, paint, rendering, zinc.
	Combustion particles	Buildings soiling.
Crops	NO_x, SO_2	Yield change for: Wheat, barley, rye, oats, potato, sugar beet.
	O_3	Yield change for :Wheat, barley, rye, oats, potato, rice, tobacco, sunflower seed.
	Acid deposition	Increased need for liming.

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	Nitrogen deposition, sulphur deposition	Fertilising effects.
Global warming	CO_2, CH_4, N_2O	World-wide effects due to temperature change and sea level rise on: Mortality, morbidity, coastal impacts, agriculture, energy demand, economic impacts.
Noise pollution	Noise	Amenity losses due to noise exposure.
Ecosystems	Acid deposition, nitrogen deposition, SO_2, NO_x, NH_3	Acidification, eutrophication, Potentially Disappeared Fraction of species (PDF: The fraction of species that has a high probability of no occurrence in a region due to unfavourable conditions caused by acidification and eutrophication).
Land use change	N/A	PDF of species.

2.5.1.2 ExternE Methodology

The main principles of ExternE methodology are shown below (3) (4):

- The impacts assessment or weighting is, if it is possible, carried out with quantitative figures and procedures, because the transparency and reproducibility of them is carried out through the use of quantitative algorithms (3) (4).
- The impacts are transformed into a monetary unit, which entails the following advantages (3) (4):
    - Units are conceivable.
    - Monetary values are transferable from one application to another.
    - Comparison of costs with benefits (converting benefits into monetary units).
    - Internalization of external effects with taxes.
- The preferences (transformed into measurements) of the affected people are used to evaluate the impacts (3) (4).
- Interviewed people must be well informed and understand the damages of the impacts evaluated in order to obtain reliable results (3) (4).
- The methodology should be able to calculate site and time dependent external costs (a close appreciation of site, time and technology can only be reached through a detailed bottom-up calculation). Therefore, the so-called "Impact Pathway Approach" is used for most environmental impacts (3) (4).
- Average or aggregated external costs can then be calculated depending on the nature of the policy question (3) (4).

The core of ExternE is the "Impact Pathway Approach" (IPA), which was developed within the "ExternE Project-Series". IPA evaluation is a bottom-up-approach in which environmental benefits

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and costs are estimated by following the pathway from source emissions via quality changes of air, soil and water to physical impacts, before being transformed into monetary benefits and costs (3) (4).

The following figure shows the main steps of IPA methodology for the case of pollutant emissions:

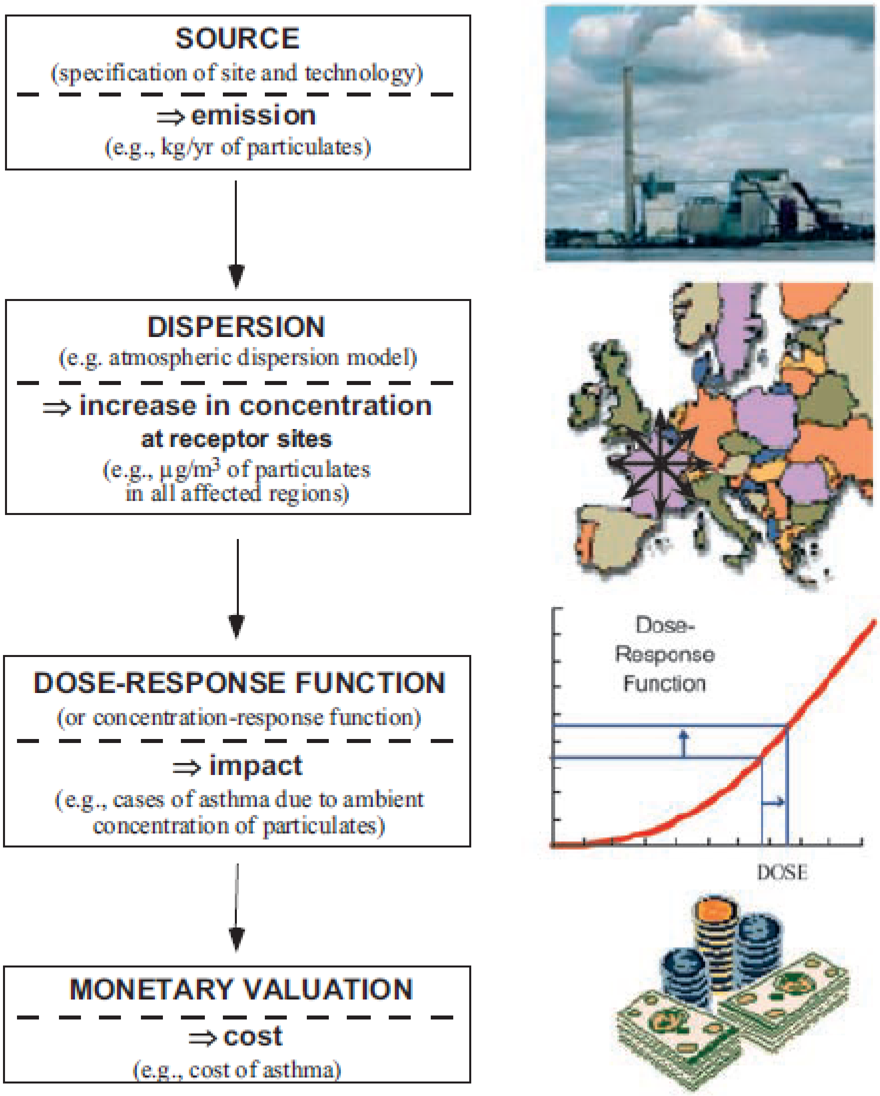

Figure 2: Impact Pathway Approach for pollutant emissions (7)

Two emission scenarios are needed for each calculation, a reference scenario and a case scenario. Highlight that not only the local damages must be taken into account, air pollution is transported causing damages at distances of even hundreds of kilometres away from the source. Therefore, a local, European wide and hemispheric modelling is required (6).

In the next step of IPA exposure-response models are used to include physical impacts on the receptor database together with the concentration levels of air pollutants (6).

By last, the physical impacts are transformed into monetary units in the last IPA step. Based on the welfare theory, damages represent welfare losses for individuals. For some of the impacts (crops and materials), market prices can be used to evaluate damages. However, for non-market goods (human

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health), the evaluation is only able through the use of the basis of the willingness-to-pay or willingness-to-accept approach based on individual preferences (6).

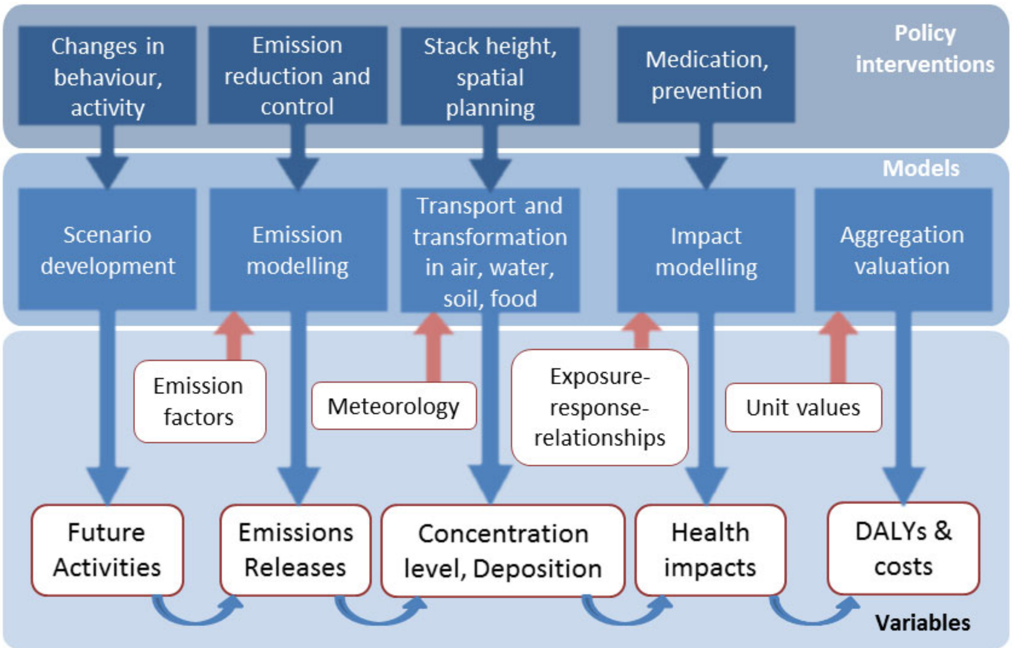

Figure 3: Impact Pathway Approach for pollutant emissions (8)

Beside environmental impacts, which are quantified using the IPA, ExternE includes global warming impacts, accidents and energy security (3) (4).

The included impact categories are analysed below:

- **Environmental impacts:** Impact Pathway Approach is the methodology used for impacts caused by releasing either substances (PM10, PM2.5, chemical compounds, etc.) or energy (heat, radiation, energy, etc.) (3) (4).
- **Global warming impacts:** The recommended methodology is an avoidance cost approach, due to the uncertainty of damages estimation (3) (4).
- **Accidents:** They are divided into impacts to the public and occupational accident risks, being calculated multiplying the damage by the probability of the accident. ExternE does not take into account the so-called "Damocles' risks", for which high impacts with low probability are considered more dangerous than low impacts with high probability (3) (4).
- **Energy security:** For instance, the unforeseen changes in availability and prices of energy carriers have a direct impact on economic growth (3) (4).

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Methods used in ExternE to quantify and value impacts are summarized in the following table:

Table 8: ExternE evaluation and quantification methods (7)

Impacts	Air pollution			Global warming
	Public health	Agriculture, building materials	Ecosystems	
ExternE, Impact Pathway Approach (IPA)				
Quantification of impacts	Yes	Yes	Yes (critical loads)	Yes (partial)
Valuation	Willingness to pay	Market prices	N/A	Yes (WTP and market prices)
Extension: Valuation based on preferences revealed in;				
Political negotiations	N/A	N/A	UN-ECE; NEC	Implementing Kyoto, EU
Public referenda	N/A	N/A	N/A	Swiss referenda

Below are shown some issues which have an important role for the decision process, despite not being considered as External Costs by ExternE (3) (4):

- **Impacts on employment:** They have an important weight in the investment decision process, being the distribution of working places the local effect that has a bigger influence (3) (4).
- **Depletion of non-renewable resources:** They are Internal Costs, due to the depletion of exhaustible resources is considered in the prices of the resources (Hotelling's Theory) (3) (4).

ExternE is applied through the use of the software package EcoSense (it is out of scope of the SO WHAT project, but could be included in potential future developments during commercialisation) that provides harmonised air quality and impact assessment models together with a database containing the relevant input data for the whole of Europe (6).

In addition to the analysis of the operation of the technology, the evaluation includes other stages of the lifecycle, such as construction, dismantling, fuel lifecycle, transport of materials and fuels (6).

2.5.1.3 ExternE Applications

One of the first targets of ExternE was to analyse the technologies of electricity generation. The research valued the impacts for the following fuels, technologies and locations (6):

- **Fossil fuels:** Coal, oil, natural gas, CHP (Combined Heat and Power), Orimulsion.
- **Nuclear:** PWR (Pressurized Water Reactor).
- **Renewable:** Onshore and offshore wind, hydropower, biomass fuels (wood waste, crops, etc.).

In the case of transport (road, rail, aircraft and navigation), ExternE focused on the specific requirements of emission and dispersion modelling and the extension and update of Dose-Response Functions (DRF: Relationship between the concentration of a pollutant and the physical impact on a

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receptor). Noise and accidents were also taken into account, together with the use of alternative fuels in city buses or the introduction of electric or CNG-fuelled vehicles (6).

The below figure shows a DRF graph with the following characteristics (7):

- **Point "P":** Lowest dose at which a response has been measured.
- **Linear response:** Straight line from the origin to "P".
- **Nonlinear response:** Curve line from the origin to "P" with incremental slope.
- **Response with fertilizer effect:** A small dose causes a benefit (crop yield increases due to small doses of NO_x and SO_2).
- **Response with threshold ("hockey stick"):** Zero response until the dose exceeds a threshold (thresholds due to organism natural repair mechanisms).

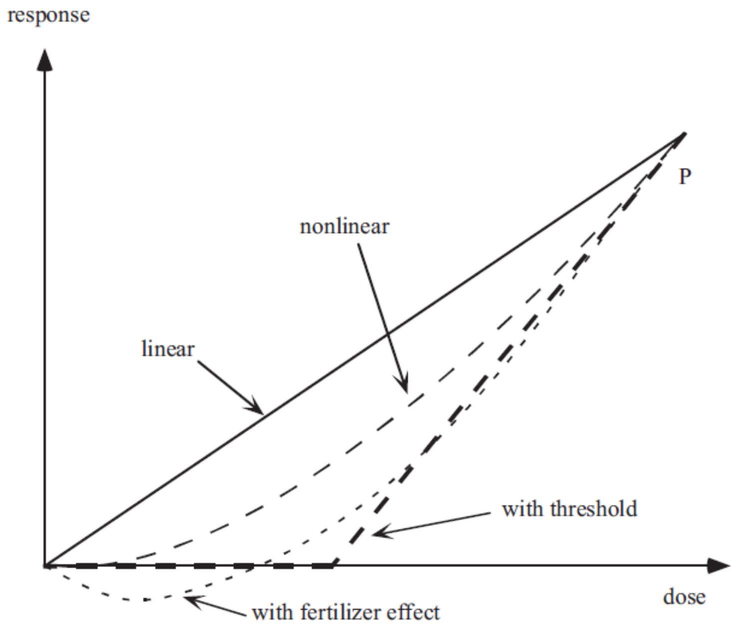

Figure 4: Dose-Response Function (DRF) (7)

ExternE methodology has been applied to support several policy decisions and legislative proposals, as well as to perform economic evaluations, as it is shown below (6):

- Draft directive on non-hazardous waste incineration.
- Large combustion plant directive.
- EU strategy to combat acidification.
- UN-ECE Multi-pollutant: Costs and benefits, multi-effect protocol and proposals (for instance NO_x and VOC control).
- Costs and benefits for the emission ceilings directive.
- Air quality limits for PAHs (Polycyclic Aromatic Hydrocarbons).
- Transport of PVC from incineration to landfill and recycling.
- Benefits of compliance with the EU environmental acquisitions: Quantification of the benefits of air quality improvements.
- Costs and benefits of acidification and ground level Ozone.

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- Regulatory appraisal of the SO_2, NO_2 and PM_{10} air quality objectives for UK Department of the Environment, Transport and the Regions.
- Air quality guidelines on CO and benzene.
- Environmental costs of lorries (study to incorporate environmental costs in vehicle excise duty rates in UK).
- Second UN-ECE NO_x Protocol (economic aspects of abatement strategies).
- The CAFE Programme (Clean Air For Europe) (3) (4).

2.5.1.4 ExternE Uncertainties and Reliability

The uncertainty and reliability of a methodology firstly depend on whether the chosen methods for its development are appropriate, and secondly on the forefront of them (new knowledge change the results) (6).

Individual sources of uncertainty then have to be identified and quantified, grouping them into different categories (it exists possibility of overlap) as it is shown below (6):

- **Data uncertainty:** Slope of a Dose-Response Function, cost of a day of restricted activity, deposition velocity of a pollutant, etc.
- **Model uncertainty:** Assumptions about causal links between a pollutant and a health impact, assumptions about form of a Dose-Response Function, choice of models for atmospheric dispersion and chemistry…
- **Policy and ethical choices uncertainty:** Discount rate for intergenerational costs, value of statistical life, etc.
- **Uncertainty about the future:** Potential for reducing crop losses by the development of more resistant species, etc.
- **Idiosyncrasies of the analyst:** Interpretation of ambiguous or incomplete information, etc.

The most important uncertainties focus on the exposure-response function for health impacts. In spite of these uncertainties, the usefulness of ExternE methodology lies in the following (6):

- The knowledge of a possible range of the external costs is an aid when making policy decisions.
- Identification of the relative importance of different impact pathways.
- Identification of the important parameters or key drivers that cause high external costs.
- More transparency and comprehensibility of the decision making process.
- Identification of areas for priority research.

2.5.1.5 ExternE Research Team

The ExternE principal objectives were the airborne pollutants from power plants and the development of the Impact Pathway Approach. The main organizations which contributed to achieve these goals are shown below (3) (4):

- Institute of Energy Economics and the Rational Use of Energy (IER), University of Stuttgart, Germany.
- Centre d´Énergétique - Ecole Nationale Supérieure des Mines / ARMINES, Paris, France.
- Department of Economics and International Development, University of Bath, Bath, Great Britain.

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- Institute of Occupational Medicine, Edinburgh, Scotland.
- Vlaamse Instelling voor Technologisch Onderzoek NV (VITO), Mol, Belgium.
- AEA Technology (formerly ETSU), Didcot, United Kingdom.
- Institute of Terrestrial Ecology (ITE), Cumbria, United Kingdom.
- Research Centre for Energy, Environment and Technology (CIEMAT), Madrid, Spain.
- Centre d'étude sur l'Évaluation de la Protection dans le domaine Nucléaire (CEPN), Fontenay-aux-Roses, France.
- Swedish Corrosion Institute (SCI), Stockholm, Sweden.
- Instituut voor Milieuvraagstukken (IVM), Vrije Universiteit Amsterdam, The Netherlands.

2.5.1.6 ExternE Tools

The main tools developed in the wake of ExternE are described below:

- **EcoSense (integrated environmental impact assessment model):** The main software system calculates location specific marginal external costs of stationary sources (such as power plants) due to emissions of air pollutants. EcoSense uses the so-called source-receptor matrices (instead of a full atmospheric dispersion model) based on the EMEP/MSC-W (European Monitoring and Evaluation Programme/Meteorological Synthesizing Centre-West) dispersion model, which entails a faster computation time, before applying concentration-response-functions. Data are finally transformed into monetary and DALY (Disability Adjusted Life Years) units (3) (4) (5).

EcoSense

Figure 5: EcoSense logo (4)

The following figure shows the structure of the EcoSense model:

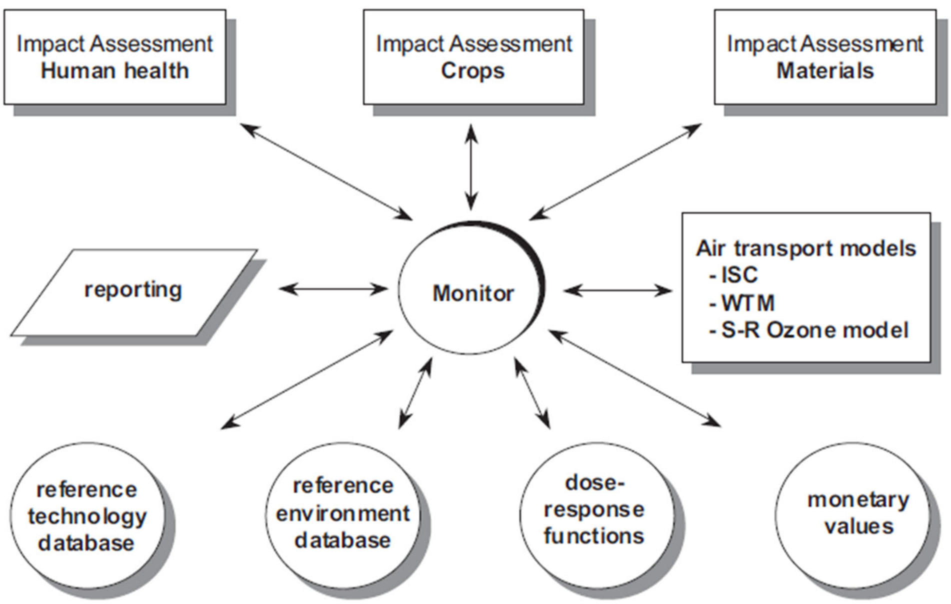

Figure 6: EcoSense model structure (7)

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Where air transport models are the following (3) (4):

- **ISC:** Industrial Source Complex.
- **WTM:** Windrose Trajectory Model.
- **S-R:** Source-Receptor.

In addition, there are the following EcoSense versions (3) (4):

- **Transport:** Calculation of transport external costs.
- **Multi-Source:** Calculation of external costs of all sources of a sector/country/UE.
- **WATSON:** Calculation of external costs of water and soil pathways.

- **EcoSenseLE (simplified online version of EcoSense):** Online tool for costs estimation due to of a typical source (for example a power plant, industry, transport, etc.) or all sources of an EU country sector or group of EU countries. It is based in a European database of receptor distribution (population, crops, building materials, etc.), background emissions (amount and spatial distribution) and meteorology. The annual emission of NO_x, SO_2, PM_{10}, NMVOC (Non-Methane Volatile Organic Compounds), CO_2, N_2O and CH_4 make up the required input. O_3, SO_2, PM_{10}, sulphates, nitrates and greenhouse gases make up the considered pollutants. The external costs are calculated through the exposure-response function and monetary values (3) (4).

Figure 7: EcoSenseLE logo (4)

- **RiskPoll (software implementation of the Uniform World Model):** Software tool that estimates the impacts (and optionally cost) due to "stack height" sources. The pollutant emission rate and deposition together with the population density in an area of 500-100 km around the emission source make up the minimum required input data (the results can be improved through the knowledge of more input data, such as meteorology). SO_2, NO_x, CO, PM, sulphates, nitrates, and toxic metals are the considered pollutants (4).

Figure 8: RiskPoll logo (4)

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2.6 Social Impact

Sustainable energy solutions, such as industrial WH/C recovery and its application to district heating/cooling networks, have sometimes suffered from the perception that they involve too much investment, at the expense of the socio-economic development they produce. Undoubtedly, as governments around the world strive to deliver on the 2015 Paris climate agreement, they must grapple with the urgency of the energy transition in parallel with many other considerations that affect society well-being. Fortunately, renewable energy sources provide climate-safe solutions that also support a wide range of socioeconomic benefits (9):

The main RES social impacts are listed below:

- **Impacts on global GDP and welfare:** In addition to supporting climate stabilisation goals, a significant uptake of RES and energy efficiency measures offers important macroeconomic benefits. The increase in economic activity is stimulated by the investment in RES and energy efficiency as well as by enabling policies, including carbon pricing and the recycling of revenues from reduced income taxes (9).
  However, indicators such as GDP alone does not represent the human welfare gains, such as employment, health, education, reduced GHG emissions and changes in material consumption. Welfare gains are the result of reduced negative externalities such as pressure on ecosystems (reduction of coal, oil and gas extractions) and impacts on human health (lower exposure to air and water pollutants derived from fossil-fuel use). In addition, there are positive social impacts in the form of employment and income gains (9).

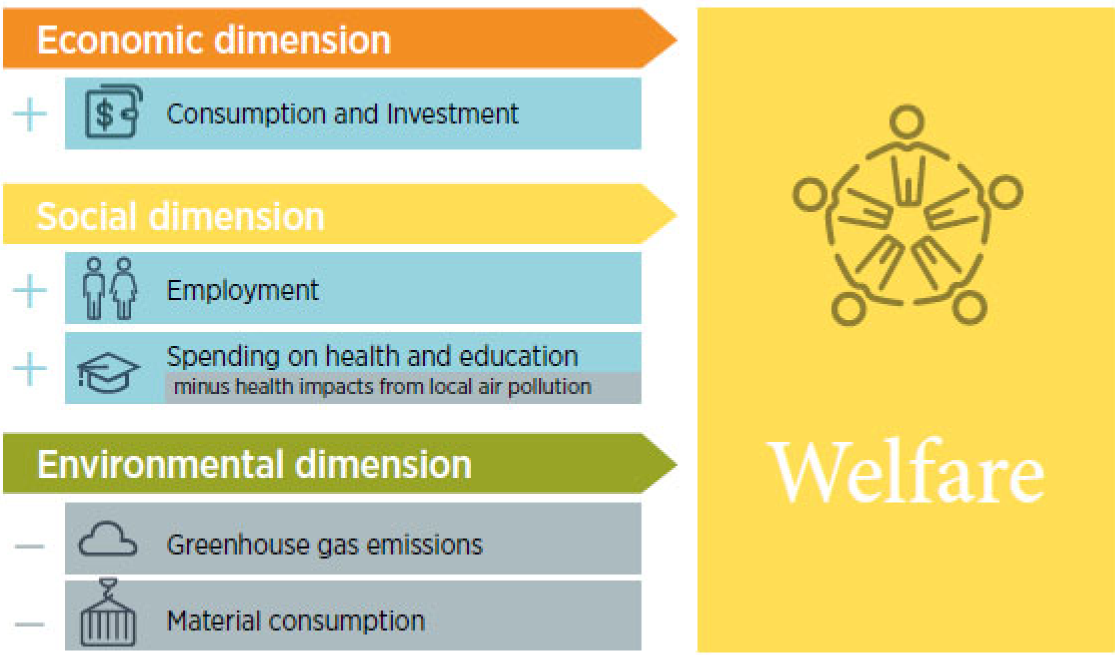

Figure 9: Welfare improvements (9)

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- **Growth in RES employment:** Direct and indirect employment has experienced a considerable increase over the last few years. The results from an IRENA (International Renewable Energy Agency) survey in 2016 showed that women represented on average the 35% of the labour force in the modern RES sector, a share higher than in the conventional energy sector, which is traditionally male-dominated (9).
  Several member states of the EU were among RES early 21st century pioneers. However, competitive pressures and adverse policy changes, especially since 2008, have led to significant job losses in solar PV, while wind industry continues to be a global leader (9).
  Regarding the RES value chain, O&M, manufacturing, construction and installation are the most representative activities. Construction workers, factory workers and technicians are among the predominant occupations. Many of the occupations that can be filled locally (especially in construction) do not require highly RES-specific skills and thus offer accessible entry points for employment (9).
- **Occupational patterns and skills:** RES sector encompasses a wide range of occupations and skill requirements. Filling some of these high-skilled positions can be challenging. In this context, a better coordination of approaches and policies between the industry and the education sector, including the integration of RES modules into the syllabus of the subjects, is essential. Adequate public financing for RES education and training also carries great importance (9).
  The RES sector can draw on skilled personnel from other industries, like the ones listed below (9):
    - Semiconductors sector.
    - Electrical equipment sector.
    - Shipbuilding.
    - Glass manufacturing.
    - Fossil-fuel sector.
- **Net employment effects and fossil-fuel employment loss:** New employment creation in RES and energy efficiency would more than offset the employment losses in the conventional energy sector. In recent years, the RES sector has continued creating jobs, whereas the conventional energy sector has struggled to retain them (9).
- **Localising the value chain and ensuring community benefits:** Localisation of the value chain is, to some extent, a precondition of generating community benefits, ensuring that a certain percentage of revenue streams flows to areas that are involved in providing inputs to the sector (9).
  Large-scale renewable energy projects are driven principally by national policy goals and industry interests, which do not always accord with the specific needs of local communities. To maximise socio-economic development opportunities and transformational change, policies and projects need to draw as much as possible on the local workforce, offer skills training programmes, and promote gender fairness and equality (9).

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3 Levelized Cost of Heat (LCOH)

LCOE (Levelized Cost of Energy) calculation is a standard approach to calculate the average net present cost of the unit of energy (usually KWh) produced by a generation plant over its lifetime. LCOE is usually calculated as the ratio between all the discounted costs over the lifetime divided by a discounted sum of the actual energy amounts delivered and is used to compare different methods of electricity generation on a consistent basis. The LCOE represents the average revenue per unit of energy generated that would be required to recover the costs of building and operating a generation plant during an assumed financial life and duty cycle.

The energy considered in LCOE approach of course depends on the type of power plant considered and on the type of service provided and can be related to the production of the electricity as well as heat or both. Consequently, the CAPEX, OPEX and fuel costs considered as well as the lifetime are related to the corresponding equipment involved in the specific generation.

Among different sources, excess heat (or waste heat) is a particular type of heat recovered from natural sources (sea, rivers, aquifers), industrial equipment (condensers, chimneys, dry coolers, radiators) or urban environments (sewage, underground, data centre) which exploitation foresees costs that have to be taken into account when considering the profitability of the intervention of recovery.

This conceptual framework has been extended to calculate the Levelized Cost of Excess Heat (LCOH) that is injected in an already existing distribution grid, in order to evaluate the maximum distance from the point of production to generate revenues. LCOH method has been modified in order to serve as a criterion for investment into the excess heat utilization equipment.

In this study, a step beyond has been done by considering the use case (as for the SO WHAT demo-sites of ENCE and LIPOR) where the heat is recovered inside the facility and then distributed outside to a final-user via a district heating network. Given the amount of heat distributed, the yearly equivalent operating hours, the different costs related to the acquisition, installation and operation of the system over the lifetime of the equipment, a maximum distance from the generation point can be calculated in order to have positive revenues. In case the distance is fixed, the amount of energy delivered, the cost for piping installation and the yearly equivalent operating hours can be used as decision-making variables.

3.1 Calculation Methodology

Different approaches can be applied in order to calculate the LCOH distributed by a district heating network. The choice of the approach depends on the configuration of the analysed plant, in particular on the origin of heat (it can be waste heat, or heat generated by a thermal plant specifically used for this purpose). The approaches that have been analysed are:

- Standard approach.
- Alternative approach.
- Excess Heat approach.

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3.1.1 Standard Approach

The standard approach consists on the calculation of the LCOH from the knowledge of all the terms that concur to the determination of the final cost. The calculation of the LCOH is based on the following equation (10):

$$LCOH = \frac{I_c\, CFR\, (1 - T\, D_{pv})}{8760\, i\, (1 - T)} + \frac{O_{total}}{8760\, i} + c_{fuel}$$

Formula 8: Levelized Cost of Heat (LCOH)

Where:

- I_c is the capital cost of the production facility and distribution network (€/kW)
- CFR is the capital recovery factor which discount the investment [-]
- T is the tax rate [-] and depends on the country in which the plant should be installed.
- D_{pv} is the present value of depreciation [-] and depends on the country in which the plant should be installed.
- i is the capacity factor of the production facility expressed as the ratio between the total operative full load hours and the annual hours (8,760 h) [-]
  O_{total} are the total O&M costs obtained as the sum of the fixed cost and the total variable cost over the years during which the plant is operative (€/kW)
- c_{fuel} is the cost of the fuel being used to produce the heat including the cost of the recovered excess heat in case present (€/kWh)

The Capital Recovery Factor (CRF) is calculated by the following formula (11):

$$CFR = \frac{D\,(1 + D)^N}{(1 + D)^N - 1}$$

Formula 9: Capital Recovery Factor (CRF)

Where:

- D is the discount rate [-]
- N is the number of years during which the plant is active [-]

3.1.2 Alternative Approach

The formula to calculate the LCOH is the same of the standard approach, however in this case the network installation costs are excluded from the capital cost (I_c) and are considering in the formula of the revenues. The equation that has been used for the calculation of the revenues is the following (10):

$$R = Q\, c_h - Q\, LCOH - l_s\, c_p$$

Formula 10: Potential Revenue for a DHN (R)

Where:

- R is the potential revenue for a district heating system (€)
- Q is the heat demand (kWh)
- c_h is the price of the heat sold to the final-user (€/kWh)
- l_s is the network length (m)
- c_p is the cost of the distribution network installation (€/m)

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Given the amount of available heat that can satisfy the demand, this solution allows to determine the network lengths for which the value of the revenues is greater than zero, that is the possibility to identify the maximum area that could be feasible for the district heating network implementation.

3.1.3 Excess Heat Approach

This approach is focused on the possibility to recover the excess heat deriving from a power plant or other activities in the surrounding area of the site in which the heat grid installation should be done. In this case the formula of the Levelized Cost of the Excess Heat (LCOEH) becomes the following (10):

$$LCOEH = \frac{I_{HE}\ CFR\ (1 - T\ D_{pv})}{8760\ i\ (1 - T)} + \frac{O_{HE,total}}{8760\ i} + c_{excess\ heat}$$

Formula 11: Levelized Cost of Excess Heat (LCOEH)

Where:

- I_{HE} is the investment cost of the facilities (i.e. heat exchangers) excluding installation costs of the excess heat distribution network (€/kW)
- $O_{HE,total}$ are the total O&M costs for the heat exchangers (€/kW)
- $c_{excess\ heat}$ is the cost of the excess heat (€/kWh)

The exclusion of the network installation costs from the investment cost has been done in order to calculate the maximum potential distance of the heat source from the end-user/point of injection in the existing grid that allows to have a positive revenue. In this case the formula for the revenues calculation can take into account both the LCOH and the LCOEH and can be expressed as follow (10):

$$R_{EH} = Q\ c_h - (E_{EH}\ LCOH + E_{DH}\ LCOH) - l_s\ c_p$$

Formula 12: Revenues Value (R_{EH})

Where:

- R_{EH} is the revenues value (€)
- Q is the heat demand (kWh)
- c_h is the price of the heat sold to the final-user (€/kWh)
- E_{EH} is the available excess heat (kWh)
- E_{DH} is the remaining heat demand covered by the already existing system (kWh)
- l_s is the network length (m)
- c_p is the cost of the distribution network installation (€/m)

In this case, given all the other parameters and imposing equal to zero the R_{EH} value it is possible to find the maximum distance l_s from the excess heat source.

3.1.4 Mixed Approach

This approach has been introduced in order to apply the LCOEH calculation to ENCE and LIPOR demo-sites and in general to all the cases where the waste heat is recovered inside the production site and distributed to outside final-users. In this case the LCOEH formula is a compromise between the Excess Heat approach and the Alternative approach to consider the fact that here the variable is the distance from the excess heat generation point (the facility) and the final-user:

- The investment cost (I_{HE}) and the total O&M cost ($O_{HE,total}$) consider also the equipment that exploit the excess heat at the end-users site in addition to the heat exchangers used to recover the heat.

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- The cost of the excess heat ($c_{excess\ heat}$) is set to zero because in these demo-sites the production of heat from the excess heat does not cause additional costs.

Moreover, also the formula of the revenues is the same of the Excess Heat approach with a major modification, only the E_{EH} is present and the heat provided by other sources (E_{DH}) is set to zero.

The assumptions about the values of the different parameters in these formulas applied to demo-sites have been applied in the following chapters.

3.2 Techno-Economical Descriptions

LCOEH calculation following the Mixed approach has been applied to the demo-sites of ENCE in Navia (Spain) and LIPOR in Maia (Portugal). In both demo-sites the objective is to recover the waste heat derived from internal processes and deliver it to different nearby final-users by a heat distribution grid. The technical descriptions of the demo-sites configurations are reported in the following chapters.

3.2.1 ENCE Navia Pulp Mill (Spain)

In the ENCE demo-site in Navia (Spain), the pulp mill produces both paper pulp and renewable electricity from biomass. Nowadays, the heat is recovered from the bleaching stage in order to use it for the biomass dryer and other internal processes. The possibility to increase the amount of heat recovered has been identified, considering the waste heat derived from the causticization stage, the bleaching stage and the effluent treatment stage. In this future scenario the heat could be employed to increase the capacity of the biomass dryer (WH from the causticization stage) or shared with nearby public buildings (WH from the bleaching stage and the effluent treatment stage), such as Navia town hall and other public buildings.

The future scenario to which the LCOH calculation has been applied in this document is characterized by the heat recovered from the bleaching stage and the effluent treatment stage by new water/water heat exchangers. The waste heat recovered will be shared to public buildings (i.e. Navia town hall) by a 5 km grid. The investments in the exchangers and the grid is planned for 2022.

Scenario assumptions:

- The heat amounts recovered during a year from the bleaching stage and the effluent treatment stage are respectively 42,147MWh and 47,728MWh (total waste heat recovered 89,875MWh).
- The heat grid length is 5 km (datum provided by ENCE) and the losses are assumed 10% (12).
- The cost of the heat exchangers has been provided by ENCE.
- The district heating substations are assumed to be of industrial size and the technical parameters and costs associated with the heat grid and substations have been estimated. The substation losses are assumed 2%.
- The ratio between the equivalent operative full load hours and the annual hours amount has been set to 0.4137 (datum provided by ENCE)
- The present value of depreciation has been set to 95% (assuming a European average value of tax depreciation equal to 5%) (13).
- The discount rate for generation plant has been set to 4% (14).
- The tax rate set is 21% for Spain.

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Table 9: Techno-economical characteristics of the future scenario technologies for ENCE

Component	Technical Lifetime (years)	Investment Costs (€/kW)	Fixed Operation and Maintenance (O&M) Costs (€/kW)
Heat exchanger (bleaching stage)	15 x 2	5.27 x 2	0.224
Heat exchanger (effluent treatment stage)	15 x 2	5.34 x 2	0.197
Heat grid	30	100.81	0.001
Substation	20	99	0.500

3.2.2 LIPOR Maia Waste-to-Energy Plant (Portugal)

LIPOR is responsible for the management, recovery and treatment of the municipal waste in eight associated municipalities, among them the Maia municipality (15). In 2019, 74% of the municipal waste sent to LIPOR was used for energy recovery generating approximately 170,000MWh of electricity. Nearly 90% of the electricity produced is sent to the grid, while the rest is consumed internally. Nowadays, LIPOR waste-to-energy plant produces steam for electricity production and the excess is not exploited.

The future aim is to recover heat from the waste incinerator. The recovered heat will be shared with Porto Airport, where it will be used for space heating and cooling (nowadays gas boilers for heating and electrical chillers for cooling are used and need to be reinvested in the 2020). For this purpose, the investment in 3 absorption chillers (with 12,000 kW total cooling power capacity), pumps, heat exchangers and 4km long heat grid has been planned. The investment year should be the 2020.

Scenario assumptions:

- The heat recovered during a year from the waste incinerator is 40,800MWh.
- The heat that reaches the airport and used for the space heating and cooling purpose is 19,200MWh.
- The technical parameter and cost of the equipment have been provided by LIPOR or estimated.
- The equivalent operative full load hours have been set to 3,400 h/y (obtained by the ratio between the heat recovered and the power of the heat exchangers) for all the technologies except the absorption chillers.
- The absorption chillers equivalent operative full load hours have been set to 1,450 h/y.
- The present value of depreciation has been set to 95% (assuming a European average value of tax depreciation equal to 5%) (13).
- The discount rate for generation plant has been set to 4% (14).
- The tax rate set is 23% for Portugal.

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Table 10: Techno-economical characteristics of the future scenario technologies for LIPOR

Component	Technical Lifetime (years)	Investment Costs (€/kW)	Fixed Operation and Maintenance (O&M) Costs (€/kW)
Hydraulic heating network	30	182.20	0.91
Heat exchangers	10 x 3	0.78 x 3	0.329
Absorption chillers	25	81.25	0.81
Pumps	20	5.28	1.64

3.3 Results

The Mixed approach for the calculation of the LCOEH presented in Chapter 3.1.4 has been applied for both the demo-sites described in Chapter 3.2 there has been assumed that all the demand is satisfied by the recovered heat and no other fuels are used to increment the total amount of delivered heat (i.e. E_{DH} set to zero). Therefore, also the fuel cost ($c_{excess\ heat}$) has been set to zero, indeed the waste heat recovered is a product of other processes and its exploitation does not require an increase in the fuel consumption. For each demo-site there have been evaluated:

- The LCOEH and the minimum heat selling price (that is the selling price obtained setting the revenues value to zero).
- The trend of the minimum heat selling price by changing the cost of construction of the heating grid expressed in euro per linear meter.
- The trend of the minimum heat selling price by changing the amount of heat recovered and delivered (considering a demand rise due to an increase of the end-user gross floor area or of the number of buildings connected to the pre-existing grid).
- The trend of the minimum heat selling price by chancing the equivalent full load hours of the demo-sites plants therefore increasing the operative hours due to different final-use considered.

3.3.1 ENCE Navia Pulp Mill (Spain)

For ENCE the value of the LCOEH, obtained considering the Mixed approach reported in Chapter 3.1.4 and the techno-economic assumptions listed in Chapter 3.2.1, is approximately equal to 0.034€/kWh when considering a cost for distribution grid of 500 €/m (reference value provided by ENCE). In this case the LCOEH value has the same order of magnitude obtained for the district heating levelized cost calculation (16). The gas price for household consumers within the range of 20-200GJ gas consumption is 0.0718€/kWh in Spain (17), so it is possible to increase the heat selling price from the minimum without losing the economic competitiveness with the natural gas heating technologies and achieving a positive value for revenues.

In order to evaluate the possible variation about the heat grid installation cost expressed in euro per linear meter, thus considering a variability of realization costs mainly dependent from the ground conditions where the pipes are placed, a sensitivity analysis has been carried out changing "c_p" in the formula of the revenues. The results are reported in Figure 10. As expected, the rise of the network

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cost leads to increase the minimum heat selling price. This trend affects the possible revenues value (if the minimum selling price is higher the difference between its value and the gas price for household consumers is lower causing a lower possible increase of the heat selling price without losing the economic competitiveness with the natural gas heating technologies and so lower possible revenues).

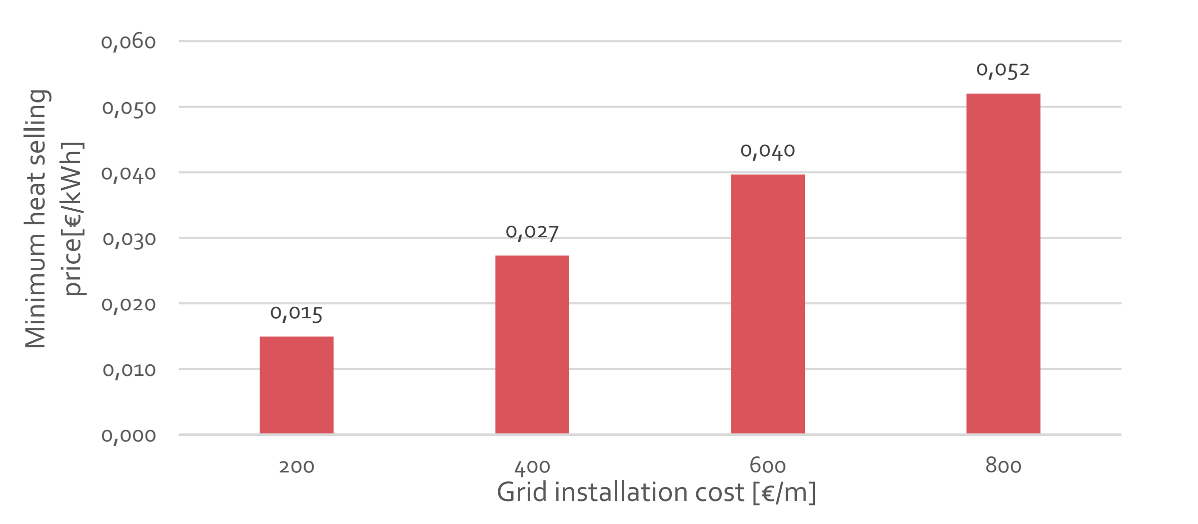

Figure 10: Minimum heat selling price trend as a function of the heat grid installation cost for ENCE

In order to evaluate the influence of the delivered heat amount on the minimum heat selling price, a sensitivity analysis has been carried out by changing "Q" in the formula of the revenues and the corresponding amount of heat delivered by the considered technologies in the LCOEH formula. The increase of the delivered heat amount affects the pipe installation cost and this is taken into account using the formulas of Chapter 3.1 (setting the piping system and the ground condition factors to zero). These formulas allow to obtain the highest pipe installation costs reported in Table 11 and the other values have been obtained scaling down the highest ones. It has been imposed that the change in the amount of delivered and recovered heat does not affect the technologies costs (these costs are function of technologies type and model that are fixed and only the number of installed units varies with the heat amount). The results of this analysis are shown in Figure 11. Fixing the pipe installation cost level, the increase in the heat delivered to the end-user leads to a lower minimum heat selling price and the possibility to reach higher revenues value. However, the decrease of the minimum heat selling price becomes lower increasing the heat recovered; this result highlights a smaller advantage, proportionally, to invest in the increment of the grid potential at high delivered heat amount respect to low delivered heat amount.

Table 11: Pipe costs as a function of the heat delivered by the grid for ENCE

Heat delivered by the grid (MWh)	Pipe cost low (€/m²)	Pipe cost medium (€/m²)	Pipe cost high (€/m²)
40,443.84	230	430	630
80,887.68	300	500	700
121,331.52	350	550	750
161,775.36	380	580	780

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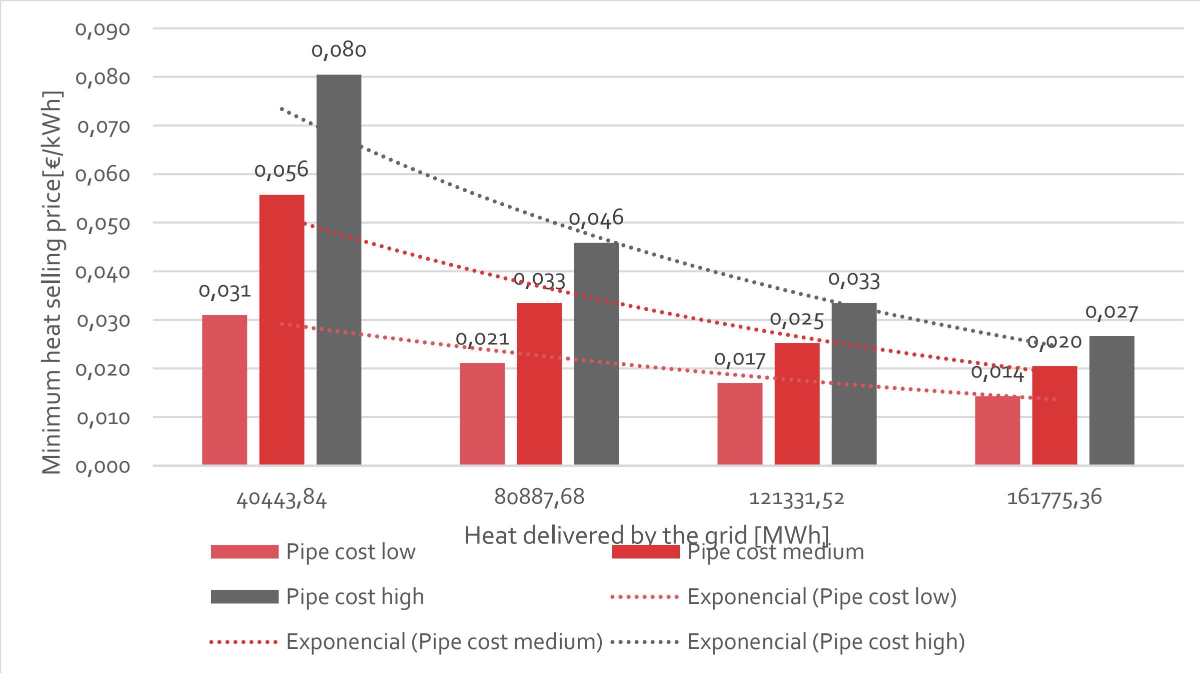

Figure 11: Sensitivity analysis of the minimum heat selling price changing the heat delivered for ENCE

In order to evaluate the influence of the equivalent operative full load hours of the demo-sites plants on the minimum heat selling price thus considering the possibility to exploit the recovered heat for longer periods (i.e. final-users needing heat and cool for other purposes than air conditioning), a sensitivity analysis has been carried out by changing "i" in the formula of LCOEH. The modification of the equivalent operative full load hours affects the LCOEH and the revenues calculation in two ways, first it leads to different management of heat generated, and second it allows to amortize the technologies costs differently. Three different scenarios are listed in Table 12, the case A corresponds to the starting scenario reported in Chapter 3.2.1 to which absorption chillers are added (techno-economic data about it in Table 13) in order to increase the ratio of the operational hours to 0.5792 h for the technologies already present, the case C corresponds to the highest exploitation condition of the technologies (8,500 h/y), and the scenario B is a midway between the scenarios A and C. The absorption chillers installation affects the LCOEH value that has the higher value in case A, equal to 0,006€/kWh, and decreases up to the value of 0,003€/kWh in case C. The equivalent operational hours change causes a variation of pipe cost due to the increasing heat managed from scenario A to C, this is considered with the formulas of Chapter 3.1 as for the sensitivity analysis on "Q". The results are reported in Figure 12 and shown that the favourable minimum heat selling price reduction decreases with the increase of the equivalent full load hours.

Table 12: Scenarios of the sensitivity analysis on equivalent full load hours for ENCE

Case	Equivalent operative full load hours for technologies already installed in starting scenario (h)	Equivalent operative full load hours for absorption chillers (h)	Pipe cost low (€/m2)	Pipe cost medium (€/m2)	Pipe cost high (€/m2)
A	5074 (3624H + 1450C)	1450	340	540	740
B	6787 (4250H + 2537C)	2537	380	580	780
C	8500 (4876H + 3624C)	3624	390	590	790

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Table 13: Absorption chillers characteristics

Component	Technical Lifetime (years)	Investment Costs (€/kW)	Fixed Operation and Maintenance (O&M) Costs (€/kW)
Absorption chillers	15	70.41	0.813

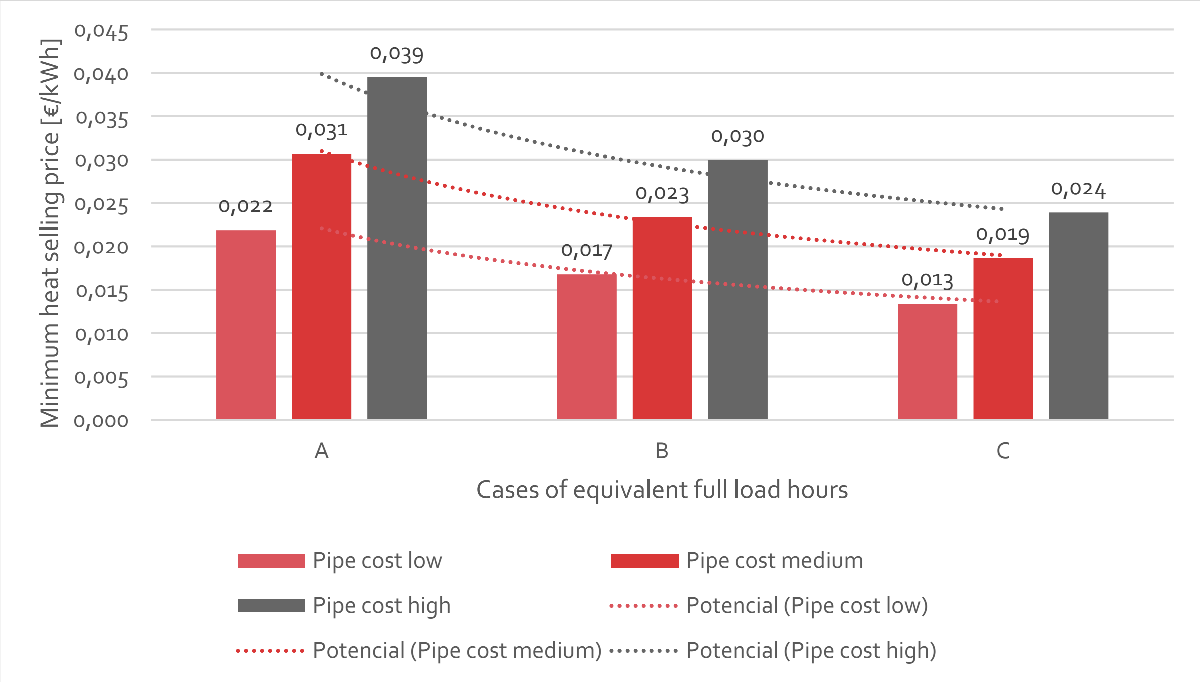

Figure 12: Sensitivity analysis of the minimum heat selling price changing the equivalent full load hours for ENCE

3.3.2 LIPOR Maia Waste-to-Energy Plant (Portugal)

For LIPOR the value of the LCOEH, obtained considering the Mixed approach reported in Chapter 3.1.4 and the techno-economic assumptions listed in Chapter 3.2.2, is approximately equal to 0.059€/kWh when considering a cost for distribution grid of 547 €/m (reference value provided by LIPOR). Also in this case the LCOEH value has the same order of magnitude obtained for the district heating levelized cost calculation in (16). The gas price for household consumers within the range of 20-200GJ gas consumption is 0.0643€/kWh in Portugal (17), so also in this demo-site, it is possible to increase the heat selling price from the minimum without losing the economic competitiveness with the natural gas heating technologies and achieving a positive revenues value.

In order to evaluate the possible variation about the heat grid installation cost expressed in euro per linear meter, thus considering a variability of realization costs mainly dependent from the ground conditions where the pipes are placed, a sensitivity analysis has been carried out changing "c_p" in the formula of the revenues. The results are reported in Figure 13. As expected, the rise of the network cost leads to increase the minimum heat selling price. In this demo-site, the installation of a heat grid coupled with the technologies having the characteristics reported in Chapter 3.2.2 would not be economically competitive with the natural gas heating technologies if the pipes installation cost achieved 600€/m^2,because the minimum heat selling price would be equal to the national gas cost. However, the environmental advantages to recover the waste heat and to exploit it using a heat grid remain intact.

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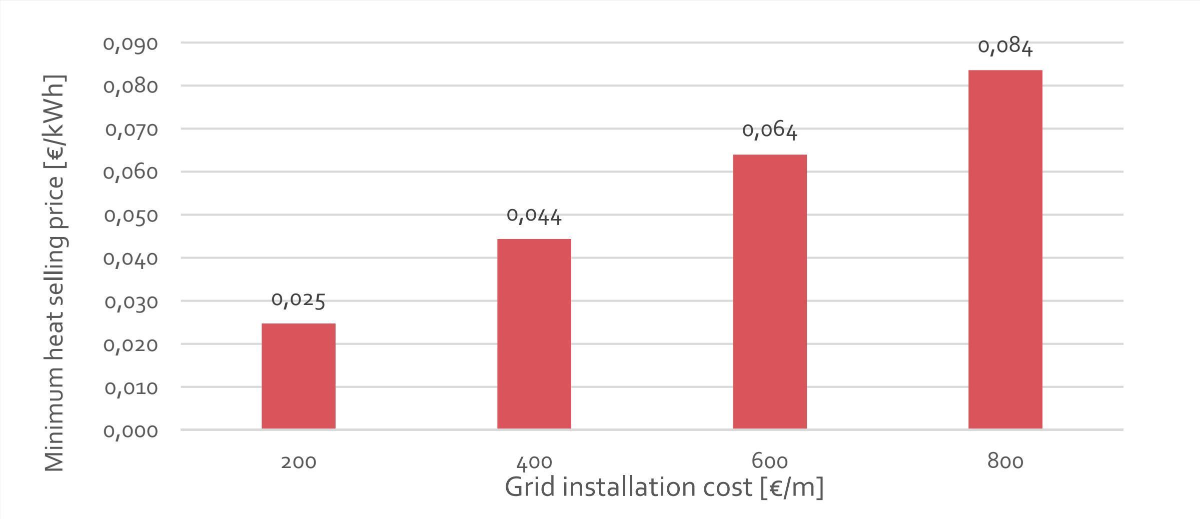

Figure 13: Minimum heat selling price trend as a function of the heat grid installation cost for LIPOR

In order to evaluate the influence of the delivered heat amount on the minimum heat selling price as done per ENCE demo-site, a sensitivity analysis has been carried out changing "Q" in the formula of the revenues and the amount of heat managed by the different technologies in the LCOEH formula. The increase of the delivered heat amount affects the pipe installation cost and this is taken into account using the formulas of Chapter 3.1 (setting the piping system and the ground condition factors to zero). These formulas allow to obtain the highest pipe installation costs reported in Table 14 and the other values have been obtained scaling the highest ones. It has been imposed that the change in the amount of delivered and recovered heat does not affect the technologies costs (these costs are function of technologies type and model that are fixed and only the number of installed units varies with the heat amount). The results of this analysis are shown in Figure 14, fixing the pipe installation cost level, the increase in the heat delivered to the end-user leads to a lower minimum heat selling price and the possibility to reach higher revenues value. However, like for ENCE demo-site, the decrease of the minimum heat selling price becomes lower increasing the heat recovered; this result highlights a lesser advantage, proportionally, to invest in the increment of the grid potential at high heat amount respect to low heat amount. Moreover, in this case the decrease of the heat recovered to 20,400MWh leads to lose the economic competitiveness with the natural gas heating technologies, indeed the minimum heat selling price is again higher than the natural gas national price considering a high or a medium pipes cost.

Table 14: Pipe costs as a function of the heat delivered by the grid for LIPOR

Heat delivered by the grid (MWh)	Pipe cost low (€/m²)	Pipe cost medium (€/m²)	Pipe cost high (€/m²)
20,400	280	480	580
40,800	350	550	650
61,200	400	600	700
81,600	430	630	730
102,000	450	650	750

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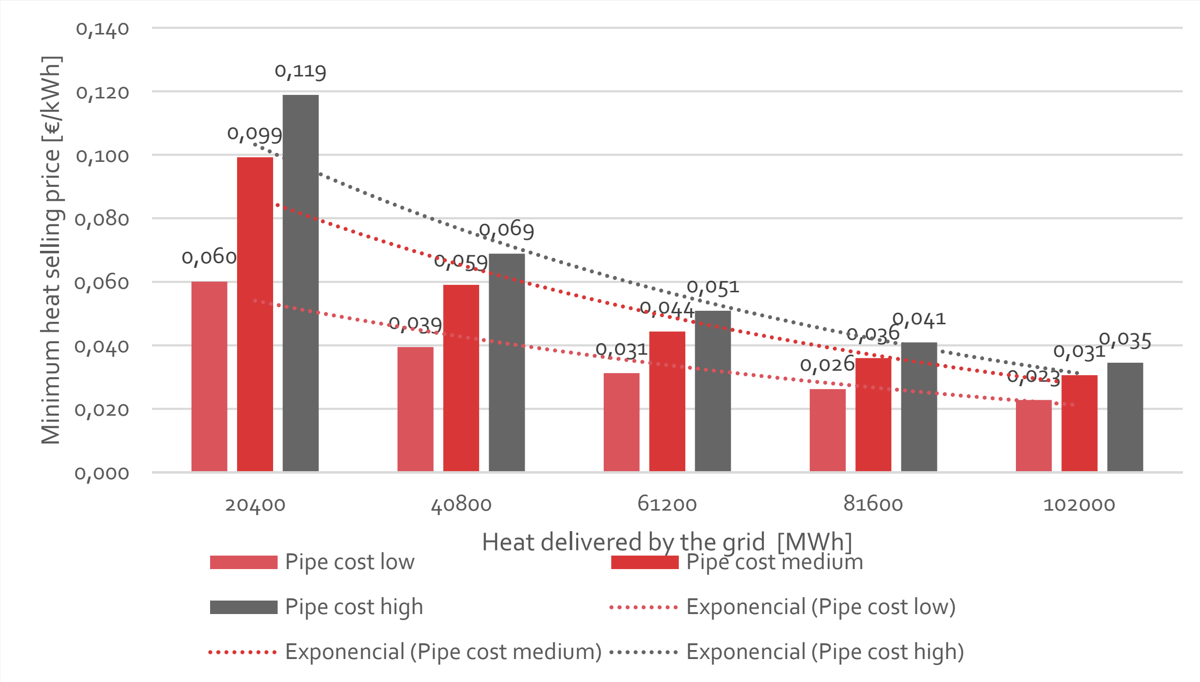

Figure 14: Sensitivity analysis of the minimum heat selling price changing the heat delivered for LIPOR

In order to evaluate the influence of the equivalent full load hours of the demo-sites plants on the minimum heat selling price, considering the same conditions as per ENCE demo-site, a sensitivity analysis has been carried out changing "i" in the formula of LCOEH. The modification of the equivalent operative full load hours affects the LCOEH and the revenues calculations in two ways, first it leads to different managed heat values, and second it allows to amortize the technologies costs differently. Three different scenarios are listed in Table 15, the case A corresponds to the starting scenario reported in Chapter 3.2.2, the case C corresponds to the condition of maximum exploitation of the technologies, and the scenario B is a midway between the scenarios A and C. The equivalent operational hours change causes a variation of pipe cost due to the increasing managed heat from scenario A to C, this is considered with the formulas in Chapter 3.1 as for the sensitivity analysis on "Q". The results, reported in Figure 15, show that the favourable minimum heat selling price reduction decreases with the increase of the equivalent full load hours. Moreover, considering that the heat transferred by the grid in case C is equal to the highest value of "Q" in the previous sensitivity analysis, it is possible to highlight that the rise of "i" has a more advantageous effect on the reduction of the minimum heat selling price compared to the rise of the heat recovered if the same installed technologies are taken into account. This effect is due to the dependency of the LCOEH from the equivalent full load hours and not from the amount of heat delivered, from case A to case C the value of the levelized cost of the excess heat change from 0.005€/kWh to 0.002€/kWh.

Table 15: Scenarios of the sensitivity analysis on equivalent full load hours for LIPOR

Case	Equivalent operative full load hours for technologies excluded the absorption chillers (h)	Equivalent operative full load hours for absorption chillers (h)	Pipe cost low (€/m2)	Pipe cost medium (€/m2)	Pipe cost high (€/m2)
A	3400 (1950H + 1450C)	1450	350	550	650
B	5950 (3413H + 2537C)	2537	420	620	720
C	8500 (4876H + 3624C)	3624	450	650	750

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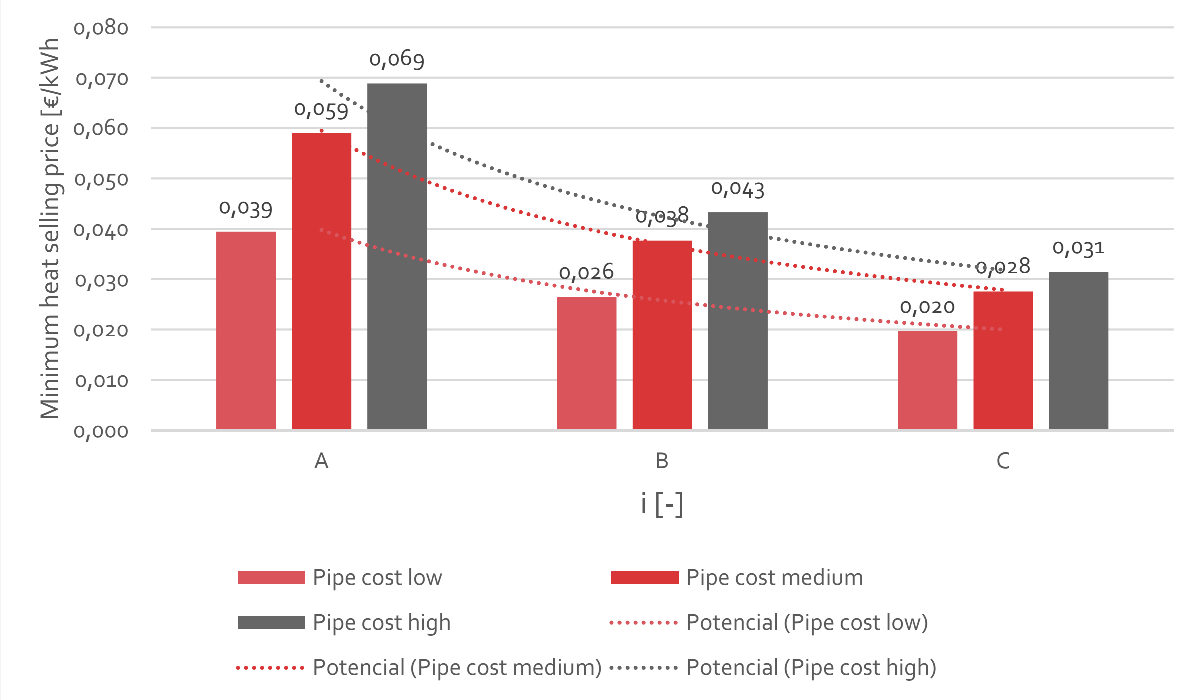

Figure 15: Sensitivity analysis of the minimum heat selling price changing the equivalent full load hours for LIPOR

3.4 Conclusion of the SO WHAT Demo-Sites LCOEH

The calculation of LCOEH for ENCE and LIPOR demo-sites has been carried out. For both demo-sites there has been assumed that all the demand is satisfied by the recovered heat and no another fuels are used to increment the total amount of delivered heat (i.e. E_{DH} set to zero in the LCOEH formula). Therefore, also the fuel cost ($c_{excess\ heat}$ in the revenues equation) has been set to zero, indeed the waste heat recovered is a product of other processes and its exploitation does not require an increase in the fuel consumption. For each demo-site there have been evaluated:

- The LCOEH and the minimum heat selling price.
- The trend of the minimum heat selling price changing the cost expressed in euro per meter for the construction of the heat grid.
- The trend of the minimum heat selling price changing the amount of heat that is recovered and delivered (considering a demand rise due to an increasing of the end-user gross floor area or of the buildings number connected to the pre-existing grid).
- The trend of the minimum heat selling price chancing the equivalent full load hours of the demo-sites plants.

In the analysis carried out the LCOEH values that have been obtained are equal to 0.034€/kWh for ENCE and 0.059€/kWh for LIPOR. that are lower than the gas national price (respectively 0718€/kWh and 0.0643€/kWh) (17). For this reason, both plants configurations provided by the firms are economically competitive with the natural gas heating technologies, in addiction to have environmental advantages deriving from the waste heat recover and exploitation by heat grids.

In order to evaluate the possible variation about the heat grid installation cost expressed in euro per linear meter, a sensitivity analysis has been carried out changing "c_p" in the revenues equation. For both demo-sites, the rise of the network costs leads to increase the minimum heat selling prices and,

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moreover, for LIPOR causes a level of the minimum heat selling price higher than the gas national price and the consequent loss of the economic competitiveness with the natural gas heating technologies.

To evaluate the influence of the delivered heat amount on the minimum heat selling price, a sensitivity analysis has been carried out changing "Q" in the formula of the revenues and the amount of heat managed by the considered technologies in the LCOEH formula. The increase of the delivered heat amount has been taken into account for the pipe installation costs, however it has not been considered for technologies costs (assuming that technologies types and models are fixed and only the number of installed units varies with the heat amount). Fixing the pipe installation cost level, the increase in the heat delivered to the end-user leads to a lower minimum heat selling price for both demo-sites. However, the advantageous decrease of the minimum heat selling price becomes lower increasing the heat recovered causing, proportionally, a lower economic advantage to invest in the increment of the grid potential at high heat amount respect to low heat amount. Moreover, the delivered heat reduction for LIPOR leads to a minimum heat selling price higher than the gas national price again and to the consequent loss of the economic competitiveness with the natural gas heating technologies.

In order to evaluate the influence of the equivalent operative full load hours of the demo-sites plants on the minimum heat selling price, a sensitivity analysis has been carried out changing "i" in the formula of LCOEH. The variation about the equivalent operative full load hours affects both the amount of heat recovered and the amortization of the technologies' costs. The results reveal that the minimum heat selling price decreases with the increase of the equivalent full load hours, however the advantageous reduction is lesser at high values of "i". Moreover, considering LIPOR demo-site, it is possible to highlights the stronger dependency of the minimum heat selling price reduction by the "i" rise respect to the "Q" rise.

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4 Value Chains of the SO WHAT Demo-Sites

In this chapter, generic value chains for WH/C and the most common RES have been developed, which then have been adapted for each demo-site based on information extracted from online interviews with the SO WHAT demo-sites partners and the completion of information checklists.

4.1 Introduction of the Value Chain Concept

Michael E. Porter, of Harvard Business School, introduced the concept of "Value Chain" in his book "Competitive Advantage: Creating and Sustaining Superior Performance" (1985) (18). The following excerpt from the book defines Porter's ideology of competitive advantage:

"Competitive advantage cannot be understood by looking at a firm as a whole, it stems from the many discrete activities a firm performs in designing, producing, marketing, delivering, and supporting its product" (18).

Value chain is a strategic analysis tool that helps to determine the competitive advantage of companies, with the aim of generating a value increase.

Figure 16: Value Chain concept definition

In a very summary way, value is "what clients are willing to pay for what a company offers". A profitable company is one whose value is higher than the costs of producing a product or offering a service. Therefore, the objective of any business strategy should be to maximize the value and minimize the costs, being the value and not the costs what is analysed to measure the market position of a company.

Through a value chain analysis, it is possible to examine and divide a company into its most relevant strategic activities in order to understand how costs work and where the differentiation lies.

Value chain analysis establishes four aspects of the competitive landscape:

- **Degree of integration:** All those activities carried out in the company itself (not in other independent companies) are defined.
- **Industrial landscape:** Market and the sectors related to the company and in which it competes.
- **Segment landscape:** Variations to which the product (or service) and the clients may be affected.
- **Geographical landscape:** Countries, cities or regions where the company competes.

In his value chain concept, Porter splits business activities into "primary" and "support" (specific activities in each category vary in function of the industrial sector of the company):

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- **Primary activities:** Primary activities are essential for adding value and creating competitive advantage:
    - Inbound logistics: Receiving, warehousing, and managing inventory.
    - Operations: Procedures of transforming raw materials into final products.
    - Outbound logistics: Storage and distribution of final products.
    - Marketing & Sales: Strategies to improve visibility and target suitable clients, such as advertising, promotion and pricing.
    - After-sales service: Programmes to maintain product and improve the experience of clients, such as customer service, maintenance, repair, refund, and exchange.

- **Support activities:** The target of support activities is to increase the efficiency of primary activities.
    - Firm infrastructure: Company systems and composition of its management team, such as planning, accounting, finance and quality control.
    - Human resource management: Search, recruitment and motivation of staff who will fulfil the business strategy of the company.
    - Technology development: Research-Development-Innovation stage (R+D+I), such as designing and developing manufacturing techniques and automating processes.
    - Procurement: Acquisition of raw material or services from an external source.

The following figure shows Porter's value chain:

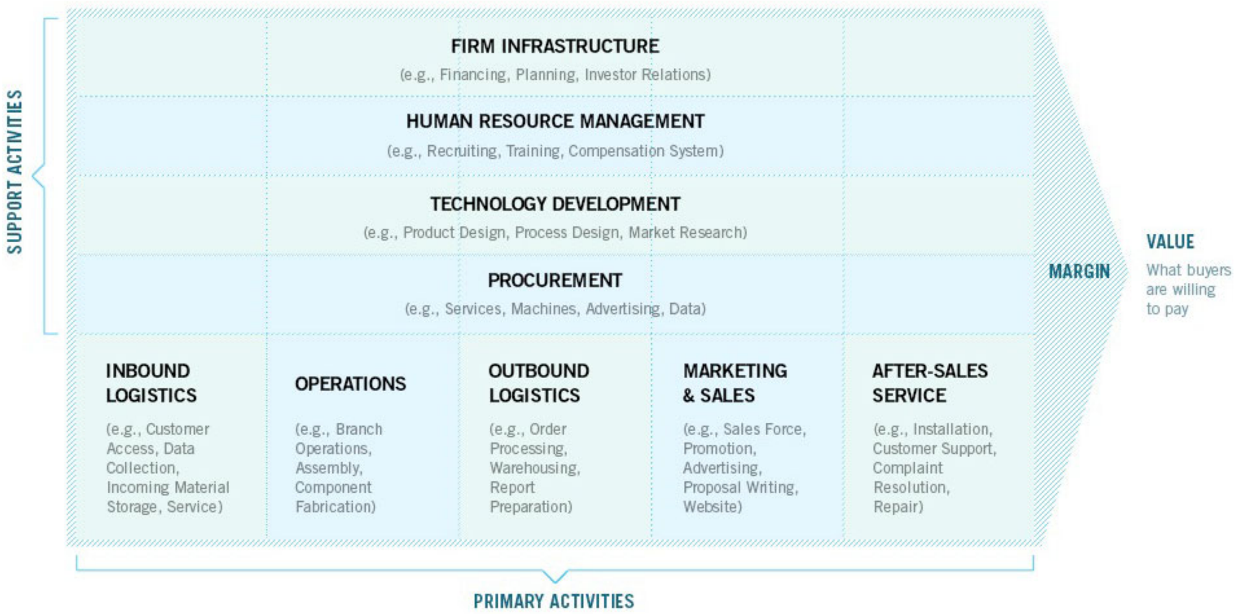

Figure 17: Michael E. Porter's Value Chain (19)

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Value chain improvement may be developed through one of the following competitive advantage strategies:

- **Low-cost provider:** Value chain analysis focuses on costs and how a company can reduce those costs.
- **Specialization:** Value chain analysis focuses on the activities that increase value, such as the creation of a unique product or the differentiation in service.

4.2 Generic WH/C Value Chain

The generic value chain developed for WH/C implementations is made up of the following five categories:

- **Planning and design:** This category is of utmost importance, since it depends on its development whether the other categories are carried out or not. Energy consultants have a main role in decision-making regarding both the technical (hardware and software definition) and the investment analysis. The execution of grants, permissions and licenses can define the viability of a project, as well as the public procurement.
- **Components supply:** The type of facility defines the components, both hardware and software, to be supplied. The planning of the receipt of components directly affect the project deadlines.
- **Installation:** During the installation, many companies of different kinds tend to coexist throughout all its phases, so that good planning is essential. The execution of inspections, calibrations and commissioning are essential in this category.
- **Operation & Maintenance**: Considering the lifetime of the facility, the O&M phase is the most expensive. Good O&M lengthens the lifetime of the facility and prevents critical failures. ESCOs and energy contracts are defined in this category.
- **Value added:** Depending on the aims of the project, many aspects can be developed, starting from a common focus as the green value. Technological innovation (R+D+I) has also an important weight in this category.

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The following table shows the generic value chain developed for WH/C implementations:

Table 16: Generic WH/C Value Chain

WH/C VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Energy consultants	**Hardware supply:**	**Installation companies (labour)**	**Energy Service Companies (ESCOs)**	**Local job creation**
Hardware definition:	• Heat exchangers	**Hardware installation**	**Energy contracting**	**Growth of the local economy**
• WH/C generation points	• Absorption refrigerators	**Software installation**	**Subcontracted companies**	**Technological innovation (R+D+I)**
• WH/C recovery technologies	• Water pumps	**Inspections**	**Monitoring**	**Green value:**
• Pump system	• Piping	**Commissioning**	**Service & Maintenance**	• Lowered GHG emissions
• Distribution network	• Measuring equipment	**Calibration**	**Metering & Invoicing**	• Primary energy-savings
Software definition:	**Software supply:**			• Energy efficiency
• Calculation/simulation software	• Control system (SCADA)			
• Control system	• Visualization tool			
Permissions and licences				
Grants				
Public procurement				

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4.3 Generic RES Value Chains

There have been developed generic value chains for the most common RES technologies, following the same structure as for the WH/C implementation.

The RES technologies are listed below:

- Biofuels.
- Biomass & Waste.
- Geothermal (Deep & Shallow).
- Small Hydro.
- Solar (PV & Thermal).
- Onshore Wind.

The following tables show the generic value chains developed for each RES technology, starting with the Biofuels generic value chain below:

Table 17: Biofuels Value Chain

BIOFUELS VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Consultancy-Technical	Distribution & Blending	Hardware installation	Integrated service provider	Technological innovation (R+D+I)
Market research	Feedstock suppliers	Software installation	Consultancy-Operation & Maintenance (O&M)	Green value
Banking-Corporate	Producers	Testing & Certification services	Education & Training	Distributor
Banking-Custody	Retailing/ International Oil Companies (IOC)		Contract maintenance	Public relations company
Trust & Deposit	Hardware supply		Contract manufacturing	
Insurance provider	Control room systems		Inspection & Maintenance	
Lawyer-Commercial			Specialist services	
Lawyer-Financial markets				
Lawyer-Project finance				
Recruitment/Search				

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The following table shows the generic Biomass & Waste value chain:

Table 18: Biomass & Waste Value Chain

BIOMASS & WASTE VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Consultancy-Technical	Feedstock supply	Hardware installation	Integrated service provider	Technological innovation (R+D+I)
System integration	Manufacturing equipment	Software installation	Consultancy-Operation & Maintenance (O&M)	Green value
Market research	Control room systems	Testing & Certification services	Education & Training	Distributor
Banking-Corporate			Contract maintenance	Public relations company
Banking-Custody			Contract manufacturing	
Trust & Deposit			Inspection & Maintenance	
Insurance provider			Specialist services	
Lawyer-Commercial			Power generation	
Lawyer-Financial markets				
Lawyer-Project finance				
Recruitment/Search				

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The following table shows the generic Geothermal (Deep & Shallow) value chain:

Table 19: Geothermal Value Chain

GEOTHERMAL VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Consultancy-Technical	Turbine & Power block	Hardware installation	Integrated service provider	Technological innovation (R+D+I)
Balance of plant	Control room systems	Software installation	Consultancy-Operation & Maintenance (O&M)	Green value
Pre-Drilling exploration	Heat exchanger	Production drilling	Education & Training	Distributor
Exploration drilling	Well pumps	Testing & Certification services	Contract maintenance	Public relations company
Well & Resource confirmation	Measuring equipment		Contract manufacturing	
Market research			Inspection & Maintenance	
Banking-Corporate			Specialist services	
Banking-Custody			Power purchase	
Trust & Deposit				
Insurance provider				
Lawyer-Commercial				
Lawyer-Financial markets				
Lawyer-Project finance				
Recruitment/Search				
Permission and licenses				

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The following table shows the generic Small Hydro value chain:

Table 20: Small Hydro Value Chain

SMALL HYDRO VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Consultancy-Technical	Turbines	Civil works/Builder	Integrated service provider	Technological innovation (R+D+I)
Market research	Pipes network	Hardware installation	Consultancy-Operation & Maintenance (O&M)	Green value
Banking-Corporate	Control room systems	Software installation	Education & Training	Distributor
Banking-Custody		Testing & Certification services	Contract maintenance	Public relations company
Trust & Deposit			Contract manufacturing	
Insurance provider			Inspection & Maintenance	
Lawyer-Commercial			Specialist services	
Lawyer-Financial markets			Power purchase	
Lawyer-Project finance				
Recruitment/Search				

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The following table shows the generic Solar (PV & Thermal) value chain:

Table 21: Solar Value Chain

SOLAR VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Consultancy-Technical	Cells	Hardware installation	Integrated service provider	Technological innovation (R+D+I)
Market research	Polysilicon / Ingots	Software installation	Consultancy-Operation & Maintenance (O&M)	Green value
Balance of plant	Modules	Testing & Certification services	Education & Training	Distributor
Banking-Corporate	Raw feedstock (solar-grade silicon)		Contract maintenance	Public relations company
Banking-Custody	Wafers		Contract manufacturing	
Trust & Deposit	Control room systems		Inspection & Maintenance	
Insurance provider	Solar thermal panels		Specialist services	
Lawyer-Commercial	Heat accumulation tanks		Energy Performance Contract (EPC)	
Lawyer-Financial markets	Pumping system		Owner/Operator	
Lawyer-Project finance				
Recruitment/Search				

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The following table shows the generic Onshore Wind value chain:

Table 22: Onshore Wind Value Chain

ONSHORE WIND VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Consultancy-Technical	Bearings	Hardware installation	Integrated service provider	Technological innovation (R+D+I)
Market research	Blades	Software installation	Consultancy-Operation & Maintenance (O&M)	Green value
Banking-Corporate	Gearboxes	Testing & Certification services	Education & Training	Distributor
Banking-Custody	Generators		Contract maintenance	Public relations company
Trust & Deposit	Power generator		Contract manufacturing	
Insurance provider	Turbines		Inspection & Maintenance	
Lawyer-Commercial	Control room systems		Specialist services	
Lawyer-Financial markets				
Lawyer-Project finance				
Recruitment/Search				

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4.4 Demo-Site: LIPOR Maia Waste-to-Energy Plant (Portugal)

LIPOR is participating in the SO WHAT project mainly with respect to its Waste-to-Energy (WtE) plant located in Maia, Portugal, which treats 380,000 tons of waste per year.

The WtE Plant uses the high temperature of the gases from the waste combustion to produce steam for electricity production. In this framework, it was developed in 2017 a study concerning the assessment of the technical-economic feasibility of recovery waste heat of LIPOR's WtE Plant and implementation of a district heating system connecting LIPOR and Francisco Sá Carneiro Airport, in Oporto.

Multiple different options were considered (additional burning of waste in the boiler, additional drawing of turbine steam in medium pressure extraction, heat recovery of the exhaust gas from the boiler) and the second one has subsequently been the subject of detailed techno-economic feasibility analysis (option considered: 3 absorption chillers of 4,000 kW of cooling power). Thanks to SO WHAT, LIPOR will go further in waste heat and cold WH/C valorisation investments related to Oporto Airport.

Table 23: LIPOR Description

Demonstration Site	LIPOR Maia Waste-to-Energy Plant
Partner	LIPOR
Location	Maia (Portugal)
Sector	Waste-to-Energy (WtE)
Process	Two treatment lines in a continuous and automatic operation burn and treat 380,000 tons/year of waste.
Temperature	150°C

Figure 18: LIPOR Waste-to-Energy Plant in Maia (Portugal)

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The following table shows the LIPOR WH/C value chain (high importance activities are highlighted):

Table 24: LIPOR WH/C Value Chain

LIPOR WH/C VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Energy consultants	**Hardware supply:**	**Installation companies (labour)**	**Energy Service Companies (ESCOs)**	**Local job creation**
Hardware definition:	• Heat exchangers	**Hardware installation**	**Energy contracting**	**Growth of the local economy**
• WH/C generation points	• Absorption refrigerators	**Software installation**	**Subcontracted companies**	**Technological innovation (R+D+I)**
• WH/C recovery technologies	• Water pumps	**Inspections**	**Monitoring**	**Green value:**
• Pump system	• Piping	**Commissioning**	**Service & Maintenance**	• Lowered GHG emissions
• Distribution network	• Measuring equipment	**Calibration**	**Metering & Invoicing**	• Primary energy-savings
Software definition:	**Software supply:**			• Energy efficiency
• Calculation/simulation software	• Control system (SCADA)			
• Control system	• Visualization tool			
Permissions and licences				
Grants				
Public procurement				

For LIPOR demo-site the following WH/C value chain categories involve a value increase:

- **Planning and design:** Energy consultants give advice in order to make decisions and gain knowledge about market energy positioning. The definition of the WH/C generation points is the main core of the project, everything comes after that. The WH/C recovery technologies will have an influence on the energy rate and efficiency of the process, together with the pumps, that will be the distributors of the energy, being their liability and dimension decisive. The distribution network will affect the viability of the plant and the business model. The calculation/simulation software will predict the energy needs and availability, while the control system will guarantee that all works accordingly. Permission and licenses are needed in order to develop and implement the project without setbacks, while grants are needed to finance the project.
- **Components supply:** Heat exchangers are a vital piece of hardware to the whole plant, because they are responsible for recovering the heat, as well as water pumps and pipping for distribution. The measuring equipment is important for monitoring the general functioning and preventive maintenance. the control system (SCADA) is vital for data collection, decision making and monitoring, while the visualization tool is important for a general comprehension of the system functioning.
- **Operation & Maintenance (O&M):** Energy Service Companies (ESCOs), energy contracting, subcontracted companies and service & maintenance are important for the reliability and

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operation of the plant. Monitoring provides knowledge and awareness of the operation of the plant, while metering & invoicing are important for the business model.

- **Value added:** Spreading the economic and social advantages of WH/C, incrementing and adding value to the local economy are important objectives for LIPOR. Investing in technological innovation (R+D+I) means incrementing knowledge and future replication. Lowered GHG emissions mean be in line with the EU CO2 reduction targets, as well as the local targets, like the ones assumed in the "Covenant of mayors".

The following table shows the LIPOR Biomass & Waste value chain (high importance activities are highlighted):

Table 25: LIPOR Biomass & Waste Value Chain

LIPOR BIOMASS & WASTE VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Consultancy-Technical	**Feedstock supply**		Integrated service provider	Technological innovation (R+D+I)
System integration	Manufacturing equipment		Consultancy-Operation & Maintenance (O&M)	**Green value**
Market research	Control room systems		Education & Training	Distributor
			Contract maintenance	**Public relations company**
			Contract manufacturing	
			Inspection & Maintenance	
			Specialist services	
			Power generation	

For LIPOR demo-site the following Biomass & Waste value chain categories involve a value increase:

- **Components supply:** The security of the feedstock supply is essential, in order to ensure the continuous operation of the plant.
- **Value added:** The green value (lowered GHG emissions) means be in line with the EU CO2 reduction targets, as well as the local targets, like the ones assumed in the "Covenant of mayors". Due to LIPOR is a company with high visibility throughout the metropolitan area, this project can be seen as an example that solid waste processing has a very important "green" value, being not just a waste collector.

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The following table shows the LIPOR Solar PV value chain (high importance activities are highlighted):

Table 26: LIPOR Solar PV Value Chain

LIPOR SOLAR PV VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Consultancy-Technical	Cells	Hardware installation	Integrated service provider	Technological innovation (R+D+I)
Balance of plant	Polysilicon / Ingots	Software installation	Consultancy-Operation & Maintenance (O&M)	**Green value**
Banking-Corporate	Modules	Testing & Certification services	Education & Training	Distributor
Banking-Custody	Raw feedstock (solar-grade silicon)		Contract maintenance	**Public relations company**
Insurance provider	Wafers		Contract manufacturing	
Lawyer-Commercial	Control room systems		Inspection & Maintenance	
Lawyer-Financial markets			Specialist services	
Lawyer-Project finance			Energy Performance Contract (EPC)	
			Owner/Operator	

For LIPOR demo-site the following Solar PV value chain categories involve a value increase:

- **Planning and design:** Get technical and economical advice is essential in order to make decisions and gain knowledge about market energy positioning. The balance of plant provides the correct dimensioning for an optimum performance. Banking-corporate and banking-custody define the financing model. The insurance provider assures the viability of the service and/or equipment. The commercial lawyer is linked with commercial contracts, while financial markets lawyer is linked with financial contracts. The project finance lawyer manages the overall financing of the project/plant.
- **Value added:** The green value (lowered GHG emissions) means be in line with the EU CO_2 reduction targets, as well as the local targets, like the ones assumed in the "Covenant of mayors". Due to LIPOR is a company with high visibility throughout the metropolitan area, this project can be seen as an example that solid waste processing has a very important "green" value, being not just a waste collector.

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4.5 Demo-Site: ISVAG Waste-to-Energy Plant (Belgium)

ISVAG's location, close to the city of Antwerp, Belgium, drove the company to plan the construction of a new waste-to-energy plant where the focus will be on maximising energy efficiency by additionally recovering heat for a district heating network. The incineration of the residual household waste takes place in a grate furnace.

Different studies were carried out related to the recovery of residual heat (feasibility study small scale district heating grid, feasibility study large scale district heating network, design heat recovery in the existing plant, design new waste-to-energy plant). The first step to this project is the construction of a small scale district heating network, which will be powered with heat from the existing waste-to-heat plant, while the large scale district heating network and brand new plant are foreseen to be taken into operation in 2023.

ISVAG's role in the SO WHAT project is multiple, considering that they have already an incineration plant running and they are planning the construction of a new one in parallel to a district heating network.

Table 27: ISVAG Description

Demonstration Site	ISVAG Waste-to-Energy Plant
Partner	Kelvin Solutions (KELVIN)
Location	Antwerp (Belgium)
Sector	Incinerator
Process	ISVAG superheated steam power plant valorises via incineration local wastes and WH from the boilers.
Temperature	400°C

Figure 19: ISVAG Waste-to-Energy Plant in Antwerp (Belgium)

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The following table shows the ISVAG WH/C value chain (high importance activities are highlighted):

Table 28: ISVAG WH/C Value Chain

ISVAG WH/C VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Energy consultants	**Hardware supply:**	**Installation companies (labour)**	**Energy Service Companies (ESCOs)**	**Local job creation**
Hardware definition:	• Heat exchangers	**Hardware installation**	**Energy contracting**	**Growth of the local economy**
• WH/C generation points	• Water pumps	**Software installation**	**Subcontracted companies**	**Technological innovation (R+D+I)**
• WH/C recovery technologies	• Piping	**Inspections**	**Monitoring**	**Green value:**
• Pump system	• Measuring equipment	**Commissioning**	**Service & Maintenance**	• Lowered GHG emissions
• Distribution network	**Software supply:**	**Calibration**	**Metering & Invoicing**	• Primary energy-savings
Software definition:	• Control system (SCADA)			• Energy efficiency
• Calculation/simulation software	• Visualization tool			
• Control system				
Permissions and licences				
Grants				
Public procurement				

For ISVAG demo-site the following WH/C value chain categories involve a value increase:

- **Planning and design:** Energy consultants are the main core of starting a WH/C business, because they contribute with their experience and know-how in order to make decisions. WH/C generation points and recovery technologies are the main components of the facility. The calculation/simulation software must be widely accepted (tool with good reputation and proven success). Permission and licenses are required due the occupation of public area for the distribution network. Grants are needed to make the investment competitive due to the low gas prices in Belgium. Not yet known if applicable for ISVAG case, if so, public procurement has a big impact on the process speed.
- **Components supply:** Heat exchanger are the main component of the facility, due to as recuperators of the waste heat, their performance is crucial.
- **Installation:** The correct selection of the installation companies is of vital importance for the future of the project. The quality of the hardware installation has a big impact on the value chain, having a bad installation to be corrected by inspections. Commissioning guarantees the proposed quality of the installations.
- **Operation & Maintenance (O&M):** ISVAG is not sure of going to exploit the WH/C, therefore, ESCOs may or may not be part of the project. Energy contracting is directly related to the control of OPEX costs. Service & maintenance must be focused on giving customers a high

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supply certainty, while metering and invoicing provide reliability of supplier and certainty of income.

- **Value added:** Local job creation will be a driver to keep the company located as it is now, while growth of the local economy will be a driver to keep the companies involved located as they are now. The entire project would project a "green" image for producers and clients.

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4.6 Demo-Site: RADET Constanta DHN (Romania)

RADET Constanta, established in 1991, is the District Heating Company of the municipality of Constanta, Romania, ensuring 70% of the urban heating demand of 170,000 inhabitants.

At the current state, RADET does not employ waste heat in its district heating network but thanks to the SO WHAT project it aims at injecting heat from neighbouring industries (petrochemical, manufacturing etc.) to become less fossil fuel dependent and to promote new business models. In this framework, the project will also promote the knowledge transfer from the world class district heating and waste heat recovery from the Swedish cluster to less advanced system in EU, becoming front-runner for Eastern Europe district heating networks renovation thanks to waste heat valorisation.

Table 29: RADET Description

Demonstration Site	RADET Constanta DHN
Partner	RADET
Location	Constanta (Romania)
Sector	DHN, WH (from local industries)
Process	RADET aims to renovate this old DHN valorising local industries WH.
Temperature	(70°C;250°C)

Figure 20: RADET District Heating Network in Constanta (Romania)

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The following table shows the RADET WH/C value chain (high importance activities are highlighted):

Table 30: RADET WH/C Value Chain

RADET WH/C VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Energy consultants	**Hardware supply:**	**Installation companies (labour)**	**Energy Service Companies (ESCOs)**	**Local job creation**
Hardware definition:	• Heat exchangers	**Hardware installation**	**Energy contracting**	**Growth of the local economy**
• WH/C generation points	• Absorption refrigerators	**Software installation**	**Subcontracted companies**	**Technological innovation (R+D+I)**
• WH/C recovery technologies	• Water pumps	**Inspections**	**Monitoring**	**Green value:**
• Pump system	• Piping	**Commissioning**	**Service & Maintenance**	• Lowered GHG emissions
• Distribution network	• Measuring equipment	**Calibration**	**Metering & Invoicing**	• Primary energy-savings
Software definition:	**Software supply:**			• Energy efficiency
• Calculation/simulation software	• Control system (SCADA)			
• Control system	• Visualization tool			
Permissions and licences				
Grants				
Public procurement				

For RADET demo-site the following WH/C value chain categories involve a value increase:

- **Planning and design:** Regarding WH/C generation point, the project consists on the conversion of secondary heat distribution station into a district heating plant, integrated in the district heating network. By this conversion, the power plant shall use only solar and biomass and will be fully autonomous from the supply side. Regarding WH/C recovery technologies, the heat produced by the new power plant shall be recovered and distributed to the local dwellings and condominiums. It shall be used the existing secondary network and the heat transfer and accumulation units will be upgraded. The project is a pilot plant and the business model has to be tested and validated using an appropriate calculation/simulation software. Taking into account that the business model includes a partnership between two SMEs and RADET, the control system is a fundamental need for an appropriate control of the processes.
- **Components supply:** The new power plant integrating solar and biomass has to be integrated into an existing secondary heat distribution station and in this respect, there are required several changes of the architecture of the piping network. The measurement of parameters is a fundamental element for an appropriate business development between the two SMEs and RADET. In this respect, the parties shall agree and establish appropriate and commonly agreed measurement system. RADET has implemented a high performance SCADA system for the operation of the entire DHN of Constanta city. In this context, the new pilot plant shall be integrated into the SCADA system of RADET.

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- **Installation:** The installation of the new equipment has to be performed taking into consideration the existing constrains in the station building. In this respect, the installation companies have to assure highly skilled labour force. Regarding the hardware installation, the entire system, including two pellet boilers with pellet supply and storage, chimneys and ancillaries, shall also include an innovative type of filters for stack gases that have to operate in real time adaptive parameters. The solar installation shall include 100 solar thermal panels that will have a special treatment of active surfaces with anti-static protection. In the pilot phase, there have been defined specific inspections for the evaluation of the proper operation of the system. In the commissioning phase, there were defined specific aspects related to the integration of the new installation in the existing building. The inspection works shall evaluate the structural integrity of the building and the proper hydro-thermal insulation. Also there will be evaluated the aspects related to the safety and security of operators. Using the feedback from the monitoring and inspection process, there will be adjusted the operational parameters and if necessary, there shall be adjusted the architecture of the installation.
- **Operation & Maintenance (O&M):** The operation and maintenance activities will be subcontracted. It shall be a later decision if the subcontract will be executed by the RADET squad or by specialized companies. The monitoring activities will be executed by all partners that are connected to this project, such as RADET, the companies providing solar and biomass equipment and the university team. Metering and invoicing will be organized between RADET and the two companies that are providing solar and biomass equipment.
- **Value added:** The integration of solar thermal panels shall have an important impact in the reduction of GHG emissions. Additionally, the pellet boilers are very high efficiency (<90%) that shall also contribute to the decrease of the GHG emissions. The plant using solar and biomass energy shall be coupled to the main piping system from the district heating network. In this way, the entire quantity of energy produced locally shall contribute to the diminishing of equivalent primary energy consumption from the thermal power plant. The new plant using solar and thermal energy replaces the existing distribution loop of thermal energy produced from the thermal power plant and distributed via the district heating piping network. The estimated efficiency at the power plant is in the range of 60% and the efficiency of distribution piping is 70%. So the overall efficiency is around 40%. The new plant is going to have 90% efficiency of the boilers and there is also the reduction of the losses from the primary distribution piping. This will lead to very important improvement of the energy efficiency of the new value chain. The project is an innovative project from three perspectives as following:
  1- The solar panels are protected with special layers for anti-static protection, based on the specific analysis of the dust composition from the location.
  2- The biomass equipment has integrated a system of dynamic filtering of stack gases, in order to minimize any king of particulate emissions.
  3- The operation of the plant has to match the demand curve of thermal energy by maximizing the use of solar thermal energy and appropriate operation of the boilers, in order to minimize the emissions.

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The following table shows the RADET Biomass & Waste value chain (high importance activities are highlighted):

Table 31: RADET Biomass & Waste Value Chain

BIOMASS & WASTE VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Consultancy-Technical	**Feedstock supply**	**Hardware installation**	Integrated service provider	**Technological innovation (R+D+I)**
System integration	**Manufacturing equipment**	Software installation	**Consultancy-Operation & Maintenance (O&M)**	**Green value**
Market research	Control room systems	**Testing & Certification services**	Education & Training	Distributor
Banking-Corporate			**Contract maintenance**	Public relations company
Banking-Custody			Contract manufacturing	
Trust & Deposit			**Inspection & Maintenance**	
Insurance provider			Specialist services	
Lawyer-Commercial			Power generation	
Lawyer-Financial markets				
Lawyer-Project finance				
Recruitment/Search				

For RADET demo-site the following Biomass & Waste value chain categories involve a value increase:

- **Planning and design:** The new generation of high efficiency pellet boilers require detailed knowledge of the processes, feedstock, emissions and automation. The pellet boilers will operate in an integrated system with solar thermal panels. The integration has to take into consideration the characteristics of the two systems and specific knowledge on matching with the target required characteristic of the integrated system.
- **Components supply:** The key factor for the success of the project is to assure the supply of the pellets from the local producers. There were identified several producers and there is already a plan for ensuring a continuous and secure supply. The advantage of this project is the involvement of a manufacturer of high performance pellet boilers, based on a Romanian patent. For extending this project to many other plants, it has been signed an agreement between the manufacturer and RADET, in order to be involved in the manufacturing of some of the components.
- **Installation:** The installation of the hardware shall be performed by the manufacturer, in order to assure all the requirements for reaching the performance standards. In order to obtain the permit for operating the new plant based on solar and biomass energy, there is a special regulation to perform appropriate tests and certify the plant for the production of thermal energy.
- **Operation & Maintenance (O&M):** The high performance of the boilers requires an appropriate knowledge for their operation and maintenance, mainly due to the integration

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of the system with a solar thermal installation. The manufacturer of pellet boilers has some local contract partners that are offering maintenance services onsite. The inspection and maintenance activities in the pilot phase of the project (2020-2022) will be carried out by RADET, by the contract partner of the manufacturer and by the university.

- **Value added:** The main technological innovation consists on the development of highly versatile filters that could operate with dynamic adaptation to the concentration of pollutants in the stack gases. The pellet boilers are high efficiency (>90%) and might be integrated in local loops for selection and incineration of waste biomass. If is taken into consideration that the waste biomass is generated by aerobic and anaerobic methane processes, having the intensity of GHG 22 comparative to CO_2, it results that the reduction of GHG gases is synergic combination of biomass waste neutralization and high efficiency of the burning process.

The following table shows the RADET Solar Thermal value chain (high importance activities are highlighted):

Table 32: RADET Solar Thermal Value Chain

SOLAR THERMAL CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Consultancy-Technical	Control room systems	**Hardware installation**	Integrated service provider	**Technological innovation (R+D+I)**
Market research	**Solar thermal panels**	Software installation	**Consultancy-Operation & Maintenance (O&M)**	**Green value**
Balance of plant	**Heat accumulation tanks**	**Testing & Certification services**	Education & Training	Distributor
Banking-Corporate	Pumping system		**Contract maintenance**	Public relations company
Banking-Custody			Contract manufacturing	
Trust & Deposit			**Inspection & Maintenance**	
Insurance provider			Specialist services	
Lawyer-Commercial			Energy Performance Contract (EPC)	
Lawyer-Financial markets			**Owner/Operator**	
Lawyer-Project finance				
Recruitment/Search				

For RADET demo-site the following Solar Thermal value chain categories involve a value increase:

- **Planning and design:** The intermittence of solar radiation and the associated performance of solar panels in the production of thermal energy is a new type of knowledge for the operators of the district heating system. In this perspective, the consultancy is provided by

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MEDGREEN. The integration of solar thermal equipment in the renewable energy plant requires specific procedures for managing the BOP (blow-out preventer). The procedures will be defined by RADET in collaboration with the manufacturer of solar thermal panels and will be validated during the pilot phase.

- **Components supply:** Solar thermal panels are high performance panels that have in addition a treatment with antistatic layer that is tailored to the composition of particulate suspensions on the site of the plant. The system of thermal energy accumulation is required both by the intermittence of solar radiation and the variability of the consumption of thermal energy. There were selected high performance accumulation tanks.
- **Installation:** The installation process of the hardware requires very specific adjustments of positioning and fixing the panels, and an appropriate match with the structural framework of the roof. For this reason, there will be used highly specialized experts. In order to obtain the permit for operating the new plant based on solar and biomass energy, there is a special regulation to perform appropriate tests and to certify the plant for the production of thermal energy.
- **Operation & Maintenance (O&M):** The high performance of the solar thermal panels requires appropriate knowledge for operation and maintenance, mainly due to the integration of the system with a pellet boiler installation. The manufacturer of solar thermal panels has some local contract partners that are offering maintenance services onsite. The inspection and maintenance activities in the pilot phase of the project (2020-2022) will be carried out by RADET, by the contract partner of the manufacturer and by the university. The owner of the installation is its manufacturer and the operator is RADET, based on a contract between the parties.
- **Value added:** The solar panels that are operated in urban agglomerations have some problems due to the deposition of dust and dirt on the active surface. The location of the plant is also close to the seashore and there are additional suspensions of sand and abrasive micro-particles. For this purpose, it has been conducted detailed analyses of the composition of deposited dust and dirt on the site and there were conceived antistatic paints tailored for the type of suspensions in the specific location of the plant The production of thermal energy using solar thermal panels has a minimal content of carbon footprint. Only taking into consideration the Lifecycle Assessment including the manufacturing and transport on location of the panels and electricity associated to the pumping process, it may be counted a very small amount of GHG.

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4.7 Demo-Site: UMICORE Rare Material Centre (Belgium)

UMICORE is a global player in materials technology that develops technologies and produces/recycles materials for high-grade solar cells, rechargeable batteries, LED applications and catalytic converters.).

The UMICORE plant is close to the current heat-users on the Olen Campus site, which are all supplied with steam generated in two cogeneration turbines and multiple steam boilers.

A pre-feasibility study is ongoing to integrate a campus-wide heat network. This would enable the valorisation of multiple sources of waste heat, to share them with neighbouring companies, and possibly even up to the city of Herentals, and/or to integrate new sources of renewable heat. The already identified sources of waste heat derives from processes as hydrogenation and pyrogenation but other exothermic reactions could be a viable source of waste heat. These opportunities will be studied thanks to the support of KELVIN Solutions.

Table 33: UMICORE Description

Demonstration Site	UMICORE Rare Material Centre
Partner	Kelvin Solutions (KELVIN)
Location	Olen (Belgium)
Sector	High-Tech Manufacturing
Process	UMICORE's Olen site revolves around recycling and production of high-tech materials based on cobalt and germanium.
Temperature	(50°C;265°C)

Figure 21: UMICORE Rare Material Recycling and Production Centre in Olen (Belgium)

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The following table shows the UMICORE WH/C value chain (high importance activities are highlighted):

Table 34: UMICORE WH/C Value Chain

UMICORE WH/C VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Energy consultants	**Hardware supply:**	**Installation companies (labour)**	**Energy contracting**	**Local job maintenance**
Hardware definition:	• Heat exchangers	**Hardware installation**	**Subcontracted companies**	**Growth of the local economy**
• WH/C generation points	• Water pumps	**Software installation**	**Monitoring**	**Technological innovation (R+D+I)**
• WH/C recovery technologies	• Piping	**Inspections**	**Service & Maintenance**	**Green value:**
• Pump system	• Measuring equipment	**Commissioning**	**Metering & Invoicing**	• Lowered GHG emissions
• Distribution network	**Software supply:**	**Calibration**		• Primary energy-savings
Software definition:	• Control system (SCADA)			• Energy efficiency
• Calculation/simulation software	• Visualization tool			
• Control system				
Permissions and licences				
Grants				
Public procurement				

For UMICORE demo-site the following WH/C value chain categories involve a value increase:

- **Planning and design:** Energy consultants are the main core of starting a WH/C business, because they contribute with their experience and know-how in order to make decisions. WH/C generation points and recovery technologies are the main components of the facility. The calculation/simulation software must be widely accepted (tool with good reputation and proven success). Grants are needed to make the investment competitive due to the low gas prices in Belgium.
- **Installation:** The correct selection of the installation companies is of vital importance for the future of the project. The quality of the hardware installation has a big impact on the value chain, having a bad installation to be corrected by inspections. Commissioning guarantees the proposed quality of the installations.
- **Operation & Maintenance (O&M):** Energy contracting is directly related to the control of OPEX costs. Service & maintenance must be focused on giving customers a high supply certainty, while metering and invoicing provide reliability of supplier and certainty of income.
- **Value added:** Local job maintenance is basic for the balance of the local economy. The entire project would project a "green" image for producers and clients.

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The following table shows the UMICORE Deep Geothermal value chain (high importance activities are highlighted):

Table 35: UMICORE Deep Geothermal Value Chain

DEEP GEOTHERMAL VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Consultancy-Technical	**Control room systems**	**Hardware installation**	**Integrated service provider**	**Technological innovation (R+D+I)**
Balance of plant	**Heat exchangers**	Software installation	**Consultancy-Operation & Maintenance (O&M)**	**Green value**
Pre-Drilling exploration	**Well pumps**	**Production drilling**	**Education & Training**	Distributor
Exploration drilling	**Measuring equipment**	**Testing & Certification services**	**Contract maintenance**	**Public relations company**
Well & Resource confirmation			**Inspection & Maintenance**	
Market research			**Specialist services**	
Banking-Corporate			**Power purchase**	
Banking-Custody				
Trust & Deposit				
Insurance provider				
Lawyer-Commercial				
Lawyer-Financial markets				
Lawyer-Project finance				
Recruitment/Search				
Permissions and licenses				

For UMICORE demo-site the following Deep Geothermal value chain categories involve a value increase:

- **Planning and design:** Energy consultants are the main core of starting a deep geothermal business, because they contribute with their experience and know-how in order to make decisions. An analysis of the balance of plant is of high importance due to deep geothermal projects need long-term investment. Pre-drilling exploration, exploration drilling, and well & resource confirmation reduce the risk of failure in a potential well. Banking-corporate is of vital importance due to deep geothermal projects need intensive investments, and trust & deposit in order to obtain a bank loan. Insurance providers and lawyers (commercial, financial markets, and project finance) are needed due to the high risk of financial loss by failed well. Deep geothermal projects are based on uncommon technologies, so recruitment/search is an essential step. Permission and licenses are needed for deep geothermal wells.

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- **Components supply:** Control room systems and measuring equipment are important to control the fluctuation process of deep geothermal energy and to be compliant with the exploitation license. Well pumps and heat exchangers are critical and expensive components.
- **Installation:** Hardware installation is a critical procedure due to the complexity of well installations. A good well is critical and expensive, being production drilling a high importance activity. Testing & certification services are needed for the critical components on the well side.
- **Operation & Maintenance (O&M):** Due to high investments and complexity (risks) an integrated service provider is needed. Deep geothermal are high specialist projects, so they need consultancy support for a correct operation & maintenance (O&M), together with specialist services, which involves a continuous education & training. Maintenance contracting, together with power purchase, are directly related to the control of OPEX costs. Inspection & maintenance are important to keep control the fluctuating process of deep geothermal energy and supply of heat.
- **Value added:** In Belgium geological research is still limited, hence the importance of technological innovation investments (R+D+I) for future applications. Nowadays the "green value" is booming due to the big amount of RES. Deep geothermal projects must be advertised and explained for general public, because what is unknown is unwanted, hence the importance of public relation companies.

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4.8 Demo-Site: IMERYS Manufacturing Centre (Belgium)

IMERYS Graphite & Carbon is the world leader in high-tech, high performance solutions based on specialized graphite and carbons. IMERYS is situated on the industrial site of Willebroek Noord and in the direct vicinity of the industrial site of Puurs Pulaar and the municipality of Willebroek with its own residential development projects. This offers an opportunity to valorise IMERYS waste heat to industrial consumers, public buildings and residential consumers. Considering the fact that today almost no heat is recovered, a district heating network would make the site significantly more sustainable and futureproof. As a matter of fact, during the process of Carbon Black, a mixture of combustible gas is formed, which is currently burned in a furnace and no heat is recovered.

The production is 24/7, creating a continuous flow of waste heat at about 600°C, available from the chimney gasses of the furnaces. In order to valorise the waste gas stream, a study has been performed looking into different industrial options ranging from electricity production, over carbon valorisation via the production of chemicals, as well as heating circuits. This study will be used in SO WHAT as a benchmark for what it concerns both the techno-economic solution proposed and the necessary time and effort under the supervision of KELVIN Solutions.

Table 36: IMERYS Description

Demonstration Site	IMERYS Manufacturing Centre
Partner	Kelvin Solutions (KELVIN)
Location	Willebroek (Belgium)
Sector	Chemical
Process	IMERYS manufactures Carbon Black producing a mixture of combustible gas as by-product which is currently burned in a furnace whose WH could be recovered.
Temperature	600°C

Figure 22: IMERYS Carbon Black Manufacturing Centre in Willebroek (Belgium)

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The following table shows the IMERYS WH/C value chain (high importance activities are highlighted):

Table 37: IMERYS WH/C Value Chain

IMERYS WH/C VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Energy consultants	**Hardware supply:**	**Installation companies (labour)**	**Energy Service Companies (ESCOs)**	**Local job creation**
Hardware definition:	• Heat exchangers	**Hardware installation**	**Energy contracting**	**Growth of the local economy**
• WH/C generation points	• Water pumps	**Software installation**	**Subcontracted companies**	**Technological innovation (R+D+I)**
• WH/C recovery technologies	• Piping	**Inspections**	**Monitoring**	**Green value:**
• Pump system	• Measuring equipment	**Commissioning**	**Service & Maintenance**	• Lowered GHG emissions
• Distribution network	**Software supply:**	**Calibration**	**Metering & Invoicing**	• Primary energy-savings
Software definition:	• Control system (SCADA)			• Energy efficiency
• Calculation/simulation software	• Visualization tool			
• Control system				
Permissions and licences				
Grants				
Public procurement				

For IMERYS demo-site the following WH/C value chain categories involve a value increase:

- **Planning and design:** Energy consultants are the main core of starting a WH/C business, because they contribute with their experience and know-how in order to make decisions. WH/C generation points and recovery technologies are the main components of the facility. The calculation/simulation software must be widely accepted (tool with good reputation and proven success). Permission and licenses are required due the occupation of public area for the distribution network. Grants are needed to make the investment competitive due to the low gas prices in Belgium. Not yet known if applicable for ISVAG case, if so, public procurement has a big impact on the process speed.
- **Components supply:** Heat exchanger are the main component of the facility, due to as recuperators of the waste heat, their performance is crucial.
- **Installation:** The correct selection of the installation companies is of vital importance for the future of the project. The quality of the hardware installation has a big impact on the value chain, having a bad installation to be corrected by inspections. Commissioning guarantees the proposed quality of the installations.
- **Operation & Maintenance (O&M):** IMERYS is not going to exploit the WH/C, therefore, there is an opened door for ESCOs to be part of the project. Energy contracting is directly related to the control of OPEX costs. Service & maintenance must be focused on giving customers a

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high supply certainty, while metering and invoicing provide reliability of supplier and certainty of income.

- **Value added:** Local job creation will be a driver to keep the company located as it is now, while growth of the local economy will be a driver to keep the companies involved located as they are now. The entire project would project a "green" image for producers and clients.

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4.9 Demo-Site: MARTINI & ROSSI Pessione Distillery (Italy)

In Martini & Rossi's (M&R) Pessione industrial site all the products of company are produced: Martini, sparkling wines and liquors, following their recipes. M&R demo-site has been identified as particularly relevant for the SO WHAT project as the stabilization of sparkling wines requires low temperatures, which are achieved via glycol-based refrigerators.

The overall cooling production is of about 10GWh/year employed in different areas of the plant: considering the remarkable amount of low temperature fluids related to this production M&R is interested in analysing the possibility and potential benefits related to waste cold recovery. As a consequence of the refrigerating power, in the plant it is produced a large amount of low temperature waste heat which is cooled in evaporative condensers and it accounts for about 15GWh/year and which potential has already been identified as interesting. Moreover, another waste heat stream has been identified in the cooling circuit of air compressors, which is currently cooled in an evaporative tower but it could be otherwise employed for about 170MWh/year. Finally, M&R is committed in employing Renewable Energy Sources (RES) and the installation of solar thermal panels for process purposes is planned in the framework of SHIP2FAIR H2020 project: for the present reason, M&R is an optimal test case for the analysis of RES integration and its direct impact on the production.

Table 38: MARTINI & ROSSI Description

Demonstration Site	Martini & Rossi Pessione Distillery
Partner	Martini & Rossi (M&R)
Location	Pessione (Italy)
Sector	Food & Beverage
Process	M&R Pessione plant processes require heating (distillation, bottle warming, etc.) and cooling (CO_2 injection, product conservation, etc.).
Temperature	(-8°C;60°C)

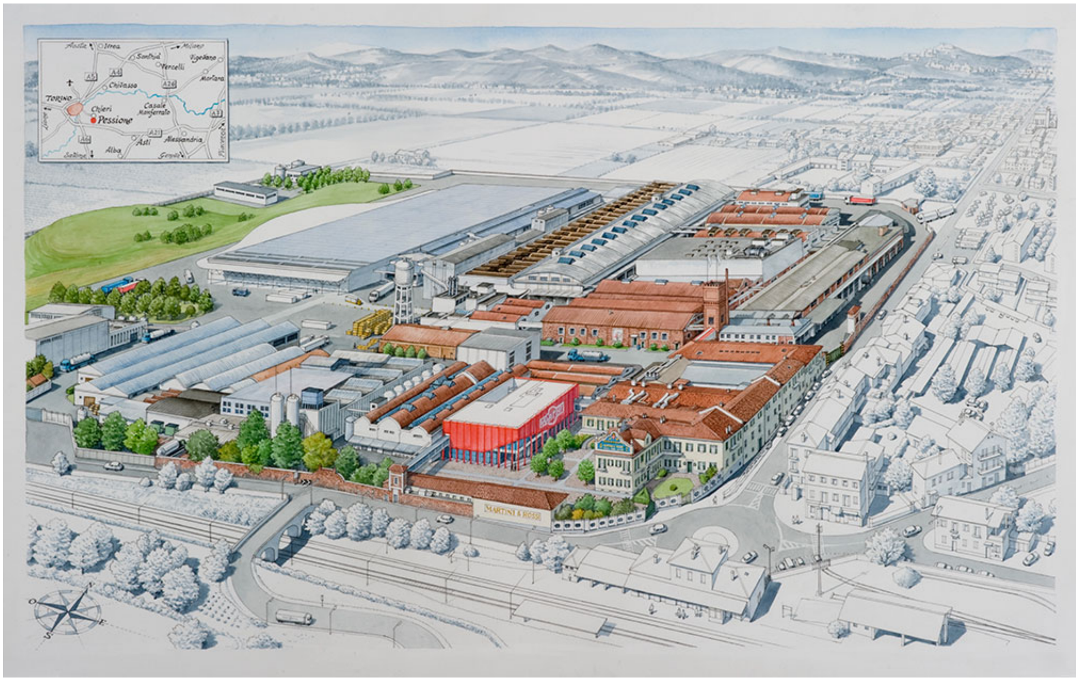

Figure 23: Martini & Rossi Distillery in Pessione (Italy)

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The following table shows the MARTINI & ROSSI WH/C value chain (high importance activities are highlighted):

Table 39: MARTINI & ROSSI WH/C Value Chain

MARTINI & ROSSI WH/C VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Energy consultants	Hardware supply:	Installation companies (labour)	Monitoring	Technological innovation (R+D+I)
Hardware definition:	• Heat exchangers	Hardware installation	Service & Maintenance	Green value:
• WH/C generation points	• Absorption refrigerators	Software installation	Metering & Invoicing	• Lowered GHG emissions
• WH/C recovery technologies	• Water pumps	Inspections		• Primary energy-savings
• Pump system	• Piping	Commissioning		• Energy efficiency
• Distribution network	• Measuring equipment	Calibration		
Software definition:	Software supply:			
• Calculation/simulation software	• Control system (SCADA)			
• Control system	• Visualization tool			
Permissions and licences				
Grants				

For MARTINI & ROSSI demo-site the following WH/C value chain categories involve a value increase:

- **Planning and design:** For M&R demo-site the software definition is essential, the calculation/simulation software to estimate the energy-savings and justify the investment, and the control system due to a remote control is needed. Permissions and licenses must be in accordance with national and local regulations. M&R WH/C projects could apply for available regional and EU grants to increase the chances of investments validation.
- **Components supply:** Measuring equipment is basic to evaluate the energy-savings, while the control system (SCADA) and the visualization tool are needed to have a remote supervision and control system.
- **Installation:** For M&R demo-site the installation phase is essential to generate a value increase in its WH/C recovery business, due to both the installation and commissioning must not interfere with the production activity in order to not affect the main business.
- **Operation & Maintenance (O&M):** Monitoring and service & maintenance would be carried out by M&R personnel, without the intervention of subcontracted companies, having direct control of the most expensive phase of the project (O&M).
- **Value added:** The reduction of GHG emission is a key target of M&R plant, while both primary energy-savings and energy efficiency contribute to reduce the payback and justify the investment (the shorter the payback, the more attractive an investment is usually).

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4.10 Demo-Site: ENCE Navia Pulp Mill (Spain)

ENCE is the leading company in Europe in eucalyptus pulp production. The bio-factories in Navia (Asturias) and Pontevedra have a total high-quality eucalyptus pulp production capacity of 1,200,000 tons/year. Moreover, ENCE is Spain's leading producer of renewable energy using biomass.

In 2018 ENCE Pontevedra generated more than 232 GWh of energy through two backpressure turbines that use biomass derived from trees in the pulp production process. The installed capacity of ENCE Pontevedra bio-factory for renewable biomass power generation is 35 MW.

ENCE Navia generated around 519 GWh of renewable energy in the same year. After its expansion, ten years ago, THE ENCE Navia bio-factory has doubled its power generation capacity, reaching an installed capacity of 77 MW through a backpressure turbine (for lignin) and a condensation turbine (for forest waste biomass).

ENCE's pulp bio-factories have a technology that allows them to be self-sufficient in terms of energy, using renewable resources. The biomass dryer in Navia is actually working with heat recovered from the bleaching stage. In the framework of the SO WHAT Project, the heat from the bleaching stage and the effluent treatment stage will be analysed in order to use it for the heating of the hospital and the town hall of Navia.

Table 40: ENCE Description

Demonstration Site	ENCE Navia Pulp Mill
Partner	ELEUKON (ELEU)
Location	Navia (Spain)
Sector	Pulp Mill
Process	This is the pulp mill with the largest production capacity belonging to ENCE Group (685,000 tons/year) and the most efficient on the eucalyptus market in Europe.
Temperature	(40°C;280°C)

Figure 24: ENCE Pulp Mill in Navia (Spain)

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The following table shows the ENCE WH/C value chain (high importance activities are highlighted):

Table 41: ENCE WH/C Value Chain

ENCE WH/C VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Energy consultants	**Hardware supply:**	**Installation companies (labour)**	**Energy Service Companies (ESCOs)**	**Local job creation**
Hardware definition:	• Heat exchangers	**Hardware installation**	**Energy contracting**	**Growth of the local economy**
• WH/C generation points	• Water pumps	**Software installation**	**Subcontracted companies**	**Technological innovation (R+D+I)**
• WH/C recovery technologies	• Piping	**Inspections**	**Monitoring**	**Green value:**
• Pump system	• Measuring equipment	**Commissioning**	**Service & Maintenance**	• Lowered GHG emissions
• Distribution network	**Software supply:**	**Calibration**	**Metering & Invoicing**	• Primary energy-savings
Software definition:	• Control system (SCADA)			• Energy efficiency
• Calculation/simulation software	• Visualization tool			
• Control system				
Permissions and licences				
Grants				
Public procurement				

For ENCE demo-site the following WH/C value chain categories involve a value increase:

- **Planning and design:** The support of energy consultants is essential to start a district heating project, due to their experience and know-how they can define the main concepts to start this kind of business. The WH/C generation points define the type of recovery technology and the distribution network size together with the maximum end -users in terms of heat amount. The calculation/simulation software must be well-tested, well-extended and be reliable. For ENCE demo-site, permissions and licenses has a high importance due to the district heating network would cross an environmental protected area (marsh), together with part of Navia town. Grants are always important to carry out this type of projects due to the large initial investment involved, being sometimes decisive. Due to the end-user would be public buildings, public procurement should be taken into account.
- **Components supply:** Heat exchangers are the main component of the facility, must being well selected in terms of type (plate heat exchangers for ENCE demo-site), size depending on the planned amount of heat recovered, and materials depending on the type of heat transfer fluids (pH must be taken into account). The control system (SCADA) should be designed specifically thinking about the facility operators (working mode) and allow the storage of databases, while the visualization tool must allow the development of trends, being interesting the visualization of instantaneous and accumulated consumptions for end-users.

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- **Installation:** The quality of the hardware installation is essential, having installation mistakes to be corrected through inspections and commissioning, increasing the installation cost and producing delays. especially when jobs are carried out in parallel and several installers are involved at the same time, with the possibility of overlapping and security issues.
- **Operation & Maintenance (O&M):** The operation & maintenance (O&M) is where more resources and money are allocated throughout the lifetime of the facility. For ENCE demo-site a continuous heat supply would reduce the effluent treatment cooling towers consumption. Subcontracted could be an option for the maintenance of the components which are outside the factory (district heating network and final measuring and elements).
- **Value added:** ENCE is the main economic engine of the Navia region, both directly and indirectly through subcontracted companies, generating a significant amount of jobs in the forest area of the company. The "green" image is also very important for ENCE, since until not long ago the company did not enjoy a very good image, especially due to pulp mill odour, a field in which a significant investment was made, obtaining great results. Carrying out a project of this category would involve an important collaboration with the Navia town hall, which would benefit from the investment made by ENCE.

The following table shows the ENCE Biomass & Waste value chain (high importance activities are highlighted):

Table 42: ENCE Biomass & Waste Value Chain

BIOMASS & WASTE VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Consultancy-Technical	**Feedstock supply**	Hardware installation	Integrated service provider	Technological innovation (R+D+I)
System integration	Manufacturing equipment	Software installation	**Consultancy-Operation & Maintenance (O&M)**	**Green value**
Market research	Control room systems	Testing & Certification services	**Education & Training**	Distributor
Banking-Corporate			**Contract maintenance**	**Public relations company**
Banking-Custody			Contract manufacturing	
Trust & Deposit			**Inspection & Maintenance**	
Insurance provider			**Specialist services**	
Lawyer-Commercial			**Power generation**	
Lawyer-Financial markets				
Lawyer-Project finance				
Recruitment/Search				

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For ENCE demo-site the following Biomass & Waste value chain categories involve a value increase:

- **Components supply:** The security of the feedstock supply is essential, in order to ensure the continuous operation of the plant. On one hand establishing a minimum safety stock is essential, on the other hand having too much stock incurs in high occupancy spaces and the possibility that the stock deteriorates over time.
- **Operation & Maintenance (O&M):** The operation & maintenance (O&M) is where more resources and money are allocated throughout the lifetime of the facility. Specific components as the recovery boiler and the biomass boiler need to past regulated inspections every year, being interesting to contract specialist maintenance for this type of equipment. The education & training is basic to increase the capacities of the plant operators, which translates into greater production reliability (reduction of critical failures, increased equipment reliability, etc.). The production of electricity for ENCE demo-site is as important as the production of paper pulp, which encourages energy self-sufficiency.
- **Value added:** ENCE is the main economic engine of the Navia region, both directly and indirectly through subcontracted companies, generating a significant amount of jobs in the forest area of the company. The "green" image is also very important for ENCE, since until not long ago the company did not enjoy a very good image, especially due to pulp mill odour, a field in which a significant investment was made, obtaining great results.

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4.11 Demo-Site: ROMPETROL Petromidia Refinery (Romania)

ROMPETROL Refinery in Petromidia of Navodari is the largest asset held by the KazMunayGas (KMG) International Group in Romania. The three production facilities of ROMPETROL Refinery operate under an integrated system, in full synergy, by offering a wide range of products. Thus, Petromidia Refinery is one of the most complex refineries, which supplies the entire feedstock for the Polypropylene plant within the Petrochemical Division, which is the sole Romanian producer of polyolefins. The refinery produces relevant amount of excess heat, in the framework of SO WHAT project two main areas of interest have been identified, two furnaces which discharge heat at 450°C to the stack and heat recovery from hot condensate from amine unit (140°C), currently dissipated in cooling water. The project to recover the heat from hot condensate from amine unit is under development and will be studied thanks to MEDGREEN.

Table 43: ROMPETROL Description

Demonstration Site	ROMPETROL Petromidia Refinery
Partner	MEDGREEN
Location	Navodari (Romania)
Sector	Refinery
Process	Petromidia is the largest refinery in Romania, one of the most modern refineries in South East EU.
Temperature	(140°C;450°C)

Figure 25:ROMPETROL Refinery in Petromidia of Navodari (Romania)

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The following table shows the ROMPETROL WH/C value chain (high importance activities are highlighted):

Table 44: ROMPETROL WH/C Value Chain

ROMPETROL WH/C VALUE CHAIN ACTIVITIES				
Planning and design	**Components supply**	**Installation**	**Operation & Maintenance (O&M)**	**Value added**
Energy consultants	**Hardware supply:**	**Installation companies (labour)**	**Energy Service Companies (ESCOs)**	**Local job creation**
Hardware definition:	• Heat exchangers	**Hardware installation**	**Energy contracting**	**Growth of the local economy**
• WH/C generation points	• Absorption refrigerators	**Software installation**	**Subcontracted companies**	**Technological innovation (R+D+I)**
• WH/C recovery technologies	• Water pumps	**Inspections**	**Monitoring**	**Green value:**
• Pump system	• Piping	**Commissioning**	**Service & Maintenance**	• Lowered GHG emissions
• Distribution network	• Measuring equipment	**Calibration**	**Metering & Invoicing**	• Primary energy-savings
Software definition:	**Software supply:**			• Energy efficiency
• Calculation/simulation software	• Control system (SCADA)			
• Control system	• Visualization tool			
Permissions and licences				
Grants				
Public procurement				

For ROMPETROL demo-site the following WH/C value chain categories involve a value increase:

- **Planning and design:** Calculation/simulation software is fundamental for estimating the amount of energy-savings for internal recovery that could justify the decision of implementing the project.
- **Components supply:** The operation of the installation with the new parameters modifying the condensing temperature depends on the detailed control of the process, hence the importance of the control system (SCADA).
- **Installation:** The software is the same as the current one, but there were modified the operation parameters and the definition of functions that include the correlations with the modified parameters. For the proper operation there were enforced the inspection procedures and a detailed evaluation has been conducted in the commissioning phase, together with the calibration of the operation parameters following several iterative loops.
- **Operation & Maintenance (O&M):** During the operation of the installation the monitoring of the parameters and performances of the processes is essential. Effective adjustments, based on predictive maintenance procedures have to be taken into consideration, in order to prevent critical failures.
- **Value added:**

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4.12 Conclusion of the SO WHAT Demo-Sites WH/C Value Chains

Analysing the data from the demo-sites WH/C value chains together, radar charts have been developed by category and activity, obtaining general conclusions about which parts are more interesting to invest in to create competitive advantages with the aim of generating a value increase.

The following figure shows the radar chart of the WH/C value chain categories:

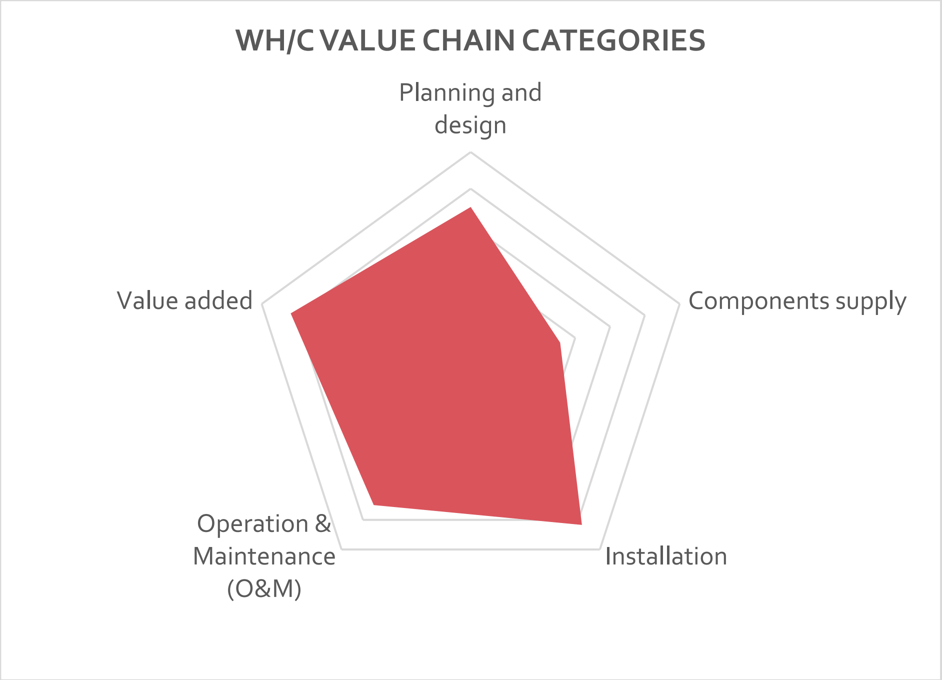

Figure 26: WH/C Value Chain Categories Radar Chart

It is observed that both "Installation" and "Value added" are considered of utmost importance for generating value in WH/C projects, while "Planning and design" and "Operation & Maintenance (O&M)" are located in a lower step. "Components supply" is the category considered least important.

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The following figure shows the radar chart of the WH/C value chain "Planning and design" category:

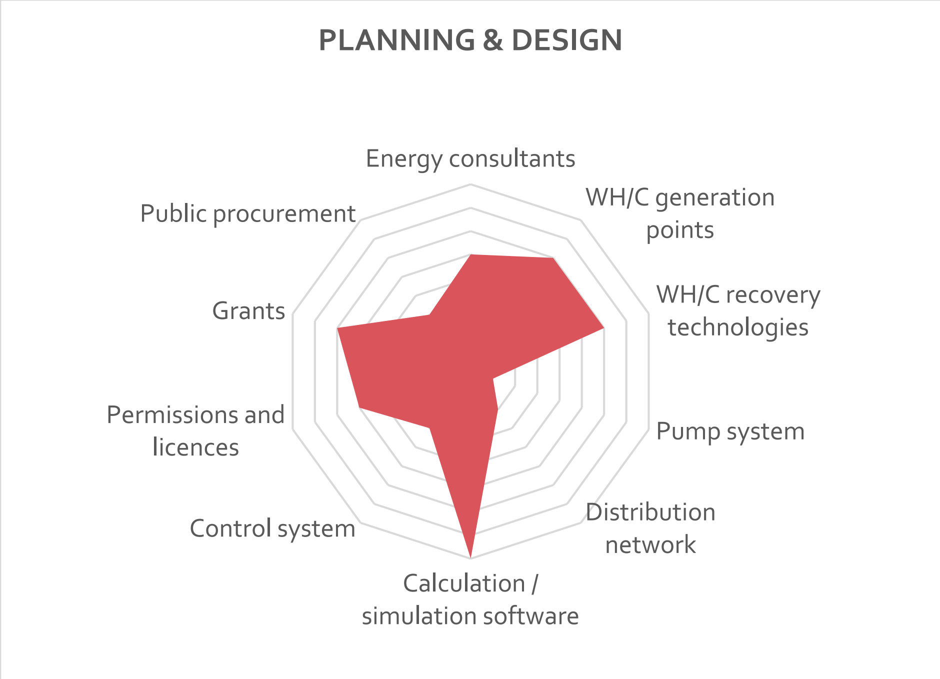

Figure 27: Planning & Design Radar Chart

It is observed that "Calculation / simulation software" is considered of utmost importance for generating value in WH/C projects inside "Planning and design" category. "Grants", "Energy consultants", "WH/C generation points", "WH/C recovery technologies", and "Permission and licenses" (depending if the WH/C recovery is for internal or external use) are located in a lower step, while "Pump system", "Distribution network", "Control system" and "Public procurement" are considered less important.

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The following figure shows the radar chart of the WH/C value chain "Components supply" category:

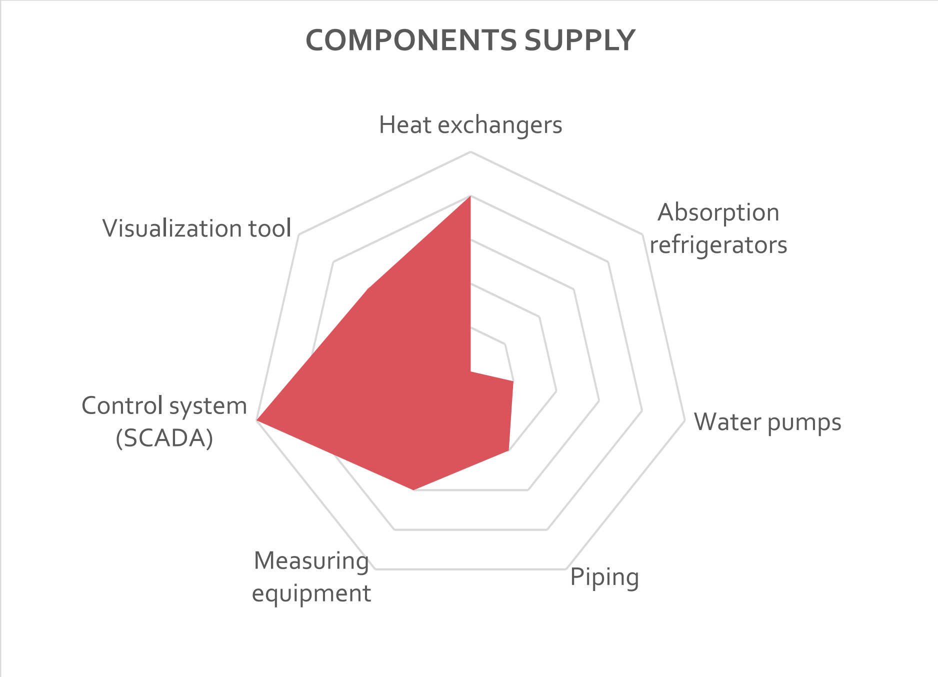

Figure 28: Components Supply Radar Chart

It is observed that "Heat exchangers", as the main equipment for a WH/C recovery facility (a suitable heat exchanger selection and design is essential to maximize the heat recovered), crowns the head outstanding in importance together with "Control system (SCADA)" for generating value in WH/C projects inside "Components supply" category. This is also due to the fact that the rest of the categories correspond to widely used equipment in the industry (apart from "Abortion refrigerators", whose importance depends if cooling is integrated into the project or not). "Visualization tool" together with "Measuring equipment" have also an important weight within "Components supply" category, while "Piping", "Water pumps" and "Absorption refrigerators" are considered less important.

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The following figure shows the radar chart of the WH/C value chain "Installation" category:

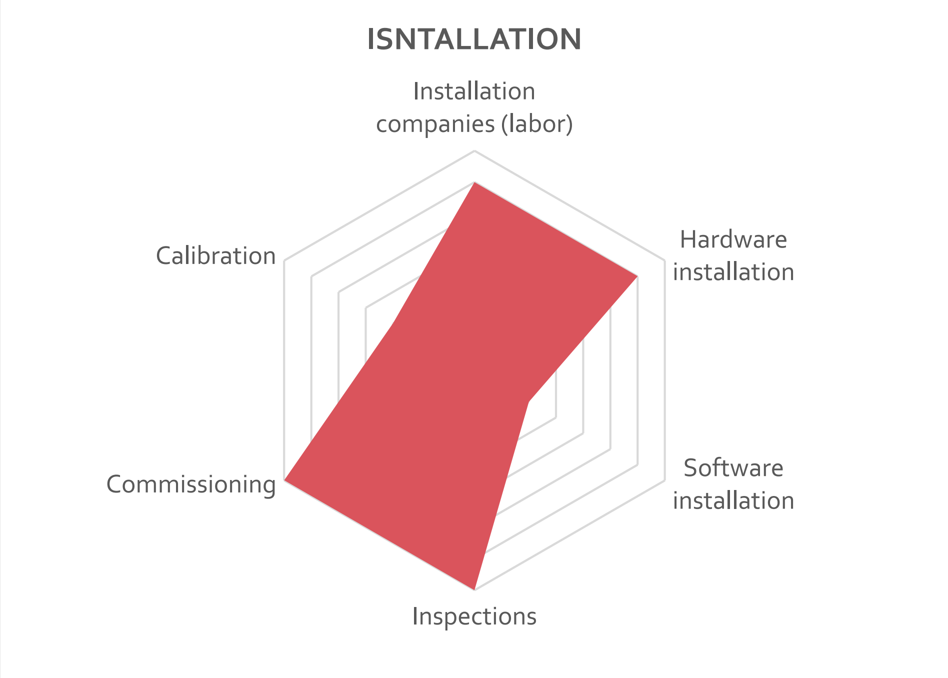

Figure 29: Installation Radar Chart

It is observed that both "Installation companies (labour)", "Hardware installation", "Inspections" and "Commissioning" are considered of utmost importance for generating value in WH / C projects inside "Installation" category, while "Software installation" and "Calibration" have a reduced weight. A good planning of the installation phase of the project, together with a good follow-up, is essential to prevent cost overruns, overlapping works and security issues.

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The following figure shows the radar chart of the WH/C value chain "Operation & Maintenance (O&M)" category:

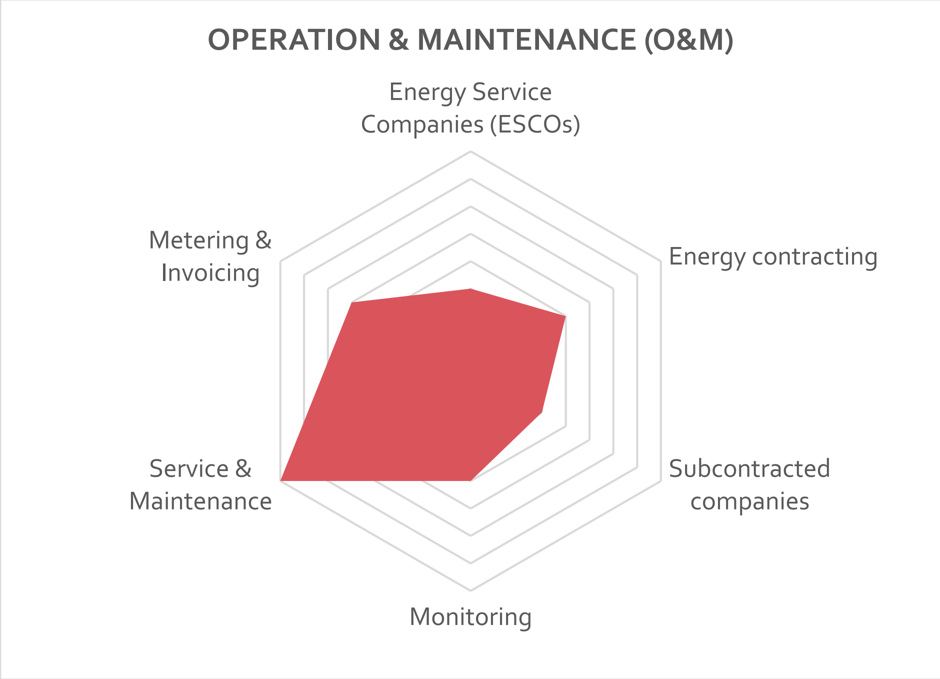

Figure 30: Operation & Maintenance (O&M) Radar Chart

It is observed that, "Service & Maintenance" is considered of utmost importance for generating value in WH/C projects (most expensive phase) inside "Operation & Maintenance (O&M)" category. "Energy contracting", "Monitoring" (consumption monitoring of the end-users) and "Metering & Invoicing" are located in a lower step (depending if the WH/C recovery is for internal or external use), while "Subcontracted companies" (sometimes contracted for specialized equipment maintenance, as absorption refrigerators) and "Energy Service Companies (ESCOs)" (depending on the need to hire or not an ESCO for operating and maintaining the facility) are considered less important.

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The following figure shows the radar chart of the WH/C value chain “Value added” category:

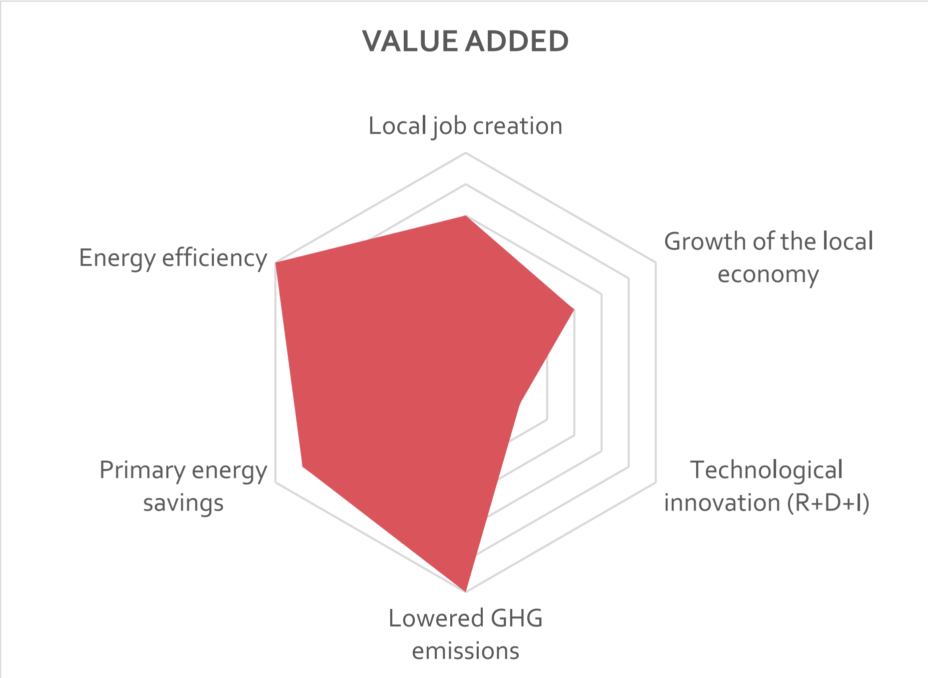

Figure 31: Value Added Radar Chart

It is observed that "Lowered GHG emissions”, “Primary energy-savings” and “Energy efficiency” are considered of utmost importance for generating value in WH/C projects inside “Value added” category, while "Growth of the local economy" and "Local job creation” are located in a lower step. This derives from the fact that most demo-sites are economic engines of their regions, and how important the “green” image nowadays is in order to improve the industry. It surprises that "Technological innovation (R+D+I)" is considered the least important, unlike in most value chains, maybe due to the fact that the equipment used for WH/C projects is not high-tech, but the contribution of new materials to this field should be taken into account.

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5 Financing Schemes

WH/C recovery, DH/C networks and RES plants are expensive projects, both in the initial investment and in the operation phase, requiring periodic maintenance and reinvestment. For this reason, financing schemes are a key factor to guarantee the viability of the projects (20).

For DH/C projects local governments play a very important role, since they are responsible for granting the authorizations corresponding to the installation. But, in addition, they can actively participate in the project, with the degree of involvement and funding they decide (20).

There are many possibilities for local entities to participate in district heating/cooling networks, both in their promotion and in their operation, from full ownership and control by the local entity of all elements of the network to the mere support to private entities through grants and loans, but without participating in ownership or exploitation (20).

As an intermediate possibility, a local entity can invest directly in only one part of the installation (such as the distribution network) and seek private collaboration and even other public organisms, both in promotion and exploitation, through various methods, or even form a cooperative with citizens and other entities to carry out the investment (20).

Both ownership and operation of the urban district heating/cooling network can be (20):

- 100% by a local entity.
- 100% private.
- Mixed public-private.
- In cooperative, with or without participation of the local entity.

The most widespread model is that of promotion through mixed companies, formed by public organisms and private entities, leaving the management outsourced to private Energy Services Companies (ESCOs), which exploit, maintain and reinvest in the facility (20).

The different existing financing schemes are further developed below:

5.1 Ownership and OPERATION 100% by a Local Entity

This model is more frequent in countries where historically this type of initiative was always public. Even in these cases, the current trend is towards privatization or collaboration with the private sector (20).

The local entity can benefit from the aid mechanisms that exist for the construction of this type of facilities, both in the European Union and in the different national administrations (20).

There are two additional variants to the basic model of ownership and exploitation by a local entity (20):

- The local entity can seek collaboration with another public organism, whatever the scope. In this case, the urban network is still public, but not local (20).
- The local entity that owns and operates a district heating/cooling network can acquire and/or exploit networks of other municipalities, to create synergies and take advantage of economies of scale, just as private companies do (20).

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5.2 100% Private Property and Exploitation

When the district heating/cooling network is privately owned and operated, the local entity may limit itself to supporting it with repayable loans, non-refundable grants, or even tax advantages or other benefits (20).

In any case, the support would be justified by the interest of the local entity in promoting the efficient use of energy, supporting the development of renewable energy sources, reducing the environmental impact of energy consumption and fighting against climate change, promoting sustainable development. The local entity can make the economic contribution to the project based on the CO_2 that is expected to stop emitting thanks to the implementation of the project, or some other indicator of global energy efficiency (20).

5.3 Public-Private Model

An intermediate investment model is the mixed public-private. The local entity can seek the collaboration of the private sector, both in the ownership of district heating/cooling networks and in the operation. Both parties benefit from this collaboration, in general, the private sector is used to managing risk and attracting capital, while local entities are fully familiar with urban infrastructures (20).

In this model, the presence of the local public administration as part owner of the network is considered of great interest, due to the administrative complexity involved in each of the phases in the execution and start-up of the facility (20).

The collaboration formulas vary in function of the involvement and influence that each part aspires to have in the model (20):

- ESCO Contract.
- Concession.
- Leasing.
- Property differentiated by elements.
- Mixed society with selected minority private capital.
- Mixed society with minority private capital from investment funds.
- Mixed society with majority private capital.

EPC is booming, so it will be developed more deeply than the other formulas.

5.3.1 ESCO Contracts

ESCO contracts (analysed more deeply in the Chapter 6.7 “Energy Contracting”), understood in their broadest sense, are performance or benefit contracts. They involve an agreement between an Energy Service Company (ESCO) and the property for the implementation of measures to improve energy efficiency, in such a way that the investments in these energy conservation measures are recovered through the savings obtained. In this way, the payment of the services provided is based, in part or totally, on obtaining improvements in energy efficiency and on meeting the other agreed performance requirements (20).

Benefits may include (20):

- Construction, installation or transformation of works, equipment and systems.
- Maintenance, update or renewal of equipment and systems.

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- Exploitation or management derived from the incorporation of efficient technologies.
- Supply of useful energy.

In any case, they must be associated with verifiable, measurable or estimable energy-savings (20).

Benefits indirectly related to energy efficiency may also be included in the agreement, including, and not having to provide simultaneously (20):

- Energy audits and feasibility studies.
- Measurement and verification of savings.
- Implementation of improvements in energy infrastructures not generating savings, but security.
- Productivity or operability.
- Total equipment warranty.
- Financing of investments.

Depending on the form of distribution of the savings achieved and the operational and financial risk, energy service contracts can be of various types (20):

- Guaranteed savings.
- Shared or mixed savings.

In EPCs, the savings obtained through the implementation of measures to improve energy efficiency are normally one of the basic remuneration parameters. It is therefore essential to define these in the agreement between the parties, specifying (20):

- Measurement and verification protocols.
- Energy-savings (performance risk)
- Savings in monetary units (risk of unit energy costs)
- Baseline or for calculating savings.
- External or internal correction factors for calculating savings.

In addition to the above aspects, EPCs must necessarily contemplate the following elements (20):

- Contract period.
- Services to be provided by the ESCO and their temporary distribution.
- Remuneration, including its revision in time, if applicable.

It is highly recommended to also include (20):

- Financing policy and ownership of new assets (investments in reconstruction, new developments, expansion of the network and connection of new-users).
- Connection, disconnection and update policy.
- Relationship with property.
- Strategic, environmental and social responsibility plan.
- Forms of termination or transmission of the contract.

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5.3.2 Concession

The concession is a contract whose purpose is to carry out works and associated works by the concessionaire, such as civil engineering, including restoration and repair of existing buildings, as well as the conservation and maintenance of the built elements (20).

In the case of district heating/cooling networks, the consideration in favour of the concessionaire consists of the right to exploit the network by selling energy to users, although this right may also be accompanied by the right to receive a price or fee (20).

The concession contract is executed at the risk and luck of the concessionaire. In addition to the concession conditions themselves, the contract must include, at least, the following aspects (20):

- The adaptation, reform and modernization of the installation to adapt it to the technical and functional characteristics required for the correct provision of services to users (20).
- The replacement and major repair actions that are required in relation to the elements that the facility must meet to remain apt, so that the services subject to the concession can be adequately developed in accordance with economic and social demands (20).

The concession contract may also provide that the concessionaire is obliged to design, execute, conserve, replace and repair those facilities or equipment that are accessories or are linked to the main one and that are necessary for it to fulfil its purpose and that allow its better operation and exploitation, as well as to carry out the environmental actions related to them that are foreseen therein (including energy efficiency or the use of renewable energies) (20).

Since concession contracts tend to be of very long duration, it is important for the property to ensure that the contract includes all its demands and requirements, even when periodical review clauses of the conditions are foreseen (20).

5.3.3 Leasing

In a leasing the lessee rents the district heating/cooling network to the property for a specified period of time, usually long. The operation, maintenance, investments and all management are the responsibility of the lessee, who periodically pays an amount to the property or invests a certain amount of capital in the infrastructure (or a combination of both options) (20).

In the leasing contract, the ownership of the facility does not change, it belongs to the lessor, while in the concession contract the concessionaire owns the facility until delivery, at the end of the concession period (20).

As in the case of the concession, the duration of the leasing contract is usually very long, so it is essential that the agreement includes all the requirements of the property, including those related to maintenance; otherwise, there is a risk that at the end of the leasing the residual value of the installation will be very low (20).

5.3.4 Property Differentiated by Elements

Another possibility is to divide the ownership of the urban network into elements, each with a different form of ownership and exploitation. Thus, for example, the generation plant can be privately owned and the local entity distribution network (20).

In this case, the local entity would recover the direct investment by charging a fee for the use of the distribution network (20).

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5.3.5 Mixed Society with Selected Minority Private Capital

A local entity can look for private partners both to make the investment and to operate the facility. In this case, the local entity looks for partners with a specific profile and solvency, creating with them a mixed society in which it contributes capital in a majority way, with the corporate figure it deems appropriate. In this way, the local entity retains control of the urban network and benefits from the experience and resources of companies in the sector (20).

To undertake the investments, the joint venture may resort to financing by third parties (20).

5.3.6 Mixed Society with Minority Private Capital from Investment Funds

An alternative to the previous model is for the local entity to create a company and seek private capital in the market, through investment funds. This society is the one that makes the investment and exploits the urban network, its value in the market depending on the returns obtained. In turn, this same value will determine the ease and price of third-party financing necessary to carry out the investments. Market participation always carries a certain degree of uncertainty and risk (20).

The main difference with the previous model is that, in this case, it is the private investors who choose the investment project of the local entity and not the local entity that selects its partners (20).

5.3.7 Mixed Society with Majority Private Capital

In this model, the local entity contributes a minority capital to the mixed society that makes the investment. In this way, the local entity is not in control, but still have influence on the project whose interest is justified by the environmental benefits it produces (20).

5.4 Financing Schemes Summarize

The following table summarizes the financing schemes described:

Table 45:Financing Schemes summarize

<table>
<tr><th colspan="3">Financing Schemes</th></tr>
<tr><td rowspan="8">Ownership and OPERATION 100% by a Local Entity:
• Collaboration with another public organism.
• Acquisition and/or exploitation of networks of other municipalities.</td><td rowspan="8">100% Private Property and Exploitation:
Supports of the local entity:
• Repayable loans.
• Non-refundable grants.
• Tax advantages.
• Other benefits.</td><td>Public-Private Model:</td></tr>
<tr><td>• ESCO Contracts (analysed more in depth in Chapter 6)
— Guaranteed savings.
— Shared or mixed savings.</td></tr>
<tr><td>• Concession</td></tr>
<tr><td>• Leasing</td></tr>
<tr><td>• Property Differentiated by Elements</td></tr>
<tr><td>• Mixed Society with Selected Minority Private Capital</td></tr>
<tr><td>• Mixed Society with Minority Private Capital from Investment</td></tr>
<tr><td>• Mixed Society with Majority Private Capital</td></tr>
</table>

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5.5 Grants

Apart from the financing instruments that have been described, local entities can count on aid from various organizations when investing in a district heating/cooling network, being the one described below the most representative for this type of facility (20).

5.5.1 European Local Energy Assistance (ELENA)

The European Commission and the European Investment Bank (EIB) make a fund available to regional and local authorities to help them develop their investment potential in sustainable energy. It is the so-called ELENA mechanism, which gives access to direct financing from the European Investment Bank or other banks. It is funded through the Intelligent Energy Europe II (IEE) program (20).

The ELENA mechanism aims to promote investment projects in areas such as energy efficiency, renewable energies and sustainable urban transport, and to reproduce the successes achieved in other parts of Europe. The district heating/cooling networks are one of the investments specifically contemplated in the mechanism (20).

The ELENA mechanism finances the technical assistance necessary for local or regional authorities to prepare, execute and monitor a sustainable energy action plan. Some of the eligible expenses are the performance of energy audits, feasibility and market studies of the investment proposals, and the preparation of the bidding procedures for the execution of the proposals. In addition, funding can be obtained for the execution of the proposals (20).

All the information can be obtained through the following website: http://www.eib.org/elena (21)

Figure 32: ELENA (European Local Energy Assistance) (21)

5.6 Swedish Lighthouse Cluster

VEAB and GOTE partners have shared their knowledge about financing schemes and contractual arrangements as representatives of the Swedish Lighthouse cluster. Experiences from both VEAB and GOTE is to split the profit between the actors and by that make the contractual arrangement a "win-win". This procedure is crucial to how the price is set. The first step is to develop a common profitability calculation, for then negotiate system boundaries and ownership of the equipment.

In the following sections, the particularities of each demo-site will be presented separately, starting from a brief description.

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5.6.1 Demo-Site: VEAB Varberg WH DHN (Sweden)

The demo-site in Varberg, Sweden, is represented by Varberg Energy (VEAB), which is an energy company owned by the municipality that provides district heating and other services in the area. The directive they received as company is to invest in sustainable energy resources on a local market and, following it, they identified waste heat from a pulp mill situated about 20 km from the city as a promising source to be fed into the district heating network. Before the construction of Varberg district heating network, the pulp mill was forced to cool away heat and release it into the environment. Hence, both the municipality and the industry had incentives to join the collaboration.

Waste heat is the main source for the network (85%) but as complement and security, there are conventional heat boilers integrated in the network, based on woodchips, biogas and bio oil. All the complementary fuels are bio based. VEAB and the pulp mill are currently investigating the possibility to increase the amount of waste heat injected in the network through action both at heat exchanger level and at customer level (such as lowering the return temperature).

Furthermore, they are currently investigating the possibility to provide district cooling during summer via absorption chiller exploiting waste heat from the pulp mill. That would decrease the demand for cooling towers at the pulp mill during summer, when the cooling demand is the highest.

Table 46: VEAB Description

Demonstration Site	VEAB Varberg WH DHN
Partner	Varberg Energi (VEAB)
Location	Varberg (Sweden)
Sector	DHN, WH (from Pulp Mill)
Process	VEAB DHN is linked to the nearby pulp mill providing WH via heat exchangers.
Temperature	(80°C;95°C)

Figure 33: Varberg Energi WH DNH in Varberg (Sweden)

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The transmission pipeline to connect the pulp mill with the district heating network in Varberg has a length of 20 km and was partly financed by a state aid. The investment cost was 126 million SEK (approximately 12 million€), where of 25 million SEK (approximately 2.5 million€) was covered by a state aid. The transmission line was written off in 10 years, which is faster than common district heating lines. The political incentives overcame the risks of the investment.

The collaboration between the two parties has developed over time. Both companies have invested in the collaboration (for example the pulp mill owns the first pumps after the pulp mill, and VEAB owns the others and the transmission line). Also, VEAB owns the back-up boilers. Since one partner is public and one is private, they have different ways to manage depreciation of equipment. The clear division of ownership makes this possible to manage easily. Also, it makes the division of responsibility for operation and maintenance clear. The ownership of facilities reflects the risk diversification (VEAB owns the transmission line). Since VEAB have the delivery responsibility toward the end-users, they have chosen to be in charge of the back-up boilers in case of disruption of heat delivery from the pulp mill. Because of this, the price of the heat is set lower than if the contractual arrangements were designed for different conditions. The renegotiation of price and quality takes place every second year. Examples of factors that affect the price negotiations are other energy prices, such as the electricity price since part of the excess heat at the pulp mill is steam that could be used for electricity generation, and the oil price. Otherwise, it is the requirements for the partners to repay their investments that are the main factor.

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5.6.2 Demo-Site: GOTE Göteborg WH DHN (Sweden)

Göteborg Energi (GOTE) has a world-class district heating network, covering 90% of the city's demand and where only 5% of the heat production is based on fossil fuels; the vast majority of energy production is based on excess heat (80%) originating from CHP waste incineration and oil refining, and biofuels (15%). The waste heat is coming from Refinery ST1, PREEM and waste incineration (Renova), as GOTE has used waste heat for district heating since the 1970's. In addition, GOTE is offering district cooling to the network based on absorption chillers driven by waste heat from industries which in summer months could not be exploited due to low heat demand. In parallel, free-cooling (cooling towers or river water) and compressors are employed to offer a reliable service. GOTE is acting as lighthouse partner for the SO WHAT project, but it also benefits from it for its next development forecasted activities:

1- By 2024, they will need to expand cooling production by another 15 MW to meet the sales forecast. The demo will be under investigation and today they are looking at two types of absorption machines. Within 10 years will they expand cooling production with 100 MW.
2- They also look at utilizing low temperature heat for district heating networks (such as server halls, data test cells, etc.).

Table 47: GOTE Description

Demonstration Site	GOTE Göteborg WH DHN
Partner	Göteborg Energi (GOTE)
Location	Gothenburg (Sweden)
Sector	DHN, WH (from refinery and waste incineration)
Process	GOTE DHCN is linked to different industrial facilities covering 90% of city demand. It is willing to expand this service.
Temperature	(70°C;100°C)

Figure 34: Göteborg Energi WH DHN in Gothenburg (Sweden)

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The current contractual length is 10 years (based on the expected 10-year payback) but depends on the size of the investment. The contract period reflects the payback of the district heating company and how much the excess heat supplier has invested. The risk assessment for waste heat collaboration is made by the excess heat supplier by hiring an external consultant as a light due diligence before the collaboration begins. The risk that the industrial waste heat may be removed is always taken into calculation. According to the contract, the waste heat deliverer will need to compensate economically if that should occur.

The arrangement varies, in some cases GOTE takes the entire investment cost and in other cases the heat supplier takes a large share of the investment. If the heat supplier is interested in a short contractual length, the supplier also takes a larger share of the investment in the beginning. Since GOTE is 100% owned by the municipality, it has a long-term investment horizon which facilitates decisions on major infrastructure investments. In the investments so far, no aid from the state or EU has been needed. The demand of district heating is increasing in Gothenburg. Even though new buildings have lower energy demand, the increased number of buildings compensate for that. However, GOTE has restriction for their costumers to not use district heating for top load only, for example with geothermal a heat pump as base load which is common in Sweden.

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6 ESCO Model

Since the recent economic crisis, the continuous rise in the price of energy (from electricity to the different kind of fuels, with the exception of the decrease in oil prices in recent years, which has reached historically low values), restrictions on emissions to reduce the global warming and other negative environmental effects, the importance of saving energy has become a principal issue for companies, in order to increment their benefits. Energy efficiency business models can be divided into three groups:

- **Product manufacturers and marketers of energy efficient products:** They represent the most traditional energy efficiency business model. The concern for this group resides in the sales quantity of their products, not in the improvement of energy efficiency that the installation of them entails (22).
- **ESCOs:** The acronym ESCO refers to Energy Service Company. The main target of ESCOs is to reduce energy consumption through the design and implementation of energy solutions in order to change the ways the customer consumes energy. There is also the possibility that ESCOs in "deregulated markets" (markets that allow energy competition) can supply energy to customers (22).
- **Utilities offering for-profit energy efficiency services:** Unlike ESCOs, most utilities are regulated to some extent by commissions appointed by state or local governments. This implies that investment returns are limited, but reduces investment risk, due to regulators practically guarantee returns based on energy demand projections (22).

6.1 Historical Background

The appearance of ESCO model took place at the end of the 1970s, because of the fact that the energy crisis forced entrepreneurs to look for solutions to combat the energy costs rise. Time Energy, a Texan company, became one of the first ones to apply ESCO model due to its light switching automation device. Doubts regarding the potential savings of its device forced Time Energy to install it in advance and charge based on a percentage of the savings achieved, which led to a notable increase in sales and profits (23).

In the late 1970s ESCO model had an exponential growth, made up of small divisions of large energy companies or small upstart independent companies. In the 1980s this growth stagnated due to the end of the energy crisis (23).

In the 1990s, the energy costs increase and the development of more energy-efficient technologies, mainly in the field of lighting and HVAC (Heating, Ventilation and Air Conditioning), encouraged the application of ESCO projects. In addition, there was an expansion of ESCOs towards the market of energy generation, building district power plants or developing cogeneration projects (22).

Starting in the 2000s, there was a consolidation of ESCOs, increasing year after year their knowledge on energy efficiency, assuming significant investments in the wake of the recent economic crisis to date (22) (24).

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6.2 Introduction

The principal convincing incentive of ESCOs lies in the fact that they often assume the investment risks, obtaining a benefit in function of the savings generated by their energy-saving solutions during a contractual period. The absence of customer investment and the assurance of energy-savings are the two main weight arguments that customers value of ESCOs.

The main energy solutions designed and implemented by ESCOs are the following (22):

- Energy-savings projects.
- Retrofitting projects.
- Energy conservation projects.

ESCOs can also provide the following services (the most interesting for the SO WHAT project), which differentiates them from common energy companies that focus only on supplying energy to consumers (22):

- Energy infrastructure outsourcing.
- Power generation and energy supply.
- Financing.
- Risk management.

ESCOs features are summarized below (25):

- **Ownership:** Listed below are the different types of ESCO ownerships.
  - Privately owned companies (independent or part of a large conglomerate).
  - State-owned companies.
  - Non-profits companies.
  - Joint ventures.
  - Manufacturers.
  - Manufacturers subsidiaries.
- **Clients:** In general, ESCOs tend to specialize according to application sectors (industrial, utilities, real estate, etc.), ranging from large-scale projects (district heating) to small ones (lighting).
- **Technology:** ESCOs may be specialized in specific industrial processes or technologies (HVAC, lighting, heat exchangers, pumping fluids, etc.), or work in a wide range of applications.
- **Project financing:** ESCOs may self-finance projects or rely on third-party financing, in function of their financing capabilities.

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6.3 Methodology

The following figure shows the main phases of ESCO model, which will be analysed deeper subsequently:

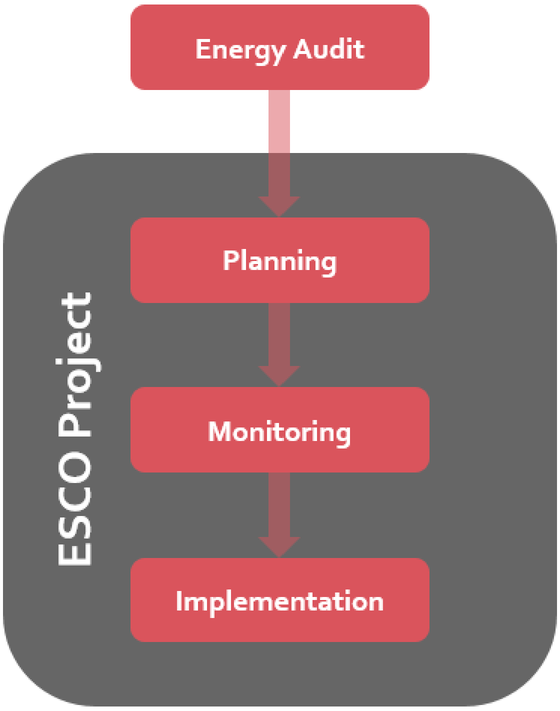

Figure 35: ESCO model phases (26)

- **Energy Audit:** The most common way of development events is for the ESCO to contact the customer in order to present it an energy-saving project and a performance contract (there is also the possibility that the customer may contact ESCOs due to a specific need of energy-saving). After this first contact, the client has the possibility of continuing with this ESCO or presenting an offer to other ESCOs. The next step is to carry out the Energy Audit (also known as "feasibility study" in the literature) in order to identify and evaluate energy-saving opportunities. The Energy Audit is a research and investigation task done by an energy auditor of the ESCO (generally developed without cost to the client). This step, despite not being part of the ESCO Project, is of vital importance due to its energy-saving solutions and estimations will lead to the development or refusal of the ESCO Project.
- **ESCO Project:**
  - **Planning:** Energy efficiency engineers design and develop energy-saving solutions, also known as Energy Conservation Measures (ECMs) in the literature, based on the Energy Audit carried out previously. The main objective is to maximize de energy-saving potential, leading to more accurate costs and savings estimations. There are a wide range of possible applicable ECMs, such as highly efficient lighting and HVAC, Variable Frequency Drives (VFD) for variable speed of pump or fan motors, centralized Energy Management Systems (EMS), etc.
  - **Implementation:** After the signature of the performance contract takes place the execution and commissioning of the ECMs.

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- **Monitoring:** The monitoring and maintenance step, also known as Measurement and Verification (M&V) in the literature, aims to calculate the amount of energy saved due to the implementation of the ECMs, instead of the energy costs, which can be affected by many factors, such as energy prices. This procedure is developed based on the "M&V Plan", agreed prior to the implementation of the ECMs, and as a general rule, following the International Performance Measurement and Verification Protocol (IPMVP) (27) of the Efficiency Valuation Organization (EVO) (28).

Depending if M&V phase is included or not into the Performance Contract, there are the following three options to consider by the customer (ordered from lowest to highest cost) (29):

- The only warrantee is the one provided by the equipment.
- ESCO provides M&V during a short period of time since the finish of the commissioning.
- ESCO provides M&V during the entire Payback Period.

In a common procedure, ESCOs borrow cash in order to implement ECMs and buy the necessary equipment. Customers pay ESCOs their regular energy cost (or a contractual percentage of it). Due to the energy-savings generated by the ECMs implementations, the payment that ESCOs have to afford to energy suppliers due to the energy consumption is less than the regular one. Discounting the interest rate of the borrowed cash from this difference the profit is obtained.

6.4 ESCO Selection Process

In the case of state funded projects (for which an ESCO was required), the government puts the project "out to bid", allowing ESCOs to bid on the project under specific requirements, giving transparency and equality to the selection process. The usual steps to follow are listed below:

- Creation of a "Request for Qualifications" (RFQ).
- Send of the corporate resumes of the interested ESCOs to the RFQ.
- Customer review of the corporate resumes of the applicants.
- Selection of the most suitable ESCOs for the realization of the project.
- Send of the "Request for Proposal" (RFP). This document must contain the following sections (normally, the minimum period to collect the information is six weeks):
    - Energy Conservation Measures (ECMs).
    - Necessary equipment
    - M&V Plans.
    - Performance Contract
- Customer review of the proposals (it may include interviews with the applicants).
- Final selection of the ESCO that will carry out the project taking responsibility for (30):
    - Identification and evaluation of energy-saving opportunities.
    - Development of engineering designs and specifications.
    - Management of the project from design to installation and monitoring.
    - Organization of the financing.
    - Staff training.
    - Provider of ongoing maintenance services.
    - Guarantee that savings will cover all project costs.

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The next step, after the implementation of the ECMs, consists of calculating the energy-savings generated by the project, in order to present the savings results to the customer, also known as "energy-saving tracking". Normally, this is done through energy flows measurements before and after the implementation of the ECMs. To guarantee the reliability of the calculations done, they must be carried out following a standard protocol. In the next chapter the International Performance Measurement and Verification Protocol (IPMVP) (27) of the Efficiency Valuation Organization (EVO) (28) will be introduced (further information in Appendix A).

6.5 Measurement and Verification of Savings: IPMVP

The protocol for measurement and verification of savings should be one of the main activities described in ESCO contracts (specially for EPC and IEC, that will be analysed in the Chapter 6.7 "Energy Contracting"). For this reason, the use of the International Measurement and Verification Protocol (IPMVP) is spreading.

The IPMVP is a guidance document that provides a conceptual framework for measuring, computing, and reporting savings achieved by energy efficiency projects in commercial and industrial facilities. It defines key terms and outlines issues that must be considered in developing a Measurement & Verification (M&V) plan (31).

Developed through a collaborative effort involving industry, government, financial, and other organizations, the IPMVP serves as the framework for M&V procedures. It provides four M&V options and addresses issues related to the use of M&V in third-party-financed and utility projects (31).

The IPMVP does not grant any certification, but gives reliability and transparency for clients. The following chapters describe the main characteristics of the IPMVP, which can be consulted in greater detail in Appendix A.

6.5.1 IPMVP Structure

Due to the nature of savings, absence of energy/water consumption or demand, they cannot be measured directly. So they have to be calculated through the comparison of the measured consumption or demand before and after the implementation of the Energy Conservation Measures (ECMs), making suitable adjustments for changes in conditions. The calculation of savings is done using the following general M&V formula (32):

$$Energy\ Savings = (\text{Baseline Period Energy} - \text{Reporting Period Energy}) \pm Adjustments$$

Formula 13: Energy-Savings general equation

Where (32):

- **Baseline:** Referring to the systems, time period, energy use, or conditions that provide a reference to which later performance of an ECM can be compared.
- **Baseline Period:** Defined period of time chosen to represent the operation of the installation or system before the implementation of an ECM.
- **Baseline Period Energy:** Energy Consumption or Demand occurring during the Baseline Period without adjustments.

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- **Reporting Period:** Defined period of time chosen for the purpose of verifying savings after the implementation of an ECM.
- **Reporting Period Energy:** Energy Consumption or Demand occurring during the Reporting Period without adjustments.

The following graph shows the Energy Consumption or Demand during a M&V process, before and after the implementation of an ECM (32):

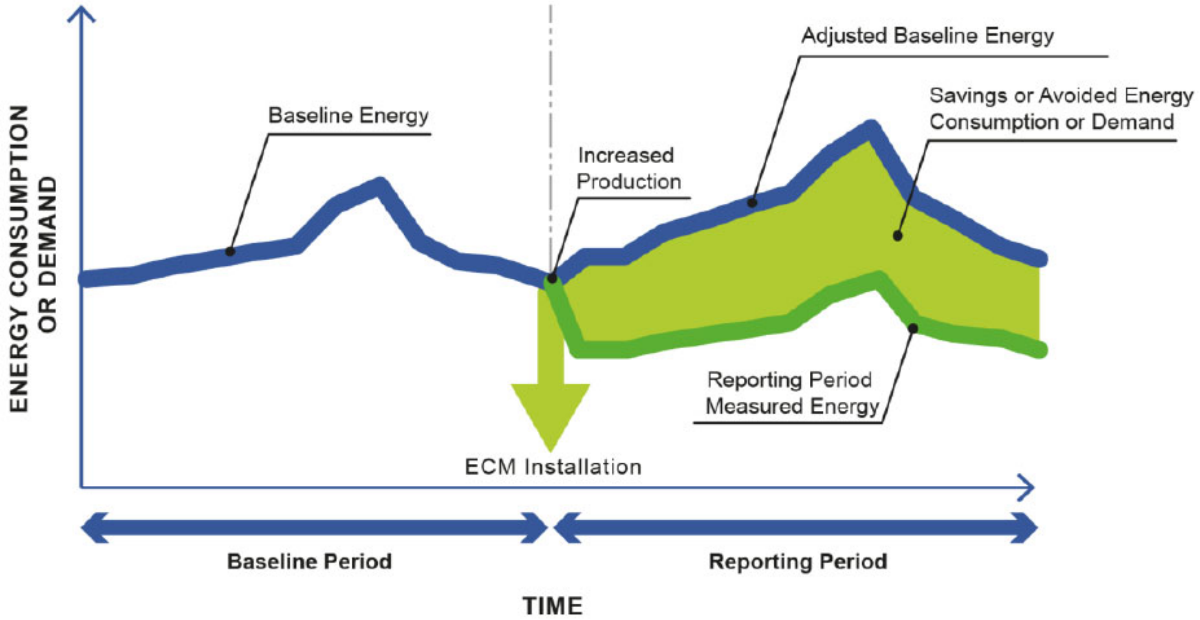

Figure 36: Energy Consumption or Demand during a M&V Process (32)

The IPMVP Structure should be well integrated into the processes of identification, development, purchase, installation and operation of the ECMs and requires the happening of certain activities at key points. The IPMVP Structure describes other important activities that must be included as part of the M&V process (32).j

6.5.2 IPMVP Options

The IPMVP provides four different options for determining energy-savings (Table 48: Options A, B, C and D). These options require data on Energy Consumption or Demand and other parameters of the facility where the ECM is implemented. The choice of the most suitable option involves many considerations, including the selection of the ECM Measurement Limits. The Energy-Consumption or Demand required for the different energy-savings formulas can be measured through one or more of the following methods (32):

- Invoices or reading from the measuring equipment of the energy of fuel supply companies, making the same adjustments to the readings that they make.
- Special measuring equipment that isolate an ECM or a part of the facility from the rest of it. The measurements may be periodic or continuous during the Baseline or Reporting Periods.
- Other measurements independent of the parameters used for determining the Energy Consumption or Demand.
- Measurement of Proxy variables for Energy Consumption or Demand.

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- ○ **Proxy Measurement:** A measured parameter that substitutes a direct measurement of an energy parameter, where the relationship between both has been proved in situ.
- Calibrated simulation with respect to actual operating data of the system or facility which is being modelled.

If an energy parameter is already known with suitable accuracy or when the investment for its measurement do not justify the obtained uncertainty reduction, then the measurement of this energy parameter may be no necessary or appropriative. In these cases, some ECM parameter may be estimated, whiles others must be measured (Option A) (32).

If it is decided to determine the energy-savings at the facility-wide level, the options C or D are preferable. However, if only the performance of the ECM by itself is of concern, the options A, C, or D, are more suitable (32).

In the table below there are summed up the main characteristics of the different IPMVP options:

Table 48: IPMVP Options (32)

IPMVP Option	Methodology	Savings Calculation Method	Typical Applications
Retrofit-Isolation: Key Parameter Measurement (Option **A**)	• The savings are determined by field measurement of the key parameter(s), which define the energy consumption and the demand of the system(s) affected by the ECM, in other words, the success of the project. • The measurement frequency varies from short-term to continuous, depending on the expected variations of the measured parameter and the length of the reporting period. The values for not selected parameters for field measurements are estimated. The estimations can be based on historical data, manufacture specifications, or engineering judgment. • The documentation of the source or the justification of the Estimated Value is required. The plausible saving error arising from estimation rather than measurement is evaluated.	• Engineering calculation of the baseline period and the reporting period energy in base of the Estimated Values and the short-term or continuous measurement of the key parameter(s). • Realization of routine and non-routine adjustments as required. The key parameter(s) are measured during both baseline and reporting period.	• A lighting retrofit where the power draw is the key parameter measured and secondly, lighting operating hours are estimated based on the facility schedule and the occupants behaviour.

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Retrofit-Isolation: All Parameter Measurement (Option **B**)	• The savings are determined by field measurement of the energy consumption and/or related independent or Proxy variables of the system affected by the ECM. • The measurement frequency varies from short-term to continuous, depending on the expected variations of the savings and the length of the reporting period.	• Short-term or continuous measurements of the baseline and reporting period energy, or engineering computations using measurements of proxies of energy consumption. • Realization of routine and non-routine adjustments as required	• Installation of a Variable Frequency Drive (VFD) in the motor of a pump in order to adjust the pump flow. Electric power measurement with a wattmeter (reading time setting "every minute") installed on the electrical supply to the motor. In the baseline period this meter is in place for a week to verify constant loading. The meter is in place during the reporting period to measure the power consumption and demand. • The same methodology is applicable for fans.
Whole Facility (Option **C**)	• The savings are determined by energy consumption and demand measurement at the whole facility through the measuring equipment of the energy supplier company. • Continuous measurements of the energy consumption and demand of the entire facility during the reporting period.	• Analysis of the baseline and reporting period meter data of the whole facility (measuring equipment of the energy supplier company). • Realization of routine adjustments as required, using techniques such as "simple comparison" or "regression analysis". • Realization of non-routine adjustments as required.	• Multifaceted energy management programs affecting many systems in a facility. Measurement of the energy consumption and demand through the measuring equipment of the energy and gas supplier companies for a twelve-month baseline period and during the reporting period.

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Calibrated Simulation (Option **D**)	• The savings are determined through simulation of the energy consumption and demand of the whole facility or a sub-facility. • The simulation routines demonstrate that the actual energy performance in the facility is adequate. • This option requires a considerable calibrated simulation skill.	• Energy consumption and demand simulation calibrated with hourly or monthly invoicing data of the energy supplier company. Data from energy or performance measuring equipment may be use in model refinement.	• Multifaceted energy management program affecting many systems in a facility without measuring equipment during the baseline period. • After the installation of gas and electric measuring equipment, the energy consumption and demand measurements are used to calibrate a simulation. • The baseline period energy, determined using the calibrated simulation, is compared to a simulation of the reporting period energy consumption and demand.

6.5.3 Adherence with IPMVP

The IPMVP is based on the following principles (32):

- The IPMVP represents a framework of terminology and methods for properly evaluate savings in energy or water consumption or demand.
- The IPMVP guides users in developing M&V Plans and Reports for specific projects.
- The IPMVP is written to allow maximum flexibility in creating and implementing M&V procedures, always adhering to the principles of accuracy, completeness, conservativeness, consistency, relevance and transparency.

The M&V represents a process implemented to assure that savings are verified according to the application of the IPMVP procedures. The steps of a typical M&V process are listed below (32):

1- An estimation of savings for the project is developed. This may be from an energy audit or a technical study realized for the proposed project. Usually, the proposed savings estimation is made to evaluate the business aspect of the project.
2- The M&V Plan is reviewed to verify the adherence with IPMVP methods, procedures and principles. The review may be performed by qualified third-part, such a Certified Measurement and Verification Professional (CMVP).
3- The Savings Reports are developed as described by the M&V Plan.
4- The Savings Reports are reviewed to verify the adherence with the M&V Plan and IPMVP methods, procedures and principles.

This results in an adherent project through the latest Reporting Period (32).

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The following fugure shows a flowchart of a M&V process with its typical adherence activities:

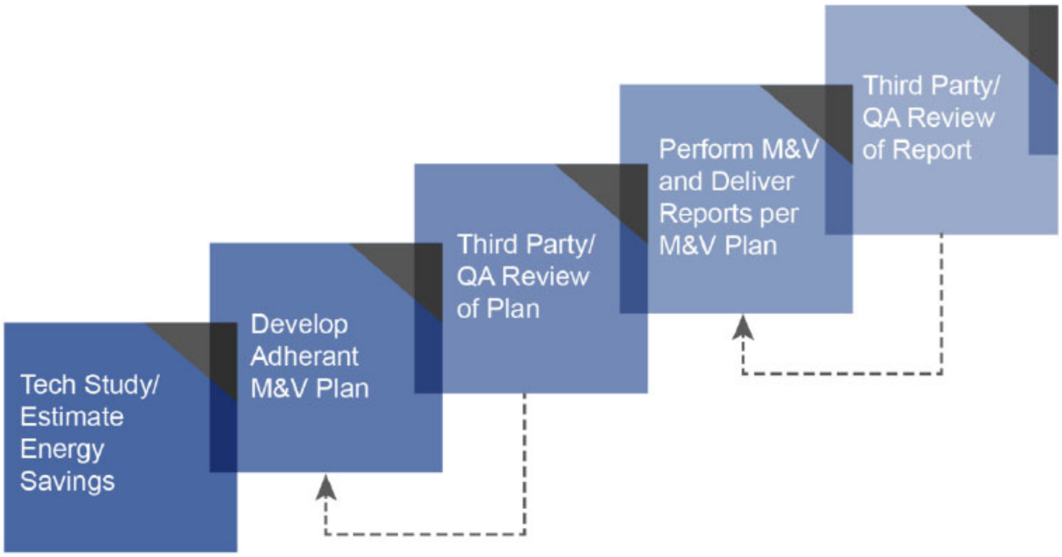

Figure 37: Flowchart of M&V Process with typical adherence activities (32)

Users that adduce an adherence with IPVP must (32):

- Identify the person responsible for approving the site-specific M&V Plan and for making sure that the M&V Plan is followed during the Reporting Period.
- Develop a complete M&V Plan which (32):
    - Clearly states the date of publication or the version number of the IPMVP Edition and Volume being followed.
    - Uses terminology consistent with the definitions in the version of IPMVP cited.
    - Includes all the information mentioned in the M&V Plan.
    - Defines the contents of the Savings Reports and the frequency that energy-savings will be reported.
    - Is approved by all parties interested in the adherence with IPMVP.
    - Is consistent with the Principles of IPMVP.

Implement the approved IPMVP adherent M&V Plan and assure that its procedures are followed according to the Principles of IPMVP. This may include the realization of a quality assurance review of all M&V activities, including inspections, measurements, calculations and reports. For each project, the quality assurance procedures are described in the M&V Plan. A knowledgeable and experienced professional should conduct the review process, such a Certified Measurement and Verification Professional (CMVP) (32)

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6.6 Use of Savings

The most common operation way of ESCOs and performance contracts is that once the project is completed, the immediate results of energy-savings (normally between 15-35%) and the long term maintenance costs reduction may be reinvested in order to improve the energy system (30). The project is done without customer investment, making the payment to the ESCO in base of a percentage (or the total) of the obtained savings during a contractual period. The customer has also the possibility of making an initial investment in order to reduce the saving percentage payment. The payback period is often between 5 to 20 years. Once the contractual period has ended, the customer is entitled to the total savings generated by the project.

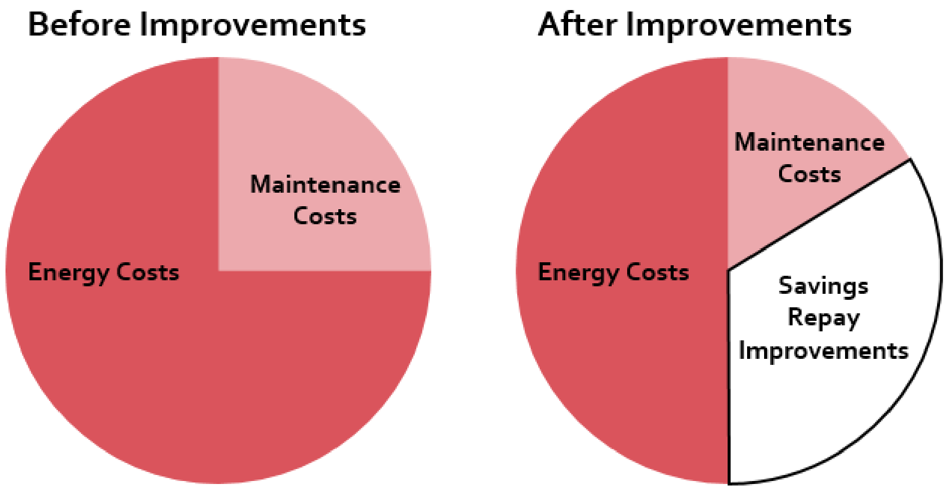

Figure 38: Energy-Savings after and before Improvements (30)

6.7 Energy Contracting (EC)

Energy Contracting (EC) is a comprehensive energy service concept to execute Energy Efficiency projects in buildings or production facilities according to minimize project cycle cost (33).

EC is cited many times as a smart multipurpose instrument which will help to overcome the barriers related with Energy Efficiency projects (33).

The EC concept shifts the focus away from selling units of final energy (such as fuel oil, natural gas or electricity) towards the desired benefits and services derived from the use of energy, such as the lower cost of keeping a room warm, air-conditioned or illuminated (33).

EC is not based in any particular technology, instead it is a flexible and modular "efficiency tool" to execute energy efficiency projects, according to the goals of the facility owner. EC is an instrument to minimize project cycle cost, including the operation phase. ESCOs act as coordinator and manager of interfaces towards the customer and has to deliver the commissioned energy service at all-inclusive prices (33).

ESCO products provide either useful energy (Energy Supply Contracting; ESC) or energy-savings (Energy Performance Contracting; EPC) to the end-user, achieving environmental benefits due to the

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associated energy and emission savings, as well as non-energetic benefits, such as increase in comfort or image gains (33).

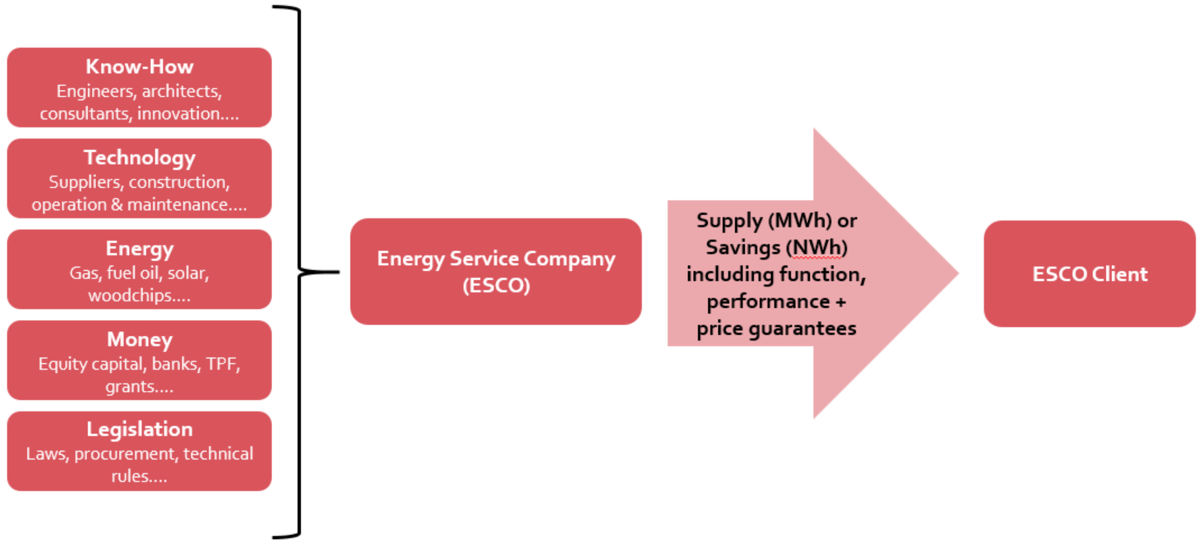

Figure 39: Energy Contracting flowchart (33)

The three types of EC business models are listed below will be described in the subsequent chapters:

- Energy Supply Contracting (ESC)
- Energy Performance Contracting (EPC)
- Integrated Energy Contracting (IEC)

6.7.1 Energy Supply Contracting (ESC)

The Energy Supply Contracting (ESC) is a contrasted business model to implement efficiency supply (from fossil and/or RES) in new or existing buildings and industrial processes. The target is to achieve a reduction in the final energy demand, although the efficiency benefits are generally limited to the energy supply system (34).

Under ESC models, ESCOs are only remunerated for the useful energy output, in other words, ESCOs supply useful energy, such as electricity, heat or steam, under a long-term contract to a customer. Therefore, ESCOs are interested in reducing the final energy demand. The output is measured and verified in MWh delivered. ESC models are executed under long-term contracts of commonly from 10 to 15 years, depending of the technical lifetime of the equipment implemented (34).

ESC model is interesting for the SO WHAT demo-sites with potential for RES, and also for the end-users of industrial excess heat from the SO WHAT demo-sites.

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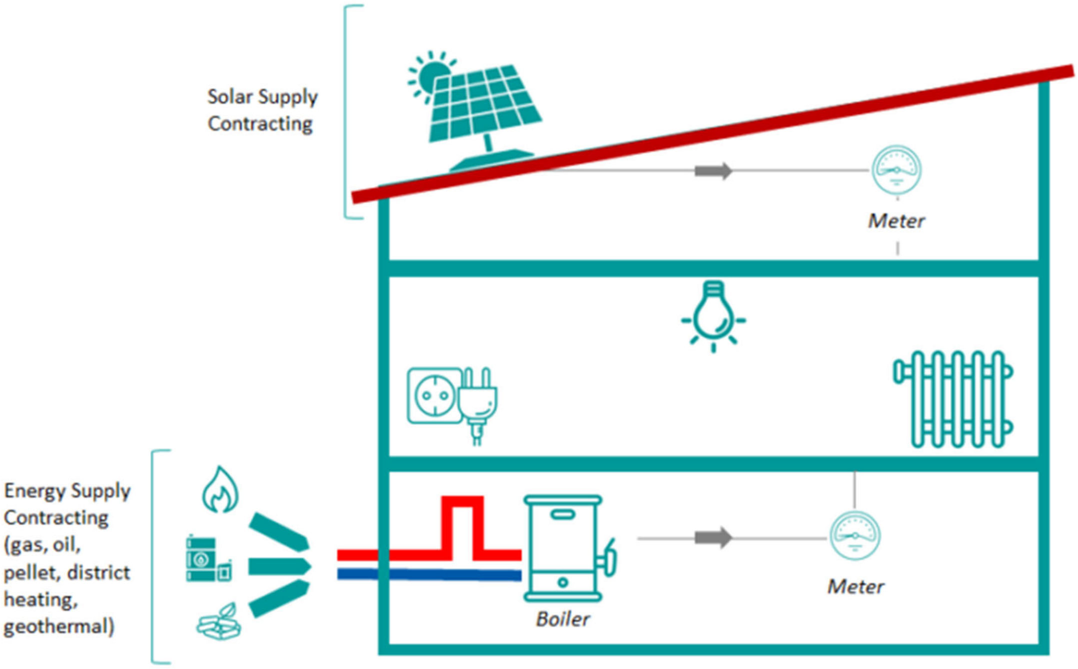

Figure 40: Energy Supply Contracting (ESC) diagram (34)

The customer has the opportunity of outsourcing technical and economic risks related to energy supply activities (such as planning, installation, operation maintenance, and financing of equipment for heating, cooling or electricity generation) hiring a professional company, paying for services instead of buying individual components. ESC often includes the final energy supply through an ESCO (34).

Due to the profit of the ESCO is based on performance and depends on the useful energy output delivered, the ESC model provides an incentive to increase the efficiency of the energy conversion and to reduce the primary energy demand. The contract covers the outcome and all costs of the services, as well as the commercial, technical and operational risks of the project. ESC may accelerate the uptake of Renewable Energy Technologies (RET) if they are cost competitive over the lifecycle of the project, due to the inherent interest of ESCOs in reducing the lifecycle costs (34).

The objective of the ESC model is to optimize the efficiency of the energy supply and provide security of supply. The benefits of ESC are the following (34):

- Efficiency increase.
- Clear and optimized operational costs.
- Supply assurance increase.
- Application of the most recent safety standards.

ESCOs supply useful energy, such as hot water, steam, (back-up) electricity or compressed air from a large variety of technologies based on conventional or renewable resources (34).

ESC model involves the following activities (34):

- Purchasing of fuel.
- Energy delivery.

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- Energy invoicing.
- Management of energy distribution.
- Energy production plants:
    - Financing.
    - Engineering design.
    - Planning.
    - Construction.
    - Operation and maintenance.

ESC is particularly suitable for the implementation of RET, like solar or geothermal, due to the easiness of measuring their energy outputs. The most applied technologies in the ESC model are the following (34):

- Efficient boilers (biogas, wood chips and pellets).
- Combined heat and power (CHP) systems (gas turbines and reciprocating engines).
- District and small-scale heating networks.
- Solar Thermal Energy (STE) installation
- Solar Photovoltaic (PV) installations.

The ESCO is financially responsible of the implementation and operation of the energy supply package, assuming the expenses and risks, according to the project-specific requirements stablished by the customer (34).

The ESCO is remunerated for the useful energy delivered, depending on the actual consumption in combination with a flat rate for Operation & Maintenance (O&M). The remuneration is made of the following three price components (34):

- **Energy Price (per MWh of useful energy measured):** It covers the marginal cost related with the consumption per MWh of useful energy supplied. To take into account the evolution of the final energy price during the contractual period, the energy price of the ESCO should be adjusted by the application of statistical energy price indices in function of the fuel used (such as electricity, gas or biomass index). In order to avoid selling more energy than the needed, the calculation of the ESCO energy price should only include the cost related to consumption (the marginal costs), in other words, only the expenditure for fuel and auxiliary electricity (34).
- **Service (or basic) Price for Energy Supply (flat rate):** It includes all operational cost, in other words, the cost for Operation & Maintenance, personal, insurance, management, etc. of the energy supply infrastructure, as well as the business risks. During the contractual period, the prices are usually adjusted (normally every year retrospectively) by the application of statistical indices, such as wage or investment materials indices. The Service Price for Energy Efficiency (flat rate) is determined in analogy to the above service price, including all operational cost of the ECMs (34).
- **Capital Cost (optional):** If the ESCO (co)-finance the equipment, its remuneration also includes a fee for its capital cost minus any subsidy for the RET equipment which it may have received (34).

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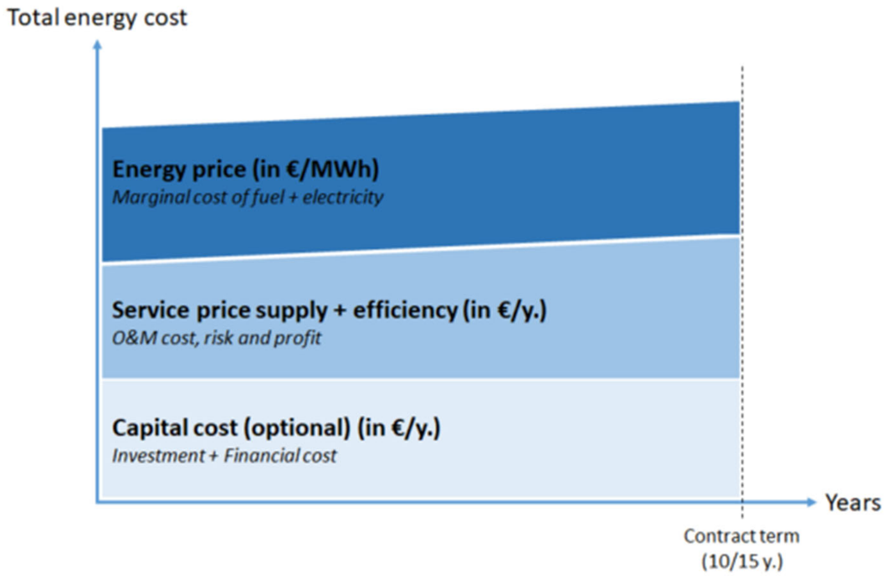

Figure 41: Energy Supply Contracting (ESC) Remuneration (34)

6.7.2 Energy Performance Contracting (EPC)

The EPC model is based on providing energy-savings compared to a Baseline Period. In this model, an ESCO stablishes arrangements with facility-owners in order to improve the Energy Efficiency of their facilities by implementing ECMs. The ESCO guarantees energy-savings in comparison to the Baseline Period energy cost. For its services and the energy-savings guarantee, the ESCO receives a performance-based remuneration in relation to the energy-savings achieved, which normally, can only be measured indirectly as the difference between the consumption before and after implementation of the ECM (35).

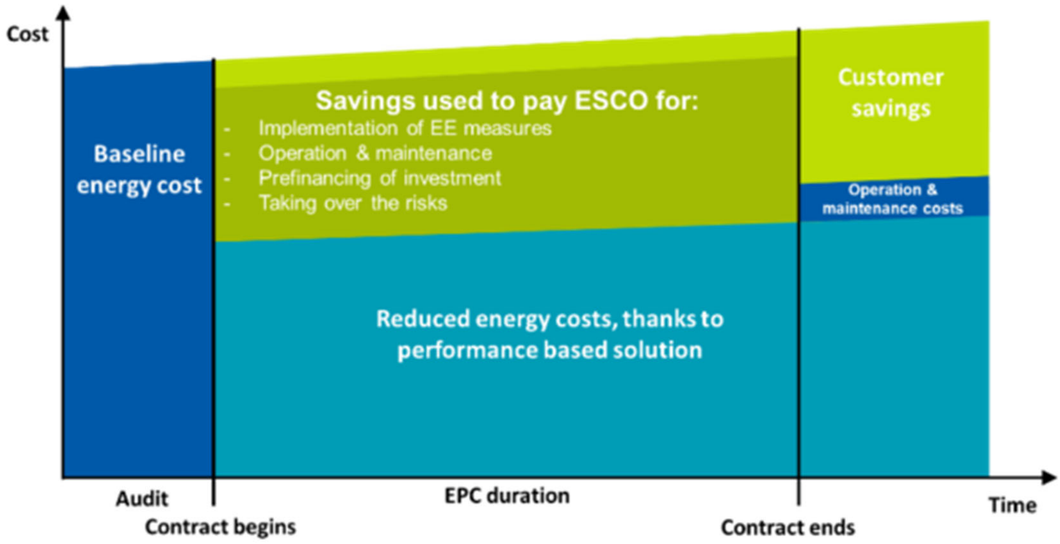

Figure 42: Energy Performance Contracting (EPC) diagram (35)

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Most EPC projects focus on the implementation of ECMs in the fields of lighting, HVAC, energy management and control, and envelope insulation. Normally, the EPC models are executed under long-term contracts with durations from 10 to 15 years, depending on the payback time of the ECMs and the specification of the facility owner (35).

The ESCO provides a customized service package, which includes (35):

- Design.
- Installation.
- (Co)-Financing.
- Operation & Maintenance.
- Optimization.
- Customer specifications.

For many customers the financing is the most attractive part of the EPC model. In other words, the risks transfer and the capacity to improve the facility energy infrastructure without making an investment and through external expertise and guarantee of performance. The objective is saving energy at the point of use first, before optimizing the supply of that energy (35).

The ESCO is responsible for the implementation and operation of the ECMs under their own expenses and risks, according to the project specific requirements defined by the customer and the ESCO. Generally, the purchasing of final energy (such as electricity or fuels) remains in the hands of the facility owner (35).

The costs for the ESCO include the implementation of the ECMs, their Operation & Maintenance, the financing of the investment and the taking over risks according to the project specifications defined in the contract. Measurement and Verification (M&V) costs of EPC projects are high. Determining and adjusting the Baseline is a crucial issue in the EPC model (because of this it can generate a considerable degree of insecurity and monetary risks for the ESCO) and needs to be performed for all performance-based billing periods over the entire contract period (35).

In the EPC model, the remuneration of the ESCO is based on the performance, due to (35):

- It guarantees the result and all-inclusive costs of the services.
- It assumes commercial as well as technical and operational risks over the project period.

There are two types of EPC business models:

- **EPC with Shared Savings:** The ESCO shares an agreed percentage of the actual energy-savings over a fixed period with the customer. Generally, the share of savings of ESCOs is a value within the range of 65% to 85% (35).

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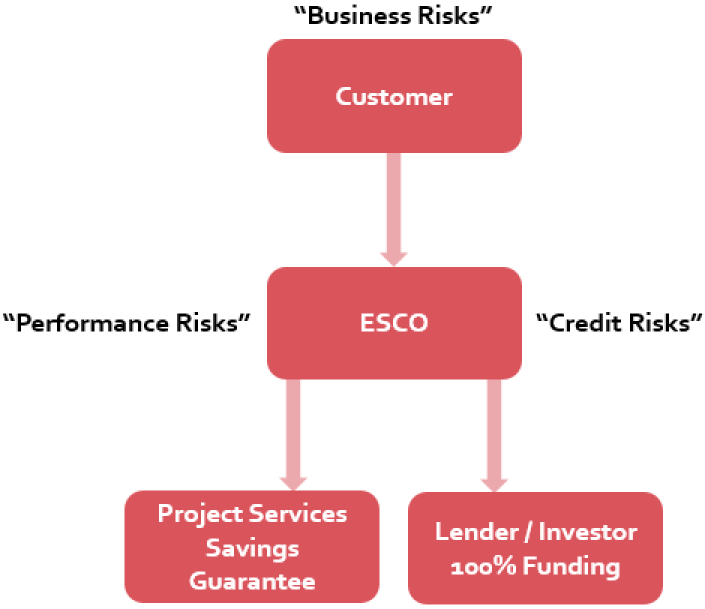

Figure 43: EPC with Shared Savings diagram (36)

- **EPC with Guaranteed Savings:** If the energy-savings are less than expected, the ESCO covers the shortfall. If the energy-savings are overachieved, the ESCO can recover the excess. After the end of the contract period, the facility owner benefits from the full energy-savings cost (35).

Figure 44: EPC with Guaranteed Savings diagram (36)

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The following table summarizes the main characteristics these two types of EPC business models:

Table 49: EPC Business Models characteristics (36)

Characteristic	Guaranteed Savings	Shared Savings
Performance	Related to the level of energy saved.	Related to the cost of the energy saved (the ESCO bills upon actual results).
Value	The value of energy saved is guaranteed to meet debt service obligations down to a floor price.	The value of payments to ESCO is linked to the energy price (betting on price of energy can be risky).
Risk	• ESCO carries performance risk. • Customer carries credit risk.	ESCO carries performance and credit risk, due to it generally carries out the financing.
Debt	If the customer borrows, then debt appears on its balance sheet.	Usually, the debt is off the balance sheet of the customer.
Financing	Requires a creditworthy customer.	Can serve customers that do not have access to financing.
M&V equipment	Extensive M&V.	The equipment may be leased.
Effort	ESCO can do more projects without getting highly leveraged.	Favours large ESCOs, due to small ESCOs become too leveraged to get involved in more projects.
Other characteristics	More comprehensive.	Favours projects with short payback periods.

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6.7.3 ESC vs EPC

The main difference is that EPC goes beyond ESC. While ESC is a business model based on the guarantee of energy supply, EPC is a business model focused on energy-savings, whose objective is to avoid wasting energy and to invest the savings in Energy Efficiency (37).

The following figure shows a diagram of these two models of Energy Contracting:

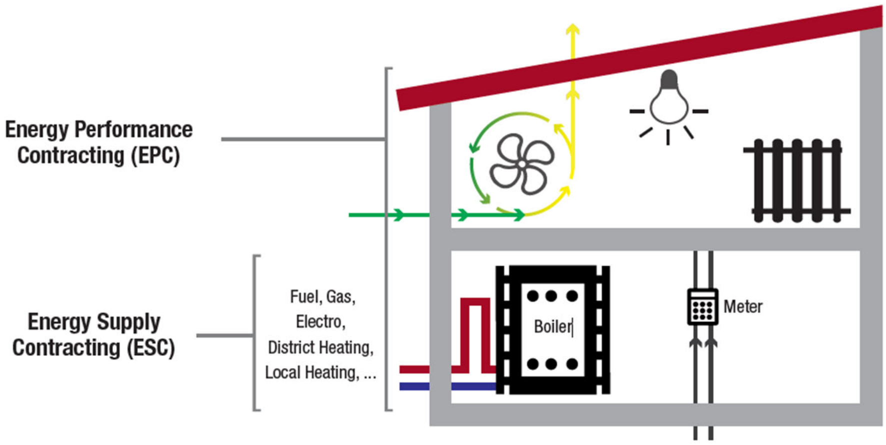

Figure 45: ESC and EPC Business Models diagram (37)

The following figure shows the Value Chain of these two models of Energy Contracting:

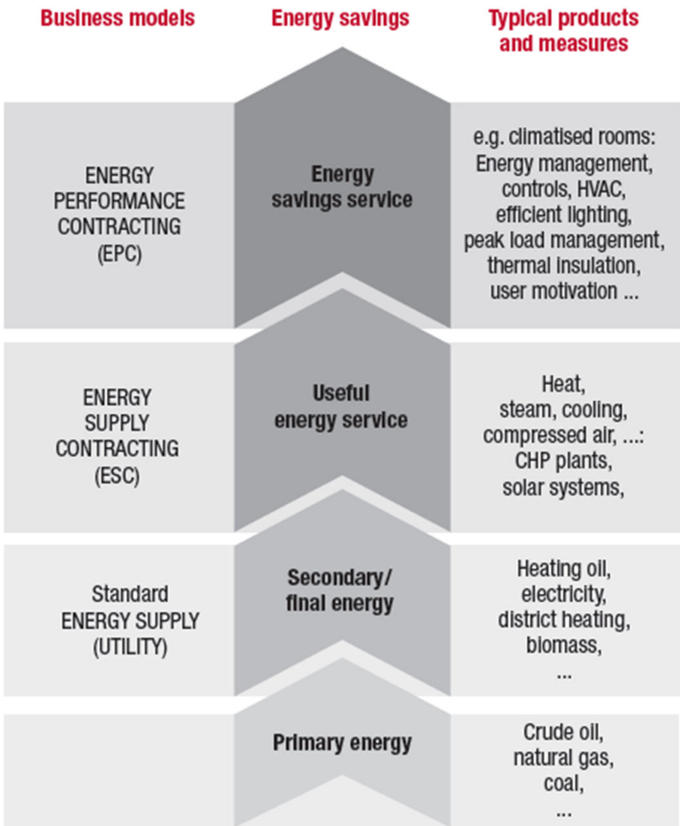

Figure 46: Value Chain of ESC and EPC Business Models (37)

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The ESC and EPC market properties are listed below:

- **ESC Market Properties** (38):
  - Heat supply projects dominate the ESCO market and are common in several end-use consumption sectors, such as housing, commerce and industry, public buildings and the tertiary sector.
  - ESC projects are suitable for the implementation of renewable supply projects or innovative technologies, such as combined heat and power systems.
  - The minimum energy cost baseline of heat supply projects is 20,000 €/year, are at least one order of magnitude below those of EPC projects.
  - The ESC model is more robust and flexible with respect to changes in the energy consumption, due to the direct measurement and billing of the useful energy delivered.
- **EPC Market Properties** (38):
  - The EPC model provides a more comprehensive approach and involves the saving potentials in the entire facility.
  - In practice, a number of (methodological) problems, mainly in the areas of Baseline determination and maintenance, Measurement & Verification, as well as appraisal of risks and cost of the savings guarantee hinder a more widespread distribution.
  - With an ESCO market share of about 10%, the market acceptance of EPC is significantly lower than with ESC and almost limited to the public sector and special purpose buildings, such as hospitals, swimming pools or universities.

The ESC and EPC market properties are summarized in the following table:

Table 50: ESC vs EPC Market properties (38)

Market property	ESC	EPC
End-use markets	Public institutions, residential, commerce and industry.	Public institutions (including universities, hospitals and
Project size: Minimum energy cost Baseline	> 20,000 €/year	> 100,000 €/year
Efficiency potentials	15-20% (limited scope of service)	20-25% (up to 30-50%)
Share in ESCO market (Germany 2008)	85-90%	10-15%
Business model / Performance measurement	Useful energy (MWh)	Energy-savings ("NWh"): • Baseline problems

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The EPC model is based on delivering energy-savings in comparison to a historical cost baseline. Hereby, three sets of problems may arise (EPC baseline problems) (38):

1- In general, energy-savings ("NWh") can only be measured indirectly as difference between consumption before and after the implementation of ECMs. In reality, two main difficulties occur (38):
    - The Baseline may be difficult to determine with enough accuracy, due to a lack of availability of historic data (such as from bills or measuring equipment) (38).
    - The determined energy cost Baseline is not a constant but subject to changes in climate conditions and in energy prices. Moreover, changes in utilization may cause considerable difficulties, cost and insecurity for ESCOs and facility owners in adjusting the Baseline (38).

2- EPC Measurement and Verification (M&V) of the energy-savings may cause high expenses in relation to the saving potentials (38).

3- For ESCOs, the risks associated with the EPC savings guarantee may cause considerable safety surcharges and generate additional costs for the client. For the savings guarantee, ESCOs should account for possible increases in energy consumption (38).

6.7.4 Integrated Energy Contracting (IEC)

The Integrated Energy Contracting (IEC) model is a combination of the ESC and EPC models, developed in order to avoid the limitations and involve the market properties of each model separately.

The IEC model combines two objectives (38):

1. Reduction of energy demand through the implementation of ECMs in the fields of building technology (HVAC and lighting), building shell and user motivation.
2. Efficient supply of the remaining useful energy demand, preferably from renewable energy sources.

These objectives are reached through (38):

- Combining energy conservation and (renewable) energy supply into an integrated approach or product.
- Building on success of the ESC model to reach out to additional end-use markets.
- Increasing the saving potential of the ESC model.
- Reducing the transaction and Measurement & Verification (M&V) costs.
- Making performance-based ESCO services available to smaller projects.

The IEC model is more widespread and robust and is supplemented by quality assurance instruments for the energy ECMs, which serve as a substitute for the potentially complex and costly M&V (38).

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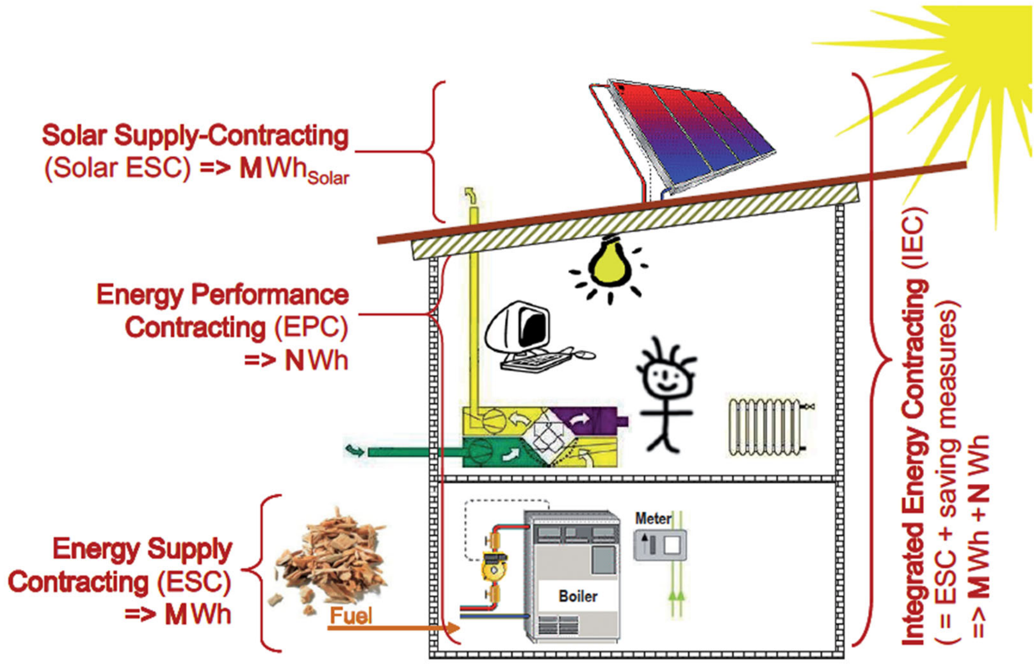

Figure 47: Integrated Energy Contracting (IEC) diagram (38)

The ESCO will take over implementation and operation of the energy service package at its own expenses and risk according to the project specific requirements set by the client. In return, the ESCO will get remuneration for the useful energy delivered, depending on the actual consumption as well as flat rate remuneration for O&M, including quality assurance. Financing is a modular component of the service package (38).

The remuneration of the ESCO is made up of the following three price components:

- **Energy price (per MWh of useful energy measured):** It covers the marginal cost related with the consumption per MWh of useful energy supplied. To discard incentives to sell more energy, the ESCO calculation of the energy price should only include the cost related to consumption (in economic terms: the marginal cost), in other words, exclusively the expenditure for fuel and auxiliary electricity. To take into account the final energy price evolution during the contractual period, the energy price of the ESCO should be adjusted by the application of statistical energy price indices depending on the fuel used (such as electricity, gas or biomass index), which are defined in the IEC Contract. Therefore, the risk (and chances) of final energy price development remains with the client of the ESCO (38).
- **Service Price (or basic) for Energy Supply (flat rate):** It includes all operational cost, in other words, the cost for Operation & Maintenance, personal, insurance, management, etc. of the energy supply infrastructure, as well as the business risks. During the contractual period, the prices are usually adjusted (normally every year retrospectively) by the application of statistical indices, such as wage or investment materials indices. The Service Price for Energy Efficiency (flat rate) is determined in analogy to the above service price, including all

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operational cost of the ECMs. As is shown in the Figure 48, the two Basic Prices can be combined (38).

- **Capital Cost (of Energy Efficiency and Supply Investments):** It may or may not be part of the service package. If (co)-financed by the ESCO, the ESCO will get a remuneration for its capital cost minus subsidies and building cost allowances. During the contractual period, the prices may be adjusted by the use of statistical indices, such as the 6-Month Euribor (Euro Interbank Offered Rate) (38).

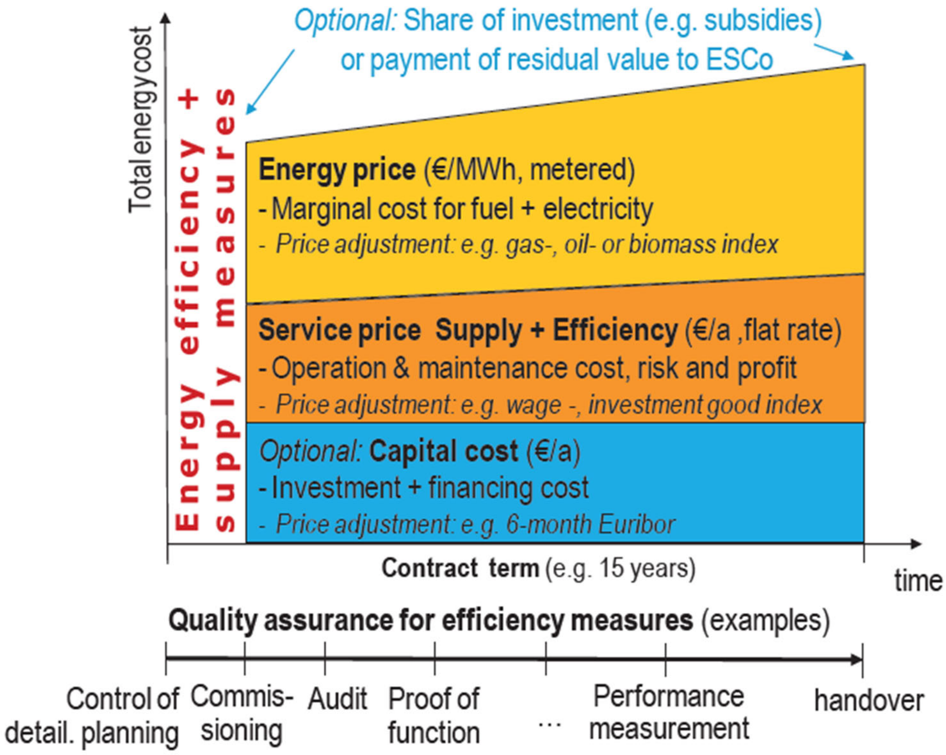

Figure 49: Integrated Energy Contracting (IEC) Remuneration (38)

6.7.4.1 Quality Assurance

To avoid or at least to reduce the EPC Baseline problems, the Measurement and Verification (M&V) procedure of the actual energy-savings achieved is replaced by quality assurance and simplified M&V procedures (such as deemed savings) (38).

The individual Quality Assurance Instruments (QAIs) for the ECMs installed shall secure their functionality and performance, but not their exact quantitative outcome over the entire project cycle, due to the outcome may largely depend on the influence of external factors (such as changes in the climate conditions). The objective is to simplify the business model and to reduce the transaction cost by balancing M&V cost and accuracy (38).

Appropriate QAIs will need to be defined specifically for each ECM implemented. QAIs can be specified either by the client or suggested by the ESCO. The selection of QAIs, as well as their exact design, will depend on the specific requirements of the project scope and the parties involved (38).

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An important point to take into account is to find a reasonable ratio between quality assurance and verification efforts, on the one hand, and expenditure for M&V on the other hand. A guiding principle is the following: "As little effort as possible and as much as necessary in order to secure the general project savings goals" (38).

On the other hand, it needs to be analysed if the saving incentives and control through QAIs are sufficient to motivate the ESCO to continual efficient operations and optimization (38).

Possible QAIs for ECMs that can be provided by the client or third parties are the following (39):

- Functional specifications to communicate and document energy-related objectives and requirements: Quality standards, maximum energy indicators, request of renewable energy resources with proof of origin, etc.).
- Coaching and control of detailed planning by an (independent) energy specialist.
- Installation supervision by an (independent) energy specialist.
- "Acceptance" after installation phase (compliance with functional specifications, thermographic pictures, blower door test, proof of function, etc.).
- Energy bookkeeping comparison of target and actual values (alternatively provided by the ESCO).
- Expertise by an (independent) energy specialist (2nd opinion report).

Possible QAIs for ECMs that can be provided by the ESCO are the following (39):

- Detailed analysis of the planned ECMs.
- Proof of function: Commissioning, parameter and operating protocols, etc.
- One-time verifications after commissioning: Performance tests, efficiency measurements, blower door test, acceptance protocols, etc.
- Recurring verifications: Proof of user motivation, efficiency measurements, control of emission values, return temperature limitations, compliance with heating curves, etc.
- Obligation for annual reporting (auditing): Energy balances, comparison of target and actual values or benchmarks, suggestions for ECMs, etc.
- Computational saving verifications: Nominal power savings times, operating hours, etc.
- Maintenance protocols.

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The following figure shows sample QAIs as substitute for saving measurements in the IEC model:

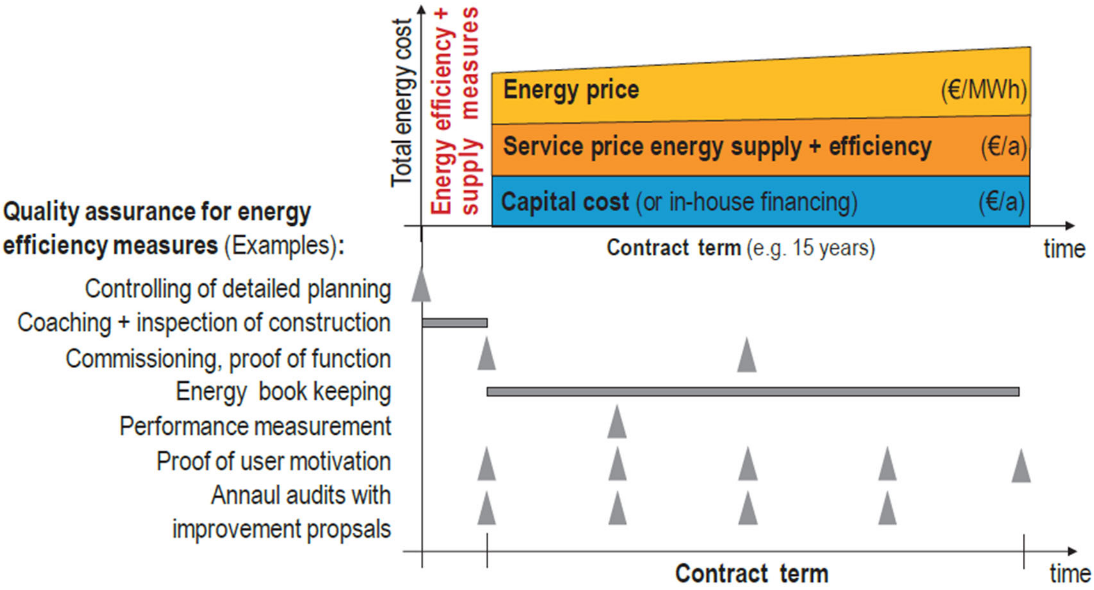

Figure 50: IEC Model: Sample QAIs as substitute for saving measurements (38)

6.7.5 Energy Contracting Summarize

The following table summarizes the Energy Contracting business models described:

Table 51:Energy Contracting business models

Energy Contracting business models		
Energy Supply Contracting (ESC):	**Energy Performance Contracting (EPC):**	**Integrated Energy Contracting (IEC):**
Objectives: — Efficiency increase. — Clear and optimized operational costs. — Supply assurance increase. — Application of the most recent safety standards. Remuneration: — Energy Price (per MWh of useful energy measured): — Service (or basic) Price for Energy Supply (flat rate): — Capital Cost (optional)	• **EPC with Shared Savings:** The ESCO shares an agreed percentage of the actual energy-savings over a fixed period with the customer (65%-85%). • **EPC with Guaranteed Savings:** If the energy-savings are less than expected, the ESCO covers the shortfall. If the energy-savings are overachieved, the ESCO can recover the excess. After the end of the contract period, the facility owner benefits from the full energy-savings cost.	Objectives: — Reduction of energy demand through ECMs. — Efficient supply of the energy demand, (preferably from RES). Remuneration: — Energy price (per MWh of useful energy measured). — Service Price (or basic) for Energy Supply (flat rate). — Capital Cost (of Energy Efficiency and Supply Investments).

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7 Financing and ESCO Models of the SO WHAT Demo-Sites

In this chapter, after summarizing the Financing Schemes and ESCO Models that will be considered, are presented the different options of investment analysed by each demo-site (LIPOR and Martini & Rossi demo-sites, there have not yet been defined the options of investment that should be considered). Then are presented the Financing Schemes and ESCO Models selected by each demo-site, with the exception of Martini & Rossi demo-site, which have not yet been defined.

7.1 Financing Schemes and ESCO Models Summarize

The following table summarizes the financing schemes described in Chapter 5:

Table 52: Financing Schemes summarize

<table>
<tr><th colspan="2">Financing Schemes</th><th></th></tr>
<tr><td rowspan="8">Ownership and OPERATION 100% by a Local Entity:
Collaboration with another public organism.
Acquisition and/or exploitation of networks of other municipalities.</td><td rowspan="8">100% Private Property and Exploitation:
Supports of the local entity:
Repayable loans.
Non-refundable grants.
Tax advantages.
Other benefits.</td><td>Public-Private Model:</td></tr>
<tr><td>ESCO Contracts (analysed more in depth in Chapter 6)
— Guaranteed savings.
— Shared or mixed savings.</td></tr>
<tr><td>Concession</td></tr>
<tr><td>Leasing</td></tr>
<tr><td>Property Differentiated by Elements</td></tr>
<tr><td>Mixed Society with Selected Minority Private Capital</td></tr>
<tr><td>Mixed Society with Minority Private Capital from Investment</td></tr>
<tr><td>Mixed Society with Majority Private Capital</td></tr>
</table>

Apart from the previous financing instruments, local entities can count on grants from various options when investing in WH/C recovery, DH/C networks and RES plants, like the ELENA Mechanism created by The European Commission and the European Investment Bank (EIB). Another option could be the EU funds, national managed and available on multi-year programmes.

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The following table summarizes the Energy Contracting business models (ESCO Models) described in Chapter 6 and considered by demo-sites in the selection process:

Table 53: Energy Contracting business models

Energy Contracting business models		
Energy Supply Contracting (ESC): Objectives: — Efficiency increase. — Clear and optimized operational costs. — Supply assurance increase. — Application of the most recent safety standards. Remuneration: — Energy Price (per MWh of useful energy measured): — Service (or basic) Price for Energy Supply (flat rate): — Capital Cost (optional)	**Energy Performance Contracting (EPC):** • **EPC with Shared Savings:** The ESCO shares an agreed percentage of the actual energy-savings over a fixed period with the customer (65%-85%). • **EPC with Guaranteed Savings:** If the energy-savings are less than expected, the ESCO covers the shortfall. If the energy-savings are overachieved, the ESCO can recover the excess. After the end of the contract period, the facility owner benefits from the full energy-savings cost.	**Integrated Energy Contracting (IEC):** Objectives: — Reduction of energy demand through ECMs. — Efficient supply of the energy demand, (preferably from RES). Remuneration: — Energy price (per MWh of useful energy measured). — Service Price (or basic) for Energy Supply (flat rate). — Capital Cost (of Energy Efficiency and Supply Investments).

7.2 Demo-Sites Options of Investment

During the selection process of the most appropriated financing scheme and ESCO model, each of the demo-sites have defined previously the options of investment to be considered, accordingly to different technological solutions available or analysed, which are summarized in the following table:

Table 54: Demo-Sites Options of Investment

Demo-Sites Options of Investment	
LIPOR Maia Waste-to-Energy Plant (Portugal)	At the moment LIPOR demo-site does not know if and what investment will be made. This is the main reason why this demo-site has not indicated one specific scenario for financing and ESCO model selection. However, LIPOR has indicated the Financing and ESCO model that will be selected if the investment will be made.
ISVAG Waste-to-Energy Plant (Belgium)	**Scenario 1: Small district heating network** - Waste heat is recovered from the flue gases of the existing waste-to-energy plant and from the boilers. Waste heat is distributed through a small-scale district heating network (2020/2021)
	Scenario 2: Large district heating network - A new waste-to-energy plant as well as a larger district heating network is taken into operation (2023/2030)

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RADET Constanta DHN (Romania)	**Scenario 1: Pellets boiler and Solar thermal** - Thermal energy from biomass pellets and solar thermal is replacing the heat demand in the existing DHN (2020)
UMICORE Rare Material Centre (Belgium)	**Scenario 1: Internal use of excess heat from processes** - Internal heat grid (2021) - Heat recovery (heat exchangers; 2021) - Old investment: Steam grid (natural gas CHP/boilers; less use)
	Scenario 2: Geothermal energy - Heat recovery (heat exchangers; 2021)
IMERYS Manufacturing Centre (Belgium)	**Scenario 1: Heat recovery** - Heat is recovered from the chimney gases of the furnace and shared with customers through a heat grid that will be constructed. - Heat recovery from furnace chimney gases (2023) - Heat grid (2023)
MARTINI & ROSSI Pessione Distillery (Italy)	At the moment MARTINI & ROSSI demo-site does not know if and what investment will be made. This is the main reason why this demo-site has not indicated one specific scenario for financing and ESCO model selection.
ENCE Navia Pulp Mill (Spain)	**Scenario 1: Internal use of excess heat from causticization stage** - Town hall uses heat from individual natural gas boilers. - Increase of the biomass dryer capacity with heat recovered from the causticization stage (gas/water heat exchanger)
	Scenario 2: External use of excess heat from bleaching and effluent treatment stages - Town hall (and other public buildings) uses heat recovered from the bleaching stage (water/water heat exchanger) and the effluent treatment stage (water/water heat exchanger)
ROMPETROL Petromidia Refinery (Romania)	**Scenario 1: Internal recovery of heat** - Petromidia will make energy efficiency improvements, mainly by recovering waste heat from two furnaces.

7.3 Financing and ESCO Models of the SO WHAT Demo-Sites

After defining the different options of investment to be considered, each demo-site need to select the most suitable and appropriated financing scheme and ESCO model. The results of this selection process is presented in the following sub-chapters.

Some demo-sites have not yet defined the options of investment (LIPOR and MARTINI & ROSSI demo-sites) and others the financing schemes and ESCO models (MARTINI & ROSSI demo-site).

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7.3.1 Demo-Site: LIPOR Maia Waste-to-Energy Plant (Portugal)

Table 55: LIPOR Financing and ESCO Model Selection

Demonstration Site LIPOR Maia Waste-to-Energy Plant	 *Figure 51: LIPOR Waste-to-Energy Plant in Maia (Portugal)*
Financing and ESCO model selection	
Investment Costs	Owner (EU grants) + Owner Financing + Owner Loan
Operation and Maintenance (O&M) Costs	ESCO Contract (private financing)
Reinvestment Costs	Owner Financing and/or Owner Loan
ESCO Contract	Energy Supply Contracting (ESC)

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7.3.2 Demo-Site: ISVAG Waste-to-Energy Plant (Belgium)

Table 56: ISVAG Financing and ESCO Model Selection

Demonstration Site ISVAG Waste-to-Energy Plant	 *Figure 52: ISVAG Waste-to-Energy Plant in Antwerp (Belgium)*
Scenario 1: Small district heating network	
Investment Costs	Owner (EU grants) + Owner Financing
Operation and Maintenance (O&M) Costs	Owner Financing
Reinvestment Costs	Owner Financing
ESCO Contract	N/A
Scenario 2: Large district heating network	
Investment Costs	Owner (EU grants) + ESCO Contract (private financing)
Operation and Maintenance (O&M) Costs	ESCO Contract (private financing)
Reinvestment Costs	ESCO Contract (private financing)
ESCO Contract	Integrated Energy Contracting (IEC)

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7.3.3 Demo-Site: RADET Constanta DHN (Romania)

Table 57: RADET Financing and ESCO Model Selection

Demonstration Site RADET Constanta DHN	 *Figure 53: RADET District Heating Network in Constanta (Romania)*
Scenario 1: Pellets boiler and Solar thermal	
Investment Costs	Owner (EU Funds)
Operation and Maintenance (O&M) Costs	Owner Financing
Reinvestment Costs	Owner Financing
ESCO Contract	N/A

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7.3.4 Demo-Site: UMICORE Rare Material Centre (Belgium)

Table 58: UMICORE Financing and ESCO Model Selection

Demonstration Site UMICORE Rare Material Centre	 *Figure 54: UMICORE Rare Material Recycling and Production Centre in Olen (Belgium)*
Scenario 1: Internal use of excess heat from processes	
Investment Costs	Owner (EU grants) + Owner Financing + Owner Loan
Operation and Maintenance (O&M) Costs	Owner Financing
Reinvestment Costs	Owner Financing
ESCO Contract	N/A
Scenario 2: Geothermal energy	
Investment Costs	Owner (EU grants) + ESCO Contract (private financing)
Operation and Maintenance (O&M) Costs	ESCO contract (private financing)
Reinvestment Costs	ESCO contract (private financing)
ESCO Contract	Integrated Energy Contracting (IEC)

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7.3.5 Demo-Site: IMERYS Manufacturing Centre (Belgium)

Table 59: IMERYS Financing and ESCO Model Selection

Demonstration Site IMERYS Manufacturing Centre	 *Figure 55: IMERYS Carbon Black Manufacturing Centre in Willebroek (Belgium)*
Scenario 1: Heat recovery	
Investment Costs	Owner (EU grants) + ESCO Contract (private financing)
Operation and Maintenance (O&M) Costs	ESCO contract (private financing)
Reinvestment Costs	Owner Financing and/or Owner Loan
ESCO Contract	Integrated Energy Contracting (IEC)

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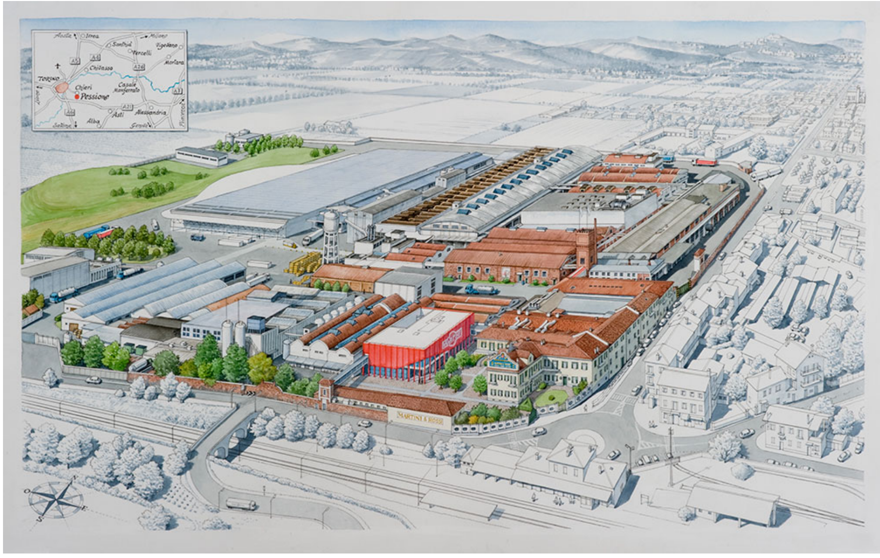
7.3.6 Demo-Site: MARTINI & ROSSI Pessione Distillery (Italy)

Table 60: Martini & Rossi Financing and ESCO Model Selection

Demonstration Site Martini & Rossi Pessione Distillery	 *Figure 56: Martini & Rossi Distillery in Pessione (Italy)*
Financing and ESCO model selection	
Investment Costs	Not yet defined
Operation and Maintenance (O&M) Costs	Not yet defined
Reinvestment Costs	Not yet defined
ESCO Contract	Not yet defined

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7.3.7 Demo-Site: ENCE Navia Pulp Mill (Spain)

Table 61: ENCE Financing and ESCO Model Selection

Demonstration Site ENCE Navia Pulp Mill	 *Figure 57: ENCE Pulp Mill in Navia (Spain)*
Scenario 1: Internal use of excess heat from causticization stage	
Investment Costs	Owner financing
Operation and Maintenance (O&M) Costs	Owner financing
Reinvestment Costs	Owner financing
ESCO Contract	Not applicable (internal operation)
Scenario 2: External use of excess heat from bleaching and effluent treatment stages	
Investment Costs	Owner financing
Operation and Maintenance (O&M) Costs	Owner financing
Reinvestment Costs	Owner financing
ESCO Contract	N/A (reduction of the electricity consumption of the cooling towers in the effluent treatment stage; no remuneration for the heat supply)

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7.3.8 Demo-Site: ROMPETROL Petromidia Refinery (Romania)

Table 62: ROMPETROL Financing and ESCO Model Selection

Demonstration Site ROMPETROL Petromidia Refinery	 *Figure 58: ROMPETROL Refinery in Petromidia of Navodari (Romania)*
Scenario 1: Internal recovery of heat	
Investment Costs	Owner Financing
Operation and Maintenance (O&M) Costs	Owner Financing
Reinvestment Costs	Owner Financing
ESCO Contract	N/A

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7.4 Conclusion of the SO WHAT Demo-Sites Financing and ESCO Models

In the following table are presented the results of the selection process of the most suitable and appropriated financing schemes and ESCO models for each the SO WHAT the demo-sites. As has been mentioned before, there are cases of demo-sites that have not yet defined the scenarios of options of investment to be considered (LIPOR and Martini & Rossi demo-sites) and other that even having defined the scenarios, have not yet selected the financing and ESCO models (Martini & Rossi demo-site). Analysing the options selected, there can be concluded that there are several combinations of financing schemes and ESCO models solutions, with a combination of public and private financing, complemented by EU grants, as well public and private O&M.

Table 63: Financing and ESCO Models Selection

Financing and ESCO Models Selection					
Demo-Sites	**Scenarios**	**Investment Costs**	**Operation and Maintenance (O&M) Costs**	**Reinvestment Costs**	**ESCO Contract**
LIPOR Maia (Portugal)	Not yet defined	Owner (EU grants) + Owner Financing + Owner Loan	ESCO Contract (private financing)	Owner Financing and/or Owner Loan	Energy Supply Contracting (ESC)
ISVAG (Belgium)	Scenario 1: Small district heating network	Owner (EU grants) + Owner Financing	Owner Financing	Owner Financing	N/A
	Scenario 2: Large district heating network	Owner (EU grants) + ESCO Contract (private financing)	ESCO Contract (private financing)	ESCO Contract (private financing)	Integrated Energy Contracting (IEC)
RADET (Romania)	Scenario 1: Pellets boiler and Solar thermal	Owner (EU Funds)	Owner Financing	Owner Financing	N/A
UMICORE (Belgium)	Scenario 1: Internal use of excess heat from processes	Owner (EU grants) + Owner Financing + Owner Loan	Owner Financing	Owner Financing	N/A
	Scenario 2: Geothermal energy	Owner (EU grants) + ESCO Contract (private financing)	ESCO Contract (private financing)	ESCO Contract (private financing)	Integrated Energy Contracting (IEC)
IMERYS (Belgium)	Scenario 1: Heat recovery	Owner (EU grants) + ESCO Contract (private financing)	ESCO Contract (private financing)	Owner Financing and/or Owner Loan	Integrated Energy Contracting (IEC)
MARTINI & ROSSI (Italy)	Not yet defined	Not yet defined	Not yet defined	Not yet defined	Not yet defined
ENCE (Spain)	Scenario 1: Internal use of excess heat from causticization stage	Owner Financing	Owner Financing	Owner Financing	N/A (internal operation)
	Scenario 2: External use of excess heat from bleaching and effluent treatment stages	Owner Financing	Owner Financing	Owner Financing	N/A (reduction of the consumption of the cooling towers)
ROMPETROL (Romania)	Scenario 1: Internal recovery of heat	Owner Financing	Owner Financing	Owner Financing	N/A

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8 Conclusion

For any kind of WH/C or RES project, a deep techno-economic analysis is fundamental in order to make secure investment decisions. An analysis of the company business expenses together with the project capital budgeting evaluation, will provide economic indicators which are helping tools in the decision-making process. A shorter Payback Period or a lower Levelized Cost of Energy/Heat (LCOEH) should always be synonyms of attractive investments, but these quantitative indicators are affected by other qualitative and difficult to measure ones, such as the environmental and social impact, which are directly related to the place of implementation of the project and must to be seriously taken into account.

A deep analysis of the business value chain (strategic tool) is basic in order determine competitive advantages, with the aim of generating a value increase. For the SO WHAT demo-sites WH/C scenarios, it is observed that both "Installation" and "Value added" activities are considered of utmost importance for generating value, while "Planning and design" and "Operation & Maintenance (O&M)" activities are located in a lower step. "Components supply" activities is the category considered least important.

The selection of the most suitable financing scheme together with the ESCO model are essential for two reasons, determine, on the one hand, the viability of the investment, and on the other hand the operation and maintenance (O&M) of the facility along its lifecycle. For the SO WHAT demo-sites, there can be concluded that there are several combinations of financing schemes and ESCO models solutions, with a combination of public and private financing, complemented by EU grants, as well public and private O&M.

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9 Input to the SO WHAT Tool

The following flowchart shows an overview of how the results from this report will be further used in the SO WHAT project. Results will be used to develop guidelines for algorithms development in D3.6. The guidelines will then be used in the development of the SO WHAT tool in WP4.

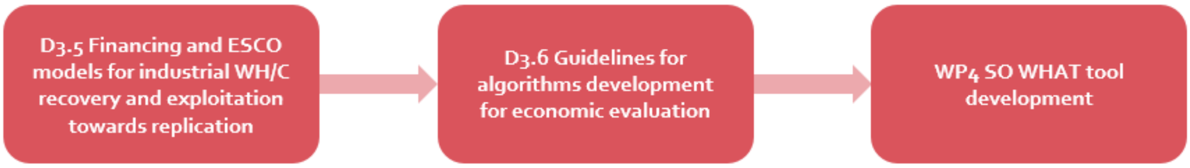

Figure 59: Input flow from D3.5 to the SO WHAT tool

As a conclusion of the report the following list summarizes the report input that should be integrated into the So WHAT tool:

- A different interface of the tool should be shown depending on the type of user (ESCO or industry). A checklist could adapt the information shown to the knowledge and targets of the user.
- The links for the current EU grants for WH/C projects should be displayed and updated along the lifetime of the tool (such as ELENA: European Local Energy Assistance).
- The calculation of the LCOH should be integrated into the tool, providing a comparative indicator (together with other economic indicators, such as payback) that helps the user to make decisions.
- The different financing schemes and energy contracts (EPC, ESC and IEC) should be deeply explained in the tool (using real applications as an example is always helpful), guiding the users towards the ones that best suits their casuistries.
- Generation of "generic" ESCO contracts with the basic characteristic recommended to be included in them (5.3.1 ESCO Contracts).
- Tools with a step by step interface are always clearer and more intuitive, making them easier to work with.

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A. Appendix A: International Performance and Verification Protocol (IPMVP)

The International Performance Measurement and Verification Protocol (IPMVP) is the leading international protocol for Measurement and Verification (M&V). IPMVP has been developed and is continuously upgraded by the Efficiency Valuation Organization (EVO), specifically by the IPMVP Committee (founded in 1995). The main defining characteristics of EVO are (32):

- **EVO`s Vision:** Create a world that has confidence in energy efficiency as a reliable and sustainable energy resource.
- **EVO´s Mission:** Ensure that the savings and impact of energy efficiency and sustainability projects are accurately measured and verified.

IPMVP defines in a structured way the common principles and terms that are basic for a correct M&V process (IPMVP do not define the M&V activities for every application). For each application the M&V project must be individually designed. This individual design is recorded in the M&V Plan, which is used as a guide for the savings calculation process. It is recommended that the development of the M&V Plan is carried out by a qualified professional such as a Certified Measurement and Verification Professional (CMVP) (32).

IPMVP promotes efficiency investments by engaging in the following activities (32):

- Documenting the common terms and methods to evaluate the performance of efficiency projects.
- Providing methods with different levels of cost and accuracy for determining saving for the whole installation or for individual ECMs.
- Providing guidance in its application for industrial processes or buildings (commercial or residential, existing or new).
- Specifying the contents of a M&V Plan.

A.1 IPMVP Normative References

IPMVP is closely related to the following referenced publications (32):

- M&V: Guidelines: Measurement & Verification for Performance Based Contracts, Version 4.0, U.S. Department of Energy Federal Energy Management Program (FEMP).
- ASHRAE Guideline 14: Measurement of Energy and Demand Savings.
- Italian Standard on Energy Service Companies UNI/CEI 11352.
- UNE-EN 15900:2010 Energy Efficiency Services Directive 2006/32/EC.
- U.K. Electricity Demand Reduction Scheme Pilot Phase II – Measurement and Verification Manual.
- U.K. Department of Energy and Climate Change – Guide to Energy Performance Contracting Best Practices.
- European Code of Conduct for Energy Performance Contracting.

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A.2 Terms & Definitions

- **Adjusted Baseline Energy:** The Baseline Period Energy Consumption modified through Routine and Non-Routine adjustments to reflect changes in the Reporting Period (32).
- **Avoided Energy Consumption or Demand:** Reduction of the Energy Consumption or Demand during the Reporting Period, relative to the Baseline Period, adjusted to the Reporting Period conditions thorough Routing and Non-Routing Adjustments (32).
- **Baseline Period Energy:** Energy Consumption or Demand occurring during the Baseline Period without adjustments (32).
- **Baseline Period:** Defined period of time chosen to represent the operation of the installation or system before the implementation of an ECM (32).
- **Baseline:** Referring to the systems, time period, energy use, or conditions that provide a reference to which later performance of a ECM can be compared (32).
- **Building Automation System (BAS):** A measure realized through the use of the buildings control system, that allow access to trend data that will be used to evaluate operational and energy performance of the implemented ECMs. The results are used to verify the energy-saving calculations (32).
- **Demand:** A measure of the rate at which work is done or energy is converted (32).
- **Energy Conservation Measure (ECM):** Action or set of actions designed to improve the efficiency, conserve energy or water, or manage the Demand (32).
- **Energy Consumption:** Quantity of energy applied to any load (32).
- **Energy End Use:** Application of energy for a specific purpose (heating, cooling, lighting, industrial processes, etc.) (32).
- **Energy Performance Contract (EPC):** Agreement between two or more parties where the payment is based on achieving specific results, such as reduction in energy costs or payback of investment within a scheduled time (32).
- **Estimated Value:** Parameters used in energy-saving calculations determined through methods other than taking measurements. The methods used to estimate values may range from arbitrary assumptions to engineering estimations derived from manufacture ratings of equipment performance (the parameter values derived from equipment performance tests or other measurements that that are not made in situ must be considered Estimated Values to be in accordance with the IPMVP) (32).
- **Independent Variable:** Parameter that is expected to chain routinely and has an impact on the Energy Consumption or Demand (32).
- **Interactive Effect:** Energy impacts generated by an ECM that cannot be measured within the Measurement Limits (32).
- **Key Parameter:** Identified critical variable that has a significant impact on the energy-savings associated with the implementation of an ECM (32).
- **Measurement and Verification (M&V):** Process of planning, measuring, collecting and analysing data with the purpose of verifying and reporting the energy-savings resulting from the implementation of ECMs in an individual installation (32).
- **Measurement Limits:** Estimated limits drown around the equipment, system or installation in order to segregate those which are relevant to the saving calculation from those which are

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not. All Energy Consumption or Demand within the limits of the installation must be measured or estimated (32).

- **Non-Routine Adjustment:** Individually engineered calculations to account for the effects in the Energy Demand or Consumption due to changes in the Static Factors within the Measurement Limits (32).
- **Normalized Savings:** Reduction of the Energy Consumption or Demand during the Reporting Period, relative to the Baseline Period, adjusted to a common set of conditions thorough Routing and Non-Routing Adjustments. The common set of conditions may be a long-term average set of conditions, or an agreed set of conditions different from the Reporting Period conditions (32).
- **Operational Verification:** Confirmation that Energy Conservation Measures are installed and operating as per the design intent and have the potential to perform and generate savings. This may involve inspections, functional performance testing, and/or data trending with analysis (32).
- **Proxy Measurement:** A measured parameter that substitutes a direct measurement of an energy parameter, where the relationship between both has been proved in situ (32).
- **Reporting Period Energy:** Energy Consumption or Demand occurring during the Reporting Period without adjustments (32).
- **Reporting Period:** Defined period of time chosen for the purpose of verifying savings after the implementation of an ECM (32).
- **Routine Adjustment:** Individually engineered calculations to account for the expected effects in the Energy Demand or Consumption due to changes in the Independent Variables within the Measurement Limits (32).
- **Savings:** Value, in energy units, of the reduction of Energy or water Consumption, or Demand, calculated through the comparison of the measured energy values before and after the implementation of an ECM, realizing suitable Routing and Non-Routing Adjustments in function of changes in conditions. The energy unit saving and the resulting cost savings may be reported in form of Avoided Energy Consumption (or Demand) or Normalized Savings (32).
- **Static Factors:** Those characteristics (fixed, environmental, operational and maintenance) of an installation which affect the Energy Consumption or Demand, within the defined Measurement Limits, that are not expected to change, and therefore not included into as Independent Variables. If they change, Non-Routine Adjustments need to be calculated and applied in order to taken into account these changes (32).

A.3 IPMVP Principles

The IPMV fundamental principles that provide the basis for evaluating the adherence to the M&V process are listed below (32):

- **Accurate:** M&V reports should be as accurate as possible, taking into account that the M&V costs should represent a small percentage of the evaluated savings. The cost and accuracy of the M&V methodology should be evaluated as part of the project development. A loss of accuracy leads to less reliable analysis. Accuracy is a guiding principle of IPMVP (32).

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- **Complete:** The energy-savings report should include all effects of the project. M&V activities should use measurements to quantify the significant effects, while the least significant ones may be estimated (32).
- **Conservative:** The savings should be estimated in a responsible way, avoiding overestimations, leading to reasonable and conservative results (32).
- **Consistent:** The energy performance report of a project should be consistent and comparable across (32):
    - Different types of energy efficiency projects.
    - Different energy management professionals for any project.
    - Different period of time for the same project.
    - Energy efficiency projects and new energy supply projects.
- **Relevant:** The determination of savings should be based on current measurements and information of the installation affected by the ECMs implementation. The performance parameters that are of concern or that are least well known should be measured, while the least critical or more predictable may be estimated (32).
- **Transparent:** All M&V activities should be clearly documented and fully disclosed (M&V Plan and saving reports). The methodology developed (data compilation, data preparation techniques, algorithms, spreadsheets, software, assumptions used, and analysis) should follow industry standard practices as closely as possible, in order to be comprehensible for any involved party or external reviewer (32).

A.4 IPMVP Structure

Due to the nature of savings, absence of energy/water consumption or demand, they cannot be measured directly. So they have to be calculated through the comparison of the measured consumption or demand before and after the implementation of the ECMs, making suitable adjustments for changes in conditions. The calculation of savings is done using the following general M&V formula (32):

$$Energy\ Savings = (\text{Baseline Period Energy} - \text{Reporting Period Energy}) \pm Adjustments$$

Formula A.1: Energy-Savings general equation (32)

Where (32):

- **Baseline:** Referring to the systems, time period, energy use, or conditions that provide a reference to which later performance of an ECM can be compared.
- **Baseline Period:** Defined period of time chosen to represent the operation of the installation or system before the implementation of an ECM.
- **Baseline Period Energy:** Energy Consumption or Demand occurring during the Baseline Period without adjustments.
- **Reporting Period:** Defined period of time chosen for the purpose of verifying savings after the implementation of an ECM.
- **Reporting Period Energy:** Energy Consumption or Demand occurring during the Reporting Period without adjustments.

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The following graph shows the Energy Consumption or Demand during a M&V process, before and after the implementation of an ECM (32):

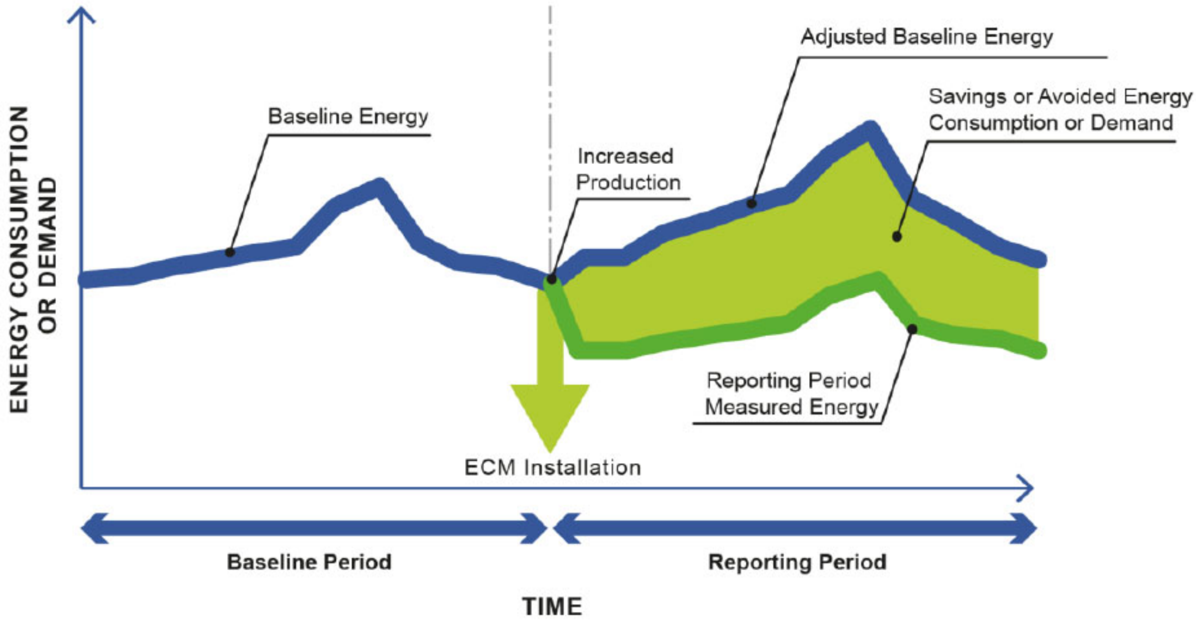

Figure A.1: Energy Consumption or Demand during a M&V Process (32)

Where:

- **Measurement and Verification (M&V):** Process of planning, measuring, collecting and analysing data with the purpose of verifying and reporting the energy-savings resulting from the implementation of ECMs in an individual installation (32).
- **Energy Conservation Measure (ECM):** Action or set of actions designed to improve the efficiency, conserve energy or water, or manage the Demand (32).
- **Demand:** A measure of the rate at which work is done or energy is converted (32).
- **Energy Consumption:** Quantity of energy applied to any load (32).
- **Adjusted Baseline Energy:** The Baseline Period Energy Consumption modified through Routine and Non-Routine adjustments to reflect changes in the Reporting Period (32).
- **Non-Routine Adjustment:** Individually engineered calculations to account for the effects in the Energy Demand or Consumption due to changes in the Static Factors within the Measurement Limits (32).
- **Routine Adjustment:** Individually engineered calculations to account for the expected effects in the Energy Demand or Consumption due to changes in the Independent Variables within the Measurement Limits (32).
- **Measurement Limits:** Estimated limits drown around the equipment, system or installation in order to segregate those which are relevant to the saving calculation from those which are not. All Energy Consumption or Demand within the limits of the installation must be measured or estimated (32).
- **Static Factors:** Those characteristics (fixed, environmental, operational and maintenance) of an installation which affect the Energy Consumption or Demand, within the defined Measurement Limits, that are not expected to change, and therefore not included into as

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Independent Variables. If they change, Non-Routine Adjustments need to be calculated and applied in order to taken into account these changes (32).

- **Independent Variable:** Parameter that is expected to chain routinely and has an impact on the Energy Consumption or Demand (32).
- **Savings:** Value, in energy units, of the reduction of Energy or water Consumption, or Demand, calculated through the comparison of the measured energy values before and after the implementation of an ECM, realizing suitable Routing and Non-Routing Adjustments in function of changes in conditions. The energy unit saving and the resulting cost savings may be reported in form of Avoided Energy Consumption (or Demand) or Normalized Savings (32).
- **Avoided Energy Consumption or Demand:** Reduction of the Energy Consumption or Demand during the Reporting Period, relative to the Baseline Period, adjusted to the Reporting Period conditions thorough Routing and Non-Routing Adjustments (32).
- **Normalized Savings:** Reduction of the Energy Consumption or Demand during the Reporting Period, relative to the Baseline Period, adjusted to a common set of conditions thorough Routing and Non-Routing Adjustments. The common set of conditions may be a long-term average set of conditions, or an agreed set of conditions different from the Reporting Period conditions (32).

The IPMVP Structure should be well integrated into the processes of identification, development, purchase, installation and operation of the ECMs and requires the happening of certain activities at key points. The IPMVP Structure describes other important activities that must be included as part of the M&V process. The key elements of the IPMVP Structure will be analysed in the following chapters (32).

A.4.1 Measurement Limits

The energy-savings may be calculated for an entire installation or a part of it, depending on the characteristics of the implemented ECMs and the purpose of the M&V report (32):

- If the purpose of the report is verifying the energy-savings of the equipment affected by the ECM, the Measurement Limits should be defined around that equipment and the measurement requirements can be determined regarding these limits. The energy calculation may be realized by direct energy-flow measurements or by direct "Proxy Measurements" of the Energy Consumption or Demand, that can be used to calculate the Energy Consumption or Demand in a reliable way. (Table A.2: IPMVP Options A or B).
  Where (32):
    - **Proxy Measurement:** A measured parameter that substitutes a direct measurement of an energy parameter, where the relationship between both has been proved in situ (32).
- If the purpose of the report is verifying and/or managing the energy performance of the entire installation, the energy supply measuring equipment of the installation can be used to evaluate the performance and energy-savings. (Table A.2: IPMVP Option C) (32).
- If the Baseline Period or Reporting Period data are unavailable or unreliable, the Energy Consumption or Demand data from a Calibrated Simulation can replace the missing data, both for part and for the entire installation. (Table A.2: IPMVP Option D) (32).

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- Any effect on energy outside the Measurement Limits is considered an Interactive effect. The magnitude of the Interactive Effects needs to be estimated or evaluated in order to estimate the energy-savings associated with an ECM. Although it is not ideal, the Interactive Effects may be ignored in some cases, as long as the M&V Plan includes a remark about each effect and its magnitude is small compared to savings from the primary effects (32).
  Where:
    - **Interactive Effect:** Energy impacts generated by an ECM that cannot be measured within the Measurement Limits (32).

A.4.2 Measurement Period Selection

There are two measurement periods, the one selected before the implementation of an ECM, known as Baseline Period, and the one selected before, known as Reporting Period. Both are analysed below (32):

A.4.2.1 Baseline Period

Care should be taken when selecting the Baseline Period, which should be established with the purpose of (32):

- Representing the operating modes of the facility or the equipment during a normal operating cycle. The Baseline Period should contain a full operating cycle from the maximum Energy Consumption or Demand to the minimum (32).
- Including time periods for which fixed and variable facts that control the Energy Consumption or Demand of the facility are known. (the extension of the Baseline Period backyards in order to include multiple operating cycles do not contribute more knowledge) (32).
- Coinciding with the period immediately before the implementation of the ECM. (periods further back in time may not reflect the existing conditions before the implementation of the ECM, not providing a proper Baseline Period for measuring the ECM effects) (32).
- Supporting the ECM planning. (a study period longer than the Baseline Period may help the planner to understand the facility performance and determine the normal operating cycle length) (32).

A.4.2.2 Reporting Period

The developer of the M&V Plan and the energy-savings reports should be the responsible of determining the length of the Reporting Period. The Reporting Period should contain at least one normal operating cycle of the facility or equipment, in order to fully characterize the effectivity of ECM energy-savings in the normal operating modes (32).

The ECM lifespan and its performance reduction over time should be taken into account in the selection of the Reporting Period length. Independently of the Reporting Period length, the measuring equipment may be left in place as support to provide ECM performance data, being its measurement frequency modified as appropriate (32).

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A.4.3 Methods of Adjustment

The adjustments should be calculated from identifiable physical facts about the energy-governing characteristics of the equipment within the Measurement limits. The two types of adjustments are analysed below (32):

Routine Adjustments

Adjustments for energy-governing factors expected to change routinely during the Reporting Period (weather, production volume, etc.). The techniques used to define the adjustment technology may be as simple as a constant value (no adjustment) or as complex as several multiple parameters non-linear equations, which correlate energy with one more Independent Variables. Valid mathematical techniques must be used to obtain the adjustment method to each M&V Plan (32).

Non-Routine Adjustments

Adjustments for energy-governing factors that are not usually expected to change (the facility size, the design and operation of the installed equipment, the number of weekly production shifts, etc.). The associated Static Factors monitored in order to record changes throughout the Reporting Period (32).

Therefore, the Energy-Savings can be calculated through the following formula:

$$Energy\ Savings = (Baseline\ Period\ Energy - Reporting\ Period\ Energy)$$
$$\pm Routing\ Adjustments \pm Non\ Routing\ Adjustments$$

Formula A.2: Energy-Savings general equation (32)

The adjustments are used to modify the Baseline Period energy data in order to reflect the same set of conditions as the measured data after the ECM implementation. The mechanism for making adjustments depends if the energy-savings are going to be reported based on the conditions of the Reporting Period, or normalized with respect to other fixed set of conditions (32).

A.4.4 Savings Accounting Approaches

The following listed Savings Accounting Approaches will be analysed below (32):

- Reporting Period Basis, or Avoided Energy Consumption or Demand.
- Normalized Savings.
- Consecutive Measurement Periods (On/Off Tests).
- Basis for Adjustment or Type of Savings.

A.4.4.1 Reporting Period Basis, or Avoided Energy Consumption or Demand

When the energy-saving are reported under the condition of the Reporting Period, they can also be called Avoided Energy Consumption or Demand of the Reporting Period. The Avoided Energy Consumption or Demands quantifies the energy-savings in the Reporting Period relative to the Energy Consumption or Demand without the implementation of the ECM. Due to all of this, the Baseline Period Energy need to be adjusted to the Reporting Period conditions. The term "forecasting" is sometimes used to describe the adjustment of the Baseline Period Energy to the Reporting Period conditions (32).

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This energy-savings estimation process can be expressed as:

$$Avoided\ Energy\ Consumption = \begin{pmatrix} Baseline\ Period\ Energy \\ \pm Routine\ Adjustments\ to\ Reporting\ Period\ Conditions \\ \pm Non\ Routine\ Adjustments\ to\ Reporting\ Period\ Conditions \end{pmatrix} - Reporting\ Period\ Energy$$

Formula A.3: Avoided Energy Consumption general equation (32)

This formula is often simplified to:

$$Avoided\ Energy\ Consumption = Adjusted\ Baseline\ Energy$$
$$-Reporting\ Period\ Energy \pm Non\ Routine\ Adjustments\ to\ Reporting\ Period\ Conditions$$

Formula A.4: Avoided Energy Consumption simplified equation (32)

Where the Adjusted Baseline Energy is the Baseline Period Energy plus any Routine Adjustment required to adjust it to the Reporting Period Conditions (32).

The Adjusted Baseline Energy is often calculated by first through a mathematical model, which correlates the actual Baseline Period Energy data with suitable Independent Variables for the same period. Each Independent Variable measured in the Reporting Period is then inserted into this mathematical model in order to obtain the Adjusted Baseline Energy (32).

This energy-savings calculation process may also be used backwards, adjusting the Energy Consumption or Demand of the Reporting Period to the Baseline Period conditions (calculation of the energy-savings under the Baseline Period conditions). This method has sense when more data is available in the Reporting Period to develop the mathematical models of Energy Consumption or Demand. The term "backcasting" is sometimes used to describe the adjustment of the Reporting Period Energy to the Baseline Period conditions (32).

This energy-savings estimation process can be expressed as:

$$Avoided\ Energy\ Consumption = Baseline\ Period\ Energy$$
$$-(Reporting\ Period\ Energy \pm Routine\ Adjustments\ to\ Baseline\ Period\ Conditions$$
$$\pm NonRoutine\ Adjustments\ to\ Baseline\ Period\ Conditions)$$

Formula A.5: Avoided Energy Consumption general equation (32)

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This formula may be simplified to:

$$\begin{aligned}&Avoided\ Energy\ Consumption\\&= Baseline\ Period\ Energy - Adjusted\ Reporting\ Period\ Energy\\&\pm NonRoutine\ Adjustments\ to\ Baseline\ Period\ Conditions\end{aligned}$$

Formula A.6: Avoided Energy Consumption simplified equation (32)

A.4.4.2 Normalized Savings

Other conditions, different from the Reporting Period ones, may be used as the basis for the adjustments. One of the following conditions may be applied (32):

- Baseline Period conditions.
- Arbitrary period conditions.
- Set of typical, average or normal set of conditions.

The adjustments to a fixed set of conditions (such as the typical annual production) provides a type o saving called Normalized Savings of the Reporting Period. In this method, the Reporting Period Energy and eventually the Baseline Period Energy are adjusted from their actual conditions to the common or normal set of conditions selected. The term "chaining" is sometimes used to describe the process of reporting energy-savings under different conditions than the Baseline or Reporting Period ones (32).

The Normalized Savings can be expressed as:

$$\begin{aligned}&Normalized\ Energy\ Savings =\\&(Baseline\ Period\ Energy \pm Routine\ Adjustments\ to\ Fixed\ Conditions\\&\quad \pm NonRoutine\ Adjustments\ to\ Fixed\ Conditions)\\&-(Reporting\ Period\ Energy \pm Routine\ Adjustments\ to\ Fixed\ Conditions\\&\quad \pm NonRoutine\ Adjustments\ to\ Fixed\ Conditions)\end{aligned}$$

Formula A.7: Normalized Energy-Savings (32)

The calculation of the Reporting Period Routine Adjustments normally involves the development of a mathematical model, which correlates the Reporting Period Energy with the Reporting Period Independent Variables. This model is used to adjust the Reporting Period Energy to the chosen fixed conditions. Furthermore, if the fixed set of conditions is not from the Baseline Period, a mathematical model is required in order to the Baseline Period Energy to the chosen fixed conditions (32).

A.4.4.3 Consecutive Measurement Periods (On/Off Tests)

When an ECM can be turned on and off easily, the Baseline and Reporting Period may be selected consecutively in time. A control logic change is an example of an ECM that can often be enabled and disabled easily without negatively affecting the facility operation (32).

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The ON/OFF tests involve energy measurements with the ECM enabled and then immediately disabled, so that the operating mode returns to the pre-ECM (Baseline) conditions. The difference of Energy Consumption or Demand between the two consecutive measurement periods is the energy-saving generated by the ECM (32).

If the energy-influencing factors are the same in both period, the Energy-Savings are calculated without adjustments through the following formula (32):

$$Energy\ Savings = Baseline\ Period\ Energy\ Consumption\ or\ Demand - Reporting\ Period\ EnergyConsumption\ or\ Demand$$

Formula A.8: Energy-Savings (32)

This method can be applied under Retrofit-Isolation and Whole-Facility options (Table A.2: IPMVP Option A, B and C)., always taking into account that Measurement limits must be so that it is possible to easily detect a significant difference in the measured Energy Consumption or Demand when the equipment or systems are turned on and off (32).

The consecutive periods used for the On/Off test should be long enough to represent the stable operation and cover the range of normal facility operations. To cover the normal range, the On/Off test may need to be repeated under different operating modes, such as different production rates (32).

The ECMs that can be disabled may be at risk of being accidentally or purposely turned off when they should be enabled. Efforts should be made to ensure the persistence of such ECMs (32).

A.4.4.4 Basis for Adjustment or Type of Savings

The factor to take into account when choosing between Avoided Energy Consumption or Demand and Normalized Savings include (32):

- Avoided Energy Savings:
  - They depend on the Reporting Period operating conditions.
- Normalized Savings:
  - They are not affected by the Reporting Period conditions, due to the fixed set of condition are not changed once are established.
  - They can be directly compared with energy-savings generated by other ECMs calculated under the same set of fixed conditions.
  - They can only be reported after a complete Reporting Period cycle, so that the mathematical correlation between the Reporting Period Energy and the operating conditions can be deducted.

A.4.5 Operational Verification

The Operational Verification consists of a set of activities that aim to help ensure that an ECM is installed, commissioned and performing as it was designed and has the potential to generate energy-savings (32).

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The Operational Verification works as a first low-cost step for evaluating the energy-savings potential or verifying the performance of the ECM over time. The Operation Verification should be included into the M&V Plan and precede other post-installation energy-savings verification activities. The Operational Verification does not have to be a responsibility of the M&V performer, however, it should be verified and documented a part of the M&V process (32).

In the following table there are summed up the main characteristics of the different Operational Verification methods. The selection of the most suitable method depends on the characteristics of the ECM, the level of uncertainty involved, and the magnitude of the energy-savings at risk. The data collected during the Operational Verification may be used during the actual M&V process (32).

Table A.1: Operational Verification Methods (32)

Operational Verification Method	Typical ECM Application	Activities
Visual Inspection	The ECM will perform as intended when properly installed. The direct measurement of the ECM performance is not possible.	Review and verification of the physical installation of the ECM (insulation, passive devices, etc.).
Sample Spot Measurements	The achieved ECM performance may vary regarding the data published by the manufacturer, according to installation details or components	Measurement of a singles or multiple Key Parameters for a representative sample of the installation of the ECM.
Short-Term Performance Testing	The ECM performance may vary depending on the actual load, the control or the interoperability of the components.	Realization of tests for verifying the functionality of the ECM and the suitability of the control (measurement of Key Parameters). It may require carrying out tests designed in order to capture the equipment performance across its entire operating range, or over a sufficient period of time to characterize it.
Data Trending and Control-Logic Review	The ECM performance may vary depending on the actual load and the control. Monitoring and control of the system through Building Automation System (BAS) or independent measuring equipment.	Review data of control logic and set up trends. The measurement period may last from a few days to a few weeks, depending on the period required to capture the entire operating range.

Where:

- **Building Automation System (BAS):** A measure realized through the use of the buildings control system, that allow access to trend data that will be used to evaluate operational and

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energy performance of the implemented ECMs. The results are used to verify the energy-saving calculations (32).

- **Key Parameter:** Identified critical variable that has a significant impact on the energy-savings associated with the implementation of an ECM (32).

During an independent review of the reported energy-savings, in addition to the field verification of the ECM, the reviewer shall carry out the necessary activities in order to confirms that the ECM is based on solid scientific principles and that there are independent evidences to support the energy-savings assertions before the M&V process (32).

The Operational Verification can be integrated into the commissioning, coordinating the data collection and the analysis tasks. When the M&V process continues after the end of Reporting Period, the Operational Verification may continue ensuring the correct performance of the ECMs, in other words, ensuring the permanence of the energy-savings year after year (32).

A.5 IPMVP Options

The IPMVP provides four different options for determining energy-savings (Table A.2: Options A, B, C and D). These options require data on Energy Consumption or Demand and other parameters of the facility where the ECM is implemented. The choice of the most suitable option involves many considerations, including the selection of the ECM Measurement Limits. The Energy-Consumption or Demand required for the different energy-savings formulas can be measured through one or more of the following methods (32):

- Invoices or reading from the measuring equipment of the energy of fuel supply companies, making the same adjustments to the readings that they make.
- Special measuring equipment that isolate an ECM or a part of the facility from the rest of it. The measurements may be periodic or continuous during the Baseline or Reporting Periods.
- Other measurements independent of the parameters used for determining the Energy Consumption or Demand.
- Measurement of Proxy variables for Energy Consumption or Demand.
    - **Proxy Measurement:** A measured parameter that substitutes a direct measurement of an energy parameter, where the relationship between both has been proved in situ (32).
- Calibrated simulation with respect to actual operating data of the system or facility which is being modelled.

If an energy parameter is already known with suitable accuracy or when the investment for its measurement do not justify the obtained uncertainty reduction, then the measurement of this energy parameter may be no necessary or appropriative. In these cases, some ECM parameter may be estimated, whiles others must be measured (Option A) (32).

If it is decided to determine the energy-savings at the facility-wide level, the options C or D are preferable. However, if only the performance of the ECM by itself is of concern, the options A, C, or D, are more suitable (32).

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In the table below there are summed up the main characteristics of the different IPMVP options, which will be analysed more deeply in the following chapters:

Table A.2: IPMVP Options (32)

IPMVP Option	Methodology	Savings Calculation Method	Typical Applications
Retrofit-Isolation: Key Parameter Measurement (Option **A**)	• The savings are determined by field measurement of the key parameter(s), which define the energy consumption and the demand of the system(s) affected by the ECM, in other words, the success of the project. • The measurement frequency varies from short-term to continuous, depending on the expected variations of the measured parameter and the length of the reporting period. The values for not selected parameters for field measurements are estimated. The estimations can be based on historical data, manufacture specifications, or engineering judgment. • The documentation of the source or the justification of the Estimated Value is required. The plausible saving error arising from estimation rather than measurement is evaluated.	• Engineering calculation of the baseline period and the reporting period energy in base of the Estimated Values and the short-term or continuous measurement of the key parameter(s). • Realization of routine and non-routine adjustments as required. The key parameter(s) are measured during both baseline and reporting period.	• A lighting retrofit where the power draw is the key parameter measured and secondly, lighting operating hours are estimated based on the facility schedule and the occupants behaviour.

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Retrofit-Isolation: All Parameter Measurement (Option **B**)	• The savings are determined by field measurement of the energy consumption and/or related independent or Proxy variables of the system affected by the ECM. • The measurement frequency varies from short-term to continuous, depending on the expected variations of the savings and the length of the reporting period.	• Short-term or continuous measurements of the baseline and reporting period energy, or engineering computations using measurements of proxies of energy consumption. • Realization of routine and non-routine adjustments as required	• Installation of a Variable Frequency Drive (VFD) in the motor of a pump in order to adjust the pump flow. Electric power measurement with a wattmeter (reading time setting "every minute") installed on the electrical supply to the motor. In the baseline period this meter is in place for a week to verify constant loading. The meter is in place during the reporting period to measure the power consumption and demand. • The same methodology is applicable for fans.
Whole Facility (Option **C**)	• The savings are determined by energy consumption and demand measurement at the whole facility through the measuring equipment of the energy supplier company. • Continuous measurements of the energy consumption and demand of the entire facility during the reporting period.	• Analysis of the baseline and reporting period meter data of the whole facility (measuring equipment of the energy supplier company). • Realization of routine adjustments as required, using techniques such as "simple comparison" or "regression analysis". • Realization of non-routine adjustments as required.	• Multifaceted energy management programs affecting many systems in a facility. Measurement of the energy consumption and demand through the measuring equipment of the energy and gas supplier companies for a twelve-month baseline period and during the reporting period.

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Calibrated Simulation (Option **D**)	• The savings are determined through simulation of the energy consumption and demand of the whole facility or a sub-facility. • The simulation routines demonstrate that the actual energy performance in the facility is adequate. • This option requires a considerable calibrated simulation skill.	• Energy consumption and demand simulation calibrated with hourly or monthly invoicing data of the energy supplier company. Data from energy or performance measuring equipment may be use in model refinement.	• Multifaceted energy management program affecting many systems in a facility without measuring equipment during the baseline period. • After the installation of gas and electric measuring equipment, the energy consumption and demand measurements are used to calibrate a simulation. • The baseline period energy, determined using the calibrated simulation, is compared to a simulation of the reporting period energy consumption and demand.

Where:

- **Energy Performance Contract (EPC):** Agreement between two or more parties where the payment is based on achieving specific results, such as reduction in energy costs or payback of investment within a scheduled time (32).
- **Energy End Use:** Application of energy for a specific purpose (heating, cooling, lighting, industrial processes, etc.) (32).
- **Estimated Value:** Parameters used in energy-saving calculations determined through methods other than taking measurements. The methods used to estimate values may range from arbitrary assumptions to engineering estimations derived from manufacture ratings of equipment performance (the parameter values derived from equipment performance tests or other measurements that that are not made in situ must be considered Estimated Values to be in accordance with the IPMVP) (32).
- **Key Parameter:** Identified critical variable that has a significant impact on the energy-savings associated with the implementation of an ECM (32).

A.5.1 Options A and B: Retrofit-Isolation

When the ECM only affect a part of the facility, the Retrofit-Isolation allows the narrowing of the Measurement Limits with the purpose of reducing the effort required to monitor Independent Variables and Static Factors. However, smaller limits than the total of the facility require additional measuring equipment, and also introduce the possibility of "leakage" through unmeasured Interactive Effects (32).

- **Interactive Effect:** Energy impacts generated by an ECM that cannot be measured within the Measurement Limits (32).

Since the measurement comprises only part of the facility, the Retrofit-Isolation results may not carry over to the energy supplier invoices. Facility changes beyond the Measurement Limits and unrelated

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to the ECM will not be reported by Retrofit-Isolation techniques, but will have an effect in the Energy Consumption or Demand measured by the energy supplier (32).

There are two options for isolating the Energy Consumption or Demand of the equipment affected by an ECM from the Energy Consumption or Demand of the rest of the facility (32):

- **Option A:** Retrofit-Isolation: Key Parameter Measurement.
- **Option B:** Retrofit-Isolation: All Parameter Measurement.

The Retrofit-Isolation measuring equipment should be placed at the Measurement Limits, between the equipment affected by the ECM and which are not. When defining the Measurement Limits, care should be taken when considering any energy-flow affected by the ECM beyond the Measurement Limits. A method must be developed in order to estimate such Interactive Effects. However, if the Measurement Limits can be expanded to cover the Interactive Effects, there is no need to estimate them (32).

Apart from small estimated Interactive Effects, the Measurement Limits define the measuring points and the scope of the adjustments, which may be used in any of the energy-savings formulas. Only the changes in energy systems and operating variables within the Measurement Limits must be monitored in order to calculate the adjustment term(s) (32).

The parameters may be continuously or periodically measured for short periods, depending on the amount of variation expected. A parameter which is not expected to change, may be measured immediately after the ECM implementation, and checked occasionally during the Reporting Period. The checking frequency may be reduced or stopped once the parameter is proved to be constant. To maintain the control of the energy-savings as the measurement frequency is reduced, more frequency inspections might be performed to verify the correct performance (32).

The continuous measuring provides a greater reliability of the reported energy-savings and more data about the equipment performance. This information can be used to improve or optimize the equipment performance on real-time, improving the benefits of the ECM itself (32).

If the measuring is not continuous and the measuring equipment are removed between the readings, the location of the measuring points and the specification of the measuring equipment should be recorded in the M&V Plan, along with the calibration procedure of the measuring equipment used. Where a parameter is expected to be constant, the measuring interval can be once or short and occasional. Where a parameter is expected to change periodically, occasional measurements representative of the normal system behaviour should be realized (32).

Where a parameter may vary diary or hourly, such as in HVAC systems, the continuous measuring may be the most suitable option. For weather dependent loads, the measurements should be taken over a long enough period in order to characterize adequately the loading pattern during a normal annual cycle, and be repeated as many times as it takes along the Reporting Period (32).

Where multiple units of the same ECM are installed within the Measurement Limits, representative statistical samples may be used as valid measurements of the total parameter (32).

Portable measuring equipment may only be used if short-term measurements are needed. Permanently installed measuring equipment provide feedback to the operating staff or the automated control equipment in order to optimize the system (32).

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A.5.1.1 Measurement Issues

Retrofit-Isolation usually requires the installation of additional measuring equipment, either for short-term or continuous measuring. This measuring equipment may be installed during an energy audit to help to characterize the Energy Consumption or Demand before the design of the ECM. Alternatively, measuring equipment may be installed in order to measure the Baseline Period performance for a M&V Plan (32).

Due to the fast evolution of measurement practices and measuring equipment, using the last versions of them is the best way to calculate energy-savings with a reasonable accuracy and repeatability, in other words, reliability (32).

- **Electricity Measurements:**

To measure electricity accurately it is necessary to measure, the voltage, amperage and power factor, or True-Root Mean Square (True-RMS) wattage with a single instrument. However, measurements of amperage and voltage alone can adequately define the wattage of purely resistive loads, such as incandescent lamps and resistance heaters. When measuring power, the electrical wave-form of the resistive load must not be distorted by other devices in the facility. RMS values can be reported by solid-state digital instruments that record the net power with wave distortion of circuits with alternative loads (32).

Electricity demand measurement methods may vary among energy supplier companies. The method of measuring electricity demand through a measuring equipment installed at the measuring point should replicate the method that the energy supplier company uses for its billing measuring equipment (32).

- **Calibration:**

Measuring equipment should be calibrated as recommended by the manufacturer and following the procedures stablished by recognized authorities. Whenever possible there should be used primary standards and no less than third-order-standard traceable calibration equipment. Sensors and measuring equipment should be selected based on the ease of calibration and the ability to stay calibrated. An attractive solution is the selection of self-calibrating equipment (32).

- **Best Applications:**

Retrofit-Isolation techniques are suitable when (32):

  - Only the performance of the systems affected by the ECM is of concern (the energy-savings generated by the implementation of the ECM are too small to be detected using the Whole Facility option; Table A.2: Option C).
  - The Interactive Effects of the ECM on the Energy Consumption or Demand of other equipment of the facility can be reasonably estimated, or considered as negligible.
  - Possible changes in the facility, beyond the Measurement Limits, would be difficult to identify or evaluate.
  - The Independent Variables which affect the Energy Consumption or Demand are not excessively difficult or expensive to monitor.
  - Parallel measuring equipment, that isolate the Energy Consumption or Demand of the system, already exist.

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   - The measuring equipment installed at the Measurement Limits can be used for purposes such as operational feedback.
   - The measurement of the parameters is cheaper than the Wholes Facility (Table A.2: Option C) simulations or the Calibrated Simulation (Table A.2: Option D) adjustments.
   - There is no need to reconcile the energy-savings reports with the changes in payments to energy suppliers.

A.5.2 Option A: Retrofit-Isolation: Key Parameter Measurement

Under Option A, the energy quantities are defined by the formulas displayed previously (Chapter A.4 "IPMVP Structure") and obtained using a combination of measurements of some parameters and estimations of the others. These estimations should only be used where their combined uncertainty will not significantly affect the reported energy-savings: The contribution of each parameter to the overall uncertainty of the reported energy-savings should be considered in order to decide which parameters need to be measured and which should be estimated. If a parameter is significant to evaluate the performance of the ECM, it should be measured. The Estimated Values and their significance should be included into the M&V Plan (32).

Estimations may be based on historical data, such as (32):

- Recorded operating hours from the Baseline Period.
- Equipment manufacturer ratings.
- Laboratory tests.
- Average climatological data

If a parameter, such as hours of use, is expected to be constant and not affected by the ECM, then its measurement in the Baseline or Reporting Period is enough. In the case of a parameter, known to vary independently of the energy, is not measured in both periods, then it should be treated as an Estimated Value (32).

When planning an Option A procedure, the variation of energy in the Baseline Period and the energy impact of the ECM should be considered before establishing which parameters have to be measured and for what duration. The following examples show the range of scenarios that may arise (32):

- The ECM reduces a constant load without changing its operating hours.
- The ECM reduces the operating hours while the load is unchanged.
- The ECM reduces both, the equipment load and the operating hours.

Generally, the conditions of variable load or variable operating hours require more rigorous measurements and calculations (32).

A.5.2.1 Calculations

Under Option A, Routine or Non-Routine Adjustments may not be required, depending on (32):

- The location of the Measurement Limits.
- The nature of any Estimated Values.
- The length of the Reporting Period.
- The amount of time between the Baseline and the Reporting Period measurements.

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Similarly, the Baseline Period Energy or the Reporting Period Energy measurements may involve the measurement of only one parameter under Option A, and the estimation of the other parameters. Therefore, in some cases for Option A, the general formula may be simplified to the following (32):

$$Option\ A\ Energy\ Savings = Hours\ of\ Use$$
$$x\ (Baseline\ Period\ Measured\ Rate\ of\ Energy\ Use$$
$$-\ Reporting\ Period\ Measured\ Rate\ of\ Energy\ Use)$$

Formula A.9: Option A Energy-Savings (32)

A.5.2.2 Installation Verification

Due to some values may be estimated under Option A, a great care is needed in order to review the engineering design and the installation to ensure that the estimations are realistic, achievable and based on equipment that can really produce the desired energy-savings (32).

The installation should be repeatedly inspected at defined intervals during the Reporting Period, in order to verify the correct operation and performance of the installation and equipment, ensuring the continuation of the potential to generate the predicted energy-savings and validate the Estimated Values. The frequency of these re-inspections is determined by the probability of performance changes. Such probability can be established through initial frequent inspections in order to determine the stability of the equipment performance (32).

A.5.2.3 Procedure Cost

Energy-savings determination under Option A can be less costly than under other options, because as a general rule, the cost of estimating a parameter is significantly less than measuring it. However, in some cases where the estimation is the only possible way, a good Estimated Value may be costlier than if a direct measurement were possible (32).

The cost planning for Option A should consider the following elements (32):

- Analysis.
- Estimation.
- Measuring equipment installation.
- Operational costs derived from data reading and recording.

A.5.2.4 Best Applications

Option A is suitable where (32):

- The estimation of Non-Key Parameters may avoid difficult Non-Routine Adjustments, that would possibly be difficult to realize when changes happen in the future within the Measurement Limits.
- The uncertainty created by estimations is acceptable.
- The continued effectiveness of the ECM can be evaluated by simple routine re-testing or re-inspections of the Key Parameters.
- The estimation of some parameters is less costly than the measurement of them under Option B (Table A.2: Retrofit-Isolation, All Parameter Measurement) or simulation under Option D (Table A.2: Calibrated Simulation).

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- The Key Parameter(s) used to judge the performance of the project or the calculation of the energy-savings can be readily identified.

A.5.3 Option B: Retrofit-Isolation, All Parameter Measurement

Option B requires the measurement of energy quantities, or parameters, needed to calculate the energy-savings using Formulas A.1 and A.2 (Energy-Savings general equations). The energy-savings generated by most types of ECMs can be calculated by Option B. However, the degree of difficulty and costs increase as the metering complexity increases. Generally, Option B methods will be more difficult and costly than those of Option A, but as consequence, they will generate more certainty results where loads or saving patterns are variable. These additional costs may be justifiable if the contractor is responsible for factors, in addition to performance, that affect the energy-savings (32).

A.5.3.1 Calculations

Formulas A.1 and A.2 (Energy-Savings general equations) are used in IPMVP calculations, however, under Option B there may be no need of Routine or Non Routine Adjustments, depending on the location of the Measurement limits, the length of the Reporting Period, or the amount of time between the Baseline and Reporting Period measurements. Therefore, in some cases for Option B, the general formula may be simplified to the following (32):

$$Option\ B\ Energy\ Savings = Baseline\ Period\ Energy - Reporting\ Period\ Energy$$

Formula A.10: Option B Energy-Savings (32)

A.5.3.2 Best Applications

Option B is suitable where (32):

- The measured equipment added for Retrofit-Isolation will be used for other purposes, such as operational feedback.
- The measurement of the parameters is less costly than the simulation under Option D (Table A.2: Calibrated Simulation).
- The energy-savings within the Measurement Limits are variable.

A.5.4 Option C: Whole Facility

Option C involves the use of the energy suppliers measuring equipment, the whole facility measuring equipment, or measuring equipment installed in parallel, in order to evaluate the energy performance of the whole facility. The Measurement Limits may encompass the whole or a major section of the facility. This option determines the collective energy-savings generated by the ECMs applied to the part of the facility that is being monitored by the energy measuring equipment. Furthermore, due to the Whole-Facility measuring equipment are being used, the reported energy-savings under Option C include the positive or negative effects occurred in the facility which are non-related to the ECM (32).

Option C is intended for projects where the expected energy-savings are large compared to the random or unexplained energy variations which occur at the whole-facility level. If the energy-savings are large compared to the unexplained variations in the Baseline Period Energy data, then identifying the energy-savings will be easier. Furthermore, the longer the period of energy-savings analysis after

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the ECM installation, the more data are available, and the less significant is the impact of short-term unexplained variations (32).

As a general rule, if only monthly billing data are available for Energy Consumption or Demand, the energy-savings must exceed the 10% of the Baseline Period Energy if it is expected to confidently discriminate the energy-savings from the unexplained variations in the Baseline data (32).

When short-time interval Energy Consumption or Demand data are available, the advanced mathematical modelling may be more accurately than the linear models used for monthly analysis, may being able to verify the expected energy-savings that are lower than the 10% of the annual Energy Consumption or Demand. In either case, an evaluation of the Baseline model accuracy with the expected energy-savings and the monitoring period duration is required (32).

The main challenge of Option C is identifying the changes in the facility that will require Non-Routine Adjustments, particularly when the energy-savings are monitored for long periods. Therefore, periodic inspections of all equipment and operations in the facility should be realized during the Reporting Period, in order to identify changes in the Static Factors of the Baseline Period conditions. A lower cost alternative suitable for smaller projects or facilities consist on monitoring the Energy Consumption or Demand over time, normalizing it for the operating conditions, and realizing inspections in the facility looking for changes when the adjusted performance shows a persistent change (32).

A.5.4.1 Energy Data Issues

Where the utility energy supply is only measured at a central point for a group of facilities, measuring equipment installed in parallel are required at each facility or group of facilities for which performance is being evaluated on an individual basis (32).

Several measuring equipment may be used to measure the flow one energy type into a facility. For systems that interact with other systems, directly or indirectly, the energy measuring equipment data should be included in the whole-facility energy-savings determination (32).

The energy measuring equipment that does not interact with the ECM can be ignored. The energy-savings should be determined separately for each direct or in parallel energy measuring equipment in order to evaluate the performance changes for each monitored part of the facility. However, where a measuring equipment only measures a small fraction of the total use of a type of energy, it may be totalled with the larger measuring equipment to reduce data management tasks, taking into account that small consumption measuring equipment often do not have demand data associated with them, so that the totalled consumption data will no longer provide meaningful load factor information (32).

If several different measuring equipment are read on separate days, then each measuring equipment that has a unique billing period should be separately analysed. If the dates are reported, the resultant energy-savings can be combined after the analysis of each individual measuring equipment (32).

If any of the energy data from the Reporting Period are missing, a Reporting Period mathematical model can be created to fill in the missing data. However, the reported energy-savings for the missing period should be identified as missing data (32).

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A.5.4.2 Energy Invoice Issues

Energy data for Option C often come from measuring equipment of energy supplier companies, either through direct reading of the measuring equipment, or from utility invoices. Where utility invoices are the source of data, it should be taken into account that the measurement reading need of the energy supplier companies is not usually at the level of needs of a M&V process, due to utility invoices sometimes contain estimated data, especially for small accounts. Sometimes it cannot be determined from the invoice itself whether the data came from an estimation or a real measuring equipment reading. Unreported estimated measurements create unknown errors for the estimated month and also for the subsequent months. However, the first invoice with a real measuring equipment reading after one or more estimations will correct the previous error in energy quantities. Energy-savings reports should take into account when estimation is part of the energy supply company data. When an energy supply company estimates a measuring equipment reading, no valid exist for the energy demand of that period (32).

Energy may be supplied indirectly to a facility through on-site storage installations, such as propane or oil deposits. In these situations, the shipment invoices of the energy suppliers do not represent the real consumption of the facility during the period between shipments. The ideal situation would be the implementation of a measuring equipment downstream of the storage installation which would measure the Energy Consumption or Demand of the facility. However, where there is no downstream measuring equipment, periodic inventory-level adjustments for each invoice period should supplement the invoices (32).

A.5.4.3 Independent Variables

Common Independent Variables are weather, production volume and occupancy. The weather for whole-facility analysis is often just the dry-bulb temperature. The production is typically expressed in mass unit or volumetric units of each product. The occupancy is defined in many ways, such as office-building occupancy hours or occupied days (weekdays or weekend) (32).

The mathematical models can evaluate the Independent Variables if they are cyclical. The regression analysis and other forms of mathematical modelling can determine the number of Independent Variables to consider in the Baseline Period data. The parameters that have a significant effect on the Baseline Period Energy, should be included in the Routine Adjustments when determining energy-savings using one of the following formulas (32):

$$Option\ C\ Energy\ Savings =$$

$$(Baseline\ Period\ Energy - Reporting\ Period\ Energy) \pm Routine\ Adjustments \pm Non\ Routine\ Adjustments$$

Formula A.11: Option C Energy-Savings (32)

$$Avoided\ Energy\ Consumption =$$

$$Adjusted\ Baseline\ Energy - Reporting\ Period\ Energy \pm Non\ Routine\ Adjustments\ to\ Reporting\ Period\ Conditions$$

Formula A.12: Avoided Energy Consumption (32)

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$$\text{Normalized Savings} = (\text{Baseline Period Energy} \pm \text{Routine Adjustments to Fixed Conditions} \pm \text{Non Routine Adjustments to Fixed Conditions}) - (\text{Reporting Period Energy} \pm \text{Routine Adjustments to Fixed Conditions} \pm \text{Non Routine Adjustments to Fixed Conditions})$$

Formula A.13: Normalized Savings (32)

The Independent Variables should be measured and recorded during the same time period as the energy data (32).

A.5.4.4 Calculations and Mathematical Models

For Option C, the Routine Adjustments term in the following formula is calculated by developing a valid mathematical model of the energy-use pattern for each energy measuring equipment (32).

$$\text{Option C Energy Savings} = (\text{Baseline Period Energy} - \text{Reporting Period Energy}) \pm \text{Routine Adjustments} \pm \text{Non Routine Adjustments}$$

Formula A.14: Option C Energy-Savings (32)

A model may be as simple as an ordered list of twelve measured monthly energy quantities without any adjustments. However, a model can also be based on interval data, and often includes factors derived from regression analysis that correlate the energy to one or more Independent Variables, such as outdoor temperature, measuring period length, production, occupancy or operating mode. The models can also include a different set or regression parameters for each range of conditions, such as for seasonal energy consume variations (32).

Option C should usually use complete years (for example 12, 24 or 36 months) of continuous data during the Baseline Period, and continuous data during the Reporting Period. For short-time interval data may be used fewer months, however, there should be taken care to assure that the data range is representative of the entire Baseline year. The model that use other number of months (for example 9, 13 or 16 months) can create statistical bias by under or over-representing unusual operating modes. Such models should be checked for bias (32).

Measure whole-facility data can be hourly, daily or monthly, and may be combined into longer time intervals to limit the number of Independent Variables required to develop a reasonable Baseline model, without significantly increasing the uncertainty of the calculated energy-savings. Many statistical model are appropriate for Option C, however, to select the most suitable for the application, there should be considered the statistical-evaluation indices, such as the Coefficient of Variation of the Root Mean Squared Error (CV{RMSE}), the Mean Bias Error (MBE) (32).

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A.5.4.5 Measurement

The energy suppliers measuring equipment, which can be used for the whole-facility energy measurements, are considered 100% accurate for determining the energy-savings because their data define the payment for energy. These data are subject to local commercial accuracy regulation for the sale of energy (32).

The measuring equipment of energy suppliers may be equipped or modified to provide an electrical pulse output that can be recorded by the monitoring equipment of the facility. The energy-per-pulse constant of the pulse transmitter should be calibrated against a known reference, such as similar data recorded by the utility measuring equipment (32).

Independent measuring equipment installed by the facility owner can measure the whole-facility energy for Option C. The accuracy of these measuring equipment should be considered in the M&V Plan, together with a way of comparing their reading with the ones of the energy suppliers measuring equipment (32).

A.5.4.6 Procedure Cost

The cost of Option C depends on the source of the energy data and the difficulty of tracking Static Factors within the Measurement Limits to enable Non-Routine Adjustments during the Reporting Period. The energy suppliers measuring equipment or the existing in parallel measuring equipment work well if the measuring equipment data are properly recorded. This choice requires no extra measuring cost (32).

The cost of tracking changes in Static Factors depend on (32):

- The size of the facility.
- The probability of Static Factors changes.
- The difficulty of detecting changes.
- The surveillance processes already installed.

A.5.4.7 Best Applications

Option C is suitable where (32):

- The energy performance of the whole facility will be evaluated, not just the ECMs.
- There are many types of ECMs in one facility.
- The ECMs involve activities whose individual Energy Consumption or Demand is difficult to separately measure.
- The energy-savings are large compared to the variance in the Baseline and Reporting Period data.
- Retrofit-Isolation techniques (Options A or B) are excessively complex and costly.
- Significant future changes in the facility are not expected during the Reporting Period.
- There can be stablished a system of tracking Static Factors to enable possible future Non-Routine Adjustments.
- Reasonable correlations can be found between the Energy Consumption or Demand and other Independent Variables.

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A.5.5 Option D: Calibrated Simulation

Option D involves the use of building energy simulation software to predict the use of energy of the facility, typically when a Baseline does not exist. When measured data for the Baseline or existing condition are available, the simulation model is calibrated so that it predicts the energy and the load shape that approximately matches the real measured data (32).

Option D may be used to evaluate the performance of the ECMs for the whole facility, like Option C. However, the whole-facility simulation model can also be used to provide an estimate of the energy-savings attributed to each ECM within a multiple ECM project (32).

Option D may also be used to evaluate just the performance of individual systems within a facility, like Option A and B. For this application, the Energy Consumption or Demand of the system must be isolated from that of the rest of the facility by appropriate measuring equipment, which will be used for the calibration of the simulation model (32).

A.5.5.1 Types of Simulation Programs

Whole-building simulation programs usually use hourly calculation techniques. The utilization of simulation software packages that are widely used and have been evaluated by ASHRAE 140 is preferable. However, proprietary simulation software may also be used if the algorithms are transparent and well documented. System-level simulation models may be used if the meet the above criteria and take into account the ECM interactions. Other types of special-purpose programs may be used to simulate the energy use associated with the operation of devices or industrial processes (32).

The software used must be well understood by the user. The software should be capable of simulating the energy use types, the space types, as well as the ECMs of the project. Due to the wide variety of available software, it is prudent to receive the acceptance by the owner or the project authority about the proposed modelling program before starting the analysis (32).

A.5.5.2 Calibration

The energy-savings determined with Option D are based on physical models and numerical solution techniques, whose accuracy depend on the proficiency of the user, the model robustness and the level of calibration (32).

When calibrated, the simulation model should reasonably predict the load shape and the energy use of the facility or system. This is determined by the comparison of the model the results to the measured data, Independent Variables and Static Factors (32).

Normally, the calibration of the whole-facility simulation is performed with twelve consecutive months of the energy supplier billing data over a stable operating period. In a new installation this may not occur until after several months when occupation and operation stabilize. The calibration time period and the data that are going to be utilized should be documented in the M&V Plan (32).

The calibration data should include (32):

- Operating characteristics.
- Occupancy.
- Weather.
- Loads.
- Equipment efficiency.

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The parameters should be measured at an appropriate interval (day, week, month, etc.) or be extracted from existing operating logs or trend data logs. The accuracy of measuring equipment should be verified for critical measurements. The level of calibration should be established in the M&V Plan and reflect the level of effort and accuracy justified for the project (32).

Following the Calibration Data Collection, the below Calibration Steps should be performed (32):

1- Assume other necessary input parameters; document their values and sources.
2- Whenever possible, gather actual weather data from the calibration period, especially if the weather conditions vary significantly from a standard-year weather data. Use available simulation software tools to create the actual weather file or adjust the standard weather file to better represent actual conditions.
3- Run the simulation and verify that the systems meet the loads and the zone set-points (such as temperature).
4- Compare the simulated energy results with the measured energy data from the calibration period, on an hourly or monthly basis.
5- Compare the results with the detailed operating and measured performance data to ensure that they represent the actual facility or system operation.
6- Evaluate the consistency of the load shapes and other energy-use patterns between the simulation results and the calibration data. Bar charts, monthly percent difference time-series graphs, and monthly x-y scatter plots help to identify discrepancies.
7- Revise the input data values established in the Step 1. Repeat the Steps 3-5 to obtain the expected results within the project calibration specifications. If it is necessary, collect more operating data from the facility.
8- The development of the simulation model and the calibration is time consuming. Using monthly rather than hourly energy data helps to limit the effort needed for the calibration. However, if the simulation will be used to determine the energy-savings at the ECM level, it is recommended to realize the calibration using hourly or daily data for the impacted end-uses, systems, and/or equipment.

The accurate computer modelling and the model calibration are the major challenges associated with Option D implementation. To balance costs with accuracy, the following points should be considered (32):

- The simulation analysis should be realized by trained personnel, with experience in the software and calibration techniques.
- Record evaluated data, monitored data, and assumptions used to define input values. The calibrated simulation model should be saved in paper and electronic files. The simulation software release version should be recorded and saved to support quality assurance reviews.
- Document the specific changes made to the simulation model in order to represent each ECM impact.
- When possible for new construction projects, retain the building energy modeller that created the as-designed model to create the calibrated, as-built and adjusted Baseline models.

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A.5.5.3 Calculations

The energy-savings can be determined using calibrated simulation result that represent the Baseline and Reporting Periods. If the Baseline Period does not exist (new constructions), the Reporting Period calibrated model can be used to develop the Baseline model. If the Baseline Period exists, a calibrated model that represents the actual facility conditions can be developed to predict the impact of the ECMs. After the ECM installation, the Reporting Period Energy Consumption or Demand will be used to calibrate the initial Baseline model with the predicted ECMs (as-designed model for new construction) to develop the Reporting Period model. Once calibrated, the ECMs will be removed from the model to create the Baseline model. The model represents the existing facility under the Reporting Period Conditions. If it is desired to report energy-savings under normal conditions, the Reporting Period calibrated model should be modified to represent normal conditions (such as normal weather conditions, other normal Independent Variables, etc.) and then the ECMs should be removed to develop the Baseline model (32).

For projects that develop a hypothetical Baseline model (such as code-compliant Baseline for a new construction project) the Baseline model for M&V must be developed from the calibrated Reporting Period model with ECMs removed, as described above (32).

In either case, the models and the measured energy data must be under the same set of operating conditions, similar to Option C (32).

The energy-savings with Option D can be estimated using two forms of the Energy-Savings Formula. Both forms suppose that the calibration error equally affect both Baseline Period and Reporting Period models. The same energy-savings will be determined from the two formulas for any given set of data and simulations (32).

$$\begin{gathered} Option\ D\ Energy\ Savings = \\ Baseline\ Period\ Energy\ from\ the\ Calibrated\ Model\ \text{"}without\ ECMs\text{"} \\ -\ Reporting\ Period\ Energy\ from\ the\ Calibrated\ Model\ \text{"}with\ ECMs\text{"} \end{gathered}$$

Formula A.15: Option D Energy-Savings form 1 (32)

One of the model-derived energy terms in the formula above may be replaced by the actual measured energy. However, the calculation must be adjusted for the calibration error for each month in the calibrating period, using the formula below (32):

$$\begin{gathered} Option\ D\ Energy\ Savings = \\ Baseline\ Period\ Energy\ from\ the\ Calibrated\ Model\ \text{"}Baseline\ without\ ECMs\text{"} \\ -\ Actual\ Reporting\ Period\ Energy \\ \pm Calibration\ Error\ in\ the\ Corresponding\ Calibration\ Reading \end{gathered}$$

Formula A.16: Option D Energy-Savings form 2 (32)

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A.5.5.4 Savings Reporting

If a multi-year performance evaluation is required, the models must be recalibrated each year of the Reporting Period. As an alternative, Option D may be used for the first year after the implementation of the ECMs. For following years, Option C may be applied with the Baseline Period based on the measured data from the Reporting Period of the first year under steady operation. In this case, Option C is used in the following years to track energy-savings persistence (32).

A.5.5.5 Best Applications

In general, Option D is used when other options are not feasible. Option D is suitable where (32):

- The Baseline Period Energy data are unavailable or unreliable, such as for new construction projects or facility expansions that need to be evaluated separately from the rest of the facility.
- Centrally measured facilities where there is no individual measuring equipment during the Baseline Period, but where they will be available after the ECM installation.
- There are too many ECMs to evaluate using Option A or B.
- The performance of each ECM will be estimated individually within a multiple ECM project, so that the costs of Options A or B would be excessive.
- The interactions between the ECMs are complex and significant, making the isolation techniques (Options A and B) impractical.

A.6 IPMVP Adherent M&V Plan and Report

This chapter describes the requirements for developing and implementing an adherent M&V Plan and report (32).

A.6.1 IPMVP Adherent M&V Plan

A key component towards IPMVP adherence involves the development of a clear and transparent project-specific M&V Plan, which describes the different measurements and data to be gathered, the analysis methods employed and the verification activities that are realized to evaluate the performance of a ECM or a project. An adherent M&V Plan will ensure that the ECM or the project can realize their maximum potential and that the energy-savings can be verified with enough certainty. For performance contract projects, an adherent M&V Plan needs to be developed and agreed to as part of the final contract approval and/or before the installation of the projects ECMs (32).

An adherent M&V Plan meets all the criteria from 1 to 14 which are presented below. The additional adherence requirements for Options A and C are included after these general compliance criteria (32).

A.6.1.1 Facility and Project Description

A M&V Plan should include a complete description of the facility and the proposed project together with the list of the ECMs that are part of the project. This chapter should also include references to any energy audit reports or other analysis that were used to scope the project (32).

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A.6.1.2 ECMs Purpose

This section of a M&V Plan should provide a clear understanding of each ECM scope and purpose. At a minimum, this chapter should include (32):

- A description of each ECM.
- How the ECM saves energy or other resources (such as efficiency improvement, reduction of operating hours, water consumption reduction, etc.).
- Affected equipment inventory.
- Expected energy-savings

A.6.1.3 Selected IPMVP Option and Measurement Limits

A M&V Plan must specify the IPMVP Option that will be used to evaluate the energy-savings. In this chapter the Measurement Limits for the energy-savings determination must also be identified. A Measurement Limit may be as narrow as the flow of energy through a pipe or wire, or as broad as the total Energy Consumption or Demand across many facilities. This chapter should also describe the nature of any Interactive Effect beyond the Measurement Limits together with their possible effects on the project energy-savings. The quantified Interactive Effects should also be included in this chapter with the appropriate justification (32).

A.6.1.4 Baseline Period

This chapter of the M&V Plan documents the Energy Consumption or Demand of the facility during the Baseline Period, along with the influencing parameters beyond with the Measurement Limits (32).

The Baseline Period description must be well documented. The Baseline data may come from many sources, such as from short-term measurements, spot measurements, or manufacturer specification sheets. The extend of the needed information is determined by the selected IPMVP Option, the Measurement Limits chosen or the scope of the energy-savings determination (32).

The Baseline Period documentation should include the following information:

- Identification of the Baseline Period

This is the time period over which the facility Baseline conditions are evaluated and documented. This Baseline Period tends to be a year, but can be any period depending on the specific M&V needs (32).

- Baseline Utility Consumption or Demand Data

For Option C the Baseline utility may be billing data, while for Options A or B it could be field collected interval data or spot measurement data. This includes the data over the measurement period. These data can be used to extrapolate the Energy Consumption or Demand over the entire Baseline Period, and this analysis should be included. These data are normally considered as Dependent Variables (32).

- Utility Influencing Variable Data

The utility influencing data need to be gathered at the same time period as the utility data gathering. This may include variables such as production data, temperature, speed, pressure or any other variable collected through spot measurements, short-term or long-term measuring. These data are

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normally considered as Independent Variables or variables that affect the above Dependent Variables (32).

- Operating Conditions

Definition of the predominant operating conditions corresponding to the Dependent and Independent Variables (such as the Baseline Utility Consumption or Demand Data and the Utility Influencing Variable Data) during the identification of the Baseline Period. These predominant conditions (also known as Static Factors) are expected to remain constant, but may change and have to be treated as part of the Non-Routine Adjustments if it is necessary. Some examples of Static Factors are the following (32):

- Occupancy type, occupancy density and run times.
- Operating conditions (such as set points, lighting levels, ventilation levels, etc.) for each Baseline Period and season.
- Significant measuring equipment problems our outages during the Baseline Period. In these cases, the Baseline Period Energy should be adjusted so that it reflects the operation of the facility complying with the regulations or after the necessary repairs.
- Identification of planned changes in the conditions that affect the Baseline Period Energy (such as adding a shift).

A.6.1.5 Reporting Period

The Reporting Period is a selected interval for evaluating and quantifying the post-installation performance of the ECMs. A M&V Plan should identify the Reporting Periods for which the ECM or the project is being evaluated. The Reporting Period may be a short-term period right after the installation of the ECM to ensure that the performance is fulfilling the expected, or it could be a longer time period at periodic intervals, such as a year, multiple years, or other time periods (32).

In cases where the Baseline Period and the Reporting Period have a different length, it is important to explain how the time frames are normalized, so that the Baseline and Reporting Period Energy Consumption or Demand are compared evenly and reliably (32).

In a performance contract, the performance period refers to the duration of the project guarantee and is made up of various Reporting Periods. Normally, the contractor is required to report about the performance of the project and the ECMs regularly throughout the entire duration of the performance period (32).

A.6.1.6 Basis for Adjustments

The operating conditions that affect the Energy Consumption or Demand may differ between the Baseline and Reporting Periods. It is important to make adjustments in order to take into account these changes in the operating conditions (32).

A M&V Plan should provide details outlining how the Baseline and/oy Reporting Period Energy Consumption or Demand will be adjusted to allow for a valid comparison and energy-savings calculation. The Basis for Adjustments can be made by (32):

- Projecting the Baseline Energy Consumption or Demand to the Reporting Period Conditions.

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- Projecting the Reporting Period Energy Consumption or Demand to the Baseline operating conditions.
- Projecting both, the Baseline and the Reporting Period Energy Consumption or Demand, to standard conditions (such as a Typical Meteorological Year TMY).

The conditions for the Basis for Adjustments determine whether the energy-savings are reported as Avoided Energy or Normalized Savings (32).

Another Basis for Adjustments is to account for factors that are not expected to change (Static Factors) during the Reporting Period. However, in the likelihood that these factors change, their effects need to be accounted through suitable Non-Routine Adjustment procedures. Some examples may include the addition of a new production shift or the increasing of the operating hours that are not part of the Baseline or the installed ECM (32).

A.6.1.7 Calculation Methodology and Analysis Procedure

A M&V Plan should specify the data analysis procedures, the model descriptions and the assumptions used in the calculation of energy-savings for each of the Reporting Periods (32).

For each model used should be (32):

- Identified and defined all Independent Variables, Dependent Variables, and other model-related terms.
- Reported all coefficients, constants, statistical metrics, and other model elements or terms.
- Reported the range of Independent Variables over which the models are valid.

A.6.1.8 Energy Prices

A M&V Plan should also specify the energy supplier billing prices, or tariffs that will be used to calculate the cost of the energy-savings associated with the ECM or project, and how the monetary value of the energy-savings will be adjusted if the utility prices changes during the life of the ECM or project. The M&V Plan should clearly define and report any assumed or stablished values such as an inflation and/or escalation rate in the utility prices, or other variables that affect the M&V results (32).

A.6.1.9 Measuring Equipment Specifications

A M&V Plan should specify the measuring points that will be used to gather the M&V data, both for spot and continuous measuring. For non-utility measuring equipment, the M&V Plan should specify (32):

- Type, model and characteristics.
- Specifications, including accuracy and precision.
- Reading and witnessing protocol.
- Commissioning procedure.
- Calibration procedure.
- Methodology of dealing with lost data and data transfer.

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A.6.1.10 Monitoring Responsibilities

A M&V Plan should assign responsibilities for gathering, analysing, archiving and reporting the data. The management of the M&V data should be assigned to an efficient and skilled team in evaluation and data management, assuring the providing of effectively data sets. The monitored data that must be managed includes (32):

- Energy data.
- Independent Variables.
- Static Factors within the Measurement Limits.
- Periodic inspection findings.

A.6.1.11 Expected Accuracy

A M&V Plan should include the expected accuracy associated with the measurements, data gathering, sampling and data analysis. This evaluation should include qualitative and quantitative considerations related to the level of uncertainty in the measurements and describe the adjustments that are going to be used in the planned energy-savings report (32).

A.6.1.12 Budget

A M&V Plan should include the budget and the resources required for the energy-savings determination, including the cost of the initial setups and ongoing tasks for evaluating, documenting and reporting the performance for each of the Reporting Periods (32).

A.6.1.13 M&V Report Format

A M&V Plan should specify how the results will be reported and documented for each of the Reporting Periods, including the frequency of reporting (32).

A.6.1.14 Quality Assurance

A M&V Plan should include the quality-assurance procedures that will be used for the Baseline and Reporting Periods data gathering, calculations, energy-savings reports and any intermediate step in the reports' development. The quality assurance should include inspections at regular frequencies to ensure that ECM and the equipment continue operating under the terms of the contract (32).

A.6.2 Additional M&V Plan Requirements for Option A

A.6.2.1 Justification of Estimations

A M&V Plan should clearly identify the variables that are going to be estimated as part of the energy-savings calculation. This must include the actual values used and the source of the Estimated Values. It is necessary to show the global impact of these estimations to the total expected energy-savings by reporting the range of possible energy-savings associated with the range of plausible values of the estimated parameters (32).

A.6.2.2 Periodic Inspections

The M&V plan should specify the periodic inspections that will be performed during the Reporting Period in order to verify that the equipment is still in place and operating as expected (32).

A.6.3 Additional M&V Plan Requirements for Option D

A.6.3.1 Software Identification

A M&V Plan should report the name and the version number of the simulation software used to calculate the energy-savings (32).

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A.6.3.2 Input / Output Data

A M&V Plan should provide copies of the input and output files used for the simulation, including calculations and any post-processing method (32).

A.6.3.3 Measured Data

A M&V Plan should describe the process of obtaining any measures data, including which input parameters were measured and which estimated. The actual measured data should also be reported and the raw data should be archived and be available as needed. This may include periodic measurement data and energy supplier invoices (32).

A.6.3.4 Calibration

A M&V Plan should report about the energy and operating data used for calibration, including the calibration requirements (such as CV{RMSE}, MBE, etc.) and the accuracy with which the simulation results match the calibration energy data. Data should be provided at a minimum of one moth intervals, although a higher resolution is preferable (32).

A.6.3.5 Future Changes

A M&V Plan should provide a description of the method for making relevant Non-Routine Adjustments. Non-Routine Adjustments may require a review of the model and a recalculation of the Baseline and Reporting Period energy use (32).

A.6.4 M&V Reports

A M&V Report should include at a minimum the following information (32):

- Project background.
- ECM description.
- IPMVP Option chosen for the ECM or project as part of the M&V Plan.
- Reporting Period star and end dates.
- M&V activities developed during the Reporting Period, including (32):
    - Start and end time of the measurement period.
    - Energy use data.
    - Data for Independent and Static Variables.
    - Description of inspection activities realised.
    - Verified energy-savings calculations and methodology.
    - Detailed description of data analysis methodology.
    - Updated list of assumptions and source of data used in the calculations.
    - Details of any Baseline Energy adjustment, including both Routine and Non-Routine Adjustments to account for changes.
    - Details of utility costs used to calculate the reported energy-savings.
    - Clear presentation of verified energy-savings, energy-savings cost and comparison with the proposed energy-savings.

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A.7 Adherence with IPMVP

The IPMVP is based on the following principles (32):

- The IPMVP represents a framework of terminology and methods for properly evaluate savings in energy or water consumption or demand.
- The IPMVP guides users in developing M&V Plans and Reports for specific projects.
- The IPMVP is written to allow maximum flexibility in creating and implementing M&V procedures, always adhering to the principles of accuracy, completeness, conservativeness, consistency, relevance and transparency.

The M&V represents a process implemented to assure that savings are verified according to the application of the IPMVP procedures. The steps of a typical M&V process are listed below (32):

1- An estimation of savings for the project is developed. This may be from an energy audit or a technical study realized for the proposed project. Usually, the proposed savings estimation is made to evaluate the business aspect of the project.
2- The M&V Plan is reviewed to verify the adherence with IPMVP methods, procedures and principles. The review may be performed by qualified third-part, such a Certified Measurement and Verification Professional (CMVP).
3- The Savings Reports are developed as described by the M&V Plan.
4- The Savings Reports are reviewed to verify the adherence with the M&V Plan and IPMVP methods, procedures and principles.

This results in an adherent project through the latest Reporting Period (32).

The following fugure shows a flowchart of a M&V process with its typical adherence activities (32):

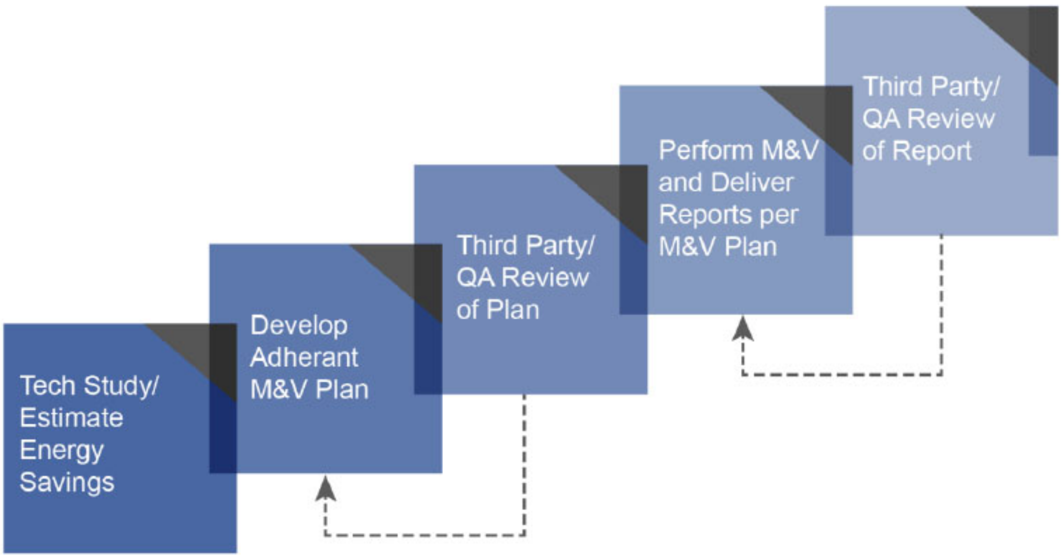

Figure A.2: Flowchart of M&V Process with typical adherence activities (32)

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Users that adduce an adherence with IPVP must (32):

- Identify the person responsible for approving the site-specific M&V Plan and for making sure that the M&V Plan is followed during the Reporting Period.
- Develop a complete M&V Plan which (32):
    - Clearly states the date of publication or the version number of the IPMVP Edition and Volume being followed.
    - Uses terminology consistent with the definitions in the version of IPMVP cited.
    - Includes all the information mentioned in the M&V Plan chapter (Chapter A.6 "IPMVP Adherent M&V Plan and Report").
    - Defines the contents of the Savings Reports and the frequency that energy-savings will be reported.
    - Is approved by all parties interested in the adherence with IPMVP.
    - Is consistent with the Principles of IPMVP.

Implement the approved IPMVP adherent M&V Plan and assure that its procedures are followed according to the Principles of IPMVP. This may include the realization of a quality assurance review of all M&V activities, including inspections, measurements, calculations and reports. For each project, the quality assurance procedures are described in the M&V Plan. A knowledgeable and experienced professional should conduct the review process, such a Certified Measurement and Verification Professional (CMVP) (32).

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