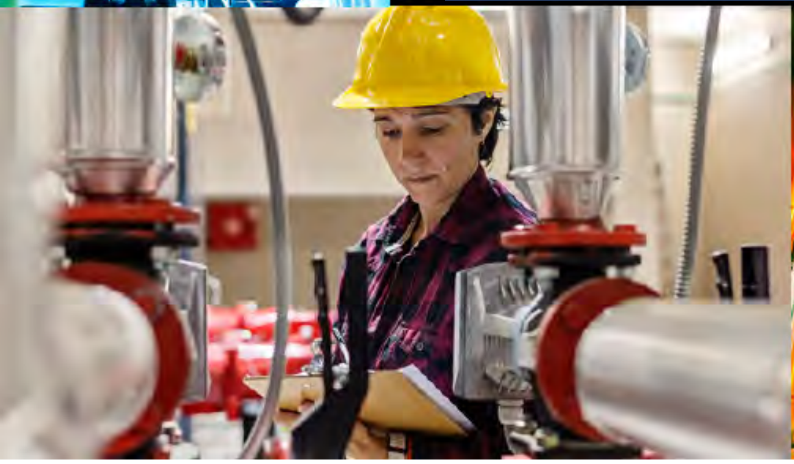
PROJECT 6-25

A Guideline to analyze and prioritize energy efficiency projects in Energy Intensive Industry to increase shareholder value



A Guideline to analyze and prioritize energy efficiency projects in Energy Intensive Industry to increase shareholder value

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1. EXECUTIVE SUMMARY

The energy intensive industry is faced with the challenge of further reducing the use of energy as part of an even bigger challenge to drastically minimize global emissions of greenhouse gases. Energy efficiency as a whole has the largest potential contribution to achieving net zero in 2050 according to the IEA. Specifically, energy efficiency in energy intensive industry has negative abatement costs per ton of CO_2 (saving money while reducing CO_2) compared to other carbon reduction solutions. Energy efficiency measures in industry can contribute to all CO_2 reduction goals, whether national, European, global (Paris goals) or company specific corporate goals. At the same time it can achieve significant operational cost reductions to increase the return on capital. This leads to a higher shareholder value and improved competitiveness in the globalized environment of industry.

The objective of this paper is to provide the energy intensive industries - which to a large extent boils down to all companies which are part of the EU-ETS scheme and large power users - with a methodology to evaluate and prioritize business cases of energy efficiency projects in relation to the total project portfolio, and in accordance with company KPI's. Typically, such companies are manufacturers of steel, aluminum, cement, fertilizer, fuel products (refineries), chemicals, power, glass, ceramics and the larger food and beverage companies. The purpose of this methodology is to optimize the use of both CAPEX and human capital in the company and to align corporate and operational goals.

The paper has three prime readerships: First, it is being targeted as a user guide for operational staff who are in charge of bringing energy efficiency ideas and programs into reality in a plant, i.e. energy managers, but also operations, technology, maintenance, finance, plant managers who are involved in leading energy efficiency operations. The second target group is senior plant management to ensure that budgets and incentives are such that everybody is stimulated to work on energy efficiency and support the projects and their mutual synergy. The third target group are senior managers in operations, technology, finance and government regulations at corporate level to ensure global deployment of successful projects and technologies, disseminate best practices and know-how and to allocate sufficient CAPEX to plants for the portfolio of energy efficiency projects.

Other existing studies have already analyzed the financial evaluation methods for energy efficiency in relation to the overall company investment priorities both at plant level (operations) and at corporate level. It turns out that at plant level energy efficiency projects are usually developed by a bottom-up approach and ranked by Payback period. These energy efficiency projects have to compete with other operational projects that aim at for instance reduction of maintenance costs or increase of production.

At corporate level different KPI's are used like market share, financial KPI's as EBITDA, operational margin, or sustainability KPI's expressed in CO_2 reduction. The implementation of these corporate KPI's is usually done by a strategic top-down approach leading to capital- and manpower intensive flagship projects involving senior management. The corporate ranking of these large projects takes into account the strategic drivers of the company and uses the NPV and IRR financial assessment methods.

The consequence of the different corporate and operational ranking of investment opportunities with respect to energy efficiency has been analyzed in various publications by e.g. David March (2013)[4] and Yueming Qiu (2015)[1]. It can be concluded that energy efficient technologies that are "cost effective" according to the NPV method with a reasonable discount rate enjoy only limited market success. The capital allocation for energy efficiency projects at plant level is typically so small that one in seven projects is selected. This is the well-recognized phenomenon of "energy efficiency gap".

To address this issue Ernst Worrel (2003)[2] demonstrates the importance of incorporating non-energy benefits in the financial analysis of projects, as it might double the return on project investment compared to energy efficiency alone. Catherine Cooremans (2011, 2012)[3] also states that a higher uptake of energy efficiency opportunities is possible when identifying and quantifying on top of cost savings a broader range of impacts and aligning these to the more strategic objectives of a company. Cooremans calls this the multiple benefits analysis, i.e. analysis of all the benefits of a technology beyond reducing energy costs.

The authors of this report propose a new method (the 6-factor method) that build upon these recommendations and maximizes the synergy between the projects in the portfolio while balancing KPI's, both at corporate level and at plant level. The 6-factor method is an integral part of the following project prioritization process:

1. <u>Financial investment appraisal of all projects within a project portfolio:</u>
   This requires for all projects, energy efficiency projects and other projects, a common appraisal period of typically 15 years and uniform financial analysis based on the NPV method. The NPV is by far the preferred tool for ranking projects as it relates directly to shareholder value and enables a direct comparison between energy efficiency and all other investments in the company, both operational and non-operational. For energy efficiency projects, especially, use:
   - WACC as a default discount factor (usually between 6 and 10 %). The risk profile of projects within a project portfolio can vary which can be reflected by applying risk-adjusted discount rates to prioritize low risk projects within a project portfolio. Many energy efficiency have a low risk profile, and using the company WACC as discount factor is appropriate.
   - Exchange-based market-prices for energy and CO_2
   - Inclusion of non-energy benefits as revenues.

2. <u>Bottom-up Energy efficiency Project prioritization</u> based on costs benefit analysis, project effort, risks, timing and alignment to operational drivers.

3. <u>Strategic prioritization of projects within the overall project portfolio (6-factor method)</u>. The degree of correlation amongst projects is determined with the aim to find project synergies to increase the effectiveness of energy efficiency implementation while reducing time, risks and costs and thereby optimize the cash to be earned. This method can greatly improve the deployment of energy efficiency investments.

4. <u>Organizational alignment</u> and change in terms of staffing, sharing best practices, developing know-how and setting up a center of excellence to optimally deploy the new appraisal and development process for projects. Cooperation has to be rewarded, both in the plant and between the plants and the corporate departments

to optimally use both CAPEX and human capital. Senior management has a role in shaping the required business process as well as the culture, incentives and KPI's.

The process described above has the potential to become a strong catalyst for strategic positioning of energy efficiency projects and hence a more competitive industry. It will require bold steps and focus. It will need substantially more CAPEX and staff to identify, develop and implement projects. The rewards are more shareholder value and a lower CO_2 footprint. Finally, this process should be supported by adequate government regulations and subsidies to smoothen and accelerate the process.

2. FINANCIAL APPRAISAL METHODS

Most energy saving projects incur up-front costs and yield annual savings, hence the need for financial appraisal of the project investment. A cost-benefit analysis estimates the benefits and costs of an investment to either determine if the project fulfills financial criteria or to compare the project investment with other competing projects. It allows decision makers to appraise projects in a consistent and comparable manner. This chapter presents the basic elements used to determine the cost-effectiveness of projects and a few of the most popular measures of cost-effectiveness of (par. 2.1), methods for evaluating energy savings (par. 2.2), and methods for evaluating non-energy savings (par. 2.3).

2.1 TYPES OF COST BENEFIT ANALYSIS

There are a number of different approaches that can be used to evaluate a project. The selected approach is often determined by the complexity and investment size of a project. For energy-saving measures specifically, the following choices are often considered:

2.1.1 The Payback Period

The Payback Period (PBP) technique is the most familiar way of evaluating and expressing the cost effectiveness of projects. Dividing the project's cost by the annual savings tells us how long it will take to recoup the initial investment sum. In other words, the year following the project payback period will see net savings and benefits to the project.

This method is suitable for energy efficiency projects that are relatively small and require a short development time.

$$\textbf{1)}\ \boldsymbol{PBP = \frac{Initial\ Investment\ Sum}{Savings\ per\ Year}}$$

with:

PBP:	simple payback period;
Savings:	annual net cashflow out of the investment;
Initial Investment Sum:	investment sum of all equipment required for the project including installation;

When investments are already planned to address other issues than energy efficiency investments, and an energy efficient equivalent is being considered, then the initial investment sum is the difference between the Energy Efficient (EE) alternative and the *planned investment sum. For example, when existing equipment reaches its End Of Life, then we have the option for an EE equipment or like-for-like. When calculating the PBP the initial investment sum is then only the difference between the cost for the EE equipment minus the cost for a like for like equipment. This makes the PBP a lot better. This effect can often be overlooked when the full investment cost are being taken into account. See also par 3.3: Dealing with planned replacement projects.*

The Simple Payback Period

Initial Investment Sum includes the purchasing & installation costs of the equipment, minus subsidies, if applicable. The savings per year are the savings in energy costs, i.e.:

2) Saving = (Energy use per year x Energy price) ref situation

- (Energy use per year x Energy prince) new situation

The maximum payback period for an energy efficiency investment to be considered financially viable is typically 5 years, except when the lifespan of a project is less than 10 years, see Table 1. Usually, the lifespan of equipment is 15 years or more, though.

Lifespan (years)	Maximum PBP (years)
5	3.4
6	3.8
7	4.2
8	4.5
9	4.8
10 or more	5

Table 1: The maximum payback period for a project to be financially viable

The Variable Payback Period

This calculation includes savings in energy costs and in non-energy costs. This method is the middle road between the Simple Payback Period method and the Net Present Value method based on discounted cash flows, as described the in next paragraph. As described in chapter 2.3, the payback period of energy efficiency projects could be halved when including non-energy improvements in the evaluation.

2.1.2 Discounted Cash Flows: Internal Rate of Return and Net Present Value

For large CAPEX projects that have a long development time with investments spread over several years, or for projects with non-constant cash flows, greater accuracy may be desired. The most fair way to evaluate is on the total cash flows which are represented by the NPV (Net Present Value). In that case it is not only important to capture the cash flows over the years, but also *the value* of continued savings in the future. In discounted cash flow calculations, all the project’s current and future costs and incomes are aggregated into a single figure, but with due allowance made for the fact that cash flows in the far future have less weight than those in the near future.

2.1.2.1 Fundamentals

Discount Rate

The value of money in the present is viewed as higher than the value in the future. The further a potential benefit or cost is in the future, the less its value. This concept is made tangible by a process called discounting. This is where a discount rate is applied to anticipated cashflow of a project over the duration or 'life span' of the project to convert the value of a return in the future into today's value. Hence, for instance, the returns of a multi-year project are usually referred to as discounted returns.

The lower the discount rate, the higher the return value of the project's future costs and benefits. Conversely, the higher the discount rates the lower the future return value will be.

The selection of the appropriate discount rate is important to ensure that future project returns are not being over- or underestimated in today's value. In theory, the discount rate should just be the cost of capital, so the WACC, see hereunder. It is higher, when the specific project risk is higher than the company average. Sometimes risk-adjusted discount rates for different asset classes are used to reflect the different risk profiles.[4] As the risk profile of many energy efficiency investments is considerably lower than that of the enterprise, lower discount rates can be applied to energy efficiency projects as shown by Yueming Qui[1] (2015). However, the imposed hurdle rate for the return on energy efficiency investments appears to be much higher (more than 20 %) for other low carbon investment in e.g. clean energy (6 till 18 %) according to this analysis based on EPA data in the USA.

The minimum attractive rate of return, MARR, is the lowest rate of return that a company will consider acceptable for any investment. The calculated IRR should be higher than the MARR.

Weighted Average Costs

The Weighted Average Cost of Capital (WACC), see (3), commonly referred to as the firm's cost of capital, takes into account the weighted cost of different sources of capital: debt & equity. Typically for large energy intensive industrial companies the WACC varies between 6% and 10%, often it is 8%, whereby the costs of equity is always higher than the cost of debt.[1]

$$\text{3)}\ \boldsymbol{WACC = (\%equity * cost\ of\ equity + (100\% - \%\ equity) * costs\ of\ debt) * (100\% - \%tax)}$$

[1] In recent years, the WACC for companies is lower than in the past because federal banks, like ECB in Europe and FED in the USA, have decreased the interest rates (the cost of debt) through their monetary policy, for several years now. As a result, many companies have increased their percentage of debt (which is 100% - % of equity) in financing, and hence decreased their %-equity. As the costs of equity is always higher than the cost of debt, this decreases the WACC. So, the WACC has become lower due to lower interest rates and a higher percentage of debt. However, above a certain % of debt shareholders and bondholders and their analysts will get concerned that the company will not able to pay its debt and its credit-rating goes down leading to a higher costs of debt. Thus, the WACC goes down with the % of debt till a certain value and then rises steeply.

2.1.2.2 Total Cost of Ownership & Life Cycle Costing

Total Cost of Ownership (TCO) is a methodology that includes all direct and indirect costs of a product or system during the total lifecycle, rather than simply the purchase cost of equipment. It seeks to calculate the full cost – application engineering, acquisition, installation, commissioning, operation, maintenance, training, etc. – of the equipment, machinery and systems throughput the life of the project. It enables decision makers to look at asset procurement based on total cash to level the playing field when choosing among competitive technologies, beyond the lowest acquisition price. TCO will for example highlight that the maintenance costs will increase as equipment gets older.

Life Cycle Costing (LCC) is the technique to establish the total cost of ownership in which the costs are discounted to a base year using net present value analysis. As LCC does not address benefits and returns it can be used for ranking or selecting among mutually exclusive alternatives that provide exactly the same benefits and returns, for example for the evaluation of two different heat pumps with the same COP.

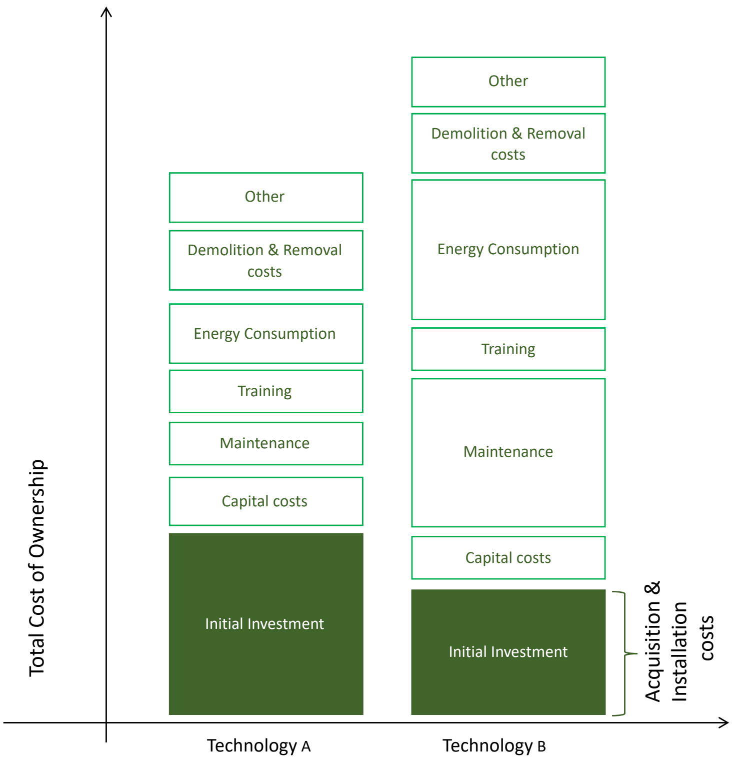

Figure 1: Total Cost of Ownership throughout the life cycle of a product for several investment options

Asset investments are often based on the short-term costs of design, purchasing, installation and construction. If such investment has been made without proper analysis of required maintenance and operational costs, the initial saving may result in increased expenditure throughout the asset's life. Often these longer-term costs can be a significant proportion of the whole-life cost. Some energy saving technologies may have a higher purchase price (not always, though) than the alternative technologies using more energy, but if we analyze the Total Cost of Ownership, including the energy and non-energy costs of the equipment the energy saving alternative in most cases prove to be the most cost effective over time.

2.1.2.3 Net Present Value

The net present value (NPV), see equation (4), relates to the total discounted cash flows generated by the project. In other words NPV relates to the shareholder return. It is a proxy for "the money" earned by the company if the project is carried out. A project with NPV greater than EUR 0 is a project that creates value for the company and is therefore considered to be viable. A project with a higher NPV as compared with another project with a lower NPV is measured to be more lucrative. In other words, the higher the NPV, the greater the calculated benefits of the project for the company.

$$4)\quad \mathbf{NPV} = \sum_{t=o}^{T} \frac{Cash\ Flow_t}{(1+i)^t}$$

with:

NPV:	Net Present Value;
i:	annual discount rate (%);
t:	time period;
T:	lifetime in years;
Cash $Flow_t$	cashflow in year t;

In order to evaluate Net Present Value of a project, the cash flows (savings minus investments) are evaluated for each year as per Appendix 2, and the sum of the discounted cashflows is calculated as per equation (4).

2.1.2.4 Internal Rate of Return

The Internal Rate of Return (IRR) of a project is the annual discount rate at which the NPV is zero, see equation (5) . Projects with an IRR equal to or greater than a predefined hurdle rate, often the discount rate, are considered viable. In simple terms the IRR describes the interest rate of a fixed rate savings account which – with the same amount invested – returns the same final financial outcome as the investment project. In other words, this is a proxy for the return that one makes on the money that one invests in the project.

Typically an IRR return of > WACC can be regarded as a good project, with a WACC typically between 6% and 10%

$$5)\quad \mathbf{NPV = 0} = \sum_{t=o}^{T} \frac{Cash\ Flow_t}{(1+x)^t} \Rightarrow x = IRR$$

2.1.3 Sensitivity Analysis

When investments have a longer time-horizon they are subject to uncertainty, particularly in relation to future prices, costs and benefits. For larger projects a sensitivity analysis should be used, whereby results are calculated for various scenarios.

2.1.4 Cost Benefit Analysis Method Selection

Energy Efficiency decisions can be based on different Cost Benefit Analysis Methods. Larger projects are typically evaluated with detailed NPV and IRR analysis. These evaluations require some investments in time as they include both energy and non-energy savings throughput the life of the equipment. Smaller energy efficiency projects idea's, typically generated from the plant, are ranked by the payback period.

The Payback period is effective for establishing the time period required to recover the initial investment. It is simple to calculate but does not consider a number of very important factors: saving continue for the life of the equipment or project life; an Euro today is worth more than a Euro tomorrow; and a safe Euro's worth more than a risky one.

It also does not take into account the relative size of the investment and saving potential. In other words, if we selected a small project with the lowest Payback Period or highest IRR we could pass up an opportunity to invest in a project that could decrease operating costs much more and improve the financial position of the company. The Net Present Value is therefore the preferred method for evaluating projects, even smaller projects. It takes into account non-constant cash flows, time value of money and project length. As such, it can for example highlight differences in maintenance costs increase as different equipment gets older. With NPV the risk of the project can also be taken into account by selecting an appropriate discount rate for the investment. In the example below, Figure 2, Cost Benefit Analysis is performed for 3 competing projects. Each method selected would result in another selected project. The smaller Project B would provide a lower Payback Period and higher Internal Rate of Return than project A, but if this project would be selected a (discounted) cash flow of € 1.140k would be missed! Project C, with a smaller time horizon than project A would provide the best Payback Period but a negative discounted cash flow!

Cost Benefit analysis of 3 competing projects

Discount rate: 8%
Investment duration: 15 years

	Project A	Project B	Project C
Net present value (NPV)	€1.327 k	€185 k	- €148 k
Internal rate of return (IRR)	22,7%	34,6 0%	16,6%
Payback Period	4,7 years	2,9 years	2,2 years
Year 0	-€ 1.000.000	-€ 100.000	-€ 1.000.000
Year 1	€ 20.000	€ 35.000	€ 450.000
Year 2	€ 50.000	€ 35.000	€ 450.000
Year 3	€ 350.000	€ 35.000	€ 450.000
Year 4	€ 350.000	€ 35.000	€ 0
Year 5	€ 350.000	€ 35.000	€ 0
Year 6	€ 350.000	€ 35.000	€ 0
Year 7	€ 350.000	€ 35.000	€ 0
Year 8	€ 350.000	€ 35.000	€ 0
Year 9	€ 350.000	€ 35.000	€ 0
Year 10	€ 350.000	€ 35.000	€ 0
Year 11	€ 350.000	€ 35.000	€ 0
Year 12	€ 350.000	€ 35.000	€ 0
Year 13	€ 350.000	€ 35.000	€ 0
Year 14	€ 350.000	€ 35.000	€ 0
Year 15	€ 350.000	€ 35.000	€ 0

Figure 2: Sample scenario of 3 competing projects with different cash flow patterns and time horizons.

The Payback period, if it includes non-energy benefits, does have merit because of its simplicity. But when used, the Payback cut-off hurdle should reflect the IRR cut-off hurdle! In Figure 2 above, solution 2 has a Payback period of 2,86 years with an IRR of 34,6%, which is much higher than the typical 10% IRR hurdle rate for capital investments. A project with constant savings over 15 years with Payback time of 5 years relates to an IRR of more than 15% (18,4 %), therefore Payback time cut-off hurdle should therefore not be less than 5 years from a shareholder perspective!

Project Evaluation	*Payback Period* 5 years	*Internal Rate of Return* > 15%	*Net Present Value*
Easy to Understand	√		
Built-in Excel function		√	√
Considers cash of entire project		√	√
Considers time value of money		√	√
Reflects cash of entire project			√
Different risk profiles			√
Mutually exclusive projects			√

Table 2: Decision table cost benefit analysis methods. The Net Present Value is the preferred method for evaluating mutually exclusive projects. Payback period, when including non-energy benefits, can be used to evaluate same sized projects with same time horizon and risks

2.1.5 Investments Cost Benefit Analysis versus Financial Performance of the Enterprise

The financial performance of a company is measured with different KPI's and the cashflow parameters EBIT, and EBITDA are crucial to measure financial performance of companies and their production plants in energy intensive industries. Profit, profit margin, price/earning ratio and market value are, on the other hand, strongly influenced by the tax regime, goodwill, write-offs and market expectations. Cashflow parameters like EBIT, EBITDA and operational margin are purely influenced by the production plant performance with feedstock prices, energy prices and product prices. They are therefore preferred parameters to judge project and plant performance as they are not influenced by subjective and external factors. Therefore the saying goes: "Cash flow is a fact, profit is an opinion"

EBIT: Earnings Before Interest & Tax (expressed in euro/year)
This is the yearly sales value of products sold minus the yearly purchasing value of feedstock and energy (+ additives, cooling water etc.) to make the products minus the costs for depreciation of stock value (feedstock and products) and depreciation of production equipment.

EBITDA: Earnings Before Interest Tax Depreciation and Amortisation (expressed in euro/year)
This is the yearly sales value of products sold minus the yearly purchasing value of feedstock and energy (+ additives, cooling water etc.) to make the products. One can determine the EBITDA for one specific production plant or for the company as a whole. It can be seen as a proxy for the net operational cash flow, thus cash flows not including capital related costs, tax and interests. It is a transparent way to evaluate the financial performance of production plants in a company.

Operational margin: margin in EBITDA in %
This is yearly sales value of products minus the yearly purchasing value of feedstock (+ energy etc.) divided by the yearly sales value of products. For a healthy company the operational margin should at least be 10 % in order to be able to pay for all the other capital related costs.

OPEX: operational expenditure
This is the yearly purchasing value of feedstock, energy and all other variable costs related to production.

2.2 EVALUATING ENERGY SAVINGS

In order to evaluate the cost benefits of energy efficiency investments, energy savings in relation to a reference situation have to be assessed over the life time of a project.

2.2.1 Base-lining and Energy KPI's

The reference situation is the situation, based on the current circumstances, which will arise in the future if the energy efficiency measure is not put in place. It allows the organization to compare energy performance before and after a change is made. It has to discriminate against changes in energy consumption caused by other measures or circumstances (e.g. weather, production, product changes etc.).

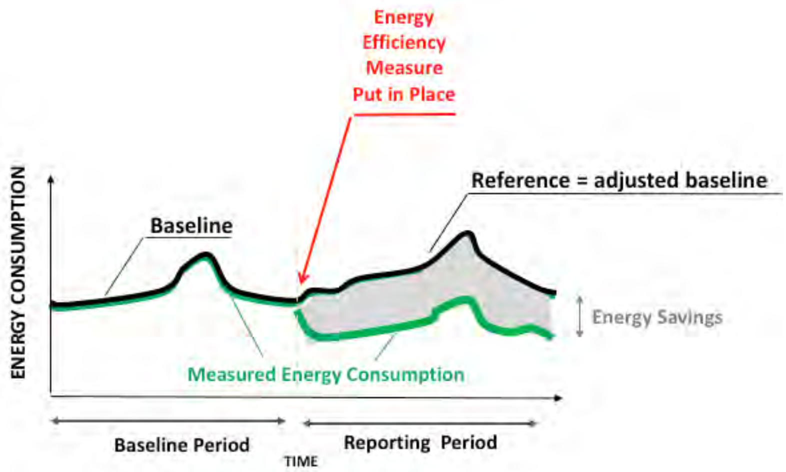

Figure 3: An energy baseline is a reference tool to compare energy performance before and after a change is made.

Without an accurate baseline, the effectiveness of an investment cannot precisely be monitored.
There are many approaches for establishing an energy baseline but they all follow the same five key concepts that govern an energy management system:

1. Identify the system boundaries
2. Identify the energy sources
3. Define the baseline period
4. Define the different variables affecting the baseline i.e. historical energy data, process data, weather data, context information, and put the analytics in place to define the baseline.
5. Set the energy performance indicators (EnPIs) in order to evaluate the impact of the investments on the operations.

Step 4 can be challenging, due to lack of readily available reliable and accurate data. Advanced sensors/submetering[2] technologies and advanced analytics are well suited for this purpose, and often make additional saving opportunities visible. These digital technologies, when further deployed, can provide additional energy savings in a number of different ways, e.g. through better optimization tools, increased availability of processes and more efficient maintenance management. The recommendation, though, is to take manageable steps, with the vision in mind, to assess what can be achieved in specific situations.

2.2.2 Energy Price

Once the reference situation is defined, energy savings have to be estimated and translated into cost savings. Several sources for energy prices can be used to evaluate project feasibility, including internal energy prices.

Energy prices can be very volatile. Therefore, for more accurate project cost benefit analysis the use of future energy prices[3] of the year in which projects become operational as listed on an exchange as e.g. ENDEX are recommended.

A description of the energy price components can be found in Appendix 2. The variable component of to the energy price is then as follows:

Price Electricity = ENDEX future call price electricity + Energy Tax

Price thermal biogenic energy = ENDEX future call energy + Energy Tax

Price thermal non-biogenic energy = ENDEX future call energy + Energy Tax

Equations 6: Energy Prices

with:

ENDEX future:	European Energy Derivatives Exchange;
Biogenic energy:	Energy from biomass and waste. One does not pay for the CO_2 emissions, the reasoning is that over time plants and trees absorb the necessary CO_2 from the atmosphere again;

An example of ENDEX Future prices for November 2020 and May 2021 can be found in Tables 3 and 4 below. As you can see, the base load electricity future for 2022 was 42,59 Euro/ton in November 2020, and 55,72 Euro/ton in May 2021, demonstrating the volatility of energy prices.

[2] Typical measurements/ monitoring could include: kW (kilowatt power input); kV (kilovolts—impressed voltage); I (amperes—electrical current); PF (power factor of induction electric equipment); Hz (frequency of alternating current); N (rpm or speed of rotating equipment); P (pressure of liquid/gaseous streams); DP (pressure drops in input/output liquid and gaseous streams); Lux (light intensity); GCV, NCV (gross and net calorific value of fuels); etc.

[3] Energy futures represent contracts to either buy or sell one of the fossil fuels or products related to them at a predetermined future date and price. Futures contracts are used by investors to reduce their exposure to price fluctuations of the underlying assets.

Periode (€/MWh)	Base	Peak
Cal-21	↑ 42,1919	↑ 47,2835
Cal-22	↑ 42,5809	↑ 48,8892
Cal-23	↑ 43,8396	↑ 51,3878
Cal-24	↑ 44,2849	↑ 55,0822

November 2020

Periode (€/MWh)	Base	Peak
Cal-22	↑ 55,7255	↑ 62,8318
Cal-23	↑ 53,7540	↑ 60,3028
Cal-24	↑ 51,0167	↑ 57,6902
Cal-25	↑ 51,0523	↓ 57,1336

May 2021

Table 3: ENDEX Future Call prices for Electricity (€ per MWh)

Periode (€/MWh)	Base	Verschil
Cal-21	13,8520	↑ 0,3357 (2,45 %)
Cal-22	14,4626	↑ 0,2137 (1,49 %)
Cal-23	14,5627	↑ 0,1146 (0,79 %)

November 2020

Periode (€/MWh)	Base	Verschil
Cal-22	18,4971	↑ 0,1167 (0,63 %)
Cal-23	17,1746	↑ 0,0291 (0,17 %)
Cal-24	16,1309	↓ -0,0694 (-0,43 %)

May 2021

Table 4: ENDEX Future Call prices for Gas (€ per MWh)

Note: There is another variable component related to the thermal non-biogenic energy fuel that is sometimes overlooked, which is the CO_2 price, see par. 2.3.2.

2.3 EVALUATING NON-ENERGY SAVINGS

Technologies to improve energy efficiency frequently also offer benefits beyond energy savings, such as increased production, less CO_2, NOx and SOx emissions and waste, increased uptime and maintenance cost reduction. Experience has shown that extending financial assessments to include less obvious benefits often helps significantly when evaluating the economic viability of the option. Research indicates that if non-energy benefits are included, the true value of the energy efficiency projects might be more than 2 times higher than if analyzing the energy efficiency improvements alone (Worrel et al. 2003; Lung et al. 2005; Bement and Skumatz 2007)

2.3.1 Categorization of Non-Energy benefits

The operational non-energy benefits can be categorized as follows:

Cost Savings	**Emissions**	**Maintenance Costs**	**Waste**
	- Reduced CO_2 costs	- Reduced wear and tear on equipment/machinery - Reductions in labor requirements - Reduced need for engineering controls	- Residual heat upgrade - Use of waste fuels - Materials reductions - Reduce product waste - Reduce hazardous waste
Risk Reductions	**Safety and Health**	**License to operate**	**Reduction of Liabilities**
	- Increased production safety - Increased workplace safety & health - Reduced accident risks and occupational disease	- Less waste and emissions	
Value Increase for Operations	**Availability Improvements**	**Product Quality Improvements**	**Throughput Improvements**
	- Reduction of planned stops i.e. reduced maintenance intervals and/or time to perform maintenance - Reduction of unplanned stops	- Improved product quality / less impurities - Rework/recycle reduction	- Increased output and yields

Table 5: Potential non-energy benefits from energy efficiency measures

Examples:

- Condition monitoring analytics tools will not only reduce energy costs, but also maintenance costs and will reduce the costs related to equipment downtime.
- The soft-start effect of a variable speed drive can not only reduce peak demand in power, but can also increase the life of both the motor and mechanical drive train by reducing electrical stresses and mechanical shocks. This extends the mean time between failure, so reduces operational interruptions, and as a consequent increases facility reliability.
- Any control which reduces idle running, hence power consumption, will also extend the life of equipment and reduce maintenance costs.
- Advanced control will bring the process variation within a smaller range around the optimum setpoint. This will not only reduce energy consumption, but also improve yields and product quality.
- Magnetic couplings avoid friction and vibrations; leading to lower wear and power consumption, but also leading to lower maintenance cost and increased production reliability.

2.3.2 Carbon Pricing

In this section, we will pay special attention to one specific non-energy benefit, sometimes overlooked, and tightly related to energy usage, i.e. carbon pricing. Carbon pricing is a policy instrument that helps shift the burden of the damage to those who can influence it. This is usually in the form of a price on scope[4] 1 greenhouse gas (GHG) emissions, i.e. a price expressed as a value per ton of carbon dioxide equivalent (tCO_2e). The CO2e unit takes next to CO_2, all other GHGs into account (like methane and nitrous oxide) by putting them in terms of carbon dioxide.

There are two main types of carbon pricing: through emission trading systems (ETS) and through government carbon taxes:

$$\mathbf{CO_2\ price = CO2\ ETS\ price\ + CO_2\ Tax} \qquad (7)$$

A carbon tax directly sets a price on carbon by setting a tax rate on either GHG emissions or on the carbon content of fossil fuels. It guarantees the carbon price in an economic system but gives an uncertain environmental outcome. CO_2 tax is a national policy measure and varies by country.

An Emissions Trading System (ETS) is a system in which emitters are allocated allowances. To meet that target they can either take internal reduction measures or acquire emission allowances from the carbon market, depending on the relative costs of these options. By creating supply and demand of emission units, an ETS sets a market price for GHG emissions. It defers from the carbon tax by providing certainty about the environmental impact, but the price remains flexible. The EU-ETS is the trading system used in Europe. As an example, below, in Table 6, you can see that the CO_2 future for 2022 in November 2020 was 28 Euro/ton. Only 6 months later, in May 2021 it was 45 Euro/ton CO_2.

[4] The Greenhouse Gas Protocol (GHG Protocol) is one of the most widely used emissions reporting standards. It requires companies to break down their emissions into three categories, or scopes. Scope 1 emissions are greenhouse gas (GHG) emissions caused by own sources within the organization, i.e. production related activities. This is in contrast to the indirect scope 2 (purchased electricity or heat) or scope 3 (caused by the business activities of customers) emissions.

Periode (€ per ton CO²)	Base	Verschil
Cal-21	28,2523	↑ 0,0367 (0,13 %)
Cal-22	28,4980	↑ 0,0500 (0,18 %)

November 2020

Periode (€ per ton CO²)	Base	Verschil
Cal-22	44,6659	↑ 0,2649 (0,59 %)
Cal-23	0,0000	⇄ 0,0000 (0,00 %)

May 2021

Table 6: ENDEX Future Call prices for CO_2 (€ per ton CO_2)

Businesses can use internal carbon pricing to evaluate the impact of mandatory carbon prices on their operations. For project feasibility evaluations, the use the future CO_2 prices as listed on an exchange are recommended. The following equation would then apply for non-biogenic energy:

$$\textbf{CO}_2\textbf{ price thermal non-biogenic energy = ENDEX future ETS + CO}_2\textbf{ Tax} \qquad (8)$$

2.3.3 Evaluating non-energy benefits

Ernst Worrell (2003) laid out a number the steps involved in evaluating non-energy benefits[10]. This approach begins by asking broadly: aside from energy conservation, what impacts does this technology have on the production process? These impacts then need to be translated into economic terms wherever possible. This framework is useful for making the cost calculations and it makes the evaluation process transparent for the analyst and other stakeholders.

1. *Identify and describe the Non-Energy Benefits associated with a given measure*. This involves listing all the significant impacts of a measure aside from energy savings. These benefits will fall into the general categories listed above but should be described as specifically as possible.
2. *Quantify these impacts as much as possible.* The benefits identified above should be quantified in the most direct terms possible, and all assumptions to get to these quantifications should be listed. Some benefits may be deemed 'non-quantifiable'. For example, adopting a technology may enhance a firm's reputation as an innovator and leader, but this is too intangible to quantify.
3. *Identify all the assumptions needed to translate the benefits into cost impacts;*
4. *Calculate the savings impact of Non-Energy Benefits.*

The benefits as calculated above can now be incorporated into the cost benefits analysis.

2.3.4 Example: Electrification of a compressor system at ENI

Electrification of a compressor system at ENI S.p.A.

An energy audit of an upstream gas plant in Fano, Italy was conducted in 2019. The audit highlighted the opportunity to electrify the compressor driver instead of using the gas turbine. Electrification of the compression system would shift the main energy consumption of the plant from natural gas to electrical energy.

Replacing natural gas turbines in the compressor unit with electric motors would save 14500 Ton of Oil Equivalent/year ~ 350k Ton CO_2 emissions/year ~ 69%

Financial Analysis

Discount rate: 6,4%
Investment duration (NPV, IRR): 20 years
Non-energy benefits include:

- Reduced down-time of equipment
- Reduced maintenance costs
- Simplified HSE procedures
- Reduced cost of CO_2 taxes

	Energy - only benefits	All benefits
Net present value (NPV)	9 000 k€	23 000 k€
Internal rate of return (IRR)	6%	15%
Payback Period	11 years	6 years

Table 7: Financial Analysis of an Energy Efficiency Project, from Library of Multiple benefits

Note, that at the time the project was implemented EU-ETS prices of CO_2 were around 24 euro/ton). The EU-ETS prices in mid 2021 are around 50 euro/ton. The returns in 2021 would therefore be much higher than was calculated at the time of investment.

2.3.5 Split incentives and accountability as a consequence of evaluating all investment savings

When evaluating all the cost savings - energy and non-energy savings - that can be obtained by the implementation of an energy saving technology, one has to realize that these savings will accrue in different departments where they might not always be visible. As a consequence, unless departments/plants pay for their own energy costs, department/plant managers might have little incentive to invest in energy efficiency technologies because the benefits in terms of energy cost savings accrue elsewhere. Furthermore, they might be concerned that they might be made accountable for the full savings of the project in their department. For example, a maintenance manager who wants to invest in a technology that reduces maintenance costs, could be concerned that his yearly budget following the investment could be reduced by the total expected savings: expected savings in its department PLUS energy savings PLUS other non-energy savings.

Similarly, the person responsible for purchasing equipment may have a strong incentive to minimize capital costs, but may not be accountable for operating costs (including energy costs). To conclude, incentives and accountabilities have to reflect energy efficiency company drivers, a topic which will be addressed in Chapter 4.

2.4 RECOMMENDATIONS FINANCIAL APPRAISAL METHODS

The steps to determine the economic viability of Energy Projects can be found in Appendix 4. Our recommendations for conducting cost benefit analysis on energy efficiency investments are as follows.

1. Use Net Present Value as the preferred methods for evaluating projects, even smaller projects. It provides the most accurate project evaluation as, it takes into account real cash flows, time value of money and project length. It enables to compare operational and non-operational investments in the same manner.

2. Consider applying risk-adjusted discount rates for different asset classes to prioritize low risk projects within a project portfolio. See also Chapter 3.1 for further discussions on project risks. As most energy efficiency projects relate to low-risk investments a company WACC (typically between 6% and 10%) can be used as discount rate for these projects.

3. If Payback Period is used, also evaluate non-energy benefits, and use a period of 5 years to be in line with IRR hurdle rates. Payback period calculations are most accurate when comparing same-sized projects with constant savings over time.

4. When evaluation multiple benefits, energy and none-energy benefits, make sure that the right accountability and incentives are put in place, i.e. departments are made accountable for the savings they will get in their departments but get incentives on reducing overall savings.

5. Rather than using internal energy prices and CO_2 prices, the use of future energy prices and CO_2 prices of the year in which projects become operational as listed on an exchange are recommended.

3. METHODOLOGY FOR PROJECT INVESTMENT PLANNING

Investment planning is not an easy task. Large industrial sites usually have a large portfolio of potential projects. Some are still in the idea phase, others have matured into a basic design and business case. In most cases, the feasibility analyses will indicate that different options have different levels of technical feasibility, economic viability, and environmental performance. This chapter will cover prioritization of energy efficiency projects within an energy efficiency portfolio (par. 3.1), after which methods are introduced that lead to strategic prioritization of energy efficiency projects within a larger project portfolio (par. 3.2). Finally, we will also look at interaction with other plants in an industrial cluster (par. 3.3).

3.1 ENERGY EFFICIENCY PROJECTS PRIORITIZATION

Among the project portfolio, an organization may have several good energy efficiency improvement projects, often originated in the plant at operational or maintenance level. These bottom-up projects are prioritized based on costs benefit analysis, project effort, risks and timing. Prioritization is required to fit the activities within the local constraints of capital and staff. In Table *8* below, an Energy Efficiency Investment evaluation table is presented where a number of investment attributes are listed with increased priority from left to right.

Characteristics	Investment Attributes: priority increase from left to right
Cost Benefit Analysis	
Net Present Value	>0, >>0, >>>0
Internal rate of return	Low (<7%), medium (7-15%), high (>15%)
Payback Period	Long (>8 years), medium (5-8 years), short (2-5 years), very short (<2 yr)
Initial Investment	High, medium, low
Non-energy benefits	Negative, none, small, large
Effort & Timing of Implementation	
Project development time	Many years, a year, few months, few weeks
Timing of Implementation	During shutdown, in alignment with other projects, immediately or anytime
Risks related to Technology Implementation	
Type of Modifications	Technology Substitution, technology replacement, technology add-on, organizational measure
Knowledge for planning and implementation	Technology expert, engineering personnel, maintenance personnel
TRL	High (7) to very high (9)
Risks related to the Process Changes	
Distance to core process	Close (core process), distant (ancillary process)
Scope of impact	System (system-wide effects), component (local effects)
Sectoral applicability	Process related, cross-cutting
Other key operational issues being adressed?	
KPI's	Cost savings, Product & capacity improvements, Necessary replacements & reliability, Availability, License to operate, Safety

Table 8: Energy Efficiency Investment Evaluation Table, adapted from Fleiter et al (2012)

After having ranked energy efficiency proposals, projects with high returns, low risks, and easy implementation can still be missed or ignored, even when non-energy benefits are included in the cost benefit analysis. This is often due to CAPEX ceiling constraints made in budgets and operational priorities.

Energy efficiency projects often address other key operational issues, though, and could drive competitive advantage and innovation beyond reducing energy and operational costs. This information has to be visible before project prioritization and funding. So, the next step is highlighting the other operational drivers an energy efficiency project is addressing, as described in the last section of Table 8. Table 9 lists typical operational priorities on a plant. Cost saving, as achieved through energy efficiency projects, is often at the bottom of the priority list. Other drivers often have a higher priority.

1. Safety	
2. License to operate	?
3. Availability	
4. Necessary replacements / reliability	
5. Product / capacity improvements	
6. Cost savings ←	Cost benefit analysis

Table 9: Typical Operational priorities

Example: Impact of condition monitoring analytics on other operational drivers

Condition monitoring analytics reduces costs by optimizing power usage on rotating equipment, reducing maintenance costs and reducing costs of downtime. Degrading equipment consumes more power, and condition based maintenance is more cost effective. The cost benefit analysis would include these energy and non-energy savings. Increased reliability can be achieved via conditioned based maintenance to reduce the number of failures with roughly 90 %[19]. Condition based maintenance might also increase plant availability and safety. It can optimize the time between scheduled inspections, and minimize unplanned outages of rotating equipment. Note, that typically 5% - 15%[19] of rotating assets fail each year. Often critical process equipment is made redundant.

1. Safety	
2. License to operate	
3. Availability	
4. Necessary replacements / reliability	← **90% of upcoming failures detected**
5. Product / capacity improvements	
6. Cost savings	← Power Savings, Maintenance Savings, Savings of downtime

Other energy efficiency related investment attributes could be added in the evaluation. As an example, something that is increasingly important to end customers is the value of product with a lower carbon footprint. And in that context obtaining "good scores" on CO_2 or EE performance certifications, like for instance CDP[5] can also be of value.

[5] The **CDP** (formerly the **Carbon Disclosure Project**) is an international non-profit organization that helps companies and cities disclose their environmental impact. It aims to make environmental reporting and risk management a business norm.

In other words, a higher uptake of energy efficiency opportunities is possible when identifying and quantifying on top of cost savings a broader range of impacts and aligning these to the more strategic objectives of a company. Cooremans (2011, 2012)[5] calls this the multiple benefits analysis, i.e. analysis of all the benefits of a technology beyond reducing energy costs.

3.2 STRATEGIC PROJECT PRIORITIZATION

Most energy efficiency projects tend to originate at the plant level and are bottom-up investments. The plant capital budget available for these bottom-up investments is small compared to the investment needs of all projects that meet the financial criteria. Besides the Capex ceiling, there is often also a lack of staff, capacity and expertise in the plant to implement all the project opportunities. The often-small energy efficiency projects also have to compete with attention and manpower for urgent operational issues. Joachim Schleich[5] has made an extensive overview for UNIDO of the different barriers that hamper Energy Efficiency project implementation.

At the same time, many companies have sustainability targets at corporate level to reduce CO_2 emissions (sometimes both scope 1, scope 2 and scope 3). To reach these corporate goals companies are investing in large, flagship projects, such as CCS, blue/green hydrogen, electrical boilers for electrified processes or even new production plants etc. Often these high-profile projects get high senior management attention at corporate level and are therefore able to attract more resources and capital as they are added to the capital project list and pass the NPV and IRR analysis. This is logical as there is a large repeat potential for the many production plants around the world in a global corporation. While these projects are necessary to help achieve climate goals, they may not be in the best financial interest for the shareholder in comparison to the large number of smaller, less risky, energy efficiency investments.

In comparison, the decision process at plant level is much more capital constrained than at corporate level. March concluded that energy efficiency projects have on average a much lower risk profile and much higher return on capital while their capital allocation is 7 times lower than corporate investments with lower return on capital and higher risk profile.[1] The difference in capital allocation is also influenced by the fact that corporate KPI's are different than operational KPI's at plant level. Corporate KPI's may involve financial targets such as EBITDA, operational margin, return on investment and commercial targets such as market share.

In this chapter a project prioritization approach will be explained that aims to align the corporate targets and plant targets in to one approach for selecting project investments to get the best results for the corporation in terms of shareholder value and energy efficiency / CO_2 reduction. This approach is using the financial cashflow (NPV) analysis as previously described. It leads to a more strategic positioning of the current bottom-up energy efficiency project approach. Therefore, it is called the strategic project prioritization.

In this section, the following strategic project evaluation considerations will be discussed and illustrated by various examples:

1. Balancing production, financial and corporate KPI's.
2. Evaluating energy efficiency projects in the context of a large “must do” project.
3. Dealing with planned replacement projects.
4. Replication and bundling of many small projects into one large project.
5. Global roll-out of successful technologies over many industrial sites.
6. Energy efficiency projects on power consuming equipment to create space for expansion or electrification via the power network.

We call this the 6-factor method.

Strategic project prioritization requires an evaluation of the total project portfolio that not only includes the energy efficiency projects but also projects to increase capacity, improve maintenance, as well as compliance projects, etc. The degree of correlation amongst these projects should be determined with alignment to strategic drivers, to give a planning of the project portfolio as final result. This will increase the effectiveness of energy efficiency implementation together with all other projects, and at the same time reduce time, risks and costs. This approach requires the budgets for all the categories listed above to be added up for the total investment planning, and part of the savings achieved by implementing energy efficiency projects to be used to fund upcoming projects.

3.2.1 Balancing production, financial and corporate KPI’s

When aligning energy efficiency projects to company drivers, a distinction has to be made between production, financial and corporate performance. Production performance is typically related to HSE/compliance, availability, production capacity, energy efficiency, maintenance costs, etc. These categories are often evaluated separately and often have different budgets, KPI’s and financial criteria. Financial performance is measured with different KPI's, for example the EBITDA[6].

In many companies the added value of higher availability[7] is of overriding importance. Availability is strongly related to the plant shutdowns, and therefore has a direct impact on the net cashflows out of production. In figure 4, below, a fictive example of the EBITDA financial reporting is shown, including the impact of the plant shutdowns.

[6] EBITDA: Earnings Before Interest, Taxes, Depreciation, and Amortization.
[7] Availability is defined as the number of operating hours per year or as a percentage of production hours versus total hours.

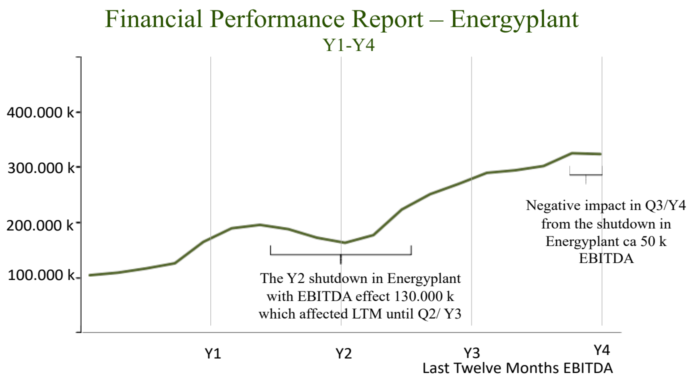

Figure 4: Fictive example of EBITDA financial reporting and the impact of plant shutdowns.

Some larger energy efficiency (EE) projects need to be implemented during a planned shutdown which might then take longer, and which as a consequence decreases plant availability, hence decreases the net cashflows out of production. As availability is considered of overriding importance, this could be a reason NOT to implement the large project. However, the on-going extra cashflow generated from implementing innovation projects often outweighs the negative one-off impact of the longer shutdown in the first year. This is especially the case with EE projects, as energy costs are a high percentage of the OPEX costs, and therefore have a high impact on OPEX. On top of that, most new energy efficiency technologies have a higher reliability than installed technologies, which as a consequence reduces unplanned outages and increases the availability of a plant. A day without production due to an unplanned showdown is much worse than a day without production due a planned maintenance shutdown. That is why reliability is so important.

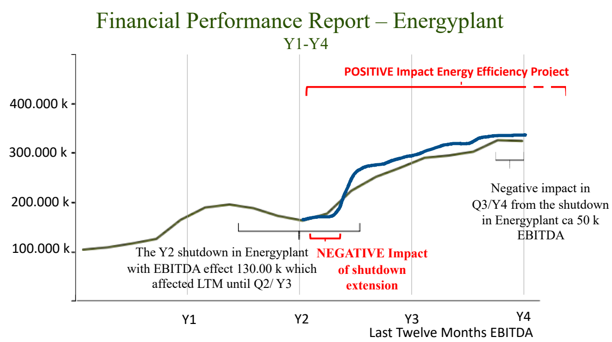

Figure 5: An energy efficiency investment can put a one-off little dent in the margins when maintenance shutdowns have to be prolonged, but generates on-going incremental margins.

Example: Installation of a fictive Energy Efficiency Project which requires a longer shutdown and increases the operational margins

Energy Efficiency Project Assumptions

Product prices per ton of product: 100 units per ton.
Yearly CAPEX & labor small compared to OPEX costs, so OPEX costs ~ production costs
OPEX before implementation of EE project: 90 units per ton
Energy Cost before implementation of EE measure: 36 units per ton
Energy Savings with EE project: 2,8%
Availability before implementation of EE project: 92 %
Installation time needed to install EE equipment on top of the planned shutdown: 4 days
Impact of planned shutdown are not included in the calculations, to simplify the exercise

Analysis

	No measures taken		**Year 1 prolonged shutdown**		**Subsequent years**	
	units / ton product		units / ton product		units / ton product	
Product Price	100		100		100	
Operational Margins	10	10%	10,87	10,87%	11	11%
Margins Increase				8,7%		10%
OPEX cost	90		89,02		89	
Energy cost	36	40%	35	39,3%	35	39,3%
Energy savings			1	2,8%	1	2,8%
Production days		336		332		336
Availability		92%		91%		92%

The Energy Efficiency Project would decrease plant availability by 1 % in Year 1, but operational margins, hence the EBITDA, would increase by 8,7%. Recurrent EBITDA increase of 10% would be achieved in the following years.

Graphical Representation of the operational margins increase

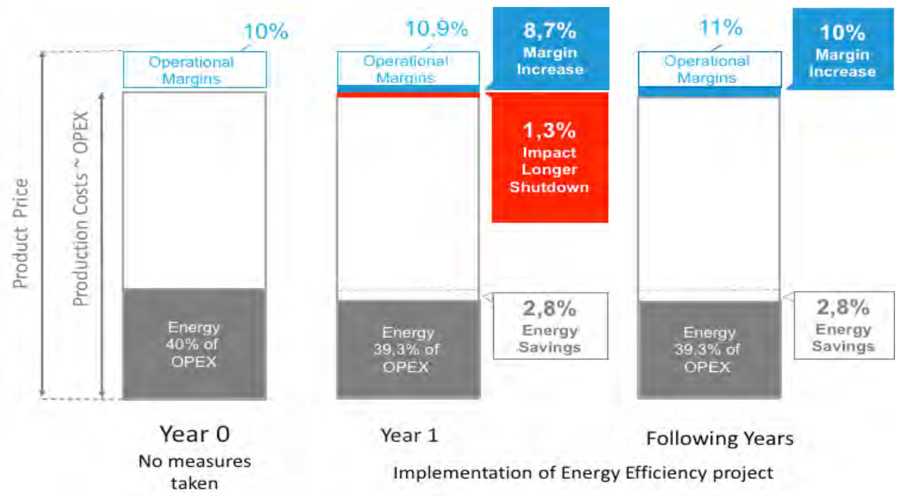

Figure 6: Example that demonstrates the increase in operational margins of a large energy efficiency project, in spite of a temporary reduction in availability.

In above example, the impact of the reduced availability is financially insignificant compared to the ongoing 10% higher operational margin and thus 10% higher EBITDA. In addition, projects that increases the reliability of the process equipment and the production process in general will reduce the unplanned shutdowns and thereby increase the availability. This highlights the quantitative relationship between energy efficiency and availability and the EBITDA. As a conclusion, it makes sense to evaluate the impact, and thus the priority of energy efficiency projects in relationship to all the KPI's, with a balanced view to these KPI's.

3.2.2 Evaluating energy efficiency projects in the context of a large "must do" project

Often a large high priority project requires a lot of attention and resources. This may be an approved project for capacity increase or a compliance project. Such project can act as an "anchor" for smaller projects. It may be worthwhile to link the energy efficiency project portfolio to this high priority project to evaluate whether these include alternatives.

In the following fictive example, figure 7, the "must do" project is a compliance project to reduce NOx emissions that arise from flue gases from an old gas fired boiler. At first instance it seems logical to replace the old boiler by a novel boiler that meets the NOx emissions requirements or to install a NOx removal unit on the current boiler. The latter is likely the lowest CAPEX solution but does not generate OPEX savings, as it doesn't increase efficiency, which can be seen on the investment evaluation table below. In the energy efficiency project portfolio we find three alternatives. For each alternative the combination of the various synergies allows a positive investment decision, that would not incur if projects would be analyzed in isolation.

Example: Evaluating energy efficiency projects in the context of a large "must do" project

MUST DO PROJECT: NOx REDUCTION		Existing Equipment	Option 1	Option 2
	Equipment	Boiler	Novel Boiler	NOx Removal Unit
Function	Main Function	Water Heating	✓	From existing boiler
Function	Investment Objective	NOx Removal	✓	✓
Cost Benefit Analysis	Energy Efficiency	Low	Medium	No
Cost Benefit Analysis	Initial Investment		High	Low
Cost Benefit Analysis	NPV		Medium	<0
Risks	Technology investment risks		Medium *Replacement*	Low *Add-on*
Risks	Process change risks		Medium *Core*	Low *Ancillary*
Other KPI's	License to Operate		✓	✓
Other KPI's	Necessary replacement /reliability		✓	
Other KPI's	Capacity Improvement		✓	

NON-EXCLUSIVE ALTERNATIVES FROM PORTFOLIO EFFICIENCY PROJECTS				
	Equipment	Heat Pump	Flue Gas Heat Exchanger	Advanced Sensing & Control
Function	Main Function	Residual Heat Upgrade	Flue Gas Heat Recovery	Combustion Optimisation
Function	Investment Objective	✓	✓	✓
Cost Benefit Analysis	Energy Efficiency	Very High	High	High
Cost Benefit Analysis	Initial Investment	Medium	Low	Medium
Cost Benefit Analysis	NPV	>>0	>>0	>>0
Risks	Technology investment risks	High *Substitution*	Low *Add-on*	Medium *Add-on but needs shutdown*
Risks	Process change risks	High *Scope of Impact*	Low *Ancillary*	Medium *Scope of Impact*
Other KPI's	License to Operate	✓	✓	✓
Other KPI's	Necessary replacement /reliability	✓		✓
Other KPI's	Capacity Improvement	?		✓

ENERGY EFFICIENT ALTERNATIVE SELECTED AS AN ADD-ON TO AN ACHOR PROJECT

The following energy efficiency alternatives to the "must do" can now be evaluated :

- Flue Gas Heat Recovery: A low temperature heat recovery unit that allows condensation of water vapor out of the flue gases. This will also reduce NOx as it will dissolve in the condensed water. Subsequently, the condensed water needs to be treated. Standalone, the heat recovery unit may not suffice the pay-back criterium of less than 5 years but with the integrated view of the purpose of NOx reduction it will be financially a much better solution than a NOx removal unit that has no positive cashflow.
- Large Heat Pump: A unit that transforms residual low temperature heat to the required power and higher temperature level for the old boiler to be replaced. In a standalone calculation the heat pump may turn out to have a pay-back of let's say 7 years and would therefore not pass through the selection process**.** In the new approach the pay-back period of the heat pump is much smaller because the CAPEX requirement for the new boiler or NOx removal unit is no longer needed. In addition, there is also a reduction in OPEX because CO_2 emissions and fuel costs from the old boiler are eliminated. On top of this re-using residual heat might eliminate the production loss during very warm days in summer when dumping waste heat water in rivers is more restricted.
- Automated combustion optimization through advanced control & sensing to find the optimum fuel to air ratio for maximum heat-rate and minimized NOx, CO and CO_2 emissions. It also enables flexible use of different fuels, load variance to enable renewables to operate on the grid, etc.. With older less reliable O_2 sensor technologies a dedicated person has to micromanage the combustion processes.

Figure 7: Fictive example and analysis. Energy efficiency risks & payback periods can be reduced when combined with "Must Do" projects. This can lead to a positive investment decision that would not incur if projects would be analyzed in isolation.

3.2. Replication and bundling of many small projects

Many energy efficiency projects are small in CAPEX and although they may have a good return it may be hard to get management attention let alone approval. Examples of these projects are thermal insulation of hot equipment (pipelines, tanks and valves) and upgrading motors, drives and/or motor coupling. The same is true for industry 4.0 solutions (instrumentation, advanced process control, asset management). Achieving superior results requires a thorough analysis which is time consuming and costly, making small projects uneconomic from the viewpoint of staff availability.

In the new portfolio investment appraisal and planning such a project should then be defined as the integrated sum of all the hundreds of smaller projects to allow a fair comparison with the other larger projects in terms of priority, CAPEX and cashflow. By doing so, the CAPEX will add up to a large amount with good return which enables to get management attention. Upon implementation of a large number of bundled projects two types of synergies emerge that further increases the return on projects while decreasing risks and creates option value as well.

For example, energy efficiency improvement by upgrading selected motors and drives is small CAPEX but good return on CAPEX. Thus, when hundreds of large motors and drives are analyzed in several plants with knowledge sharing during the same period more economy of scale is realized with also more learning during the process. As a consequence, each subsequent small project will be implemented faster and better due to the learning process. The same effect takes place for thermal insulation and industry 4.0 solutions (instrumentation, asset management, advanced process control).

Besides the learning effect leading to more economy of scale and lower risk there is an additional benefit of bundling. New equipment (e.g. motors, drives, industry 4.0 solutions) is better instrumented and yields more data from sensors. Data analysis from these sensors creates more process insights and thereby better performance in terms of lower variability, less energy and less required maintenance. The maximum benefit is achieved when not only single equipment is instrumented but the whole production process leading to a better process model and improved process control which is the basis for further innovations.

Therefore, for several technology categories there is an accelerating effect; as a spin-off from energy efficiency one gains more opportunities by better process understanding. That is how innovation works in practice. Thus, besides economy of scale there is also an option value attached to these projects.

We recommend to carefully analyze all technical solutions and opportunities in an integrated manner and to implement them on large scale to maximize the return and the learning that goes with it.

3.2.5 Large scale technology implementation

The risk perception of technology implementation that has not been done before in a specific plant is high. The technology may already exist for more than a decade and be implemented in many different plants in industry. If it is new for the sector or specific plant than the risk perception is high and consequently the chance on implementation low unless superior returns are expected.

How do we deal with this aspect in strategic investment planning? Let us assume that the industrial company has 100 production sites globally where the specific energy efficiency technology could be applied. The technology requires an investment of 20 million euro and yields a pay-back period of 4 years for each project. If the technology turns out to be successful as it is in other sectors and plants, it will be deployed globally within the company. The cumulative investment over time is than 100 times 20 million euro; thus 2 billion euro. The global additional cashflow over time is than 500 million euro annually. Now, if the first implementation fails and the equipment and installation cost will not be refunded, there will be a loss of 20 million euro (excluding possible missed production). That is only 4 % of the extra global annual cashflow out of this technology if it successfully implemented. This example shows that a failed project might be a nightmare for the local plant manager but that this risk is actually rather insignificant on a global scale compared to the value it generates. Take into account that upon each new implementation the risk becomes smaller due to the experience gained by the learning effect.

Therefore, it is highly recommended to analyze the risks of energy efficiency projects with novel technologies from a global company perspective and not from a local site perspective.

3.2.6 Improved utilization of energy grid connections

Energy efficiency projects can reduce capacity needs of an energy grid connection, and therefore reduce expansion costs of another project. It can also help avoid investment delays due to connection capacity expansion waiting times. Current waiting times for increased capacity network connections can reach up to several years. This investment timing effect should therefore also be included in the payback evaluation
For example, an energy efficiency project that reduces the power demand creates more space on the local power grid. This could facilitate the installation of MVR or high power heat pumps, for instance, without the need for extra investments in transformer stations or novel high capacity connections.

3.2.6.1 Reduce power consumption

The example below illustrates the possible impact of a power reduction measure on future thermal energy efficiency investments. In general, power reduction measures, although they don't reduce direct scope 1 emissions, they do facilitate further power-to-heat projects which do reduce direct emissions.

Example expansion cost reduction through the implementation of a power reduction project:

Motor system efficiency improvement enables heat pump installation

A small fictive project demonstrates how one energy efficiency project can enable another project. Process plant is considering replacing their old motor systems with state of the art motor systems to reduce maintenance cost, reduce unexpected downtime and increase motor systems efficiency. Advanced asset monitoring tools will be used for motor systems sizing.
The plant also needs to install a new hot water boiler. Instead of a boiler, a heat pump is also being considered, given the available residual heat on the site. However, the payback time of heat pump would be higher than the pay-back of 5 years. The problem is not only the higher investment cost of the heat pump, but also the very high power connection expansion costs.

The Payback time of the heat pump would be 171 years because of the very high power connection expansion costs, but only 2,7 years if spare connection capacity is created on the power network project because of a motor system upgrade.

Assumptions

- Motors:
  - The existing power network connection capacity for the plant is in the 1750 kVA - 3000 kVA range.
  - The power consumption of the plants' motor system is 2,5 MWe
  - The expected reduction in power demand is 10 % to give a power saving of 0,25 MWe.
- Heat Pumps:
  - COP = 4
  - Input of 0,25 MWe to provide a 1MWth heat savings
  - The heat pump is used 8000 hours per year.
  - Annual operational costs, maintenance and operation, 3% of the investment
  - Life span of the heat pump: 15 years, no residual value is adopted.
  - The costs for electricity and gas in this example are respectively 0,10 €/kWh and 0,24 €/Nm3
- The company is not subject to ETS & CO_2 tax benefits for the avoided CO_2 is not considered in this case

NPV calculations

	Water boiler	Heatpump Capacity extension	Heatpump No capacity extension needed
Initial Investment sums - equipment & installation - one-time additional power network costs	€100.000	€200.000 €6.262.000, *see appendix 2*	€200.000
OPEX Costs - Maintenance costs - Energy Costs	€3.000/yr €240.000/yr gas	€6.000/yr €200.000/yr	€6.000/yr €200.000/yr Electra
Payback Period *on incremental investments*		171 Years	2,7 Years

Table 10: Example expansion cost reduction through the implementation of a power reduction project

3.2.6.2 Improve power quality.

There are also other ways to improve power grid connection utilization, next to power consumption reduction, and that is to increase the power quality. The power quality is the grid's ability to supply a clean and stable power supply

High power quality ideally creates a perfect power supply that is always available, has a pure noise-free, sinusoidal wave shape, and is always within voltage and frequency tolerances. With increasing and varying energy demands from various industrial processes, many loads regularly impose disturbances on the grid, making deviations from ideal conditions a frequent occurrence. This is known as poor power quality. Due to lower power quality, the industrial user (and all other power users on the grid) consume more power than needed when the power factor would be 1 when in addition there also more network distribution losses. Increasing the power factor is therefore a major contributor to lower energy use, lower costs and lower CO_2 emissions.

The power connection infrastructure has to accommodate for this, which might lead to increased costs. This can also lead to equipment underperformance and energy losses. See Appendix 4: Power Quality.

3.3 INTERACTION WITH OTHER PLANTS IN AN INDUSTRIAL CLUSTER

Most industrial sites need both thermal energy and electrical energy. Thermal energy is usually based on steam derived from either a boiler or a CHP fueled by natural gas. Dutch industrial clusters are characterized by their high integration and synergy. For instance, a powerplant converts/co-fires a waste hydrocarbon stream from a chemical plant into steam that is delivered to that same chemical plant. Sometimes steam is supplied by a separate company for several industrial plants e.g. USG for the Chemelot complex and Getec for the Emmtec premises in the Netherlands. Depending on the temperature needs for the different installations there can be 3 networks; for high pressure (HP) steam, medium pressure (MP) steam and low pressure (LP) steam. Exothermic production processes might also supply heat to the steam network. In principle optimization of all the processes for an integrated industrial complex can use the same methodology as previously described for a single plant. In this chapter the focus is the comparison of the different energy networks and the impact of the various energy efficiency projects.

Bundling several users for one central steam supplier generates economy of scale but also a mutual dependency and might limit the introduction of technologies that strongly reduce heat demand as a certain baseload of steam is required to operate a stable heat supply system. An example is process gases with a high caloric content that are also burned although they may contain valuable components that have a higher value than the caloric value e.g. hydrogen. In a few sites also biomass or waste fueled boilers are used.

Heat pumps and MVR (Mechanical Vapour recompression) solutions reduce the total steam demand as they can convert residual heat or LP steam (often in excess available) to MP steam or even HP steam. They consume power to achieve this. For an average COP of 4, the extra power demand is only 25 % of the reduced thermal energy demand. For chemical heat-pumps the COP is much higher as is the temperature lift. How to choose and evaluate expansion or reduction in power or steam demand and their resulting networks in energy efficiency projects?

The following considerations can be used for the analysis:

1. The gas and power grid operator is a regulated business by law and responsible for the grid network stability. These grid companies operate a network with a very large group of suppliers and customers and they have many tools to adapt to major changes of demand and supply. The utility operator that supplies steam is not a regulated busi ness and will require long term contracts to safeguard their business. Also the number of suppliers and customers is much smaller. This implies more operational flexibility for the industrial customer when using gas or power although the exergy utilization with steam and its different pressure/temperature levels is higher.
2. The energy loss of transporting power and gas over a certain distance is much lower than for transporting steam (especially for LP steam). The opportunities of applying heat pumps and MVR between different process units, that might be integrated in steam supply and demand, are thus strongly dependent on distance and the available space for installation. Check distance, steam pressure and energy loss versus the alternatives.
3. Check on future planned abandonment/ replacement of boilers, CHP's and other energy production units and large energy users (distillation columns, cryogenic separation) that might change the energy architecture. An example are the installations that will be switched off from low caloric Groningen gas ultimately 2022 that had to evaluate the costs of the capacity connections for high caloric gas versus alternatives. Getting high(er) capacity network connections from grid operators might, depending on the locations take several years which will delay project implementation. Check your location on timing of new connections and/or transformer stations.
4. Check on potential electrification of the production process via MVR or heat pumps via analysis of the thermal energy and power requirements. This might be beneficial if the high temperature heat demand is small while there is excess low temperature (residual) heat.

Subsequently, this analysis needs to be tested against the portfolio of energy efficiency options on the criteria mentioned in paragraph 3.1 and in addition:

- Timing and planning of own site versus connected sites
- Required flexibility of operations
- Time horizon current operations in view of future changes
- Desire to outsource operational responsibilities versus being in control

The portfolio of energy efficiency solutions can be divided in the following categories:

1. Solutions that reduce power demand: drives (more efficient motors, compressors and pumps, variable frequency drives, magnetic couplings, eliminating chokes and valves), industry 4.0 solutions, membranes for gas separation versus cryogenic separation
2. Solutions that reduce thermal energy demand: heat pumps, MVR, membranes that partially replace more energy intensive separations as distillation.

3. Solutions that generate more value than caloric value (e.g. H_2, syngas) out of residual fuels, currently burned, via e.g. membranes. This leads to increased thermal energy demand.

Ideally, the portfolio of options will be chosen to such an extent that all connections (steam, gas and power) stay at the same, or even better, a lower capacity level with subsequently lower costs. By doing so, projects can be more quickly implemented without waiting on future higher capacity grid connections.

4. IMPACT OF EXPERTISE, ORGANISATON AND HUMAN RESOURCE MANAGEMENT

The focus of this report is on the business case methodology and associated financial and operational parameters in the strategic context. However, the expertise, know-how and capabilities of company staff plays a crucial role as well. This section will highlight some important characteristics to get the most out of the invested CAPEX from a human resource management point of view.
Imagine a large project development department with staff that has many complementary skills and know-how on various operational/technology areas relevant for energy efficiency and the production process. Naturally, the company or plant with this large department will be able to identify, develop and implement much more projects than a small department with less skills and know-how. Thus, in order to effectively develop the project portfolio one needs not only CAPEX but also the human capacity and the know-how. We define know-how here as the combination of expertise, experience and capabilities. Besides the number of staff and their know-how also organization is important. In large organizations projects need to be developed across several departments and procedures, processes, priorities and cooperation comes into play as well.
In section 2.3.5 already the importance of incentives or split incentives, sometimes expressed in KPI's, is described and how it will influence the behavior of people with respect to setting their priorities in work. Besides individual capabilities of staff and formal cooperation between departments as organized by management there are also informal attributes of an organization sometimes described as culture. In a more entrepreneurial culture a seemingly weird but brilliant project idea will have a larger chance of maturing into an approved investment proposal than in a less entrepreneurial culture.
Muhibul Haq[6] (2016) has demonstrated in his overview article that there is a clear link between the competitive advantage of a company and its human capital resources expressed in social capital, relational capital and knowledge.
Thus, the new CAPEX allocation mechanism and strategic project prioritization can not be executed in isolation but needs to be implemented with additional staffing and organizational alignment. That might involve both a business process as well as cultural elements of the organization. A practical approach can be to set up a global center of excellence where expertise and experience between corporate departments and operational plants is effectively shared and applied.

This leads to the following organizational recommendations for senior management which will also require extra human capital:

1) set up best practice sharing globally between energy/technology experts at each plant via a global (virtual) corporate center of excellence and stimulate multidisciplinary project development

2) stimulate and reward development of local operational/energy efficiency investment opportunities and subsequently global deployment

3) align corporate and plant KPI's and management incentives (at financial, operational, strategic level) to stimulate operational project development and cooperation

5. CONCLUSIONS AND RECOMMENDATIONS

Several financial calculation methods for energy efficiency projects have been analyzed in relation to the selection of all investment opportunities both at plant level (operations) and at corporate level. It turns out that at plant level energy efficiency projects are usually developed by a bottom-up approach and ranked by pay-back period. Energy efficiency projects have to compete with other operational projects that aim at for instance reduction of maintenance costs or increase of production and that have higher ranking KPI's such as safety, availability and reliability.

At corporate level different KPI's are used like financial KPI's as EBITDA, operational margin, return on investment and NPV. Then, there are corporate KPI's like market share and sustainability expressed in for instance quantitative time bound targets in CO_2 reduction of scope 1, scope 2 and scope 3 emissions. The implementation of these corporate KPI's is usually done by a strategic top-down approach leading to capital- and manpower intensive flagship projects involving senior management. The corporate ranking of these large projects takes into account the strategic drivers of the company and the financial drivers via the NPV and IRR methods.

The consequence of the different corporate and operational ranking of investment opportunities with respect to energy efficiency has been analyzed in various publications by e.g. David March (2013)[4]. It can be concluded that the capital allocation for energy efficiency projects at plant level is much smaller than the number of financially feasible energy efficiency projects. Thus, implementing many more energy efficiency projects will increase shareholder value. In addition, publications of Ernst Worrel (2003)[2] and Catherine Cooremans (2001, 2012)[3] show the synergy of incorporating non-energy benefits in the financial analysis of projects and the impact on project selection. Cooremans also makes a strong case for a more strategic top-down approach for energy efficiency projects compared to the current bottom-up approach.

The authors of this report propose a new method (the 6-factor method) that build upon these theories and also quantifies the interaction between the various projects in an investment opportunity portfolio. This method enables to balance the KPI's (both at corporate level and at plant level) and maximize the synergy between the projects in the portfolio. This requires a uniform financial analysis to be used and it is recommended to use the NPV method with the company WACC as discount factor and a valuation period of 15 years as this aligns both corporate and operational KPI's. This method is in line with the TCO approach where the Total Cost of Ownership of production assets is minimized. The 6-factor method is an integral part of the following project prioritization process:

1) <u>Financial investment appraisal of all projects within project portfolio:</u>
   This requires for all projects, energy efficiency projects and other projects, a common appraisal period of typically 15 years and uniform financial analysis based on and the NPV method. The NPV is by far the preferred tool for ranking projects as it relates directly to shareholder value and enables a direct comparison between energy efficiency and all other investments in the company, both operational and non-operational. For energy efficiency projects, especially, use:

a. WACC as a default discount factor (usually between 6 and 10 %). The risk profile of projects within a project portfolio can vary which can be reflected by applying risk-adjusted discount rates to prioritize low risk projects within a project portfolio. Many energy efficiency projects have a low risk profile, and using the company WACC as discount factor is appropriate.
b. Exchange-based market-prices for energy and CO_2
c. Inclusion of non-energy benefits as revenues.

2) Bottom-up Energy efficiency Project prioritization based on costs benefit analysis, project effort, risks, timing and alignment to operational drivers.

3) Strategic prioritization of projects within the overall project portfolio (6-factor method). The degree of correlation amongst projects is determined with the aim to find project synergies to increase the effectiveness of energy efficiency implementation while reducing time, risks and costs and thereby optimize the cash to be earned. This method can greatly improve the deployment of energy efficiency investments.

4) Organizational alignment and change in terms of staffing, sharing best practices, developing know-how and setting up a center of excellence to optimally deploy the new appraisal and development process for projects. Cooperation has to be rewarded, both in the plant and between the plants and the corporate departments to optimally use both CAPEX and human capital. Senior management has a role in shaping the required business process as well as the culture, incentives and KPI's.

These recommendations will have a very positive impact on the definition, selection and implementation of energy efficiency projects and as such is in the best interest of the shareholder. These projects turn out to be less risky and yield a higher return on capital than the majority of company investments. In addition, these projects also lead to a major contribution to the sustainability targets as CO_2 emission reduction scope 1 and scope 2.

Implementation of all these recommendations will reveal more energy efficiency investment opportunities that require more CAPEX but requires changes in the organization as well to prevent bottlenecks in staff capacity and expertise as well at plant level and corporate level. This leads to the following organizational recommendations for senior management which will also require extra human capital:

1) Set up best practice sharing globally between energy/technology experts at each plant via a global (virtual) corporate center of excellence and stimulate multidisciplinary project development.

2) Stimulate and reward development of local operational/energy efficiency investment opportunities and subsequently global deployment.

3) Align corporate and plant KPI's and management incentives (at financial, operational, strategic level) to stimulate operational project development and cooperation.

APPENDIX 1: DUTCH GOVERNMENT REGULATIONS, TAXES AND SUBSIDIES

1.1 CO2 pricing

Since January 1st 2021, there is a national Dutch tax on CO_2 emissions[7] in industry to complement the EU ETS. The Dutch Emissions Authority (NEa) implements the scheme, see tax on industrial[8] CO_2 emissions". CO_2 tax is added to the EU ETS price. Where emissions prices rise, the CO_2 tax decreases, and the other way around too. The tax is planned to start at 30 Euro / ton of CO_2 in 2021 and is planned to reach 125 Euro / ton CO_2 by 2030. The tax payable will be the difference between the tax level and the price in the EU ETS for that year, so that the total carbon price never exceeds the CO_2 tax.

$$CO_2 \text{ price} = CO_2 \text{ ETS price} + CO_2 \text{ Tax} \tag{1}$$

The CO_2 emission tax is due on direct emissions, i.e. scope 1 emissions caused by own sources within the organization: production related activities. This is in contrast to the indirect scope 2 (generated by purchased and consumed electricity or heat) or scope 3 (caused by the business activities of customers) emissions.

1.2 Energy Efficiency Plan (EEP)

In the Dutch "Energieakkoord" of 2013 the agreement was made to reach 100 PJ of energy savings by 2020. In that context, the Long-Term Energy Efficiency Agreement 2001-2020 (MJA3) and the Long-Term Energy Efficiency Agreement for ETS Enterprises (MEE) were concluded: the MJA3/MEE covenants. The purpose of the covenants was to stimulate the industry to invest in energy efficiency projects in order meet the targets of roughly 2 % energy efficiency improvement per year.

Each company participating in an MEE / MJA3 agreement, had to draw up an Energy Efficiency Plan[8] (EEP) for RVO (Netherlands Enterprise Agency) which had to be updated every 4 years. The EEP provides insight into the energy situation and the savings options of the company. It was a tool for planning energy efficiency measures and could be an important part of a company's sustainability and strategic policy. The agreement was valid until January 1st 2021, and there is discussion on a possible follow-up. A follow-up is highly recommended to create insight in status and progress on industrial energy efficiency investments.

1.3 Subsidies and tax schemes

In order to improve the profitability of EE measures, the government offers various funding tools in the form of subsidy and tax schemes, see Table 1. A financial analysis of energy efficiency projects done by RVO in 2018[9] shows that there is a large number of projects with a pay-back time longer than 5 years that are not being implemented. Thus, clearly subsidies can increase the % of project opportunities that will be implemented.

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[8] In addition to installations covered by EU ETS, the carbon tax also covers waste incineration plants and nitrous oxide installations. Electricity production and installations producing district heating are already covered by another CO_2 tax, which is at a lower rate.

RVO subsidies and tax schemes are based on standard energy prices, which depend on the level of consumption of the industrial plant, see Table 2. So, in that case, no account is taken of possible future changes in energy prices.

	Tax Schemes		Operational Subsidies	
	Energie Investering Aftrek10 (EIA)	Milieu Investering Aftrek[11] (MIA) / (VAMIL)	Versnelde Klimaatinvestering en Industrie[12] (VEKI)	Demonstratie Energie- en Klimaatinnovatie[13] (DEI+)
	www.rvo.nl/eia. **Investment cost deductions from taxable profits**		**Subsidies on investment costs**	
	up to 45.5%	up to 36% for MIA up to 75% for VAMIL	between 30% and 70%.	30% of the additional costs compared to a less environmentally friendly investment.
Requirements – PBP	Between 5 and 15 years		>5 years	
Requirements – Technology	On Efficiency Measures List as published in the Government Gazette	On "Milieu lijst" as published in the Government Gazette	Proven effect: technology has already been demonstrated at least three times in the Netherlands	For a pilot or demonstration project when investing in novel innovative techniques to reduce CO_2 emissions
Expected savings on investment	average 10%	up to 12%		The grant amount is at least € 125,000 and maximum € 3 million.

Table 1: Potential non-energy benefits from energy efficiency measures

If an investment is eligible for more than one subsidy or tax scheme among EIA, MIA and VEKI, one has to select one of the schemes or split the investment costs between the schemes.

To calculate Payback Periods for subsidy and tax scheme purpose, default energy prices are to be used, unless savings are made on an energy carrier other than natural gas or electricity. In that case, the energy price paid by the company should be used.

See default prices on the date of publication of this document, July 2021, in Table 2 below:

Natural gas

	Energy use of existing equipment [Nm3 per year]	Price per Nm3
1	Not higher than 170.000 Nm3	€ 0,58
2	Higher than 170.000 not higher than 1.000.000 Nm3	€ 0,30
3	Higher than 1 million, not higher than 10 million Nm3	€ 0,24
4	Higher than 10 million Nm3	€ 0,23

Electricity

	Energy use of existing equipment [kWh per year]	Price per kWh
1	Not higher than 10.000 kWh	€ 0,20
2	Higher than 1.000 not higher than 50.000 kWh	€ 0,16
3	Higher than 50.000, not higher than 10 million kWh	€ 0,10
4	Higher than 10 million kWh	€ 0,05

Table 2: Default energy costs for subsidies and tax schemes[14]

The recommendations to government with relation to subsidies for stimulating energy efficiency investments:

- An important distinction is whether subsidies are fiscal (like EIA, MIA and VAMIL) or operational (VEKI, DEI). Fiscal subsidies are dependent on the profit of the company and are dealt with at the headquarters of the company. The local production plant has no influence on the profit allocation. As a consequence, the business case analysis for energy efficiency projects never takes fiscal subsidies into account. Therefore, from an incentive point of view, operational subsidies, as the VEKI, are preferred as the production sites have more insight into the subsidy allocation.
- Ideally, the subsidy budget should be open for application during the whole year instead of a predefined timeslot to mitigate planning problems with the project proposal submission.
- More consistency and clarity on the assumptions and calculation methods for the different subsidies would increase the incentive to deploy them and thus the impact on energy efficiency implementation in industry, i.e use the same payback period calculation formula for all subsidies.

APPENDIX 2: ENERGY PRICES IN THE NETHERLANDS

1. End-user energy price components

For business consumers, the end-user price comprises of the following components, see equations (1) and (2) below:

1. Natural gas, or Electricity, price as traded on the markets
2. Network charges:
   - Main transport of natural gas by Gasunie, or transmission of electricity by TenneT
   - Local distribution of both natural gas and electricity, when applicable, by regional distributor operators (Stedin, Liander, Enexis)
   - Administrative costs
3. All applicable taxes and duties: Energy Tax & ODE. Value Added Tax (VAT) is not included.

2) **Electricity Price = Market Price Electricity + Network Charges + Energy Tax & ODE**

3) **Natural Gas Price = Market Price Natural Gas + Network Charges + Energy Tax & ODE**

2. Electricity

2.1 Network Charges

This includes the costs of transmission & distribution from system operators for their services to end users. The national transmission grid operator TenneT operates the Dutch high-voltage grid and interconnectors. Eight distribution system operators (DSO) manage the regional distribution networks. The DSO are largely owned by municipalities and regions. Network charges are made out of two components:

Figure 1: Map of Distributed System Operators in The Netherlands

Connection fees applies to connections to the high-voltage network or networks that are directly or indirectly connected to the high-voltage grid. These include initial connection fees as well as periodic connection fees. It is measured by the energy demand (kVA) and can be found on the network operator's website. Below, in Tables 1 and 2, an overview of the connection fees for electricity for large users (>3 x 80A) with a connection to Stedin's [15]electricity network in 2021. Very large users (> 10.000 kVA) get a customized price.

Aansluitcapaciteit	Aansluitvergoeding in € excl. BTW per aansluiting[1]	Tarief meerlengt in € excl. BTW per mete
> 3 x 80A t/m 3 x 125A	4.530,00	51,0
> 3 x 125A t/m 175 kVA	5.750,00	54,0
> 175 kVA t/m 630 kVA	39.800,00	90,0
> 630 kVA t/m 1.000 kVA	41.000,00	100,0
> 1.000 kVA t/m 1.750 kVA	50.000,00	269,0
> 1.750 kVA t/m 3.000 kVA	213.000,00	340,0
> 3.000 kVA t/m 10.000 kVA	290.000,00	382,0

[1] *Exclusief de kosten voor een vereiste meetinrichting*
[2] *Als er een verbinding tussen knip en beveiliging van meer dan 25 meter nodig is*

Table 1: One-off network connection fee – Stedin, 2021

Aansluitcapaciteit	Aansluitcategorie[3]	In € excl. BTW per jaar	In € ex per
	LS[5]	35,0000	
> 80A t/m 175 kVA	Trafo MS/LS	83,0000	
> 175 kVA t/m 1.750 kVA	MS-distributie	765,0000	
> 1.750 kVA t/m 3.000 kVA	Trafo HS+TS/MS	1.680,6137	1
> 3.000 kVA t/m 10.000 kVA	Trafo HS+TS/MS	8.360,0000	6
> 10.000 kVA	TS	Maatwerk	Ma

[3] *Geldt voor aansluitingen aangelegd na 1 januari 2007. Aansluitingen die daarvoor zijn angelegd, zijn ingedeeld op i van aangesloten netvlak. De aansluitcategorieën zijn weergegeven in volgorde van oplopend netvlak*
[4] *Voor aansluitingen > 3.000 kVA en ≤ 10.000 kVA. Daarnaast geldt een periodieke aansluitvergoeding voor meerlengte > 3MVA van € 6,3500 per meter per jaar*
[5] *Geldt alleen voor aansluitingen aangelegd vóór 1 januari 2007: grootverbruik aansluitingen die op LS-net zijn aang*

Table 2: Yearly connection fee – Stedin, 2021

Transmission fee Grid costs for the transmission and distribution of electricity. For large consumers, the transport allowance consists of a fixed and variable part. The fixed part is the transmission independent fare “TOVT”, or “vastrecht”. The variable part “TAVT” consists of the rate – depending on the contracted transport capacity, a part that depends on consumption. The contracted transport capacity is the maximum required power that you expect to need at any time in the year. Blind power consumption fee will be charged if **COS Φ** is outside predefined limits.

Transportcategorie	Grens gecontracteerd transport-vermogen[6]	Transportdiensten					
		Vastrecht	Variabele tarieven[11]				
		Transport in € per maand	kW contract in € per maand per kW	kW max in € per maand per kW[7]	Dubbel tarief normaal in € per kWh[9]	Dubbel tarief laag in € per kWh[10]	Blind verbruik in € per kVARh
LS	t/m 50 kW	1,50	0,7292	-	0,0357	0,0220	0,0082
Trafo MS/LS	51 t/m 150 kW	36,75	1,9167	1,5665	0,0094	0,0094	0,0082
MS	151 t/m 1.500 kW	36,75	1,0296	1,5665	0,0094	0,0094	0,0082
Trafo HS+TS/MS reserve	> 1.500 kW	230,00	0,9583	0,8515[8]	-	-	0,0082
Trafo HS+TS/MS	> 1.500 kW	230,00	1,9167	2,4600	-	-	0,0082
TS reserve	> 1.500 kW	230,00	0,9083	0,8792[8]	-	-	0,0082
TS	> 1.500 kW	230,00	1,8167	2,5400	-	-	0,0082

[6] Geldt voor aansluitingen aangelegd na 1 januari 2007. Daarnaast geldt dat de transportcategorie (netvlakniveau) niet hoger kan zijn dan de aansluitcategorie (zie tabel 2)
[7] De hoogste, in elke verbruiksmaand afzonderlijk opgetreden, belasting uitgedrukt in kilowatt (kW), en bepaald als gemiddelde belasting van een periode van 15 minuten tenzij anders met Stedin is overeengekomen
[8] Wordt per week berekend
[9] Geldt van maandag t/m vrijdag van 7.00 uur tot 23.00 uur
[10] Geldt voor alle overige uren en op feestdagen, te weten: Nieuwjaarsdag, 2e Paasdag, Koningsdag, Hemelvaartsdag, 2e Pinksterdag, 1e en 2e Kerstdag.
[11] Als waarden niet zijn ingevuld, betekent dit dat de tariefdrager niet van toepassing is voor deze specifieke categorie

Table 4: Transmission fee - Stedin, 2021

More information on electricity network connection prices can be found on the regional operator websites:
Stedin: The cost of large consumption can be found here.
Enexis: The cost of large consumption can be found here.
Liander: The cost of large consumption can be found here

2.2 State-regulated components

The State-regulated components finance the cost of energy policy instruments or channel revenues to the state budget. These components include taxes and levies, as well as the costs of meeting established quotas.

Electricity tax The Dutch electricity tax has very high rates for the low consumption levels and lower rates for high consumption levels. Power generation, chemical reduction, electrolysis, metallurgical processes and use of electricity in cogeneration plants are exempt from the tax. Industrial companies that consume more than 10 GWh per year and have an energy management system in place, receive a discount, which reduces the total expenditure for the SDE+ -surcharge and the energy tax to the European minimum tax rate of 0.05 ct/kWh. The rates can be found on the website of the Dutch Tax and Customs Administration;

ODE stands for “Opslag Duurzame Energy”. It was introduced by the government in 2013 to stimulate investment in renewable energy. Ode is an additional tax that every user who buys energy need to pay in addition. for each kwh of electricity or gas consumed, you pay ode. the subsidy for the financing of the sustainable energy production (SDE+) is financed by this. from 2020, the ode is also be used for climate transition.

3. Natural Gas

Fees for large users (>40 $m^{3/}$ hour) for natural gas connection with Stedin[16], can be found below[15]:

3.1 Connection fees:

Aansluitcapaciteit (in m^3(n)/h)	Aansluit-vergoeding in € excl. BTW per aansluiting[1] in LD[2]	Tarief meer-lengte in € excl. BTW per meter in LD[2]	Aansluit-vergoeding in € excl. BTW per aansluiting[1] in HD[3]	Tarief meer-lengte in € excl. BTW per meter in HD[3]
> 40 en ≤ 65	7.823,55	100,34	21.793,35	104,71
> 65 en ≤ 100	7.823,55	100,34	21.793,35	104,71
> 100 en ≤ 160	15.283,78	106,27	23.017,79	106,35
> 160 en ≤ 250	15.283,78	106,27	23.017,79	106,35
> 250 en ≤ 400	15.283,78	106,27	23.017,79	106,35
> 400 en ≤ 650	24.507,22	106,89	24.507,22	106,89
> 650 en ≤ 1.000	n.v.t.	n.v.t.	24.507,22	106,89
> 1.000 en ≤ 1.600	n.v.t.	n.v.t.	24.507,22	106,89
> 1.600 en ≤ 2.500	n.v.t.	n.v.t.	Maatwerk	Maatwerk
> 2.500	n.v.t.	n.v.t.	Maatwerk	Maatwerk

Table 5: One-off network connection fee – Stedin, 2021

Aansluitcapaciteit (in m^3(n)/h)	In € excl. BTW in LD per jaar	In € excl. BTW in LD per maand	In € excl. BTW in HD per jaar	In € excl. BTW in HD per maand
> 40 en ≤ 65	278,8400	23,2367	776,7228	64,7269
> 65 en ≤ 100	278,8400	23,2367	776,7228	64,7269
> 100 en ≤ 160	544,7300	45,3942	820,3705	68,3642
> 160 en ≤ 250	544,7300	45,3942	820,3705	68,3642
> 250 en ≤ 400	544,7300	45,3942	820,3705	68,3642
> 400 en ≤ 650	873,4616	72,7885	873,4616	72,7885
> 650 en ≤ 1.000	n.v.t.	n.v.t.	873,4616	72,7885
> 1.000 en ≤ 1.600	n.v.t.	n.v.t.	873,4616	72,7885
> 1.600 en ≤ 2.500	n.v.t.	n.v.t.	Maatwerk	Maatwerk
> 2.500	n.v.t.	n.v.t.	Maatwerk	Maatwerk

Table 6: Yearly connection fee – Stedin, 2021

Transport fees:

In € per jaar excl. BTW	In € per maand excl. BTW
18,0000	1,5000

Table 7: Fixed Transport fee - Stedin, 2021

Aansluitcapaciteit	In € excl. BTW per jaar	In € excl. BTW per maand
> 40 m³/h ≤ 65 m³/h	1.161,2240	96,7686
> 65 m³/h ≤ 100 m³/h	1.886,9890	157,2490
> 100 m³/h ≤ 160 m³/h	2.903,0600	241,9216
> 160 m³/h ≤ 250 m³/h	4.644,8960	387,0746
> 250 m³/h	7.257,6500	604,8041

Table 8: Transport dependent rate - Stedin, 2021

APPENDIX 3: STEPS TO DETERMINE THE ECONOMIC VIABILITY OF ENERGY PROJECTS

1. Determine “old” costs (existing baseline conditions)
   Life cycle re-investments - Old equipment probably needs periodic re-investment to keep going.
   - Annual energy costs: Old annual energy * cost of energy
   - Annual Non-energy cost: CO_2 emissions, operations & maintenance (O&M) costs, other costs
2. Determine “new” costs (implementation and beyond).
   1. Initial investment plus life cycle re-investments
   2. Annual energy costs
   3. Annual non-energy costs: CO_2 emissions, operations & maintenance (O&M) costs, other costs
3. Include Subsidies
4. Choose analysis period, most often 15 years
5. Calculate Cash-in minus Cash out for each year
   - Life cycle investments
   - Annual saving
6. Choose discount rate, often WACC of 8% as energy projects are often low risk projects
7. Conduct Cost Benefit Analysis
   - NPV, IRR or PBP -> preferably NPV

Cash Out-Cash in for every year of the analysis period

Investment Sums

		Old k€	New k€	Delta k€
1. Purchase of new installation				
2. Engineering & Development				
3. Demolition & Removal costs old Installation				
4. Construction & Installation				
5. Yield old installation				

Savings

			Old k€	New k€	Delta k€
1.	Energy				
	Energy saving:	Gj			
	Energy price :	€/GJ			
2.	CO_2				
	CO_2 reductions:	Ton/Yr			
	CO_2 price:	€/TonYr			
3.	Maintenance				
4.	Waste				
5.	Operation				
6.	Additional production				
7.	Other				
8.	Pre-tax result				
9.	Tax				
10.	Result after tax				
11.	Depreciation (adjustment)				

Total Annual Cash Flow

APPENDIX 4: POWER QUALITY

<table>
<tr>
<td>PEAK SHAVING</td>
<td>

Transients: Rapid change in the sine wave that occurs in both voltage and current waveforms. Caused by switching devices, start- and stop of high-power equipment.

Some energy efficiency technologies enable peak shaving, so a reduction of peak demand in power. The maximum electricity purchase of a plant (the peak) often determines the contract form with the grid operator, even if the peak only extents just over 15 minutes per year. And if the maximum contracted electricity purchase is exceeded, even extra high tariffs are charged by the grid operator. With peak shaving, the baseload on the site network can increase, which enables capacity expansion or further electrification.

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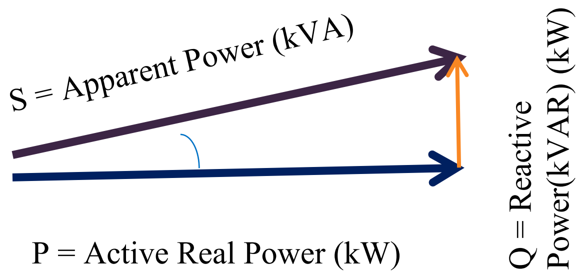
<tr>
<td>TRUE OWER FACTOR INCREASE</td>
<td>

Reactive power:



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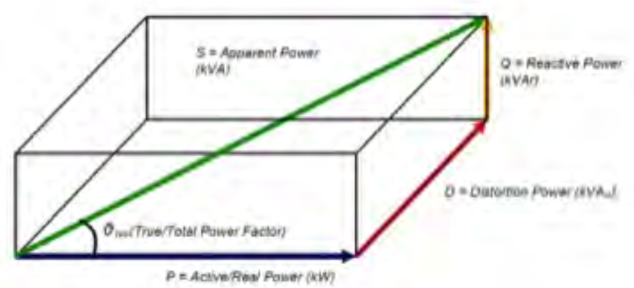
</table>

Reactive loads such as inductors and capacitors dissipate zero power, yet the fact that they drop voltage and draw current gives the deceptive impression that they actual dissipate power. The power connection has to accommodate this “phantom power” called reactive power, which is measured in a unit called Volt-Amps-Reactive (VAR), rather than Watts m an example, electric motors and transformers generate a magnetic field. To maintain this magnetic field, they consume blind current (kVar). It creates an extra load on the installation, equipment and transport infrastructure (such as cables and pipes).
In industry, this blind current is measured and is often charged if the cos phi < 0.85 by the grid operator.
The actual amount of power being used, or dissipated, in a circuit is called *Active Real Power*, and it is measured in Watts. The combination of reactive power and true power is called *apparent power*, and is measured in the unit of *Volt-Amps* (VA)

A low cos ϕ , power factor, could therefore result in a higher connection bill. On top of that you also need to pay extra transportation fees for an excess in blind power consumption (kVARh). (See Appendix 2)

Harmonics: Multiples of the supply frequency, i.e. the fifth harmonic would be 250 Hz if the supply frequency is 50 Hz. Caused by e.g. power electronic loads such as variable speed drives and UPS systems (e.g. condensators).



Non-linear devices draw current that does not have the same waveform as the supply voltage, the relationship between current and voltage is not linear and are sources of harmonics. This places undue burden on the electrical infrastructure and increasing equipment downtime.

Active or passive power factor correction devices may be used to counteract the distortion and raise the true power factor. This could increase investment cost, so alternative solutions, like magnetic coupling and ultra-low harmonic drives could be investigated.

Network unbalance: Different line voltages. Caused by single-phase loads, phase-to-phase loads and unbalanced three-phase loads like welding equipment.

	Voltage variations: Includes dips, sags, swells, brown-outs. The line voltage is higher or lower than the nominal voltage for a shorter period. Caused by e.g. network faults, switching of capacitive loads, and excessive loading.
	Flicker: Random or repetitive variations in the voltage. Caused by e.g. mills, EAF operation (arc furnaces), welding equipment and shredders.
	Oscillations (resonances): The flow of electrical energy, e.g. between the magnetic field of an inductor and the electric field of a capacitor, changes direction periodically.

APPENDIX 5: TOOLS

From The Netherlands enterprise agency (RVO):

- Tools and examples to calculate the Simple Payback Period and the NPV can be found on RVO.nl: https://www.rvo.nl/onderwerpen/duurzaam-ondernemen/energie-besparen/mja3-mee/tools/rendementsberekening.

- Tool to calculate the Payback Period with Financing Cost for VEKI subsidy can be found on https://www.rvo.nl/subsidie-en-financieringswijzer/klimaatinvesteringen-industrie

- Calculation model is to provide insight into the CO_2 tax: https://www.emissieautoriteit.nl/onderwerpen/co2-heffing-voorlichting/documenten/hulpdocument/2020/11/24/rekenmodel

Others:

- https://www.mbenefits.eu a European Funded project has developed tools to evaluate multiple benefits (energy and non-energy benefits).

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