A decision-making tool incorporating multiple benefits of motor systems retrofits

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Abstract

Investments into energy efficiency in companies are currently considered rather one-sided; for the most part focusing on financial aspects only. Further benefits such as operational security, employee productivity, etc. are not systematically included in the investment analysis.

According to the final report of the research project Management as a Key Driver of Energy Performance from 2018, 'Energy efficiency provides numerous benefits to companies, including improvements in worker comfort, product quality, overall flexibility and productivity, as well as reductions in maintenance cost, risk, production time and waste'. The overall benefits of energy efficiency improvements are not only related to energy but also include non-energy aspects, and are often referred to as multiple benefits. Non-energy benefits can have more importance than energy benefits only and ultimately help in convincing company management to invest into energy efficiency – having a positive overall impact on companies' competitiveness. Thus, multiple benefits, which include both energy- and non-energy aspects, have a significant potential in triggering the (timely) replacement of existing installations. [8], [9]

A Swiss project aims to develop a decision-making tool for motor systems that supports decision makers in small and large companies, incorporating the aspects of multiple benefits. Since electric motor systems are widely used in companies of all sizes across different sectors (primarily in the industrial and services sectors), the market potential of such a decision-making tool is considerable. In addition to a technical approach, socio-economic as well as investment-related aspects will be incorporated, so that the basis for decision-making has the necessary breadth. The final product shall be a web-based tool, which is easily available and applicable for the target group.

The project is implemented in three phases and concluded by mid-2020:

1. Phase 0: In this preparatory phase, the general approach was established, taking into account technical, behavioural and financial aspects. Interviews were conducted with four organisations, laying down the ground work.

2. Phase I: Following the preparatory phase, relevant multiple benefits will be further elaborated, identified and validated, based on interviews and data analysis. Four applications of motor systems will be analysed, namely air compressors, cooling compressors, fans and pumps (and in addition as an option variable frequency drives).
3. Phase II: The results of Phase I will be integrated into a web-based decision-making tool.
4. Phase III: Dissemination of the tool to relevant stakeholders.

This paper focuses on the methodological approach taken and the results so far (Phase 0).

Introduction

Electric motor systems are responsible for around 50% of total electricity consumption in Switzerland - and worldwide. In the industrial sector alone, their share of electricity consumption is above 70%. The average savings potential for improving motor systems is around 20% - 30% [1], [2].

Switzerland implements a CO_2 law and has a system of voluntary target agreements in place since approx. 20 years, with the primary purpose of saving CO_2-emissions. As electricity generation in Switzerland is almost CO_2-neutral (the bulk of this from hydropower and as of now still from nuclear power), in this context, measures for decreasing electric energy consumption were less in the focus of companies, especially measures for improving their electric motor systems.

Investments into improving the energy efficiency of motor systems are hindered by many different barriers; the most significant barriers include technical complexity and associated risk aversion as well as lack of resources (know-how, time, financial resources) at the end-users. While investment decisions are considered to focus on financial aspects only, there are other valid reasons for improving machinery, beyond only saving energy and costs.

What are multiple benefits?

What are the reasons for improving the efficiency of motor systems? For energy efficiency advocates, cutting energy consumption and thereby contributing to a sustainable future clearly stands at the forefront. For the affected companies, profitability considerations are on top of the agenda. However, there are also numerous other considerations - besides saving costs and energy - that can be strategically important for companies and come hand in hand with efficiency improvements.

The benefits of energy efficiency improvements are not only related to energy but also include non-energy aspects, and are often referred to as multiple benefits. Non-energy benefits can have more importance than energy benefits only and ultimately help in convincing company management to invest into energy efficiency – having a positive overall impact on companies' competitiveness. Thus, multiple benefits, which include both energy- and non-energy aspects, have a significant potential in triggering the (timely) replacement of existing installations.

According to the International Energy Agency [3], there are a wide range of multiple benefits deriving from industrial energy efficiency projects (see Table 1).

Benefit	**Description**
Competitiveness	
Ability to enter new markets/ increased market share	Overcoming technical barriers to trade or overcoming market perceptions or resistance (e.g. perception about carbon dioxide [CO2] footprints).
	Expanded capacity or new product features that enable entrance in new markets.
Reduced production costs	Reduced costs per unit or enabling the company to access and capitalise on a new complementary or substitute factor of production and in doing so opening up new opportunities for growth.
Deferred plant capital investments	Optimising processes or upgrading equipment or extended equipment lifetime can defer the need for capital costs in replacing equipment. Optimising processes for energy efficiency can also lead to situations where certain equipment is redundant.
Corporate risk reduction	Mitigation of corporate risk through reducing liabilities and helping to achieve or go beyond current regulatory requirements.

Improved reputation, corporate image	Improved corporate image through publicising energy efficient (sustainable) business. Improvement of corporate image through CSR that incorporates the wider range of benefits (both private benefits and public benefits).	
	Better brand reputation through product or service quality improvements.	
Production		
Capacity utilisation	More efficient equipment or processes can lead to shorter process times and use of lower cost factors of production (labour and materials), which can lower production costs and enable higher product output.	
Improved product quality	Downstream improvements in reductions in product defects and warranty claims as well as contributing to enhanced brand reputation.	
Increased product value	Improved quality and consistency contribute to added value which in turn can contribute to enhanced brand reputation.	
Operation & Maintenance		
Improved operation	Improved operation and process reliability leads to reduced equipment downtime, reduced number of shutdowns or system failures and can entail reduced process time (which can contribute to increased productivity), process optimisation can also reduce staff time required to monitor and operate a processing plant is therefore reduced, which reduces overhead costs.	
Reduced need for maintenance	Energy efficiency projects can lead to investments in new equipment, system optimisation, optimisation or change of processes which in turn can lead to lower maintenance requirements (or avoidance of extraordinary maintenance), reduced costs for maintenance, reduced cost for maintenance materials.	
Working environment		
Improved site environmental quality	Improved work environment from improved thermal comfort, lighting, acoustics and ventilation. Improved conditions can help retain and attract skilled staff. Improved work conditions and work environment can increase labour output.	
Increased worker health and safety	Process improvements and equipment upgrades implemented as part of energy efficiency projects can reduce the risk and incidence of work-related accidents or negative impacts on worker health. Such improvements can lead to reduced health insurance costs and medical expenses (as well as reduce corporate risk – liability in case of accidents).	
Environment		
Reduction of air pollution and emissions	Reducing energy use or optimising processes can reduce sulphur oxides (SOx), nitrogen oxides (NOx), carbon monoxide (CO), chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), as well as CO2 emissions and associated credit or reduced compliance costs. Process changes reduce combustion and process emissions can be important to industry when there are regulatory or compliance issues and associated cost savings include avoiding fines or taxes.	
Solid waste reduction	Reducing waste streams through e.g. production improvements, product redesign, improved operation result in less waste, which reduces waste disposal/abatement costs and input materials purchase cost.	
Waste water reduction	Process optimisation, improved operation, improved maintenance can reduce water needed to run processes or water needed for cleaning purposes. Reducing wastewater has environmental benefits but can also entail reduced costs for wastewater treatment.	
Reduction of input materials, e.g. water	Reduction of input materials reduces upstream environmental impacts from extraction, processing and transport.	

Table 1 Company-level benefits from industrial energy efficiency projects (Source: [3])
Categories and benefits are not listed in order of importance. This is not an exhaustive list.

Next to the IEA, a growing body of research and projects are dedicated to the topic of multiple benefits and to the quantification of these, in an attempt of making these benefits more visible to different stakeholders, including end-users (a few examples - non exhaustive: [3], [5], [6], [7], [12], [13]).

Researchers in Switzerland are also dedicated to this topic. The Lucerne University of Applied Sciences and Arts developed a comprehensive and standardised three-phase methodology to assess the multiple benefits of a wide range of industrial processes and energy efficiency measures. The methodology was validated based on ten case studies performed between 2016 and 2018 in the Swiss industrial sector. The study has shown that the consideration of monetizable multiple benefits may reduce the payback time of energy efficiency measures by up to 40% - 85%. [11] The results are expected to inform the 'Multiple benefits for electric motor systems' project.

'Multiple benefits for electric motor systems': project background

Goal

This paper presents the project 'Multiple benefits for electric motor systems'. This project aims to develop a decision-making tool for motor systems, supporting decision makers in small to large size companies, incorporating the aspects of multiple benefits. The final product shall be a web-based tool, which is easily available and applicable for the target group.

Framework

The project is supported by the Swiss Federal Office of Energy (SFOE). SFOE is the national governmental body in Switzerland responsible for establishing Minimum Energy Performance Standards (MEPS) for energy using equipment including motor systems, market monitoring and the design and implementation of market transformation programmes for energy efficiency via specific policy tools, such as financial incentive programmes, awareness raising, training, etc. This project was chosen to be supported via a public tender, focusing on innovative projects and approaches to advance the increased efficiency of electric motor systems.

Project phases

The project is implemented in three phases:

1. Phase 0: In this preparatory phase, the general approach was established, taking into account technical, behavioural and financial aspects. Interviews were conducted with four organisations, laying down the ground work.

2. Phase I: Following the preparatory phase, relevant multiple benefits will be further elaborated, identified and validated, based on interviews and data analysis. Four applications of motor systems will be analysed, namely air compressors, cooling compressors, fans and pumps (and in addition as an option variable frequency drives).

3. Phase II: The results of Phase I will be integrated into a web-based decision-making tool.

4. Phase III: Dissemination of the tool to relevant stakeholders.

Up until now, Phase 0 has been concluded. The whole project shall be concluded by mid-2020.

Project partners

The project is led by act (Cleantech Agentur Schweiz / Cleantech Agency Switzerland), an energy agency tasked with supporting Swiss companies in the industrial and services sectors to implement target agreements to reduce their energy consumption and CO_2-emissions. Further project partners:

- Lucerne University of Applied Sciences and Arts (HSLU): bringing in technical, organisational and methodological know-how; responsible for conducting the interviews;

- Zurich University of Applied Sciences (ZHAW), bringing in insights from psychology and behavioural economics;

- Impact Energy, an independent consulting company focused on energy efficiency in industry and manager of the Swiss information and networking platform Topmotors (www.topmotors.ch), bringing in technical experience from working with industrial facilities.

Methodology

The approach taken in Phase 0 of the project is as follow:

1. Identification of the target group (see Figure 1). Following an analysis of the electricity consumption of companies in the industrial and services sectors in Switzerland, the following categories of companies were defined as the target groups of the project:

   a. Small size companies: 0.1 - 0.5 GWh/a electricity consumption;

   b. Medium size companies: 0.5 - 3 GWh/a electricity consumption;

   c. Large size companies: above 3 GWh/a electricity consumption.

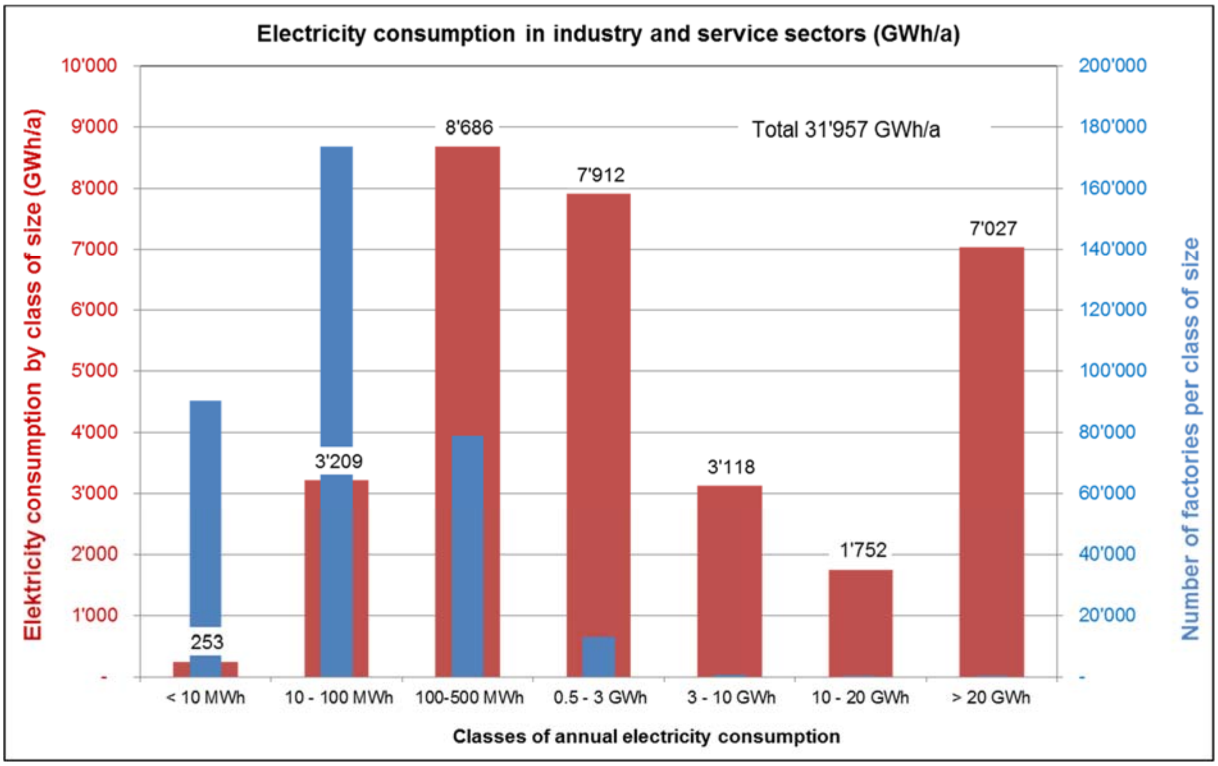

Figure 1 Electricity consumption and number of companies in Switzerland in the industrial and services sectors (Source: [2])
Note: the blue bar (and values on right vertical axis) shows the number of all companies within one size category, the red bar (and values on left vertical axis) shows the total electricity consumption in GWh/a of all companies within one size category. For example, there are only a few factories which consume more than 20 GWh/a of electricity (blue bar almost not visible) and the total consumption of them within this size category amounts to 7 027 GWh/a.

2. Identification of the different people involved in the efficiency improvement of motor systems within a company: analysis and definition of different "personas", i.e. person profiles of such people.

3. Analysis and definition of 'trigger events' or trigger points where actors need to take decisions with regard to their equipment as follow:

   a. Regular operation and planned maintenance

   b. Changes of law (e.g. tighter energy efficiency requirements for motor systems)

   c. Unexpected breakdown of equipment

   d. Increasing capacity of one machine (upgrade)

   e. Modernization of an entire facility with full system re-design

4. Analysis and identification of methodological approach for the decision-making tool.

5. Definition of survey questions for the interviews to be conducted.

6. Conducting first surveys (results if needed will be incorporated for subsequent interviews).

In the subsequent project Phases, the following is foreseen:

7. Conduct further interviews.

8. Build-up of tool.

9. Dissemination of the tool.
(A first report is planned to be delivered at the Motor Summit 2019 Switzerland.)

Results

Preparation

Based on previous research [11], different multiple benefits associated with different replacement reasons were identified.

This was followed by identifying and describing the different personas involved in the efficiency improvement of motor systems within a company. The following main personas were identified:

- Persona "Engineer", further differentiating according to company sizes and responsibilities:
    - Energy manager on site / for more sites (in case of large company with different sites)
    - Maintenance person
    - Factory or Production unit manager
- Persona "External expert", e.g. supplier (equipment manufacturer, OEM), service provider, engineering consultant
- Persona "Finance", further differentiating into:
    - Procurement
    - Chief Financial Officer
- Persona "Chief Executive Officer" (CEO).

For all personas, the following criteria were assessed and described in detail:

- Goal / motivation of actions
- Responsibilities
- Know-how: level of education, technical knowledge
- Resources (people, money, time), i.e. what resources the respective persona can utilize
- Decision power.

Then, journey maps for all trigger events in all different-size companies were drawn. The journey map represents an activity stream (journey) including the actors involved, their job/tasks and information

The rationale behind drawing journey maps is to identify the points in time where decisions are made and to provide relevant information on the multiple benefits during these points in order to enable an investment decision that leads to increased efficiency. Figure 2 shows the journey map of an unexpected breakdown as an example including the different personas involved.

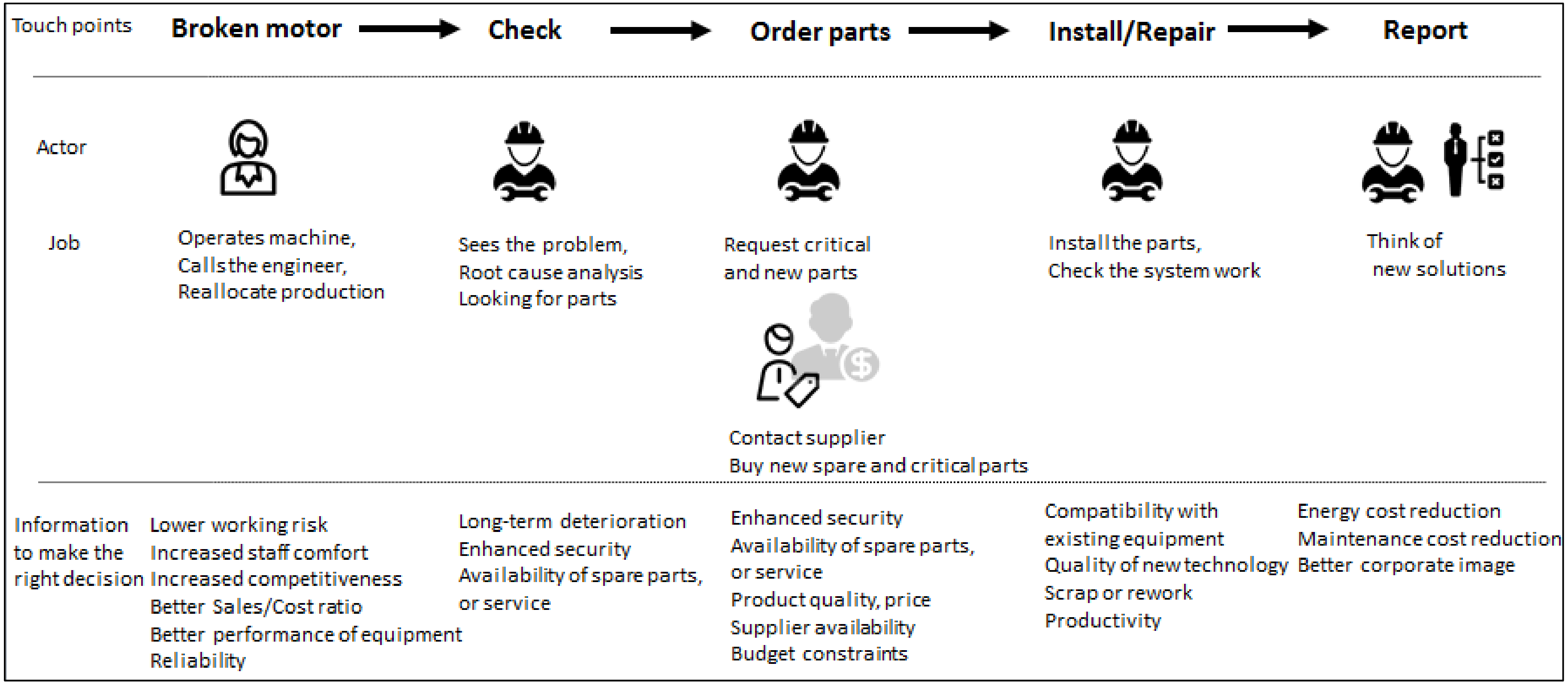

Figure 2 Journey map in the event of a breakdown in a medium size company: people involved and potential decision triggers (Source: [14])

Interviewee	1	2	3	4
Persona	**Chief Executive Officer**	**Energy efficiency engineer**	**Chief Executive Officer**	**Chief Financial Officer**
Motivation	Innovation: products that are easy to commission, last long, energy efficient	Support companies to meet the energy efficiency requirements and go beyond that	Increasing competitiveness and profitability	Increase business value
Relevance of motors in work	High (part of refrigeration system)	Medium (part of energy efficiency)	High (main focus of repair jobs)	High (capital intensive)
Trigger events	Law, government incentives or information campaign, pressure from environmental activists, scandals (machine failure->unsafe food->food poisoning)	Analyses in companies revealing savings potentials, frequent breakdowns, old equipment, high maintenance costs.	Government incentives, cost reduction, frequent breakdown.	checking fixed assets (equipment) and replacement needs for budgeting, increased cost of maintenance & repair
Benefits from motor upgrade/ replacement	Understanding Total Cost of Ownership, less failure, lower maintenance costs, more floor space available.	Energy efficiency, reliability of production, better performance, improved quality, higher profit.	Improved production processes, reduced losses, energy cost reduction	Lower repair needs and less unplanned maintenance leading to lower costs and less administration
Risks	Lack of knowledge, conflicts of interest, replacement time after breakdown	None for performance. In financial terms: energy savings can be overestimated (prediction uncertainty).	None in terms of equipment operation. Procurement driven by saving, tend to buy at lower price.	Uncertainty associated with new technology and planned investment (prediction uncertainty).
What information would be needed to decide for energy efficiency?	Benchmarking against competitors, education of engineers and managers.	Government tools and support, access to information (OEMs catalogue), training. Big companies can afford energy specialist, develop tools for smaller companies.	Equipment specifications (data sheet, OEMs catalogue), technical knowledge within companies.	Cost and cash forecasting, price negotiation with supplier.
Personas involved in the decision-making process	Mechanic, controller, facility manager, technical manager, CEO, Procurement and Finance.	Technicians, CEO, Chief Technical Officer, Chief Financial Officer.	Finance and Procurement.	Engineer (technician), CEO, Procurement, Finance.

Table 2 Interviewees' responses to survey questions, summary

Interviews

In a next step, four interviews were conducted with persons (personas) of the following profiles, in four different organisations:

1. Chief Executive Officer
    a. Company profile: automation of chillers and in building technology;
    b. Interviewee's responsibilities: provides energy efficient solutions for refrigerator systems.
2. Energy efficiency engineer
    a. Organisation profile: canton (public authority)
    b. Interviewee's responsibilities: consults large scale industrial energy users (> 0.5 GWh/a of electricity consumption) on energy efficiency improvements, helps them to meet regulatory requirements, understand obligations and which actions to undertake, tools to use.
3. Chief Executive Officer
    a. Company profile: technical service company
    b. Interviewee's responsibilities: works primarily with motor systems; design technical solutions, strategy, orders and contacts.
4. Chief Financial Officer
    - Company profile: organizing luxury cruises & tours, owning different large-size ships
    - Interviewee's responsibilities: Senior Finance accountant.

The goal of the interviews was to identify and better understand the importance of and satisfaction with multiple benefits that decision makers associate with more energy efficient motors.

The interviews investigated the following:

1. Information about the interviewee: daily tasks, motivation, relevance of work to motor systems
2. Trigger events: on which occasions did the interviewee consider replacing or upgrading motor systems? Which benefits / risks did the interviewee associate with such replacement / upgrading?
3. Decision making process for equipment replacement / upgrade: who is involved and what information is needed? Does the interviewee have access to that sort of information? Who would make the final decision?
4. Multiple benefits: what value does the interviewee attribute to the different multiple benefits? For this, benefits with ecological, economical, social and financial aspects were assessed.

Table 2 gives an overview of the interviewees' responses.

During the interviews, interview respondents were asked to assign points from 0 (not relevant) to 10 (highly relevant) to different multiple benefits, assessing both their importance for them and satisfaction with how much these benefits were already exploited. For example, taking the benefit of decreasing time loss due to unscheduled system failures, interview respondents found this an important benefit but were not satisfied yet with meeting it and found that an appropriate measure (motor system optimisation) would help to meet this aspect to a greater extent.

Based on the interview answers, the list of multiple benefits was classified (see Table 3) using the following main categories:

- Overserved: respondents find these aspects relatively important and are very satisfied
- Served appropriately: respondents find these aspects important and are satisfied
- Underserved: respondents find these aspects very important but are not satisfied.

See Table 3 for the detailed list of classified multiple benefits.

Classification of benefits according to respondents' evaluation
Overserved (relatively important and respondents are very satisfied with these aspects)
Renewal of the manufacturer's warranty
Simplification through standardization
Preparation for emergency replacement (e.g. incompatibility)
Reputation through more stable system
Improvement of plant documentation
Securing the annual targets through high availability of the system
Reduction of operating costs (maintenance and repair costs)
Reduction of energy cost
Avoid non-budgeted expenditures (budget compliance)
Preservation of plant value and modernization
No unplanned write-offs in case of breakdown
Tax optimisation
Reduction of insurance costs (example: risk of loss of production)
Less failures lead to less administrative processes

Served appropriately (important and respondents are satisfied)
Opportunity for innovation
Systematic review of plant design
Improved site environmental quality
Better sustainability rating
Improve operational control
Less maintenance effort, time saving
Improved availability of spare parts and suppliers
Preservation of plant value and modernization
Performance improvement
Increase reliability of workflow / system
Avoid non-budgeted expenditures
Ability to enter new markets/ increased market share
Improved product quality
Personal profiling through innovation
Personal profiling through constant output
Possibility for process optimization
Compliance (law, regulations)
Company reputation / Green signaling
Corporate risk reduction
Increased worker health and safety
Following asset renewal program as planned

Underserved (very important but respondents are not satisfied with current state)
Reduction of energy consumption
Reduce system failure
More stable process handling
Operational cost optimization
Energy cost savings as part of the cost of production
Improved and more reliable margins
Increase production reliability
Ensuring product quality
Availability of floor space
Understanding (predicting) Total Cost of Ownership
Increased product value
Less workload due to unscheduled maintenance work
Building up knowledge / further education / improving internal know-how
Increase competitiveness
Opportunity for process optimization
Decreasing time loss due to unscheduled system failures
Attractive Payback Times / Net Present Value
Investment and financing planning possible
Plannable depreciation and amortization (impact on tax, profit and cash flow payment)

Table 3 List of identified multiple benefits and classification according to interview respondents' evaluation. Colour scheme:

Economical aspects
Social aspects
Financial aspects
Ecological aspects

An example for quantifying the multiple benefits associated with motor replacement is shown in Figure 3. In Figure 3, the dark orange bar shows the total investment into a new motor, of which the individual elements are represented by the lighter orange bars:

- Purchase price of the motor (65%),
- Shipping cost (10%),
- Installation and commissioning (25%).

The dark green bar shows the multiple benefits, i.e. the sum of all relevant individual beneifts. The individual benefits are represented by the lighter green bars, each calculated for the duration of one year:

- Energy saving (3%),
- Revenue gain (74%) through increased reliability of production (higher number of production hours thanks to increased hours of machine availability) leading to higher number of produced units,
- Reduced waste (22%) through improved production process and less waste generated,
- Reduced maintenance and reduced insurance cost (1%) through improved reliability of equipment.

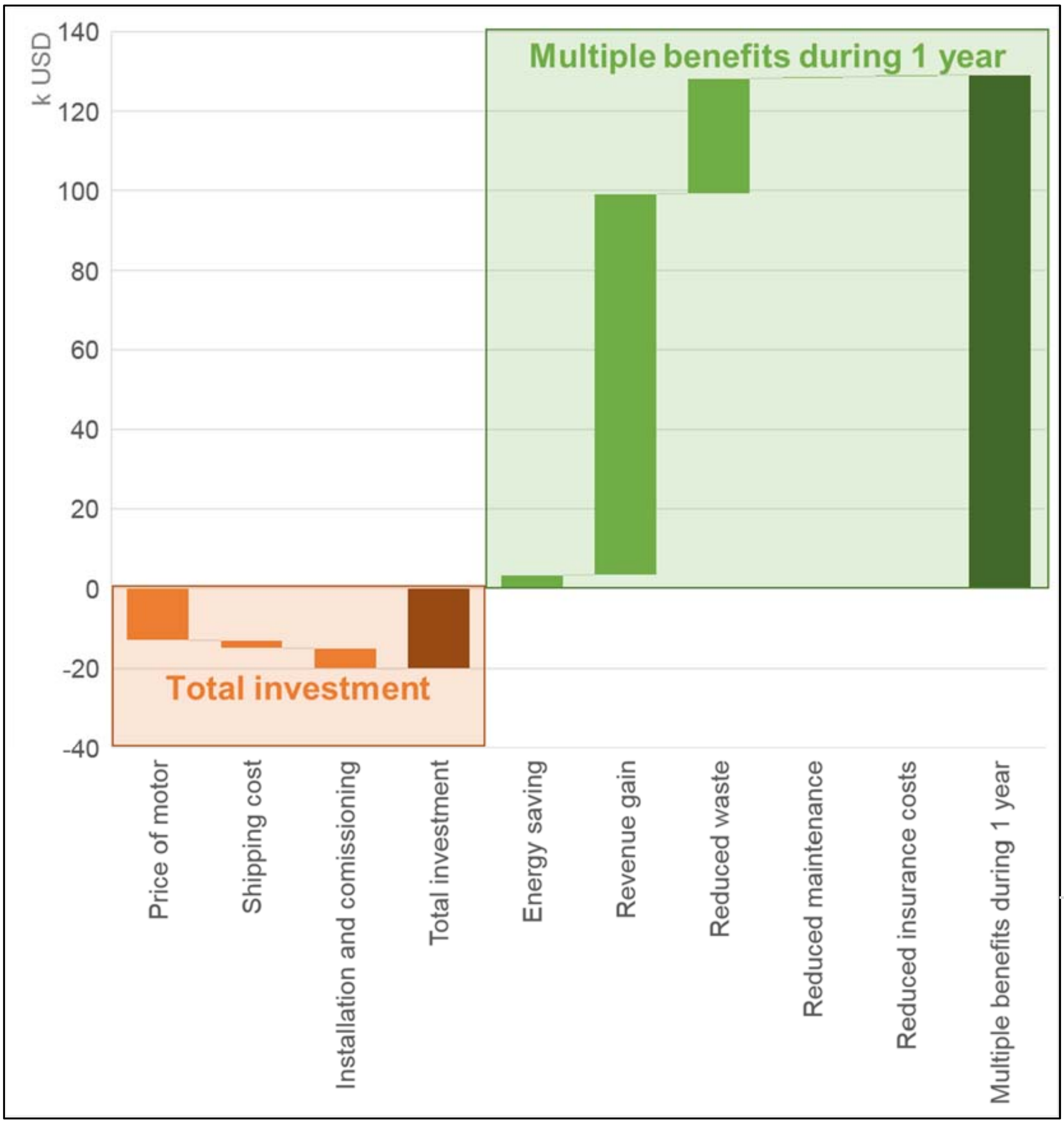

Figure 3 **Example of total investment (20 000 USD) vs. the monetary value of multiple benefits during one year (130 000 USD)**

Outlook

After concluding Phase 0 by now, Phase I of the project is about to be launched with further online and personal interviews, clarifying and validating the multiple benefits identified. The focus in Phase I will be on understanding the priorities set by the different interviewees to improve the classification of the multiple benefits. In Phase II, the findings will be used to elaborate the tool. First results will be presented at the Motor Summit Switzerland on 4 December 2019 in Berne. The project is expected to conclude by mid-2020.

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