PEER-REVIEWED PAPER

Financial incentive program for efficient motors in Switzerland: lessons learned

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Abstract

How can industrial users be convinced to retrofit their existing motor systems? An analysis of 4,142 motors in Switzerland shows that 56 % of these have been running twice as long as their operating life expectancy. This suggests there is barely any continuous improvement process for replacing old, mostly oversized, and inefficient motor systems. Since 2010, the Swiss Agency for Efficient Energy Use (S.A.F.E.) has led "Easy," a Swiss audit program for motor systems efficiency paired with financial benefits. To date, the electric motors of ten factories have been analyzed. Factories went through a four-step audit program called Motor-Check. The Motor-Check includes four phases: 1) an estimate of the motor systems' savings potential, 2) a list of all relevant motor systems, 3) a focused electric load-measuring campaign leading to a cost-benefit analysis, and 4) the implementation program of the most cost-effective energy efficiency improvements. The implementation of several cost-effective energy savings in electric motor systems is currently ongoing.

During the first three years of Easy, six key issues were identified:

- A better understanding of strategic aspects involved in the decision-making process is necessary to influence efficiency investment decision-making in organizations.
- Training is needed to develop the skills, capacity and responsibility of in-house industry personnel essential to implementing and maintaining a sound energy management system (based on ISO 50001 and on the Motor-Check method).
- In order to improve the quality of energy management in industry and to increase the level of positive decisions regarding energy-efficient motors, the decision making process of energy efficiency investments has to be better understood.
- The necessary preparatory analyses and engineering have to be improved, shortened, and provided at a lower cost.
- Subsidies are a good starting point to open the door for audit and to support regular improvement measures.
- Motor manufacturers, original equipment manufacturers, and service companies need to be trained to better promote energy efficiency and explain its benefits to their clients; it is beneficial to their business and both parties eventually benefit from energy-efficiency measures.

The aim of this paper is to explain these findings in further detail and to discuss approaches to possible solutions.

Introduction

The Swiss Agency for Efficient Energy Use (S.A.F.E.) has been working on electric energy efficiency in industry since 2007. An analysis at 25 industrial and infrastructure plants has shown that 87.8 % of the total electricity consumption of a plant is due to motor systems (see Figure 1). This number is higher than the 70 % average share of motor systems' electricity consumption in industry on the global scale, as suggested by literature [2].

The analysis highlights the huge potential contribution of motor systems to reducing industrial electricity consumption.

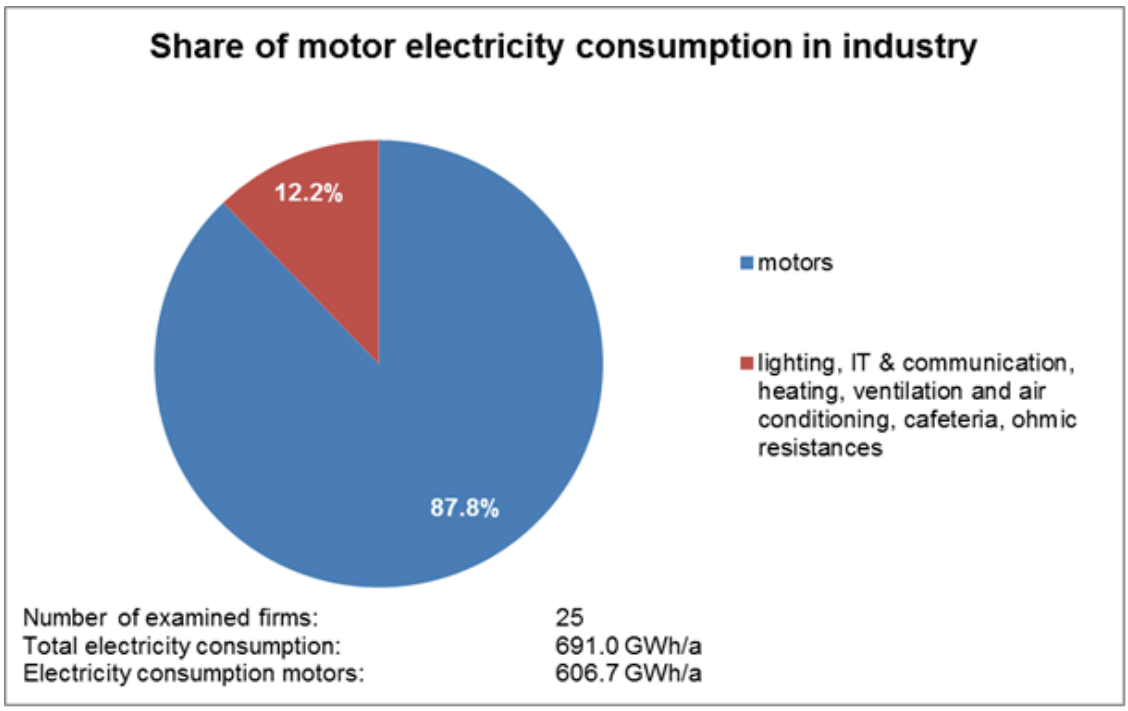

Figure 1. Share of electricity consumption of motor systems in Switzerland. Source: S.A.F.E., 2014.

According to [2], the savings potential of motor systems is between 20 to 30 %.

In 2010, S.A.F.E. launched Easy ("Effizienz für Antriebssysteme," or Efficiency for Motor Systems), an audit and retrofit program aimed at assessing and improving electric motor systems in the Swiss industry, paired with financial benefits. The program has an overall budget of 830,000 euros. It is financed through a surcharge on the electricity tariff, and runs for four years, until 31 October 2014. It targets industrial and infrastructure plants and large buildings with electricity consumption higher than 10 GWh/a. S.A.F.E. set 10 GWh/a as the lower limit for program participation, equivalent to one million euros in electricity cost per year, so that the annual savings of electricity cost within one plant is clearly higher than the minimum cost of the audit.

The paper is organized into four sections: the first two sections describe the goals and the structure of the Swiss audit program for motor systems efficiency coupled with financial benefits, "Easy". The third section describes the best solutions identified by Easy as capable of accelerating the replacement of old motors in the Swiss industry. The fourth section briefly discusses the major lessons learned in the first three years of the program. In conclusion we formulate some recommendations.

Goals

The following goals have been included in the design of the Easy program:

1. Energy-efficiency measures focus on electricity as this is the field where the most acute lack of know-how has been observed. The highest share of electricity in industry is used in rotating machinery (pumps, fans, compressors, mechanical traction and process machines).
2. Financial incentive proposed by the program serves primarily to "open the door" for the necessary analysis and to implement a systematic four-step Motor-Check audit program (see below).
3. The primary barriers to overcome are the high up-front time and cost for the necessary analysis and engineering of efficient systems and technologies. The explicit goal of the program was to overcome these barriers by providing a larger share of subsidies for the preliminary analyses.
4. Real, lasting and large energy savings come from system improvements, which are by nature more complex than simple changes of single components. Easy wants to take on the challenge of making new inroads on these tied up saving potentials.
5. Industries learn how to search for and implement energy efficiency measures in their own facilities with new tools and their in-house capacity. They are empowered to continue and expand a systematic annual review and improvement process after some initial training and a pilot audit with Easy.
6. Build-up of a database of systematically analyzed and/or measured motor systems in order to gain statistical evidence for the best practice.

Program sequence

The program follows the Motor-Check methodology, previously developed by S.A.F.E. [3]. The Motor-Check consists of four steps. The first three steps are composed of preliminary

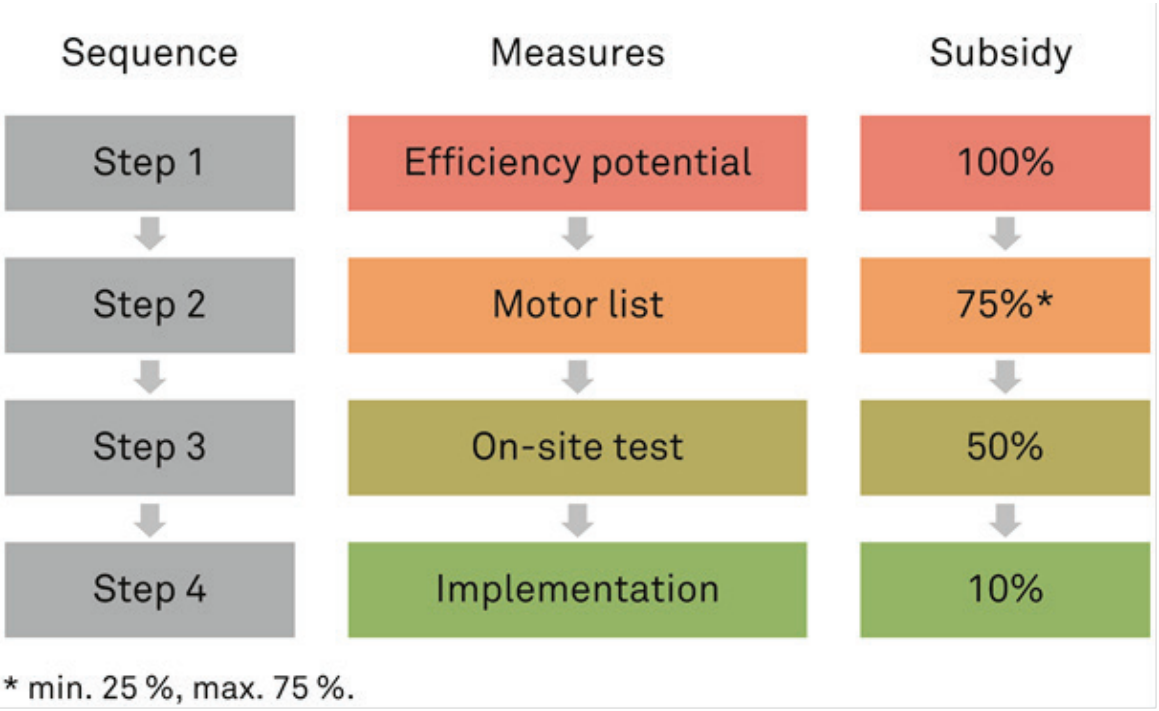

Figure 2. Easy four-step audit. Source: S.A.F.E., 2014.

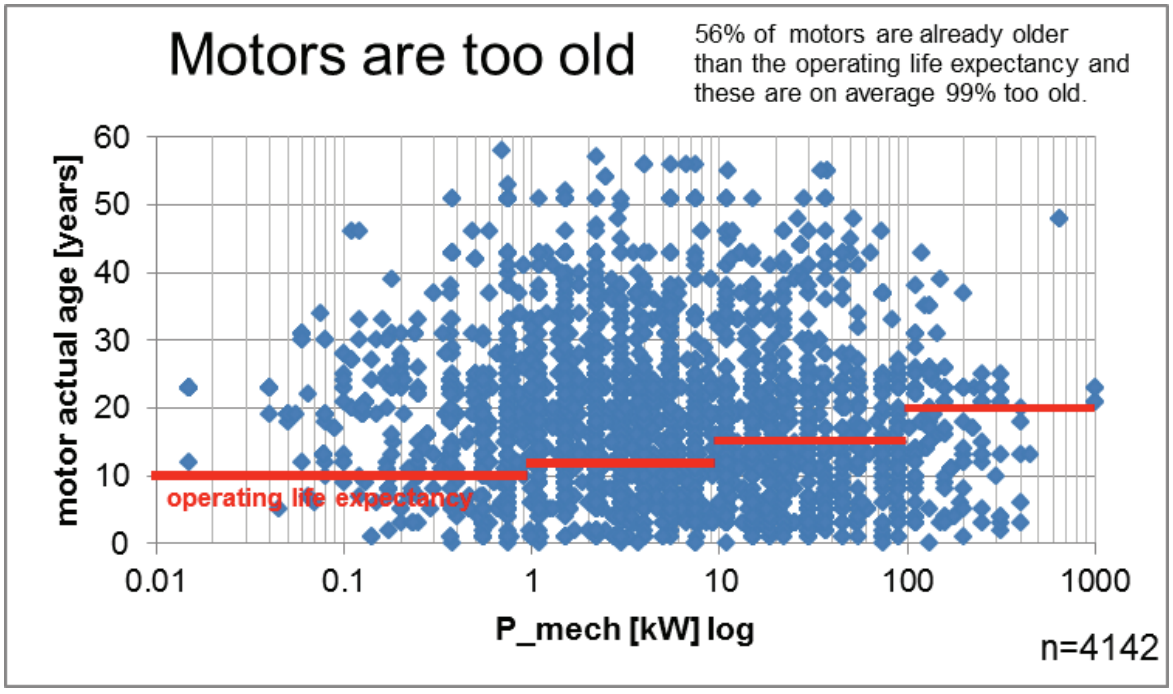

Figure 3. Analysis of 4,142 electric motors in Switzerland. Source: S.A.F.E., 2014. Operating life expectancy according to [4].

analyses, with the fourth step being the implementation of some efficiency measures identified (see Figure 2). S.A.F.E. acknowledged that while the preliminary analyses are necessary for exploiting the savings potential to the fullest extent, they are also cost- and time-intensive, thereby constituting a barrier for the industrial users.

Until now, S.A.F.E. has assessed 4,142 electric motors in Switzerland. The results show that 56 % of them are older than their operating life expectancy (see Figure 3). On average, these motors run twice as long as their expected lifetime. The oldest motor has been in operation for 64 years.

Less than 20 % of the motors assessed have variable frequency drives to control their load. From the 104 motors measured, 68 % are oversized (average load factor below 60 %).

S.A.F.E. has continuously reported on the results of the program and its analyses, for the latest update see [1]. The authors

identified four key challenges and possible solutions during the implementation of the program that they wish to further discuss in this paper.

Key challenges and solutions

SOLUTION #1: INDUSTRY NEEDS BETTER ENERGY MANAGEMENT

Energy management has been a well-known approach to energy efficiency in industry for many years. In 2011, the international standard ISO 50001 "Energy management systems – Requirements with guidance for use" was published, offering a framework for setting up energy management within a company. Although this standard gave a push and increased attention to the issue in industry, the reality is that energy management does not perform well enough in many factories. Part of the problem is that energy costs may not create a high enough share within total costs so that the reduction of energy costs would be seen as a priority. The lack of technical expertise often prohibits more complex technical changes that would result in considerable energy savings, especially when it comes to motor systems. Furthermore, if a certain level of technical expertise exists within a company, the responsible person may not be trained for managing people. Energy management has to be better understood to be effective.

Energy management focuses on managing energy use in a company. This means that it defines – in part – procedures to treat new investment proposals.

According to [5], financial considerations are important but – contradicting mainstream economic theory – insufficient to decide on an investment in energy efficiency. The deciding factor is really the strategic character of an investment. An investment is considered strategic if it contributes to a company's durable competitive advantage, which is defined in these three dimensions: cost, risk and value. Therefore, if an investment in energy efficiency reduces risk and cost, as well as brings value to a company, it is most likely to be implemented.

- Current and future risks need to be understood and assessed. An investment in energy efficiency can reduce hazardous waste, interruption for maintenance and failures, influence of carbon and energy price volatility, energy supply disruption and increase reliability of components and systems, for example.
- All relevant cost parameters need to be analyzed and understood. An investment in energy efficiency can reduce product waste, waste water, emission of pollutants and particles, process cycle time, need for protective equipment, noise, needs for engineering controls and increase productivity of output, improve efficiency of used materials (or substitutes), equipment performance, and indoor air quality, for example.
- An investment in energy efficiency can increase value to the company: improved product quality or purity, increased reliability in production, improved temperature control, increased facility reliability, improved public image, positive brand recognition, and such.

The strategic character of efficiency investments should be highlighted and energy management systems can be a useful tool for that. An interdisciplinary Swiss team (INFRAS Zurich, University of Geneva, University of Neuchâtel, and S.A.F.E.) has launched a new research project in Switzerland (see Figure 4). The goal of the project is to investigate if and how energy management systems contribute to:

1. the perception of efficiency investments' strategic character
2. a higher realization of efficiency projects
3. an increased energy performance of companies.

SOLUTION #2: TRAINING PROGRAM FOR ENERGY TECHNOLOGY AND MANAGEMENT IN INDUSTRY

One of the most important lessons learned during the implementation of Easy was that industrial users lack resources – specifically human resources – time, responsibilities, technical know-how and financial resources necessary for the implementation of motor systems efficiency projects.

S.A.F.E. identified the lack of responsibilities and know-how as being the most crucial. In an attempt to help overcome this malaise, S.A.F.E. introduced a training program: "Energy technology and management in industry." The program targets technical people, endowing them with both managerial and technical skills.

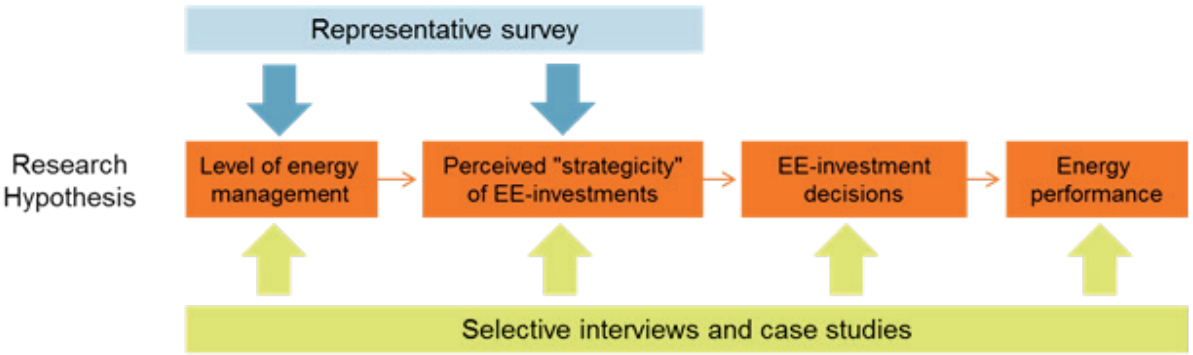

Figure 4. Research methodology for the role of energy management systems in efficiency investment decisions. Source: INFRAS, 2013.

Table 1. Optimization measures at the meat processing factory. Source: S.A.F.E., 2014.

No.	Optimization of	Investment [k EUR]	Savings [MWh/a]	Savings [k EUR/a]	Payback [a]
1	Air compressors	7	35	4	1.5
2	Ventilation system	44	56	6	7.3
3	Cooling compressors	54	308	33	1.7
Total		**105**	**399**	**43**	**2.4**

The successful implementation of motor systems retrofit projects requires:

- The ability to convince top management to invest in motor systems retrofit projects (a package of projects can easily add up to several hundred thousand euros; a cost of such magnitude makes the total investment a management decision).
- The ability to work with people across different departments. For example, to be able to convince the purchase department that life cycle costing prevails over the payback period approach and it does make sense to purchase a more expensive but more efficient motor system.
- The ability to negotiate with motor and machine suppliers and service providers, insisting on a more efficient system solution or on the delivery of an IE3 motor, and not being intimated by the threats of suppliers to cease providing a warranty on either their machine or their service.

S.A.F.E. in cooperation with the University of Geneva is currently working on a feasibility study regarding this training program which will be implemented in Switzerland. The University of Geneva started a continuing education program for energy management (based on ISO 50001) in January 2013 which was very successful. The goal is to integrate this into a larger scale program.

Evidently, creating a supply of skilled technical professionals is only one part in solving the problem. The other part is creating demand for hiring these newly-trained experts. The Swiss parliament decided in 2013 to introduce a system of voluntary agreements for electricity-intensive companies. If these companies commit to improving their electric energy efficiency, they are entitled to a refund of the electricity tariff surcharge. S.A.F.E. welcomes this initiative and sees the opportunity it brings along, namely an increased demand for skilled personnel being able to carry out efficiency projects.

SOLUTION #3: PREPARATORY ANALYSES: CHEAPER, SHORTER AND FINANCED?

The Easy methodology has proven to be very comprehensive, but also in many cases, too long and exhausting for the staff involved. Regularly, one to three years pass between the first visit at the factory (step 1: efficiency potential) and the first efficiency measure's actual implementation (step 4: implementation). Experience from the measurement campaign has shown that the cost of measuring one motor system and elaborating recommendations for the efficiency improvement (including cost and savings calculations, thus profitability) is between 1,000 and 1,500 EUR. The number of motors measured in the pilot phase was between 10 and 30 in each factory.

Although S.A.F.E. believes that these costs can hardly be reduced, an alternative approach is to group the electric motor systems to be analyzed during one period and establish a multi-annual retrofit plan for a continuous improvement process. Possible approaches:

1. Analyze applications one after another, *i.e.* ventilation systems, pump systems, cooling systems, compressed air systems, handling & processing equipment, conveyor belts, etc. The sequence could be settled based on a "quick scan" during one of the early visits at the factory in order to identify the oldest or most promising systems. Another possibility could be based on recommendations from the factory personnel itself, in case they are aware of malfunctions of one particular system.
2. Narrow the scope from the whole factory to one particular, well-defined unit within the factory (*e.g.* one factory hall or one big process machine).

This way, projects can be implemented step by step, with one step at a time followed by immediate success, which then motivates further projects.

At a meat processing plant, implementation of efficiency measures was recommended concerning three different systems: the air compressors, the ventilation system and the cold compressors (see Table 1). The factory first improved the air compressors and saved more energy than expected. In a second step – motivated by the success of the first measure – they continued on with the ventilation system and implemented efficiency measures to an even greater extent, then recommended by the program. Currently, the factory is working on implementing the last set of measures on the cold compressors.

SOLUTION #4: MOTIVATE THE MOTORS AND SYSTEMS SUPPLIERS

Another lesson learned from Easy is that it is crucial to involve the suppliers of components and systems into the analysis and retrofit of motor systems from an early stage.

Looking at the life cycle of a motor, it is being manufactured, offered for sale, sold and used (either in a factory, in an infrastructure plant or in a large building) as the essential part of a system. An efficient motor system is adapted to the necessary load, not oversized, depending on the load type equipped with a variable frequency drive and uses an efficient, properly sized and operated application (pump, fan, compressor, etc.). It must be ensured that it is running efficiently at the place of operation of the end user.

Working together with the suppliers of components and systems from an early stage is crucial to ensure the delivery of properly sized, efficient products. This not only helps the end

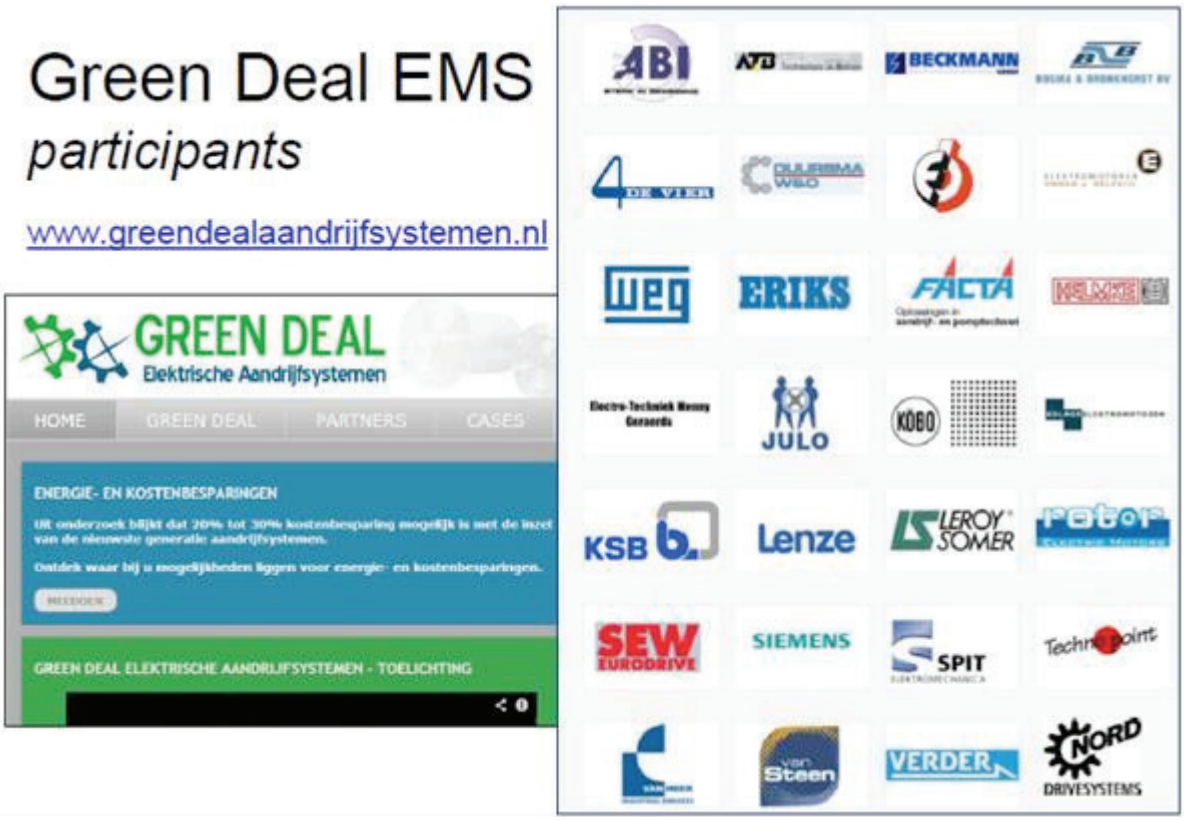

Figure 5. List of motor suppliers and service companies working together in the Dutch Green Deal Efficient Electric Motor Systems. Source: TPA consultants, 2013.

users in reducing their energy demand but is also beneficial for the suppliers of components in developing their efficiency know how with regard to the analysis, design, timely delivery and installation of complex, efficient systems, opening the market towards a more service-oriented approach.

SOLUTION #5: LEARNING FROM OTHER GOOD EXAMPLES

The program managers of Easy are also involved in the international Electric Motor Systems Annex (EMSA) of the IEA 4E Implementing Agreement[1]. EMSA brings together six countries (Australia, Austria, Denmark, Netherlands, Switzerland, and USA) to exchange experience on motor policies. This provides an excellent international platform for learning from good examples applied in other countries.

EMSA will publish the "Policy Guidelines for Electric Motor Systems" (see also [6]) later this year, based on best practice examples all over the world. A good example for involving suppliers as mentioned under solution #4 is included in the Policy Guidelines from the Netherlands, namely the Green Deal Efficient Electric Motor Systems (GDEMS) program (see Figure 5).

GDEMS is one of more than 100 other initiatives within the Green Deal program, which is run by the Dutch Ministry of Economic Affairs. The GDEMS started at the end of 2012 and will run until the middle of 2015. It was initiated by a consortium of 28 manufacturers and service companies of efficient motor systems in industry.

One very important element in GDEMS is to involve the manufacturers from the outset. Manufacturers and motor suppliers make analyses at the industrial user site, recommend better solutions and convince the end user to implement efficiency improvements. In this way, the suppliers can slowly develop a new business model based on efficient components and systems while the industrial users save energy.

Another important element of GDEMS is the exchange of experience and information, including a demonstration of the best practices among participants (manufacturers of components and systems, service companies, end users).

Lessons learned

The Easy program was carefully conceived in detail and proved to work in principle. Many elements within the Motor-Check proved to be more complex than anticipated and required more time, more external expertise and more money to reach the goals. Some of the major lessons learned are presented here:

- The technical improvements for rotating machines and their interaction in electric motor systems are more or less alike in many different kinds of industries. Most basic processes are the same and are determined by the application of electromechanical understanding of the laws of physics. It is not true that a stone mill and a chocolate factory need different kinds of know-how for energy savings.
- The understanding of a process within a manufacturing plant can be delivered by the in-house operators and their

1. The 4E Efficient Electrical End-Use Equipment (www.iea-4e.org) is an Implementing Agreement of the International Energy Agency.

technical staff. This is what they know best. However, thermal or electro-mechanical thinking is not yet widespread.

- This said, it follows that the interaction of the (often external) energy experts and the (mostly internal) industrial process experts is crucial. To date, there is no culture for this and almost no framework and training available.
- Currently, the skills and effort needed to identify and to describe the most important machines in a factory and to estimate their energy savings potential is considerable. With a budget of one million euros for electricity per year, the analytical and engineering effort can quickly add up to 100,000 euros before 1 kilowatt-hour has been saved.
- The decision making culture encountered in factory management declared sustainable development goals. In reality, however, life cycle cost investments in energy efficiency improvement and continuous systems improvement plans were not observed. It was more likely that the cheapest replacement offer of a motor was accepted when occasionally some extra money was available that could not be better used for production capacity enlargement.
- Industry staff tends to rely on quick fixes and advice given to them by their regular internal or external maintenance crew without any deeper engineering analysis and certainly without any systematic energy efficiency approach.

Conclusions and recommendations

Industries react ambiguously towards subsidies: they are motivated to benefit from the financial support but they also want to remain free in deciding and acting without any government interference with their company.

A financial incentive program for industries has to be carefully designed and implemented in a responsible and fully transparent way for managers to understand their benefits. It needs to have five to ten year duration to be designed, organized, set up and to succeed. Confidentiality is a key component, which requires written mutual agreements from the outset. The relatively important time span needed for the first results to come to light (one to three years), the considerable factory staff capacity required, and the money involved for both engineering analysis and investments for implementation projects has to be estimated and communicated clearly from the outset.

A respectful, regular and reliable relationship has to be built between the external efficiency program managers and the technical leaders. Open communication is a key to better optimizing annual plans and deciding on the sequence of analysis and implementation programs.

Impartial analysis and recommendations from experienced industry energy efficiency experts, independent of any ties with a specific product or manufacturer is an advantage.

A strategic energy efficiency plan has to be established in each company, designed and implemented by a company energy team that has the ear of the management and is able to have annual investment budgets, as well as success in mid- and large-scale improvement projects. ISO 50001 as a backdrop helps but does not alone provide the specific annual plan of the best improvement packages.

Learning from good examples applied in other countries improves the success rate of every program.

References

[1] Brunner, C.U., Werle, R., Tieben, R., (2013), "Easy" program for electric motor systems efficiency in Switzerland, in proceedings of the 8th International Conference on Energy Efficiency in Motor Driven Systems, 28–30 October 2013, Rio de Janeiro, Brazil.

[2] Waide, P., Brunner, C. U., et al. (2011), Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems, International Energy Agency Working Paper.

[3] Nipkow, J. (2010), Erfahrungen mit industriellen Pilotprojekten (Motor Check), in: proceedings Motor Summit 2010, Zurich Switzerland.

[4] de Almeida, A., et al. (2008), EUP Lot 11 Motors, ISR – University of Coimbra.

[5] Cooremans, C. (2012). Investment in energy efficiency: do the characteristics of investments matter?, Energy Efficiency, November 2012, Volume 5, Issue 4 pp. 497–518.

[6] Brunner, C.U., Kulterer, K., Lackner, P., Werle, R., (2014), How to achieve efficiency through the right mix of policies? Guidelines for electric motor policy implementation, in: proceedings of the eceee industrial summer study 2014.

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