Tackling the efficiency gap with capacity building in industrial energy optimisation

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Abstract

Electric motor systems are responsible for more than 70 % of industrial electricity consumption worldwide. Audits in 25 Swiss factories analysing 4,142 motor systems have shown that many motor systems are old, inefficient, oversized, not load controlled and need to be optimised systematically. The efficiency potential of optimising existing motor systems is between 20 % and 30 %. [1] This optimisation has been hampered by different barriers, including a lack of know-how, competence and capacities of in-house technical staff.

Within the electric motor policy in Switzerland, Minimum Energy Performance Standards (MEPS) for new industrial equipment and financial incentives are key elements. With the new Swiss five-year training program Industrial Energy Optimisation (IEO) training is now included in the policy framework, as an effective and cheap instrument to speed up the market transition towards more efficiency in existing factories.

IEO aims to train factory engineers working in industrial plants, building a pool of skilled professionals to implement motor systems optimisation projects for the next years. IEO is the first training program of its kind in Switzerland and is unique in the sense that it combines technical knowledge and management skills with a strong practical focus.

The goal of IEO is to teach the technical fundamentals of electric motors, applications (pumps, fans, air and cold compressors, conveyors, etc.) and system optimisation including the audit methodology Motor-Systems-Check (www.topmotors.ch). Plus, to train technical staff how to lead in-house energy efficiency projects and explain the necessary investments in order to convince the company management.

First lessons learned include:

- A unique selling proposition of the program is necessary to distinguish it from the numerous competing training programs in energy efficiency and renewable energy use.
- A practical focus on understanding and improving machines in the participants' factories is necessary to differentiate from theoretical classroom training programs.
- The available time for training of industrial staff is limited: six days spread over the period of one to two months seem to be the maximum at present.
- The build-up of the program in two languages required a considerable effort with a preparatory phase of more than two years. The funding of this phase – before costs can be covered by participation fees – is necessary.
- The support of the Swiss Federal Office of Energy and the choice of two renowned technical universities as training sites were important elements for attracting participants, lending credibility and securing the aspired level of quality of the program.
- The teachers of the program are both academic professors and external experts with practical experience. The preparation of the training material needed careful coordination to make sure that the level of the training material is fit for the target audience and to avoid duplications, contradictions, agree on a common terminology, key messages, etc. Adapt-

ing the training material to a target group that is different from the usual tertiary education audience proved to be a challenge.

- An intensive marketing campaign is necessary before the first editions to secure the necessary number of training participants.

Courses will be introduced both in the German and French part of Switzerland, in both languages. After the first training editions in the summer of 2016, possibilities for a longer training duration and introduction in other countries will be investigated.

IEO is supported by the Swiss Federal Office of Energy and managed by Impact Energy, a member of the Swiss Agency for Efficient Energy Use.

The aim of this paper is to give an overview of IEO, including the program design, pilot implementation and first lessons learned.

Introduction

HISTORICAL FOCUS ON THERMAL ENERGY

In the Swiss energy landscape, the topic of reducing CO_2 emissions has been long present. Large-scale consumers are required by law to reduce their CO_2 emissions which they can achieve by entering into long term agreements. As electric energy generation in Switzerland is almost CO_2-neutral (with roughly 40 % nuclear and 60 % hydropower), the reduction of electric energy use was not much affected by these activities. Consequently, the (continued) education and financial incentive programs focused on reducing thermal energy in buildings and renewable energy. Electric energy consumption and efficiency were a neglected topic so far.

After the Fukushima nuclear catastrophe in 2011 in Japan, Switzerland changed its official energy policy with the decision to abandon new and to phase out existing nuclear power plants. An Energy Strategy for 2050 was presented by the government based on increased electric efficiency measures covering the household, commercial, transport and industry sectors. The contribution of electricity savings by industrial efficiency programs is considered to be the major part to achieve a lower consumption. [8]

MOTOR EFFICIENCY POLICY

Within the policy framework for energy efficiency in electricity for the Swiss industry, Minimum Energy Performance Standards (MEPS) for newly sold equipment, namely motors, water pumps, circulators and fans, are the most cost-effective element and contribute (according to national energy demand scenarios up to 2050 [8]) the largest part of potential electricity savings. While Switzerland is not part of the European Union, the MEPS are synchronized with the respective European Ecodesign requirements. Also, with the successful start of the ProKilowatt[1] public competitive tenders for efficiency projects and programs in 2010, financial incentive programs have been launched. Training programs are embedded into the national energy efficiency policy program of SwissEnergy[2] and are considered to be a very effective instrument for the improvement of existing overaged, oversized and inefficient industrial motor systems.

TOPMOTORS FOR EFFICIENT MOTOR SYSTEMS

Topmotors[3] is an awareness raising and training program for efficient electric motor systems that has been in place in Switzerland since 2007, supported by the Swiss Federal Office of Energy. Topmotors is run by Impact Energy, a member of the Swiss Agency for Efficient Energy Use (S.A.F.E.)[4]. Topmotors:

- is organising the training program "Industrial Energy Optimisation – with focus on electric motors, systems and energy management" with the first edition in 2016;
- is staging the international conference Motor Summit (www.motorsummit.ch) in Zurich since 2007, with the 6th edition taking place on 11–12 October 2016;
- has organised a number of workshops evolving around specific topics related to efficient motor systems, such as efficient elevators, hydraulic systems, frequency converters, transmissions, machine tools, on site measurements, etc.;
- publishes a number of fact sheets on how to design efficient pump and fan systems, use of frequency controllers and is now working on fact sheets for compressors (air and cold);
- has carried out a number of pilot projects for motor systems retrofits in Swiss industrial facilities and published its systematic findings (on motor stock, age, operating hours, load factor and the use of variable frequency drives). [2]

Between 2010 and 2014 the program management of Topmotors has run an audit program for motor systems retrofits coupled with financial incentives: Easy ("Efficiency for motor systems" www.topmotors.ch/easy). Easy was targeting industrial facilities, infrastructure plants and large buildings and analysed in total 4,142 motor systems in 18 factories. [3] Easy was supported through the competitive tenders (ProKilowatt) of the Swiss Federal Office of Energy. [6]

Based on the experience of these optimisation projects in the framework of Topmotors and Easy the following observations and conclusions were made:

- 56 % of motor systems are already older than their operating life expectancy (see Figure 1). These motor systems run on average twice as long as their operating life expectancy. The oldest motor observed was in place since 64 years.
- The efficiency optimisation of motor systems is complex and requires appropriate know-how, time and financial resources. These are currently lacking (or available only to a very limited extent) in the factories that operate motor systems.

1. ProKilowatt, public competitive tenders: www.bfe.admin.ch/prokilowatt/.

2. SwissEnergy (EnergieSchweiz), Implementing program for energy efficiency and renewable energy: www.energieschweiz.ch/utilities/ueber-energieschweiz.aspx.

3. Topmotors, awareness raising and training program for energy efficient motor systems: www.topmotors.ch.

4. S.A.F.E.: www.energieeffizienz.ch.

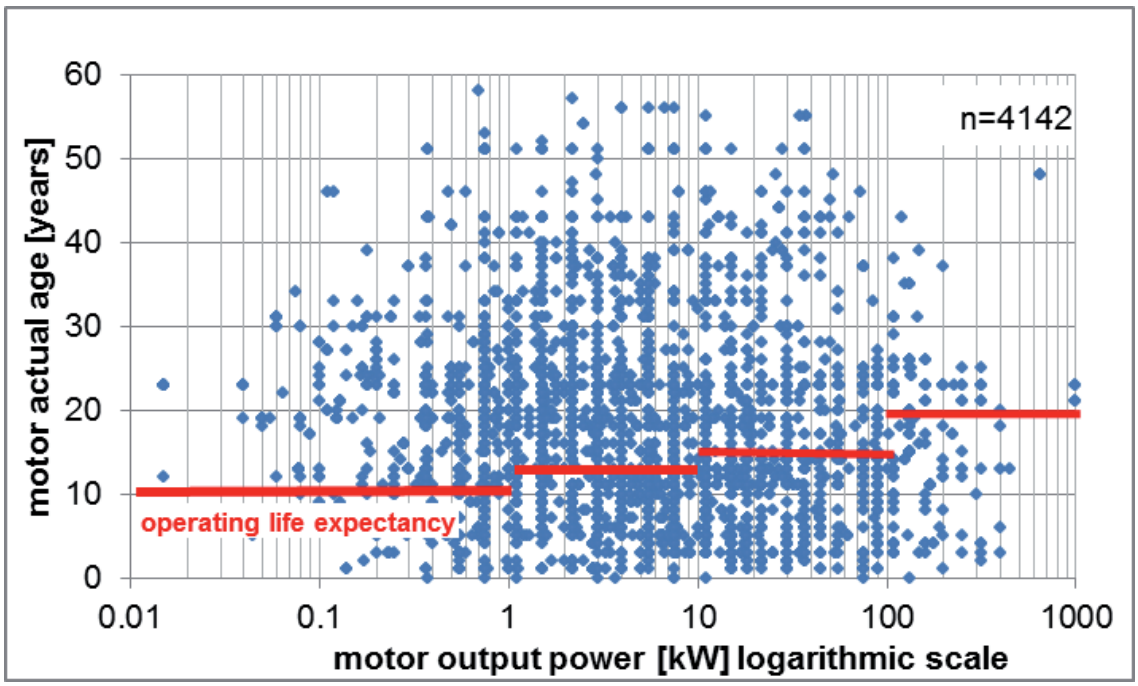

Figure 1. Motor systems by output power and age: motors are too old. Source: S.A.F.E. 2013.

- Energy management (based on ISO 50001) can help in the continued renewal process of motor systems, is however being implemented only to a very limited extent in Switzerland.

These observations and conclusions were the starting point for developing a training program, to specifically cover the need for trained in-house factory staff with appropriate knowledge to identify and implement motor systems retrofit projects within their own factories.

TRAINING PROGRAMS ABROAD

Several large national training programs for efficient motor systems have been held in the last decades in the USA (Department of Energy, Washington State University, etc.), in China (Ministry of Industry and Information Technology), in Austria (klima:aktiv) and also by UNIDO (United Nations Industrial Development Organization) [5] in a number of countries. The focus has traditionally been on a theoretical understanding of the functionality and performance of electric motors for engineers and less on the practical on-site observation and guidance of factory staff for the systematic analysis and improvement of complete motor systems.

Preparatory work for training program

FEASIBILITY STUDY

In 2014, Topmotors carried out a feasibility study to:

- assess the Swiss tertiary and continued education landscape, screening all programs pertinent to efficient electric motor systems;
- assess potential training sites (educational institutions) for the training program;
- screen interest of potential partners to contribute to the training program;
- assess the need, potential interest of participants, duration, structure and topics of a training program focusing on motor systems.

The analysis of already existing programs found that the landscape of continued education programs is quite diverse, with many programs focusing on energy efficiency in buildings and renewable energy. Some programs had elements dealing with thermal energy in industry, not touching in-depth on electric energy and efficient motor systems.

In the framework of the feasibility study, a survey interviewing 34 different organisations was carried out based on a detailed questionnaire (see Figure 2).

In total, 16 educational institutes were interviewed during the survey throughout the German and French parts of Switzerland. Potential education sites included mainly universities of applied science, but also other educational institutes. The majority of them expressed their interest to be a host for IEO.

The results of the survey can be summarized as follow:

- The training should be mainly targeting technical staff working in industrial factories, not managers.
- The training should include both energy management and energy technology. These two elements should be combined into one package and not be offered as separate, stand-alone courses.
- While a Certificate of Advanced Studies (CAS) was the preferred format by most respondents, other potential training formats (e.g. multiple-day-course) were also mentioned.
- The majority of respondents were interested to contribute to the training program in some way (e.g. training site, of-

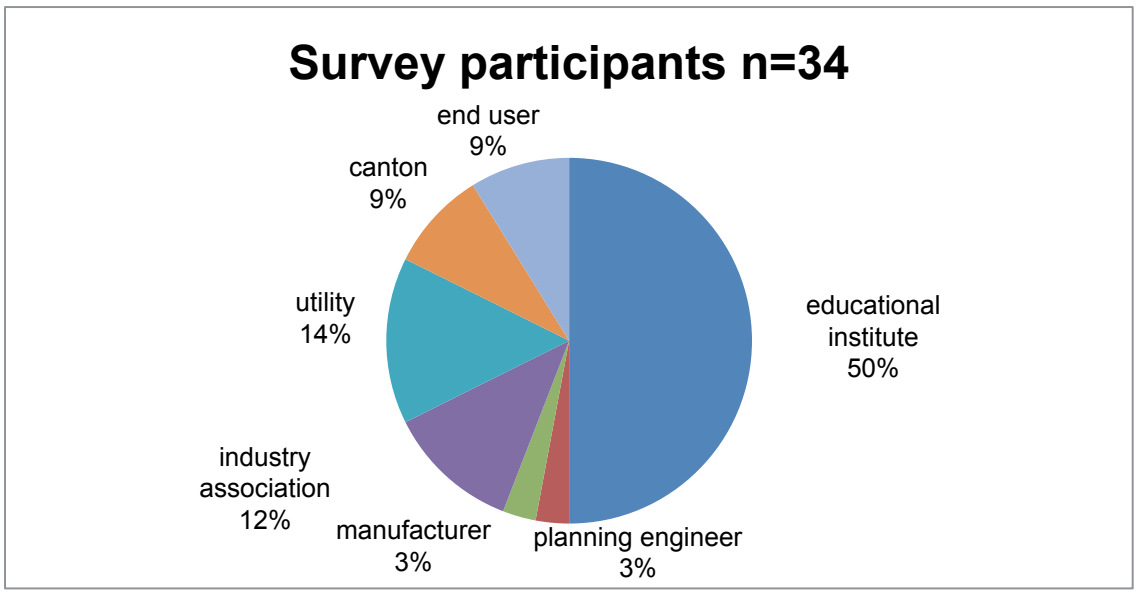

Figure 2. Participants of the survey carried out in the framework of the feasibility study for IEO.

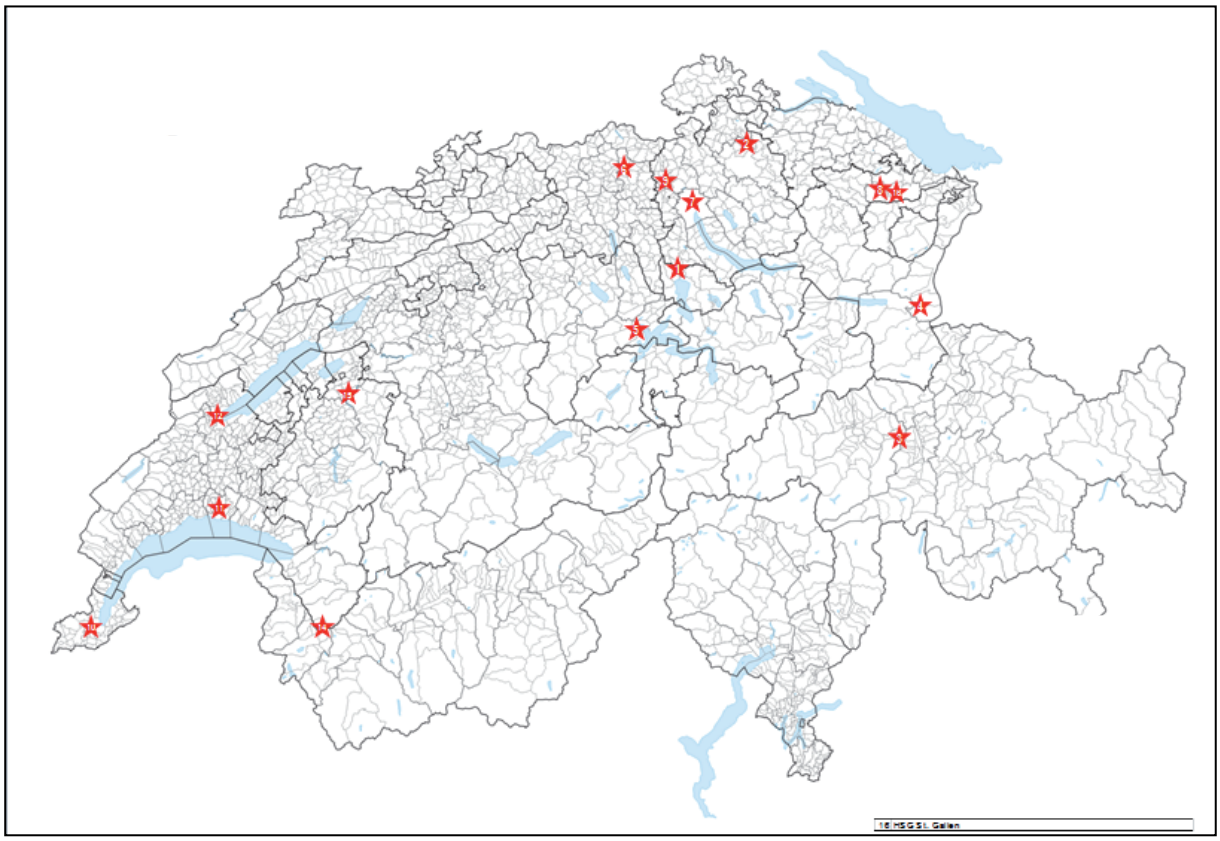

Figure 3. Interviewed educational institutes as potential sites for the IEO program.

fering teachers, marketing activities, supporting potential participants, etc.).

- The majority of the survey respondents ranked not having enough paying participants for the training as the highest risk.
- The majority of responding utilities, cantons (local government), industrial associations, manufacturers and industrial users stated that a training participation would be interesting for their employees and that they would be ready to support them by either by giving a contribution to the course fee or by not having to compensate the working hours spent for the training.

The survey gave a good opportunity to inform relevant organisations and stakeholders in the field about the planning of the training and to investigate their interest in joining the organisation of the training.

BUILD-UP PHASE

In 2015, Topmotors prepared the implementation of the training program. First, the two training sites needed to be chosen where the training would take place. In parallel, also the organisational model of the program was clarified and set up.

Choice of training sites

Following up on the interviews with educational institutes carried out during the feasibility study, the program management invited in a first step all institutes to submit a letter of interest for hosting the training program. The following criteria were taken into account for the evaluation of these letters:

1. Motivation of the educational institution to be a host of the training program.
2. Central location, geographically well-positioned to reach a large number of potential program participants.
3. Easy transport access (availability by public transportation).
4. Available type and size of class rooms.
5. Availability of a testing laboratory: size, measurement equipment, possibilities for testing motors, pumps, fans, compressors, availability of lab trainers.
6. Availability of teachers for the different topics of the training program (including accompanying the individual practical assignments of training participants), their professional and didactic qualification and experience.
7. Reputation of the educational institution in the field of energy efficiency.
8. Experience of the institution with building up and executing continued education programs.
9. Courses already offered or planned with similar content as IEO.
10. Target group and profile of participants of continued education programs already offered or planned by the institution.
11. Network for reaching potential participants (marketing).
12. Existing contacts to industrial producers (e.g. motor and machine manufacturers) and industrial users.
13. Possibility for obtaining European Credit Transfer System (ECTS) points for a successful completion of the training.
14. In kind contributions for class rooms, laboratory, teachers and marketing activities.

In a second step, the program management prepared a shortlist of interested and well-positioned institutes and made a site visit to these. Following the site visits, the shortlisted institutes were invited to submit a detailed bid including their cost proposal for hosting the program. The final decision was made on this basis, choosing the following two training sites for the program:

- Lucerne University of Applied Sciences and Arts (Hochschule Luzern HSLU) in the German-speaking part of Switzerland
- Haute École d'Ingénierie et de Gestion du Canton de Vaud (HEIG-VD) in the French-speaking part of Switzerland.

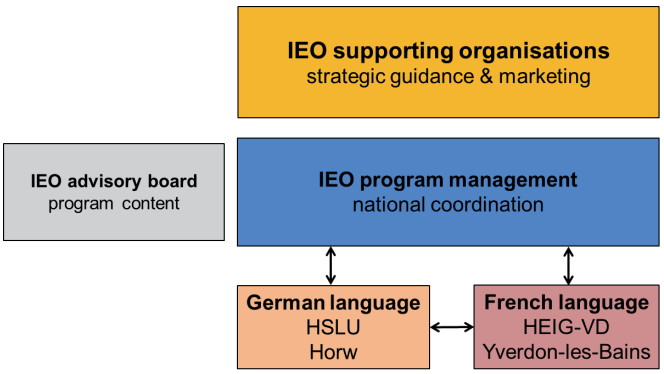

Figure 4. Organisational model of IEO.

Organisational model

The goal of the program management was to set up a permanent organisational structure for a coordinated national training program (see Figure 4) that will be operational for at least five years.

The role of the supporting organisations is to provide strategic guidance, appoint the training program management, approve the yearly budget and accounting and to bear a part of the financial risk if they decide so. Furthermore, supporting organisations promote the training course through their networks to potential participants. Currently two national agencies, an industry association and a utility represent the supporting organisations of IEO.

The role of the advisory board is to provide support concerning the training content and the elaboration of the training materials, with the aim to secure that the training is well adapted to the target group. Currently representatives of the federal government, industrial end-users, utilities and technical experts for motor systems are part of the advisory board.

The program management is the leading the build-up phase and takes responsibility for the national coordination of the training program, ensuring that the German and French versions of the training are well synchronized.

The two training sites are the hosts of the program and provide the majority of the teachers; the other teachers are external practical experts (including experts from Impact Energy).

Training program

GOAL

The goal of the training is to empower technical staff in industrial factories to:

1. establish a long-term, continuous improvement process for motor systems within the factory
2. lead and implement efficiency optimisation projects for motor systems involving external specialists, manufacturers and service providers
3. present the optimisation projects and convince upper management to invest into them on a regular basis.

While the scope of the optimisation projects is not limited to investments into hardware only (operational control improvements are also encouraged), one specific goal of the program is

to convey the message of system improvements. A 1:1 replacement of the motor may bring energy savings of a few percentage, but only a systematic system approach can lead to energy savings of 20 % to 30 %. The system approach means looking at the whole motor system (see Figure 5), assessing and adjusting the necessary output (flow/pressure/temperature, etc.) and the individual system components (variable frequency drive, motor, transmission, application with pump, fan, compressor, etc.).

TARGET GROUP

The training targets technical people working in industrial factories, i.e. mechanical and electrical engineers, machine programmers and operators and their technical leaders, internal and external maintenance staff, and also external process and efficiency consultants. Participants are also expected from engineering consultants, utilities, state authorities, etc.

While the training program is open for technical people from all types and sizes of factories, most participants are expected from mid- and large-size factories with an electrical energy consumption above 0.5 GWh/a. These factories represent 4 % of the total number of factories within Switzerland and use 62 % of the electric energy in the industry and service sectors (see Figure 6). Mid- and large-size factories on the one hand are more likely to have in-house staff dealing with energy and energy efficiency issues within the organization and on the other hand, they show a higher potential in terms of energy savings.

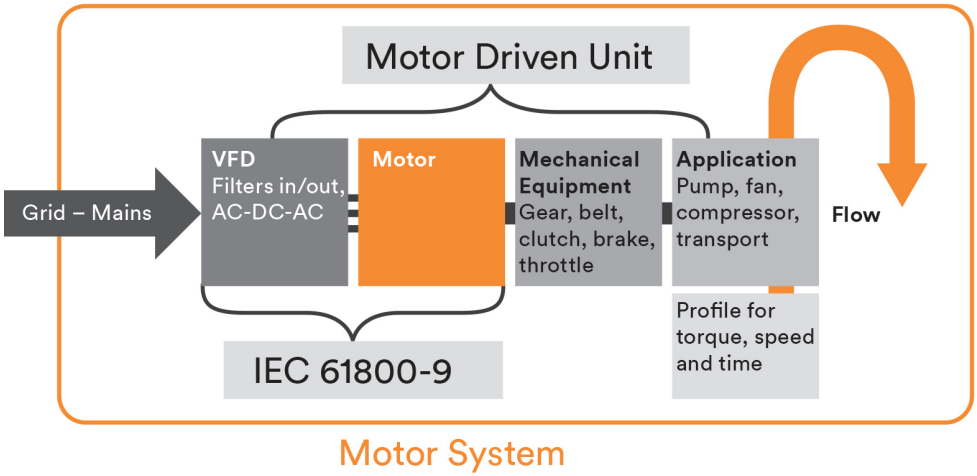

Figure 5. Motor system. Source: Impact Energy, 2014.

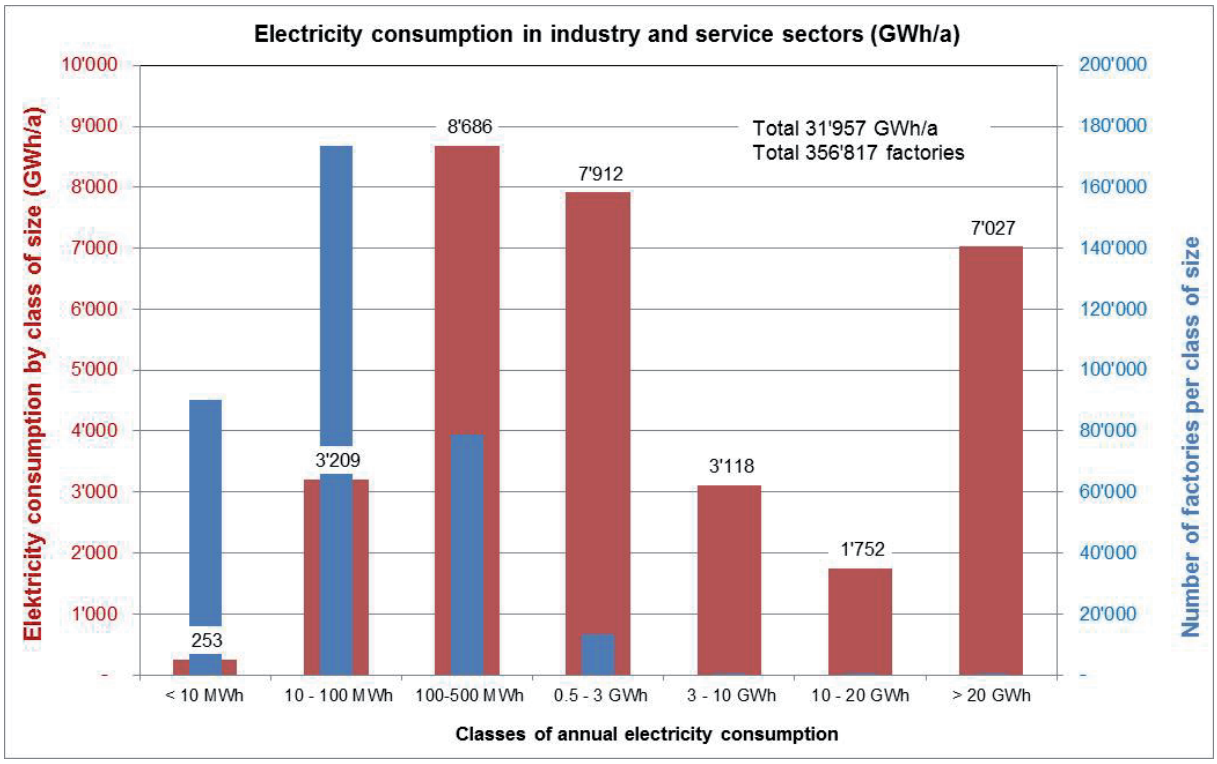

Figure 6. Small and large factories in Switzerland. Data source: Swiss Federal Office of Energy, 2011.

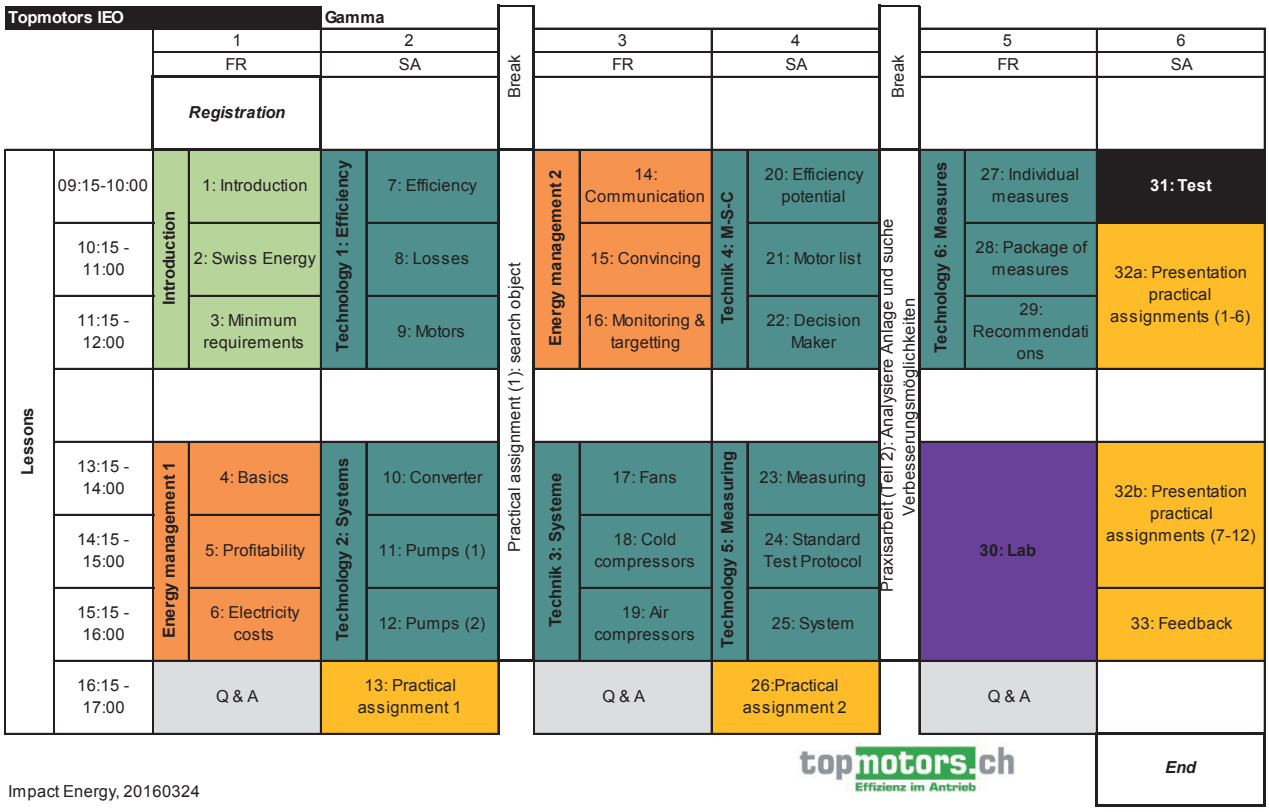

Figure 7. IEO overview of training contents.

DURATION

While the outcomes of the survey suggested a CAS format with 12 days for the training, the program management decided to start with a compact six-day training format. The major reason for this was to account for the limited available time of the target group, able to spend it away from the factory floor.

The training will be held in three blocks, during the course of one month. One block consist of two days, a Friday and the following Saturday respectively. Thus, three from the six training days will be held during the weekend. This setup was chosen in an attempt to reduce the number of working days that participants need to be away from their factories. Hence, participants will need to invest equally from their work and social (or free) time.

A shorter training duration with six days implies that the time available for delivering the training material is limited; hence it will not be possible to go into too much depth for the individual topics – which is fully in line with the intended results of IEO. The goal of the training program is not to train specialists with detailed technical knowledge, but to enhance participants' general understanding of efficient systems and processes, empowering them to work together with external specialists, if needed, and to enable them to follow a stepwise audit methodology.

The ultimate long-term goal is to extend IEO from 6 days to the originally envisaged 12 days which would constitute a CAS.

CONTENT

The training focuses on developing and enhancing practical skills. It consists of class room training, laboratory exercises and a practical assignment in the participants' factory.

The class room training consists of the following three main parts (see Figure 7):

1. Introduction to energy efficiency policy and legal requirements (one half day).
2. Energy management, communication and how to convince management (one day).
3. Technology, focusing on motor systems and audit methods (three days).

The last day of the training is reserved for the final exam, consisting of a short written test and the presentation of the practical assignment of the participants.

LABORATORY DEMONSTRATION

Bringing in the practical aspect of working with motor systems is a crucial element in the training design. This played an important role in the choice of the training sites, therefore universities of applied science with appropriate laboratory infrastructure were selected.

In HEIG-VD, a pump demonstrator (see Figure 8) helps to showcase how energy consumption varies if using different pump systems, with or without a frequency converter.

The concept of the demonstrator is to facilitate the training through comparing a clearly designed number of options: in this case how to achieve the highest system efficiency (input electrical power needed [kW], defined flow [liter/sec] and pressure [Pa]) for a given flow and pressure with three small and one bigger pump, all of them potentially driven in fixed or variable speed (each with full or partial load). Through mechanical and electronic switches the desired result can be achieved

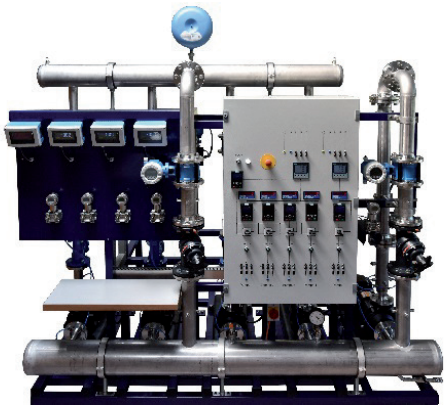

Figure 8. Pump demonstrator.

either by trial and error or by calculating the required peak and average loads. The goal of the demonstrator is to show quickly the efficiency potential comparing several system configurations in a playful, practical and effective way.

A similar demonstrator is planned to be built up for pumps and fans in HSLU.

PRACTICAL ASSIGNMENT

For a successful completion of the training, participants are required to make a practical assignment within their factory or any other suitable object. For this, participants have to:

- identify a suitable object for the analysis (i.e. a pumping or fan system)
- describe the system, its parameters for peak and average load, annual operation characteristics
- understand the energy performance of the chosen object and its shortcomings
- investigate variants for optimizing the energy efficiency
- present the recommendations.

Financial aspects

From the participants' view (based on the feasibility study) a continuous education fee of CHF 3,000 for a six-day program is considered acceptable. Employers are encouraged to subsidize the fee of the participants: they dedicate besides the three working days also three days of their free time. Their added competence will certainly help the factories to better implement their economic and environmental targets.

The program management analysed the costs of the training program for a period of five years based on a business plan. From the program management point of view, it was clear from the outset – based on this business plan – that the operational phase of the training could cover its cost through the fees of the participants, but the preparation of the program needed additional financial support. This was secured through support from the national and local governments as well as other interested parties (power utilities, professional associations, etc.).

For the hosting universities of applied science the IEO program was a welcome enlargement of their field of competence and programs offered, a dual use of their resources in rooms, laboratories, presenting a new angle for the teachers as well. At the same time, it was also evident that a subsidy was necessary both to secure a good start and to improve the demonstrating equipment for motor systems in their laboratories.

First experiences

Although the reality check of the program will only happen in the summer of 2016 (the presentation of this paper at the eceee Industrial Summer Study will include the results), several observations can already be made:

- A unique selling proposition of the program is necessary to distinguish it from the numerous competing training programs in energy efficiency and renewable energy use.
- The available time for training of industrial staff is limited. Based on the feasibility study the program management decided that six days spread over the period of one to two months seem to be the maximum at present.
- The focus on competence for the practical understanding and improvement of machines similar to the ones in the participants' factories is necessary to differentiate from theoretical class room training programs.
- The hosting by renowned universities of applied science is critical to secure the success of the first and subsequent trainings.
- The support of the national energy efficiency program SwissEnergy helps to attract students and lends credibility to the training program.
- A funding of the preparatory phase – before costs can be covered by fees – is necessary.
- An intensive marketing campaign is needed to introduce the program to potential participants before the first editions. A successful training and satisfied participants (word of mouth) are strong marketing tools for gathering participants following the first editions.

Next steps

IEO is currently planned to be organised for a period of five years. For 2016 and 2017, one German-language and one French-language training is planned for a minimum number of 12 participants (ideally around 20 participants per training) per year. Between 2018 and 2020 two German-language and one French-language training courses are planned per year.

On the long term, the program management would like to export the concept and experience of IEO to other countries as well. The adaptation to German and French speaking countries (such as Germany, Austria, France) should be smooth, given that the training is already being conceived in these two languages. Translation into English and Chinese is foreseen.

Conclusions

The experience with the design and build-up of IEO as a Swiss program in industry shows that it takes a considerable effort to start a training program aimed at closing the efficiency gap. It needs a strong financial support in the preparatory and build-up phases to arrive to a fully documented set of lessons. Even if the continuation of the program can be covered through the course fee paid participants, the build-up phase needs additional financial sources.

An important conclusion is certainly that continued education and practical experience for technical personnel in industry cannot be confused with a university degree program. The training program needs to be much more focused, shorter, give practical skills more weight than theoretical background materials; the time invested by both companies and trainees needs to be worthwhile. Otherwise, a program is designed and launched but no participants are available because they cannot get the necessary time away from work.

Also, for the teachers of basic tertiary education in bachelor and master programs it proved to be a challenge to adapt the material to a level that suits the target group of the program which is different from the audience they are used to work with. Much of the existing teaching material had to be reworked and rephrased to be understood by practical technicians in this context.

Since the teachers in the program are both academic professors with a deep theoretical knowledge and external experts working with industrial factories and ample practical experience, a careful coordination of teaching materials was essential in the preparatory phase. On the one hand, to make sure that the sequence of lessons is well aligned, avoiding duplications or contradictions, using a common terminology, key messages to be conveyed, etc. and on the other hand to ensure that the whole training material suits the level of the target group and is close enough to their practical field of work.

The time spent between the first concept through the feasibility study and the preparatory phase also shows that such a program cannot be launched overnight. Two years were needed before the first lessons start in June 2016. The fact that a program in two languages (German and French) had to be built up from the outset made the entire planning complex.

The upcoming reports on IEO will focus on the participants' feedback and the update with the lessons learned for the second year of the program in 2017.

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